ASSOCIATION OF ENGINEERS, ARCHITECTS AND GRADUATES IN TECHNOLOGICAL SCIENCES IN ISRAEL

OASIS 7

International Conference and Exhibition on Optics and Electro-Optics

1-2 April 2019
David InterContinental Hotel

Digital Abstract Book

Conference Website: www.oasis7.org.il

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Oasis 7th Conference and Exhibition on Electro-Optics

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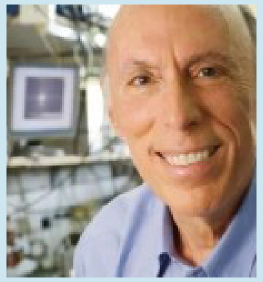

Dear Friends and Colleagues,

It gives us great pleasure to invite you to OASIS 7 (Optical Engineering and Science in Israel) of ILEOS (The Israel Lasers and Electro Optics Society). The meeting will be held on 1-2 April 2019 in Tel-Aviv, Israel.

The fields of optics and electro optics continue to grow rapidly in Israel, especially over the last few years. It is estimated that there are more than 10000 optics and electro-optics professionals involved in seven universities, several colleges and over 400 companies in Israel. The OASIS meetings present the latest advances in the field of electro-optics worldwide, as well as to be a showpiece for Israeli optics, electro-optics and laser research and technologies. The OASIS 6 meeting was held in Tel-Aviv in February 2017 with more than 1000 participants. Four distinguished scientists gave plenary talks more than 100 lectures were given in 13 sessions. 60 companies exhibited their products and there was a large delegation of European companies.

The OASIS 7 meeting will focus on encouraging interdisciplinary research as well as international cooperation. The meeting's program reflects some of the areas of current interest in modern optics, including sessions on Non - linear Optics, Spectroscopic and Optical Sensing, Micro and Nano Optics, Electro Optics in Industry, Ultrafast Phenomena, Defense and Optical Engineering, Solar Energy, Atomic and Quantum Optics, Medicine and Biology, Optical Engineering, Lasers and Applications, Electro Optics Devices and Optical Fiber Lasers.

The conference will again host distinguished plenary speakers. In addition there will be several keynote speakers and over a hundred lectures in thirteen sessions. The target audience includes optical scientists and engineers working in these fields.

We encourage students from all institutions of higher learning to participate in this meeting. We will have short tutorials that will introduce students to modern topics in electro-optics. OASIS 7 will expose them to the latest research and development, and help them interact with representatives of Academia and Industry.

I invite you to actively participate in our seventh OASIS meeting.

Yours Sincerely,

A. Katzir

Prof. Abraham Katzir
Conference Chairman, Organizing Committee

Oasis 7th Conference and Exhibition on Electro-Optics

Organizing Committee

Conference Chair

Prof. Abraham Katzir, Tel-Aviv University

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Prof. David Cahen, Bar-Ilan University & Weizmann Inst. of Science
Prof. Oren Cohen, Technion
Dr. Rami Cohen, ELOP, Elbit systems-ISTAR
Prof. Barak Dayan, Weizmann Institute of Science
Prof. Dror Fixler, Bar Ilan University
Dr. Hanni Inbar, Israel Aerospace Industries
Prof. Dan Marom, The Hebrew University
Dr. Ayala Ronen, Israel Institute for Biological Research
Dr. Joelle Schlesinger, Rafael
Prof. Koby Scheuer, Tel-Aviv University
Dr. Yoav Sintov, Ph.D, Soreq NRC
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Prof. Hagai Eisenberg, The Hebrew University of Jerusalem
Prof. Amiel Ishaaya, Ben-Gurion University
Mr. Gal Kalmani, IMOD
Dr. Moshe Oron, KiloLambda Technologies Ltd.
Mr. Haim Rousso, EL-OP, Israeli Innovation Authority
Prof. Moti Segev, Technion - Israel Institute of Technology
Prof. Zeev Zalevsky, Bar-Ilan University
Mr. Jo Van Zwaren, JLM-BioCity

Oasis 7th Conference and Exhibition on Electro-Optics

Monday, April 1, 2019

08:00 - 09:00 Coffee and Registration

09:00 - 10:55 **Opening Session - Plenary Hall**

09:00 - 09:30 **Chairperson: Prof. Abraham Katzir,**
Chairman of Oasis 2019

09:30 - 10:15 **Plenary Lecture:**
Passion Extreme Light
Prof. Gérard Mourou, *Nobel Prize Winner, École Polytechnique, Palaiseau, France*

10:15 - 10:55 **Plenary Lecture:**
Seeing the Unseen in Patients: Advancing Disease Prevention and Treatment through Microimaging
Prof. Guillermo Tearney,
Mass General Hospital, Harvard University, MIT, Cambridge, MA, USA

10:55 - 11:25 Coffee Break and Posters Review of Topics: *Micro and Nano Optics, IFLA - International Fiber Lasers and Applications*

Monday, April 1, 2019 | 11:30 - 13:00 | Parallel Session 1

11:30 - 13:00 | Parallel Session 1

Hall A
Optical Engineering
Dr. Hanni Inbar

- Photonics-Based Particle Acceleration
Peter Hommelhoff, Robert L. Byer, R. Joel England, *Physics Department, Friedrich Alexander University ErlangenNuremberg, Germany*
- SWIR to Visible Up-Conversion Devices Development
Gabby Sarusi, *Photonics and Electrooptics Engineering Unit and Ilsa Katz Center for Nano Scale Sciences, Ben-Gurion University Beer-Sheva, Israel*

Non-Paraxial Fourier and Fresnel Optics in Design of Diffractive Optical Elements and Meta-Surfaces
Michael A. Golub, *Tel Aviv University, School of Electrical Engineering- Physical Electronics, Israel*

Joint Design of Optics and Post-Processing Algorithms Based on Deep Learning for Generating Advanced Imaging Features
Shay Elmalem, Harel Haim, Raja Giryes, Alex M. Bronstein and Emanuel Marom, *Faculty of Engineering, Tel Aviv University, Israel*

A K-Domain Method for Fast Propagation of Electromagnetic Fields through Graded-Index Media
Huiying Zhong, Site Zhang, Rui Shi and Frank Wyrowski, *LightTrans International UG, Germany*

Hall B
Lasers and Applications
Dr. Ariel Bruner

- Challenges in Further Power Scaling of Single-Mode Fiber Lasers
Liang Dong, *Clemson University, USA*
- Femtosecond Pulse Generation by Using Single-Layer Graphene and Voltage-Controlled Graphene Supercapacitor Structures
Alphan Sennaroglu, Isinsu Baylam, Ferda Canbaz, Can Cihan, Nurbek Kakenov, Coskun Kocabas, Umit Demirbas, and Sarper Ozharar, *Koç University, Turkey*

Axiparabola: A Long Focal Depth, High Resolution Mirror for Broadband High Intensity Lasers
Slava Smartsev, Clement Caizergues, Kosta Oubrerie, Julien Gautier, Jean-Philippe Goddet, Amar Tafzi, Kim Ta Phuoc, Victor Malka, Cedric Thaury, *Department of Physics of Complex Systems, Weizmann Institute of Science, Israel*
Laboratoire d'Optique Appliquée, Ecole Polytechnique, ENSTA, CNRS, Palaiseau, France

Micron Precision Assembly for Sensors and Laser Systems on a Reconfigurable Industrial Platform
Tobias Mueller, Sebastian Sauer, *Fraunhofer Institute for Production Technology, Germany*

High Energy Tunable Narrow Bandwidth Tm:YAP Laser
Salman Noach, Uzziel Sheintop, Eytan Perez, Rotem Nahear, Pavel Komm, Gilad Marcus, *Jerusalem College of Technology, Israel*

Hall C
Medicine and Biology
Prof. Dror Fixler
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- Wide-field Time-correlated Single Photon Counting (TCSPC) for Fluorescence Lifetime Imaging (FLIM) Microscopy
Klaus Suhling, *King's College London, UK*
- All Optical Monitoring of Cancer Treatment Efficiency with Overtone Absorption Spectroscopy on Microfibers with Random Surface Roughness
Alina Karabchevsky, *Ben-Gurion University, Israel*

Improved Photoacoustic Image Reconstruction of Clinical Data
Idan Steinberg, David M. Huland, Sarah Hooper, Sanjiv Sam Gambhir, Tal Klap (*Independent*)*;Stanford School of Medicine, USA*

Advanced Fiber Optic Solutions for Biomed Photonics in 0.3-16µm Range
Viacheslav Artyushenko, *Art Photonics GmbH, Germany*

Infrared Fiber-Optic Sensing Method for Early Detection of Melanoma and other types of Skin Cancer
Svetlana Basov, Max Platkov, Ilan Goldberg, Eli Sprecher, Andrey Goriachev, Yosef Raichlin, Yair Dankner, Marcelo Weinstein, Abraham Katzir, *Nuclear Research Center Negev (NCRN), Israel*

Automated Transscleral Laser Trabeculoplasty
Zachary Sacks, *Belkin Laser Ltd., Israel*

Hall D
Electro Optics in Industry
Dr. Rami Cohen

- Optimize Electro-Optics Mechanical Design for Additive Manufacturing
Elad Yosef, *Mechanical Engineer, Elbit Systems-ISTAR, Israel*
- Embedded 3D Interconnects in Glass Substrates by a Combined Laser Trenching and Printing Process
Yuval Berg, *Department of Physical Electronics, Faculty of Engineering, Tel Aviv University, Israel*
- State Of The Art Precision Metrology with Ultra-Low-Noise Optical Frequency Combs
Benjamin Sprenger, Dag Schmidt, Michele Giunta, Wolfgang Haensel, Marc Fischer, Ronald Holzwarth, *Menlo Systems, Germany*

Development of Thin Glass-based Technologies for Photonic System Integration
Henning Schröder, *Fraunhofer IZM, Germany*

Review on Free Form Optics: Advantages and Challenges Of An Emerging Technology
Raginski Igor, *Optical Designer, Electro - Optics Department, Rafael, Israel*

Hall E
IFLA - Specialty Fiber
Dr. Yoav Sintov

- Materials Development for Advanced Optical Fibers
John Ballato, *Clemson University, USA*
- Image Transport through Glass-Air Disordered Optical Fiber
Axel Schülzgen, Jian Zhao, Yangyang Sun, Zheyuan Zhu, Jose Enrique Antonio-Lopez, Rodrigo Amezcua Correa, Shuo Pang, *CREOL, The College of Optics and Photonics, University of Central Florida, USA*
- Large Mode Area Fiber Designs for Megawatt Peak Power Generation in REPUSIL-Based Tapered Amplifiers
Matthias Jäger, Martin Leich, André Kalide, Martin Lorenz, Tina Eschrich, Anka Schwuchow, Jens Kobelke, Jörg Bierlich, Claudia Aichele, Katrin Wondraczek, Dörte Schönfeld, Andreas Langner, Clemens Schmitt, Jaqueline Plass, Gerhard Schötz, Heraeus Quarzglas, *Leibniz Institute of Photonic Technology, GmbH & Co. KG, Germany*
- Mode Area Scaling Through a Multicore Supermode Fibre
Seongwoo Yoo, *Nanyang Technological University, Singapore*

Oasis 7th Conference and Exhibition on Electro-Optics

13:00 - 14:00 | Lunch Break
13:30 - 14:00 | Posters Review of Topics: *Electro Optics in Industry and Medicine and Biology*

Monday, April 1, 2019

14:00 - 15:30 | Parallel Session 2

14:00 - 15:30 | Parallel Session 2

Hall A
Micro and Nano Optics
Prof. Koby Scheuer

♦ Kerr-Microresonator Solitons for Ultraprecise Measurements
Scott B. Papp, *NIST and University of Colorado, USA*

Parametrical Optomechanical Oscillations in Microbubble Resonators: Suppression, Enhancement and Route to Chaos
Silvia Soria, Xavier Rosello-Mecho, Daniele Farnesi, Gabriele Frigenti, Martina Delgado-Pinar, Miguel V. Andrés, Giancarlo Righini, Gualtiero Nunzi Conti, *IFAC-CNR Institute of Applied Physics "N. Carrara", Italy*

Optomechanically-Driven Microstructures for Targeted Drug Delivery Applications
Pavel Ginzburg, Ivan I. Shishkin, Hen Markovich, Hani Barhom, Andrey Machnev, Roman E. Noskov, Yael Roichman, *Tel Aviv University, Israel*

Optical Skyrmions: A New Texture of Light
Shai Tsesses, Kobi Cohen, Evgeny Ostrovsky, Bergin Gjonaj, Netanel H. Lindner, Guy Bartal, Andrew and Erna Viterbi, *Department of Electrical Engineering, Technion - Israel Institute of Technology, Israel; Faculty of Medical Sciences, Albanian University, Tirana, Albania; Physics Department, Technion - Israel Institute of Technology, Israel*

Spin-Locking In 2D and 3D Plasmonic Structures
Yuri Gorodetski, *Ariel University, Israel*

Hall B
Atomic and Quantum Optics
Prof. Barak Dayan

♦ Quantum-Dot Quantum Nanophotonics
Nir Rotenberg, *University of Copenhagen, Denmark*

Effect of Stokes Shift on Polariton Dynamics
Jussi Toppari, Gerrit Groenhof, Tero Heikkilä *Nanoscience Center and Departments of Physics and Chemistry, University of Jyväskylä, Finland*

Quantum Free-Electron Wavepacket Interactions with Light and Matter
Avraham Gover, Yiming Pan, Bin Zhang *Department of Electrical Engineering Physical Electronics, Tel Aviv University, Israel; Department of Physics of Complex Systems, Weizmann Institute of Science, ISRAEL; National Laboratory of Solid State Microstructures and School of Physics, Nanjing University, CHINA*

Strong Coupling of THz Fields to Collective Molecular Vibrations
Sharly Fleischer, Ran Damari, Omri Weinberg, Natalia Demina, Katherine Akulov, Daniel Krotkov, Tal Schwartz, *Tel Aviv University Physical Chemistry Department and Tel Aviv Center for Light-Matter Interaction, Israel*

Photonic Quantum Walks with Cyclic Geometry as Versatile Quantum Simulators
E. Cohen (*Bar Ilan University*), **W.-W. Pan, X.-Y. Xu, Q.-Q. Wang, Z. Chen, M. Jan, Y.-J. Han, C.-F. Li, G.-C. Guo** (*University of Science and Technology of China*); *Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Israel*

Hall C
Medicine and Biology
Prof. Dror Fixler
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♦ On-Chip Silicon Photonic Biosensors
Sharon M. Weiss, *Vanderbilt University, USA*

♦ Stain-Free Quantitative Phase Imaging of Sperm Cells for In Vitro Fertilization
Natan T. Shaked, *Faculty of Engineering, Tel Aviv University, Israel*

Three Photon Adaptive Optics for in-vivo Mouse Brain Imaging
David Sinefeld, Fei Xia, Mengran Wang, Chunan Wu, Tianyu Wang, Hari P. Paudel, Dimitre G. Ouzounov, Thomas G. Bifano and Chris Xu, *Applied and Engineering Physics, Cornell University, USA*

Imaging Tympanic Membrane Surface Vibrations - In Vivo
Matan Hamra, Shadi Shinnawi, Ariel Weigler, Mauricio Cohen Vaizer, Dvir Yelin, *Biomedical Engineering, Technion - Israel Institute of Technology, Israel*

Eye Tracking Control in Visual Prostheses
Avi Caspi, *Jerusalem College of Technology, Israel*

Hall D
Start-up Session
Ms. Salit Lev

Prof. Gabby Sarusi, *SenSWIR*
Dr. Yaakov Amitai, *Oorym*
Mr. Ran Bar-Yosef, *Spectralics*
Dr. Zachary Sacks, *Belkin Lasers*
Prof. Ibrahim Abdulhalim, *Photonicsys*
Dr. Assaf Anderson, *MaterialsZone*
Mr. Ofer Harpak, *Oxitone*
Dr. Ilya Fine, *Elfi-Tech*
Dr. Dan Haronian, *Enervibe*
Prof. Yossef Ben-Ezra, *Cellowireless*
Dr. Cristina Canavesi, *LighTopTech*
Mr. Jon Donner, *Nano-Fabrica*
Mr. Eduardo Svetliza, *Retsight*
Mr. Itai Hayot, *Scopiolabs*

Hall E
IFLA - Mid-IR Fibers and Sources
Prof. Amiel Ishaaya

♦ Silica-Based Hollow-Core Optical Fibres: A New Paradigm for the Mid-Infrared
Jonathan Knight, *Department of Physics, University of Bath, UK*

♦ Recent Advances in Mid-Infrared Fiber Lasers
Real Valle, M. Bernier, V. Fortin, F. Maes, S. Duval, F. Jobin, Y.O. Aydin, P. Paradis, *Center for Optics Photonics and Lasers, Laval University, Canada*

♦ Bringing Infrared Fiber Components to the Market
Eric Geoffrion, *Mohammed Saad Thorlabs (Formerly IRPhotonics), Canada*

♦ Fiber-Bulk Hybrid Mid-Infrared Lasers Based on Transition Metal Doped Ceramic Chalcogenides
S.B. Mirov, I.S. Moskalev, M.S. Mirov, S. Vasilyev, V.V. Fedorov, D.V. Martyshkin, O. Gafarov, V. Smolski, *Department of Physics, University of Alabama at Birmingham, USA; IPG Photonics Corporation, Southeast Technology Center, 100 Lucerne Ln, USA*

Key: ♦=Invited/Keynote Speaker

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Monday, April 1, 2019

16:00 - 17:30 | Parallel Session 3

15:30 - 16:00 | Coffee Break and Posters Review of Topics: *Non-Linear Optics and Lasers and Applications*

16:00 - 17:30 | Parallel Session 3

Hall A

Micro and Nano Optics
Prof. Koby Scheuer

Multifunctional Spectrally Interleaved Geometric Phase Metasurface
Elhanan Maguid, Michael Yannai, Arkady Faerman, Qitong Li, Jung-Hwan Song, Vladimir Kleiner, Mark L. Brongersma, Erez Hasman,
Faculty of Mechanical Engineering and Russell Berrie Nanotechnology Institute, Technion - Israel Institute of Technology, Israel

Guiding Surface Plasmon Polaritons on Curved Surfaces
Ana Libster-Hershko, Roy Shiloh, Ady Arie, *Faculty of Engineering, Tel Aviv University, Israel*

Reconfigurable Semiconductor Metasurface Resonators
Tomer Lewi, *Bar-Ilan University, Israel*

Non-Equilibrium Theory of "Hot" Electron Generation in Plasmonic Nanostructures under Illumination - Thermal vs. Non-Thermal Effects
Yonatan Sivan, Yonatan Dubi, *Ben-Gurion University, Israel*

Optimization of Coupling Gratings for Lightguide-Based Displays
Huiying Zhong, Site Zhang, Roberto Knoth, Stefan Steiner, Site Zhang, Yichen Liu, Christian Hellmann, Frank Wyrowski, *LightTrans International UG; Applied Computational Optics Group, Friedrich-Schiller-Universität Jena, Germany; Wyrowski Photonics GmbH Applied Computational Optics Group, Friedrich-Schiller-Universität Jena, Germany*

Random Topological Defects-Induced Spin-Enabled Photonic Transport by Metasurfaces
Bo Wang, Elhanan Maguid, Michael Yannai, Vladimir Kleiner, Erez Hasman, *Technion - Israel Institute of Technology, Israel*

Hall B

Lasers and Applications
Dr. Ariel Bruner

♦ Progress in VECSEL Technology and Emerging Applications
Mircea Guina, Jussi-Pekka Penttinen, *Tampere University, Finland; Vexlum Ltd., Tampere, Finland*

♦ An Overview of the Israeli Consortium on Advanced Laser Technologies for Industrial Applications (ALTIA)
Kobi Lasri, *V-Gen Ltd., MKS Spectra-Physics, Israel*

Optically Pumped Flip-Chip Wafer-Fused Vecsels Emitting at 1.55-μm Wavelength
Eli Kapon, Alexandru Mereuta, Kostiantyn Nechay, Andrei Caliman, Grigore Suruceanu, Pascal Gallo, Mircea Guina, *Lake Diamond SA, Switzerland; Tampere University of Technology, Optoelectronics Research Centre, Tampere, Finland; Ecole Polytechnique Federale de Lausanne-EPFL, Laboratory of Physics of Nanostructures, Lausanne, Switzerland*

Towards Room Temperature Operation of Terahertz Quantum Cascade Lasers: Carrier Leakage Engineering as a Novel Design Concept
Asaf Albo, *Bar Ilan University, Israel*

Micron-Scale Additive Manufacturing Using Laser Transfer of Metals
Niv Gorodesky, Sharona Cohen, Marc Altman, Zvi Kotler, Zeev Zalevsky, *Faculty of Engineering and the Nanotechnology center, Bar-Ilan University; Additive Manufacturing Lab, Orbotech Ltd*

Hall C

Spectroscopic and Optical Sensing
Dr. Ayala Ronen

♦ Atmospheric Optics: Beauty and Science
Joseph A Shaw, *Montana State University, USA*

Accurate Synchronization of Spectrometers for Laser Induced Breakdown Spectroscopy Using New CMOS Sensors
Niv Gorodesky, Sharona Cohen, Marc Altman, Zvi Kotler, Zeev Zalevsky, *Faculty of Engineering and the Nanotechnology center, Bar-Ilan University; Additive Manufacturing Lab, Orbotech Ltd*

Design of an All-Optical Ultrasound Transducer Based on a Microcavity Resonator
Silvia Soria, Gabriele Frigenti, Fulvio Ratto, Lucia Cavigli, Gualtiero Nunzi Conti, Alberto Fernandez-Bienes, Sonia Centi, Andrea Barucci, Roberto Pini, Tupak Garcia-Fernandez, *IFAC-CNR Institute of Applied Physics "N. Carrara", Italy*

NDIR Gas Measurement in Harsh Environments by Advanced IR Components and Packaging Technologies
Steffen Biermann, André Magi, Patrick Sachse, *Micro-Hybrid Electronic GmbH, Germany*

Measurements and Modeling of Laser Propagation in Fog and Clouds
O. Yaron, A. Ronen, *Rafael Advanced Defense Systems Ltd; IIBR, Israel institute for Biological Research*

Application of Hyper-Spectral LIF-LIDAR Based on ICCD for Detection and Identification of Bio-Aerosol Clouds & Studding its Formation Dynamic
Ofir Shoshanim, Adva Baratz, *Israel Institute for Biological Research, Israel*

Hall D

Non-Linear Optics
Dr. Haim Suchowski

♦ Quantum Design of Coherent X-rays with Spin and Orbital Angular Momentum
Tenio Popmintchev, *Physics Department, Center for Advanced Nanoscience, University of California San Diego, USA; Photonics Institute, TU Wien, Austria*

Loss of Time Reversibility in Absorption-Free Focusing Media
Amir Sagiv, Adi Ditkowski, Gadi Fibich, *Faculty of Engineering, Tel Aviv University, Israel*

High Energy KGW/Tm:YLF Raman Laser
Uzziel Sheintop (*JCT*), **Pavel Komm** (*HUJI*), **Gilad Marcus** (*HUJI*), **Salman Noach** (*JCT*); *Jerusalem College of Technology, Israel*

Thermo-Optical Nonlinearity of Single Metallic Nanoparticle
Ieng Wai Un, Shi-Wei Chu, Yonatan Sivan, *Ben Gurion University, Electro-Optics Engineering, Israel*

Indefinitely Switchable Nonlinear Optical Nanoantennas for Ultrafast Stream Cryptography
Roman E. Noskov, Pujuan Ma, Lei Gao, Pavel Ginzburg, *Tel Aviv University, Israel; Soochow University, Suzhou, China*

Hall E

IFLA - Fiber Lasers and Applications I
Dr. Boaz Lissak

♦ Prospects in Power Scaling of Coherently Coupled Fiber Lasers and Amplifiers
Andreas Tünnermann, Jens Limpert, *Fraunhofer Institute for Applied Optics and Precision Engineering, Center of Excellence in Photonics, Jena, Germany*

♦ Amplifiers and Lasers with Active Tapered Double Clad Fibers
Valery Filippov, *Ampliconyx, Finland*

♦ Beam Cleaning Effects in Multimode LD-Pumped GRIN-Fiber Raman Laser
S. A. Babin, E. A. Evmenova, A. G. Kuznetsov, S. I. Kablukov, E. V. Podilov, *Novosibirsk State University; Institute of Automation and Electrometry SB RAS, Novosibirsk, Russia*

♦ High Pulse Energy Single Frequency 1.55micron Fiber Amplifiers
Shibin Jiang, *AdValue, US*

Robust Setup for Generation of High-Power CW Green Laser
Yishai Albeck, Steven Jackel, Avraham Boubli, Ziv Gross and Gabi Teller, *CIVAN Advanced Technologies, Israel*

Key: ♦=Invited/Keynote Speaker

Tuesday, April 2, 2019

08:00 - 09:00	Coffee and Registration
09:00 - 11:30	**Opening Session - Plenary Hall**
09:00 - 09:10	**Chairperson: Prof. Abraham Katzir,** *Chairman of Oasis 2019*
09:10 - 09:15	**Eng. Ehud Noff,** *Chairman of AEAI - Association of Engineers, Architects and Graduates in Technological Sciences in Israel*
09:15 - 09:55	**Plenary Lecture:** Recovering Lost Information in the Digital World **Prof. Yonina Eldar,** Weizmann Institute of Science, Israel
09:55 - 10:35	**Plenary Lecture:** Gravitational-wave Interferometers: A Revolution in the Way We Observe the Universe **Prof. David Reitze,** *The LIGO Laboratory, Caltech, Pasadena, CA, USA*
10:35 - 10:50	Coffee Break
10:50 - 11:30	**Plenary Lecture:** Landmarks in Quantum Optics: From Photons to Atoms **Prof. Alain Aspect,** *Institut d'Optique, Paris, France*
11:30 - 11:50	Coffee Break and Posters Review of Topics: *Atomic and Quantum Optics, Photonics in Defense, and Electro Optics Devices*

Oasis 7th Conference and Exhibition on Electro-Optics

Tuesday, April 2, 2019

11:50 - 13:20 | Parallel Session 4

Tuesday, April 2, 2019

11:50 - 13:20 | Parallel Session 4

Hall A

Solar Energy
Prof. David Cahen

♦ Experimental Realization and Theoretical Understanding of High Open-Circuit Voltages in LeadHalide Perovskites
Thomas Kirchartz, *Faculty of Engineering and CENIDE, University of Duisburg-Essen, Duisburg, Germany; Forschungszentrum Jülich, Germany*

♦ Stability Studies of Perovskite PV Materials and Devices Using Concentrated Sunlight
Iris Visoly-Fisher, *Dept. of Solar Energy and Environmental Physics, J. Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Midreshet Ben-Gurion, Israel* Low Dimensional Perovskite: Stability, Solar Cells and Nanostructures
Lioz Etgar, *The Institute of Chemistry, The Hebrew University of Jerusalem, Israel*

Photovoltaics for Internet of Things vs. Solar Power - the Optics Factor
Barry Breen, *CEO, 3GSolar Photovoltaics Ltd, Israel*

On Optimization of Heliostat Fields for Solar Central Receiver Plants
Pinchas Doron, Leon Karni, Marina Izmailov, Jacob Karni, *Azrieli College of Engineering, Jerusalem, Israel; SolPeD International Ltd., Rehovot, Israel*

Hall B

Electro Optics Devices
Prof. Dan Marom

♦ Highly Integrated Silicon Photonic Subsystems For Real World Applications
Christopher Doerr, *Acacia Communications, USA*

The Multiple-Functionality of Double Injection
Roei Aviram Cohen, Dr. Ofer Amrani and Prof. Shlomo Ruschin, *Tel Aviv University, Israel*

Eight-Channel Dense-Wavelength-Division Multiplexer in Silicon Photonics
D. Munk, M. Katzman, N. Inbar, Y. Kaganovskii, A. Misra, M. Hen, M. Priel, A. Bergman, M. Feldberg, M. Tkachev, M. Vofsi, M. Rosenbluh, T. Schneider, and A. Zadok, *Faculty of Engineering, Bar-Ilan University, Israel; Bar-Ilan Institute for Nano-Technology and Advanced Materials (BINA), Bar-Ilan University, Israel; Tower-Jazz Semiconductors, Migdal-Ha'Emek, Israel; Department of Physics, Bar-Ilan University, Israel; Institute for High-Frequency Technology, Technical University of Braunschweig, Germany*

Maxwell Fisheye for Integrated Optics
Y. Blinder, O. Bitton, R. Bruch, and U. Leonhardt, *Weizmann Institute of Science, Israel*

Complex Fiber Micro Devices
Shir Shahal, Moti Fridman, *Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Israel*

♦ Exploring 2.5 and 3D Integration to Meet the Bandwidth Density Challenge
Oded Raz, Chenhui Li, Teng Li, Patty Stabile, *Department of Electrical Engineering, TU/ Eindhoven, Netherlands*

Hall C

Photonics in Defense
Dr. Joelle Schlesinger, Dr. Ami Yaacobi

♦ Performance Assessment of Electro-optical Imagers: TRM4 Model and Imaging Simulation
Stefan Kessler, *Department of Optronics, Fraunhofer Institute of Optronics, System Technologies, and Image Exploitation IOSB, Ettlingen, Germany*

Quantification of Human Color Perception Applied in TRM Model for Range Prediction of Imaging Color Systems
Ephi Pinsky, *RAFAEL Advanced Defense Systems Ltd. Israel*

New Devices and Materials for Infrared Detectors
P.C. Klipstein, *SemiConductor Devices Research Department, Israel*

Applications of High Power Lasers in the Battlefield
Yehoshua Kalisky, *Electrical and Electronics Engineering Department, SCE, Israel*

Breaking Through the Atmospheric Barrier
Daniel Golubchik, *Rafael, Israel*

Hall D

Optical Engineering
Dr. Hanni Inbar

♦ Transforming Optical Networks Design - Intelligent Networks in the Nonlinear Regime
Polina Bayvel, *Department of Electronic & Electrical Engineering, University College London, UK*

♦ Nonlinear Optical Holograms for Shaping of Light Beams
Ady Arie, *School of Electrical Engineering, Tel Aviv University, Israel*

♦ Sub-Nanometer Overlay Metrology
Yuri Paskover, *KLA, Israel*

Beam Shaping Based on Aspheres and Freeforms
Stefan Klinzing, *Ulrike Fuchs, Thomas Hegenbart; Asphericon GmbH, Germany*

Layout and Analysis of Fused Silica Precision Glass Molding Processes
Tim Grunwald, Olaf Dambon, Thomas Bergs, *Fraunhofer IPT, Fine Machining and Optics Department, Germany; Tool Machine Laboratory (WZL) of RWTH Aachen University, Germany*

Hall E

IFLA - Fiber Lasers and Applications II
Dr. Zachary Sacks

♦ Unconventional High-Power Fiber Lasers for Improved Wavelength Coverage
Johan Nilsson, *University Southampton UK*

♦ Recent Developments in High Power Industrial Fiber Lasers
Scott Christensen, *IPG Photonics, USA*

♦ Advanced Fiber Laser Design with Pulse-On-Demand for
Next Generation Airborne Lidar Applications
Doron Barness, *VGen, Israel*

♦ Multi KW, High Power Laser with Single Mode (SM)
Dynamic Beam using Coherent Beam Combining (CBC)
Benayahu Urbach, Yaniv Vinde and Eyal Shekel, *Civan Ltd., Israel*

Fiber Optic Distributed Acoustic Sensing (DAS) Data Processing via Artificial Neural Networks
Lihi Shiloh, Avishay Eyal Raja Giryes, *PhD student, Faculty of Engineering, Tel Aviv University, Israel*

13:20 - 14:20 | Lunch Break (Lobby Floor)

13:50 - 14:20 | Posters Review of Topics: *Optical Engineering, and Ultrafast Phenomena*

Key: ♦=Invited/Keynote Speaker

Oasis 7th Conference and Exhibition on Electro-Optics

Tuesday, April 2, 2019

14:20 - 15:50 | Parallel Session 5

14:20 - 15:50 | Parallel Session 5

Hall A

Ultrafast Phenomena
Prof. Oren Cohen

♦ Spatiotemporal Dynamics of Optical Pulse Propagation in Multimode Fibers
Frank Wise, *Department of Applied Physics Cornell University, USA*

Self-Compressed Polarization Controlled Red Shifted Soliton from Supercontinuum for 1 µm CPA Systems
Zaharit Refaeli, Yariv Shamir, and Gilad Marcus, *Soreq, Israel*

Interferometric Attosecond Lock-In Measurement of Extreme Ultraviolet Circular Dichroism
Doron Azoury, Omer Kneller, Michael Krüger, Barry D. Bruner, Oren Cohen, Yann Mairesse, Nirit Dudovich, *Weizmann Institute of Science, Israel*

Two-photon Excitation of an Exciton-Polariton Condensate
Nadav Landau, Dmitry Panna, Sebastian Brodbeck, Christian Schneider, Sven Höfling, Alex Hayat, *Department of Electrical Engineering, Technion, Israel; Technische Physik, Universität Würzburg, Germany*

♦ Revealing the Motion of Hybrid Light-Matter Excitations by Ultrafast Microscopy
Tal Schwartz, Georgi Ro, *Physical Chemistry Department and Tel Aviv Center for Light-Matter Interaction, Tel Aviv University, Israel*

Hall B

Non-Linear Optics
Dr. Haim Suchowski

Opto-Mechanical Time-Domain Reflectometry
G. Bashan, H. H. Diamandi, Y. London, E. Preter, A. Zadok, *Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, Bar-Ilan University, Israel*

Observation of Strong Nonlinear Interactions in Parametric Down-Conversion of X-Rays into Ultraviolet Radiation
Or Sefi, *Bar-Ilan University, Israel*

THz Generation and Manipulation by a Nonlinear Metasurface Fresnel Zone Plate
Eviatar Minerbi, Shay Keren-Zur, Tal Ellenbogen, *Faculty of Engineering, Tel Aviv University, Israel*

Enhanced Frequency Doubling of High-Power CW Fiber Lasers in The Presence of Doubler Phase-Mismatch Through Injection of a Conjugate Seed Beam
Steven Jackel, Yishai Albeck, *Civan Advanced Technologies, Israel*

Stabilizing Soliton-Based Propagation in Nonlinear Optical Waveguide Loops by Frequency-Dependent Linear Gain-Loss and the Raman Self-Frequency Shift
Avner Peleg, Debananda Chakraborty, *Ort Braude College of Engineering, Israel ,New Jersey City University, USA*

Advantageous Hurdles in Rotational Echo Spectroscopy
Dina Rosenberg, Sharly Fleischer, Ran Damari, *School of Chemistry, Tel Aviv University, Israel*

Hall C

Photonics in Defense
Dr. Joelle Schlesinger, Dr. Ami Yaacobi

Mission Ready Optics: Conquering Frontiers in Aerospace & Defense Contamination Control with First Contact Polymers
James Hamilton, *University of Wisconsin-Platteville, Department of Chemistry & Engineering Physics, USA*

Controlled Distortion for Optical-Equivalent Zoom Lens with No Moving Parts
Paula Roit, *Rafael, USA*

Lenses on Diet
Oded Arnon, *Arnon Optical Engineering, Israel*

Bullet Speed System - Calibration Method
Uri Maurice, *QCC Hazorea, Israel*

♦ Photonic Integrated Interferometric Telescopes - Scalable and High-Resolution Imaging with 2D/3D Integrated Photonic Chips
S. J. Ben Yoo, *UC Davis, USA*

Hall D

Atomic and Quantum Optics
Prof. Barak Dayan

♦ Quantum Photonics for Computer Security and other Applications
Philip Walther, *Faculty of Physics, University of Vienna, Austria*

♦ New Frontiers for Light Storage at Room Temperature
Ofer Firstenberg, *Weizmann Institute of Science, Israel*

Demonstration of a Two-Qubit Photon-Atom Gate and Engineering Quantum States of Light
Ziv Aqua, Orel Bechler, Adrien Borne, Serge Rosenblum, Gabriel Guendelman, Ori Ezrah Mor, Moran Netser, Tal Ohana, Niv Drucker, Ran Finkelstein, Yulia Lovsky, Rachel Bruch, Doron Gurovich, Ehud Shafir, Barak Dayan, *Weizmann Institute of Science, Israel*

Quadrature Phase Detection in Atom Interferometry
Chen Avinadav, Dimitry Yankelev, Nir Davidson, Ofer Firstenberg, *Weizmann Institute of Science, Physics of Complex System, Israel; Rafael Ltd., Israel*

Squeezing-Enhancement of Stimulated and Spontaneous Raman Spectroscopy
Yoad Michael, Leon Bello, Michael Rosenbluh, Avi Pe'er, *Bar-Ilan University, Israel*

Hall E

IFLA - Ultrafast Fiber Sources and Related Applications
Dr. Zeev Zalevsky

♦ Coherent Pulse Stacking Amplification - Extending Fiber Chirped Pulse Amplification by Two Orders of Magnitude
Almantas Galvanauskas, *University of Michigan, USA*

♦ The Myths, the Reality, and the Unexplored Potential of SESAM Technology for Mode-Locking
Mircea Guina, *Optoelectronics Research Centre, Tampere University, Finland*

♦ Tailoring the Spectral Response in Fibers by Localized Fs Laser Modifications
S. Nolte, T. A. Göbel, M. Heck, R. G. Krämer, C. Matzdorf, D. Richter, *Friedrich Schiller University Jena, Institute of Applied Physics*

♦ Asynchronous Optical Sampling Technique for Pump-Probe Measurements
Benjamin Sprenger, *Friedrich Schiller University Jena, Institute of Applied Physics*

♦ Megawatt Single-Mode Lasers
Frank Wise, *Cornell University, USA*

15:50 - 16:20 | Coffee Break and Posters Review of Topics: *Solar Energy and Spectroscopic and Optical Sensing*

Key: ♦=Invited/Keynote Speaker

Oasis 7th Conference and Exhibition on Electro-Optics

Tuesday, April 2, 2019

16:20 - 17:50 | Parallel Session 6

16:20 - 17:50 | Parallel Session 6

Hall A
Solar Energy
Dr. Iris Visoly-Fisher

♦ Coupling "Regular" Quantum Dots with Lead Halide Perovskites
Dan Oron, *Dept. of Complex Systems Weizmann Institute of Science, Israel*

♦ Magnetism in Nominally Non-Magnetic Semiconductor Nanocrystals
Efrat Lifshitz, *Schulich Faculty of Chemistry, Russell Berrie Nanotechnology Institute, Solid State Institute, Technion, Israel*

Luminescent Solar Power-Quantum Separation between Free-Energy and Heat For Cost-Effective Base-Load Solar Energy Generation
Carmel Rotschild, Einat Carmon, Bar Simor, Bella Mali, Beatrice Uziely, Tamar Sella, *Department of Surgery, Department of Pathology, Sharet Institute of Oncology, Department of Radiology, The Hebrew University Hadassah Medical School; Mechanical Engineering Department, Technion - Israel Institute of Technology, Israel*

Observing the Green Flash in the Laboratory
Stephen G. Lipson, Tomer ben Aroush, Saber Boulahjar, *Physics Dept, Technion - Israel Institute of Technology, and Physics Dept, Ort Braude College, Israel*

Photon Management Utilizing Deep-Subwavelength Sidewall Features in Nanopillar Arrays for Broadband Absorption Enhancement of the Solar Radiation
Ashish Prajapati, Yevgeny Faingold, Shay Fadida, Jordi Llobet, Mariana Antunes, Helder Fonseca, Carlos Calaza, João Gaspar, Gil Shalev, *Ben Gurion University Electrical and Computer Engineering Department, Israel*

Hall B
Spectroscopic and Optical Sensing
Dr. Ayala Ronen

Measuring the BRDF Optical Properties of Surfaces
Dan Sheffer, Adam D. Devir, Alexey Kravchouk, Yair Bar Ilan, Gal Yehuda, Benny Milgrom, *IARD SENSING SOLUTIONS LTD, Israel*

Toward UAV Based Compact Thermal Infrared Hyperspectral Imaging Solution for Real-time Gas Detection Identification and Quantification
Stephane Boubanga Tombet, Frederick Marcotte, Eric Guyot, Martin Chamberland, *Telops Inc., France*

Multispectral and Thermal Detection Methods for Finding Missing Persons
Yishay Bruckental, Ori Cohen, Meir Chen, Yoav Stoler, Benny Milgrom, Gal Yehuda, Dan Sheffer, *IARD Sensing Solutions Ltd., Israel*

Snapshot Spectral Imaging Using Two Cameras, Optical Diffuser and Compressed Sensing Algorithms
Jonathan Hauser, *Faculty of Engineering, Tel Aviv University, Israel*

Silver Halide Fiber Sensors with Surface Chemistry for Specific Protein Immobilization Using Infrared Evanescent Wave Spectroscopy
H. Michael Heise, Sven Delebeck, Benjamin Schmitz, Andreas Nabers, Klaus Gerwert, Anne Habermehl, Ulrich Lemmer, *South-Westphalia University of Applied Sciences, Germany; Ruhr-University Bochum, Germany; Karlsruher Institut für Technologie, Germany*

Multi-Modal Fiber-Probe Spectroscopy for Tissue Diagnostics and Biological Fluid Sensing
F. S. Pavone, R. Cicchi, C. Credi, E. Baria, C. Dallari, O. Bibikova, V. Artyushenko, S. Centi, F. Ratto, R. Pini, *LENS, Italy*

Hall C
Electro Optics in Industry
Dr. Rami Cohen

Optical Wafer Inspection Challenges - Optimizing Optical Configuration for Detection
Tal Kuzniz, *Applied Materials, Process Development, Israel*

♦ Permanent USP Laser Marking of Stainless Steel Devices without Post-Processing
Daniel Seitz, *Coherent Munich GmbH&Co, Germany*

Early Detection of Fires from Space
Shimshon (Steven) Lashansky, Michael Gilichinsky and Yuval Erez, *Elop, Elbit system, Israel*

Yb: YAG and Nd:YAG Crystals for High Energy DPSSL
Karel Nejezchleb, Jana Preclíková, Štěpán Uxa, Martin Divoký, Mihai-George Muresan, *CRYTUR, spol. s r.o., Czech republic*
HILASE IoP ASCR

♦ The Recent Advances in Quantitative Imaging and Spectroscopy Instrumentation for EUV-SWIR Regime
Ravi Guntupalli, *Princeton Instruments, USA*

Hall D
Electro Optics Devices
Prof. Dan Marom

♦ Integrated Nanophotonics Technology and Applications
Y. Fainman, *Department of Electrical and Computer Engineering, University of California, San Diego, USA*

Superconducting Light-Emitting Diode
Shlomi Bouscher, Dmitry Panna, Krishna Balasubramanian, Alex Hayat, *Department of Electrical Engineering, Technion - Israel Institute of Technology, Israel*

E-SWIR High Operating Temperature P-N Photodetectors
I. Shafir, D. C. Elias, N. Sicron, M. Katz, N. Snapi, O. Klin, A. Glozman, E. Weiss, and G. Sarusi, *Solid State Physics Department, Applied Physics Division, Soreq NRC, Israel; SCD-SemiConductor Devices, Haifa, Israel; Electrooptics and Photonics Engineering Unit, Ben-Gurion University of the Negev, Beer-Seva, Israel*

Optical Gas Imaging Using Liquid Crystal Absorption Properties
Karni Wolowelsky, Amir Gil, Moshe Elkabets, Iliya Romm, Cukurel Beni, Carmel Rotschild, *Technion - Israel Institute of Technology, Israel*

♦ Chip-Scale Metrology: Coupling and Interfacing Atoms, Kerr Frequency-Combs and Cavitie
Liron Stern, *National Institute for Standards and Technology, CO, USA*

Hall E
IFLA - Fiber Components
Prof. Amiel Ishaaya

♦ Functionalized Micro-Nano-Fibres and Hybrid Photonic Crystal Fibres: The Role of New Materials
George Kakarantzas, *Theoretical and Physical Chemistry Institute, Athens, Greece*

♦ In-Fiber Speckle-Based Interferometry for Fabric Integrated, Non-Contact Bio-Sensor of Vital Signs
Zeev Zalevsky, *Faculty of Engineering, Bar Ilan University Israel*

♦ Water-Wave Lasers
Tal Carmon, *Technion - Israel Institute of Technology, Israel*

Improved Sensitivity and Spatial Resolution in Fiber Bragg Gratings Dynamic Strain Sensing System via Iterative Soft Thresholding Algorithm
Roy Shen-Tzur, Lihi Shiloh, Avishay Eyal and Raja Giryes, *Physical Electronics Department, Tel Aviv University, Israel*

High Resolution Heterodyne Measurement of Phase Shifted
Fiber Bragg Gratings
Garry Berkovic, Ehud Shafir, *Applied Physics Department, Soreq NRC Yavne, Israel*

Key: ♦=Invited/Keynote Speaker

Plenary Speakers

Professor Gérard Mourou, Nobel Prize Winner

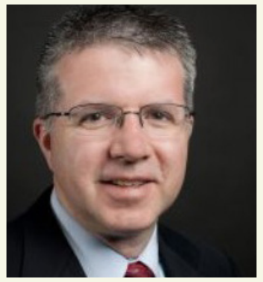
Gérard Mourou is Professor Haut-Collège at the École polytechnique. He is also the A.D. Moore Distinguished University Emeritus Professor of the University of Michigan. He received his undergraduate education at the University of Grenoble (1967) and his Ph.D. from University Paris VI in 1973.

He has made numerous contributions to the field of ultrafast lasers, high-speed electronics, and medicine. But, his most important invention, demonstrated with his student Donna Strickland while at the University of Rochester (N.Y.), is the laser amplification technique known as Chirped Pulse Amplification (CPA), universally used today. CPA revolutionized the field of optics, opening new branches like attosecond pulse generation, Nonlinear QED, compact particle accelerators.

It extended the field of optics to nuclear and particle physics. In 2005, Prof. Mourou proposed a new infrastructure; the Extreme Light Infrastructure (ELI), which is distributed over three pillars located in Czech Republic, Romania, and Hungary. Prof. Mourou also pioneered the field of femtosecond ophthalmology that relies on a CPA femtosecond laser for precise myopia corrections and corneal transplants. Over a million such procedures are now performed annually.

Prof. Mourou is member of the U.S. National Academy of Engineering, and a foreign member of the Russian Science Academy, the Austrian Sciences Academy, and the Lombardy Academy for Sciences and Letters. He is Chevalier de la Légion d'honneur and was awarded the 2018 Nobel Prize in Physics with his former student Donna Strickland.

Oasis 7th Conference and Exhibition on Electro-Optics



Professor Guillermo Tearney

Guillermo Tearney M.D., Ph.D. is Professor of Pathology at Harvard Medical School, Mike and Sue Hazard Family MGH Research Scholar, an Affiliated Faculty member of the Harvard-MIT Division of Health Sciences and Technology (HST), Fellow of the American College of Cardiologists (FACC), Fellow of the College of American Pathologists (FCAP) and heads his lab www.tearneylab.org at the Wellman Center for Photomedicine at the Massachusetts General Hospital. Dr. Tearney received his MD magna cum laude from Harvard Medical School and received his PhD in Electrical Engineering and Computer Science from the Massachusetts Institute of Technology.

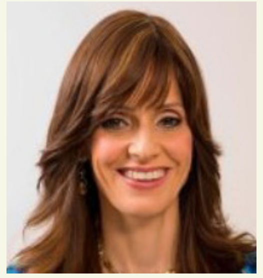
Dr. Tearney's research interests are focused on the development and clinical validation of noninvasive, high-resolution optical imaging methods for disease diagnosis. Dr. Tearney's lab was the first to perform human imaging in the coronary arteries and gastrointestinal tract in vivo with Optical Coherence Tomography (OCT), which provides cross-sectional images of tissue architectural microstructure at a resolution of 10 µm. He has also conducted many of the seminal studies validating OCT and is considered an expert on OCT image interpretation. Recently, Dr. Tearney's lab has invented a next generation OCT technology, termed µOCT, which has a resolution of 1 µm and is capable of imaging cells and sub cellular structures in the coronary wall.

Dr. Tearney has also developed several other technologies, including a confocal endomicroscope capable of imaging the entire esophagus, an ultraminiature three-dimensional endoscope, a highly efficient form of near field scanning optical microscopy (NSOM), and novel fluorescence spectroscopy and multimodality imaging techniques. Dr. Tearney is co-editor of The Handbook of Optical Coherence Tomorgraphy and has written over 200 peer-reviewed publications, including papers that have been highlighted on the covers of Science, Nature Medicine, Circulation, Gastroenterology, and Journal of American College of Cardiology.

Dr. Tearney's work extends beyond his laboratory at MGH, many of his technologies are being produced commercially and he has founded the International Working Group on Intracoronary OCT Standardization and Validation, a group that is dedicated to establishing standards to ensure the widespread adoption of this imaging technology.

Professor David Reitze

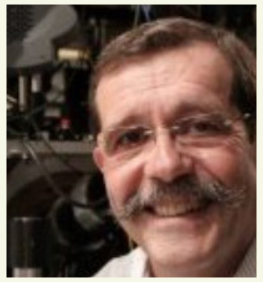
David Reitze holds joint positions as the Executive Director of the LIGO Laboratory at the California Institute of Technology and as a Professor of Physics at the University of Florida. His research focuses on the development of gravitational-wave detectors. He is a Fellow of the American Physical Society and the Optical Society, and was jointly awarded the 2017 US National Academy of Sciences Award for Scientific Discovery for his leadership role in LIGO. He is also a member of the international LIGO Scientific Collaboration that received numerous awards for the first direct detection of gravitational waves in 2015.



Professor Yonina Eldar

Yonina Eldar is a Professor in the Department of Mathematics and Computer Science, Weizmann Institute of Science, Rechovot, Israel where she heads the center for Biomedical Engineering and Signal Processing. She was previously a Professor in the Department of Electrical Engineering at the Technion. She is also a Visiting Professor at MIT, a Visiting Scientist at the Broad Institute, and an Adjunct Professor at Duke University and was a Visiting Professor at Stanford.

She received the B.Sc. degree in physics and the B.Sc. degree in electrical engineering both from Tel-Aviv University (TAU), Tel-Aviv, Israel, in 1995 and 1996, respectively, and the Ph.D. degree in electrical engineering and computer science from the Massachusetts Institute of Technology (MIT), Cambridge, in 2002. She is a member of the Israel Academy of Sciences and Humanities, an IEEE Fellow and a EURASIP Fellow. She has received many awards for excellence in research and teaching, including the IEEE Signal Processing Society Technical Achievement Award (2013), the IEEE/AESS Fred Nathanson Memorial Radar Award (2014) and the IEEE Kiyo Tomiyasu Award (2016). She was a Horev Fellow of the Leaders in Science and Technology program at the Technion and an Alon Fellow. She received the Michael Bruno Memorial Award from the Rothschild Foundation, the Weizmann Prize for Exact Sciences, the Wolf Foundation Krill Prize for Excellence in Scientific Research, the Henry Taub Prize for Excellence in Research (twice), the Hershel Rich Innovation Award (three times), the Award for Women with Distinguished Contributions, the Muriel & David Jacknow Award for Excellence in Teaching, and the Technion's Award for Excellence in Teaching (two times). She received several best paper awards and best demo awards together with her research students and colleagues, was selected as one of the 50 most influential women in Israel, and was a member of the Israel Committee for Higher Education. She is the Editor in Chief of Foundations and Trends in Signal Processing and a member of several IEEE Technical Committees and Award Committees.



Professor Alain Aspect

Born in 1947, Alain Aspect is an alumnus of Ecole Normale Supérieure de Cachan (now ENS Paris-Saclay) and Université d'Orsay. He has held positions at Institut d'Optique, ENS Yaoundé (Cameroon), ENS Cachan, ENS Paris/Collège de France, and CNRS. He is currently a professor at Institut d'Optique Graduate School (University of Paris-Saclay), and at Ecole Polytechnique, in Palaiseau.

He is a member of several science academies in France, USA, Austria, Belgium, UK, and Italy. Among many awards, he has received the CNRS Gold medal (2005), the Wolf Prize in Physics (2010), the Balzan prize on quantum information (2013), the Niels Bohr Gold medal (2013), the Albert Einstein medal (2013), the Ives medal of the Optical society of America (2013).

Alain Aspect research has borne on tests of Bell's inequalities with entangled photon (PhD, 1974-1983), wave-particle duality for single photons (1984-86, with Philippe Grangier); laser cooling of atoms below the one photon recoil (1985-1992, with Claude Cohen-Tannoudji); ultra-cold atoms, quantum gases, quantum atom optics and quantum simulators (1992- , in the Atom Optics group he has established at Institut d'Optique).

Oral Presentations

Monday, April 1, 2019

Opening Session

Passion Extreme Light

Gerard Mouro, Nobel Prize Winner
Ecole polytechnique, Palaiseau

Extreme-light laser is a universal source providing a vast range of high energy radiations and particles along with the highest field, highest pressure, temperature and acceleration. It offers the possibility to shed light on some of the remaining unanswered questions in fundamental physics like the genesis of cosmic rays with energies in excess of 1020 eV or the loss of information in black-holes. Using wake-field acceleration some of these fundamental questions could be studied in the laboratory. In addition extreme-light makes possible the study of the structure of vacuum and particle production in "empty" space which is one of the field's ultimate goal, reaching into the fundamental QED and possibly QCD regimes.

Looking beyond today's intensity horizon, we will introduce a new concept that could make possible the generation of attosecond-zeptosecond high energy coherent pulse, de facto in x-ray domain, opening at the Schwinger level, the zettawatt, and PeV regime; the next chapter of laser-matter interaction.

Seeing the Unseen in Patients: Advancing Disease Prevention and Treatment through Microimaging

Guillermo Tearney
Mass General Hospital, Harvard University, MIT

Today's gold standard for medical diagnosis is histology of excised biopsies or surgical specimens where tissue is removed from the body, processed, sectioned, stained, and looked at under a microscope by a pathologist. There are many limitations to this paradigm, including the facts that it is inherently invasive, time consuming, costly, and dangerous for some organs. Furthermore, oftentimes the diseased tissue is not readily seen by visual inspection. In these instances, the tissue is sampled at a random location, which can be highly inaccurate. If we could instead conduct microscopy inside the body, then we could overcome these limitations and provide real-time tools for screening, targeting biopsies, making diagnoses, and guiding intervention with cellular-level precision. This promise has motivated the development of a new field, termed in vivo microscopy, the goal of which is to obtain microscopic images from living human patients. Two in vivo microscopy technologies, confocal microscopy and optical coherence tomography, are currently available and in clinical use. Upcoming developments, such as whole organ microscopy, swallowable microscopy capsules, molecular imaging, and very high resolution microscopic imaging devices are in the pipeline and will likely transform how disease is diagnosed and medicine is practiced in the future.

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Session: Optical Engineering - Dr. Hanni Inbar

♦ Photonics-Based Particle Acceleration

Peter Hommelhoff, Robert L. Byer, R. Joel England
Physics Department, Friedrich Alexander University ErlangenNuremberg, Germany

Particle accelerators have a variety of uses from fundamental science and medical applications to semiconductor manufacturing, and they are often thought of as large, expensive facilities or instruments. The Accelerator on a Chip International Program (ACHIP), funded by the Gordon and Betty Moore Foundation, aims to use advances in fabrication and laser technologies to create a shoebox-sized particle accelerator that is a nano-photonic version of classical accelerators. With the help of transparent dielectric nanostructures, pulsed laser fields can accelerate electrons propagating in the nearfield of these structures to realize a principle identical to that of classical microwave accelerators, but shrunk in dimensions by around five orders of magnitude and driven with fields whose frequencies are larger by the same amount. Since the proof-of-concept experiments in 2013, the ACHIP team has now demonstrated all the elements required for building the "accelerator on a chip" including deflection and beam steering, as well as optical focusing and beam position monitors. Stable particle transport and acceleration from sub-100 keV up to 1 MeV has recently been conceived, putting the team even closer to one of the ACHIP goals of attaining a 1 MeV electron beam from a millimeter long chip.

♦ SWIR to Visible Up-Conversion Devices Development

Gabby Sarusi
Photonics and Electrooptics Engineering Unit and Ilsa Katz Center for Nano Scale Sciences, Ben-Gurion University Beer-Sheva, Israel

Short wavelength infrared (SWIR) imaging is an evolving field in the infrared detection and imaging thanks to its ability to provide good infrared capabilities and at the same time to work in room temperature. Most of the detector technologies are based on InGaAs photodiodes arrays attached to Si read-out circuit what makes them expensive choice similar to mid and far infrared sensors.

We propose a new approach of using SWIR detection and imaging by an upconversion device that we have developed in two main versions: The first architecture is based on InP/InGaAs Heterojunction focal plane array of 640x512 with 15mm pitch that was attached to a liquid crystal spatial light modulator. In this case the diode photocurrent induced local bias on the liquid crystal interface generation local light valve when using visible LED as the backlight.

As an alternative architecture, we propose an OLED based visible emitting section instead of the Liquid crystal, that is grown in this case on quantum dots based layer or nano columnar based layer of PbS or PbSe, respectively. Due to quantum size effect we experienced a blue shift from their original wavelength response as well as increases of the absorption induced by their large Bohr radius. Such concept is simpler and can provide a very clear image. The main advantage is the device can be attached to ant CMOS visible sensor that will convert it to SWIR sensor.

Non-Paraxial Fourier and Fresnel Optics in Design of Diffractive Optical Elements and Meta-Surfaces

Michael A. Golub
Tel-Aviv University, School of Electrical Engineering- Physical Electronics, Israel

Modern applications of diffractive optical elements (DOEs) and meta-lens surfaces frequently arrive to physical limits in achieving large fan angles and numerical apertures (NA). Fourier and Fresnel transforms are widely used in physical optics for calculations of light propagation and diffraction, albeit customarily restricted to paraxial approximation, low NAs and fail to account for actual wavefront aberrations. This research generalizes the approaches of Fourier optics in order to support highly convergent and divergent beams and large diffractions angles in DOE design.

Our combined use of stationary phase approximation and light diffraction resulted in formulation of a generalized “equivalent” Fresnel transform for off-axis and highly convergent or divergent light beams. Vectorial angular spectrum approach was applied for incorporation of the light polarization effects. Derived new diffraction integral makes use of a ray-tracing arrangement as a skeleton of a high-NA beam and provides local Fresnel-type transform for analysis of the diffraction effects, even in the far-field zone. The diffraction analysis on top of the geometrical structure of non-paraxial light beams match to well-known coherent imaging phenomena in laser light. We found out that the DOE phase function in non-paraxial design can be derived from respective paraxial solution by application of a tailored combination of local coordinate mapping with spatially variable rotation, magnification and astigmatism. Blurring effects on the output diffraction patterns of a structured light in the near and far fields were considered. It is shown that computational effectiveness of the developed design methods enables diffraction calculations for all fine details of an output light field in electrooptical systems with large fan-out angles. Computer simulation results for resonance-domain diffractive beam shapers of structured light will be presented.

Results of the research may have important applications in augmented and virtual reality, head mounted displays, gesture recognition, structured light, 3D imaging and sensing.

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Joint Design of Optics and Post-Processing Algorithms Based on Deep Learning for Generating Advanced Imaging Features

Shay Elmalem, Harel Haim, Raja Giryes, Alex M. Bronstein and Emanuel Marom
Faculty of Engineering, Tel-Aviv University, Israel

The recent and on-going Deep-Learning (DL) revolution (originated mostly from Computer Vision-CV), introduces a paradigm shift in almost all disciplines of signal processing. Traditionally, CV and Image Processing (IP) methods were based on hand-crafted feature extraction from the initial optical image, and then some hand-crafted classifier/filter was defined to achieve the result. The machine learning approach seeks to learn the 'classifier' stage using labeled data, i.e. the decision rule is not explicitly derived a priori from the data, but implicitly optimized using large set of manually labeled examples. DL methods take this approach to the next level, so that the feature extraction stage is also learned. In such approach the design is done by defining a parameterized computational model, and then training it (i.e. optimizing its parameters) end-to-end, using labeled data. After the tremendous success of DL for IP/CV applications, these days almost every signal processing task is analyzed using such tools. In the presented work, the DL design revolution is brought one step deeper, into the optical image formation process. By considering the lens as an analog signal processor of the incoming optical wavefront (originating from the scene), the optics is modeled as an additional 'layer' in a DL model, and its parameters are optimized jointly with the 'conventional' DL layers, end-to-end. This design scheme allows the introduction of unique feature encoding in the intermediate optical image, since the lens 'has access' to information that is lost in conventional 2D image. Therefore, such design allows a true holistic design of the entire IP/CV system. The proposed design approach will be presented with two different applications: an extended Depth-Of-Field (DOF) camera design and a passive depth estimation solution based on a single image from a single camera. Experimental results, as well as possible future research, will be presented and discussed.

A K-Domain Method for Fast Propagation of Electromagnetic Fields through Graded-Index Media

Huiying Zhong, Site Zhang, Rui Shi and Frank Wyrowski
LightTrans International UG, Germany

Graded-index (GRIN) media are widely used to model different situations: some components are designed specifically for GRIN modulation, e.g., multi-mode fibers, optical lenses or acousto-optical modulators; on the other hand, we might also talk of undesired effects where the refractive-index variation is due to stress or heating; there are also some natural effects which exhibit GRIN behavior, e.g., air turbulence or biological tissue. Modeling of such situations is quite challenging. It may require the application of finite-difference techniques in frequency or time domain, or other rigorous solutions of Maxwell's equations, which often results in too high a numerical effort for practical application. In this work we offer a k-domain-based method for the fast calculation of fields propagating through GRIN media. It is potentially fast because of two reasons: (1) in the k domain, Maxwell's equations for GRIN media become ordinary differential equations, so that we can take advantage of Runge-Kutta-type mathematical approaches to reduce the numerical effort; (2) taking advantage of fast Fourier transform algorithms to convert the convolution-type calculation (O(N2)) into a multiplication (O(N)). Several advantages arise when comparing this work with the famous split-step method: there is no paraxial approximation and the GRIN dependence along the main propagating direction can be accurately modeled.

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Session: Lasers and Applications - Dr. Ariel Bruner

♦ Challenges in Further Power Scaling of Single-Mode Fiber Lasers

Liang Dong
Clemson University, USA

Commercial fiber laser market has been experiencing rapid growth from almost nothing in 2000 to multi-billion US dollars today. Much of this growth is by displacing conventional solid-state and gas lasers. Fiber lasers are increasingly important industrial tools for machining, welding, marking, and material processing. Recently, increasing amount of the growth of fiber laser market is from the development of new markets such as dicing and material processing in semiconductor industry and glass machining and processing in electronics industry. A key factor in the rapid market growth is the robust and maintenance-free nature of high-power fiber lasers. Further power scaling of fiber lasers is critical to future market growth by increasing fiber lasers' capability and performance, and to expand fiber lasers' applications in new areas such as science frontiers (particle accelerators, space explorations, satellite launch, etc.) and defense (against drone, mortar, artillery shells, missile defense, etc.). I will review our recent studies in understanding limiting factors in average power scaling from fiber lasers, as well as in developing advanced optical fibers for high power fiber lasers.

♦ Femtosecond Pulse Generation by Using Single-Layer Graphene and Voltage-Controlled Graphene Supercapacitor Structures

Alphan Sennaroglu, Isinsu Baylam, Ferda Canbaz, Can Cihan, Nurbek Kakenov, Coskun Kocabas, Umit Demirbas, and Sarper Ozharar
Departments of Physics and Electrical-Electronics Engineering, Koç University, Turkey

Single-layer graphene and voltage-controlled graphene super capacitors can be employed as fast saturable absorbers to initiate femtosecond pulse generation from lasers. In particular, the ultrabroad absorption band of graphene makes it possible to initiate mode-locked operation of lasers over a broad spectral range. Furthermore, voltage-controlled graphene-based super capacitors can be employed as fast saturable absorbers with adjustable loss and can enable pulse generation from low-gain lasers. The presentation will describe some of our recent experiments, where single-layer graphene and/or voltage-controlled graphene supercapacitors were employed to generate femtosecond pulses from Cr^{4+}:forsterite (1250 nm), Cr^{3+}:LiSAF (850 nm), Ti^{3+}:sapphire (800 nm), and alexandrite (750 nm) lasers operating in the near infrared. By using single-layer graphene, pulses as short as 19 fs were generated near 850 nm.

Axiparabola: A Long Focal Depth, High Resolution Mirror for Broadband High Intensity Lasers

Slava Smartsev[1-2], Clement Caizergues[2], Kosta Oubrerie[2], Julien Gautier[2], Jean-Philippe Goddet[2], Amar Tafzi[2], Kim Ta Phuoc[2], Victor Malka[1-2], Cedric Thaury[2]

1. *Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 7610001, Israel*
2. *Laboratoire d'Optique Appliquée, Ecole Polytechnique, ENSTA, CNRS, Palaiseau, France*

Diffraction puts a fundamental limit to the distance over which a light beam can remain focused. For about 30 years, several techniques to overcome this limit have been demonstrated. Here, we propose a free-form reflective optics, namely the axiparabola, which allows to extend the production of "diffraction-free" beams to high peak power and broadband laser pulses. A 20 mm focal depth, off-axis axiparabola was manufactured. A focal line with a transverse size and an intensity which remained below 7 µm and beyond 4•10^17 Wcm^ (-2) respectively was successfully produced using a 0.85 J, 30 fs laser pulse. Achieved peak intensity (limited here by damage threshold of the mirror) can easily reached intensities above 1•10^18 Wcm^ (-2) when using 2.5 J laser pulse, opening a route for exploring relativistic regime over a long distance. As a first example of application, the axiparabola was able to generate a 10 mm plasma channel in a low density hydrogen gas and to guide a 20 TW laser over nearly its 10 Rayleigh lengths with 47% efficiency. We believe this novel optic will have a strong impact and will boost fields of research related to high laser power sciences.

Micron Precision Assembly for Sensors and Laser Systems on a Reconfigurable Industrial Platform

Sebastian Sauer, Tobias Mueller

Fraunhofer Institute for Production Technology, Germany

The assembly of high-end optical systems such as lasers is a delicate task. Traditionally it is done manually by well-trained personnel and proprietary knowledge of the company. Small sized and fragile components in lots of variants need to be handled on smallest surfaces, aligned in submicron precision and bonded with minimal impact on the alignment through the curing process. With rising numbers the need for industrial-level automated production solutions increases. Fraunhofer Institute for Production Technology managed to bring together the two worlds of traditional manual or semi-automated lab assembly to industrial level high volume production with the setup of a reconfigurable automated assembly cell tailored to the needs of optics industry.

The platform integrates active and passive alignment processes together with the modularity to run different products on the same machine. Due to the innovative software environment the company's personnel can bring in its expertise to the assembly process without expertise in industrial control or revealing knowledge to third parties. For ultra-precision bonding modules for pico liter dispensing and calibration are integrated.

So far the active alignment of FAC lenses, automotive headlight, LiDAR and driving assistant cameras as well as fiber assembly processes and gesture recognition sensors have been produced on the platforms. Fraunhofer Institute for Production Technology's activities in the field of optics assembly starting from prototyping to high volume production, assembly platform as well as sample applications will be presented in this talk.

High Energy Tunable Narrow Bandwidth Tm:YAP Laser

Salman Noach (JCT) ,Uzziel Sheintop (JCT), Eytan Perez (JCT), Rotem Nahear (JCT), Pavel Komm (HUJI), Gilad Marcus (HUJI)

Jerualem College of Technology, Israel

The 2µm wavelength range offers the basis for a wide range of applications such as material processing, medical applications, sensing and atmosphere monitoring, defense and basic research as a pumping source for the mid infrared region lasers [1] some of those applications require the laser source to have one or more properties such as tunability, narrow spectral bandwidth, nearly diffraction limited beam and pulsed radiation. Tm lasers are efficient dopants at this spectral range allowing to achieve high energy pulses due to their long life-time and the cross relaxation effect increasing quantum efficiency.

The Tm:YAP is a promising laser due the excellent optical and the thermomechanical parameters. The Tm:YAP emission is naturally polarized and its wavelength is coincide with water peak absorption.

In contrast to CW lasers, tunability with Q-switch pulsed lasers exhibited until now, relatively poor results from 10µJ up to 180 µJ per pulse [2-4].

Here we demonstrate for the first time a combination of a narrow band-width, active Q-switched tunable Tm:YAP with high energy pulses. The spectral bandwidth was narrowed down to 0.15 nm FWHM, while 35 nm of tuning range between 1926 nm and 1961 nm was achieved using a pair of YAG Etalons. The laser was actively Q-switched using an acousto-optic modulator, producing mJ level energy pulses along the whole tuning range at a repetition rate of 1 kHz. Up to 2.3 mJ of energy per pulse was achieved at a pulse duration of 29 ns at a wavelength of 1935 nm, corresponding to a peak-power of 79.2 kW and at a slope efficiency of 25 %. The combination of both high energy pulsed lasing and spectral tunability, while maintaining narrow bandwidth across the whole tunability range, enhances the laser abilities, which could enable new applications in the sensing, medical and material processing fields.

Session: Medicine and Biology - Prof. Dror Fixler

♦ Wide-field Time-correlated Single Photon Counting (TCSPC) for Fluorescence Lifetime Imaging (FLIM) Microscopy

Klaus Suhling

King's College London, UK

Time-correlated single photon counting (TCSPC) is a widely used, sensitive, precise, robust and mature technique to detect photon arrival times, for example in fluorescence spectroscopy and microscopy. In fluorescence microscopy, it is often implemented with beam scanning and single point detectors, to perform Fluorescence Lifetime Imaging (FLIM). However, here we have implemented a camera-based wide-field TCSPC method, where the position and the arrival time of the photons are recorded simultaneously. This has some advantages for certain types of microscopy.1

We employ a photon counting image intensifier in combination with a 1 MHz frame rate CMOS camera, thus combining an ultra-fast frame rate with single photon sensitivity. Compatibility of this method with live-cell imaging was demonstrated by imaging europium-containing beads with a lifetime of 570 µs in living HeLa cells, as well as decays of ruthenium compound Ru (dpp) with lifetimes from around 1 to 5 µs.2,3 Moreover, the invariant phosphor decay of the image intensifier screen can be used for accurate timing of photon arrival well below the camera exposure time. By taking ratios of the intensity of the photon events in two subsequent frames, decays of ruthenium and iridium-containing compounds with lifetimes of around 1 µs were measured with 18.5 µs frame exposure time (54 kHz camera frame rate), including in living HeLa cells.4 These approaches bring together advantageous features for time-resolved live cell imaging such as low excitation intensity, single photon sensitivity, ultra-fast camera frame rates and short acquisition times.

We also report on nanosecond FLIM microscopy based on a 40 mm diameter crossed delay line anode detector with 100s of picosecond time resolution, where the readout is performed by three standard TCSPC boards.5,6 We apply this wide-field TCSPC detector to FLIM of cells labelled with membrane dyes imaged with a TIRF microscope.

♦ All Optical Monitoring of Cancer Treatment Efficiency with Overtone Absorption Spectroscopy on Microfibers with Random Surface Roughness

Alina Karabchevsky
Ben-Gurion University, Israel

Ovarian cancer is the fifth leading cause of female cancer deaths due to the low survival rates, largely driven by the late stage diagnoses. The diagnosis at earlier stages of ovarian cancer has a 5-year relative survival rate of 92%. Unfortunately, when a patient is diagnosed at a late stage, the survival rate of such a patient is as low as 30%. This poor survival rate is primarily related to recurrent disease of chemotherapy-resistant tumors, hence, adjustment of the appropriate second and third line of chemotherapy (or targeted therapy) is required to improve survival rate. However, a response to treatment is currently monitored weeks after initial treatment and adjustment of ultimate treatment in a personal manner is not yet feasible.

Nowadays, cancer progression and response to therapy is determined primarily by imaging. Here, we developed the guided-light microfiber device with random surface roughness for monitoring the ovarian cancer treatment efficiency. We studied the optical mode evolution in microfibers while varying the diameter of the core in aqua medium and found that 2.5 mm is an optimal core diameter for efficient excitation of molecular overtone vibrations in the inter-cellular medium of cancer cells. As a proof-of-concept, we demonstrated that anti-cancer treatment using, PI3K inhibitor, induced both growth arrest and altered the spectral lines associated with the ovarian cancer cells. We observed that 500 nM GDC-0032 affects tumor cells proliferation and their spatial distribution. We anticipate that such infrared-sensitive spectral system can be used to early detection of response to cancer therapy and further utilized for the bedside applications to speed-up the therapeutic decision and to adjustment of appropriate treatment.

Improved Photoacoustic Image Reconstruction of Clinical Data

Idan Steinberg[1], David M. Huland[1], Sarah Hooper[1], Tal Klap[2], Sanjiv Sam Gambhir[1],
1. Stanford University
2. Independent

Molecular photoacoustic imaging of targeted agents in vivo can be a valuable tool for surgery and biopsy guidance. Recently, we've developed a clinical combined photoacoustic and ultrasonic system. The system was used for imaging both resected ex vivo pancreatic cancer samples labeled with functionalized IRDye-800 as well as in vivo transrectal imaging of prostate cancer patients with and without Indocyanine green (ICG) contrast agent. Delay and sum algorithms were used for the reconstruction of images in real-time, albeit with a relatively low Signal to Background Ratio (SBR). The low contrast resulted in poor image quality that limited the clinical value of such a system. Here, we aim to improve the image quality by utilizing model-based photoacoustic reconstruction.

To that end, the relationships between each grid point on the imaging plane and the measured signals were studied and formulated. We included the effects of non-ideal detector elements and the medium. Non-negative inversion of those relations allowed for real-time accurate photoacoustic imaging. The improved algorithm was applied to clinical data previously acquired from ex vivo resected samples of pancreatic cancer patients (N=5) as well as in vivo clinical prostate trans-rectal pre-biopsy scans (N=20) with and without ICG.

Results from all studies show that despite the low number of elements (<64) and minimal viewing angle (<10o) of the current device, the improved reconstruction technique was capable of reconstructing high-quality images. Imaging of a wire phantom showed a two-fold improvement in resolution as well as an increased SBR by 20 dB. For ex vivo imaging of pancreatic tumors, better localization of the tumor site and its extent were achieved. In vivo results pre- and post-injection show that the model-based reconstruction is more sensitive to the absorption of ICG. Our results demonstrate the feasibility and potential of the system for tumor-specific imaging.

Advanced Fiber Optic Solutions for Biomed Photonics in 0.3-16μm Range

Viacheslav Artyushenko

Art Photonics GmbH, Germany

Review of the latest progress reached in specialty fiber optics of very broad spectral range span from 400nm to 16μm. The most actual fiber solutions for minimal invasive laser medicine and biomedical diagnostics using IR-imaging and key spectroscopy methods will be presented with hot examples of new applications: multi-spectral tissue diagnostics to detect malignant tissue ex-vivo and in-vivo, minimal invasive laser angioplasty, inter-corporal InfraRed-imaging of tissue during RFA procedures in heart, etc. Fiber optics enable to realize more effective and less invasive operations by intraoperative control - with the resulted fusion of diagnostics with therapy procedures in so called "theranostics".

Spectral fiber sensing for label free analysis of tissue composition helps to differentiate malignant and normal tissue to secure minimal invasive, but complete tumor removal or treatment. All key methods of Raman, fluorescence, diffuse reflection & MIR-absorption spectroscopy will be compared when used for the same spot of tissue - to select the most specific, sensitive and accurate method or to combine them for the synergy enhanced effect. Examples of multi-spectral tissue diagnostics will be presented for several organs together with the preclinical trials of the 1st tumor sensor prototypes.

The 1st results on Mid IR-fiber endoscopy imaging will be presented - used for thermography control of RadioFrequency Ablation (RFA) for pulmonary vein isolation (PVI) - the common treatment used against atrial fibrillation (AF).

Unique advantage of PIR-fiber transmission in Mid IR-range 3-16μm enables also to run non-contact temperature control for various laser-tissue operations: ablation, coagulation and welding of vessels, - providing non-contact control of tissue temperature at the spot of laser beam on tissue. This feature helps to design "smart" laser systems for minimal invasive operations.

Infrared Fiber-Optic Sensing Method for Early Detection of Melanoma and other types of Skin Cancer

Svetlana Basov[1], Max Platkov[2], Ilan Goldberg[3], Eli Sprecher[3], Andrey Goriachev[4], Yosef Raichlin[4], Yair Dankner[5], Marcelo Weinstein[2], Abraham Katzir[1]

1. *Tel-Aviv University, Israel*
2. *Nuclear Research Center Negev (NCRN), Israel*
3. *Tel-Aviv Medical Center, Israel*
4. *Ariel University, Israel*
5. *Shenkar College, Israel*

Background: Melanoma is an aggressive skin cancer with the highest skin-cancer mortality rate worldwide. The annual melanoma incidence has increased dramatically over the past few decades. Melanoma thickness and prognosis are directly related; while curable at early stages, higher mortality is associated with thicker, advanced, tumors. Melanoma may sometimes resemble benign lesions or nevi and lack of treatment on time may pose a risk to the patient. Therefore, an accurate early detection of melanoma and distinguishing between it and other types of skin cancer is crucial for patients' survival. Mid-IR spectroscopic methods are capable of detecting such skin transformations at very early stages by assigning spectroscopic fingerprints to the various forms of disease. This may be used for the detection of various types of skin cancers and in particular for the early detection of melanoma.

Methods: The Applied Physics Group at Tel-Aviv University (TAU) developed a novel system for measuring the mid-IR spectrum of biological tissues, without a need for biopsy. It is based on mid-IR transmitting optical fibers. We performed preliminary measurements on the skins of patients at the Dermatology Department, at the Tel-Aviv Medical Center. When a physician revealed a suspected tumor, we carried out mid-IR spectral measurement. The tumor was then biopsied and sent to traditional histopathology, for diagnosis.

Results: 90 patients were measured. Out of them 5 had melanoma, 7 basal-cell-carcinoma and 3 squamous-cell-carcinoma. We developed an algorithm to distinguish between the mid-IR spectra of the lesions and the non-melanoma ones. Clear spectral differences were seen between pathological and benign samples. The preliminary application of our algorithm was very promising.

Conclusion: The new method will be used for the detection and the identification of various types of skin cancer, without the need for biopsy. This will have far reaching effects on dermatology.

Automated Transscleral Laser Trabeculoplasty

Zachary Sacks

Belkin Laser Ltd., Israel

Conventional Selective Laser Trabeculoplasty (SLT) is a well-established, safe, and effective therapy. The conventional method requires multiple manual beam targeting of the trabecular meshwork through a goniolens placed in physical contact with and rotated on the cornea. Due to the skill level required, this procedure, although effective in lowering intra-ocular pressure (IOP), has not achieved significant penetration as a first line glaucoma treatment. We describe a very rapid automatic Direct Selective Laser Trabeculoplasty (DSLT) delivery system based on trans-scleral application of the laser to the trabecular meshwork and report on the preliminary results of our first-in-human clinical study. Geffen, et al. (2017), have demonstrated the effectiveness of trans-scleral SLT in reducing IOP, by applying 100 laser shots of a conventional SLT laser directly to the sclera overlying the trabecular meshwork without a gonioscope. We have developed a device that has automated this procedure to deliver about 100 laser shots in about one second. The device consists of a double Nd:YAG 66Hz laser, automatic image acquisition scanner to aim the beams on target, and an eye tracker assembly to compensate for eye movements. Patient safety and treatment effectiveness are ensured by validated software and algorithms. This device is now undergoing First-in-man clinical trial in Sheba Medical Center, Israel. The current results indicate IOP reduction similar to traditional SLT, with the advantages of an automated procedure and shorter treatment time enabling the use of this procedure as a first line glaucoma treatment by general ophthalmologists. The GLAUrious (Horizons 2020) randomized multicenter controlled masked trial has been initiated to validate the initial results.

Session: Electro Optics in Industry - Dr. Rami Cohen

♦ Optimize Electro-Optics Mechanical Design for Additive Manufacturing

Elad Yosef

Mechanical Engineer, Elbit Systems-ISTAR, Israel

Electro-optics mechanical design challenges required new thinking and advance tools in order to achieve the desire goals, systems requirements became more and more restricted considering LOS (Line of Site) accuracy and total system weight and volume.

In order to achieve light weight systems and still keep systems performance Mechanical designers need to adapt new advance structure optimization tools that change the traditional way of thinking of parts design, this new advance tools help to achieve light weight structure while keeping structure stiffness to maintained systems performance.

In this talk we will review topology optimization tools advantage and limitations, the gaps that still need to be covered and how this method related to Additive manufacturing technology.

♦ Embedded 3D Interconnects in Glass Substrates by a Combined Laser Trenching and Printing Process

Yuval Berg

Department of Physical Electronics, Faculty of Engineering, Tel-Aviv University, Israel

Control of grooved structured profiles can be achieved by a femtosecond laser ablation process in different materials - dielectrics, semi-conductors and metals. In addition, high accuracy additive manufacturing techniques, e.g. laser induced forward transfer (LIFT), provide flexibility in 3D printed structures deposited on a variety of substrates. The combination of those two laser technologies allows the integration of embedded circuitry and other components, such as microfluidic and micromechanical systems, paving the way to a wide range of applications where conventional subtractive patterning is a problem. Embedding is advantageous in terms of mechanical stability and adherence of the printed metal allowing a favorable aspect ratio and thereby providing improved electrical properties of the conducting lines as well as planar and debris-free surfaces. In this work we report on a combination of laser grooving and laser printing processes and demonstrate the manufacturing of buried copper structures in a grooved borosilicate glass substrate.

Oasis 7th Conference and Exhibition on Electro-Optics

♦ State Of the Art Precision Metrology with UltraLow-Noise Optical Frequency Combs

Benjamin Sprenger, Dag Schmidt, Michele Giunta, Wolfgang Haensel, Marc Fischer, Ronald Holzwarth

Menlo Systems, Germany

The newest generation of optical clocks, based on trapped single ions or optical lattices, are approaching accuracies of 10^-18. The optical frequencies are on the order of hundreds of THz, so conventional electronics cannot keep up.

Ultra-low-noise optical frequency combs can be used as a clockwork, if their stability approaches 10^-19 and beyond. We show state of the art frequency comb characterization, which proves their ability to function as optical clockworks. Furthermore, the ability to transfer spectral purity throughout the visible and infrared spectral regions is demonstrated.

This is a prerequisite for comparisons of clocks based on different atomic species. A comparison is drawn to the traditional transfer oscillator scheme, with a fully locked ultra-low-noise optical frequency comb.

Development of Thin Glass-based Technologies for Photonic System Integration

Henning Schröder

Fraunhofer IZM, Germany

Monolithic chip-level integration of electronics and photonics advances and increase I/O challenges in terms of photonic integration and packaging dramatically. Precise assembly capabilities and approaches are fundamentally demanded to provide reliable electronic interconnects and high optical coupling efficiency. Thin glass is a very attractive material for integration of optical functionalities in electronic substrates and glass core and glass body photonic interposer are promising integration platforms for PIC. The talk presents glass body interposer realised for mid-board-engines by thermal, RF, and optical design and advanced technology. Furthermore thermal ion exchange will be presented for graded index buried single mode optical waveguides in thin glass sheets which can be laminated within PCB stack-ups resulting in so-called EOCB.

Review on Free Form Optics: Advantages and Challenges Of An Emerging Technology

Raginski Igor

Optical Designer, Electro - Optics Department, Rafael, Israel

Free form optical elements are lenses or mirrors with generalized profiles that do not follow the axial or spherical symmetries which are common in classical optical elements. Such components can be used in optical designs for solving asymmetrical problems, and for decreasing systems' weight, volume and costs by reducing the number of optical elements.

This new technology imposes different challenges for the optical community, designers and manufacturers. For example, choosing the suitable geometrical and mathematical model, performing analysis with tolerances. The greatest challenges nowadays are manufacturing and metrology of free form elements, since most of the existing machinery and measuring methods were developed for spherical or aspherical elements.

We will discuss the advantages of free form optics and present some examples of applications with free form elements. Then we will show a few challenges that we have encountered using such elements in the design process, and methods of dealing with them. Finally, we will present some examples for challenges we have faced in the manufacturing process.

Session: IFLA - Specialty Fiber - Dr. Yoav Sintov

♦ Materials Development for Advanced Optical Fibers

John Ballato
Clemson University, USA

This talk provides a road-map for simple core/clad optical fibers exhibiting marked reduced optical nonlinearities achieved through judicious consideration of the enabling materials from which they are made. More specifically, the material properties that give rise to parasitic (Brillouin and Raman) scattering and transverse mode instabilities (TMI) are discussed as are results on fibers developed based on this materials approach. Optical power scaling estimations and property diagrams associated with Brillouin gain and thermo-optically induced mode instabilities are employed to graphically represent general trends with composition. The goal is to provide compositional directions to realize intrinsically low nonlinearity, silica-based optical fiber that can achieve the power-scaling goals of future high energy fiber laser applications.

♦ Image Transport through Glass-Air Disordered Optical Fiber

Axel Schülzgen, Jian Zhao, Yangyang Sun, Zheyuan Zhu, Jose Enrique Antonio-Lopez, Rodrigo Amezcua Correa, Shuo Pang
University of Central Florida, CREOL

We present results on image transport based on specialty optical fiber with a random silica-air distribution in the transverse plane and an invariant cross-section in the longitudinal direction. Due to transverse Anderson localization caused by strong random scattering in the transverse plane, light propagating through the fiber experiences a localization effect that can be utilized to transport images. Based on the low attenuation of the air-silica fiber, we achieve robust and high-quality optical image transfer through meter-long fibers even if the fiber is strongly bend. The quality of images transported through this fiber is shown to be comparable to, or even better than, that of images sent through commercial multicore imaging fiber. The effects of variations of wavelength and feature size on transported image quality are investigated experimentally.

Combining the glass-air disordered transmission fiber with image reconstruction by a trained deep neural network, we demonstrate a fully flexible, artifact-free, and lensless fiber-based imaging system. The system provides the unique property that the training performed within a straight fiber setup can be utilized for high fidelity reconstruction of images that are transported through either straight or bent fiber making retraining for different bending situations unnecessary. In addition, high quality image transport and reconstruction is demonstrated for simple objects as well as for various cells that are several millimeters away from the fiber input facet eliminating the need for additional optical elements at the distal end of the fiber. This novel imaging system shows great potential for practical applications in endoscopy including studies on freely behaving subjects.

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♦ Large Mode Area Fiber Designs for Megawatt Peak Power Generation in REPUSIL-Based Tapered Amplifiers

Matthias Jäger[1], Martin Leich[1], André Kalide[1], Martin Lorenz[1], Tina Eschrich[1], Anka Schwuchow[1], Jens Kobelke[1], Jörg Bierlich[1], Claudia Aichele[1], Katrin Wondraczek[1], Dörte Schönfeld[2], Andreas Langner[2], Clemens Schmitt[2], Jaqueline Plass[2], Gerhard Schötz[2], Heraeus Quarzglas[2]
1. Leibniz Institute of Photonic Technology (IPHT) Jena, Germany
2. GmbH & Co. Hanau, Germany

We report on various all-solid LMA fiber designs for achieving very high peak powers in Ytterbium-doped fiber amplifiers with nearly diffraction-limited beam quality. The investigated LMA fibers are step-index fibers based on the powder-sinter (REPUSIL) technology ensuring cost efficiency and a homogeneous dopant and refractive index distribution. In particular, we are exploring fiber designs with very large core-to-clad ratios (from 1:3 to 1:4.5), resulting in very short fiber amplifiers for efficient suppression of undesired nonlinear optical effects. The LMA fibers are characterized as main amplifier stage in a picosecond master oscillator power amplifier (MOPA) setup. Local adiabatic tapers are employed for proper mode field matching and fundamental mode excitation, enabling a robust monolithic coupling of the 28ps seed pulses. Various fiber designs with core diameters between 45 and 60µm are experimentally investigated, including different level of Yb-doping as well as different core-to-clad ratios to achieve high pump absorption. To reduce fiber core NA we have codoped our highly Yb-doped REPUSIL fiber with fluorine.

We have achieved a nearly diffraction-limited beam quality with M2=1.2 for a low Yb-doped fiber with high pump absorption of 40dB/m @ 976nm. The highest efficiency of the low Yb-doped fiber is 65%, strongly depending on its length. For this fiber design the optimal length is examined and found to be a trade-off between efficiency and stimulated Raman threshold. The fluorine co-doped fiber is presented for the first time showing a very high peak power in in excess of 1 MW at 0.75m fiber length with a measured M2 value of 1.5 and without significant stimulated Raman scattering (SRS).

♦ Mode Area Scaling Through a Multicore Supermode Fibre

Seongwoo Yoo
Nanyang Technological University, Singapore

Muti-core fibres are receiving more attention due to its unique feature - multiple waveguides in a shared common cladding platform. Muti-core fibres with a large pitch size have been investigated for spatial division multiplexing (SDM) fibre communication as well as title aperture beam combining. Alternatively, a multi-core fiber can be designed with a small pitch size to promote cross-talk among the individual cores, leading to supermode generation and beam combining. We recently explored this option in collaboration with Ben-Gurion University. This talk will present the recent collaborative efforts for fibre development and laser performances. Furthermore, a new approach to high absorption low NA fiber will be presented as an effort to provide a large-mode-area step index fibre for pulsed laser applications.

Session: Micro and Nano Optics - Prof. Koby Scheuer

♦ Kerr-Microresonator Solitons for Ultraprecise Measurements

Scott B. Papp
NIST and University of Colorado, USA

Optical-frequency combs are versatile tools for measuring time, identifying chemicals, sensing distance, and supporting quantum-information science. A new direction is to produce frequency combs through intriguing nonlinear behaviors of light in Kerr microresonators. I will discuss experiments at NIST with nanofabricated ring resonators and photonic-crystal reflectors in which we have explored novel soliton dynamics and demonstrated ultraprecise functionalities, such as optical-frequency synthesis and optical-clock metrology.

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Parametrical Optomechanical Oscillations in Microbubble Resonators: Suppression, Enhancement and Route to Chaos

Silvia Soria, Xavier Rosello-Mecho, Daniele Farnesi, Gabriele Frigenti, Martina Delgado-Pinar, Miguel V. Andrés, Giancarlo Righini, Gualtiero Nunzi Conti
IFAC-CNR Institute of Applied Physics "N. Carrara", Italy

Whispering gallery mode resonators (WGMR) have attracted a great interest in the last decade. WGMR have been fabricated in different geometries, solid and hollow, spherical, toroidal, and bottled shaped. Hollow spherical WGMR or microbubble resonators (MBR) are the last arrived in the family of resonators. The approach used for their fabrication is based on surface tension driven plastic deformation on a pressurized capillary, similar to glassblowing. Using such technique we are able to fabricate large surface area and thin spherical shells with high quality factor (Q), quite dense spectral characteristics and anomalous total dispersion.

MBR are efficient phoxonic cavities that can sustain both optical photons and acoustic phonons. It has been demonstrated that MBR can be used to study Kerr comb patterns and Stimulated Brillouin Scattering (SBS). Radiation pressure is another mechanism that also leads to excitation of acoustic phonons with lower frequencies, in the range of hundreds of kHz to tens of MHz in the case of silica MBR. The frequency of such oscillations occurs very close to the mechanical eigenfrequencies of the cavity.

MBR show two different routes to chaos: periodic and quasi-periodic doubling bifurcation and a set of discrete lines into a continuum, and finally a continuum. For very large MBR, the transition to chaos is abrupt. We have also studied the temporal behavior of the cavity, the coexistence and the suppression of the oscillation while generating Kerr combs. The oscillation suppression occurs when the light is coupled to the resonance with red detuning (the pump has a lower frequency than the resonance). In this case, we generate photons in other resonant modes equally spaced (four wave mixing processes).

Keywords: Kerr combs, parametrical optomechanical oscillations, chaos, microresonators

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Optomechanically-Driven Microstructures for Targeted Drug Delivery Applications

Pavel Ginzburg, Ivan I. Shishkin, Hen Markovich, Hani Barhom, Andrey Machnev, Roman E. Noskov, Yael Roichman

Tel-Aviv University, Israel

Targeted drug delivery is one the main research directions in biophysical investigations with far-going practical applications. Majority of the studies concentrate on statistics-based investigations, where cell cultures under test are soaked with nanoparticle solution under study followed by observation of changes using cell-counting techniques. Here, we propose a conception, where the studies can be performed on the level of individual isolated objects.

Optomechanical manipulation with the help of focused laser beams (holographic optical tweezers (HOT)) opened a venue for a variety of different studies. As the first essential part of specific addressing to individual objects concept, HOT will be used for cell manipulation, assisted by auxiliary structures. This approach also allows preventing photo-induced damage of objects under study. In particular, a new generation of auxiliary optomechanical tools, fabricated by direct laser writing technique, are developed. A set of microtools is used for demonstrations of immobilization and manipulation (displacement and 'out of plane rotation' rotation) of a range of different biological cells, including tumour cells.

The second part of the 'HOT-assisted targeted drug delivery' concept requires development of nano-scale capsules, suitable for efficient optomechanical manipulation. Here we investigate biomineral calcium carbonate nanoparticles, self-assembled in the meta-stable form of vaterite. Those structures will be shown to be efficiently manipulated with the help of optical tweezers. In particular both translational and rotational mechanical degrees of freedom can be obtained. Loading of vaterite particles with different type of materials is achieved via controlled diffusion protocols.

For the summary, 'HOT-assisted targeted drug delivery' concept will be presented. All the results are based on the very recent and unpublished developments.

Optical Skyrmions: A New Texture of Light

Shai Tsesses[1], Kobi Cohen[1], Evgeny Ostrovsky[1], Bergin Gjonaj[1,2], Netanel H. Lindner[3], Guy Bartal[1]

1. *Andrew and Erna Viterbi department of Electrical Engineering, Technion – Israel Institute of Technology, Haifa, Israel*
2. *Faculty of Medical Sciences, Albanian University, Durrës st., Tirana 1000, Albania*
3. *Physics Department, Technion – Israel Institute of Technology, Haifa, Israel*

Introduction: Skyrmions - exotic, three-dimensional topological defects - exist in a very limited range of physical systems. Most notably, skyrmions in magnetic compounds are currently considered as a promising route towards high-density magnetic information storage and transfer, as well as a possible tool in the field of spintronics.

Background: Skyrmions are defined over a given area (a lattice site, in the case of a skyrmion lattice). They also possess a winding number, called the skyrmion number (S), which is a measure for the integer number of times a normalized field spans the entire unit sphere, in that given area.

Objectives: We generate and explore the traits of a skyrmion lattice in Electro-magnetic waves, a feat which has yet to be achieved.

Methods: In our experimental system, surface plasmons are excited at a gold-air interface by a hexagonally shaped coupling slit, providing the required boundary conditions to create a plasmonic skyrmion lattice. A scattering near-field scanning optical microscope, which enables phase-resolved measurement of the out-of-plane electric field, is used for the measurement.

Results: Our calculations show that when six Transverse-Magnetic (TM) surface plane waves interfere, a skyrmion number of S=1 may appear in each lattice site created by the interference. The theoretical robustness of optical skyrmions to losses was also calculated. We experimentally verified our predictions, creating a skyrmion lattice with an average skyrmion number of S=0.997 per lattice site.

Conclusions: The optical skyrmion lattice may allow the first stimulated creation of skyrmions in matter, through light-matter interactions. Additionally, optical skyrmions could produce new schemes for optical information processing, storage, and transfer, such as the simultaneous emission of all possible polarizations in a structured, phase-locked, and coherent way through fluorescence or harmonic generation; and the creation of a complex, polarization-dependent Berry curvature via Kerr nonlinearity.

Oasis 7th Conference and Exhibition on Electro-Optics

Spin-Locking In 2D and 3D Plasmonic Structures

Yuri Gorodetski
Ariel University, Israel

Nanophotonic circuitry requires an ability to externally control and analyze optical signals tightly confined in subwavelength volumes. Various schemes of surface plasmon (SP) routing have been presented using active and passive metasurfaces. One of the most appealing approaches is the use of plasmonic spin-orbit interaction where the incident light spin state is efficiently coupled to an orbital degree of freedom of the surface wave. Recently, a major attention has been drawn to an additional plasmonic degree of freedom - the transverse spin (TS) and some application for near-field plasmonic manipulations have been presented. It has been shown that the transverse spin results from the circulation of the resultant of the vector field in a transverse plane with respect to the propagation direction. Remarkably, the TS is independent of the polarization and solely arises from the amplitude ratio between the longitudinal and the transverse field components which is directly obtained from Maxwell's equations. Accordingly, TS is locked to the SPs propagation direction and can appear with a single handedness. This additional degree of freedom has been already utilized for the spin-dependent unidirectional plasmonic excitation, for nanoparticle tweezing, etc. In contrast with the previously demonstrated spin-orbit interactions, where the handedness of the incident light polarization has leaded to the geometric phase of the SPs, here we study a direct longitudinal to transverse spin conversion (LTS). We demonstrate a number of 3D nanoscale systems where the optical behavior crucially affected by the LTS and may exhibit anomalous polarization effects due to the spin-locking phenomenon. We also propose a spin-locking metasurface incorporating a transverse spin of the SP wave to selectively route the near-field beams. Owing to the combination of the oblique incidence of circularly polarized light with the grating we achieve a precise directional control over the plasmonic distributions.

Session: Atomic and Quantum Optics - Prof. Barak Dayan

♦ Quantum-Dot Quantum Nanophotonics

Nir Rotenberg
University of Copenhagen, Denmark

The recent dramatic improvement in the optical properties of semiconductor quantum dots, coupled with their integration into high quality nanophotonic structures, make them a promising system upon which quantum networks could be based [1]. Here, we review recent experimental progress on the performance of quantum dots coupled to waveguides as a mean to engineer light-matter interactions. We discuss recent improvements in the quality of the emitted photons [2, 3] and the way in which they can be manipulated, focusing on single-photon nonlinearities [4] and chiral interactions [5]. Finally, we will touch on the functionalities enabled by this fine control over light-matter interactions at the single emitter and few photon level, for example in the creation of spin-dependent switches or a proposed bell-state analyzer.
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Effect of Stokes Shift on Polariton Dynamics

Jussi Toppari, Gerrit Groenhof, Tero Heikkilä
Nanoscience Center and Departments of Physics and Chemistry, University of Jyväskylä, Finland

The strong coupling between optically active molecules and confined light, like surface plasmon polaritons (SPP) or cavity photons, manifests itself by appearance of Rabi splitting at the energy of the molecular absorption in the absorption spectrum. The split is due to formation of new hybrid polariton states between confined light and molecules. These states change the energy landscape of the molecules and can thus lead to changes in their chemical behavior. This has initiated a field called polariton chemistry, where the strong coupling is used to control the chemistry. Thus, it is important to know polariton relaxation pathways and whether their lifetime is sufficient for the suggested control.

We have studied the dynamics of polaritons by analyzing their emission in two different cases including SPPs or optical cavities. While the emission of SPP is purely transverse magnetic (TM), the strong coupling with molecules induces transverse electric (TE) component to the emission of a SPP-molecule polariton. In the case of randomly oriented molecules the TM/TE ratio of the polariton emission clearly follows its molecular contribution. In addition, we show that the Stokes shift of the molecule influences the emission - the larger the shift the lower the TE emission. For optical cavities, the angle dependent emission of molecule-cavity-photon polaritons reveal different relaxation pathways depending on the Stokes shift. While molecules with high Stokes shift seem to undergo regular molecular relaxation after excitation and emit a polariton at the fluorescence wevelength, the system with no Stoke shift will relax to the lower polariton via coupling to vibrational states.

Our recent quantum mechanical molecular dynamic simulations show that in the case of high Stokes shift the polariton indeed very rapidly localizes to a single molecule excitation and decays to the fluorescing state. This supports well the experiments and above explanation.

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Quantum Free-Electron Wavepacket Interactions with Light and Matter

Avraham Gover[1], Yiming Pan[1,2], Bin Zhang[3]
1. Department of Electrical Engineering Physical Electronics, Tel-Aviv University, Israel
2. Department of Physics of Complex Systems, Weizmann Institute of Science, Israel
3. National Laboratory of Solid State Microstructures and School of Physics, Nanjing University, China

The wave-particle duality nature of a single free-electron quantum wavefunction, and its measurability via its interaction with radiation, have been the subject of inquiry and controversy since the early inception of quantum theory1. Based on an innovative model of finite size quantum electron wavepacket (QEW), we present a general theory of electron interaction with radiation and matter. This model encompasses on one hand, free-electron radiation sources and accelerators, such as Free-Electron Laser (FEL) and Dielectric Laser Accelerator (DLA)2, and on the other hand - Photon-Induced Near-Field Electron Microscopy (PINEM). This corresponds to transition from the classical point-particle regime, characterized by a continuous shift or spread of the electron energy spectrum, to the quantum regime, characterized by discrete quantized energy spectrum of the interacting QEW.

In the quantum regime of PINEM, the interaction is due to a process of multi-photon emission/absorption, experienced by the electron in the near field of a laser-illuminated matter structure3. Here we report a new operating regime - "Anomalous-PINEM", where the post-interaction discrete energy spectrum is due to coherent quantum interference fringes between the interaction-scattered components of the incident QEW, when it is initially energy chirped.

We further discuss the measurability of spontaneous and stimulated radiative interactions of optically modulated QEW4 in the single electron and modulation-correlated multi-particle regimes and their possible application in interrogation of quantum transitions in matter.

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Strong Coupling of THz Fields to Collective Molecular Vibrations

Sharly Fleischer, Ran Damari, Omri Weinberg, Natalia Demina, Katherine Akulov, Daniel Krotkov, Tal Schwartz

Tel-Aviv University Physical Chemistry Department and Tel-Aviv Center for Light-Matter Interaction, Israel

When light is compressed into a region comparable to its wavelength, its interaction with matter can overcome all the incoherent processes, which profoundly changes its nature. In this "strong-coupling" regime, the wavefunctions of the photons and the material excitations are mixed to form coherent light-matter states known as cavity-polaritons. During the past years, strong coupling with molecules has been increasingly drawing interest, driven by the opportunities for opto-electronic devices as well as the ability to tailor molecular properties and chemical processes. Previously, strong light-molecule coupling has been observed with electronic transitions (excitons) or intra-molecular vibrational transitions occurring in the mid-IR. Such "vibrational strong coupling" was recently shown to affect processes occurring at the electronic ground-state, by targeting a specific bond inside the molecules.

Here, we demonstrate for the first time strong coupling of collective vibrations in organic molecule crystallites, occurring at THz frequencies. Unlike previously studies of vibrational strong coupling, here the cavity mode is coupled to inter-molecular vibrations, i.e. an oscillatory motion of the molecules with respect to one another.

In our experiments, we performed THz time-domain spectroscopy on a metallic cavity filled with α-lactose crystallites, which exhibit a sharp absorption peak at 0.53 THz. We observed a Rabi-splitting of ~70 GHz, signifying strong coupling between the collective vibration in the α-lactose crystallites and the cavity. Furthermore, in the time-domain, we directly observed vacuum Rabi-oscillations with a period of ~15psec, corresponding to the reversible, quantum-coherent energy exchange between the molecules and the cavity. Interestingly, this coherence is observed at room-temperature, even though all the relevant energy scales are much lower than kT.

This observation of strong coupling with THz molecular vibrations take strong coupling into a new class of material, including polymers, proteins and other organic materials, in which collective, spatially extended degrees of freedom participate in the dynamics.

Photonic Quantum Walks with Cyclic Geometry as Versatile Quantum Simulators

E. Cohen (Bar Ilan University), W.-W. Pan, X.-Y. Xu, Q.-Q. Wang, Z. Chen, M. Jan, Y.-J. Han, C.-F. Li, G.-C. Guo (University of Science and Technology of China)

Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Israel

Quantum walks serve as novel tools for performing efficient quantum computation and simulation. I will start by presenting our recent experimental demonstration [1] of photonic quantum walks for simulating cyclic quantum systems, such as hexagonal lattices or aromatic molecules like benzene. In this experiment we explore the wavefunction dynamics and the probability distribution of a quantum particle located on a six-site system, alongside with simpler demonstration of three- and four-site systems, under various initial conditions. Localization and revival of the wavefunction are demonstrated, as well as topological invariants such as the Zak phase. I will then describe our on-going experiment [2] for entangling this cyclic quantum walk with a linear one, allowing to simulate cylindrical structures such as carbon nanotubes. Furthermore, we employ this system for simulating the Dirac equation in the 5-dimensional Kaluza-Klein (KK) theory underlying String theory. The KK theory was designed to unify the gravitational and electromagnetic forces by introducing a fifth compact dimension, which we can now simulate and analyze using our experimental setup.

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Session: Medicine and Biology - Prof. Dror Fixler

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♦ On-Chip Silicon Photonic Biosensors

Sharon M. Weiss
Vanderbilt University, USA

Silicon has traditionally been associated with being the most favorable material platform for most modern microelectronics technologies due to its electronic properties, compatibility with lithographic patterning, and earth abundance. However, silicon is also a favorable material platform for supporting light propagation. This talk will focus on design approaches for enhancing light-matter interaction on a silicon platform for the application of molecular detection of chemicals and biomolecules. Optical biosensors based on silicon hold great promise as low-cost, lab-on-chip sensor array elements due to their compatibility with both standard microelectronics processing and standard surface functionalization techniques. The sensitivity of these optical biosensors is fundamentally derived from the level of interaction between light and the target molecules to be detected. Specific approaches to increasing light-matter interaction of silicon photonic biosensors will be presented. In particular, several experimentally realized biosensor designs on silicon-on-insulator and porous silicon substrates, including photonic crystals and ring resonators will be described, along with examples of specific molecular detection of proteins, DNA, and other small molecules using these silicon photonic components.

♦ Stain-Free Quantitative Phase Imaging of Sperm Cells for In Vitro Fertilization

Natan T. Shaked
Faculty of Engineering, Tel-Aviv University, Israel

Exogenous stains are not allowed for human sperm cells during intracytoplasmic sperm injection (ICSI), a common type of in vitro fertilization, in which the clinician chooses a single sperm cell and injects it into the female egg. This leads to large margin of human error, due to the fact that the sperm morphology cannot be well analyzed. We have shown that interferometric phase microscopy (IPM) can provide a new stain-free tool for sperm morphological analysis, which is at least as good as the one provided for stained sperm. Moreover, we have lately used stain-free IPM to characterize the cell level of DNA fragmentation, providing a good predictor for DNA fragmentation, and potentially increasing ICSI success rates.

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Three Photon Adaptive Optics for in-vivo Mouse Brain Imaging

David Sinefeld, Fei Xia, Mengran Wang, Chunan Wu, Tianyu Wang, Hari P. Paudel, Dimitre G. Ouzounov, Thomas G. Bifano and Chris Xu
Applied and Engineering Physics, Cornell University, USA

Multiphoton fluorescence microscopy is a well-established technique for deep-tissue imaging with subcellular resolution [1]. Three-photon fluorescence microscopy (3PM), when combined with long wavelength excitation was shown [2,3] to allow deeper imaging than two-photon fluorescence microscopy (2PM) in biological tissues, such as mouse brain, because out-of-focus background light can be further reduced due to the strong localization of the higher order nonlinear excitation. As was demonstrated in 2PM systems, imaging depth and resolution can be by applying adaptive optics (AO) techniques which are based on shaping the scanning beam using a spatial light modulator (SLM). In this way, it is possible to compensate for tissue low order aberration and to some extent, to compensate for tissue scattering.

It was already demonstrated that the compensation for signal degradation due to aberrations will be much more significant in higher order nonlinear imaging such as 3PM than in 2PM [4, 5]. Therefore, the impact of adding AO to three photon fluorescence system should be more significant and will show stronger signal improvement resulting in deeper imaging depth and higher resolution in the mouse brain.

In this work, we present a 3PM AO system for in-vivo mice brain imaging. We use a femtosecond source at 1300 nm to generate 3-photon response in YFP mouse brain and a microelectromechanical (MEMS) SLM to apply different Zernike phase patterns. The nonlinearity of the 3PM fluorescence signal is used as a feedback to calculate the amount of phase correction without direct phase measurement, allowing fast convergence towards stronger signal.

Our results show that after applying correction we achieve signal improvement in the cortex and the hippocampus beneath 1-mm depth inside the brain and demonstrate diffraction limited imaging in the cortical layers of the brain, including imaging of dendritic spines.

Imaging Tympanic Membrane Surface Vibrations - In Vivo

Matan Hamra, Shadi Shinnawi, Ariel Weigler, Mauricio Cohen Vaizer, Dvir Yelin
Biomedical Engineering, Technion - Israel Institute of Technology, Israel

The tympanic membrane plays a key role in the human hearing by translating air pressure waves into bone vibrations, and its function and dynamics are directly linked to various pathologies and hearing disorders. Current methods for imaging tympanic membrane dynamics, including stroboscopic holography and Doppler OCT would be challenging for in-vivo applications due to high system complexity or the need for point-by-point scanning. Here, we demonstrate in-vivo imaging of the tympanic membrane dynamics of a human volunteer using interferometric spectrally encoded endoscopy (ISEE). Briefly, in ISEE, spectral interference between a reference signal and the reflectance along a spectrally encoded transverse line is captured by a high speed (50 kHz) spectrometer. Using single-axis scanning across the membrane provides a two-dimensional interferometric data that is later analyzed using specialized software. The imaging probe includes a single optical fiber, optics for light delivery and scanning of the tympanic membrane, and a dedicated port for transmitting the excitation acoustic signals comprised of multiple single-frequency stimuli. The study could be used for developing a compact system that could be incorporated into conventional clinical otoscopes for providing functional information noninvasively with unprecedented resolution and sensitivity.

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Eye Tracking Control in Visual Prostheses

Avi Caspi
Jerusalem College of Technology, Israel

Background: Visual scanning by sighted individuals is done using eye and head movements. In contrast, scanning using the Argus II is solely done by head movement, since eye movements can introduce localization errors.

Objective: To test if a scanning mode utilizing eye movements increases visual stability and reduces head movements in Argus II users.

Methods: Eye positions were measured in real-time and were used to shift the region of interest (ROI) that is sent to the implant within the wide field of view (FOV) of the scene camera. Participants were able to use combined eye-head scanning: shifting the camera by moving their head and shifting the ROI within the FOV by eye movement. Ten blind individuals implanted with the Argus II retinal prosthesis participated in the study. A white target appeared on a touchscreen monitor and the participants were instructed to report the location of the target by touching the monitor. We compared the spread of the responses, time to complete the task, and amount of head movements between combined eye-head and head-only scanning.

Results: We demonstrated that by correlating the pupil location at the onset of the stimulation with the head-centered percept location we can calibrate and align the eye tracker on Argus II users. All participants benefited from the combined eye-head scanning mode. Better precision, i.e. narrower spread of the perceived location, was observed in 8 out of 10 participants. Nine of 10 were able to adopt a scanning strategy that enabled them to perform the task with significantly less head movement.

Conclusions: Our experimental results, with implanted blind patients, show that integrating a calibrated eye tracker reduces the amount of head motion and improves visual stability in prosthesis users.

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Session: IFLA - Mid-IR Fibers and Sources - Prof. Amiel Ishaaya

♦ Silica-Based Hollow-Core Optical Fibres: A New Paradigm for the Mid-Infrared

Jonathan Knight
Department of Physics, University of Bath, UK

Silica optical fibers have been remarkably successful. Silica is inexpensive, easily available with high purity, chemically inert, physically robust and easy to draw to fiber. It also has low optical losses over a range of wavelengths extending towards 2.5 microns. At longer wavelengths into the mid-infrared, the absorption of silica increases dramatically, and it is not usually considered as a material for optical fibers beyond 3 microns wavelength. Instead, fibers for those longer wavelengths have previously been formed from softer glasses, with lower-frequency phonon absorption edge and consequently reduced optical attenuation. These alternative fiber materials do not offer all the same advantages as silica as described above.

The last few years have seen dramatic development of low-loss single-mode fibers for the mid-infrared spectral range based on the use of silica, in which the light is guided not within the silica but within a hollow core. These fibers combine the strength and robustness of silica with very low optical losses in the spectral band to 5 microns, low dispersion, single-mode performance, very low nonlinear response and high damage threshold, and are readily drawn in long lengths. Optical losses have been demonstrated to be as much as 20,000 times below those of bulk silica, making them comparable to the lowest losses ever demonstrated in any fiber for this spectral band. They thus have the potential to be a preferred solution, or even the only available solution, for many applications. The design and performance of these fibers will be reviewed, and their potential for further development discussed.

♦ Recent Advances in Mid-Infrared Fiber Lasers

Real Valle, M. Bernier, V. Fortin, F. Maes, S. Duval, F. Jobin, Y.O. Aydin, P. Paradis
Center for Optics Photonics and Lasers, Laval University, Canada

Mid-infrared (MIR) fiber lasers hold great promise for several applications in the environment and the biomedical sectors. Now, most of these applications present high requirements in terms of average or peak power, pulse energy, or in terms of spectrum coverage. To date, laser emission from mid-IR fiber lasers at wavelength longer than 2.5 mm were mainly obtained from fluorozirconate glass optical fibers doped with either Er+3, Ho+3 or Dy+3 rare-earth ions. In particular, the Er+3 ion has shown trend exceeding performances in the neighborhood of both 3.0 and 3.5 mm. Accordingly, 42W of output power near the O-H molecular bond fundamental absorption peak as well as nearly 6W at the peak of the C-H molecular bond absorption were reported. Mid-IR fiber laser pulsed counterparts were also developed involving both Q-switched and gain-switched regimes of operation and leading to pulsed output in the ns range near both 3.0 and 3.5 mm. Pulse energies exceeding the 100 mJ level with an average power of 10 W were namely produced from a rugged monolithic cavity operating at 2825 nm. The femtosecond regime was also studied via a fiber based ring laser cavity and 207 fs pulses with 3.5 kW peak power near 2.8 mm were obtained. This femtosecond FL was subsequently used to seed an Er+3-doped-fiber amplifier, resulting (via the soliton self-frequency shift process) in a watt level femtosecond fiber source tunable from 2.8 to 3.6 mm.
A survey of the previous recent developments in both cw and pulsed Mid-Infrared fiber lasers will be presented.

♦ Bringing Infrared Fiber Components to the Market

Eric Geoffrion, Mohammed Saad
Thorlabs (Formerly IRPhotonics), Canada

Fluoride glass fibers have been discovered more than 40 years ago. They have experienced extraordinary development for their theoretical ultra-low loss, 0.001 dB/km two orders of magnitude lower than silica fiber losses. Almost all research projects at that time were targeting long haul telecommunication applications. Unfortunately, after 25 years of intensive development, the ultra-low loss goal wasn't reached yet. But significant progress has been made in glass and fiber technologies. During the last two decades tremendous progress has been made in mid-infrared optical fibers technology and especially in fiber strength. We have reported the highest strength ever for infrared fiber, 136 kpsi. Current, standard commercial infrared optical fibers have loss in the range of 5 to 30 dB/km and mechanical strength ranging from 50 to 90 kpsi. These improvements have made the fibers much easier to handle and thus to be integrated in different devices. The fibers can be cleaved, polished and spliced.

The presentation will report the latest development of mid-infrared technology and some fiber lasers we already released.

♦ Fiber-Bulk Hybrid Mid-Infrared Lasers Based on Transition Metal Doped Ceramic Chalcogenides

S.B. Mirov[1,2], I.S. Moskalev[2], M.S. Mirov[2], S. Vasilyev[2], V.V. Fedorov[1,2], D.V. Martyshkin[1,2], O. Gafarov[1], V. Smolski[2]

1. Department of Physics, University of Alabama at Birmingham, Birmingham, USA
2. IPG Photonics Corporation, Southeast Technology Center, Birmingham, USA

We present a breakthrough in high-power CW Tm-fiber pumped Cr:ZnS/Se laser systems, enabling output power levels of up to 140 W near 2500 nm, and 32 W at 2940 nm with corresponding optical efficiencies of 62% and 30%.

This talk also summarizes recent improvements of output characteristics of Er-fiber pumped polycrystalline Cr:ZnS/Se master oscillators in Kerr-Lens-Mode-Locked regime.

Current research efforts include power scaling of fs Cr:ZnS/Se lasers beyond the 25 W level, development of octave-spanning oscillators, further power and energy scaling of fs Cr:ZnS/Se laser amplifiers to 1.5 mJ level, and extension of ultrafast laser oscillations to 2 - 20 μm spectral range, including a first ultrafast optical parametric oscillator based on random phase matching in disordered ZnSe ceramics.

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Session: Micro and Nano Optics - Prof. Koby Scheuer

Multifunctional Spectrally Interleaved Geometric Phase Metasurface

Elhanan Maguid, Michael Yannai, Arkady Faerman, Qitong Li, Jung-Hwan Song, Vladimir Kleiner, Mark L. Brongersma, Erez Hasman

Faculty of Mechanical Engineering and Russell Berrie Nanotechnology Institute, Technion - Israel Institute of Technology, Israel

Metasurfaces enable the manipulation of light's disorder strength in a two-dimensional photonic system. Here we report on the spectral interleaving of an ordered and a disordered system within a geometric phase metasurface. The efficiency of prevalent interleaving techniques is limited by the number of functions incorporated within the metasurface. We present a shared-aperture extinction cross-section approach relying on interleaving of spectrally selective nano-antenna arrays, each having a large extinction cross-section, thus allowing to overcome this limitation. Using this approach, we realize a Silicon based spectral interleaving metasurface for spectrum dependent disguise, holographic tagging and imaging of a target object. The shared-aperture extinction cross-section concept opens the path for the generation of multiple, efficient and spectrally-resolved functions in a two-dimensional photonic system. Moreover, metasurfaces facilitate the interleaving of multiple topologies in an ultra-thin photonic system. We realize a dielectric spectrally-interleaved metasurface generating multiple interleaved vortex beams at different wavelengths. By harnessing the space-variant polarization manipulations enabled by the geometric phase mechanism, a vectorial vortex array is implemented. The presented order-disorder interleaving approach offers new prospects for the manipulation of light's entropy; whereas the interleaved topologies concept can greatly enhance the functionality of advanced microscopy and communication systems.

Guiding Surface Plasmon Polaritons on Curved Surfaces

Ana Libster-Hershko, Roy Shiloh, Ady Arie
Faculty of Engineering, Tel-Aviv University, Israel

While the motion of a classical particle bounded to a surface depends only on the local curvature, the dynamics of a quantum particle depends also on the mean surface curvature. As was theoretically studied in the context of quantum mechanics by da Costa [PRA 23, 1982 (1981)]. The influence of the mean curvature can be experimentally observed using surface plasmon polaritons (SPPs), which are naturally surface-bounded waves. They provide an ideal environment for studying the propagation dynamics of quantum particles, relying on the similarity between the Schrodinger and the paraxial Helmholtz equation. The bending of the metal-dielectric surface provides an effective potential that enables to guide SPPs. However, up till now, the theoretical predictions on curved-surface propagation [Della Valle and Longhi, J. Phys. B: At. Mol. Opt. Phys. 43, 051002] were not tested.

Here we experimentally show a plasmonic curved-space propagation on a book-cover structure [Optica 6, 115 (2019)]. This structure is obtained by a plane bent around the surface of a cylinder of radius R_1 and an angular aperture 2θ. The fabricated structures are formed by heat assisted reflow of patterned photoresist, followed by silver deposition. A metal grating is then used to excite the SPP beam, and its propagation is measured with a near field scanning optical microscope. By using the book-cover surface curvature, a new guiding mechanism based on the curvature-induced potential was demonstrated. For the opposite case of an inverse book-cover with the same local curvature but inverted mean curvature, the SPPs rapidly diffract. This observation is in excellent agreement with the theory of a quantum particle confined to a curved surface, where the mean curvature of the surface determines the propagation dynamics. In addition to guiding, curved metal-dielectric surfaces open exciting new possibilities for manipulating SPPs, without the need for varying the refractive indices.

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Reconfigurable Semiconductor Metasurface Resonators

Tomer Lewi
Faculty of Engineering and, Institute of Nanotechnology and Advanced Materials, Bar-Ilan University, Israel

Metasurfaces exploit optical phase, amplitude and polarization engineering at subwavelength dimensions to achieve unprecedented control of light. The realization of all dielectric metasurfaces has led to low-loss flat optical elements with functionalities that cannot be achieved with metal elements. However, to reach their ultimate potential, metasurfaces must move beyond static operation and incorporate active tunability and reconfigurable functions. The central challenge is achieving large tunability in subwavelength resonator elements, which requires large optical effects in response to external stimuli.

We present here a study of various materials that exhibit large modulation of optical constants and are used to implement active tunable resonators. Starting from free carrier and thermo-optic (TO) effects in Si and Ge, we demonstrate tuning of high order Mie resonances by several linewidths. By exploiting the peak TO coefficient of Si near its bandgap, we realized reconfigurable Si metasurface modulators and tunable metafilters. We also show that at elevated temperatures, the TO coefficient has a strong dependence on the temperature, due to the excitation of thermal free carriers. Finally we show thermally tuned InSb metalens with variable focal length and operating wavelength.

Furthermore, we demonstrate ultra-wide dynamic tuning of PbTe meta-atoms fabricated via laser ablation and a novel solution processing approach. Taking advantage of the anomalously large TO coefficient and high refractive index of PbTe, we demonstrate high-quality factor Mie-resonances that are tuned by several linewidths with temperature modulation as small as $\Delta T \sim 10K$. We reveal that the origin for this exceptional tunability is due to an increased TO coefficient of PbTe at low temperatures. When combined into metasurface arrays these effects can be exploited in ultra-narrow active notch filers and metasurface phase shifters that require only few-kelvin modulation. We conclude with demonstration of broadband electrically tuned Ge-VO2 resonators capable of independent modulation of both reflection amplitude.

Non-Equilibrium Theory of “Hot” Electron Generation in Plasmonic Nanostructures under Illumination - Thermal vs. Non-Thermal Effects

Yonatan Sivan, Yonatan Dubi

Ben-Gurion University, Israel

Understanding the interplay between electrons, photons and phonons is a fundamental problem in physical chemistry. Recently, interest in this problem resurfaced in the context of non-equilibrium (aka "hot") electron distributions, which are key for applications such as photo-catalysis, photodetection, up-conversion etc.

Here, we report a formulation of the theory of hot electron generation in plasmonic nanostructures under continuous wave illumination, taking into account non-equilibrium as well as thermal effects. Specifically, we consider the effect of both photons and phonons on the electron distribution function, and calculate self-consistently the increase in electron and lattice temperatures above ambient conditions (as observed experimentally). This enables us to go well beyond the limits of existing theories, which are limited to low illumination intensities and pulsed illumination. We determine the steady-state electronic distribution and deviations from equilibrium under different conditions, and evaluate the rise in (the steady-state) electron and lattice temperatures. Doing so, we correct the multitude of errors in existing formulations of the problem. Crucially, we find that the deviation from thermal equilibrium is extremely small in metals, such that the absorbed photon power gets almost completely converted to heat, and the fraction of power causing a deviation from equilibrium is 10-12 orders of magnitude smaller.

These results have direct implication on the interpretation of the nonlinear optical response of metals, which we reveal to be essentially predominantly thermal, where the non-equilibrium effects are very weak in comparison, and observable only for coherent processes (such as wave mixing etc.). Finally, we discuss the prospect of using the hot electrons for photocatalysis in light of recent experiments, identify the efficiency and the photocatalytic performance, and show an exceedingly long series of mistakes in interpretations of experimental results published in high impact journals.

Optimization of Coupling Gratings for LightguideBased Displays

Site Zhang[1], Roberto Knoth[1], Stefan Steiner[1], Yichen Liu[2], Christian Hellmann[3], and Frank Wyrowski[2]

1. *LightTrans International UG*
2. *Applied Computational Optics Group, Friedrich-Schiller-Universität Jena, Germany*
3. *Wyrowski Photonics GmbH, Germany*

Recently, lightguide-based display devices are drawing growing interest, and one of the key technologies of such devices is the coupling gratings for the lightguides. In this work, we start with the optimization of coupling gratings for a single incident direction and analyze the effect when such optimized gratings are used in different situations. By that, it will be shown that getting uniformly high efficiencies over a wide field of view (FOV) is very challenging. Next, we analyze the situation of lightguide coupling in the spatial-frequency domain and present the possible strategies and freedom in the design. Finally, we present a complete optimization example for a desired FOV and evaluate the optimized uniformity in the diffraction efficiencies.

Random Topological Defects-Induced SpinEnabled Photonic Transport by Metasurfaces

Bo Wang, Elhanan Maguid, Michael Yannai, Vladimir Kleiner, Erez Hasman

Technion - Israel Institute of Technology, Israel

Over the past decades, topology has provided unique insights into numerous physical phenomena. Here, we report on a topological mechanism for spin-dependent photonic transport. We observe photonic topological defects of bound vortex pairs and unbound vortices generated from a two-dimensional array of nanoantennas, i.e., a metasurface, which is achieved by randomly inserting local deformations in the metasurfaces, inducing the Pancharatnam-Berry phase. The observed spin-dependent bound vortex pairs are established as the origin of the photonic spin Hall effect, i.e., a subdiffraction-limited spin-split mode in momentum space, while the spin-dependent unbound vortices induce random spin-split modes throughout the entire momentum space as a random Rashba effect. The topological phenomena - creation of bound vortex pairs and unbound vortices - indicate the universality of the topological effect for particles of different natures.

Session: Lasers and Applications - Dr. Ariel Bruner

♦ Progress in VECSEL Technology and Emerging Applications

Mircea Guina, Jussi-Pekka Penttinen

Tampere University, Finland
Vexlum Ltd., Tampere, Finland

Optically pumped vertical external cavity surface emitting lasers (OP-VECSELs) have emerged at the frontier between semiconductor and solid-state laser technologies, motivated by the need to combine essential benefits of these laser platforms [1]. The use of disk-like semiconductor gain media with optical pumping in compact external cavity architectures enables a wide range of emission properties, which has not been possible using other laser technologies. For example, VECSEL exhibit wavelength coverage from the visible to the mid-IR range, high output power up to the 100 W-level, high brightness, single-frequency operation, efficient intra-cavity frequency conversion, ultra-short pulse generation down to sub-picosecond range with GHz repetition rates, and low noise operation [2].

The progress of this field has been intensive over the last decade and yet continues to be very dynamic, boosted by ability to reach new operation frontiers and new applications. In this context, we review the recent technological development of VECSELs in connection to the new milestones that continue to pave the way towards wider use in applications.

Particular attention is devoted to the fabrication of gain mirrors at challenging wavelength regions. In terms of applications, we give an overview of experiments in quantum technology [3] and medicine [4], for which VECSELs provide a new breadth of developments. Finally, an outline on commercialization perspective is also provided.

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♦ An Overview of the Israeli Consortium on Advanced Laser Technologies for Industrial Applications (ALTIA)

Kobi Lasri

V-Gen Ltd., MKS SpectraPhysics, Israel

This presentation provides an overview of the ALTIA Consortium: Advanced Laser Technologies for Industrial Application that is supported by the Israeli Innovation Authority.
Mobile devices, automotive, energy, and electronics materials processing applications are evolving at a rapid pace and continue to drive strong industrial laser needs. As the devices are getting smaller, faster, lighter, and cheaper, their manufacturing becomes significantly more complex. For key components such as semiconductor chips, microelectronics packages, touch-screen displays, and printed circuit boards (PCBs), the industry faces continuously major challenges to drive up manufacturing yield and throughput while lowering cost. The need for sophisticated manufacturing processes of complex devices leads to a requirement for more and more advances in laser sources which are imperative for those processes.

Recognizing the need for continued evolution of laser technology with related improvements in the cost, flexibility, and reliability of product offerings, the ALTIA Consortium was formed in 2016 by industrial and academic partners to develop advanced laser and components technologies. In this talk, we review the major achievements, including: shorter wavelengths (particularly in the Green and UV regimes) for machining small features with better quality and higher precision; higher power levels and pulse repetition rates for achieving higher throughput - and all of these with lower costs and improved reliability for next generation 24/7 industrial applications.

Optically Pumped Flip-Chip Wafer-Fused Vecsels Emitting at 1.55-μm Wavelength

Eli Kapon[3], Alexandru Mereuta[1], Kostiantyn Nechay[2], Andrei Caliman[1], Grigore Suruceanu[1], Pascal Gallo[1], Mircea Guina[2]

1. *LakeDiamond SA, Rue Galilée 7, 1400 Yverdon-les-Bains, Switzerland*
2. *Tampere University of Technology, Optoelectronics Research Centre, 33720 Tampere, Finland*
3. *Ecole Polytechnique Federale de Lausanne-EPFL, Laboratory of Physics of Nanostructures, Switzerland*

High power lasers emitting high quality beams in the near infrared (1-2-μm) are important for applications in LIDAR, spectroscopy, free space communications and distributed sensing. Vertical external cavity surface emitting lasers (VECSELs) optically pumped by laser diode arrays, employing various semiconductor gain elements in an external optical cavity, can yield multi-Watt output powers with high quality beams [1]. Most VECSELs utilize GaAs-based gain chips and emit around 1-μm wavelength. Wafer-fused GaAs-InP gain chips allow extending the emission wavelength to the 1.2-1.6-μm spectral range [2]. Here we report the fabrication and performance of optically-pumped VECSELs based on flip-chip gain mirrors emitting at the 1.55-μm wavelength range. The gain mirrors employ wafer-fused InAlGaAs/InP quantum well heterostructures and GaAs/AlAs distributed Bragg reflectors, incorporated in a linear or V-cavity configurations. The flip-chip configuration and diamond heat spreader allow avoiding intracavity etalon effects, which otherwise degrade the spectral quality of the laser beam. A maximum output power of 3.65 W was achieved for a heatsink temperature of 11°C and employing a 2.2% output coupler. The laser exhibited circular beam profiles with M2 below 1.25 for the full emission power range. The demonstration represents more than 10-fold increase of the output power compared to state-of-the-art flip-chip VECSELs previously demonstrated at the 1.55-μm wavelength range.

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Oasis 7th Conference and Exhibition on Electro-Optics

Towards Room Temperature Operation of Terahertz Quantum Cascade Lasers: Carrier Leakage Engineering as a Novel Design Concept

Asaf Albo

Bar Ilan University, Israel

The terahertz spectral region is subject to intensive research in view of its potential in a number of application domains such as medical diagnostics, trace molecule sensing, astronomical detection, non-invasive quality control and more. However, maximum operating temperature achieved with terahertz quantum cascade lasers (~200 K) imposes cryogenic techniques.

In general, the ideal operation mode of a terahertz quantum cascade laser assumes that an electron injected externally into the device will generate multiple photons - one in each "energy cascade"- while transporting through the heterostructure. However, alternative scattering leakage paths deviate electron transport from the ideal picture and present a considerable effect on devices' performance. In that context, temperature-driven leakage of charge carriers out of the laser's active region states is considered as an unwanted effect that limit its temperature performance. However, as we showed in our latest works, contrary to common sense expectations, carrier leakage under some conditions can be beneficial for the device and enhance lasing.

Our results highlight the importance of the carrier leakage out of the lower laser level to the laser's performance. This understanding clearly point out to a potential improvement direction in the design of highly temperature-insensitive terahertz quantum cascade lasers, namely to minimize thermally activated leakage from the upper laser level and maximize thermally activated leakage from the lower laser level. In other word, to address a carrier leakage engineering procedure as a new design concept for high performance terahertz quantum cascade lasers.

Micron-scale Additive Manufacturing using Laser Transfer of Metals

Sharona Cohen, Zvi Kotler
Orbotech Ltd Research and Development

Laser Induced Forward Transfer (LIFT) is a digital, non-contact, high resolution, printing technology for solid metal printing as well as highly viscous rheological materials, inks and adhesives. In this method, the pure solid metal can be transferred from a layer coating a glass substrate, the "donor", to the substrate. The laser beam causes a local abrupt change of temperature, local melting of the metal layer and transfer of a molten droplet per laser pulse. The droplet volume can be controlled by tuning laser pulse parameters in the range of 100's of femtoliters.
The LIFT methods allow versatility in choice of printing materials, variable droplet volume, and accurate deposition. All this makes this multi-material printing technology very unique. For example, printing small metal droplets give rise to ultrafast cooling and solidification which enables amorphous metal alloys to be obtained with superior mechanical performance and resistance to corrosion. Another example is printing on a wide range of materials on sensitive materials such as organic materials, plastics and paper. The high resolution and high conductivity obtained with e.g. copper qualifies LIFT for electronics printing. Unlike solvent-based printing LIFT printing of pure metals avoids post processing and therefore increased printing rate along with flexibility on designing the lines aspect ratio. We will demonstrate high-speed LIFT printing technology along with examples of its use for fabrication of high-resolution electric circuitry and printed metal MEMS.

Oasis 7th Conference and Exhibition on Electro-Optics

Session: Spectroscopic and Optical Sensing - Dr. Ayala Ronen

Atmospheric Optics: Beauty and Science

Joseph A. Shaw
Optical Technology Center, Montana State University, USA

The natural world is full of beautiful optical phenomena that we can see if we know how, when, and where to look. We all have seen beautiful sunset colors and rainbows, but some tutoring may help us discover additional optical displays that we have never noticed before. Similarly, there are some atmospheric optical phenomena we do not yet understand fully. This presentation will use photographs and diagrams to show examples of beautiful natural optical phenomena that are a little bit elusive or are still being investigated today. Examples will range from elusive halos and auroras to sky polarization during a solar eclipse.

Accurate Synchronization of Spectrometers for Laser Induced Breakdown Spectroscopy Using New CMOS Sensors

Thomas Rasmussen
Ibsen Photonics, Denmark

Laser Induced Breakdown Spectroscopy (LIBS) can be used to identify and quantify atomic constituents by ablating material from the surface of a sample by a strong pulsed laser. This creates a plasma flash which is then analysed by a spectrometer. The plasma exists only shortly after the laser pulse and only for a few microseconds. Typically, expensive Echelle type spectrometers with time-gated 2D cameras are used for LIBS but, we have demonstrated that by using new fast and sensitive CMOS sensors along with low cost electronics based on a FPGA it is possible to create accurate and fast time-gating for LIBS at low cost. The new system furthermore has the advantage of being very robust against temperature variation and vibrations and are thus suitable for hand-held and out-door applications. I this presentation we will show results of single pulse LIBS experiments on metal alloys synchronized to a pulsed laser.

Design of an All-Optical Ultrasound Transducer Based on a Microcavity Resonator

Silvia Soria, Gabriele Frigenti, Fulvio Ratto, Lucia Cavigli, Gualtiero Nunzi Conti, Alberto Fernandez-Bienes, Sonia Centi, Andrea Barucci, Roberto Pini, Tupak Garcia-Fernandez
IFAC-CNR Institute of Applied Physics "N. Carrara", Italy

Over recent years, photoacoustics has drawn attention for innovative applications in biomedical optics. In particular, photoacoustic imaging has emerged as a non-invasive solution combining optical contrast and ultrasonic penetration depth and scalability in a variety of configurations, ranging from microscopy to tomography, that are already competitive for translational developments. Most photoacoustic platforms rely on piezo transducers that were developed within the venerable context of ultrasonography. However, the generation or propagation of acoustic signals in photoacoustics and ultrasonics differ in fundamental aspects that deserve innovative solutions and yield new opportunities. Here, we disclose our design and preliminary results for an all-optical photoacoustic flow spectro-cytometer that may be exploited in multiple contexts, such as the detection of circulating cells in bio fluids as well as the inspection of colloidal suspensions of artificial particles in sols or aerosols. This setup rests on the implementation of an optical microcavity resonator that may be coupled to a microfluidic interface and filled with any sample of interest. Then, its excitation with short optical pulses triggers a photoacoustic event within the cavity, which imparts a transient deformation of the glass resonator and its dielectric landscape, thus shifting its optical resonances. The advantages of this setup include its inherent feasibility for miniaturization and workability in air rather than water, as occurs with piezo transducers for ultrasonography. We illustrate these features in the analysis of the spectral fingerprints of colloidal suspensions of plasmonic particles with volumes in the nL range and repetition rates in the kHz domain.

Keywords: Whispering Gallery Microresonators, Photoacoustics, Gold Nanorods

Oasis 7th Conference and Exhibition on Electro-Optics

NDIR Gas Measurement in Harsh Environments by Advanced IR Components and Packaging Technologies

Steffen Biermann, André Magi, Patrick Sachse
Micro-Hybrid Electronic GmbH, Germany

Introduction, Background, Objectives: NDIR-gas-sensors used in a wide range for detecting and measuring infrared active gases. The advantages of this technology are high measuring accuracy, long-term stability and robustness of these systems. However most of these are subject to restrictions concerning the environmental stability, in particular the temperature resistance. The maximum storage and operating temperature of common NDIR-gas-sensors is limited at around +60 °C and applications, where the sensor is exposed to higher temperatures are highly restricted. This was the intention for Micro-Hybrid to develop a NDIR-gas-sensor with a distinct extended temperature range up to 200 °C and for harsh environments like high vapour pressure up to 250 mbar and solvent atmospheres.

Methods, Results: The performance is a feature based by advanced Micro-Hybrid infrared-components. The thermopile-detector consists of highly effective BiSb/Sb thermocouples which enables high sensitivity also at high temperatures. The MEMS-emitter, based on advanced silicon-nanostructures, enables high membrane temperatures up to 850 °C as well as a broadband emission coefficient of nearly 1. Emitter and detector are assembled by special technologies like soldering and welding to ensure the hermetic housing. Especially for optical coated IR-windows a new metallization technology for free-shaped geometries was developed. Different backfill gases enable a tuning of the system parameters. The gas-sensor based on a two-temperature-zone concept with a separated signal processing unit which operates up to 80 °C. The achieved SNR of 38 dB at 180 °C as well as the long-term stability opens a wide range of applications for the developed sensor.

Conclusions: Micro-Hybrid developed an advanced NDIR-gas-sensor which withstands extraordinary moistures and high temperatures up to 200 °C. A field of application is controlling the CO2 atmosphere in sterilisable incubators. To achieve these requirements sophisticated IR-MEMS chips, packaging technologies and the housing-components which are appropriate for high temperature stable hermetic-sealing were developed.

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Measurements and Modeling of Laser Propagation in Fog and Clouds

O. Yaron[1], A. Ronen[2]

1. Rafael Advanced Defense Systems Ltd
2. IIBR, Israel institute for Biological Research

Laser beam scattering by atmospheric aerosols has a significant influence on LIDAR systems. Mie theory predictions of scattering from small droplet wetter aerosol, namely radiation fog, exhibits a relatively large scattering probability, away from the original propagation direction, while cloud droplets are characterized by major forward and backward scattering. In order to check the theoretical model, a chamber containing the two aerosols types was used. A laser beam crossing the field of view of a calibrated camera measured the 2D scattering pattern. These measurements show the location dependent intensity. Attenuation coefficients and droplets size distribution were continuously monitored, along with temperature and humidity. The intensity measurements in large, cloud droplets, shows good agreement with calculations of first order scattering even for dense atmosphere (low visibilities). In extremely low visibilities the measured data deviates from the single scattering prediction. We assume that those deviations are caused by multiple scattering components, Hence our future work will be focused on multiple scattering calculations for accurate description of Laser scattering in dense fog and clouds.

Application of Hyper-Spectral LIF-LIDAR Based on ICCD for Detection and Identification of BioAerosol Clouds & Studding its Formation Dynamic

Ofir Shoshanim, Adva Baratz

Israel Institute for Biological Research, Israel

Using remote sensing for the detection of biological agents based on their fluorescence signature has proven to be an efficient technique to identify their presence in the atmosphere. We used a home built light-induced fluorescence (LIF) LIDAR based on an intensified CCD (ICCD) sensor to study the back-fluorescence from an aerosol cloud in various scenarios following a UV photo-excitation (266 nm). We investigated the dynamics of cloud formation inside a well-controlled 'aerosol chamber' using the LIF-LIDAR from a distance of 10-200 meters away. In these experiments, we simultaneously collect both VV & VH polarization components of the LIF signal following the instantaneous fluorescence anisotropy. We also control and monitor the generation and the size distribution of the aerosol phase and the ambient conditions inside the chamber with 1Hz resolution. The correlation of all physical parameters due to the dynamic of the bio-aerosol formation inside the chamber, including fluorescence spectral shifts, laser transmittance, and particle size distribution and concentration, are analyzed and physically rationalized.

Next, we used the LIF-LIDAR at several field campaigns for the detection & Identification (D&I) of aerosol clouds. In these campaigns, the LIF-LIDAR operated with a novel photon counting technique exploiting the full capability of the ICCD sensor to increase both spectral sensitivity and dynamic range. At daytime measurements, an updating UV-Vis BG signal was recorded by doubling the ICCD readout rate to be twice the laser repletion rate (i.e. 20 Hz). We tested these capabilities of our LIF-LIDAR at field campaigns took place at daytime in the Israeli desert and at night during the 'S/K CHALLENGE II-2015' field campaign at Dugway Proving Ground (DPG) in Utah. Our D&I algorithm was operated in real time and demonstrated an excellent D&I capabilities.

Session: Non-Linear Optics - Dr. Haim Suchowski

♦ Quantum Design of Coherent X-rays with Spin and Orbital Angular Momentum

Tenio Popmintchev
Physics Department, Center for Advanced Nanoscience, University of California San Diego, USA
Photonics Institute, TU Wien, Austria

Nonlinear optics revolutionized the ability to create directed, laser-like light particularly in the regions where lasers based on conventional population inversion are not practical. New breakthroughs in attosecond extreme nonlinear optics promise a similar revolution in the X-ray regime using different physics. In this talk, I will discuss the fundamental quantum limits and the phase matching limits of the high harmonic generation process in the context of designing coherent X-ray waveforms in the soft X-ray regime with properties that can be tailored in the moment of generation. Such a versatile light source based on attosecond control of coherent electrons is ideal for 4-dimensional studies of various bio - and nano-systems at the space-time limit with combined attosecond temporal and nanometer spatial resolution. The inherent exceptional chemical sensitivity of the X-ray light provides also access to an effective 5th dimension - the periodic table of elements. A myriad of femtosecond spectroscopic and imaging experiments typically performed only at large scale synchrotron or free electron laser facilities are already possible in many university laboratories using these novel ultrafast discovery tools. Finally, I will discuss the path forward for generating bright coherent hard X-ray pulses at photon energies of 10 keV and greater with unprecedented attosecond-to-zeptosecond pulse durations, and with arbitrary spectral, temporal shapes, and spin and orbital angular momentum. A fully spatially and temporally coherent version of the Roentgen X-ray tube with exquisite quantum control of the properties of the soft and hard X-ray light may be possible.

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Loss of Time Reversibility in Absorption-Free Focusing Media

Amir Sagiv, Adi Ditkowski, Gadi Fibich
Faculty of Engineering, Tel-Aviv University, Israel

Introduction: The reversibility of light propagation in nonlinear media has recently received theoretical and experimental attention, as medium nonlinearity may lead to improvements in holography, imaging, and phase retrieval. The methods presented in these studies, however, are limited in high-intensity focusing regimes. Here, we study reversibility in focusing media and present novel theoretical limitations to reversibility. Fundamentally, these limitations reveal a preferred "arrow of time" in nonlinear optics.

Numerical Results: In principle, the propagation of a beam in a loss-free focusing media can be backward propagated either numerically or experimentally, using a phase-conjugating mirror. In some settings, however, reversibility is highly unlikely. Consider, for example, two colliding beams that fuse into a single beam. If the output profile is known on exactly, the input profile can be recovered. Intuitively, however, how can the time-reversed beam "know" it should split? Indeed, in realistic settings where the output profile is either known only on a finite domain, measured by a digital camera, or with a band-limited detector, we observe that the reversed beam does not split and so reversibility is lost.

Theory: In the above examples, power losses due to imperfect measurement are {\em smaller than 1%}. If so, why is reversibility lost? In focusing media, as in thermodynamic systems, the beam "cools" to stable solitary waves. Hence, when the output profile is reversed, it is the in-flowing radiation that excites the beam to its unstable initial state. Since this is an unstable process, reversibility is lost for a generic non-ideal measurement.

Phase retrieval in focusing media may be particularly hard. As we show, a beam's phase becomes chaotic over many shots. Hence, even if one measures the {\em output} phase, the input phase may become increasingly irrecoverable.

Conclusion: Our study reveals theoretical limitations to reversal and imaging in the focusing regime.

High Energy KGW/Tm:YLF Raman Laser

Uzziel Sheintop (JCT), Pavel Komm (HUJI), Gilad Marcus (HUJI), Salman Noach (JCT)
Jerusalem College of Technology, Israel

High brightness sources in 2-3µm region are essential for many applications including wavelength selective microsurgery, material processing, and gas monitoring [1]. Solid state Raman lasers are one of the efficient and useful methods to extend the spectral span of high brightness sources [2]. In last 5 years, this was also implemented in the 2µm region, using BaWO4 and YVO4 as Raman crystals [3, 4].

KGd(WO4)2 (KGW) is another promising Raman crystal, former implemented only with 1064nm and 532nm. The KGW has two different Raman shifts (901 cm-1 and 768 cm-1), enables to achieve, by controlling the polarization, two different stokes wavelengths. Although the KGW has a lower Raman gain compere to the BaWO4 its advantages are with the modest thermal lensing and high damage threshold that can be suitable for high power Raman laser.

Here we present, for the first time, a KGW Raman laser for the 2µm regime with 0.4mJ energy per pulse, the highest value in the 2µm regime that has been published so far. The KGW was pumped by Tm:YLF laser λ=1880nm with 2mJ energy per pulse, 1kHz repetition rate, 30nsec pulse duration and M2 of 1.44. External cavity KGW Raman laser was designed enables selective emitting's of two wavelengths, 2197nm and 2263nm, corresponds to the two different Raman shifts of the KGW.

0.15mJ energy per pulse, 5.4nsec pulse duration and 27.8kW peak-power was achieved at 2197nm output (conversion efficiency of 7.5%). 0.4mJ energy per pulse, 21nsec pulse duration and 19kW peak-power was achieved at 2263nm output (conversion efficiency of 20%). For both Raman shifts pulse shortening were detected and improved beam quality was measured M2 = 1.03-1.2.

In conclusion, a selective wavelength Raman laser with KGW crystal is performed, achieving 0.4mJ, the highest energy per pulse that has been reported for Raman laser at the 2µm regime.

Thermo-Optical Nonlinearity of Single Metallic Nanoparticle

Ieng Wai Un, Shi-Wei Chu, Yonatan Sivan
Ben Gurion University, Electro-Optics Engineering, Israel

By using the best experimentally measured data of the temperature dependent permittivities of bulk gold and silver, going beyond the quasi-static approximation, approximately modelling by Mie theory with spatial independent parameters as well as exactly modelling by simulation, we calculate the temperature and the scattering cross section of a single nanoparticle of different finite sizes under CW illumination. We show that, quite counterintuitively, the particle temperature changes with its size non-monotonically.

Such non-monotonic behaviour can be understood by the redshift of electric dipole resonance and the quadrupole mode kicking in as the particle size increases. Secondly, the particle temperature increases with the incident intensity nonlinearly because of the nonlinearity of the absorption. We also show that the nonlinearity of the absorption exhibits interesting size dependence and plays a crucial role in the non-perturbative description of the nonlinearity of the particle temperature and the scattering. Further, we demonstrate that the nonlinear scattering coefficient of the second order depends on the particle size non-trivially, which is related to the non-monotonic dependence of the particle temperature on the particle size. Furthermore, our numerical calculation achieves a quantitative agreement with the nonlinear scattering measurement results which is much better than the previous studies. We also compare the nonlinearity of Au and Ag. Due to the much smaller value of imaginary part of the permittivity of Ag comparing to Au, the nonlinear response of Ag nanoparticle can be much stronger than of Au nanoparticle.

Indefinitely Switchable Nonlinear Optical Nanoantennas for Ultrafast Stream Cryptography

Roman E. Noskov[1], Pujuan Ma[2], Lei Gao, Pavel Ginzburg[1]

1. Tel-Aviv University, Israel
2. Soochow University, China

To bridge the gap between information science and actively-developed novel physical platforms, previous studies have been concentrated on the concepts of digital metamaterials and metasurfaces, coherent absorption and other all-optical techniques. While demonstrating promising functionalities, these and other close works, however, never addressed their integration with existing cryptographic principles, which is the key requirement for building up next-generation cryptographically well-protected information networks.

Our research shows a conceptually novel approach to securing of information exchange by revealing the phenomenon of indefinite switching in resonant bistable systems [Light Sci. Appl. 7, 77 (2018)]. From a physical viewpoint, bistability occurs when a free-energy landscape of the system contains two minima separated by one maximum. To switch between the minima, the system is disturbed with a form of activation energy, which is typically supplied by a large-amplitude input signal. For the all-optical bistable switchers reported thus far, this type of transition appears when the signal pulse intensity slightly overcomes the bistability threshold and the system returns to the initial state for weaker pulses. Here, we break with this concept by revealing the new phenomenon of indefinite switching in which the eventual steady state of a resonant bistable system is transformed into a nontrivial function of signal pulse parameters for moderately intense signal pulses. The essential nonlinearity of the indefinite switching allows realization of well-protected cryptographic algorithms with a single bistable element in contrast to software-assisted cryptographic protocols that require thousands of logic gates. As a proof of concept, we demonstrate stream deciphering of the word "enigma" by means of an indefinitely switchable optical nanoantenna. An extremely high bitrate ranging from ~0.1 to 1 terabits per second, a small size and easy integration in nanophotonic circuitry and optical fibers make such systems promising as basic elements for all-optical cryptographic architectures.

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Session: IFLA - Fiber Lasers and Applications I - Dr. Boaz Lissak

♦ Prospects in Power Scaling of Coherently Coupled Fiber Lasers and Amplifiers

Andreas Tünnermann, Jens Limpert

Fraunhofer Institute for Applied Optics and Precision Engineering, Center of Excellence in Photonics, Jena, Germany

In the past years rare-earth-doped fiber lasers have emerged as an attractive and power scalable solid-state laser concept due to the outstanding thermo-optical properties of an actively doped fiber. Using advanced fiber designs, in continuous-wave (cw) operation output powers exceeding the 10 kW-level with diffraction-limited beam quality have been demonstrated. In the pulsed regime average powers in the order of several hundred Watt even for few cycle pulses based on fiber lasers have been reported.

However, power and energy scaling of cw and pulsed single-mode fiber lasers and amplifiers are restricted due to nonlinear pulse distortions, which are enhanced by the large product of light intensity and interaction length inside the fiber core. In addition, transverse mode instabilities are observed, which degrade the beam quality emitted by high-power fiber laser systems once a certain average power threshold has been reached. Most recently, strategies have been developed to mitigate or even, ideally, to overcome these limitations - enabling a further power scaling of fiber lasers and amplifiers. These strategies are based on a combination of advanced large mode area fiber designs and coherently coupled multi-channel laser and amplifier architectures.

In this contribution the state of the art of science and technology in fiber lasers and amplifiers is reviewed. The prospects for future developments using advanced fiber designs in combination with modern laser and amplifier architectures are discussed.

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♦ Amplifiers and Lasers with Active Tapered Double Clad Fibers

Valery Filippov

Ampliconyx, Finland

We report theoretical and experimental study of active tapered double-clad fibers (T-DCF) as a gain media in a fiber amplifiers and lasers. The most important properties of T-DCF are considered in that presentation. Various issues related to the features of T-DCF clad pump absorption, influence of the longitudinal shape of T-DCF and pumping schemes on properties of devices with T-DCF are considered. The results of the experimental study of an active anisotropic T-DCF with linear (PANDA) and circular (SPUN) birefringence are presented. Numerous of amplifiers and lasers with ultra large mode area (MFD up to 100μm) anisotropic ytterbium doped T-DCF are demonstrated and discussed. The experimental results of testing high power (750W) CW Yb laser and various nanosecond and picosecond all-fiber pulsed MOPA systems are presented and discussed in details.

♦ Beam Cleaning Effects in Multimode LD-Pumped GRIN-Fiber Raman Laser

S. A. Babin[1,2], E. A. Evmenova[2], A. G. Kuznetsov[2], S. I. Kablukov[1,2], E. V. Podilov[1,2]

1. Novosibirsk State University, Russia
2. Institute of Automation and Electrometry SB RAS, Novosibirsk, Russia

Raman fiber lasers (RFLs) are able to operate at almost any wavelength in transmission window (1-2 micron) of conventional singlemode silica fibers being pumped by powerful Yb-doped fiber laser (YDFL) near 1 micron. Direct pumping of multimode graded-index (GRIN) fibers by commercial high-power multimode laser diodes (LD) at 915-940 nm provides Raman lasing below 1 micron that is problematic for conventional LD-pumped fiber lasers such as YDFL. At the same time, Raman conversion is accompanied by sufficient improvement of the output beam quality in comparison with that for multimode LDs thus resulting in brightness enhancement by >20 times. Here we review physical mechanisms leading to the beam quality improvement at Raman lasing in GRIN fibers: specific spatial features of Raman gain, mode-selective properties of fiber Bragg gratings inscribed by femtosecond pulses and transverse structure of Rayleigh backscattering both employed for the cavity feedback. As a result, high-efficiency CW generation of nearly diffraction limited output beam at 950-1000 nm in such LD-pumped all-fiber GRIN RFL has been demonstrated. High beam quality offers efficient second harmonic generation in blue spectral range that was also endeavored. Pulsed generation of the developed GRIN RFL has been realized with the use of acousto-optic modulator operating either in Q-switching or mode-locking regime. Output characteristics and potential applications of such laser sources are discussed.

♦ High Pulse Energy Single Frequency 1.55micron Fiber Amplifiers

Shibin Jiang

AdValue, US

There has been a significant need of developing a high energy single frequency optical pulse transmitter for LIDAR applications, especially at 1572nm for atmospheric CO2 LIDAR system. Robust and alignment-free single frequency fiber laser system is the ideal source for many applications. However, the pulse energy is always limited to 1mJ or less because of the stimulated Brillouin scattering (SBS).

We have demonstrated 1.8mJ, peak power of 3.5kW at 2.5 kHz single frequency optical pulses at 1572nm from an all-fiber MOPA system using our proprietary silicate glass Er-Yb co-doped fiber amplifiers. To our best knowledge, the presented pulse energy is the highest pulse energy of single frequency at 1572nm from all-fiber MOPA system. In our system, we used a 1572nm performance-improved short length of Er-Yb co-doped silicate glass fibers in multi-stage all-fiber MOPA system in combination of pulse shaping to mitigate an undesired SBS induced pulse energy limit.

Robust Setup for Generation of High-Power CW Green Laser

Yishai Albeck, Steven Jackel, Avraham Boubli, Ziv Gross and Gabi Teller

CIVAN Advanced Technologies, Israel

High-power visible light is in high demand in the field of material processing as well as for other industrial and scientific appliances. Green light, e.g. at 532 nm, can be produced by frequency doubling near infrared lasers. High conversion efficiency (70%) is easily reached using pulsed laser beams, though for some applications CW sources are advantageous. Frequency doubling of CW sources presents additional challenges because peak powers are low, whereas high average power results in thermal dephasing of the fundamental and harmonic beams. Focusing of the beam can aid in increasing the local conversion efficiency but restricts the interaction length, thus setting an upper bound to the efficiency. Internal and external resonators offer long interaction lengths but suffer from complex designs, thermal sensitivity, impaired beam stability, and may not be compatible with all types of lasers (fiber lasers).

In the doubling setup presented here, two image-relayed LBO crystals are used, in a single-pass, noncritically (type 1) phase-matched configuration to achieve high conversion efficiency. An important addition to the system was a phase-mismatch corrector (PMC) plate situated in between the crystals. In our case we used a thin fused silica window whose tilt could be controlled in order to achieve maximum doubling in the second crystal despite thermally induced phase mismatch in the first and second crystals. We reached 35% efficiency generating more than 100 W of CW green light, in a near diffraction limited beam (M2<1.2). Careful system design resulted in stable performance (<1.5% fluctuations) with no evidence of degradation over many 10s of hours of continuous, hands-off operation.

Oral Presentations

Tuesday, April 2, 2019

Oasis 7th Conference and Exhibition on Electro-Optics

Opening Session

Recovering Lost Information in the Digital World

Yonina Eldar
Weizmann Institute of Science, Israel

The conversion of physical analog signals to the digital domain for further processing inevitably entails loss of information.

The famous Shannon-Nyquist theorem has become a landmark in analog to digital conversion and the development of digital signal processing algorithms. However, in many modern applications, the signal bandwidths have increased tremendously, while the acquisition capabilities have not scaled sufficiently fast. Furthermore, the resulting high rate digital data requires storage, communication and processing at very high rates which is computationally expensive and requires large amounts of power.

In this talk, we present a framework for sampling and processing a wide class of wideband analog signals at rates far below Nyquist by exploiting signal structure and the processing task.

We then show how these ideas can be used to overcome fundamental resolution limits in optical microscopy, ultrasound imaging and more. We demonstrate the theory through several demos of real-time sub-Nyquist prototypes and devices operating beyond the standard resolution limits combining high spatial resolution with short integration time.

Gravitational-wave Interferometers: A Revolution in the Way We Observe the Universe

David Reitze
Executive Director of the LIGO laboratory, CALTECH

The first discoveries of colliding pairs of black holes and neutron stars by the LIGO and Virgo detectors have revolutionized astronomy and established gravitational waves as a powerful new way of probing the most extreme and highest energy astrophysical events in the universe. In this talk, I'll give an overview of how gravitational-wave detectors are capable of detecting changes in the space-time at a level of 10^-18 m, and present the most recent gravitational-wave discoveries. In addition, I'll preview the plans for building a new network of larger and more sensitive detectors in the next decade and beyond.

Hanbury Brown-Twiss, Hong-Ou-Mandel, and Other Landmarks in Quantum Optics: From Photons to Atoms

Alain Aspect
INSTITUT d'OPTIQUE, Paris, France

What you always wanted to know about HBT, HOM, etc… (but were afraid to ask).
The second quantum revolution is based on entanglement, discovered by Einstein and Schrödinger in 1935. Its extraordinary character has been experimentally demonstrated by landmark experiments in quantum optics.

At Institut d'Optique, we are currently revisiting these landmarks using atoms instead of photons, and after the observation of the atomic HBT[1] and HOM effects[2], we are progressing towards a test of Bell's inequalities with pairs of momentum entangled atoms[3].
This talk will be an opportunity to know "What you always wanted to know about HBT, HOM, etc… (but were afraid to ask)."

1. T. Jeltes, J. M. McNamara, W. Hogervorst, W. Vassen, V. Krachmalnicoff, M. Schellekens, A. Perrin, H. Chang, D. Boiron, A. Aspect, and C. I. Westbrook, "Comparison of the Hanbury Brown-Twiss effect for bosons and fermions," Nature 445 (7126), 402-405 (2007).
2. Lopes, R., Imanaliev, A., Aspect, A., Cheneau, M., Boiron, D., & Westbrook, C. I. (2015). Atomic Hong-Ou-Mandel experiment. Nature, 520(7545), 66-68.
3. P. Dussarrat, M. Perrier, A. Imanaliev, R. Lopes, A. Aspect, M. Cheneau, D. Boiron, and C. I. Westbrook, "Two-Particle Four-Mode Interferometer for Atoms," Physical Review Letters 119 (17) (2017).

Session: Solar Energy - Prof. David Cahen

♦ Experimental Realization and Theoretical Understanding of High Open-Circuit Voltages in LeadHalide Perovskites

Thomas Kirchartz[1,2]

1. IEK5-Photovoltaik, Forschungszentrum Jülich, Germany
2. Faculty of Engineering and CENIDE, University of Duisburg-Essen, Germany

Efficiencies of lead-halide perovskite based solar cells have increased over the last several years at a speed that is unprecedented in the history of photovoltaic technologies. What is striking is in particular how relatively little engineering was needed to achieve high open-circuit voltages (Voc) that even now come similarly close to the Shockley-Queisser limit than those of Si solar cells after 60 years of technological development. This development inspires two questions, namely how far can we go technological and how do we characterize and understand these results. Here, I will present experimental results on very high open-circuit voltages and discuss the transient and steady state characterization of these high Voc materials and devices. In the second part of the talk I will discuss what we know about non-radiative recombination in these semiconductors and discuss why the material properties of lead-halide perovskites are beneficial for achieving low recombination rates at a given charge carrier concentration.

♦ Stability Studies of Perovskite PV Materials and Devices Using Concentrated Sunlight

Iris J. Visoly-Fisher

Dept. of Solar Energy and Environmental Physics, J. Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Midreshet Ben-Gurion, Israel

The greatest challenge facing the development of low-cost, solution processed photovoltaic (PV) devices, such as perovskite- based solar cells, is combining high efficiency and stability. Concentrated natural sunlight was suggested for accelerated studies of lifetime and light-induced degradation. We recently demonstrated an experimental methodology with independent control of sunlight intensity, the sample temperature and environment during the exposure. Studies of perovskite PV materials showed a strong dependence of the stability on the materials composition, correlated with chemical bond strength, crystalline structures and defect density.[1-3] Studies of perovskite PV devices as a function of sunlight concentration were aimed at determining which degradation factors are more dominant: light and spectrum, bias or their combination? Preliminary results show that different degradation mechanisms are dominant under different stress conditions, especially various applied electrical bias.[4] we found that (sun) light intensity was more important than illumination dose for cell degradation at short circuit (SC) conditions, while a monotonic dependence of the degradation kinetics on the dose was found only at open circuit (OC). The cell operating temperature was also found to be a critical parameter for degradation.[5] Accelerated testing using concentrated sunlight is therefore a powerful tool for material screening and advanced PV device development.

1. R. K. Misra, et al., J. Phys. Chem. Lett. 6 (2015), 326–330.
2. R. K. Misra et al., ChemSusChem 9 (2016), 2572 - 2577.
3. A. A. Melvin, et al., Solar Energy 159 (2018), 794-799.
4. M. Khenkin et al., Energy and Environmental Science, DOI: 10.1039/C8EE03475C
5. Anoop KM et al., in prep.

Low Dimensional Perovskite: Stability, Solar Cells and Nanostructures

Lioz Etgar
The Institute of Chemistry, The Hebrew University of Jerusalem, Israel

Perovskite is a promising light harvester for use in photovoltaic solar cells. In recent years, the power conversion efficiency of perovskite solar cells has been dramatically increased, making them a competitive source of renewable energy.
This work will discusses new directions related to organic inorganic perovskite and their applications in solar cells.

In low dimensional systems, stability of excitons in quantum wells is greatly enhanced due to the confined effect and the coulomb interaction.

In this work we will show the dimensionality in the perovskite structure. The 2D perovskite structure should provide stable perovskite structure compare to the 3D structure. The additional long organic cation, which is added to the perovskite structure (in the 2D structure), is expected to provide hydrophobicity, which will enhance the resistivity of the perovskite to humidity. Moreover, we will demonstrate the use of 2D perovskite in high efficiency solar cells.

In addition, we will show that the black phase of cesium lead iodide can be stabilized when the perovskite dimensionality is reduced. X-ray diffraction, absorbance, and scanning electron microscopy were used to follow the degradation process of various dimensionalities under room conditions and 1 sun illumination.

Organic-inorganic halide perovskite is used mainly in its “bulk” form in the solar cell. Confined perovskite nanostructures could be a promising candidate for efficient optoelectronic devices, taking advantage of the superior bulk properties of organo-metal halide perovskite, as well as the nanoscale properties. In this part, we will present our recent progress related to the synthesis and characterization of perovskite NPs- i.e. Inorganic and hybrid organic-inorganic NPs. New nanostructures such us: NRs and NWs will be presented and the introduction of other cations such us Rb will be shown.

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Photovoltaics for Internet of Things vs. Solar Power-the Optics Factor

Barry Breen
CEO, 3GSolar Photovoltaics Ltd, Israel

Introduction/Background: Crystalline Silicon photovoltaics (PV) is the dominant technology for solar panels converting sunlight to electricity. Dark opaque crystalline silicon offers excellent efficiency in converting direct sunlight, meaning about 1000W/cm2 broad spectrum light flux density.

PV on a smaller scale is also a good energy solution for the growing world of wireless electronics and what is known as Internet-of-Things (IoT). It is an energy solution of milliwatts rather than megawatts, eliminating the need to maintain and replace batteries within the soon-to-be 50 billion connected devices around the world. The issue is most wireless IoT devices are in indoor environments, like Smart Buildings, not outdoors in direct sunlight. Crystalline silicon works poorly under low level artificial (narrow spectrum) light.

Objectives: 3GSolar created miniature PV that charges electronics from low light. Devices get a constant supply of power with no need for changing or charging batteries. Unlike silicon that performs poorly indoors, 3GSolar PV shows exceptional efficiency under fluorescent and LED lighting. The company’s first PV products are based on Dye-sensitized Solar Cell (DSSC), and Perovskite PV cells are in development. The technologies allow for low-cost printing with possibilities of color and transparency for aesthetic and optical integration into wireless products.

Results: We will present optical characteristics of 3GSolar DSSC and Perovskite PV technologies that make possible high efficiency under artificial lighting, and PV cell optical features of colors and semitransparency that allow optimal integration into IoT products. With DSSC technology, a range of optical characteristics are achieved by combining different photoactive dyes with different types and thicknesses of titania carrier layer. For Perovskite, the options are engineering the material’s bandgap and combining this with different Perovskite thicknesses. High shunt resistance of DSSC and Perovskite together with optical engineering better match these PV materials to indoor wireless electronics compared to crystalline silicon.

On Optimization of Heliostat Fields for Solar Central Receiver Plants

Pinchas Doron, Leon Karni, Marina Izmailov, Jacob Karni

Azrieli College of Engineering, Jerusalem, Israel
SolPeD International Ltd., Rehovot, Israel
Ben-Gurion UNiversity, Beer Sheva, Israel
Weizmann Institute of Science, Rehovot, Israel

Solar Central Receiver (SCR) is a leading solar-thermal technology for electricity generation and chemical processing. In an SCR, an array of sun-tracking mirrors (heliostats) reflect sunlight onto a tower-top target. A receiver installed at the target converts the reflected radiation into high-temperature thermal energy, which can be used to energize a turbine or chemical reactions.

The cost-effectiveness of the SCR plant, represented by its Levelized Energy Cost (LEC), depends on its overall efficiency, whose two major contributors are the efficiency of the heliostat field (the radiation collection system) and the efficiency of the Power Conversion Unit (PCU). Achieving optimal performance of the optical system (hence, minimizing the total heliostat reflective area for a given power output) is essential for cost reduction, as the heliostat field cost is a major portion of the overall system cost.

Numerous methodologies have been proposed for designing the layout of the heliostat field and optimizing it for maximum annual-averaged efficiency, taking into account the temporal variations of solar vector (direction and intensity). The following trends are observed:

- Overall field efficiency, for a given total power, varies little between layouts.
- In all the layouts there is a similar variation pattern of individual heliostat efficiencies:

The heliostats in a relatively small region have superior annual efficiency, 70% or greater. Heliostats outside this "core" yield lower benefit, as their efficiency could be as low as half that of the "core" heliostats.

We propose to reduce LEC of SCR plants by using modular, relatively small units, where the entire field would comprise of high efficiency “core” heliostats. In such design, the efficiency and contribution of all the heliostats would be relatively high. These SCR units would have appropriately sized PCU's to provide optimized cost-effective plant designs.

Session: Electro Optics Devices - Prof. Dan Marom

Highly Integrated Silicon Photonic Subsystems For Real World Applications

Christopher Doerr

Acacia Communications, USA

Introduction: Integrated electronics have almost always been made in silicon. Silicon is a plentiful material, easy to make in pure crystalline form, and makes good, although not the highest mobility, transistors. Integrated photonics, on the other hand, used to be mostly made in III-V materials or glass. Silicon is transparent at wavelengths above ~1 um, so it was inevitable that integrated photonics would be tried in silicon. Like silicon transistors, optical components can be made in silicon that are good, but some not as good as in other materials. However, the advantages of high yields, mature foundries, and low-cost packaging have made silicon photonics more than very attractive.

Background: Because of the high purity of silicon wafers and the maturity of silicon wafer process technologies, one can integrate many components on a single device and achieve high yields, including modulators, photodetectors, couplers, gratings, switches, variable optical attenuators, and polarization devices. Because of vast experience with silicon electronic packaging, these highly integrated devices can move rapidly into real-world applications, such as optical coherent transceivers and sensors.

Objectives: Data traffic volume is increasing and the revenue per delivered bit/s is decreasing. This drives a need for smaller, lower-cost devices.

Methods: Silicon photonic transceivers with up to 600 Gb/s per wavelength are in volume production, ranging in transmission distance from 500 m to 7000 km. Practical optical coherence tomography and LiDAR sensors in silicon photonics are being developed.

Conclusion: Silicon photonics is becoming a mature technology that is shipping over a million units per year. This is likely just the beginning as silicon photonic's strength of being able to package with silicon electronics becomes more and more relevant.

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The Multiple-Functionality of Double Injection

Roei Aviram Cohen, Dr. Ofer Amrani and Prof. Shlomo Ruschin
Tel Aviv University

A racetrack-shaped ring modulator based on Double Injection (DI) was recently reported. It is capable of delivering a variety of transform functions, and can be designed to exhibit considerably less sensitivity to deviations in parameters. The modulator is referred to as PIR20 – Parameters-Insensitive Response with a minimum extinction ratio of 20dB. The unique properties of the DI approach can override the impact of such deviations so as to obtain an extinction ratio of at least 20dB, which compares favorably with other device architectures. Such deviations may result from fabrication variations and influence sensitive components of the circuit such as coupling structures. In addition, in some architectures, e.g. Silicon Photonics, electro-optical activity generates heat due to carrier transport, which affects the circuit operation. The sensitivity of the PIR20 modulator to deviations in directional couplers and changes in temperature is analyzed and compared to other known modulators based on either a ring, MZI or Fabry-Pérot resonators. The analysis is carried out for Silicon Photonics and reveals that the PIR20 is considerably more robust to both effects compared with other devices. Comprised of only one ring and having a small footprint, makes this modulator an appealing candidate for large scale integration in interconnects systems and RF photonics.

Eight-Channel Dense-Wavelength-Division Multiplexer in Silicon Photonics

D. Munk[1,2], M. Katzman[1,2], N. Inbar[3], Y. Kaganovskii[2,4], A. Misra[5], M. Hen[1,2], M. Priel[1,2], A. Bergman[1,2], M. Feldberg[2], M. Tkachev[2], M. Vofsi[3], M. Rosenbluh[2,4], T. Schneider[5], and A. Zadok[1,2]

1. *Faculty of Engineering, Bar-Ilan University, Israel*
2. *Bar-Ilan Institute for Nano-Technology and Advanced Materials (BINA), Bar-Ilan University, Israel*
3. *Tower-Jazz Semiconductors, Israel*
4. *Department of Physics, Bar-Ilan University, Israel*
5. *Institute for High-Frequency Technology, Technical University of Braunschweig, Germany*

Dense wavelength division multiplexers (DWDMs) are key components of data communication networks. DWDM devices in silicon are realized based on Mach-Zehnder interferometers, arrayed-waveguide gratings, ring resonators or Echelle gratings. Key metrics include large channel count, uniform passbands, low out-of-band crosstalk, and sharp spectral transitions. Device performance critically depends on accurate control of phase delays over individual waveguide paths. In many cases, complexity associated with phase control limits device performance.

This work presents a silicon-photonic eight-channel multiplexer device with a channel spacing of only 0.133 nm (16.6 GHz). Devices are fabricated in a commercial silicon foundry, in 8" silicon-on-insulator wafers. The device layout consists of seven unbalanced Mach-Zehnder interferometers in a cascaded tree topology, and each interferometer unit also includes a nested ring resonator element. The transfer function of each unit is that of a maximally-flat, auto-regressive, moving-average filter. The devices are characterized by uniform passbands, sharp spectral transitions between pass and stop bands, and strong out-of-band rejection. The full width at half maximum of each output channel is 13 GHz. The worst-case optical power crosstalk is -22 dB. The wavelength-averaged crosstalk is -28 dB.

The proper function of the device requires careful control of optical phase delays over 14 distinct optical paths. Post-fabrication trimming of phase delays was performed through local illumination of a photo-sensitive upper cladding layer of chalcogenide glass. Incident light may change the refractive index of the cladding, or even remove the cladding altogether. The response of tuned devices remains stable over months. The de-multiplexing of three adjacent QAM-16, 40 Gbit/s wavelength-division channels was successfully demonstrated. The spectral efficiency of the transmission was 2.35 bit/s per Hz, in a single polarization. The devices are applicable in data-center communication and in integrated-photonic processing of radio-over-fiber waveforms.

Maxwell Fisheye for Integrated Optics

Y. Blinder, O. Bitton, R. Bruch, and U. Leonhardt
Weizmann Institute of Science, Israel

In 1854 Maxwell invented a refractive-index profile for a device later called Maxwell's fisheye where light goes in circles and every point is focused. Here we report on the fabrication of a Maxwell fisheye of unprecedented quality, made of a pure planar waveguide in silicon, and demonstrate its focusing properties. The key to the high quality of our Maxwell fisheye is the fabrication of smooth and sharp structures in one lithography and etch step, an achievement that is demonstrated for the first time, to the best of our knowledge. Our technique can also be applied to the fabrication of other devices where smooth and sharp structures need to be combined. In particular, it enables the implementation of conformal transformation optics in Silicon Photonics. There, variations in the height of the waveguide may give rise to the required refractive-index distributions and Bragg mirrors may serve as reflectors. The simplest application of transformation optics is adapting the shape of optical devices to requirements different from optics, for example to constraints set by electronic functionalities. Reshaping also provides recipes for invisibility and illusion optics. Other more sophisticated applications include the multiplication or combination of sources for lighting, the sharp bending of waveguides without causing significant loss, the facilitation of highly directional radiation, and nearly perfect cloaking. The talk will discuss the current state of our technique and ideas for improvements.

Complex Fiber Micro Devices

Moti Fridman, Shir Shahal
Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Israel

Fiber micro-devices and specifically microknots and tapered fiber devices are simple and powerful devices for detecting temperature, moister, and acceleration. However, thin fibers which enable to fabricate complex devices as well as sensitive detectors are extremely fragile and cannot replace other methods. Thick fibers which are more robust and stable do not have the same properties.

During the last year, we study tapered fiber devices with high order modes and found that such devices have the best of both worlds. They are robust and stable as well as have high sensitivity to the environment and can be combined into complex fiber devices.

We demonstrate several such complex devices and measured their optical properties. In the talk, we will give an overview of all our complex fiber devices and specifically will focus on multimode fiber microknots and their advantages.

Exploring 2.5 and 3D Integration to Meet the Bandwidth Density Challenge

Oded Raz, Chenhui Li, Teng Li, Patty Stabile
Department of Electrical Engineering, TU/Eindhoven, Netherlands

As data centers continue to grow and optical interconnect bandwidth between servers and switches is moving from 100 to 200 and shortly 400 Gb/sec per link a new paradigm for packaging of optical interconnect modules is required. A very popular technology choice for implementing optical interconnects are surface normal light emitters and detectors but their co-integration with electronic ICs at ever increasing bit-rates remains a major challenge. Also moving from traditional multi-mode devices to single mode devices brings with it new challenges.

In this talk we will present recent results from the labs of the Eindhoven University of Technology in The Netherlands on multi-mode based optical interconnect modules which are using a novel Silicon bench technology as an interposer platform for optical and electronic components. High density 48 channels modules as well as high bandwidth >400 Gb/sec examples will be presented. Looking into the challenge of moving from multi-mode to single-mode I will highlight the ambitious plans of a recently started H2020 project call PASSION which targets to co-integrate single mode VCSELs with SiPh platform to support future interconnect needs with capacities of 2-16Tb/sec.

Session: Photonics in Defense - Dr. Joelle Schlesinger, Dr. Ami Yaacobi

♦ Performance Assessment of Electro-optical Imagers: TRM4 Model and Imaging Simulation

Stefan Kessler

Department of Optronics, Fraunhofer Institute of Optronics, System Technologies, and Image Exploitation IOSB, Ettlingen, Germany

Since decades, there is a continuous development of electro-optical imaging systems. They are becoming smaller with better resolution and higher sensitivity or can be used in additional spectral bands. Having an application scenario in mind, it is natural to ask which of the imagers is better suited to perform the task or to estimate whether their performance is sufficient to carry out the intended task. In the case of reconnaissance, the key figure of merit of electro-optical imagers is their range performance, i.e. the range at which an observer can solve a target acquisition task using the imager.

The Optronics Department at Fraunhofer IOSB has a long history in evaluating electro-optical systems working from the visible to the thermal infrared spectral range. Over many years, the analytical model and software TRM4 for the range performance assessment of electro-optical imaging systems has been developed. TRM4 takes into account the whole imaging chain from the scene over the atmosphere and imager up to the observer. The range performance calculation is based on the perception of a standard 4-bar test pattern and modified Johnson criteria. A complementary method is the image-based simulation, which produces a virtual camera imagery. Here, the image degradation due to atmosphere and imager is mimicked by additional image blur or noise added to an input image, which represents the scene. The resulting output images may be evaluated in observer experiments or by means of image quality metrics. Using this approach, advanced image processing algorithms, which are often integrated in modern imagers, can be straightforwardly implemented in the simulation chain.

This talk presents an overview of current work on performance modeling and image-based simulations at Fraunhofer IOSB. Moreover, it discusses the prospect of image-based testing in the lab environment using an infrared scene projector.

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Quantification of Human Color Perception Applied in TRM Model for Range Prediction of Imaging Color Systems

Ephi Pinsky, Sarit Feldman and Ofer Yaron

Rafael Advanced Defense Systems Ltd, Israel

A technique for extending the existing TRM4 category 'Visible Reflectivity'- model for Detection, Recognition, Identification [DRI] of a monochromatic scene, is proposed to be applied to color scenes.

A quantitative expression for the 'Difference (colored) Signal'- DSc between target and background based on the framework of the TRM model was developed. The principle for Difference colored Signal derivation is to express the perception of the target/background effective difference of a color scene, initially calculated in {RGB} space in terms of intensity, as a luminosity. This is done by transforming to {L*a*b*} color space that mimics the non-linear response of the eye such that a uniform change in the {L*a*b*} color space corresponds to a uniform change in the perceived color.

Determination of the Minimum Necessary Difference Signal- MNDSc for a color target on a color background using a similar approach is in progress. MNDSc greatly depends on the colored image noise as well as the filtering property of the human eye/brain colored components. The MNDSc is derived from the total system filtered noise variance and the Average Modulation at Optimum Phase - AMOP for each color component. A method to calculate noise variance of a color image of a target on background is presented. The eye/brain MTF for the color components are based on previous works.

The expressions for the effective MNDSc and DSc are derived from common color spaces. The cross-points of these curves represent the DRI ranges for each of the MNDSc tasks curves. These functions can be presented on an effective luminosity vs. range chart in which the cross-points and range sensitivity can be visually assessed.

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New Devices and Materials for Infrared Detectors

P.C. Klipstein
SemiConductor Devices Research Department, Israel

Infrared detectors working at photon wavelengths beyond the visible are an essential component of any modern day defense and security installation. Not only do they provide a night vision capability, but they can also be designed to operate at wavelengths that are less sensitive to atmospheric absorption, turbulence and particulates, providing a clear image that cannot be attained using visible light detectors. For the best high-end devices, the traditional method of fabrication has been based on cooled Mercury Cadmium Telluride (MCT) photodiodes. MCT is an expensive II-VI material and its photodiodes are often limited by non-uniformities and poor stability. At SCD we have therefore adopted an alternative approach based on more manufacturable III-V materials. Using advanced III-V heterostructure architectures, it is possible to achieve performance comparable with the MCT alternative, both with respect to operating temperature and wavelength tunability. The principles of such a heterostructure device will be described, where a barrier enables high operating temperatures by suppressing the major source of dark current noise due to Shockley-Reed-Hall (SRH) traps. This barrier architecture can be implemented using multi-layer superlattice materials that allow the operating wavelength of the detector to be adjusted over virtually the whole of the atmospheric infrared transparency range. A quantum mechanical superlattice model is described, which is based on an advanced implementation of k.p theory. This model can simulate both the band alignments of the absorber and barrier materials for correct device design, and the full spectral response and dark current of the complete detector, for matching its performance to the system requirements. A novel design has also been simulated for a next generation "dual band" architecture operating in two different wavelength ranges at essentially the same time.

Applications of High Power Lasers in the Battlefield

Yehoshua Kalisky
Electrical and Electronics Engineering Department, SCE, Israel

Laser weapon is currently considered as tactical as well as strategic beam weapons, and is considered as a part of a general layered defense system against ballistic missiles and short-range rockets. This kind of weapon can disable or destroy military targets or incoming objects, at a speed of light, and this is attractive against short-rage rockets and mortars. Laser weapon, unlike the kinetic one, is effective at long or short distances. This is owing to beam's unique characteristics such as narrow bandwidth, high brightness, coherent both in time and space. The laser beam, aimed on a small area spot at the rocket's skin is converted into a large amount of heat, following by a temperature increase and finally-catastrophic failure by material ablation or melt.

The usefulness of laser light as a weapon has been studied for decades but only in recent years became feasible owing to advances in solid state laser materials, optics and thermal management technologies. There are two types of lasers based on the active lasing media that are being used: gas lasers and solid state lasers, including fiber lasers. All these types of lasers will be discussed. Recent applications of ultrafast solid-state lasers for non-lethal or low collateral damage applications will be presented.

Breaking Through the Atmospheric Barrier

Daniel Golubchik
Rafael, Israel

Atmospheric turbulence is one of the main limiting factors for ground-based laser systems. Refractive index fluctuations due to atmospheric turbulence create distortion in the laser wavefront, consequently causing beam spreading and scintillations and limiting the effective range of free space communication and direct energy systems to a couple of kilometers.

One of the techniques for wave-front compensation is by coherent combination of several laser beams at the target. Commonly, optimization of the reflected light intensity is used by stochastic gradient descent or similar algorithms. Due to sensitivity to the time of flight, this approach is limited to either relatively short distances or very low Greenwood frequency. To the best of our knowledge, the longest distance demonstrated for target in the loop compensation systems is 7 km.[1]

In this presentation, we show laser wave-front distortion compensation by coherent beam combination of 32 laser beams. In the experiment, we demonstrated target in the loop corrections at distances up to 13 km. We also show partial wave-front compensation at extreme turbulence regime with Fried parameter as short as 10 millimeters. Dramatic improvement in laser systems performance is achieved even when the diameter of the individual beams is much smaller than the Fried parameter. Comparison of experimental results and beam propagation simulation is also presented.

1. Thomas Weyrauch et al, Optics Letters Vol. 36, 4455 (2011)

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Session: Optical Engineering - Dr. Hanni Inbar

♦ Transforming Optical Networks Design - Intelligent Networks in the Nonlinear Regime

Polina Bayvel
Department of Electronic & Electrical Engineering, University College London, UK

Optical networks underpin the global digital communications infrastructure, and their development has stimulated the global growth in demand for data, raising fundamental questions on the ultimate capacity of the optical fibre channel [see for example, "Roadmap of optical communications", E Agrell et al, J of Optics 18, 063002 (2016); "Maximizing the optical network capacity", P. Bayvel et al, Phil Trans Royal Soc A 374, 2014.0440 (2016)]. Much of the recent work has focused on the understanding the fundamental questions on the point-to-point nonlinear fibre channel capacity and proposals of new techniques for nonlinearity mitigation to reach this capacity. Developments in nonlinearity mitigation, high - speed electronics and DSP have led to data rates per wavelength increasing to beyond 1 Tbit/s. However, the next-generation digital infrastructure needs more than raw capacity - it requires flexible resource and capacity provision in combination with low latency, simplified and modular network architectures, maximising network throughput and resilience combined with overall network security. A key challenge is, therefore, to understand how to intelligently utilise the finite optical network resources, where the transmission medium - the fibre - is nonlinear - to dynamically maximise performance, while also increasing robustness to future unknown requirements.

The network of the future must be 'self-driving': able to configure itself, monitor itself, and self-correct. It must be able to automatically provision resources to meet dynamically varying demands while self-analysing and self-optimising. These functions can be realised using coherent transceivers, forming the next-generaiton new intelligent low-complexity reconfigurable architectures for cloud applications. The talk will discuss recent progress in optimising transmission and wavelength routing in the nonlinear regime and give an outlook for future research directions to transform optical network design.

♦ Nonlinear Optical Holograms for Shaping of Light Beams

Ady Arie
School of Electrical Engineering, Tel-Aviv University, Israel

Optical holograms enable storing the amplitude and phase of a waveform. The waveform can then be reconstructed by illuminating the object with a reference beam. Originally, these holograms were obtained by interfering the image and reference beam on a light-sensitive film, but in the 1960s computer-generated holography was introduced, where the required modulation pattern is computed and printed directly on a mask.

Here I will describe how the concept of computer generated holograms can be extended to the regime of nonlinear optics. In this case, the required modulation pattern is recorded by modulating the quadratic nonlinear coefficient of the crystal, so that when a reference wave illuminates the crystal, the desired beam shape is reconstructed at a new frequency [1]. Moreover, this method can also be used to shape the complex spectral response of a nonlinear frequency mixer [2].

In addition, for the case of sum frequency generation with a strong and undepleted pump, it is possible to design a nonlinear crystal that will introduce an adiabatic geometric phase [3]. This nonlinear-optics based geometric phase can be all-optically controlled via the pump wave, thus enabling to realize broadband, robust and non-reciprocal mode converters and cylindrical lenses for the frequency converted light.

[1] A. Shapira, L. Naor and A. Arie, "Nonlinear optical holograms for spatial and spectral shaping of light waves", Science Bulletin 60, 1403-1415 (2015).
[2] A. Leshem, R. Shiloh and A. Arie, "Experimental realization of spectral shaping using nonlinear optical holograms", Optics Letters 39, 5370-5373 (2014).
[3] A. Karnieli and A. Arie, "Fully controllable adiabatic geometric phase in nonlinear optics", Optics Express 26, 4920-4932 (2018).

Sub-Nanometer Overlay Metrology

Yuri Paskover
KLA, Israel

The ever-continuing growth in density of integrated circuits (IC) components' is driving the requirements for registration between patterns produced at different stages of chip fabrication (overlay) down to 2nm. Naturally, the requirements for fidelity of overlay monitoring are an order of magnitude tighter than those for process control, getting down to below 0.2nm. This is the incentive to the research aiming to decouple geometrical shift between patterns from other types of pattern deformations.

This talk will focus on newly introduced method for overlay metrology, based on multi-wavelength scattereometry.

Standard SCatterometry for OVerlay (SCOL) method is utilizing fiducial marks fabricated at every lithographic stage, simultaneously with functional IC components, and prone to placement errors similar to pattern of interest. The signals are collected at the Fourier plane of the optical system, which allows to access individual diffraction orders. Each diffraction order is a result of interference between diffractions of fiducials from different layers, and thus carries information on their relative shift, such that slight asymmetry in the intensity of diffraction orders is interpreted as overlay. However, recent findings, show, that significant error is being introduced to this interpretation due to asymmetric deformation of fiducials. We demonstrate that using multiple wavelength, specially chosen, based on evident propagation of the light within the on-wafer multi-layer, allows to determine the signal associated solely with geometrical shift, and significantly improve measurement quality.

Beam Shaping Based on Aspheres and Freeforms

Stefan Klinzing, Ulrike Fuchs, Thomas Hegenbart
Asphericon GmbH, Germany

Introduction and Background: Due to their flexibility, Gaussian intensity profiles are widely used, especially in the field of laser material processing. Nevertheless, there are some applications, where the inhomogeneous beam profile and the energy loss at the edge of the beam is not acceptable and a different intensity distribution would be much more advantageous. In addition, a square shaped Top-Hat, rather than a round shaped distribution can be very helpful for some applications. In this case, freeform elements are needed instead of rotational-symmetric aspheres.

Aim/Objectives: It could be shown, that refractive beam shaping systems provide very good results to solve this problem. This is mainly caused by their high efficiency and flexibility (with respect to wavelength changes), their simple structure and consequently, their good manufacturability.

Methods: The paper presents three different methods for laser beam shaping depending on the individual application, which can be homogeneous illumination or certain intensity distribution at the focal plane of a laser beam. Additionally, an approach for generation of square shaped Top-Hat intensity distributions is introduced

Results: All introduced beam shaping systems are very compact and enable smooth integration into existing set-ups. It is possible to use them with a collimated laser beam or a fiber coupled source. Furthermore, the input and output beam is scalable. In his work, some selected design investigations as well as some valuable results of the practical testing of all three systems are presented.

Another approach presented is to enhance the well-known Alvarez lens to achieve a square shaped homogeneous intensity distribution. For this, also some design investigations as well as simulations to estimate the as-built performance are shown.

Conclusion: Changing the intensity distribution can improve the efficiency of laser application in many cases. Depending on the individual field of application, several solutions are presented.

Layout and Analysis of Fused Silica Precision Glass Molding Processes

Tim Grunwald[1], Olaf Dambon[1], Thomas Bergs[2]

1. Fraunhofer IPT, Fine Machining and Optics Department, Germany
2. Tool Machine Laboratory (WZL) of RWTH Aachen University, Germany

High precision Fused Silica optics are highly requested in the field of laser technology. Not only the product demands are constantly rising but also technical requirements like efficiency and scalability of the production process. By using Precision Glass Molding, a replicative manufacturing process, Fused Silica optics can be produced in just one process step in comparison to traditional manufacturing where multiple steps of grinding and polishing are required. The elevated process temperatures of almost 1400 °C and the high mechanical load of the molding tools are the biggest challenges when molding Fused Silica. However, the carbon modification "Glassy Carbon" fits these demands well and is therefore suitable as a forming tool material. Nevertheless, rapid tool wear is still a substantial threat to the process' efficiency.

Previous studies disclosed the influence of the tools' surface finish procedure on the wear behavior to be significant. In this presentation, the investigation and analysis of surface preparation processes of Glassy Carbon molds are in focus. In order to comply with standards for high precision optics, the finishing results will be analyzed by means of sophisticated measurement technology covering various scales. The subsequent molding experiments are carried out to test the molding performance in terms of wear resistance. Correlations between the surface finish of the Glassy Carbon tools and their service lifetime are traced back to fundamental physical circumstances and final conclusions for an optimal surface treatment are derived.

Session: IFLA - Fiber Lasers and Applications II - Dr. Zachary Sacks

♦ Unconventional High-Power Fiber Lasers for Improved Wavelength Coverage

Johan Nilsson

University Southampton UK

Although ytterbium is the undisputed leading dopant for high-power fiber lasers and amplifiers [1], [2], other dopants as well as fiber nonlinearities offer operation at other wavelengths, alternative pumping options, fundamentally different gain characteristics, and fiber fabrication with much improved control. High-power erbium-doped fiber sources emit at ~ 1.6 μm, which is attractive because of its relative "eye-safety" and good atmospheric transmission as well as component availability, but are limited by poor pump absorption. Erbium-doped fibers are pumped at 0.98 μm or 1.5 μm. Whereas the latter wavelength benefits from a low quantum defect and thus thermal load, our analysis shows that the larger thermal load with 0.98-μm pumping still allow for several kW of output power. Instead, pump brightness is much more important, and in this regard, 0.98-μm diode lasers are outstanding and much better than those at 1.5 μm. We will present recent results on a 0.66-kW multimode Er-doped fiber laser [3] and analyze the prospects for higher power and single-mode operation.

Even when the laser wavelength is not important in itself, the wavelength can be still be important for the functioning of a device. Fiber Raman amplifiers can employ standard telecom fibers as the gain medium. These use pure-silica or Ge-doped silica cores and can be fabricated with superb transverse and longitudinal control of the refractive index profile. This includes custom designs. The high control can reduce mode-coupling and is thus attractive for high-mode-purity amplification of higher-order modes. A short fiber also helps to maintain mode purity. Given the instantaneous but weak nature of the Raman gain, this suggests pulse-pumping. Consequently, we pumped with a pulsed Yb-doped fiber source at 1060 nm, and amplified pulses at 1115 nm with high mode purity.

The Raman gain is different from that based on stimulated emission also in the saturation characteristics. In contrast to stimulated emission the Raman gain does not depend on the local signal intensity and there is therefore no local gain saturation. Even though the pump depletion still causes gain saturation, this is non-local. This leads to different gain competition behavior, which is also important for the mode purity. We will present results on high-purity Raman amplification of higher-order Bessel-modes [4] as well as modes with orbital angular momentum [5].

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Shankar Pidishety, Sheng Zhu, Yutong Feng, Balaji Srinivasan, and Johan Nilsson, "Raman amplification of optical beam carrying orbital angular momentum in a multimode step-index fiber", Opt. Lett., (2019) in press

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♦ Recent Developments in High Power Industrial Fiber Lasers

Scott Christensen
IPG Photonics, USA

IPG Photonics is the world leader in high-power industrial fiber lasers. In this talk recent developments will be reported, covering lasers used in the high-power area for metal processing which also have uses for defense applications. High-power multi-mode broad-band lasers, single-mode broadband lasers, and narrow linewidth amplifiers will all be discussed.

♦ Advanced Fiber Laser Design with Pulse-OnDemand for Next Generation Airborne Lidar Applications

Doron Barness
VGen, Israel

Airborne LiDAR has become a mainstream technology for surface data acquisition for a variety of largescale mapping applications, including demographic planning, city and terrain mapping, disaster and flood controls and bathymetric studies. These applications are in constant demand for improved resolution, precision, SNR and scanning time. Furthermore, novel scanning methods are now requiring high-end features such as pulse-ondemand capabilities with on-the-fly PRF modulation with high pulse-to-pulse stability and record breaking repetition rates. In this talk, we review recent developments achieved towards creating practical short pulse fiber lasers with high pulse peak power levels, high repetition rates, narrow spectral characteristics, and pulse-ondemand capabilities for advanced airborne LiDAR applications. The principle challenges and techniques for generating such fiber lasers will be highlighted, along with examples of advanced laser-based airborne surveying methods.

♦ Multi KW, High Power Laser with Single Mode (SM) Dynamic Beam using Coherent Beam Combining (CBC)

Benayahu Urbach, Yaniv Vinde and Eyal Shekel
Civan Ltd., Israel

Several high power lasers, based on coherent beam combining (CBC) technology, were recently demonstrated, with two different combining schemes.

In first CBC scheme, filled aperture combination, several high power lasers are coherently combined on a diffractive element. In these lasers the output power in few kWs, the beam quality is M2 <1.1 and the CBC efficiency is higher than 95%.

In lasers based on the second CBC scheme, tiled aperture scheme, tens of beams, with total power of >10kW are coherently combined in the far field. In this combining method, also known as optical phased array (OPA) CBC, the beams of the multiple channels are directed to overlap and combine in the far field and create a diffraction pattern. The position and shape of the diffraction pattern is controlled by the relative phases of the individual channels. By manipulating the relative phases, beam steering, beam focusing and beam shaping at 20 MHz speed are demonstrated. This high power laser with dynamic beam, can provide significant advantages in material processing.

In these two combining methods, the number of combined beams can be increased in order to increase the output power up to tens of kW, without any additional physical limit. Larger number of beams will also increase the scanning range and improve the resolution of the beam shapes in the case of the dynamic beam.

Fiber Optic Distributed Acoustic Sensing (DAS) Data Processing via Artificial Neural Networks

Lihi Shiloh, Avishay Eyal and Raja Giryes

PhD student, Faculty of Engineering, Tel-Aviv University, Israel

Distributed Acoustic Sensing (DAS) technology via optical fibers has revolutionized the field of acoustic sensing. DAS facilitates deployment of sensitive and cost-effective acoustic sensors over large distances with no need for inline amplification and inline power supply and with immunity to electromagnetic interference. However, the deployment of long haul sensing systems leads to a major difficulty: the amount of data collected is huge. This, as well as the intricate characteristics of DAS data which suffers from several dominant noise sources (phase noise, acoustic noise etc.) necessitates the development of automatic detection and classification tools for its processing. This, in turn, requires large-scale tagged databases to be used in order to train machine-learning based algorithms. Collection of such databases demands a substantial amount of computer and labor resources. A considerably more efficient approach would be to use computer simulations (rather than experiments) to collect synthetic DAS data. This approach, however, requires highly accurate modeling of the optical DAS system, the generation and propagation of the seismic/acoustic waves in the medium and the interaction between the waves to the fiber. The physical parameters and details needed for such modeling are rarely available.

Here we present an approach for the efficient generation of DAS data based on Generative Adversarial Network (GAN). The efficiently generated synthetic data is refined to mimic genuine data using the GAN architecture and used to train a Deep Neural Network (DNN) for the complex task of event classification from DAS data. A finetuning training phase is done using a smaller hand-tagged experimental dataset to obtain a field data classifier. We show the advantage of the methodology with field experiments of a 5km and 20km long fiber sensors. Classification accuracies of 83% and 80%, respectively, between footsteps, vehicles and ambient noise are presented.

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Session: Ultrafast Phenomena - Prof. Oren Cohen

♦ Spatiotemporal Dynamics of Optical Pulse Propagation in Multimode Fibers

Frank Wise

Department of Applied Physics Cornell University, USA

Optical fibers designed to support multiple transverse modes offer opportunities to study wave propagation in a setting that is intermediate between single-mode fiber and free-space propagation.

A variety of qualitatively-new phenomena have been observed recently in multimode fibers. Self-cleaning of a multimode beam is observed at a fraction of the critical power for self-focusing. New instabilities, which are spatiotemporal in nature, occur. By varying the launched spatial modes, it is possible to generate dispersive waves over one octave in frequency, or continua that span multiple octaves. One or two of these new phenomena will be presented along with their connection to multimode soliton dynamics. Recent progress in spatiotemporal mode-locking in fiber lasers will then be summarized.

Possible directions for studies of new nonlinear wave physics in multimode fibers will be discussed along with potential applications.

Self-Compressed Polarization Controlled Red Shifted Soliton from Supercontinuum for 1 μm CPA Systems

Zaharit Refaeli[1,2], Yariv Shamir[1], and Gilad Marcus[2]

1. Applied Physics Division, Soreq NRC, Yavne 81800, Israel,
2. Applied Physics Department, School of Computer Science and Engineering, The Hebrew University, Jerusalem, 9190401, ISRAEL

We report a self-compressed 1 μm wavelength pulses generated directly out of a highly-nonlinear photonic crystal fiber (PCF), excited by multi-nonlinear processes and dispersion balance, generated by a far-shifted 800 nm Ti:Sa laser. Result was obtained by careful dispersion and nonlinearities management, mainly the control over Self Phase Modulation (SPM) and Soliton Self Frequency Raman Shift (SSFRS). We harnessed certain properties of the propagating media and the scheme and consequently obtained ultrashort pulses that were self-compressed up to their Fourier-Transform Limit (FTL). Moreover, pulses were significantly red-shifted to new wavelengths area of between 915 nm and 1200 nm, obviously attractive for high energies or average power amplification. Additionally, these resulted pulses obviated the need for an external free-space compressor module, many times accompanied by hard-to-tweak alignments and wave front distortions. The major handle over both spectral broadening and SSFRS was varying of the incident seed's state of polarization (SOP), inducing variable χ^3-depended polarization and change in n□ correspondingly. Moreover, SOP control enabled also Raman red shift of the soliton's central wavelength, spanned over 150 nm range. We spectrally picked-off the resulted soliton, verified its qualities using FROG retrieval device before further amplification. Finally we amplified the pulses by two orders of magnitude in a home-made fiber amplifier and prepared it for intermediate examination by re-compression. Consequently, the newborn pulses were ready for applications, e.g. starting an amplification chain for high energy or high power laser systems such as Nd:Glass or Yb ion based Chirp Pulse Amplification (CPA) system operating in the 1 μm regime. A grating-pair Treacy type compressor was designed assembled and to be tested next. As a result, we proposed in this work an alternative method to generate 1 μm ready-for-work pulses from a commonly available shorter wavelength femtosecond source, using a simple, inexpensive and flexible technique.

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Interferometric Attosecond Lock-In Measurement of Extreme Ultraviolet Circular Dichroism

Doron Azoury, Omer Kneller, Michael Krüger, Barry D. Bruner, Oren Cohen, Yann Mairesse, Nirit Dudovich

Weizmann Institute of Science, Israel

Probing vectorial properties of light-matter interactions inherently requires control over the polarization state of light. The generation of extreme-ultraviolet (XUV) attosecond pulses opened new perspectives in measurements of chiral phenomena. However, after almost 20 years of development, attosecond science remains a predominantly scalar science-the vast majority of experiments performed to date rely on the application of linearly polarized attosecond pulses. Indeed, the mechanism of attosecond pulse generation imposes a strong limitation on the ellipticity of the light - preventing the development of advanced vectorial measurement schemes.

Here, we establish an XUV lock-in detection scheme [1], allowing the isolation and amplification of extremely weak chiral signals, by achieving a dynamical polarization control. We demonstrate a time-domain approach to control and modulate the polarization state, and perform its characterization via an in-situ measurement. Our approach, resembling a birefringent crystal for the visible range, is based on the collinear superposition of two independent, phase-locked, orthogonally polarized XUV sources and the control of their relative delay with sub-cycle accuracy. We achieve lock-in detection of magnetic circular dichroism, transferring weak amplitude variations into a phase modulation. This approach holds the potential of significantly extending the scope of vectorial measurements to the attosecond and nanometer frontiers.

[1] D. Azoury, O. Kneller, M. Krüger, B.D. Bruner, O. Cohen, Y. Mairesse and N. Dudovich, Nature Photonics (2019), DOI: 10.1038/s41566-019-0350-5.

Two-photon Excitation of an Exciton-Polariton Condensate

Nadav Landau[1], Dmitry Panna[1], Sebastian Brodbeck[2], Christian Schneider[2], Sven Höfling[2] and Alex Hayat[1]

1. Department of Electrical Engineering, Technion, Israel
2. Technische Physik, Universität Würzburg, Germany

Introduction: Recent studies on microcavity exciton-polaritons have investigated two-photon excitation into the optically forbidden 2p "dark" exciton states in semiconductor quantum-wells, and relaxation into the lower-polariton branch of the hybridized 1s exciton state, as a potential source for coherent THz radiation. This transition was shown theoretically to become stimulated when feeding a Bose-Einstein condensate of exciton-polaritons at the lower branch ground state. Here we demonstrate for the first time a two-photon excitation process forming an exciton-polariton condensate, as a potential first step in that direction.

Background: Exciton-Polaritons have been shown to form a dynamical Bose-Einstein condensate at their ground state, above a characteristic threshold density. However, inducing such a condensate through optical injection has only been shown using one-photon excitation schemes.

Objectives: We experimentally observe the formation of a Bose-Einstein condensate of exciton-polaritons at the ground state, following a two-photon excitation process.

Methods: A regenerative amplifier system delivering 35fs pulses at a 1 KHz repetition rate was fed through an optical parametric amplifier, exciting our cooled GaAs-based microcavity sample at energies around half the resonance energy of the lower polariton ground state. Excitation intensity was attenuated controllably using a variable neutral density filter.
Energy-, time-, and angle-resolved photoluminescence measurements were carried out, and characterization of both the two-photon absorption and subsequent polariton condensation was performed.

Results: Our Energy- and angle-resolved measurements show the onset of macroscopic occupation of the lower polariton ground state around zero in-plane momentum, above a certain critical density, and time-resolved measurements indicate this transition becomes stimulated with increased injection.

Conclusions: We observed for the first time formation of a Bose-Einstein condensate of exciton-polaritons through two-photon excitation. Verifying injection into the 2p "dark" exciton state, or probing the excited sample for THz emission, could shed light on this effect and provide a new source of stimulated THz radiation.

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♦ Revealing the Motion of Hybrid Light-Matter Excitations by Ultrafast Microscopy

Tal Schwartz, Georgi Ro

Physical Chemistry Department and Tel-Aviv Center for Light-Matter Interaction, Tel-Aviv University, Israel

When a large ensemble of molecules is strongly-coupled to a photonic mode, the tightly-bound excitonic wavefunctions of the molecules are coherently mixed with the photonic mode of the cavity, forming hybrid light-matter particles known as cavity polaritons. Due to the collective nature of strong coupling and the partially-photonic character of the polaritons, the polaritonic wavefunctions are extended over many molecules and over distances comparable to the optical wavelength. This fascinating state was shown to give rise to spatially-coherent emission from molecules and enhanced conductivity of organic semiconductors under strong coupling, providing a means to overcome the poor mobility of organic semiconductors. However, since all previous experiments relied on steady-state measurements, until today, the spatiotemporal dynamics of polaritons remained hidden.

In my talk I will describe our recent study, where we performed ultrafast time-resolved imaging experiments on strongly-coupled organic microcavities and successfully observed the motion of polaritons, for the first time. Our results demonstrate in a direct manner that the strong coupling to photons extends the transport range in organic films, from the molecular, nanometric scale, to several microns. Surprisingly, we found that the polariton propagation velocity is much lower that theoretically predicted, which we attribute to the disordered nature of the molecules, which limits the extension of the polaritonic wavefunctions and renders their transport non-ideal. With our new approach, such effects, which govern the transport of polaritons and their spatiotemporal dynamics, can now be revealed and explored.

Session: Non-Linear Optics - Dr. Haim Suchowski

Opto-Mechanical Time-Domain Reflectometry

G. Bashan, H. H. Diamandi, Y. London, E. Preter, A. Zadok

Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, Bar-Ilan University, Israel

Optical fibers constitute an exceptional sensing platform. However, standard fibers present an inherent challenge: they confine light to an inner core. Consequently, fiber sensors are restricted to the measurement of conditions within the core. This work presents distributed analysis of media outside unmodified, standard fiber, where light cannot reach. Measurements are based on stimulated scattering by guided acoustic modes, which span the entire cladding cross-section and reach its outer boundary. The protocol overcomes a major difficulty: guided acoustic waves scatter light in the forward direction, and cannot be located using time-of-flight techniques. The solution relies on frequency-selective mapping of Rayleigh backscatter of two optical tones, which are coupled by the acoustic wave. Analysis is demonstrated over 3 km of fiber with 100 m resolution. Measurements distinguish between air, ethanol and water outside the cladding of a standard fiber [1].

The first measurements suffered from a major drawback: the standard dual-layer acrylate coating absorbs the acoustic waves and must be removed. In contrast, sensing can be performed outside commercially-available fibers coated with polyimide instead. The opto-mechanical coupling in coated fibers has been formulated from first principles. The model shows that the scattering spectra in coated fibers are more complex than those of bare fibers, and strongly depend on the exact coating diameter and the choice of acoustic mode. Nevertheless, sensing outside coated fibers was also demonstrated experimentally. Integrated measurements over 100 meters of fiber distinguish between air, ethanol and water. Spectra are in very good agreement with the analytic predictions. Further, distributed opto-mechanical time-domain reflectometry mapping of water and ethanol outside a 1.6km coated fiber is reported, with a spatial resolution of 100 meters. The results represent a large step towards practical opto-mechanical fiber sensors.

[1] G. Bashan et al., "Optomechanical time-domain reflectometry," Nature Communications 9, 2991 (2018).

Observation of Strong Nonlinear Interactions in Parametric Down-Conversion of X-Rays into Ultraviolet Radiation

Or Sefi

Bar-Ilan University, Israel

Photonics is a major field of research that is important for fundamental sciences and has led to many practical applications. A better understanding of the light-matter interactions is crucial for further developing of photonics-based technologies. Most of the approaches aiming at improving the knowledge of light-matter interactions utilize long wavelengths, thus cannot probe microscopic information, such as the valence electron redistribution in response to an external electric field. Although x-ray-based techniques are capable of probing atomic scale structures, they interact mainly with core electrons thus provide very limited information on valence electrons.

Nonlinear wave-mixing of x-rays and long wavelengths can be used to measure the microscopic properties of valence electrons in solids. This effect can be viewed as x-ray scattering from optically modulated valence electrons, hence the x-rays probe the variation of the valence electrons and provide access to the microscopic world. However, to date, nonlinear interactions between x-rays and long wavelengths have been observed only in simple crystals such as diamond and silicon. The typical efficiency and the signal-to-noise-ratio that have been reported are barely measurable.

Here we report on the observation of prominent large x-ray nonlinear effects in the non-centrosymmetric crystals GaAs and $LiNbO_3$. The measured signals are stronger by orders of magnitude from the background and the efficiencies are about four orders of magnitude stronger than the efficiencies measured in any other crystal before. Our results indicate on an unrevealed underlying physical mechanism that is responsible for these strong nonlinearities. We demonstrate the ability to perform broad-band spectroscopic measurements that enable the retrieval of information on the band structure, density of states, and atomic resonances in the crystals. As such, our work opens new possibilities for future research of nonlinear x-ray optics in complex materials and for the development of novel spectroscopy techniques based on these effects.

THz Generation and Manipulation by a Nonlinear Metasurface Fresnel Zone Plate

Eviatar Minerbi, Shay Keren-Zur, Tal Ellenbogen
Faculty of Engineering, Tel-Aviv University, Israel

The THz spectral regime ranging from about 0.1-10 THz lies between the microwave and infrared regions of the spectrum. Although this frequency regime has many important applications, including various types of nondestructive measurements, imaging through optically opaque materials, and extended communication speeds, there is still a lack of efficient THz sources and manipulation elements that are functionally comparable to those in the optical or radio frequency regimes. Therefore, there is a need to study improved ways to generate and control THz radiation.

Recently it has been shown that broadband THz emission can be efficiently generated from an ultrathin metasurface layer consisted of split-ring resonators with a few tens of nanometers thickness. Preliminary results showing some control capabilities over the emitted THz radiation were also reported. Here we show that by careful geometrical arrangement of the split-ring resonators over the metasurface, it is possible to both generate and to focus a broadband THz radiation. Specifically, we demonstrate experimentally and by simulations a method to design nonlinear diffractive Fresnel zone plates. These lenses focus each generated frequency to a different focal point, thus achieving a narrow beam waist, high intensities and spectral selectivity of both bandwidth and central frequency. Furthermore, in the experimental setup presented, we are capable to measure the temporal structure of the electric field of the generated THz.

This concept serves as a foundation for fundamental research in the THz regime and can lead to the development of efficient, active, integrated and ultra-compact optical devices for the THz spectral region.

Enhanced Frequency Doubling of High-Power CW Fiber Lasers in The Presence of Doubler Phase-Mismatch through Injection of a Conjugate Seed Beam

Steven Jackel, Yishai Albeck
Civan Advanced Technologies, Israel

Past work showed the advantages of using frequency doubling crystals separated by phase mismatch corrector plates (PMCs). This enabled achievement of 110W of CW power at efficiencies up to 40%. The PMC improved second crystal doubling by correcting thermally induced mismatched phase (TMP) from the first crystal and the first part of the second crystal. Efforts to correct for phase mismatch in the first crystal have, however, been limited to temperature retuning of Uniform Temperature Ovens (UTOs, partially successful) or through use of Gradient Temperature Ovens (GTOs, theoretically an excellent solution but more complicated). (1) It was supposed that nothing could be done to control harmonic / fundamental initial phase-difference in the first crystal because the doubling process started at the crystal's entrance face.

In this work, we show that injection of a weak, frequency-doubled seed beam with phase difference conjugated to the TMP generated from the first power doubling crystal can improve performance to the theoretical level expected in the absence of TMP. A robust solution is obtained by inserting an additional crystal plus PMC prior to the first Power Doubler (PD). The seed crystal need only double a small part of the fundamental beam so its configuration may differ from that of the PDs. Since all of the elements are placed in series from start to finish, the solution does not require interferometric alignment of separate beam-lines.

Seeder application is expected to become more significant as we continue to raise power in single beam-lines. (2)

1. Saeed Ghavami Sabouri and Alireza Khorsandi, "Active control of thermal dephasing effect in high power continuous wave single-pass second harmonic generation," IEEE J of Quantum Electron 51 (2015)
2. Steven Jackel and Yishai Albeck, "Enhanced frequency conversion via a weak high frequency seed beam collinearly generated in the primary beam," Provisional patent 42,425 (2018)

Stabilizing Soliton-Based Propagation in Nonlinear Optical Waveguide Loops by FrequencyDependent Linear Gain-Loss and the Raman SelfFrequency Shift

Avner Peleg, Debananda Chakraborty

Ort Braude College of Engineering, Israel
New Jersey City University, USA

Introduction: Stabilizing soliton propagation in nonlinear optical waveguide loops is a highly challenging problem in nonlinear optics. The challenge arises due to emission of small-amplitude waves (radiation) by soliton propagation in the presence of perturbations. In a nonlinear optical waveguide loop, the emitted radiation accumulates and interacts with the soliton. As a result, the soliton's shape becomes distorted and is eventually completely destroyed.

Background: In earlier works we developed a method for stabilizing the propagation of multiple soliton sequences in nonlinear optical waveguides by frequency-dependent linear gain-loss. We showed that the presence of frequency-dependent linear gain-loss leads to efficient suppression of transmission instability due to resonant emission of radiation. However, transmission stability remained limited due to effects of perturbations on single-soliton propagation. Furthermore, we found that additional significant enhancement of transmission stability is obtained when both the effects of frequency-dependent linear gain-loss and delayed Raman response are taken into account.

Objectives: Investigate whether the combination of frequency-dependent linear gain-loss and delayed Raman response can indeed lead to significant enhancement of transmission stability for a single optical soliton propagating in a nonlinear waveguide loop. If such stabilization is possible, characterize the mechanisms and physical principles by which the stabilization takes place.

Methods: We perform extensive numerical simulations with the perturbed nonlinear Schrodinger equation.

Results: We find that the presence of delayed Raman response leads to significant enhancement of transmission stability in waveguide loops with frequency-dependent linear gain-loss. Stability enhancement is caused by the separation of the soliton's spectrum from the radiation's spectrum due to the soliton's Raman-induced self-frequency shift and by efficient suppression of radiation emission due to frequency-dependent linear gain-loss.

Conclusions: We demonstrate a general principle for stabilizing soliton transmission in nonlinear optical waveguides, based on the interplay between frequency-dependent linear gain-loss and perturbation-induced shifting of the soliton's frequency.

Advantageous Hurdles in Rotational Echo Spectroscopy

Dina Rosenberg, Sharly Fleischer, Ran Damari

School of Chemistry, Tel-Aviv University, Israel

Since the pioneering work of E. L. Hahn [Phys. Rev. 80, 580 (1950)], echo spectroscopy has become a central methodology in all fronts of spectroscopy, enabling researchers to distinguish dephasing from decoherence dynamics. Recent years have witnessed increasing interest in rotational echo spectroscopy with resonant terahertz fields and with non-resonant optical pulses, demonstrating a variety of rotational echo responses [PRL 114, 153601 (2015), PNAS 113, 11800 (2016)]. Different from two-level systems, molecular rotors are multi-level rotational systems with few tens of populated levels and with different transition frequencies among those levels. The latter results a periodic rotational dynamics following excitation by an ultrashort laser pulse, termed 'quantum rotational revivals' with recurrences of the molecular alignment / orientation persisting under field-free condition.

An echo experiment includes two laser pulses, with time-delay apart ($\Delta\tau$, 'waiting time') that give rise to an echo signal at $t=2\Delta\tau$. By scanning $\Delta\tau$ and monitoring the echo signal at $2\Delta\tau$ one is able to extract the rotational decoherence rate. However, in multi-level molecular rotors, the echo signal is found to strongly depend on the $\Delta\tau$ invoking severe difficulties in the interpretation of the experimental results. We show that the dependence on $\Delta\tau$ results from the interference between of multiple-pathways within the rotational coherences manifold [PRL 121, 234101 (2018)]. We show that for each $\Delta\tau$ there is an optimal intensity for the second pulse (P2) that gives rise to maximal echo amplitude, and that these echo amplitudes are independent of both the $\Delta\tau$ and the intensity of the first excitation pulse (P1). We utilize these findings to perform rotational echo spectroscopy by judicious control of the pulses' intensities and demonstrate a viable methodology that enables the extraction of rotational decoherence rate. Additional desirable possibilities for high-density gas samples and large molecules will be discussed.

Session: Photonics in Defense - Dr. Joelle Schlesinger, Dr. Ami Yaacobi

Mission Ready Optics: Conquering Frontiers in Aerospace & Defense Contamination Control with First Contact Polymers

James Hamilton

University of Wisconsin-Platteville, Department of Chemistry & Engineering Physics, USA

Many precision optical surfaces such as first surface mirrors on satellite and telescope mirrors are historically “uncleanable” impacting performance. Contamination control outside a cleanroom and particulate removal is a critical technology that limits deployment on high energy laser (HEL) optical and other systems. In this talk, we will present data and examples of use of First Contact Polymer stripcoatings that provide superior cleaning & protection from recontamination for telescopes, space instruments, CCD’s and focal plane arrays. So critical is surface cleanliness, that our polymers continue to be ancritical enabling technology in both LIGO’s Gravity wave discoveries of 2016 as well as for the THAAD US Ballistic Missile Defense System and NASA’s Starshade SpaceTelescope program.

Controlled Distortion for Optical-Equivalent Zoom Lens with No Moving Parts

Paula Roit

Rafael, USA

There are many cases in which designing with a single, uniform resolution on a given detector does not meet the system requirements.

In a previous OASIS conference we presented the anamorphic solution, with different focal lengths for the X and Y axis.

This time we want to focus on changing the resolution radially, giving a high resolution center combined with a relatively large Field of view.

Actual pictures will be presented including the picture treatment to fix its side effects.

Oasis 7th Conference and Exhibition on Electro-Optics

Lenses on Diet

Oded Arnon

Arnon Optical Engineering, Israel

Every lens designer has probably faced the gap between the nominal performance of an optimization and the final ″as-built″ performance. The idea behind ″Lenses on Diet″ helps in narrowing the gap by relaxing the tolerances during optimization without adding heavy computations to the process. The method is based on reducing excessive power-load from the lens, which is considered a major source to undesired sensitivity.

The paper suggests the use of an original ″Dietary Criterion″ to select a better candidate to start the optimization and demonstrates the benefits of applying ″Dietary Optimization″ on a Cooke Triplet and a Petzval configurations.

Bullet Speed System - Calibration Method

Uri Maurice

QCC Hazorea, Israel

Introduction: In many fire-ranges one can see a set of screens meant to measure projectile speed as it passes through them. When this system of screens and chronograph needs to be calibrated to ensure accuracy and comply with quality assurance regulations, the question of how the system should be calibrated arises.

Background: The police, army and manufacturers of protective equipment must calibrate their bullet speed systems periodically. In this systems the chronograph was usually calibrated on its own, not accounting mechanical stationing and system transfer delays - which does not satisfy many regulatory requirements. When the manufacturer was contacted he claimed the systems could not be calibrated because there is no ″master-ammo″.

Objective: To develop a new and comprehensive calibration method for bullet speed systems.

Methods: A few approaches for calibration were tested, from the foil tear signal method to the construction of a similar shot through device put in series with the tested device. Eventually an alternative approach was developed and validated, in which an optical signal simulating the shadow of the bullet with a time delay between the window’s shadows was combined with measurement of the distance between the screens to calculate the bullet speed. Thus injected optical signals were used to simulate bullets through the screens and the simulated signals were sampled to an oscilloscope to determine the expected bullet speed.

Results: Since the calibration requires no actual shooting, as many ″bullets″ as desired may be ″shot″ to simulate any desired speed. Furthermore, this validated calibration method can withstand the rigorous ISO 17025 quality standard.

Conclusions: A new approach for the calibration of bullet speed systems was developed, validated and implemented using optical simulation instead of the previous partial calibration. Moreover, the new calibration method is traceable and includes an uncertainty budget to conform to regulatory demands.

♦ Photonic Integrated Interferometric Telescopes - Scalable and High-Resolution Imaging with 2D/3D Integrated Photonic Chips

S. J. Ben Yoo
UC Davis, USA

Our desires to image remote objects with fine details have driven many scientists to develop telescopes with high quality bulk optics in best known configurations since 17th century. Hans Lippershey's spyglass telescopes in 1608 have prompted Galilei Galileo to make a new 10x telescope by grinding his own lenses and placing them in a tube. Fast forwarding to 1990, the Hubble Space Telescope of 13m x 4.2m size and 11,110 kg weight have been placed on orbit by a space shuttle and continues to send remarkable images that led us to new scientific understandings. These telescopes relied on large aperture lenses or reflectors placed accurately in large tubes. We discuss a new low-mass, low-volume alternative to the traditional bulky optical telescope and focal plane detector array. The Segmented Planar Imaging Detector for EO Reconnaissance (SPIDER) concept developed in collaboration with the Lockheed Martin Advanced Technology Center consists of millions of direct detection white-light interferometers densely packed onto photonic integrated circuits (PICs) to measure the amplitude and phase of the visibility function at spatial frequencies that span the full synthetic aperture. Conventional approaches for imaging-interferometers require complex mechanical delay lines to form the interference fringes resulting in designs that are not traceable to more than a few simultaneous spatial frequency measurements. SPIDER achieves this traceability by employing micron scale optical waveguides and nano-photonic structures fabricated on a silicon PIC with micron scale packing density to achieve a 10-100× reduction in the imager's size and mass, impacting a wide range of future scientific applications. We will discuss recently demonstrated 2D photonic integrate circuits (PICs) providing interferometric imaging and new generations of 3D PIC concepts for future SPIDERs.

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Session: Atomic and Quantum Optics - Prof. Barak Dayan

♦ Quantum Photonics for Computer Security and other Applications

Philip Walther
Faculty of Physics, University of Vienna, Austria

The precise quantum control of single photons, together with the intrinsic advantage of being mobile make optical quantum system ideally suited for delegated quantum information tasks, reaching from well-established quantum cryptography to quantum clouds and quantum computer networks. Here I present that the exploit of quantum photonics allows for a variety of quantum-enhanced data security for quantum and classical computers. The latter is based on feasible hybrid classical-quantum technology, which shows promising new applications of readily available quantum photonics technology for complex data processing. As outlook I will discuss technological challenges for the scale up of photonic quantum computers, and our group's current work for addressing some of those.

♦ New Frontiers for Light Storage at Room Temperature

Ofer Firstenberg
Weizmann Institute of Science, Israel

We study schemes for quantum memories in warm atomic vapor. The first scheme is a fast ladder memory (FLAME), where we map the optical field of nanosecond-long pulses onto the superposition between electronic orbitals in the vapor. FLAME demonstrates high bandwidth and low noise, as required for quantum network synchronization. We explore the implementation of FLAME via tapered optical fibers, its performance in conjunction with our vapor-based single-photon source, and its integration with Rydberg-level excitations for quantum nonlinear optics. The second scheme we study is a ground-state memory, where the optical field is mapped onto the spin orientation of the atomic vapor. As the spin orientation is insensitive to spin-exchange collisions, we achieve a record 400- millisecond memory lifetime at room-temperature. This scheme paves the way towards hour-long memories using rare-gas nuclear spins at ambient conditions.

Demonstration of a Two-Qubit Photon-Atom Gates and Engineering Quantum States of Lights

Ziv Aqua, Orel Bechler, Adrien Borne, Serge Rosenblum, Gabriel Guendelman, Ori Ezrah Mor, Moran Netser, Tal Ohana, Niv Drucker, Ran Finkelstein, Yulia Lovsky, Rachel Bruch, Doron Gurovich, Ehud Shafir, Barak Dayan

Weizmann Institute of Science, Israel

Deterministic quantum gates between single pho-tons and single quantum emitters are a valuable building block for the distribution of quantum in-formation between remote systems [1-4], as well as for the engineering of bene cial photonic states. Recently we have demonstrated a passive photon-atom swap gate [5]. The underlying mechanism is single-photon Raman interaction (SPRINT) [6-8] - an intereference-based scheme that manifests itself in any waveguide-coupled -system where each transition is coupled to a di erent mode of the waveguide. This scheme allows for an incoming photonic qubit (described by the two modes of the waveguide) and a material qubit (defined by the two ground states of the -system) to exchange their states. Swap can be further utilized to yield universal quantum gates such as controlled-phase [9] and swap [10]. These gates will enable us to tackle the eld of multipartite entanglement by generating photonic graph states, which hold promise in quantum communication [11] and quantum computing [12]. In this talk, I will present the main results of the photon-atom swap gate and some of our plans for the future.

Quadrature Phase Detection in Atom Interferometry

Chen Avinadav[1,2], Dimitry Yankelev[1,2], Nir Davidson[1], Ofer Firstenberg[1]

1. Weizmann Institute of Science, Physics of Complex System, Israel
2. Rafael Ltd., Israel

Cold atom interferometers are among the most sensitive instruments in measuring inertial forces, such as gravity and gravity gradients, accelerations and rotations. The atomic wave function is split between two different momentum states that drift apart and later recombine to produce interference fringes, whose phase is determined by the inertial forces acting on the atoms. This phase is usually extracted from the atomic populations of two output ports, and as such, dynamic range is limited by ambiguity to pi radians, and sensitivity is greatly reduced away from mid-fringe. These limitations challenge the application of atom interferometers in field conditions.

We present new interferometric and measurement schemes which together enable full quadrature phase detection from four output ports. This allows for phase retrieval at maximal sensitivity and bandwidth, with two-fold increase in dynamic range, compared to the standard detection. We realized the new schemes in a fountain cold atom interferometer apparatus, in which we previously demonstrated gravimetric measurements at below 10 ng resolution. We investigated two schemes of quadrature measurement: single interferometer with modified final "beamsplitter", and two concurrent interferometers with a controlled phase shift between them. Detection in both cases was done with a novel detection sequence that enabled independent measurement of the four output ports.

Squeezing-Enhancement of Stimulated and Spontaneous Raman Spectroscopy

Yoad Michael, Leon Bello, Michael Rosenbluh, Avi Pe'er

Bar-Ilan University, Israel

Raman Spectroscopy is a powerful tool for the identification of molecular species. Yet, Raman spectroscopy has one major drawback - the relative weakness of the Raman response, which results in a signal that is often obscured by other light-matter interactions. Therefore, a critical goal in Raman spectroscopy is to improve the sensitivity by increasing the Raman signal while reducing the background. The sensitivity of all Raman spectroscopy schemes to date is inherently limited by shot-noise.

We suggest and present the theory of a quantum-enhanced scheme of Raman spectroscopy, which expoits two-mode squeezed light for a robust Raman measurement below the shot-noise limit. This simple method inserts the Raman sample between two external parametric amplifiers, forming a nonlinear squeezed interferometer, where the Raman interaction in the sample induces a phase shift that is detected by the interferometer with sub-shot noise sensitivity. In this scheme, the observed signal is proportional to the Raman gain of the sample multiplied by the squeezing factor of the parametric amplifiers, forming a "quantum-enhanced gain". Seeding the interferometer with coherent input further stimulates the Raman signal classically without increasing the background, leading to a squeezing-enhanced version of Stimulated Raman spectroscopy, where the squeezing enhancement is obtained on top of the classical stimulation. Additionally, the elimination of the non-resonant background occurs automatically due to the inherent phase difference between resonant and non-resonant FWM interactions in the Raman sample, where the non-resonant contribution can be negated by gain-tuning the interferometer.

A practical consideration to all squeezing applications is optical loss, which we also incorporate to our analysis: both internal (inside the interferometer) and external loss in the detection. We show that the squeezing enhancement still improves the minimum detectable signal below the shot-noise limit even in the presence of mild losses, demonstrating the resilience of this scheme to loss.

Session: IFLA - Ultrafast Fiber Sources and Related Applications - Prof. Zeev Zalevsky

♦ Coherent Pulse Stacking Amplification - Extending Fiber Chirped Pulse Amplification by Two Orders of Magnitude

Almantas Galvanauskas

University of Michigan, USA

Ultrashort pulse fiber lasers provide a pathway for scaling ultrafast laser technology to very high average powers, which is critically important for a multitude of scientific and practical applications. Main challenge on this pathway is achieving high energies with ultrashort pulse fiber lasers. Indeed, fiber chirped pulse amplification (FCPA) systems can only extract up to approximately 1% of stored energy in a fiber amplifier. This is due to the fact that optical pulse stretching and compression in CPA systems uses dispersion of, e.g. diffraction-grating or Bragg-grating devices, which fundamentally limits stretched pulse durations to ~1-ns scale.

Over the last few years we have been developing a new technique, so-called coherent pulse stacking amplification (CPSA), in which coherent time-domain pulse combining allows to overcome stretched-pulse duration limitations imposed by the dispersion, and to achieve "effective" amplified pulse durations on the scale of ~100-ns. Using CPSA we were able to demonstrate a record-breaking generation of 10-mJ and ~500-fs pulses from a fiber amplifier system based on large-core fibers (CCC fibers) with mode field diameter of approximately 42-μm. We measured that the extracted energies were corresponding to more than 90% of the stored energy, and estimated that the "detrimental" nonlinear phase was only ~5.6 radians. Equivalent nonlinearity-limited energies achievable with the same system, but using only CPA, would be on the order of 100-200 μJ. This talk will describe our continuing progress in developing this CPSA technique further, as well as our ongoing efforts to achieve simultaneous time-domain and spatial-domain combining to enable future multi-kilowatt average power and multi-terawatt peak power ultrashort-pulse laser systems.

♦ The Myths, the Reality, and the Unexplored Potential of SESAM Technology for Mode-Locking

Mircea Guina

Optoelectronics Research Centre, Tampere University, Finland

Semiconductor saturable absorber mirrors (SESAMs) have been widely used for passive modelocking of femtosecond and picosecond lasers. Their key feature include the ability to precisely tailor the nonlinear properties, and hence the mode-locking driving force. Thus, they offer access to customized absorption recovery time down to sub-ps level, nonlinear reflectivity ranging from as low as 0.1% to tens of percent, and a broad wavelength coverage (i.e. from 600 nm to 3 μm). In terms of application, SESAMs offer a robust modelocking mechanism and a practical approach to build reliable ultrashort pulse lasers with simple architecture, environmentally stable operation, and moderate cost.

SESAM technology has been largely confined to developments at 1-μm and 1.55-μm wavelength domains, where most of current volume applications are; this is in particular valid for fibre lasers where wavelength extension has been limited by the availability of mature doped-fibre technology. On the other hand, intense research activities concerning wavelength extension of solid-state lasers and other more novel ultrafast lasers platforms, such as VECSELs, have pushed the frontier of SESAM technology towards new material systems. From this standpoint, the presentation covers recent progress oin SESAM developments, in particular focused on novel approaches to tailor the absorption recovery time and the use of new material systems enabling wavelength extension. Starting from introducing the general design guidelines governing the operation of SESAMs, we define the standard approaches and limitations of current technology. Then we introduces more recent developments addressing new wavelength regions, in particular linked to applications in modelocking of Pr-doped (~640 nm), Bi-doped (~1.3 μm), and Tm/Ho-doped (~2 μm) gain media. In terms of controlling the absorption recovery time, we review key aspects concerning the ultrafast properties of GaInNAs/GaAs material system for SESAMs operating at 1–1.6 μm wavelengths, and GaSb-based SESAMs for 2–3 μm wavelengths.

♦ Tailoring the Spectral Response in Fibers by Localized Fs Laser Modifications

S. Nolte, T. A. Göbel, M. Heck, R. G. Krämer, C. Matzdorf, D. Richter
Friedrich Schiller University Jena, Institute of Applied Physics

Ultrashort laser pulses enable the precise, three-dimensionally localized modification of transparent materials. This opens various possibilities to specifically tailor the optical propagation properties in fibers.

One example is the generation of fiber Bragg gratings (FBG), which can serve e.g. as integrated mirrors in fiber laser systems. We report on our recent results of inscribing FBGs directly into large core active and passive fibers. Laser systems with output powers of 2 kW for FBGs in active and 5 kW in passive fibers are demonstrated. Apart from the inscription process and the spectral properties also the performance during laser operation is analyzed. Due to absorption of signal and pump light at defects generated during FBG inscription, the grating area shows significant heating. This leads to changes in the spectral response and might damage the fiber coating. Possibilities for annealing the defects in order to overcome such thermal limitations are discussed.

Further power scaling might also be limited by other effects like stimulated Raman scattering. Here, long period gratings (LPG) promise an interesting solution. In contrast to FBGs, LPGs couple light at the desired wavelengths to forward propagating cladding modes. Thus, LPGs can be used to suppress certain wavelengths without providing feedback into the cavity. However, it is important to minimize losses at the lasing wavelength itself. We report on our progress in this field.

In addition to applications in fiber lasers, defined refractive index modifications in fibers provide a huge potential in astrophotonics, e.g. for suppressing OH-emission lines. Here, we report on the realization of so-called aperiodic FBGs, which suppress several lines by one single grating. A layer peeling algorithm was used to derive the appropriate grating design, which was then inscribed into a single mode fiber using a line-by-line inscription technique with ultrashort laser pulses. Options for using multicore-fibers are discussed.

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♦ Asynchronous Optical Sampling Technique for Pump-Probe Measurements

Dr. Benjamin Sprenger
Friedrich Schiller University Jena, Institute of Applied Physics

Pump-probe measurements have been the gold standard for detection and analysis of ultrafast phenomena. A pump pulse triggers a reaction in the sample under test, and a probe pulse can take a temporal snapshot of the induced change with a timing resolution in the femtosecond range. By using an optical delay line, typically in the form of a retroreflector on a moving stage, one can scan in time to find out the detailed temporal dynamics of the optical excitation process in the sample under test. In this approach, which was first presented in the 1990s, the time window available is limited by the length of the delay line. New asynchronous optical sampling (ASOPS) techniques make use of two femtosecond lasers with slightly offset, but synchronized repetition rates, where one pulse train triggers the reaction, and the other probes the induced change. A delay stage is thus not necessary anymore, and fiber-coupled laser beam delivery allows for flexible applications.

Using electro-optical ultrafast switches and ASOPS enables high speed terahertz spectroscopy and nondestructive testing technologies. We demonstrate high speed imaging and high quality thin layer thickness measurements for nondestructive testing in the field of car painting."

♦ Megawatt Fiber Oscillators

Frank Wise
Cornell University, USA

Short-pulse fiber lasers have increasing impact in applications, owing to their practical benefits. The science that underlies performance increases is the control and exploitation of nonlinear processes that can otherwise limit pulse energy and duration. The Mamyshev regenerator is based on nonlinear spectral broadening followed by offset filtering, and was proposed for telecommunications applications. The pulse energy from mode-locked oscillators based on concatenated Mamyshev regenerators (so-called Mamyshev oscillators) crossed the nanojoule threshold recently, and continues to rise dramatically (Fig. 1). Environmentally-stable instruments constructed with single-mode fiber generate ~200-nJ and 40-fs pulses. The peak power thus reaches several megawatts, and further scaling appears to be possible. These lasers should offer major benefits for applications. The principles of high-power Mamyshev oscillators will be explained, and prospects for the future will be discussed.

Session: Solar Energy - Dr. Iris Visoly-Fisher

♦ Coupling "Regular" Quantum Dots with Lead Halide Perovskites

Dan Oron

Dept. of Complex Systems Weizmann Institute of Science, Israel

The study of colloidal halide perovskites nanoparticles and their formation and transformation processes grants us with new insights about the stability and phase diagram of these materials. It also highlights the tremendous possibilities in the use of nano crystals in halide perovskites solar cells. Here we present results on the formation and growth mechanism of cesium lead halide (CsPbX3) nanocrystals which highlights the tremendous effects of surface passivation on their growth and crystal habit. We then proceed to study the optoelectronic properties of hybrid solids made from perovskite nanoparticles linked with "conventional" II-VI quantum dots. These enable to better understand the photophysics of perovskite-quantum dot hybrid solar cells and the origin of their enhanced performance.

♦ Magnetism in Nominally Non-Magnetic Semiconductor Nanocrystals

Efrat Lifshitz

Schulich Faculty of Chemistry, Russell Berrie Nanotechnology Institute, Solid State Institute, Technion, Israel

The creation of magnetism in nominally non-magnetic nanoscale semiconductors is a matter of a paramount importance, affecting the development of modern memory, quantum computation and spin-electronic devices. Of particular interest is magnetism induced by photo-generation of an exciton (electron and hole) or softening motion of the semiconductor crystal. The talk at the OASIS meeting will describe a fundamental study of magnetism in two different semiconductor nanostructures, with unique spin properties.

Mn+2@CdTe/CdSe CQDs: The Mn+2 doping induces internal spin interactions between photo-generated species (electron and hole) and the dopant spins, leading to giant magnetization and consequence emission from host-dopant hybrid. The current study developed a method to position the Mn ions selectively either at the core or at the shell. The magneto-optical measurements, including the use of optically detected magnetic resonance, exhibited resonance transitions related to the coupling of the Mn spins with the individual photo-generated carriers as well as with their nuclear spins.

APbBr3 (A=Cs+, methylamonium): The magneto-optical measurements of excitons in APbBr3 individual nanocrystal were investigated by monitoring the micro-photoluminescence spectra in the presence of an external magnetic field, while monitoring either the circular or linear polarization components. Gradual band splitting occurring upon the application of a magnetic field, deviating from a common Zeeman interaction behavior, proposes the existence of a more complex mechanism. Theoretical considerations strongly supported the existence of Rashba split in the studied materials, emanated from a soft motion that broke an inversion of symmetry. Additional magnetism was explored associated with the interaction of photo-generated specie and intrinsic neutral abundance metal isotopes, known at the Overhouser effect, showing pronounced influence on spin coherence in the studied materials.

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Luminescent Solar Power-Quantum Separation between Free-Energy and Heat for Cost-Effective Base-Load Solar Energy Generation

Carmel Rotschild, Einat Carmon, Bar Simor, Bella Mali, Beatrice Uziely, Tamar Sella

Department of Surgery, Department of Pathology, Sharet Institute of Oncology, Department of Radiology, The Hebrew University Hadassah Medical School
Mechanical Engineering Department, Technion, Israel

The challenge in solar energy today is not the cost of photovoltaics (PVs) electricity generation, already competing with fossil fuel prices, but rather utility-scale energy storage costs. Alternatively, low cost thermal energy storage (TES) exists, but relies on expensive concentrated solar power (CSP). A photovoltaic/thermal (PV/T) technology, able to efficiently unify PV conversion and TES, may usher in the era of efficient base-load renewable power plants. Spectral splitting, one PV/T option where inefficient photons for PV conversion are redirected and thermally utilized, is economically limited by the low yield of each generator. Operating PVs at high temperatures while utilizing the thermalization induced heat for the thermal cycle is another possibility; yet, while conceptually supporting full utilization of solar thermal and free energy, it too is limited by PV efficiency reduction with temperature increase. Here we introduce the concept of luminescence solar power (LSP), where sunlight is absorbed in a photoluminescent (PL) absorber, followed by red-shifted PL emission matched to an adjacent PV band-edge. The PL absorber temperature rises due to thermalization, allowing spatial separation between heat and free-energy, for maximal harvesting of both. We solve the material challenge by experimentally demonstrating tailored luminescence with PL efficiency of up to 90% while operating at 600oC. At such high temperatures, LSP efficiency offers a 50% enhancement over conventional side-by-side PV/CSP efficiency under real-world conditions, leading to a potential reduction in solar energy storage levelized cost of electricity (LCOE) to below 3¢/kWh. Such a low LCOE complies with the 2030 SunShot goal, enabling future US solar energy production to reach 50%.

Observing the Green Flash in the Laboratory

Stephen G. Lipson, Tomer ben Aroush, Saber Boulahjar

Physics Dept, Technion - Israel Institute of Technology, and Physics Dept, Ort Braude College, Karmiel, Israel

The green flash is a well-known but elusive atmospheric phenomenon, in which the sun is observed as it is setting behind a clear horizon. At the last moment before its disc disappears, a green flash is observed. The phenomenon is due to vertical structure in the atmospheric refractive index which disperses the sun's light. We have simulated similar conditions in the laboratory, using a refractive index gradient in salt water in an aquarium. We photographed a white LED source simulating the sun with an artificial horizon, and a blue flash was observed as the horizon obscured the image. Using the same system, we were also able to create a non-linear refractive index profile and observe amplified mirage flashes, which are those normally observed in nature. We measured the refractive index gradient in the water with an Abbe refractometer. This work was published recently in the European Journal of Physics.

Photon Management Utilizing DeepSubwavelength Sidewall Features in Nanopillar Arrays for Broadband Absorption Enhancement of the Solar Radiation

Ashish Prajapati, Yevgeny Faingold, Shay Fadida, Jordi Llobet, Mariana Antunes, Helder Fonseca, Carlos Calaza, João Gaspar, Gil Shalev

Ben Gurion University Electrical and Computer Engineering Department, Israel

Silicon nanopillar (NP) arrays are known for their efficient light trapping and broadband absorption enhancement of solar radiation. In the current study, we examine the effect of deep subwavelength sidewall scalloping (DSSS) on the broadband absorption of the arrays. The formation of DSSS is a side effect of top-down dry etching of NP arrays of several microns height. We use finite-difference time-domain (FDTD) electromagnetic calculations to show that the presence of DSSS can result in efficient excitation of optical modes in both the arrays and the underlying substrates. We demonstrate a broadband absorption enhancement of >10% in a DSSS-NP array with an underlying substrate. We use electrical device calculations to solve the Poisson and Continuity equations to examine the effect of DSSS on the electrical performance of a photovoltaic cell, as the main concern is the degradation of the open-circuit voltage due to surface recombination (DSSS produces higher surface-to-volume ratio). We show that the effect of DSSS on open-circuit voltage is negligible. Finally, deep-subwavelength sidewall features offer a novel and an interesting photon management strategy towards absorption enhancement.

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Session: Spectroscopic and Optical Sensing - Dr. Ayala Ronen

Measuring the BRDF Optical Properties of Surfaces

Dan Sheffer, Adam D. Devir, Alexey Kravchouk, Yair Bar Ilan, Gal Yehuda, Benny Milgrom

IARD SENSING SOLUTIONS LTD, Israel

Introduction: The directional-directional reflectance properties of surfaces, also known as BRDF - Bidirectional Reflectance Distribution Function, are very important for various applications since they determine the actual "behavior" of a given surface under varying illumination and viewing conditions. Example uses of the BRDF properties are precise calculations of stray-light during design of optical instruments and systems; photo-realistic rendering of synthetic scenes in the field of computer graphics; inverse problems in computer vision such as object recognition; modeling light trapping in solar cells or low concentration solar photovoltaic systems; global illumination models; calculations of the appearance of-objects in the automobile industry, film industry, clothing design and more. Combined with the spectral reflectance properties of given objects, the BRDF properties enable modeling the thermal behavior of the objects, modeling of the appearance of objects in space and from space, development of canopy radiative transfer models, performing energy balance calculations for buildings and for natural and artificial objects.

Objectives: Recently, IARD has acquired the SOC-210BDR machine - an advanced, state of the art instrument for performing BRDF measurements in various spectral bands in the 0.4-12.0-micron range. We dwell on what are exactly the BRDF properties, what are they good for and how are they measured. We review the main capabilities of the SOC210 machine and show examples of results of BRDF measurements and how they affect the optical appearance and behavior of various surfaces

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Toward UAV Based Compact Thermal Infrared Hyperspectral Imaging Solution for Real-time Gas Detection Identification and Quantification

Stephane Boubanga Tombet, Frederick Marcotte, Eric Guyot, Martin Chamberland

Telops Inc., France

The integration of thermal infrared (TIR) hyperspectral systems into Unmanned Aerial Vehicles (UAVs) platforms is expected to open doors toward a wide variety of demanding thermal imaging applications ranging from academics and research to industry. Currently, the UAV remote sensing technology in TIR region is still in its infancy and the main expectations are the reduction of both, sensor sizes and cost while maintaining their performances at a high level.

In this communication, we report on Telops newly designed compact, light and robust TIR hyperspectral module of less than 10 kg with about 50W of power consumption. The new module can be integrated into a complete stand-alone imager with applications such as 360° Hyperspectral Surveillance. Integration in complete, highly flexible UAV based, infrared hyperspectral imaging solutions, such as airborne real-time gas detection, identification and quantification is also possible.

The need for a reliable and cost-efficient gas detection system is of prime importance especially when security threatening situations like gas leaks and emissions occur. The knowledge of the precise localization of the leaks, identification of the chemical nature of the gases involved and quantification of the gas flux emanating from the leaks are the crucial inputs needed for the incident response team to take actions based on relevant information.

Beside the newly designed compact and light TIR hyperspectral module, Telops have also developed solutions for gas detection and identification along with some tools for the quantification of gas flow rates emanating from leak source. These solutions were recently demonstrated during a flight campaign up to 4600 feet above the ground for detection and identification of ethylene, methanol and acetone gas release experiment. Detection and real time quantitative airborne chemical images of the three gas clouds were obtained paving the path toward a viable solution for gas leak surveys and environmental monitoring.

Multispectral and Thermal Detection Methods for Finding Missing Persons

Yishay Bruckental, Ori Cohen, Meir Chen, Yoav Stoler, Benny Milgrom, Gal Yehuda, Dan Sheffer

IARD Sensing Solutions Ltd., Israel

Finding missing persons is a challenge that countries have been dealing with over the years. One of the search methods is imaging of potential areas for detection of bones. However, the ability to detect bones is not unequivocal, due to the similarities between bones and other natural objects (for example: limestones). The addition of spectral information can significantly improve the detection ability. This course of action requires a selection of appropriate spectral channels in which the object and the characteristic backgrounds are separated.

In this work we present a method developed by IARD Sensing Solutions to select spectral channels in which the required object can be discovered. The method is based on a simulation of the radiation of targets and backgrounds in various conditions, as well as on the basis of conspicuity evaluation method that provides an assessment of the separation between targets and backgrounds in a single channel or a combination of channels. This method was applied for the case of separation between bones and limestones. Based on these results, spectral channels were selected.

Another possible method for bones detection is to exploit the differences between the thermo-physical properties of bones and backgrounds. These differences are mainly revealed during a significant thermal changes (like intensive warming during sunrise).

These methods were experimentally tested in collaboration with EITAN - the MIA Accounting Unit, by performing spectral imaging measurements of a scene of bones and limestones. A suitable image processing applied on the measurements results provides a good separation between bones and limestones, enabling significant improvement of bones detection ability. The results are presented and discussed.

Snapshot Spectral Imaging Using Two Cameras, Optical Diffuser and Compressed Sensing Algorithms

Jonathan Hauser
Faculty of Engineering, Tel-Aviv University, Israel

Introduction: Spectral Imaging systems are designed to capture the spatial and spectral information of an object or a scene, which is referred as "spectral cube". Since there is a strong link between the spectrum, physical state and component of matter, Spectral Imaging (SI) systems are practical in various fields such as medicine, agriculture, astronomy, biology, military and more.

Background: Snapshot Spectral Imaging (SSI) systems perform instantaneous spectral cube acquisition. However, like most existing SI systems, are generally complex, expensive and suffer from low light throughput.

Objectives: The objective of our research is to develop a simple SSI system prototype for the visible range (400-700nm), based on a regular monochromatic camera with an added "phase-only" static optical diffuser, a regular RGB (Red, Green, Blue) camera and Compressed Sensing (CS) methods for the reconstruction of the spectral cube. This concept presents a cost-effective and compact architecture with high light throughput, which is crucial for dark and fast-changing environments.

Methods: The diffuser is intended to perform spectral and spatial mixing of the imaged scene, for subsequent reconstruction of its spectral cube. The data mixing is achieved by placing the diffuser at the entrance pupil of the imaging lens, thus setting the point spread function of the monochromatic camera. After characterizing the optical system, an iterative reconstruction algorithm is used for the reconstruction of the spectral cube from the recorded dispersed and diffused monochromatic image and the sharp RGB image. While spectrum and color reconstruction are feasible solely from the monochromatic camera with the diffuser, the RGB camera provides additional spatial and spectral information about the scene, to improve the reconstruction quality.

Results: Simulation and experimental results indicate the feasibility of our suggested method in performing snapshot spectral imaging, by reconstructing spectral cubes of size 256x256x31 pixels in x, y and wavelength axes, respectively.

Silver Halide Fiber Sensors with Surface Chemistry for Specific Protein Immobilization Using Infrared Evanescent Wave Spectroscopy

H. Michael Heise, Sven Delebeck, Benjamin Schmitz, Andreas Nabers, Klaus Gerwert, Anne Habermehl, Ulrich Lemmer
South-Westphalia University of Applied Sciences, Germany
Ruhr-University Bochum, Germany
Karlsruher Institut für Technologie, Germany

Clinical chemistry assays for various body fluids have been realized by using silver halide fiber elements as infrared biosensors. Here, a specially functionalized tapered and flattened sensor is presented, which had been prepared by an N-hydroxysuccinimide (NHS) ester derivative (12-Mercaptododecanoic acid NHS ester) containing a reactive thiol group. NHS esters are often used as coupling agents to covalently bind amine-containing biomolecules (e.g., enzymes, antibodies or peptides) for the preparation of bioanalytical sensors of high selectivity. Recently, sensors for Alzheimer disease screening have been presented based on infrared attenuated total reflection (ATR) measurements with antibody-immobilized Ge-element surfaces after binding to amyloid-beta (Aβ)-monomer and oligomer peptides by studying the position of amide I absorption bands [1]. For functionalizing the silver halide fiber surfaces, different procedures have been investigated, which consider the exchange reaction of the halogen atoms by the thiol-group as one option. Another preparation method uses the chemical reduction of silver ions, either from aqueous salt solutions or of the fiber material itself. A further preparation method uses a first printing of silver nanoparticles on top of the flattened fiber sections. The reaction time for immobilizing the NHS-ester derivative is thus much reduced and more efficient compared to the untreated fiber surfaces. The binding of proteins has been successfully tested by using albumin solutions and difference spectroscopy. The combination with recently introduced quantum cascade laser spectrometers is very promising for device miniaturization suited for implementation into hospital laboratories or general practitioners' offices.

1. A. Nabers, L. Perna, J. Lange, U. Mons, J. Schartner, J. Güldenhaupt, K.-U. Saum, S. Janelidze, B. Holleczek, D. Rujescu, O. Hanson, K. Gerwert, H. Brenner, Amyloid blood biomarker detects Alzheimer's disease, EMBO Molecular Medicine 10(5) e8763 (2018)

Multi-Modal Fiber-Probe Spectroscopy for Tissue Diagnostics and Biological Fluid Sensing

F. S. Pavone, R. Cicchi, C. Credi, E. Baria, C. Dallari, O. Bibikova, V. Artyushenko, S. Centi, F. Ratto, R. Pini
LENS, Italy

We used an optical fibre-probe system combining multiple spectroscopic techniques for analysing ex vivo human fresh biopsies. The recorded data were analysed using Principal Component Analysis (PCA) for obtaining an automated classification of the examined samples based on the intrinsic spectral information provided by all three techniques. The method was successfully applied to the discrimination of malignant melanoma against melanocytic lesions, as well as for discriminating brain tumour from dysplastic brain tissue. Further, the method was used on fresh biopsies of urothelial tumour (103 samples) and healthy bladder (34 samples) collected from 63 patients undergoing Transurethral Resection of Bladder Tumours (TURBT). The larger statistics allowed us not only to successfully diagnose urothelial carcinoma but also to perform tumour grading and staging, demonstrating that multimodal spectroscopy provides high-sensitivity, high-specificity diagnostic performances, well beyond the accuracy offered by state-of-the-art individual techniques. Finally, with the attempt to demonstrate the perspectives offered by surface enhanced Raman spectroscopy (SERS) in the development of timely diagnostic devices through liquid biopsies analyses, we also report on the development of novel cap-shaped SERS sensors engineered for reversibly coupling with the distal end of the above-mentioned fibre-probe system. SERS spectra of liquid samples could be collected by dipping the fibre-cap system directly within the solution avoiding long-lasting incubation time and liquid contamination of the fibre. Then, to increase the affinity of the SERS substrates towards specific analytes recognized as pathological biomarkers, we further functionalized the sensors surfaces by covalently binding molecules acting as selective baits. Indeed, it enabled to selectively enhance the Raman signal of those molecules of interest respect to the background. Proof of concept experiments were successfully performed on a simplified model of cerebrospinal fluid to sense the Aβ peptide biomarker for the early diagnosis of the neurodegenerative Alzheimer's disease (AD).

Oasis 7th Conference and Exhibition on Electro-Optics

Session: Electro Optics in Industry - Dr. Rami Cohen

♦ Optical Wafer Inspection Challenges - Optimizing Optical Configuration for Detection

Tal Kuzniz
Applied Materials, Process Development, Israel

State of the art inspection and metrology tools are required for efficient fabrication of the advanced integrated circuit chips we all use intensively throughout the day. Current and future integrated circuits design rules and design architectures challenge the tools in aspects of sensitivity, stability and throughput. Hence, it is essential to incorporate advanced optics configurations to enhance the detection signal and overcome the noises.

This talk focuses on an inspection case study and presents some of the optical configurations that can be utilized and their effect on both the signal and the noise collected from the inspected wafer. It will be showed that choosing the correct configuration can dramatically improve the detection in such scenarios.

♦ Permanent USP Laser Marking of Stainless Steel Devices without Post-Processing

Daniel Seitz
Coherent Munich GmbH&Co, Germany

Many industries face an increasing need to create permanent marks on its products. The benefit of marking encompass features like counterfeit prevention, product traceability, long-term quality control, fraud prevention or distribution regulation as well as aesthetical decoration. Contrary to commonly used nanosecond laser systems and their conventional thermal process an optimized picosecond laser system provides permanent, contamination-free, sub-surface marks. This turnkey solution offers high contrast marks on a broad range of materials without corrosion/passivation and fading issues associated to nanosecond lasers.

In this talk I will explain mechanisms behind ps and ns marking, point out limitations and advantages and demonstrate user benefits based on real life experiences.

Keywords: Black marking, medical, corrosion-free, annealing

Early Detection of Fires from Space

Shimshon (Steven) Lashansky, Michael Gilichinsky and Yuval Erez
Elop, Elbit system, Israel

Wildfires fires cause devastating economic and environmental damage. In November 2016, Israel was inundated by a wave of fires (both wildfires and urban fires). Some of the fires occurred naturally while others were arson attacks. Many countries worldwide are also afflicted by frequent wildfires. A recent example is the November 2018 Camp fire in California that caused tremendous damage including about 100 fatalities.

The damage caused by wildfires fires could be reduced significantly if the fires were detected shortly after ignition. This requires a reliable early detection system.

There are many methods and techniques for fire detection. Ground stations can only cover small areas. The revisit time of a single LEO satellite is much too long to be useful for the early detection of wildfires. Geostationary weather satellites could provide an acceptable solution. Unfortunately the revisit time (1 frame every 15 minutes) and large GSD (ground sampled distance ~ 4 km) reduce their effectiveness.

This presentation proposes a satellite system that would shorten the fire detection time significantly.

Keywords: fire detection, remote sensing, geostationary

Oasis 7th Conference and Exhibition on Electro-Optics

Yb: YAG and Nd:YAG Crystals for High Energy DPSSL

Karel Nejezchleb, Jana Preclíková, Štěpán Uxa, Martin Divoký, Mihai-George Muresan
CRYTUR, spol. s r.o., Czech republic
HILASE IoP ASCR

Large Yb:YAG and Nd:YAG crystals were grown using of new improved core-free technology of crystal growth in CRYTUR. The diameter of crystals reached 120 mm. Optically homogenous parts of crystals were used for manufacturing of both sides polished and coated discs of the diameter larger than 50 mm. Absorption coefficient was measured for different doping concentrations of Yb:YAG at main pumping wavelengths of 940 and 968 nm. Fluorescence decay time of Yb:YAG was measured at temperatures of 300 K and 80 K. We found the fluorescence decay time of the values of 0, 95 - 1 ms at both temperatures stable and independent on the Yb3+ doping concentration. Optical homogeneity as measured using of Fizeau double pass interferometer at 633 nm resulted with PV values lower than 0,15 lambda on clear aperture of 35 mm. Polished surfaces were ideally parallel with the wedge lower than 2 arcsec. Polished discs were both sides coated by antireflection HfO2 - SiO2 layer system.

Laser properties of Yb:YAG discs were verified by amplification test in 1kW DIPOLE 100 DPSSL at HILASE center of IoP ASCR. The output energy of Yb:YAG disc with Cr:YAG cladding was comparable to Yb:YAG ceramic discs of the same geometry.

Laser induced damage threshold was measured using of 1030 nm laser, with 10 ns nearly Gaussian beam profile and 470 microns beam diameter. The LIDT of HfO2 - SiO2 coated surface reached 32, 6 J/cm2 in r-on-1 test.

Conclusion: It was confirmed, that newly developed technology allows to manufacture large Yb:YAG and Nd:YAG discs suitable for high power lasers and amplifiers. Our further development is focused on new cladding material for Nd:YAG and extra-pure Yb:YAG crystals.

♦ The Recent Advances in Quantitative Imaging and Spectroscopy Instrumentation for EUV-SWIR Regime

Ravi Guntupalli

Princeton Instruments, USA

Introduction: Photonic detectors such as charge-coupled device (CCD), complementary metal oxide (CMOS), electron multiplied (EMCCD) and intensified, gated CCD (ICCD) and InGaAs focal plane array cameras are enabling growing number of physical and life sciences applications. The detectors, when used in conjunction with latest generation of aberration corrected spectrometers are capable of providing high signal to noise ratio in Raman, photoluminescence, fluorescence and absorption/reflection and other spectroscopic measurements.

Background: Silicon based CCD detectors are typically used for low light level detection in the XUV (<1eV to 10keV) and UV-VIS-NIR range of 200nm to 1100nm. The deep cooled HiRho CCD cameras can now offer two to seven times increased sensitivity in the near infrared range compared to standard deep depletion counterparts. EMCCD and scientific CMOS cameras provide high temporal resolution and single photon sensitivity whereas ICCD cameras are ideal for applications requiring fast shuttering in sub nanosecond to microseconds range. Hybrid detectors such as emICCDs -EMCCDs fiber coupled to intensifiers -are also gaining popularity in single photon counting applications due to high sensitivity and short gate times. For shortwave infrared range of 1um to 1.7um, InGaAs detectors are preferred due to their high quantum efficiency.

Advances in optical spectrographs include aberration corrected designs to reduce astigmatism and coma and provide high signal to noise ratio. Based on advanced optical modeling tools, the traditional Czerny Turner spectrometers are capable of near ideal peak shapes through spectral deconvolution techniques.

Objectives: The presentation provides a summary of latest advances in optical and soft x-ray detectors and spectrometers as applicable to quantitative low light imaging and spectroscopy applications.

Conclusions: The advanced photonic detectors and optical spectroscopic systems enable the scientific and commercial research and development in fields as diverse as -Quantum and nanomaterial research, label free Raman spectroscopy, InVivo imaging, combustion research and astronomy.

Session: Electro Optics Devices - Prof. Dan Marom

♦ Integrated Nanophotonics Technology and Applications

Y. Fainman

Department of Electrical and Computer Engineering, University of California, San Diego, USA

Various future system applications that involve photonic technology rely on our ability to integrate it on a chip to augment and/or interact with other signals (e.g., electrical, chemical, biomedical, etc.). For example, future computing and communication systems will need integration of photonic circuits with electronics and thus require miniaturization of photonic materials, devices and subsystems. Another example, involves integration of microfluidics with nanophotonics, where former is used for particle manipulation, preparation and delivery, and the latter in a large size array form parallel detection of numerous biomedical reactions useful for healthcare applications. To advance the nanophotonics technology we established design, fabrication and testing tools at UCSD. The design tools need to incorporate not only the electromagnetic equations, but also the material, quantum physics, thermal, etc. equations to include near field interactions. These designs are integrated with device fabrication and characterization to validate the device concepts and optimize their performance. Our research work emphasizes the construction of passive (e.g., engineered composite metamaterials, filters, etc.) and active (e.g., nanolasers) components on-chip, with the same lithographic tools as electronics. In this talk, we discuss some of the passive metamaterials and active nanolaser devices that recently have been demonstrated in our labs.

Superconducting Light-Emitting Diode

Shlomi Bouscher, Dmitry Panna, Krishna Balasubramanian, Alex Hayat
Department of Electrical Engineering, Technion - Israel Institute of Technology, Israel

Introduction: We demonstrate experimentally Cooper pair injection and enhanced light emission in semiconductor-superconductor structures with a wide range of possible uses such as enhanced two-photon gain, entangled-photon generation, Bell-state detection, all of which having great significance in the field of quantum information, computing and encryption.

Background: The superconducting condensate is composed of a macroscopic number of spin-entangled electron pairs (Cooper pairs). Injection of the Cooper pairs into a light-emitting diode (LED) structure has been theoretically shown to result in emission of polarization-entangled photon pairs through recombination of the Cooper pairs with pairs of holes. The superconducting LED (SLED) can achieve a much higher entangled-pair generation rate compared to other existing methods (i.e. spontaneous parametric down conversion and bi-exciton decay cascade) while being compact and easily integrable on chip-based system.

Objectives: Our objectives are first to demonstrate Cooper-pair injection into a PN junction, which is evident through the process of Andreev reflection. Second, demonstrate enhanced electroluminescence (EL) below Tc, which is due to the additional recombination of Cooper pairs. Third, perform correlation and entanglement measurements on the emitted photons, thus proving emitted photon-pairs are polarization-entangled.

Results: We have demonstrated experimentally both Andreev reflection as well as enhanced EL in InP, InGaAs and AlGaAs based SLED devices. We then proceeded to further enhance the injection efficiency of our devices by using the resonant tunneling technique. We have also demonstrated Andreev reflection in high-Tc superconductor-semiconductor (YBCO/GaN) junctions, thus paving the way for SLED devices operating at LN temperature (77K). Current experimental work is focused on correlation measurements, followed by entanglement measurements, as well as continual improvement of SLED devices.

Conclusions: We have successfully demonstrated Cooper-pair injection into our SLED devices as well as enhanced EL below Tc, both of which are important milestones towards the demonstration of photon-pair entanglement in these devices.

E-SWIR High Operating Temperature P-N Photodetectors

I. Shafir[1], D. C. Elias[1], N. Sicron[1], M. Katz[1], N. Snapi[2,3], O. Klin[2], A. Glozman[2], E. Weiss[2], and G. Sarusi[3]
1. Solid State Physics Department, Applied Physics Division, Soreq NRC, Israel
2. SCD-SemiConductor Devices, Haifa, Israel
3. Electrooptics and Photonics Engineering Unit, Ben-Gurion University of the Negev, Israel

The extended short-wavelength infrared (e-SWIR) spectral range from 1.7-3 µm is of interest for many civil and military applications. Commercially detectors available for this range are based on the ternary alloys HgCdTe (MCT) and InGaAs, but both material systems suffer from various disadvantages. Therefore, investigation of alternative materials for e-SWIR detectors is desirable. In this study, we compare performances of p-n photodiodes fabricated from different absorbing materials with cutoff wavelengths in the 2.4-2.7 µm range. Electrical and optical characteristics are analyzed for three device absorber layers: InGaAsSb (quaternary), InAs/AlSb Type II superlattice (binary T2SL) and InGaAs/GaAsSb (ternary T2SL). The quaternary and the ternary T2SL based devices show low dark current densities at 300 K, which are only a factor of ~10 greater than predicted by the MCT Rule07.1 The quaternary photodiode showed excellent optical performance, having a quantum efficiency at 2.18 µm of ~73% without antireflective coating. This value is significantly higher than the best found for the binary and ternary T2SL's in this work and in literature, 2-4 showing that InGaAsSb is a promising material for e-SWIR detection.

Optical Gas Imaging Using Liquid Crystal Absorption Properties

Karni Wolowelsky, Amir Gil, Moshe Elkabets, Iliya Romm, Cukurel Beni, Carmel Rotschild
Technion - Israel Institute of Technology, Israel

In a previous work we showed that it is feasible to utilize liquid crystal's (LC) absorption properties in the mid wave infrared (MWIR) for gas detection. Here we describe the principles of the method, and present initial results for optical gas imaging (OGI) of hot carbon dioxide, using electrically switchable Germanium LC cell, and an MWIR imager. We are currently working to improve the method by tuning the wavelength of the LC's absorption band such that it will fully overlap the absorption band of the target gas, and by shortening the switching time of the cell.

♦ Chip-Scale Metrology: Coupling and Interfacing Atoms, Kerr Frequency-Combs and Cavities

Liron Stern
National Institute for Standards and Technology, CO, USA

Metrology, the science of measurement, strives to push the limits of human ability to measure quantities such as time, frequency, distance, temperature and mass. Nowadays, we are witnessing a universal endeavor to miniaturize such "measuring machines" with two prime motivations: understanding the fundamentals of light-matter interactions at these extreme limits, and enabling new applications in disciplines such as telecommunication, space exploration and medical devices. In this talk, I will present how we move forward to enable chip-scale frequency metrology. Specifically, I will present experimental results where Kerr-soliton frequency combs and high-finesse optical cavities are interfaced directly with atomic vapor. Moreover, novel "smart" atomic vapor cells structured in diffractive geometries, and mapping atomic states to the diffractive spatial distribution will be presented. To conclude, I will discuss the potential impact and challenges of such chip-scale metrology systems.

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Session: IFLA - Fiber Components - Prof. Amiel Ishaaya

♦ Functionalized Micro-Nano-Fibres and Hybrid Photonic Crystal Fibres: The Role of New Materials

Georgios Kakarantaz
Theoretical and Physical Chemistry Institute, Athens, Greece

A common feature of Photonic Crystal Fibres (PCFs) is that they are usually made from a single material e.g. silica. However, the existence of holes in the cladding enables the infiltration of advanced materials and liquids such as liquid crystals, ferro-fluids, metals etc. Recently, results from our group show successful infiltration of conventional and hollow core PCFs with PDMS polymers imposing high thermal tunability of all the fiber guiding parameters. The presentation will include the passive or active modifications of the main guiding properties, including nonlinearity and dispersion, of photonic crystal fibers (PCFs) and micro-nano-fibres by introducing materials which typically cannot be integrated into fibres using common techniques. The idea is to fill the hollow channels or to make films inside them or to make thin films on the waist of micro-nano-fibres with solid materials such as functionalized polymers, high refractive index soft glasses using the sol-gel technique and bio-inspired materials.

♦ In-Fiber Speckle-Based Interferometry for Fabric Integrated, Non-Contact Bio-Sensor of Vital Signs

Zeev Zalevsky
Faculty of Engineering, Bar Ilan University Israel

In this research we present a novel configuration allowing to perform high precision sensing of vital bio-signs obtained from a fiber and in a non-contact way. The sensor includes a multi-mode fiber through which a laser beam is injected. Along the fiber, special artifacts that are breaking the total internal reflection condition, are inserted. Those artifacts are causing to some portion of the injected light to escape the fiber and to interact with the nearby surrounding of the fiber, realizing a smart photonic drip. A detector analyzes the temporal-spatial changes of the speckle pattern imaged at the tip of the fiber. Strain, temperature and vibration associated variations occurring in the proximity of the fiber or in the fiber itself, cause changes in the phase, the polarization and the amplitude of the photons propagated through the fiber which leads to temporal-spatial changes in the analyzed speckle pattern. After applying proper artificial intelligence (AI) algorithmic, one may correlate those small changes with various vital bio-signs such as heart rate, heart rate variability (HRV), heart sound (phono-cardiogram), respiration rate and sound and even blood pressure.

Water-Wave Lasers

Tal Carmon
Technion - Israel Institute of Technology, Israel

Each one of us was once throwing a stone into a puddle of water and watching the resulting water-waves. I will present our recent experimental results showing how the same water-waves mediate laser emission. Furthermore, we optically sideband cool water-waves to near ground-state.
I will also tell on our experimental adventures, including how we had to climb on trees as part of one of the experiments.

Improved Sensitivity and Spatial Resolution in Fiber Bragg Gratings Dynamic Strain Sensing System via Iterative Soft Thresholding Algorithm

Roy Shen-Tzur, Lihi Shiloh, Avishay Eyal and Raja Giryes
Physical Electronics Department, Tel-Aviv University, Israel

Fiber Bragg Gratings (FBG) are often used as key elements for dynamical Optical Fiber Sensors (OFS). One common configuration is an array of weak gratings, all with the same center wavelength. Such a configuration can provide better sensitivity than Rayleigh based distributed sensors. Changes such as temperature or strain are monitored by measuring the differential phase between each two consecutive FBG's reflection peaks. The performance parameters of these systems, such as sensitivity or spatial resolution, are limited by optical considerations. For example, in an Optical Time Domain Reflectometry (OTDR) system, the width of the interrogation pulse determines the system's spatial resolution and the pulse energy directly affect the sensitivity. While the spatial resolution can be improved by using a shorter pulse, the sensitivity will deteriorate due to the decrease in the pulse energy. An interesting observation regarding an array of k FBG's is that its ideal backscatter signal (neglecting Rayleigh backscattering and assuming perfect resolution) is a k-sparse signal. An ideal k-sparse signal has k non-zero elements sparsely positioned among many zeros. Taking advantage of this observation, in this work we have used the Iterative Soft Thresholding Algorithm (ISTA) to reconstruct the sparse fiber profile from low spatial resolution OTDR measurements (the optical pulse spatial width was 300mm). ISTA algorithm is known for its remarkable results in image denoising and its ability to reconstruct sparse data. During the measurement, the fiber was dynamically strained at a rate of 1kHz. The use of ISTA not only improved the spatial resolution from 30m to 2m but also increased the SNR with which the dynamical strain was measured by 10.5dB.

High Resolution Heterodyne Measurement of Phase Shifted Fiber Bragg Gratings

Garry Berkovic, Ehud Shafir
Applied Physics Department, Soreq NRC Yavne, Israel

Fiber Bragg Gratings (FBGs) are wavelength-selective reflectors which are important components in optical communication systems, fiber lasers and in applications in strain, temperature and pressure sensing. Phase shifted FBGs are a special type of FBGs offering narrower linewidth features, down to the picometer and even sub-picometer regime.

For sensing applications, accurate measurement of the narrow features of phase shifted FBGs and changes therein is a challenging task as the features are narrower than the resolution of standard spectrometers and optical spectrum analyzers.

A new approach to measure spectral shifts of phase-shifted FBGs will be described. In this approach a pair of gratings is illuminated with spectrally filtered incoherent light, generating a heterodyne beat frequency between their picometer and sub-picometer features. This method can potentially offer high (< 1 pm) resolution, fast (microsec) measurement, and built-in strain-temperature discrimination in sensing applications.

Poster Presentations

Monday, April 1, 2019

Topic: Micro and Nano Optics - Prof. Koby Scheuer

All-Dielectric Waveguide-Overlayer System for Optical Trapping of Atoms

Angeleene Ang[1], David Groswasser[1], Mark Keil[1], Yonathan Japha[1], Alexander Shalin[2], Ron Folman[1], Alina Karabchevsky[1]

1. Electrooptical Engineering Unit, Ben-Gurion University, Israel
2. ITMO University, Russia

Particle trapping using light was first experimentally demonstrated by Ashkin in the 70's. This phenomenon of optical forces has found applications in sensing, biology, and atomic trapping. Trapped neutral atoms have been used as platforms for other work, such as studies involving elementary particles and simulating quantum many-body systems. These atoms can be confined using optical dipole traps; this can be done either using focused lasers or structured materials.

Using the field generated by a nano-antenna placed on top of a ridge waveguide, we aim to trap a single Cesium atom. This nano-antenna focuses the evanescent field; the sharp intensity gradient causes the atom to be attracted or repelled. The light's action depends on the frequency detuning from atomic resonance. Combining the red and blue-detuned fields, we obtained a stable trapping potential at a distance from the nano-antenna. This serves as an initial step for waveguide-based trapping of multiple atoms along a two-dimensional lattice.

To model the trapping system, this study uses the Finite Difference Time Domain method by Lumerical, and to calculate the potentials, we used Matlab. We defined a finer mesh around the nano-antenna and the free space above. To generate a localized field, we considered various nano-antenna geometries. A hemi-ellipse, with its major axis perpendicular to propagation, appeared to show a good trapping potential. We also compared the optical potential from the waveguide and nano-antenna structure with a plain ridge waveguide.

For further study, variables such as: the wavelength, power and amplitude of the incident fields; the materials/dimensions of the waveguide/nano-antennas, must be adjusted to generate optimal trapping potentials. Hence, optimization of the numerical system is needed in order to get the potentials faster. Additionally, for very short atom-to-surface distances, we need to consider the forces due to the Casimir-Polder and van der Waals potentials.

Utilization of Time-Resolved Leakage Microscopy for Direct Measurement of Plasmonic Group Velocity and Refractive Index of Thin Graphene Layer

Ori Azolay[1], Dima Cheskis[2], Yuri Gorodetski

1. Mechanical engineering and mechatronics dept., Physics dept, Ariel University, Israel
2. Physics dept, Ariel University, Israel
3. Mechanical engineering and mechatronics dept., Electrical engineering and electronics dept.,Ariel University

Plasmonic wave propagation on metal can be severely tailored by the presence of a thin intermediate layer, such as oxides etc. Due to the strong field confinement the effective index experienced by a plasmon cannot be directly derived from the bulk material properties. A special interest is devoted to the novel 2D materials such as graphene and transition metal dechalcogenides (TMDCs) due to their unique optical and electronic properties.

Here we propose a direct method for effective group velocity measurement of short plasmonic pulse propagating in a modified medium. From this data an effective index for plasmonic wave propagation can be extracted. We demonstrate this ability for analyzing a thin intermediate layer of graphene deposited between the glass substrate and the gold. By using our system we measure the effective index in several ways which allows us to verify their consistency.

We believe that time-resolved technique, being the direct method, is convenient and reliable as long as ultrathin 2D plasmonic systems are considered. Moreover, our simple setup allows a comprehensive and facile way of visualizing the plasmonic distribution in the medium including the phase, the polarization and the amplitude characteristics.

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Lightning-Fast Solution of Scattering Problems in Nanophotonics: An Effortless Modal Approach

Parry Y. Chen, Egor A. Muljarov, Yonatan Sivan

University of Ben Gurion, Unit of Electro-optical Engineering, Israel

Background: Nanoresonators can enhance quantum light with matter interaction by orders of magnitude, enabling for example spectroscopy on individual molecules, engineered blackbody emission spectra for energy harvesting, and potentially generating single photons for quantum computing. However, numerical design remains challenging as enhancement is highly sensitive to positions and orientations.

Objectives: Ideally, simulation methods are general, reliable, fast, and accurate, though rarely does any one method satisfy all four criteria. We demonstrate a working implementation of a method satisfying all four criteria, generating the field produced by an arbitrary arrangement of nanoparticles excited by a near field source. This yields the Green's tensor, a fundamental electromagnetic quantity necessary for simulating quantum light-matter interactions. The method's reliability enables automation, further exploiting its efficiency.

Methods: Our method expands the Green's function using the source free modes of the system. Called normal mode expansion, this efficient, simple, and rigorous method has long been used for closed systems, but its generalization to open systems relevant to nanophotonics has faced difficulties. We successfully generalize normal mode expansion (GENOME), overcoming these practical and theoretical difficulties, and recovering the simplicity and rigour of normal mode expansion for closed systems.

For practical purposes, mode generation is the most computationally intensive part of any modal expansion. While GENOME is compatible any numerical method such as COMSOL, our advantages stem from an efficient mode generation technique we developed called reexpansion. It finds modes with exponential convergence, and underpins GENOME's extraordinary efficiency and reliability.

Results: We demonstrate GENOME's working implementation, validating results against direct COMSOL simulation. We also survey results from ongoing collaborations that solve numerically difficult problems, including nanoplasmonic assisted two photon emission, thermal radiation and near field heat transfer of interacting nanoparticles, and radiation near interacting anisotropic cylinders.

Fano Interference Probing By Spin-Orbit Interaction

Dima Cheskis[1], Rajesh Desapogu[2], Sergey Nechayev[3], Shmuel Sternklar[4], Yuri Gorodetski[5]

1. Physics Department Ariel University
2. Department of Electrical Engineering and Electronics, Department of Mechanical Engineering and Mechatronics, Ariel University
3. Max Planck Institute for the Science of Light, Germany
4. Department of Electrical Engineering and Electronics, Ariel University
5. Department of Electrical Engineering and Electronics, Department of Mechanical Engineering and Mechatronics, Ariel University

The Fano-like plasmonic resonance lineshape bejhavior was experimentally investigate in a simple plasmonic system comprising of a subwavelength hole or a particle illuminated by a tightly focused Gaussian beam. We observe that for a small lateral displacement of the scatterer the k-space distribution of the plasmonic wave exhibit a strong spin-dependent azimuthal variation. We attribute this phenomenon to the sensitive light-plasmon coupling conditions arising due to the specific phase matching requirements. This effect is qualitatively described by a Fano-like interference with a complex coupling factor.

Plasmonic Enhancement of Molecular Overtone Transitions in the Near-Infrared Region

Daler R. Dadadzhanov[1], Tigran A. Vartanyan[2], Alina Karabchevsky[3]

1. ITMO University, Russia / Ben - Gurion University of the Negev, Israel
2. ITMO University, Russia
3. Ben - Gurion University of the Negev, Israel

Very high localization of electromagnetic energy around plasmonic nanoparticles makes them attractive for applications in the label-free chemical and biological sensors. In particular, plasmon-enhanced overtone spectroscopy allows detection of molecular signatures in the near-infrared region. Contrary to the already established surface enhanced infrared absorption (SEIRA) of fundamental bands that lie in the mid-infrared region, overtone spectroscopy operates in the near-infrared region that is much more convenient due to the availability of highly sensitive detector and high-power radiation sources in this spectral range. This advantage comes at the cost of much smaller (one-two order/s of magnitude) absorption cross-sections of the overtone vibrational transitions. We are aiming to enhance weak absorption of overtone transitions of the probe molecules N-Methylaniline due to the highly localized near fields of plasmonic nanoantennas. We employed COMSOL Multiphysics 5.3a software for numerical simulations. The optimum size parameters of gold nanorods that provides for overlapping plasmon resonance bands with the overtone bands were determined. Then, the gold nanorods were surrounded by a thin shell of N-Methylaniline. Based on the numerical analysis, we demonstrated that absorption of the N-Methylaniline thin shell around a gold nanorod of optimized dimensions is enhanced multiple times as compared to the absorption of the same amount of N-Methylaniline in free space. The enhancement factors are equal to 114 for the first N-H vibrational overtone located at 1492 nm and135 for the first C-H vibration overtone located at 1674 nm. Based on numerical calculations, we showed that molecular overtone transition can be amplified by a gold nanorod with a certain size. Hence, the effect of local field enhancement of nanoparticle can result in considerable sensitivity improvements of overtone spectroscopy in the near-infrared region.

Wide Range Binary Two-Dimensional Amplitude Sinusoidal Grating

Eran Daniel

Soreq NRC, Applied Physics, Israel

Diffraction gratings are optical elements that are widely used to disperse light in various regimes, from the infrared to the x-ray region. Diffraction gratings are employed in many fields such as astronomy, plasma physics, beam shaping, spectroscopy and others. Generally, diffractive gratings manipulate the phase, amplitude, or both, of an incoming beam of light. Traditionally, amplitude diffraction gratings were designed to provide a square wave transmission function. These are manifested as a series of parallel bars, which disperse light into many diffraction orders. When using the dispersive nature of these gratings for spectral analysis, it is commonly desired to reduce or eliminate the higher diffraction orders, thus preventing a spatial overlapping between orders, since it is challenging to differentiate a certain order from other rather wide spectral signals. Hence, in order to spectrally analyze a vast spectral range with no orders overlap, it is advantageous to use a diffraction grating designed to suppress all higher orders, keeping only a single diffraction order.

A grating with sinusoidal amplitude transmission function has such method of operation. This sinusoidal grating disperses light only to zero and first orders (±1) of diffraction in far field. This eliminates other higher diffraction orders so no overlap exists, while also enabling higher efficiency to the existing orders rather than spreading it into all (higher) orders as seen in the traditional binary bar grating. There are several methods for the generation of sinusoidal amplitude transmission functionality. Quantum dot array diffraction grating, trapezoidal transmission grating and quasi-sinusoidal one-dimensional transmission grating are some examples of such gratings. This work demonstrates the design, fabrication and experimental performance of several binary 2D sinusoidal transmission gratings, where two design approaches were investigated. Here we provide a useful comparative analysis of the grating's efficiencies and spectral analysis capabilities, along with theoretical calculations and simulations.

Oasis 7th Conference and Exhibition on Electro-Optics

Near-IR Wide Field-of-View Huygens Metalens for Outdoor Imaging Applications

Jacob Engelberg[1], Chen Zhou[2], Noa Mazurski[1], Jonathan Bar-David[1], Uriel Levy[1], Anders Kristensen[2]

1. Hebrew University Jerusalem, Israel
2. Technical University of Denmark

Introduction: The main aspirations for metalens research are miniaturization and economical mass production of optical systems by replacement of conventional lenses with metalenses. Almost all metalenses produced to date were designed for on-axis operation only. Those few designed for a wide FOV had a short focal length, preventing them from being directly coupled to a camera for outdoor imaging applications. In this paper we present the first Huygens-antenna based metalens capable of outdoor imaging.

Methods: The metalens is manufactured on a 1mm thick glass substrate. The aperture is 1.35mm diameter, and focal length is 3.36mm (F/2.5). The design supports field angles up to ±40˚, using a parabolic phase function. To implement the phase function, we used Huygens nano-antennas made of amorphous silicon, covered with a thin layer of PMMA (~300nm). A hexagonal lattice with a period of 500nm, and antenna height of 140nm were used, with 8 discrete antenna radii.

Results: Resolution (i.e. modulation transfer function, MTF), and efficiency of the metalens were measured, and compared to simulation results. To the best of our knowledge this is the first time metalens MTF has been measured over a broad spectral range of up to 40nm. In addition, we coupled the metalens to a standard video camera, and were able to perform indoor and outdoor imaging with various spectral band-pass filters. The actual field-of-view was limited to about ±15˚, as a result of a drop in efficiency at large incidence angles.

Conclusions: We have shown that a Huygens metalens can provide reasonable performance over a moderate field-of-view and spectral range, even without chromatic correction. A Huygens type metalens has the advantage of low nano-antenna aspect-ratio (improved manufacturability) and disadvantage of high sensitivity to wavelength and incidence angle. We hope our results will provide insight for future metalens applications.

Metasurface Assisted Mode Converters Based on SOI Technology

Yakov Greenberg, Alina Karabchevsky

Ben-Gurion University of the Negev, Electro-Optics and Photonics Unit, Israel

Introduction: Shaping the wavefront of light with conventional optical components such as lenses and polarizers, as well as diffractive elements such as gratings and prisms, relies on gradual phase changes accumulated along the optical path. Metasurfaces offer a great potential in controlling guided waves by assembling arrays of miniature, anisotropic light scatterers. As a result, the metasurfaces are able to mold the optical response of the device by introducing spatial variations in the optical response of the light scatterers and modify light by altering its phase, amplitude and polarization in a desired manner.

Background: Mode converters are key components in on-chip mode-division multiplexing systems. In our design, we propose a strip waveguide mode converter device on a conventional silicon-on-insulator platform. The mode conversion is accomplished using tilted subwavelength periodic perturbations that can be obtained by corrugating the surface or the sides of the waveguide using photo-lithographic techniques.

Methods: The proposed devices are designed and demonstrated using modified coupled mode analysis in conjunction with numerical modelling using full wave Lumerical FDTD simulations.

Results: The proposed tilted metasurface structure on SOI waveguide allows mode conversion between TE0 modes to higher order transverse-electric modes with <1 dB conversion losses over <6 μm coupling distance at 1550 nm.

Conclusions: We numerically demonstrate ultra-compact silicon waveguide mode converters with all-dielectric metasurface structure. The metasurface is composed of tilted periodic perturbations which allows engineering the coupling coefficient for the desired conversion. Silicon waveguide mode converters employing metasurface structures are numerically demonstrated. Our modified coupled mode analysis provides a general method to manipulate on-chip optical modes, and can be applied in integrated mode-division communication and optical signal processing systems.

Keywords: mode converters, dielectric metasurface, silicon photonics

Detuning Modulated Composite Pulses for Integrated Photonics

Hadar Greener[1,2], Elica Kyoseva[1,2,3], Haim Suchowski[1,2]

1. Tel-Aviv University
2. Center for Light Matter Interaction, TAU
3. Bulgarian Academy of Sciences

We introduce a detuning-modulated composite pulses control method for robust quantum information processing and implement our solutions in integrated photonic systems. These correct for errors in various parameters, achieving fidelity above the quantum information processing (QIP) threshold 10^-4.

QIP relies on high-fidelity quantum state preparation and transfer; this presents a challenge in practical realizations where the admissible error of quantum operations is smaller than 10^-4. Thus, even small systematic errors, i.e., due to imperfections in fabrication or in the experimental control knobs, reduce the fidelity of state transfer below the fault-tolerant threshold. A powerful tool to correct for such errors are composite pulses (CPs), initially developed in the field of nuclear magnetic resonance. These are a sequence of pulses with different areas and/or phases that implement accurate and robust quantum gates.

Recently, CPs were applied in many physical realizations of QIP including trapped ions and atomic systems. A promising candidate for advancing QIP technologies is integrated photonic circuits due to their scalability and on-chip integration capacity. However, the fidelity of operations remains below the QIP due to unavoidable fabrication errors. CPs have not previously been used to correct for such errors, as existing sequences require control of the phase of the coupling, which in integrated photonics is a real parameter. Our present research is the first to address this limitation and to derive CPs for any qubit architecture including integrated photonic systems.

It is straightforward to implement our sequences in nano-integrated photonic systems by sequentially changing coupled waveguides' relative widths; this creates phase jumps in the values of the effective indices of each waveguide. Our detuning-modulated CPs allow for remarkable error tolerance in qubit inversions. Thus they are perfectly suited for implementation in integrated photonic circuits to overcome inaccuracies in fabrication and provide a path for true high-fidelity QIP schemes.

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Printed Waveguides in Porous Silicon

Alexander Kellarev, Shlomo Ruschin

Tel-Aviv University, Faculty of Engineering, Department of Physical Electronics, Israel

Keywords: PSi, waveguides

We propose and demonstrate a simple and effective technique for fabrication of waveguides on a silicon substrate. The method is mask-less, based on patterning by ink-jet printing and pore filling over a porous film (patent pending). Preliminary measurements show noticeable low losses and we suggest the method as a viable alternative to the nowadays leading Silicon Photonics technology namely silicon-on-insulator (SOI) waveguides.

The objectives of our work are studying of the effect of the pore filling on optical properties of porous silicon (PSi), fabrication of waveguides in PSi and characterisation of the created waveguides.

PSi is an optical metamaterial, which can be created with a predesigned refractive index by means of controlled electrochemical etching of Si wafer and possesses high absorption capability. In a recent article (Optical Materials, vol.85, 2018, pp.113-120) we reported the modification of optical properties of PSi by pore filling.

The substrate was a Si wafer with two porous layers of different porosity and refractive indices, where the bottom layer served as cladding. Channel waveguides were printed with KDP solution over the upper layer. The wafer was cleaved to allow access to the edges of the layers. Laser light was coupled into the waveguides through a lensed fibre. Mode profiles and light scattered from the top surface were acquired by means of imaging, furnishing the spatial distribution of the transmitted light and allowing estimation of propagation loss.

Light transmission was characterized in 1-1.8micron range by means of a wideband super-continuum source and a spectrum analyser. We observed multimode and single-mode propagation. Best measured losses insofar were below 1dB/cm at 1.550microns, and total insertion losses of 3.4dB. We expect further performance improvement by edge polishing and optimizing other fabrication steps in order to advance the method as a preferred technique for Telecom and sensing applications.

Exciton-Polariton Nanofocusing

Nadav Landau[1], Shai Tsesses[1], Guy Bartal[1] and Alex Hayat[1]

1. Department of Electrical Engineering, Technion, Israel

Introduction: Nanoscale confinement of electromagnetic wavepackets has been an ongoing field of research for many years. However, this endeavor has yet to be expanded to the growing field of exciton-polaritons, which may possess very strong confinement in optical frequencies.

Background: Exciton-Polaritons are quasiparticles originating from the strong coupling of light to excitons. If the photonic mode is red-detuned from the excitonic resonance, the resulting lower polariton branch exhibits large in-plane momentum, confining electromagnetic energy far below the free-space diffraction limit.

Objectives: We prove that exciton-polaritons can be strongly confined, while attaining sufficient coherence and lifetime for nano-focusing.

Methods: We derive the spatial and temporal limits of GaAs-based microcavity exciton-polaritons by calculating their in-plane dispersion. We extract the energy, linewidth and group velocity of the lower polariton branch and analyze its dependence on the exciton-photon detuning, Rabi splitting and initial linewidths. Subsequently, we perform Huygens-Fresnel simulations to demonstrate significant focusing of the lower branch polaritons, for several regimes.

Results: Our simulations show that GaAs-based microcavity exciton-polaritons can achieve a 10-fold wavelength compression at excitation energies of ~1.6 eV. Intriguingly, the limiting factor of the lower branch polariton propagation is its coherence time, rather than its lifetime. Moreover, exciton-polaritons with larger in-plane momentum appear to have larger propagation distances, due to an increased group velocity. Our results depend on the linewidth and energy separation of the polariton branches, while requiring that the injected polariton density be kept lower than the condenstation threshold.

Conclusions: We propose a scheme for achieving significant nanofocusing of exciton-polaritons. This scheme may be implemented in several feasible experimental systems, such as dye excitons in metallic cavities and microcavities supporting Tamm-Plasmons. The small mode volumes manifested in the nanofocusing scheme can also serve as a platform for investigating very strong many-body interactions, using larger polariton densities.

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Optical Properties of Single Visible Peptide Nanodots

Nadezda Lapshina, Jonathan Jeffet, Gil Rosenman, Yuval Ebenstein, Tal Ellenbogen

Tel-Aviv University, Israel

The rapid progress of bio-imaging techniques led to an increasing interest in development of different fluorophores with appropriate photo-physical properties of photostability, biocompatibility, and small size. To date, various types of fluorescent labels such as inorganic quantum dots, carbon nanodots, organic molecular dyes, and fluorescent proteins are commonly applied in bio-imaging and super-resolution microscopy techniques. Recently also fluorescent biorganic nanodots, made of different short peptides, were discovered [1]. These peptide nanoparticles exhibit a unique bright visible fluorescence arising from inner β-sheet molecule arrangement. The main advantages of these recently discovered nanodots with respect to existing fluorescent agents are their ultrasmall size of several nanometers, biocompatibility, tunable fluorescence within the visible wavelength range, photostability, and cheap and simple synthesis.

So far studies of peptide nanodots were performed on particle ensembles in solution. In this case, the measured fluorescence signal is averaged over all emitters and can be affected by, for example, particle nonuniformities and environment. In order to understand better their photophysical properties and suitability as new fluorescent labels, studies at single-dot level are essential.

Here we perform for the first time extensive measurements of the emission characteristics of single peptide dots. We find that the fluorescence spectrum tunability measured for nanodot ensembles origins at single-particle level accompanied with an effect of slight spectral dispersion for different individual particles. Fluorescence lifetime studies demonstrate fluorescence decay with a mean value of ~ 1.3 ns. Long time scale measurements reveal pronounced fluorescence blinking involving continual bright states with a duration in the range of seconds. This gives a first evidence of the quantum emitter nature of fluorescent peptide nanodots.

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Phase Manipulation by Use of a Chiral Plasmonic Metasurface

Leeju Leeju[1], Dr.Yuri Gorodetski[1], Prof. Shumel Sternklar[1]

1. Department Of elctrical and Elctronics Engineering, Ariel University, Isreal

Chiral objects are non-superimposable on their mirror image and induce a different optical response for illumination of right and left-handed circularly polarization light. These structures offer a simpler route to negative refractive index. Excitation of collective charge oscillations in the vicinity of a metal-dielectric interface (surface plasmon polaritons) enhances chiral interactions.The spectroscopic detection and manipulation of light envisioned by chiral metamaterial. Kramer's Kroning relation between the imaginary and real part of the refractive index prescribes the same connection between the two measurable effects of the optical activity, namely, the optical rotational dispersion (ORD) and the circular dichroism (CD). At the resonance, the ORD vanishes while the CD reaches its maximum. This provides an interesting tool for output polarization control.

Here we propose to design and fabricate an array of chiral nanostructure milled by focused ion beam (100nm Au film) for near-field interaction and manipulation of the optical field distribution of surface plasmon polariton (SPP). First, we investigate the change in the phase of transmitted light due to the locally modified nanostructure chirality. The system is tuned into a resonance via the local or global structure parameters and we study its ORD and the CD signatures. The transmission of the light through the metasurface is studied by leakage radiation microscopy. The results show a pronounced chiroptical resonant responses as compared to an achiral structure. Moreover, we experimentally verify the existence of the Kremers-Kronig's relations between the ORD and the CD signals. Further research will be dedicated to (a) fundamental investigation of the optical activity dependence on various plasmonic structure parameters, (b) maximizing chirality responses in metasurface, (c) designing and investigation of functional polarization dependent structures based on chiral plasmonic metasurface (d) study of the light-matter interaction with local and collective chirality.

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Spectrally Tunable Diffractive Induced Transparency and Slow Light in Plasmonic Nanoparticle Arrays

Lior Michaeli, Haim Suchowski, Tal Ellenbogen

Raymond and Beverly Sackler School of Physics & Astronomy, Tel-Aviv University, Israel

In planar arrays of plasmonic nanoparticles the coherent buildup of scattered light at the surface can significantly alter the optical response by supporting new resonances called surface-lattice resonances [1]. These unique resonances have recently shown to support various intriguing phenomena as Bose-Einstein condensation at room temperature [2] and enhanced nonlinearity of nanostructured materials [3].

Here we experimentally demonstrate the formation of near-infrared tunable narrow transparency window within a plasmonic absorptive band of split-ring-resonators array. We show, by phase measurements and by simulations, that the enhanced transmission is accompanied by reduced group velocity. By theoretically studying the nonlocal coupling dynamics we find that the intriguing effects of absorptionless interaction on the resonant surface is attributed to a special case of photonic-plasmonic hybridization. We show that exactly at the condition of coherent scattering of the nanoparticles at the array plane, equal magnitudes and opposite phases of the incident and scattered light leads to full electric field cancellation at the nanoparticles positions. Moreover, we experimentally demonstrate the observed effects at the spectral range of two distinct counter-propagating surface waves and show tunability of the observations over a wide spectral range of ~200 nm. In addition, we show that the observed effects occur only for TE polarized light, which therefore renders this phenomenon the complementary metamaterial behavior of the conventional Brewster's angle.

We believe that this work will promote fundamental future studies of nonlocal coherent interaction in nanostructured geometries and facilitate the route towards tunable, integrable, ultra-small slow light devices with high delaying capabilities. The presented study may also find direct functionality in the fields of sensing, displays, polarizers, optical buffers, filters and enhanced nonlinear interaction.

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Curved Space Plasmonic Optical Elements

Danveer Singh, Ana Libster Hershko, Roy Shiloh, Ady Arie
Electrical Engineering Postdoctoral Fellow, Tel-Aviv University

The dynamics of surface waves can be controlled by the surface curvature. Surface curvature serves as an effective potential, described by quantum mechanics that can alter the propagation dynamics of these waves. Here, we show the ability to control surface plasmon polaritons (SPPs) waves using curved surfaces. SPPs are surface electromagnetic waves that propagate along the interface between metal and a dielectric, which are coupled to charge oscillations in the metal. The unique features of SPPs are advantageous for many important applications such as sensing, on-chip communication, and nonlinear optics.

The above studies were performed mainly on the systems where the metal-dielectric interface was planar, but recently we have shown the ability to guide SPPs on a curved surface, in the form of a book cover. However, the curvature degree of freedom provides many additional opportunities for realization of plasmonic devices, such as plasmonic lenses and deflectors. In this work, we study curvature-induced plasmonic optical elements.

We have designed with the aid of an FDTD simulation software, three different curved space structures for focusing SPP waves: a dome, a parabolic book cover lens, and a tapered book cover lens. The latter is used to squeeze the size of an SPP mode guided by the book-cover structure to subwavelength dimensions. The structures were fabricated by lithographic patterning of photoresist, followed by heat-assisted reflow and deposition of a silver layer. Grating couplers were milled into the structure using a focused ion beam, to excite the plasmonic waves from free space light. The propagation of the plasmonic waves was then measured using a near field scanning optical microscope.

Such studies open a new platform for micro-particle manipulations with a trapping potential, for compact beam shaping of SPPs, and the study of nonlinear interactions on curved spaces.

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Non-Linear Light Amplification in Superconductor-Semiconductor Plasmonic Waveguides

Nir Strugo, Krishna Balasubramanian, Alex Hayat
Technion - Israel Institute of Technology, Electrical Engineering Department, Israel

Introduction: Stimulated two-photon emission (TPE) in semiconductors can effectively produce non-linear classical and quantum effects. The TPE effect also produces two-photon gain (TPG) in electrically driven semiconductor waveguide with a PN-junction structure [1]. Growing a superconductor layer on top of such a structure, allows the injection of correlated Cooper-pairs into the semiconductor using the proximity effect. Where they participate as the free carriers in an enhanced TPG process. Under right conditions, this second-order process contribution can be comparable to the first-order process of single photon gain [2].

Background: The Cooper-pair based TPG efficiency in semiconductor waveguide structure is typically low due to small mode overlap with the active-area. The short coherent length of Cooper-pairs in the semiconductor reduces the active-area, and as a result, the overall non-linear gain.

Objectives: By utilizing the superconductor for both Cooper-pairs injection and plasmonic guiding, we propose superconductor based plasmonic-waveguide for such applications. Providing significant gain improvement, due to the large overlap between the narrow active-area and the confined plasmonic mode.

Results: A surface plasmon-polariton (SPP) mode in the optical wavelengths can be supported along the superconductor-semiconductor interface. The SPP mode is highly confined to the interface, resulting in an order of magnitude increase of mode overlapping with the active-layer, and two orders enhancement of the overall non-linear gain parameter per length unit. In addition, the plasmonic structure eliminates the refractive index constraints for optical waveguides, and makes device fabrication much simpler. We numerically show that doping density of 1018[cm-3] along with superconductor thickness larger than 50nm, yields an optimum condition for the gain.

Conclusions: Using plasmonic-waveguides for superconductor based non-linear light amplification applications, increases the overall gain parameter by two-orders.

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Keywords: non-linear, two-photon gain, superconductivity, semiconductor, surface plasmon-polariton

Dynamic Control of Plasmonic Beams

Dror Weisman
Department of Physical Electronics, Faculty of Engineering, Tel-Aviv University

Surface Plasmon Polaritons (SPPs) are surface electromagnetic waves that propagate at the boundary between a metal and a dielectric, and are coupled to collective charge oscillations in the metal. There are various methods to dynamically control the propagation of plasmonic waves, e.g. using the thermo-optic effect in dielectric loaded plasmons, liquid crystals, electro-optic effect in dielectric polymers and more. Our research focuses on dynamic shaping the entire wavefront of plasmonic beams by using the thermo-optic effect. This is achieved by selectively and dynamically changing the refractive index at specific locations, therefore controlling the accumulated phase of the plasmonic beams and as a result, we will get the desired shape.

We experimentally demonstrate the dynamic control of a plasmonic mode converter that enables us to gradually convert between a fundamental Hermite-Gauss mode with one main lobe (HG0) into HG1-like beam with two equal intensity lobes. In order to convert between the two modes, a pi phase shift between the two parts of the fundamental mode is required. By inducing electrical current through a silver stripe that serves as a heat resistor, we were able to change the temperature of the dielectric that is on top of it and as a result the refractive index of the dielectric was changed and a different phase was accumulated relative to a second silver stripe that was not heated. This process is reversible, enabling to actively switch between the two modes as a function of the applied electrical current.

We also present a tunable plasmonic lens, in which the focal length can be controlled via electrical current. This is achieved by heating a region with quadratically varying thickness, thus adding a transverse quadratic phase to the plasmonic beam and therefore it will be focused after some distance.

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Vectorial Physical-Optics Modeling of the Interaction of a Tightly Focused Beam with a Nanoparticle

Huiying Zhong[1], Rui Shi[1,2], Zongzhao Wang[1,2], Site Zhang[2], Christian Hellmann[3], and Frank Wyrowski[1]
1. Applied Computational Optics Group, Friedrich Schiller University Jena, Jena, Germany
2. LightTrans International UG, Jena, Germany, 3 Wyrowski Photonics UG, Jena, Germany

A tightly focused spot of size as small as possible is highly desired in plenty of fields, among them optical microscopy, optical lithography, optical storage. However, spot size is restricted by the diffraction limit. In recent years, the focusing of radially polarized beams with annular aperture was proposed to achieve smaller focal spots. Focusing using microspheres (a method known as “nano-jet”) was also proposed with a similar aim in mind. But the search for ever tinier focal spots continues.
In this work, we perform a physical-optics modeling of the tight focusing of linearly, circularly and radially polarized beams with full consideration of vectorial effects by high-NA condensers in the framework of field tracing. Then we perform the physical-optics modeling, with rigorous Maxwell equations’ solvers, of the interaction of the obtained focused field with three types of dielectric nanoparticles. They are cubic, disc-shaped and spherical particles of size comparable to the wavelength. We find an even tighter focal spot can be obtained after interacting with the nanoparticles. The tolerance of the misalignment of the nanoparticle is also investigated to guide the experiments.

Modeling of Diffractive/Meta-Lenses using Fast Physical Optics

Huiying Zhong[1],Frank Wyrowski[1], Site Zhang[2], Liangxin Yang[1], and Christian Hellmann[3]

1. Applied Computational Optics Group, Friedrich-Schiller-Universität Jena
2. LightTrans International UG 3 Wyrowski Photonics GmbH

The growing importance of diffractive and meta-lenses in modern optical systems makes it vital to investigate and understand their capabilities. They play an important role in various applications like imaging systems, laser-beam shaping, bio/medical-optics, etc. We propose methods for the modeling of diffractive and meta-lenses based on the concept of the fast-physical-optics approach. A diffractive or meta-lens can be modeled as a series of structures functioning locally (e.g. local gratings) on a base interface. Each local structure introduces a certain local phase modulation, and by putting all of them together, the lens functionality can be achieved. In our approach, the rigorous Fourier modal method (FMM), also known as the rigorous coupled wave analysis (RCWA), is applied for the analysis of the local micro-/nanostructures, with all vectorial effects and possible higher-order effects taken into consideration; then the phase modulations can be collected for the lens function modeling. In this manner, a multi-scale simulation of optical systems with diffractive/meta-lenses becomes feasible and efficient in practice.

Oasis 7th Conference and Exhibition on Electro-Optics

Topic: IFLA - Dr. Yoav Sintov, Prof. Amiel Ishaaya

New Approaches in Microfiber and Nanofiber Tapering and Packaging

N. Malka[1], S. Goldring[2] and B. Sfez[1,2]

1. ICAP, Israel Center for Advanced Photonics, Yavne, Israel
2. Applied physics division, Soreq NRC, Yavne, Israel

Micro-fibers and Nano-fibers (MNFs) opened vast opportunities in the last decade in the fields of light-matter interaction, connecting fiber optics with near-field optics, nonlinear optics, plasmonics, quantum optics and opto-mechanics on the wavelength or sub-wavelength scale. Yet, two major challenges need to be tackled: First, the production yield of the MNFs is very low due to their fragility and sensitivity to minute perturbations. Secondly, packing and handling such fragile components while maintaining their functionality is difficult.

The first challenge was mitigated by using a new tapering method for costume-made MNFs, based on glass processing machine with laser induced ceramic heater that was developed and implemented. In order to address the packaging issue, a semi-automatic mounting and packaging system was introduced, thereby facilitating the placement of the tapered components in their intended operational systems with reduced risk of breakage and contamination.

Using the tapering set-up, optical fibers were tapered to waist diameters as low as 500nm with less than 13.7dB transmission loss at 1310nm. Moreover, tapers with diameter fluctuations of less than 100nm were achieved. This capability is critical for the fabrication of whispering-gallery mode resonators with high Q-factors.

Two packaging arrangements are introduced, one for nano-fibers and the second for micro-resonators. The packaging systems improve the overall yield form about 5% to more than 90%. In the future, the nano-fiber's package setup will be used for sensing of elements in liquid or gas environments.

Ultrasound Detection via Low-Noise Pulse Interferometry Using a Free-Space Fabry-Pérot

Oleg Volodarsky, Yoav Hazan, Amir Rosenthal

Department of Electrical Engineering, Technion - Israel Institute of Technology

In medical application, ultrasound detection is conventionally performed by piezoelectric transducer. However, with the emergence of hybrid imaging technologies such as optoacoustic tomography, there is a need for new methods for ultrasound detection that rely on detectors that are transparent and immune to electromagnetic interference. These properties may be achieved by optical schemes for ultrasound detection, which often rely on optical resonators to enhance sensitivity. When ultrasound impinges on the optical resonator, it modulates it central wavelength, where the modulation is often monitored by using a continuous wavelength (CW) laser. In such schemes, the main noise factor is frequency noise from the laser.

We present a novel scheme for interrogating resonator-based ultrasound detectors, which is based on a pulse laser. Our scheme, termed coherence-restored pulse interferometry (PI), includes a unique filtering mechanism that can reduce the optical noise to the shot-noise level - the fundamental quantum limit. Specifically, our scheme includes a free-space Fabry-Pérot filter whose spectrum coincides with that of the pulse laser over a bandwidth of 80 nm.

The new CRPI scheme was successfully demonstrated for ultrasound detection in the frequency range of 4-20 MHz, where shot-noise detection was maintained for optical powers up to 5 mW, representing the lowest optical noise level reported for ultrasound detection, to the best of our knowledge. Accordingly, CRPI may enable the development of ultra-sensitive optical detector of ultrasound. In addition, the wide optical band in which CRPI operates enable future wavelength multiplexing of resonators, facilitating the development of all-optical ultrasound detector arrays.

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Topic: Medicine and Biology - Prof. Dror Fixler

Enhanced Entangled-Photon-Pair Interaction with Metallic Nanoparticles

Ariel Ashkenazy, Dror Fixler

Faculty of Engineering and the Institute for Nanotechnology and Advanced Materials, Bar-Ilan University, Israel

In recent years, many quantum lights-based applications were suggested, ranging from encrypted communication and precision metrology to fluorescent biomolecules detection and advanced spectroscopy schemes. Such applications mostly rely on entanglement, the property of correlations between particles which cannot be explained by classical mechanisms, to overcome classical light limitations. Some of these applications, e.g. nonlinear spectroscopy, require the use of entangled-photon-pair interaction (EPPI) with the matter. However, such entangled pairs, generated through spontaneous parametric down-conversion (SPDC), are scarce, and multi-photon interaction with matter is usually very weak and barely detectable. Therefore, an enhancement of this interaction is needed.

In our research, we investigate a novel way to achieve such an enhanced EPPI using metallic nanoparticles (MNPs), which are known for their exceptional capability of light-matter coupling at their localized surface plasmon resonance (LSPR). We present a novel way of theoretically estimating the rate of EPPI with MNPs, based on a simple method of classical light second-harmonic generation (SHG) measurements. The theory is supported with experimental results, obtained for a solution of silver NPs (SNPs). These results show an estimated six orders-of-magnitude EPPI enhancement, relative to the best organic molecules, and indicate that the use of SNPs can be advantageous for realization of advanced quantum light applications.

Development of a Miniaturized Bio-Barcode Sensor Array for Detection of Biological Events

Marianna Beiderman, Elad Segal, Menachem Motiei, Rachela Popovtzer, Dror Fixler

Bar Ilan University, Engineering Department, Israel

The healthcare industry is moving towards personalized medicine and patients seek greater role in their care. This research aims to provide greater visibility and early detection of biological events in vivo. We have developed a novel versatile bio-barcode optical sensor array for in vivo detection of biological events. The sensor comprises of an array of nanocavities for confining the electromagnetic field, nanoparticles and fluorescence molecules, allows multi detection of biological events using Surface Plasmon Resonance (SPR) and fluorescence lifetime detection modalities. The system was tested before and after cleavage with various bio-molecules and the results show a significant change both in their SPR signal and their fluorescence lifetime imaging. This sensor may has the potential to provide real-time analyses of different biological molecules, such as antibody and antigen, receptor and ligand, and complementary DNA fragments in physiological conditions.

Surface Chemistry Controls the Uptake of Gold Nanorods by Macrophages

Ruchira Chakraborty, Dorit Leshem-Lev, Dror Fixler

Bar Ilan University, Engineering Department, Israel

In recent days gold nanorods (GNR) catch the eyes not only with their unique optical behavior but also for a wide variety of application in the field of the diagnostics and therapy. When it comes to the case of in vivo studies, monitoring the pattern of the interaction of nanoparticles with the immune cells are very important. Macrophages, the proficient phagocytic immune cells, differentiated from monocytes, play a major role in our innate immunity. Recently macrophages after uptake of nanoparticles are used as a vehicle for drug delivery for cancer or, as a diagnostic tool for atherosclerosis. Though macrophages can internalize the GNRs by phagocytosis, still the surface charge and presence of particular linker can bring a huge change in the uptake and cytotoxicity pattern of GNRs. In this study, we took three different types of macrophages -macrophages isolated from blood of the healthy donor, macrophages differentiated from THP1 human monocyte cell lines and RAW 264.7 murine macrophage cell line and compared their change in viability and uptake of GNRs. We chose GNRs of same aspect ratio with different zeta potential. GNRs with positive zeta i.e. cetyl trimethylammonium bromide (CTAB), poly allylamine hydrochloride (PAH) internalized more than the GNRs with null i.e. poly ethylene glycol (PEG) or negatively charged surface i.e., poly sodium 4-styrenesulfonate (PSS), citrate. But because of high toxicity CTAB GNRs effect on cell viability, whereas PAH GNRs showed less toxicity. Overall RAW 264.7 showed more uptake than macrophages from PBMC. This study draws an idea of how surface modifications of GNRs affect their uptake by macrophages.

Absorption Based Physiological Parameter Determination from IPL Point

Idit Feder, Hamootal Duadi, Dror Fixler

Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University

The human tissue is a turbid media hence it poses a challenge for the different optical methods in extracting optical properties. Most of the methods analyze the reflected light or transmitted light. We suggest a new nanophotonic method for extracting optical properties of cylindrical tissues accurately. Our method based on the full scattering profile (FSP), which mean the angular distribution of light.

We measured the FSP of cylindrical phantoms with different concentrations of ink as an absorbing component and Intra-Lipid as a scattering component. The absorption influence the FSPs uniformly while the scattering influence the profile differently at different angles. We discovered a unique point by our FSP method and named it the Iso-pathlength point (IPL). At this point, the optical path length is not affected by the scattering of the media. Hence, it neutralizes the scattering effect and as a result, enables the measurement of the absorption accurately. Using the IPL point we can measure physiological parameters based on the changes in the absorption of the tissue, such as oxygen saturation, accurately. We show by phantom measurements in the IPL point the extraction of different absorption coefficients.

Non-Invasive Detection of Congenital Heart Diseases in Newborns by Electro-Optical Measurement in the Hand and Foot

Yohai Nitzan[1], Ohad Yossef Hay[1], Itamar Nitzan[2], Meir Nitzan[1], Robert Koppel[3]

1. *Department of Applied Physics/Electro-Optics, Jerusalem College of Technology, Israel*
2. *Department of Neonatology, Shaare Zedek Medical Center, Israel*
3. *Division of Neonatal-Perinatal Medicine, Cohen Children's Medical Center of New York/ Northwell Health, USA*

Introduction: Coarctation (narrowing) of the aorta occurs in 1/2,500 newborns, and its delayed diagnosis may result in neurologic injury and death. The ductus arteriosus is an essential blood vessel in the fetus, connecting the pulmonary artery to the aorta, bypassing the fetal lungs. In 20-50% of preterm infants, the ductus arteriosus remains open after birth (PDA - patent ductus arteriosus). Left-to-right PDA shunting may increase the pulmonary blood flow and decrease the systemic perfusion, which may lead to severe morbidity.

Background: Presence of coarctation and PDA can be determined by echocardiography, but the technique cannot be used for screening, because it is expensive and must be performed by an expert.

Objectives: Development of a simple electro-optical technique for the detection of coarctation and PDA.

Methods: Photoplethysmography (PPG) is the measurement of changes in light transmission through tissue due to cardiac-induced blood volume changes. Changes in two PPG pulse parameters in hand and foot, due to coarctation or PDA were examined: relative pulse amplitude (rAM) and foot-hand time-delay (f-hTD). Presence of coarctation and PDA was determined by echocardiography.

Results: In infants with coarctation, compared to healthy newborns, f-hTD was significantly prolonged (71.8±27.5 milliseconds (ms) vs 35.0±8.4ms, p=0.00003) and rAM value was significantly lower (0.57±0.25 vs 0.95±0.53, p=0.016). In preterm newborns with PDA, foot rAM was significantly higher than in those without PDA (Median: 1.36 vs 1.14, 95%CI: 1.19 to 2.04 vs 0.95 to 1.53, P=0.028). Despite the lower systemic perfusion in PDA, rAM was higher, probably due to reverse blood flow during diastole.

Conclusions: Foot-hand time-delay is prolonged in infants with coarctation. The relative foot PPG amplitude decreased in coarctation and increased in preterm newborns with PDA. PPG parameters in foot and hand may be utilized as a simple and convenient screening modality for congenital heart diseases in newborns.

Oasis 7th Conference and Exhibition on Electro-Optics

Magnetic Resonance Imaging of Microstructured Optical Fibers

Roman E. Noskov, Anastasia A. Zanishevskaya, Andrey A. Shuvalov, Sergei V. German, Olga A. Inozemtseva, Taras P. Kochergin, Ekaterina N. Lazareva, Valery V. Tuchin, Pavel Ginzburg, Julia S. Skibina, Dmitry A. Gorin

Tel-Aviv University, Israel
SPE LLC Nanostructured Glass Technology, Russia
Saratov State University, Russia
Skolkovo Institute of Science and Technology, Moscow, Russia
Tomsk State University, Tomsk, Russia

Optical bioimaging via using fibre-optic endoscopes has supplied a large number of opportunities for retrieving information from remote and delicate places enabling accurate visualization of pathologies, neural activity, tissue structure and many others. Specifically, optical endoscopy is considered as a promising tool for monitoring, diagnosis and detection of diseases in luminal organs. To be used in organs having natural openings, flexible endoscopes are typically made of optical fibre bundles that consist of up to ~100,000 individual fibers in a closely packed arrangement.

As an auspicious alternative allowing minimally invasive penetration into tissue, a single multimode fiber operating lens-free on principles of digital holography was offered. This system is especially attractive for high-resolution observations of neuronal activity in vivo inside deep brain areas. However, currently the precise position of the fiber endoscope after penetration into the brain can be defined post-mortem only. At the same time, the study of so complex system as a brain in vivo whose functioning is still mainly unknown requires extremely exact spatial operating with endoscopic probes in real time. Such opportunity can be provided by magnetic resonance imaging (MRI). Thin optical fibers, though, have a vanishing MRI contrast.

Here, we report on the technique which allows MRI of hollow-core microstructured fibers (HC-MFs). Our approach is based on Layer-by-Layer assembly of oppositely charged polyelectrolytes and magnetite nanoparticles on the inner core surface of HC-MFs. Incorporation of magnetite nanoparticles into polyelectrolyte layers renders HC-MFs visible for MRI and induces the red-shift in their transmission spectra. Specifically, the transmission shifts up to 60 nm have been revealed for the several-layers composite coating along with the high-quality contrast of HC-MFs in MRI scans. Our results shed light on marrying fiber-based endoscopy with MRI that opens novel possibilities for minimally invasive clinical diagnostics and surgical procedures in vivo.

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Holographic Display for Optical Retinal Prosthesis: Design and Validation

Shani Rosen, Moshe Gur, Shy Shoham

Technion - Israel Institute of Technology, Biomedical Engineering Department, Israel

Introduction: A retinal prosthesis based on artificial stimulation of retinal ganglion cells (RGCs) is one of the main approaches being pursued towards vision restoration for blind patients suffering from outer retinal degenerative diseases. In recent years, optical stimulation techniques have emerged as a revolutionary strategy for non-contact neural stimulation with cellular resolution. To fully realize the potential of this approach, we introduced a holographic wavefront shaping method suitable for power efficient patterned stimulation of RGCs in real-time.

Objectives: Here, we tackle two major challenges in translating this technology to human subjects. These include interfacing with the human eye, a highly imperfect optical system with complex dynamics, together with the development of dedicated holographic techniques designed to achieve a reliable and efficient RGC stimulation in-vivo.

Methods: We design and develop an optimized holographic display for high acuity optical retinal prosthesis. Next, we perform psycho-physical experiments on normally sighted individuals to characterize and validate the performance of our system using different speckle-elimination strategies and versatile spatial and temporal illumination conditions.

Results: In ideal viewing conditions, letter identification performance is not degraded by the holographic display. Subjects are able to identify letters < 0.3 in logMAR units, equivalent to a ~10µm stimulation spot on the retina. Spatially shifting the display to 5° eccentricity reduces the acuity level to ~0.4 in logMAR units, which is still considered enough for reading. Performance is maintained using short exposures, suggesting that continuous micro eye-movements are not necessary to maintain visual performance at high acuity levels.

Conclusions: An optimized holographic display for high acuity optical retinal prosthesis was designed and built. Psycho-physical experiments performed on normally sighted individuals assure that the system can be utilized for stimulation of retinal ganglions with cellular resolution.

Acousto-Optic Tomography Beyond the Acoustic Diffraction-Limit Using Speckle Decorrelation

Moriya Rosenfeld, Daniel Doktofsky, Ori Katz

Applied Physics Department, The Hebrew University of Jerusalem, Israel

Acousto-optic tomography (AOT) enables optical-contrast imaging deep inside scattering samples via localized ultrasound modulation of scattered light. However, the resolution of AOT is inherently limited by the ultrasound focus size, prohibiting microscopic investigations. In the last few years, advances in the field of digital wavefront-shaping have allowed the development of novel approaches for overcoming the acoustic resolution limit of AOT. However, these novel approaches require the execution of thousands of wavefront measurements within the sample speckle decorrelation time, limiting their application to static samples. Here, we show that it is possible to surpass the acoustic resolution limit with a conventional AOT system by exploiting the natural dynamics of speckle decorrelations rather than trying to overcome them. We achieve this by adapting the principles of super-resolution optical fluctuations imaging (SOFI), originally developed for imaging blinking fluorophores, to AOT. We show that naturally fluctuating optical speckle grains can serve as the analogues of blinking fluorophores, enabling super-resolution by statistical analysis of fluctuating acousto-optic signals.

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Extended Depth-Of-Field Super-Resolution Micro-Endoscopy via Speckle Fluctuations

Noam Shekel, Ori Katz

Applied Physics Department, The Hebrew University of Jerusalem, Israel

Flexible fiber-optic endoscopes provide a minimally-invasive solution for imaging at depths beyond the reach of conventional microscopes. However, most current endoscopes require focusing and/or scanning mechanisms at the distal end [1], limiting their miniaturization. As a result, developing lensless microendoscopes has been a topic under intense recent study. Novel lensless solutions that are based on computer-controlled wavefront-shaping [2], are innovative but extremely sensitive to fiber bending.

In this work, we present a lensless approach that is based on natural dynamic fluctuations of speckle patterns generated by fiber bending to allow super-resolved, extended depth-of-field lensless microendoscopy using conventional fiber bundles. Our approach is not limited by a minimal working distance and can theoretically improve fiber bundle PSF by a very large factor, limited on the acquisition time.

Our approach is based on adapting Super-resolution Optical Fluctuation Imaging (SOFI) [3], a technique developed for super-resolved fluorescence microscopy, to bundle-based endoscopy. In SOFI, the dynamic fluctuations of blinking fluorescent emitters are statistically analyzed to provide super-resolution. In our work, we replace the fluctuating emitter with fluctuating speckle patterns, generated by fiber bending, to increase the resolution and depth-of-field of bundle based lensless endoscopy. Our results extend the use of SOFI from fluorescence microscopy and photo-acoustics [4], to endoscopy.

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Diffusion Reflection, a Novel Non-Invasive Nanophotonic Method For Early In Vivo Detection of Oral Cancer

Shiran Sudri, Dror Fixler, Abraham Hirshberg

Dept. Oral Pathology and Medicine School of Dental Medicine Sackler Faculty of Medicine Tel-Aviv University Israel

Introduction: Oral squamous cell carcinoma (OSCC), have a poor prognosis and it is extremely important, to develop a good non-invasive method for early detection. Nanophotonics has emerged as a revolutionized way in the field of medicine to detect and treat cancer. We present a novel non-invasive cancer-detection technique that utilizes the unique absorption properties of gold-nanorods (GNRs) in the near infrared region. The method is based on diffusion reflection (DR) measurement of gold-nanorods bio-conjugated (C-gold-nanorods) to anti-epidermal growth factor receptor (EGFR) monoclonal antibodies exclusively attached to OSCC cells. The ability to specifically deliver and target high concentration of GNRs exclusively to the tumor significantly change its optical properties, enabling the discrimination between cancerous and non-cancerous tissues.

Objective: To develop a methodology for early in-vivo detection of oral cancer by using DR optical method in a well-known rat model of oral carcinogenesis.

Methods: DR measurements of C-gold-nanorods injected systematically were recorded from the surface of rat tongue where OSCC has been induced by the carcinogen 4-nitroquinoline-N-oxide (4NQO). 26 Wistar-derived male rats were used, divided into experimental (20 rats) and control (6 rats) groups. Experimental rats were sacrificed at 2 weeks interval following 4NQO administration. C-gold-nanorods were injected systemically to the tail vein. DR measurements were taken following washout time of 96 hours interval. The results of the DR measurements were compared with the histologic diagnosis.

Results: Dysplastic lesions appeared after week 12 and OSCC was detected in all experimental rats after week 22. Significantly high DR values were recorded in all rats with OSCC enabling to discriminat cancerous lesions from the surrounding normal mucosa.

Conclusion: The presented nanophotonic optical detection method can provide a highly sensitive and simple tool for cancer detection to guide treatment and accurately detect tumor margins, hence, improving the outcome of oral cancer.

An Optical Method to Detect Tissue Scattering: Theory, Experiments and Biomedical Applications

Inbar Yariv, Hamootal Duadi, Dror Fixler

Faculty of Engineering and the Institute for Nanotechnology and Advanced Materials, Bar Ilan University

In vivo physiological sensing is typically done either by imaging thin tissues or by examining changes in the attenuation coefficient. One known technique for thin tissue in vivo applications is the optical coherence tomography (OCT). However, deep tissue methods are usually based on diffusion reflection (DR), which correlates the optical properties to the reflected light intensity. The attenuation coefficient is composed of tissue absorption and scattering. We present a noninvasive nanophotonics technique, the iterative multi-plane optical property extraction (IMOPE) for extracting the scattering properties from a turbid medium.

The reflectance based IMOPE is most relevant for in vivo applications, hence, is this research we suggest a new theoretical description of phase accumulation in deep tissue, which is rarely mentioned in the literature, using a modified DR theory that represents the phase based on the effective pathlength.

The IMOPE records multiple intensity images, reconstructs the phase using Gerchberg-Saxton (GS) algorithm. This algorithm is usually being used for beam shaping or phase reconstruction. We propose to calculate the phase second order moment to estimate the scattering. IMOPE experiments were conducted with tissue-like phantoms for calibration purposes, as well as ex vivo and in vivo measurement.

The suggested technique was applied both in transmission and reflection mode. The transmission based IMOPE detected organic nanoparticles within tissues and the quantitative signature of milk components. The reflectance based IMOPE was applied for tissue viability test and in vivo gold nanorods and blood flow detection.

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Topic: Non-Linear Optics - Dr. Haim Suchowski

Second Harmonic Generation in Geometric-Phase Resonant Dielectric Metasurfaces

Jonathan Bar-David, Uriel Levy

Department of Applied Physics, The Center of Nanoscience and Nanotechnology, The Hebrew University of Jerusalem, Israel

Metasurfaces are artificially patterned interfaces with engineered optical properties. By properly designing metasurfaces, one may control and manipulate optical fields in the near- and far-field regimes, and determine the basic properties of reflected, transmitted and scattered radiation [1]. In recent years researchers have shown a wide variety of both metallic and dielectric metasurfaces, controlling light's properties.

Of light's basic properties, the frequency is perhaps the most-difficult to manipulate, due to the high-fields and small cross-section related to such nonlinear processes. In this work, we explore second harmonic (SH) generation, i.e. optical frequency doubling, in resonant dielectric metasurfaces [2, 3].

Following research in the linear regime, we have chosen to design an asymmetric nanoantenna, which yields intriguing results such as nonlinear diffraction from structures with no principal diffraction and nonlinear geometric phase which depends on nanoantenna symmetry [4, 5].

Our metasurfaces are made of arrays of amorphous silicon (α-Si) L-shaped nanoantennas. We demonstrate the nonlinear geometric phase concept [6, 7], where the asymmetric shape of the meta-atom adds degrees of freedom and dictates unique geometric phases unreported previously.

Clear SHG signature is observed, and its phase depends on the incident polarization as well as the meta-atom rotation rate and direction. More elaborated discussion regarding symmetries, efficiencies and pattern generation will be provided in the talk.

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Dynamics of Coupled Degenerate Parametric Oscillators beyond Coupled Ising Spins

Leon Bello[1], Marcello Calvanese Strinati[2], Emanuele G. Dalla Torre[2] and Avi Pe'er[1]

1. Department of Physics and BINA Center of Nanotechnology, Bar-Ilan University, Israel
2. Department of Physics, Bar-Ilan University, Israel

Coupled degenerate parametric oscillators have been recently proposed as a physical platform for solving general Ising spin networks, a computationally hard problem. We study theoretically and experimentally the minimal utilization of such systems, a pair of coupled parametric oscillators, and show that the observed behavior is much richer than a simple spin-1/2 description.

Parametric oscillators have attracted a significant attention during the last decades due to their potential applications ranging from quantum optics to quantum information and communication. When a parametric oscillator is driven above threshold by a pump, it oscillates with a frequency which is exactly half of the frequency of its pump, with phase of either 0 or π with respect to the pump, thus giving rise to an effective classical spin-1/2 degree of freedom. Because of this feature, networks of many coupled parametric oscillators have been proposed as a potential platform for solving complex combinatorial and minimization problems. Coupled parametric oscillators have been recently employed as simulators of artificial Ising lattices, with the potential to efficiently solve important minimization problems.

We report on a detailed study of the most minimal realization of a coherent Ising machine, i.e., two coupled degenerate parametric oscillators, exploring the entire phase diagram, in terms of pump power, phase and coupling strength, both analytically and experimentally in a radio-frequency (RF) experiment. In addition to a regime where the oscillators act as coupled spin-1/2 degrees of freedom, in the vicinity of the oscillation threshold there is a very wide range of parameters where the spin-1/2 description does not apply and the oscillators never reach steady state, but rather show persistent, full-scale, coherent beats, whose frequency reflects the coupling strength. Our study unveils the rich coherent dynamics of coupled parametric oscillators and shows a routable way to use parametric amplification to conserve coherence indefinitely.

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Point Measurements of Opto-Mechanical Interactions in Multi-Core Fibers

Arik Bergman[1], Hilel Hagai Diamandi[1], Yosef London[1], Gil Bashan[1], Javier Madrigal[2], David Barrera[2], Salvador Sales[2], and Avi Zadok[1]

1. Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, Bar-Ilan University, Ramat-Gan 5290002, Israel
2. Institute of Telecommunications and Multimedia Applications (iTEAM), Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain

Forward stimulated Brillouin scattering (F-SBS) is a nonlinear interaction between two optical field components and a guided acoustic wave. F-SBS allows for opto-mechanical sensing of media outside the fiber cladding, where light cannot reach. Recent demonstrations of F-SBS-based sensing include integrated measurements over tens of meters of fibers and distributed analysis with tens of meters resolution. However, localized point-measurements, which are the most prevalent form of fiber sensing, are yet to be achieved. Such measurements are difficult due to the weak effect of F-SBS over cm-scale segments.

Here we report point-analysis of F-SBS, and point opto-mechanical sensing outside the cladding of a commercially-available multi-core fiber (MCF). The stimulation of guided acoustic waves introduces opto-mechanical crosstalk among the constituent cores of such fibers, even when direct coupling of optical power is negligible. Guided acoustic waves are stimulated by modulated pump light at the inner core of the MCF, and they are analyzed in turn using a fiber Bragg grating (FBG) that is inscribed in an outer core of the same fiber. The acoustic waves induce temporally-varying perturbations to the refractive index of the FBG, which may be monitored through the reflection of a properly-tuned optical probe wave. Although the magnitude of index perturbations is very weak, on the order of 1e-9 refractive index units, the measurement protocol is sensitive enough to resolve them. Results identify the F-SBS spectrum in the few-cm long FBG region that is free of polymer coating. The spectrum is markedly different from that of the rest of the fiber, which is coated with standard, dual-layer acrylate coating. Measurements also distinguish between air and water outside the FBG region even though light does not leave the cores of the fiber. The concept completes an important piece in the puzzle of opto-mechanical fiber sensing.

Direct and Cascaded Collective Third Harmonic Generation in Plasmonic Metasurfaces

Ofer Doron[1-3], Lior Michaeli[1-3], Tal Ellenbogn[1,3]

1. Department of Physical Electronics, Faculty of Engineering, Tel-Aviv University, Israel
2. Raymond and Beverly Sackler School of Physics & Astronomy, Tel-Aviv University, Israel
3. Tel-Aviv Center for Light-Matter Interaction, Tel-Aviv University, Israel

Third-harmonic generation (THG) can be achieved by either direct interaction of three pump photons to produce a photon at the third-harmonic, or by a cascaded process in quadratic nonlinear materials that enables second-harmonic generation (SHG) followed by sum-frequency generation (SFG) involving the second harmonic (SH) and the pump waves. Conventional schemes to control these two separate THG mechanism mostly rely on selective phase matching of the different process, i.e. SHG, SFG, or THG.

Recently it was shown that collective nonlinear dynamics of metallic metasurfaces can play a significant role in their total nonlinear optical response. Specifically, it was demonstrated that coherent scattering at the SH, i.e. at the nonlinear Rayleigh anomaly (RAs), may substantially enhance the total conversion efficiency of SHG and show evidence of cascaded THG. These observations were phenomenology explained by extension of the conventional coupled-dipole approximation (CDA) to the nonlinear case.

In order to study the nonlinear plasmonic array response to incident light we used the nonlinear CDA for the case of THG. We found that the effective cubic hyperpolarizability is separated into its two contributions, one describes the direct process and the other describes the cascaded process. The main difference between the two contributions is a geometrical factor controlling the collective interaction at the SH and appears solely in the cascaded term. This term supports enhanced SH under the nonlinear RA condition. The separation between the direct and cascaded terms allow to obtain control on the relative phase and amplitude of the two contributions, which can lead to either constructive or destructive interference and may result in an asymmetric Fano-like spectral line shape for the THG. In the meeting we will present the complete calculations and discuss the dynamics at different points of interest including the intriguing phenomena of THG elimination.

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Ultrafast Measurement of the Entire Electric Field

Avi Klein, Moti Fridman, Inbar Sibony

Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Israel

Single-shot measurement of the amplitude, phase, and state of polarization of ultrashort signals has been a challenge for the optical community. The ability to measure the entire properties of the electric field simultaneously in high temporal resolution will help in diagnosing ultrashort phenomena, such as optical rogue wave, modulation instability, or polarization solitons in mode lock lasers.

We developed a unique method to measure the ultrafast state of polarization by exploiting the sensitivity of the four-wave mixing process to the state of polarization of the pump wave. We combined this measurement system with phase retrieval techniques to realize a single system for measuring all the components of the electric field in a single-shot.

Our method is useful for numerous schemes in nonlinear and quantum optics. We utilized our method for measuring, for the first time, the polarization dynamics of optical rogue waves which led us to new model for describing these freak waves. We also utilized the system for measuring the mode-locking dynamics in fiber lasers with polarization mode-locking. We found that the polarization of the pulse is critical for reaching mode-locking and specifically, the polarization dynamics in the pulse.

During the talk, we will present in details, the experimental setup, results and numerical simulations.

Distributed Mapping of Nonlinear Wave Mixing Due To Opto-Mechanics and Kerr Effect

Y. London, G. Bashan, H. H. Diamandi, A. Zadok

Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, Bar-Ilan University, Israel

Forward stimulated Brillouin Scattering (F-SBS) is a third-order nonlinear-optical mechanism that couples between two co-propagating optical fields and a guided acoustic mode in a common medium. F-SBS gives rise to nonlinear wave mixing along optical fibers, which adds up with four-wave mixing induced by the Kerr effect. In this work, a model for nonlinear wave mixing among co-propagating optical tones has been formulated, bringing together F-SBS and Kerr effect contributions. The model predicts that nonlinear wave mixing involving F-SBS is markedly different from four-wave-mixing due to the Kerr effect alone [1]. The dynamics are strongly dependent on the exact frequency detuning between optical field components. When the detuning is chosen near an F-SBS resonance, the process becomes asymmetric. Power is transferred from a high-frequency pump wave to a lower-frequency one, and the nonlinear amplification of Stokes-wave sidebands is more pronounced than that of anti-Stokes-wave terms. Analytic solutions are provided for the near distances in order to provide intuition toward distant results.

Distributed mapping of nonlinear wave mixing was experimentally performed over 8 km of standard fiber, using a multi-tone, frequency-selective optical time domain reflectometry setup [1]. Measurements are in very good agreement with theoretical predictions. On top of basic research interest, the results can be used to enhance the range, resolution and accuracy of new protocols for distributed opto-mechanical sensing of media outside the cladding and coating of fibers [2].

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Observation of Branched Flow of Light

Anatoly Patsyk, Miguel A. Bandres, Uri Sivan, Mordechai Segev

Physics Department and Solid State Institute, Technicon, Israel

We present the first study of optical branched flow. As light propagates in thin dielectric films it experiences scattering from inhomogeneities, forming bundles displaying the features and statistics of the phenomenon known as branched flow.

Comprehensive Theory of Frequency Conversion from Nanoparticles

K. Nireekshan Reddy[1], Parry Y. Chen[1,2], Antonio Fernández-Domínguez[3], and Yonatan Sivan[1]

1. *Unit of Electro-Optics Engineering, Ben-Gurion University, Israel*
2. *School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel-Aviv University, Israel*
3. *Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Spain*

Frequency conversion is a basic nonlinear optical phenomenon [1]. The fundamental requirements for efficient conversion in waveguide geometries are phase-matching and mode-matching. The former ensures that phase accumulation of all frequency components involved is equal, while, the latter ensures that the associated transverse mode profiles have an optimal spatial overlap. Ideally one requires both the conditions to be satisfied simultaneously for efficient conversion. In a different class of configurations, involving a single nanoparticle, phase matching is usually considered unimportant for subwavelength particle size due to the small dimensions. Recently, the link between the infinite waveguide geometries and single nanoparticles has been established using Transformation Optics [2]. We use conformal transformations to show that unlike the common belief, phase-matching plays a major role in frequency conversion in nanoparticles of sub-wavelength dimensions. We note that the mode-matching condition together with the phase-matching condition determines the frequency conversion efficiency, and in fact, the difficulty to achieve them simultaneously explains the low conversion efficiencies demonstrated so far.

Furthermore, we use the conformal transformation to provide accurate analytical solutions for a range of complicated nanostructures which apriory were expected to yield highly efficient broadband response. Using state-of-the-art numerical simulations that overcome the limitations of existing commercial software, we show that our solution is in excellent agreement with numerical results. We further discuss ways to improve the frequency conversion efficiency using the insights provided by our analytical solution. As an example, we solve for surface second-harmonic generation from the two identical touching metallic cylinder system using conformal transformation. Our results provide the means to enable the optimization of the frequency conversion process, which is crucial for enabling many applications such as nonlinear microscopy, quantum (nano-) optics.

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Thz Emission from Nonlinear Metasurfaces in Free Space and Waveguide Platforms

Symeon Sideris, Tal Ellenbogen

Department of Physical Electronics, Faculty of Engineering, Tel-Aviv University, Israel

Over the past couple of decades, particular attention has been given to the terahertz spectral regime, ranging from 0.1 - 15 THz, as it offers a great variety of important applications, including medical imaging, security scanning, fast wireless communications, and plethora of applications in materials sciences. However, conventional THz generation schemes suffer from some limitations, such as low efficiency, need for cryogenic cooling and gaps in the generated spectrum. Moreover, the control of the emitted THz radiation is challenging, thus making the development of sources and THz manipulation elements a priority.

Recently it was shown experimentally that THz radiation can be generated through optical rectification and difference frequency generation (DFG) in nonlinear metasurfaces constructed from split ring resonators (SRRs). In order to understand the generation process and to be able to design novel nonlinear metamaterial THz sources and components there is a need to develop reliable numerical models of the THz generation by nonlinear metamaterials. Here we develop a new numerical model, based on finite-element-method (FEM), and use it to study the THz emission characteristics. The nonlinear process of DFG is described by a hydrodynamic model in the frequency domain, which allows the calculation of the surface currents that emit the THz radiation. Implementing it in the FEM solver enables us to study the emission characteristics. Our results make evident that broadband and tunable THz generation is possible and allow us to obtain insight on optimization of the process. To further enhance our design, we form a parallel plate waveguide with metasurfaces on one plate and convert the THz radiation into guided modes. This structure shows great potential as a key element in forthcoming photonic devices. In the meeting we will describe our model in detail and show the THz emission characteristics in free space and in the waveguide configuration.

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Topic: Lasers and Applications - Dr. Ariel Bruner

Yellow LASER for Eye Surgery

Kobi Aflalo, Irit Juwiler, Moshe Ben-David

Center for E.O, Development of LASER Technologies and their Applications, Shamoon College of Engineering, Electro-Optics and Photonics Engineering Department, Ben Gurion University, Israel

The type of LASER and its operation depend on the ophthalmic procedure. We examine the possibility of using a pure yellow LASER for diabetic retinopathy eye surgery. The main advantages of this wavelength are higher absorption in oxyhemoglobin and lower intra-ocular scattering, which enables lower power usage and less pain due to minimal damage to the surrounding tissues.

Diabetic retinopathy is a chronic metabolic disease, which causes the growth blood vessels. These vessels increase the pressure on the retina, could cause blindness and retinal-detachment. In order to treat non-proliferative diabetic retinopathy a procedure called PRP (Panretinal-photocoagulation) is needed.

The objective of this work is to examine the use of yellow LASER for PRP and to compare its performance to other LASERs. Furthermore we will determine what should be the parameter (energy, beam diameter, pulse width, and repetition rate) in order to achieve optimal results. These parameters will be used later for planning a device.

We use the Monte-Carlo method to simulate propagation and absorption. The absorbed energy causes a temperature rise which cause coagulation. The simulation is used to compare different wavelengths and to examine its parameters influence on the temperature distribution and the resulted thermal effect. The results of the simulation will be used in Comsol-Multiphysics to take into account the heat conduction. The theoretical calculations will be compared to experimental results.

The ocular region of the eye is unaffected with radiation at the retina, once heating the damaged tissue the temperature rises suddenly to maximum, decrease exponentially and will not affect any deeper, this occur due to melanin and oxyhemoglobin concentration with high absorption for yellow wavelength, and almost negligible absorption and scattering in the rest of the eye.

Pure yellow LASER is better to treat diabetic retinopathy due to its high absorption with minimal scattering causing less pain.

Emittance Reduction by Density Tapering in Laser-Plasma Electron Acceleration

Eitan Y. Levine, Igor Andriyash, Victor Malka
The Schwartz/Reisman Intense Laser Physics Laboratory, Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot, Israel.
Laboratoire d'Optique Appliquée (CNRS, ENSTA, Ecole Polytechnique), Palaiseau, France

Laser-plasma accelerators may become a compact, affordable and powerful alternative machine for delivering relativistic electron beams of relevance for applications ranging from medical treatment and imaging to fundamental researches related to high-energy physics. However, one of the main obstacles for this approach to fulfil its promise, for some of the mentioned applications, is the beam quality with large divergence and emittance. Tapering the density of the plasma with which the high-power laser interacts is one of the possible ways to affect and mitigate the beam quality degradation upon its extraction from the plasma. The physical phenomena and the ways to approach beam extraction are the topics of this work. Theory and simulations support the feasibility of this method to improve the beam's quality, possibly qualifying the laser-plasma concept as the next generation of electron accelerators.

Efficient Laser Drilling with Temporal Laser Pulse Shaping

John Linden, Yuval Berg, Zvi Kotler
Orbotech, Israel

Short Laser pulsed ablation is a common technique integrated into microelectronics manufacturing. In a goal of enhancing material ablation quality and throughput, temporal pulse shaping, or 'burst' modes of lasers have shown impressive results [1]. The main mechanism responsible for the improvement in multiple pulses is thought to be the interaction of consecutive pulses with the plasma plume. As flexible electronics PCBs are becoming the leading trend [2] the demand for new methods is open-ended.

In this presentation, we will explore the results from an experimental fast imaging setup designed to capture this process at the nanosecond level. The results image the expansion and time dependency of plasma plume from laser ablation. The information displayed here significantly improves the means of optimizing temporal pulse shaping to effectively improve the process for each unique substrate and pulse times.

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Topologically Controlled Intra-Cavity Laser Modes by Geometric Phase Metasurface

Elhanan Maguid, Ronen Chriki, Michael Yannai, Vladimir Kleiner, Erez Hasman, Asher A. Friesem, Nir Davidson
Micro and Nanooptics Laboratory, Faculty of Mechanical Engineering and Russell Berrie Nanotechnology Institute, Technion - Israel Institute of Technology

Incorporation of a metasurface that involves spin-orbit interaction phenomenon into a laser cavity provides a route to the generation of spin-controlled intra-cavity modes with different topologies. Metasurfaces consist of metallic or dielectric subwavelength nanoantennas, capable of manipulating light by controlling the local amplitude and phase of an incident electromagnetic wave. Effective control of the electromagnetic response of the metasurface can be acquired by the geometric phase mechanism, also known as Pancharatnam-Berry phase, which enables spin-controlled phase modulation, where the photon's spin is associated with the intrinsic angular momentum of light. By utilizing the geometric phase we found a spin-enabled self-consistent cavity solution of a Nd:YAG laser with a silicon-based metasurface. Using this solution we generated a laser mode possessing spin-controlled orbital-angular momentum. Moreover, an experimental demonstration of a vectorial vortex is achieved by the coherent superposition of modes with opposite spin and orbital angular momenta. We experimentally achieved a high mode purity of ~95% due to laser mode competition and purification. The photonic spin-orbit interaction mechanism within a laser-cavity can be implemented with multifunctional shared-aperture nanoantenna arrays to achieve multiple intra-cavity topologies.

Oasis 7th Conference and Exhibition on Electro-Optics

Low Intensity LiDAR using Depth Aware Compressive Sensing and a Photon Number Resolving Detector

Yoni Sher, Lior Cohen, Daniel Istrati, Hagai S. Eisenberg

The Hebrew University in Jerusalem, Physics Department, Israel

LiDAR (LIght Detection and Ranging) systems are not a new technology, and yet are the focus of much recent work. Much of this interest comes from the field of autonomous vehicles, which are on the cusp of becoming a consumer technology. We describe a system that pushes the envelope of two major trade-offs faced by LiDAR systems for autonomous vehicles: increasing range while maintaining safety, and increasing imaging detail while maintaining fast acquisition times.

Low-Loss Fused Silica Waveguides for High-Power Photonic Devices

Maya Yevnin, Gil Atar, David Eger, Raz Gvishi

Soreq NRC, Applied Physics Department, Israel

We present a novel method to fabricate planar photonic devices using Modified Chemical Vapor Deposition (MCVD) technology. The MCVD process, usually applied to optic fibers, is here used to deposit a 25 μm thick layer of Ge doped silica on a fused silica slab. The doped layer was than heat treated by CO_2 laser (>2000°C) in order to achieve high optical quality and good damage threshold. Finally, direct laser lithography followed by deep dry etching were used to shape straight and curved large-core air-cladded waveguides with excellent sidewall regularity.

The straight waveguides are shown to have excellent propagation loss, 0.3 db/cm, with near-single-mode operation at 633nm, indicating the low sidewall roughness high layer uniformity. The curved waveguide had propagation loss of 1 db/cm, which we expect to improve by better design of the curve radius, and development of cladding material.

Carrier to Envelope Phase (CEP) Stable, 2.37μm, Ultrashort Pulses from a Hybrid Parametric - Cr:ZnSe Laser Amplifier

Pavel Komm[1], Uzziel Sheintop[1,2], Salman Noach[2] and Gilad Marcus[1]

1. *Department of Applied Physics, Faculty of Science, Hebrew University of Jerusalem, Jerusalem 9190401, Israel*
2. *Department of Applied Physics, Electro-Optics Engineering Faculty, Jerusalem College of Technology, Jerusalem 91160, Israel.*

Ultrashort mid-infrared pulses with stable CEP are highly regarded in research areas focused on the event of laser driven electron recollision, whereby a kinetic energy acquired by an electron in an intense optical field of an ultrashort pulse is transferred to its parent ion, unleashing processes for which the single photon energy of the driving laser field may be insufficient. High harmonics generation (HHG) is a well-known example of such a process, where the electron's kinetic energy is released in a form of high frequency radiation.

To obtain CEP locked ultrashort pulses in the mid-infrared we have developed a unique parametric generator - Cr:ZnSe laser amplifier tandem device. It produces 72fs (Intensity FWHM) pulses at the central wavelength of 2375nm with energies of 34μJ/pulse. The CEP stability of the parametrically generated seed stands firm at 420±50mrad (measured for 14 minutes) after 6 orders of magnitude of its laser amplification. Some of the details of the amplification process are as follows: 2.3-2.45μm, 50pJ/pulse seed is generated in a single parametric step, involving an intra-pulse difference frequency generation in a periodically poled lithium niobate (Λ = 15.1μm). The pump and the signal frequencies constitute the blue (660-685nm) and the red (910-1000nm) spectral extremities of an 8fs, 6nJ pulse from a broadband, 80MHz Ti:sapphire oscillator. Prior to the injection of the seed into the three-mirror-ring, 7-pass Cr:ZnSe geometrical laser amplifier, its rate is reduced to 1kHz in a pulse picker, and the 1.86μm, 2.3mJ/pulse Q-switched Tm:YLF laser, which pumps the gain element, is synchronized with it. After seven passes in the amplifier, the energy of the output typically exceeds 30μJ per pulse, while the signal to Amplified Spontaneous Emission (ASE) ratio is stands at 6:1.

Observation of Optical Backflow

Thomas Zacharias, Yaniv Eliezer, Alon Bahabad

Tel-Aviv University, Israel

Backflow is a surprising yet relatively unknown phenomenon discovered in 1969 in the context of the time-of-arrival problem in quantum mechanics. In quantum backflow, the local probability current of a particle can become negative even if the state of the particle is a superposition of only positive momentum eigenstates (and vice versa). Actual backwards propagation associated with backflow was never observed, not in quantum mechanics nor in any analogue coherent wave system.

We now report on the experimental observation of actual backwards propagation associated with backflow in optics. This is done through a construction of a light beam made of a particular superposition of modes having negative transverse momentum relative to a chosen axis of propagation. While the expectation value of the transverse momentum of the beam is negative, in certain locations the local value of the transverse momentum is positive. Spatial filtering such locations results in a beam of light whose transverse momentum expectation value is positive. This constitutes the first observation of this counterintuitive, delicate interference phenomenon.

Poster Presentations

Tuesday, April 2, 2019

Topic: Atomic and Quantum Optics - Prof. Barak Dayan

A Quasi-static MEMS-Scanning-Grating enabled tunable Micro External Cavity Quantum Cascade Laser (µEC-QCl) for th MIR

Jan Grahmann, André Merten, André Dreyhaupt, Richard Schroedter, Thomas Graßhoff, Markus Schwarzenber, Stefan Hugger, Christian Schilling, Ralf Ostendorf

Fraunhofer Institute for Photonic Microsystems (IPMS), Active Microoptical Systems (AMS), Germany

Broadband tuning of MIR-infrared radiation from 3 to 12 µm is a very promising way for spectroscopic study of gaseous, liquid, or solid species or intermixtures. We report a new quasi-static MEMS-Scanning-Grating for spectral tuning of an IR-light source based on a Quantum-Cascade-Laser. This concept unites the advantages of broadband sources with the advantages of coherent laser sources in a very miniaturized setup. In contrary to a resonant MOEMS device, the quasi-static drive principle allows the scanning with arbitrary trajectories and velocity and thus with potential higher spectral resolution and functioning schemes end users are used to from macroscopic tunable Quantum cascade lasers. To stabilize the trajectory the MOEMS device is controlled by a feedback loop based on on-chip integrated position sensors. We report the dynamic characteristics of the MEMS-Scanning-Grating and experimental results oftuning an EC-QCL in the wavelength range from 4150 to 4600 nm.

Beyond the Dispersion Limit of Standard Polymeric Fiber Transmission Systems

U.H.P. Fischer, S. Höll, M. Haupt, M. Joncic

Harz University of Applied Sciences

Actual communication systems using Polymer Optical Fibers are using only one channel to transmit the data. Unfortunately, the bandwidth is restricted to the transmission rate of the physical channel behavior. The use of more than one channel can overcome the limitation and is used in commercial glass fiber optical transmission systems with Wavelength Division Multiplexing. Here, different wavelengths are used in the visible spectrum to transmit data parallel over one standard step index Polymeric Optical Fiber (SPOF) with 1mm diameter. In this paper we present a new developed WDM system using polymeric optical multiplexer and demultiplexer. We demonstrate results of a demonstrator of an integrated polymeric demultiplexer produced with injection moulding and a new developed fiber integrated optical multiplexer. The demultiplexer based on an optical grid on a toric surface and acts analog to a spectrometer. The paper discusses the results of the different development steps, the measurements done with the first demonstrator and the challenges related to the injection moulding process. The overall transmission rate via 4 channels was extended to more than 14 Gbit/s over 50m of SPOF, which is for our knowledge the highest data rate for a WDM system using SPOF in literature. The demultiplexer is realized in PMMA and is also applicable in low cost spectrometers. Additionally, we propose a standardization of spectral grids in the visible spectrum for Polymeric Optical Fiber Transmission Systems, which are compatible with existing standards like ITU recommendations for WDM networks.

Multiplicative Bell Inequalities

Bar Y. Peled, Avishy Carmi, Eliahu Cohen, Amit Te'eni

Ben Gurion University, Israel

Bell inequalities are important tools in contrasting classical and quantum behaviors. To date, most Bell inequalities are linear combinations of statistical correlations between remote parties. Nevertheless, finding the classical and quantum mechanical (Tsirelson) bounds for a given Bell inequality in a general scenario is a difficult task which rarely leads to closed-form solutions. Here we introduce a new class of Bell inequalities based on products of correlators that alleviate these issues. Moreover, by being nonlinear the proposed inequalities are less sensitive to technical noise and more resistant to several loopholes. Each such Bell inequality is associated with a non-cooperative coordination game. In the simplest case, Alice and Bob, each having two random variables, attempt to maximize the area of a rectangle and the rectangle's area is represented by a certain parameter. This parameter, which is a function of the correlations between their random variables, is shown to be a Bell parameter, i.e. the achievable bound using only classical correlations. We continue by generalizing to the case in which Alice and Bob, each having now n random variables, wish to maximize a certain volume in n-dimensional space. We term this parameter a multiplicative Bell parameter and prove its Tsirelson bound. We further investigate the case of local hidden variables and show that for any deterministic strategy of one of the players the Bell parameter is a harmonic function whose maximum approaches the Tsirelson bound as the number of measurement devices increases. Some implications of these results are discussed.

Power Narrowing: Cancellation of Doppler Broadening in Two-Photon Transitions

Ran Finkelstein, Ohr Lahad, Ohad Michel, Eilon Poem and Ofer Firstenberg

Weizmann Institute of Science, Israel

Introduction: Room-temperature atomic vapors are known for their simplicity and their potential scaling-up in applications. In spite of these benefits, laser-cooled atoms have evolved to be the prevalent systems for studying strong light-matter interactions, as the latter are unhindered by Doppler broadening.

Background: Resonant two-photon transitions such as Raman absorption and Electromagnetic induced transparency (EIT) are at the heart of many optical quantum information processing protocols. However, velocity dependent light shift and residual Doppler broadening limit their performance in thermal atomic ensembles.

Objectives and Methods: Here we show the opposite example, where the wavelength mismatch in a three level ladder system facilitates the cancellation of Doppler broadening via velocity dependent light shift. We further develop a general approach which does not only provide for a "standard" Doppler-free spectrum, but also enhances the effective absorption cross-section in inhmogeneously-broadened media

Results: We realize a significant increase in two-photon Raman absorption, surpassing the hot-atom absorption limit. We find this cancellation effect to be general, common to both absorption and transparency resonances, and scales favorably with wavelength mismatch.

The counteracting effect of velocity dependent light shift is also shown to be useful to rephase and increase the coherence time of spin waves acting as quantum memories.

Conclusions: While enhancement of transitions to low lying states are measured and confirmed in this work, the same calculation shows that going up to high lying Rydberg states would yield an extremely high absorption coefficient, on the same order of magnitude as cold atoms even when taking into account relatively large homogeneous broadening.

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Spontaneous Emission from a Wide Quantum Electron

Aviv Karnieli, Roei Remez, Sivan Trajtenberg-Mills, Niv Shapira, Ido Kaminer, Yossi Lereah, Ady Arie

Raymond and Beverly Sackler School of Physics and Astronomy, Tel-Aviv University, Israel

Spontaneous radiation from free electrons has been thoroughly investigated over the years, with implications on both fundamental science and technology. Although it can be almost fully explained by a classical theory of radiation excited by the motion of point charges, the wave nature of the particles, which cannot be truly ignored, is manifested only in the quantum theory. One important example of such radiation is the Smith-Purcell (SP) effect, in which a swift electron emits light when passing next to a grating. This phenomenon has been the subject of intense research since its discovery in 1953, permitting light sources in deep-UV and X-ray.

In this work we investigate, both experimentally and theoretically, the SP radiation emitted from a single quantum electron, when the electron wavepacket is wide with respect to the emitted wavelength, but still finite. This allows us to study the effect of the electron wavefunction on the emitted radiation. We examine two semi-classical interpretations widely used in the literature to describe radiation emission phenomena: (i) radiation by a continuous current density, related to the electron's probability current density, and (ii) incoherent probability distribution of a point charge. We discuss how these two interpretations give contradictory conclusions for the radiation shape when the single electron wavefunction is wide. Following an experiment and a quantum-electrodynamics derivation, we conclude that the measurements can be fully explained by the probability distribution approach wherein the electron interacts with the grating as a classical point-charge. Our findings emphasize how a quantum interaction of an electron wavepacket can fit with the classical limit, clarify the transition between the classical and quantum regimes in electron-photon interactions, and shed light on the mechanisms that take part in general quantum-electrodynamics interactions

Topic: Photonics in Defense - Dr. Joelle Schlesinger, Dr. Ami Yaacobi

Wildfire Fighting Is an Environmental As Well As a Homeland Security Issue

Daniel Leigh
CEO, Fighting Treetop Fire, Israel

FTF pioneers a game changing environmentally clean, remote firefighting tool with a market size of billion's USD that is desperately in need of a game changing solution to control wildfires in extreme weather conditions.

Large scale violent and difficult to control wildfires are increasing worldwide as seen in California, Tennessee and Fort McCurry in Canada in 2016 and inflicts vast environmental impact and economic loss in the $ billions.

Forest fires become dangerous and get out of control under dry conditions and strong winds, and are uncontrollable, with today's wildfire fighting tools using chemicals and water in fire suppression. Furthermore g and to unpredictable fire behavior. This which make fires difficult to predict and fight and therefore may lead to trapping and endangering firefighters and residences.

Fighting Treetop Fire (FTF), is a new patented firefighting method intended to enable rapid control of wildfire, in particular to stop the uncontrollable phase of the fire. The system reduces environmental impact, economic loss, rehabilitation cost, and minimizes the use of chemicals and water in fire suppression. The common practice today is to drench the fire front with water and chemicals but the disadvantage is the high cost of water transportation and the rapid speed in which the wetted fuel (trees) dries up making the procedure redundant. FTF will therefore be able to rescue firefighters and residences overrun by wildfire. Wildfires are spread by the fine fuel in the advancing fire front. FTF's game changing method removes the fine fuel remotely creating a fire break. This stops fire cycle abruptly.

"Deforestation and forest degradation are the second leading cause of global warming, responsible for about 15% of global greenhouse gas (GHG) emissions, which makes the loss and depletion of forests a major issue for climate change." (1)

Topic: Electro Optics Devices - Prof. Dan Marom

Spatial Mode Mixing Device 3D Printed on Fiber Facet

Miri Blau, Dan M. Marom
Applied Physics Department, The Hebrew University of Jerusalem, Israel

Experiments have lately demonstrated the feasibility of mode division multiplexing using spatial modes as independent data channels over few mode fiber (FMF). FMF is an attractive method of increasing capacity over that afforded by SMF. FMF transmission requires signal processing at the receiver in order to unravel the mixed channels. Under strong mode coupling, there is a frequent energy exchange between the modes. Statistically, this fact reduces the required DSP complexity.

In order to obtain XT over all modes, together with low loss, we designed a custom 3D spatial phase mask. The non-uniform phase acquired by the mask induces mode mixing between all mode groups, while maintaining low and equal loss over the mode groups. The mode scrambler design reached as low IL as -1 dB and average XT values >-5 dB for all mode groups. For similar mode mixing by conventional methods, the insertion loss increases significantly, makes it inefficient and non-scalable.

The complex phase pattern was printed on fiber tip, using a 3D laser lithography system of "Nanoscribe GmbH" employing immersion technology. By varying the height of polymer, we achieved the required spatial phase delay. Since the device is located on the fiber's facet, we eliminate the loss of free space optics and obtain small footprint device which can be directly coupled to another fiber.

In order to characterize the mode mixing device we measured the mode mixing of two back-to-back selective photonic lanterns with and without the device to evaluate the degree of mode mixing obtained as well as the excess loss. We built the transfer matrix of the photonic lanterns and the mode mixing device. Examining the photonic lantern transfer matrix we extract the mode selectivity, above 5 dB for all modes (except LP02), while for the mode mixing device no definite selectivity can be seen.

Polarization Dependence of SPP Coupling in Au Nanowires

Rajesh Desapogu, M. Ameen Poyli, Shmuel Sternklar and Yuri Gorodetski
Department of Electrical and Electronic Engineering, Ariel University

Polarization dependence of the surface plasmon polariton (SPPs) propagation and coupling efficiency was investigated in Au nanowires by using leakage radiation microscopy (LRM). We demonstrate the manipulation of SPP propagation length and emission in the Au nanowires by polarization of the incident light. This provides an interesting possibility for future nanowire based waveguide systems, which is crucial for plasmonic circuitry devices. We found that the SPPs coupling efficiency and propagation depends on the light polarization. Results of FDTD (finite-difference time-domain) simulation obtained using Lumerical FDTD software are in good agreement with the experimental results. Our results on plasmon coupling into Au nanowire waveguide systems and their interactions offers a promising method for many applications in nanophotonics, such as plasmonic routers, couplers and polarizers.

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Dual-Mode NSOM-AFM Silicon-Based Photodetector for Advanced Surface Scanning

Emanuel Lozitsky, Avi Karsenty, Matityahu Karelits, Zeev Zalevsky

Head of ALEO - Advanced Laboratory of Electro-Optics at Lev Academic Center - Jerusalem College of Technology (JCT), Israel

Combined Near-field Scanning Optical Microscope (NSOM) tip-photodetector operating in the visible domain of wavelengths to an Atomic Force Microscope (AFM) cantilever has been simulated, processed and measured. The new tip-photodetector consists in a Platinum-Silicon truncated conical device, sharing a subwavelength aperture and processed using advanced nanotechnology tools on a commercial silicon cantilever. Such a combined device enables AFM-NSOM dual-mode measurements, when collecting the reflected light, directly from the scanned surface while having a more efficient light collection process. In addition to its quite simple fabrication process, it is demonstrated that the AFM tip, on which the photodetector is processed, is still operational, i.e. the AFM imaging capability is not altered by the process. The AFM-NSOM capability of the processed tip is presented, and obtained results show a significant improvement in surface characterization accuracy and efficiency.

NSOM Nanoscale Si-Based Advanced Photodetector for Several Scanning Configurations

Matityahu Karelits, Avi Karsenty

Head of ALEO - Advanced Laboratory of Electro-Optics at Lev Academic Center - Jerusalem College of Technology (JCT), Israel

Detection of evanescent waves through Near-field Scanning Optical Microscopy (NSOM) has been simulated in the past, using Finite Elements Method (FEM) and 2D advanced simulations of a silicon Schottky diode, shaped as a truncated trapezoid photodetector, and sharing a subwavelength pin hole aperture. Towards enhanced resolution and next applications, several scenarios of scanning have been studied towards optimization. The detector has been horizontally shifted across a vertically oriented Gaussian beam while several E-field modes, are projected on the top of the device. Both electrical and electro-optical simulations have been conducted, when varying crucial parameters such as angle, distance, wavelength and more. The results of several complex simulations are promising towards the fabrication of a second generation of such photodetector devices.

On the Chip Enhanced Raman Imager

Yaakov Mandelbaum, David Zitoun, Zeev Zalevsky, Avi Karsenty

Advanced Laboratory of Electro-Optics at Lev Academic Center - Jerusalem College of Technology (JCT), Israel

Surface-Enhanced Raman Scattering (SERS) pixel array was designed and simulated towards fabrication to provide spatially resolved measurement of chemical pH in a fluid. Ultimately, the goal is to provide real-time monitoring of a chemical reaction, when the SERS device serves as Raman pH Imager. The pixels consist of a nanostructured substrate composed of an array of projections or cavities. The shape of the nanostructures and the thickness of the metallic (Ag or Au) layer can be tuned to give maximal enhancement at the desired wavelength. The number and arrangement of nanostructures was optimized to obtain maximal responsivity. Analytical and numerical methods were used to model SERS. The primary numerical tool was the Finite Elements Method (FEM) using Comsol SW Package combined with algorithmic optimization algorithms such as Simulated Annealing and Method of Simplexes. The enhancement of Raman emission from emitters which are volume-dispersed in a fluid, as well as the possibility of near-field detection through plasmonic antennae require the use of simulation approaches. Following design and optimization, prototypes composed of silver (Ag) nanostructure arrays are fabricated using Focused Ion Beam (FIB) milling, and analyzed with TEM and NSOM methods. Measurements of the Raman spectrum will be taken in the presence of solutions of varying pH; extrapolation of the pH value from the measured spectrum will be achieved using algorithms of Machine Learning. The article presents preliminary important results which can influence the Near-Field probing domain.

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Surface Acoustic Wave-Photonic Devices in Silicon-On-Insulator

D. Munk, M. Katzman, M. Hen, M. Priel, A. Zadok

Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, Bar-Ilan University, Israel

The interactions between light and sound are widely used in basic research, quantum technologies, and in sensing and signal processing applications. Silicon photonics is the most significant technological platform for integrated optics. However, the introduction of acoustic waves to silicon devices is challenging, as silicon has no piezo-electric effect. Furthermore, the device layer in silicon-on-insulator (SOI) does not guide sound, hence all demonstrations of opto-mechanics in silicon to-date required the suspension of the device layer.

Here we report the generation and monitoring of hyper-sonic acoustic waves in photonic-integrated circuits in standard SOI. Surface acoustic waves (SAWs) are stimulated by modulated pump light that is absorbed in a metallic grating. Absorption introduces periodic heating and cooling of the aluminum grating stripes. Temperature variations are associated with alternating thermal expansion and contraction of the metal template. The resulting strain pattern is transferred to the underlying silicon layer. The strain perturbations are periodic in space according to the grating period, and in time according to the pump modulation frequency. When wavelength and frequency comply with the velocity of a SAW in the SOI layer stack, an acoustic wave may be launched. The SAWs propagate across a silicon-photonic ring resonator, where they induce photo-elastic perturbation to an optical probe wave.

The transfer of input radio-frequency waveforms from pump to probe, via SAWs, was demonstrated experimentally. Surface waves up to 7 GHz frequency were stimulated and monitored. The devices function as narrowband filters with 200 MHz bandwidths. The frequencies of stimulated acoustic waves agrees with the velocity of acoustic shear waves in silica: 3,700 m/s. The acoustic waves propagate at the surface discontinuity and do not require guiding in the bulk. The devices can implement long group delays of incident waveforms over short physical lengths, in similarity with SAW devices in electronics.

New Modes' Analysis in LiNbO3 Split Y-Junction Wave-Guide Sharing Very Low Index Difference

Eyal Terkieltaub, Yehuda Albeck, Avi Karsenty

Lev Academic Center - Jerusalem College of Technology (JCT), Israel

A Y-junction of low-difference Refractive-Index (RI), implemented on $LiNbO_3$ using soft proton exchange process, has been designed and simulated. The extraordinary refractive index is parallel to the surface and perpendicular to the propagation direction. The simulation uses Comsol Multi-Physics Software Package, allowing varying crucial parameters. The description includes detailed explanation of the simulations. The observed results enable to forecast the modes behavior inside the wave-guide (WG). An optimization of the device for single mode input has been made. This new approach of design and simulations of special Y-junction waveguide can benefit advanced optical communication.

Surface Plasmon Resonance Phase Extraction Technique Using a Liquid Crystal Waveplate and a Diverging Beam Approach

Ibrahim Watad, Ibrahim Abdulhalim

Department of Electro-optics and Photonics Engineering and the Ilse Katz Institute for Nanoscale Sciences and Technology, Ben Gurion University of the Negev, Israel

We introduce a new, simple and efficient polarimetric method to extract the light polarization changes of a reflected wave in surface plasmon resonance (SPR) sensors. The proposed setup is based on the conventional Kretschmann-Raether (KR) configuration, the diverging beam approach and a variable Liquid crystal (LC) retarder. Compared to other SPR phase extraction methods, our method is notably much simpler where only three distinct measurements are needed to extract the phase information. The method is presented theoretically and verified experimentally using different aqueous solutions of ethylene glycol showing a sensitivity of 118.7 deg/RIU and a considerably high detection limit of 1.03×10^{-7} RIU.

Topic: Optical Engineering - Dr. Hanni Inbar

Interferometric Metrology of Freeform Surfaces

Jean Pierre Lormeau, Chris Supranowitz, Chris Maloney, Paul Murphy, Paul Dumas
QED Technologies International Inc., USA

Advances in precision optics polishing and metrology address many of the challenges in the manufacture and metrology of freeform surfaces, making the fabrication of these surfaces possible today. Achieving form and mid-spatial frequency (MSF) specifications for precision freeform optics, however, remains a challenge. Interferometric metrology of freeform surfaces is highly desirable, but current capabilities are quite limited. QED demonstrates that accurate, high-resolution measurements of freeform surfaces are possible using prototype software on QED's ASI (Q) (Aspheric Stitching Interferometer).

Absolute Optimization Method for Vertical Grating Coupling

Shlomo Ruschin, Anat Demeter-Finzi
Tel-Aviv University, Electrical Engineering Department, Israel

Vertical grating couplers are an attractive option for coupling light into an optical waveguide, since they have high performance their fabrication is easy and they reduce the system tuning complexity. Here, we suggest an intuitive method based on S-matrix formalism for analytically optimizing 3-port vertical grating coupler devices.

The simulated device consists a planar grating for coupling the light from a single mode fiber directed vertically into the waveguide and a waveguide reflector for guiding the light into a specific direction. The formalism purpose is to reduce the back-reflection into the source and maximize the directional coupling efficiency. A systematic search of the grating's diffraction efficiency values allows the determination of optimal parameters similarly to that applied for coupling into a laser cavity. After assuming a steady-state regime, the expressions for the uni-directional coupled field and back-reflected field were attained. Using power conservation law and reciprocity of the system the problem was reduced into two independent variables and the device efficiencies were calculated. Following these results, a high contrast grating coupler with low transmission to the substrate was numerically simulated as an example for implementing our S-matrix model. The optimal coupling efficiency reported by Chang-Hasnain et al. for antisymmetric coupling was 88%. By combining our analytical S-matrix model together with numerical simulations, an improvement of 3% in the coupling efficiency was achieved.

In conclusion, a process for theoretically determining the optimal coupling conditions for a vertically waveguide coupling arrangement aided by back-reflection is presented. Based on S-matrix analytical formalism, the results of the numerical FDTD simulations can be optimized and maximum coupling efficiency can be achieved. Although this ultimate performance is hard to realize, the formalism provides guidelines for the design and fabrication of an optimized practical device for implementation in optical communication or sensor.

Keywords: Gratings; Waveguides; Integrated Optics.

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Simultaneous Multi-Channel Ultrasound Detection via Optical Resonators

Yoav Hazan, Amir Rosenthal
Technion, Andrew and Erna Viterbi Faculty of Electrical Engineering, Israel

In optical detection of ultrasound, high Q-factors resonators are often used to maximize sensitivity. However, parallel interrogation by conventional interferometric techniques require an overlap between the resonator spectra, which is difficult to achieve with high Q-factor resonators. In this work, a new method is developed for parallel interrogation of optical resonators with non-overlapping spectra. The method, based on a phase modulation scheme for pulse interferometry (PM-PI), requires only a single photodetector and sampling channel per ultrasound detector - making this method scalable.

The general scheme of PM-PI composes of a wideband pulse laser connected to an unbalanced Mach-Zehnder interferometer (MZI) with a phase modulator on one of its arms. The phase is switched between two values with a difference of $\pi/2$. The outputs of the MZI are connected to numerous optical resonators. The output of each resonator is switched between two interferometric states, which together enable us to monitor wavelength shifts of its resonance. PM-PI was tested with 4 channels sampled simultaneously, measuring peak-to-peak resonance shift of 1 GHZ, i.e. twice larger than the resonance width. Such a large shift cannot be properly measured using conventional CW laser interrogation.

In conclusion, we developed a novel scheme for parallel interrogation of resonator-based interferometric detectors of ultrasound. Our scheme is based on a variation of pulse interferometry, in which the pulses are phase modulated at the input of the resonators. The modulation enables the coding in time of two interference states, which facilitates digital demodulation of the desired signals from simple power measurements. PM-PI overcomes a major limitation of interferometric detectors of ultrasound - the inability to simultaneously interrogate several resonators with non-overlapping spectra. Ultrasound detector arrays based on PM-PI may be used to significantly improve the performance of hybrid imaging systems for which no compatible ultrasound detector array technology exist.

Passive Interferometric Detection of Ultrasound with a Large Dynamic Range

Yoav Hazan, Amir Rosenthal
Technion, Andrew and Erna Viterbi Faculty of Electrical Engineering, Israel

Optical detection of ultrasound often uses high Q-factors resonators to maximize sensitivity, compromising the linear range of the scheme, making it more susceptible to external perturbations and incapable of measuring strong acoustic signals. In this work, a passive pulse interferometry (P-PI) scheme was developed for high dynamic-range measurements beyond the linear range of conventional interferometric techniques.

The general scheme of pulse interferometry composes of a wide-band pulse laser connected to an optical resonator, whose output was connected to an unbalanced Mach-Zehnder interferometer (MZI) implemented in PM fibers. The birefringence of PM fibers was utilized to detect phase shifts in a MZI that was not locked to quadrature. In this scheme, the output of the resonator was connected to a dual-polarization MZI, in which by careful selection of the lengths of each segment in the interferometer, the outputs represent those of a 90° hybrid.

The performance of P-PI was tested and compared to conventional interferometric techniques for different pressure levels. The signals measured with P-PI show a linear dependency between the peak-to-peak values of the over a range of over 4 rad. For comparison, using conventional interferometric techniques results in folding of the signal at high pressure levels - incompatible with high dynamic-range measurements.

In conclusion, we demonstrated P-PI ultrasound detection scheme that is capable of maintaining a linear response under large pressure levels outside the linear range of conventional interferometric techniques without compromising the sensitivity for small signals. Accordingly, P-PI extends the applicability of pulse interferometry for ultrasound detection to scenarios in which a high dynamic range is needed. In addition, all the components in our scheme may be fabricated in photonic circuits, making it scalable.

Oasis 7th Conference and Exhibition on Electro-Optics

Embedding Metasurfaces into Contact Lenses - More Than Refractive-Error Correction

Sharon Karepov, Tal Ellenbogen
Department of Physical Electronics, Faculty of Engineering, Tel-Aviv University, Israel

Metasurfaces are ultrathin surfaces composed of customized nano-metric building blocks. The geometry, orientation, size and material composition of these building blocks determine the interaction between the metasurfaces and light. These properties make metasurfaces highly attractive for implementation into thin optical elements in general, and specifically into ophthalmologic devices such as contact lenses (CL). Here, we embed tailored, ultrathin metasurfaces into existing off-the-shelf rigid-gas-permeable CLs to provide visual aids for color vision deficiency (CVD) and macular degeneration.

The metasurface based CVD aid, by designed color filtering, increases the effective number of cones photoreceptors, and thus, improves the ability to distinguish ambiguous pigments in conditions of Deuteranomaly (~4.63% of male population) and Protanomaly (~1% of world population).

The metasurface based macular degeneration aid is designed to divert the image projected on the macula from a damaged region to a healthy region of the macula. The metasurfaces for this purpose serve as a wavelength-selective quadratic-distorted diffraction grating, thus focusing only one diffraction order onto the desired location on the image plane.

In the meeting, we will present the metasurfaces-on-CL fabrication process that was developed. We will also show in-vitro results of the CVD-correction elements including color-perception simulations. The color perception error is maximally reduced by a factor of 10 in the case of Deuteranomaly, and a factor of 600 in the case of Protanomaly, all presented on a chromaticity diagram. Finally, we will show results of the image-diversion metasurface-on-CL for macular degeneration. This element provides a clear image that can be properly interpreted in the visual cortex, rather than a distorted image with a blind spot at its center. In conclusion, metasurfaces can control the spectrum, as well as the profile of the light projected on the retina, thus presenting exciting possibilities to new, and even combined visual aids in a single element.

Compact Lidar System for the Automotive Industry

Boaz Nemet

Innoviz Technologies, Photonics Department, Israel

Lidars (Light Detection and Ranging) are going to revolutionize the Automotive industry in the next few years. Autonomous vehicles most likely will be using Lidars as their main sensor since it can generate accurate 3D imaging in the range of ~200m with high resolution at a very fast pace over a large field of view ~120 degrees. Manufacturing a compact and robust Lidar at an attractive price for Auto manufactures is a challenge in multiple disciplines. Specifically, Electro-Optical Engineering is at the heart of this technology. The optical design is driven by requirements for high performance but is highly constrained by many factors such as size, weight, heat, and stray light rejection, as well as atmospheric influence, automotive qualifications and of course price. In addition, eye safety is a critical issue since the Lidar needs to be class 1. At Innoviz we design Lidars for mass production and as a result they are considerably cheaper without compromising on performance. In this talk Lidar technology will be presented at a glance. Lidar principles and key components as well as architectures are discussed. Lasers, scanning methods, illumination and detection schemes are discussed as well as the challenges in design and production. For safe autonomous driving, computer vision algorithms were developed at Innoviz to detect and monitor in real time different categories such as pedestrians and cars as will be shown by a video demonstration.

Speckle Reduction Using Ultrasound in Interferometric Phase Microscopy

Shira Shinar, Michal Balberg, Amit Nativ, Natan T. Shaked

Department of Biomedical Engineering, Tel-Aviv University, Israel

Using highly coherent illumination in interferometric phase microscopy (IPM) enables to obtain high visibility of interference fringes on the entire sensor with minimal effort, but at the cost of degrading the output image quality due to parasitic interferences, speckle noise and ringing artifacts around sharp edges.

We will introduce a complimentary method to the existing techniques for decreasing the spatial coherence of illumination thus decreasing the speckles noise using light ultrasound interaction with minimal effect on the visibility of interference fringes.

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Analysis of Process Induced Changes in Optical Properties of Precision Glass Molded Lenses

Jan-Helge Staasmeyer, Gang Liu, Tim Grunwald, Thomas Bergs

Fraunhofer Institute for Production Technology IPT, Fine machining and optics department, Germany

Precision glass molding is a technology for mass production of aspheric glass lenses with high accuracies. Typical fields of applications are visible imaging, infrared and laser optics. At a certain level of required optical performance, it is not sufficient to evaluate the quality of molded lenses solely on geometric parameters such as form and position accuracy of optical surfaces. Molding process induced changes of optical properties of the glass such as index drop or stress induced birefringence must also be taken into account.

The talk will introduce these effects and briefly describe their impact on optical performance. The causes for the effects will be explained and analyzed. Subsequent it will be explained how to cope with the changes in optical properties by predicting and compensating the effects in the optical design phase. Therefore, a thermo-mechanical process model as well as a stress-optical model is used. It will be shown which glass specific material constants must be available for the models and how they can be measured. Finally, a comparison of measured and simulated optical properties will be shown as a model validation. The talk will conclude with an outlook on future research required to apply these models to infrared optics.

Influence of Dressing Strategies and Balancing Parameters on the Surface Quality in Ultra-Precision Grinding Of Transparent Polycrystalline Spinel

Thomas Bletek, Tim Grunwald, Thomas Bergs

Fraunhofer Institute for Production Technology IPT, Germany

Transparent polycrystalline ceramics are interesting materials for high-performance optical applications because of the high thermal and mechanical resistance. Spinel, as a representative of this brittle-hard material group, is an alternative to the established monocrystalline materials and to amorphous optical glasses, and assures high transmission in a wide wavelength range.
Due to its brittleness and hardness, the machining of this material is difficult and the optical functionality is depending on the fine machining conditions and the material removal regime. The goal is to generate damage-free surfaces through ductile regime grinding. One technology of choice is ultra-precision grinding that can be applied to generate complex geometries, but which is influenced by a range of variables. Consequently, the achievable surface integrity in terms of surface roughness and subsurface damage is influenced by these variables.
In the following investigations, the influence of the tool preparation processes on the achievable surface quality in grinding is studied. Therefore, the dressing procedures and balancing procedures for setting up a grinding tool for ultra-precision grinding of transparent polycrystalline spinel are investigated. Furthermore, as a result, the practical application of the ultra-precision grinding process is shown.

Topic: Ultrafast Phenomena - Prof. Oren Cohen

Coherent Control of the Non-instantaneous Response of Plasmonic Nanostructes

Eyal Bahar, Uri Arieli, Haim Suchowski

The Center for Light-Matter Interaction, Faculty of Exact Sciences, School of Physics and Astronomy, Femto-Nano Laboratory, Tel-Aviv University, Israel

In recent years, nonlinear metamaterials have revolutionized linear and nonlinear ultrafast optics, allowing novel abilities that expand the current available nonlinear material capabilities. Unprecedented capabilities have emerged across fields including optics, sensing, material classifications, theragnostic biomedical optics for the treatment of cancer and much more has thanks to extent research and by understanding their physics mechanism and properties.

A complete theoretical description has been found suitable to describe the geometrical contribution of nanostructures (NSs) to their nonlinear response [7]. Yet, until now, a comprehensive theory has been investigated only for the instantaneous nonlinear response. A full response, including the resonant non-instantaneous behavior brought about by their resonant linewidth, has not yet been studied.

We show, for the first time to our knowledge, resonant non-instantaneous properties by coherent control measurements of nonlinear second harmonic generation (SHG) in resonant media. Our experimental set up for coherent control of SHG in NSs is composed of a spatial light modulator (SLM) used as a spectral phase mask. The coherently altered pulse interacts with a gold NS, SHG is collected. The experiment is repeated for different spectral phases added by the SLM to create a map of SHG as a function of pulse shape. In particular, we investigate gold split ring resonators (SRR) with localized surface plasmonic resonances (LSPR) ranging from 1400-1600 nm.

We experientially demonstrate dynamical variance in the nonlinear response by coherently controlling the electric field. In contrary to common perception, we find that transform limited pulses do not yield the strongest nonlinearity in SHG. Moreover, we develop a theoretical framework, analogous to a resonant 3 level (R3L) interaction, capturing non-instantaneous resonant phenomena portraying resonant effects beyond the weak field two-photon description. These also include deviations from the conventional SHG nonlinearity which commonly is proportional to the square of the fundamental frequency intensity.

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Towards Ultrafast Phase Spectroscopy: Femtosecond Rabi Oscillations in Coupled LSPRs

Uri Arieli, Omri Meron, and Haim Suchowski

Tel Aviv University, School of Physics and Astronomy, Israel

We've built an ultra-broadband interference microscope for measuring the ultrafast response of broadband femtosecond pulses. We use this setup to unravel the ultrafast linear dynamics of coupled Localized Surface Plasmon Resonances. We observe a 20 femtoseconds Rabi oscillations between coupled LSPRs in the time domain and suggest how our method can be extended to the non-linear regime.

Ultrafast Rogue Waves in Fiber Lasers

Moti Fridman, Avi Klein, Inbar Sibony

Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University

Extreme events and specifically rogue waves play an important role in the dynamic of numerous physical systems and specifically in fiber lasers. There are three types of rogue waves in fiber lasers at three different time scales: slow rogue waves at seconds to microseconds which arise from the gain nonlinearity; fast rogue waves at hundreds of nanoseconds to tens of picoseconds which arise from soliton-soliton interactions, and ultrafast rogue waves at picoseconds and faster were their underlying mechanism is still unknown.

Over the last year, we investigated the internal structure of ultrafast rogue waves in fiber lasers and found the importance of the saturable absorber on the resulting pattern. We measured the statistics of the patterns are still missing and numerical simulations failed to reproduce these temporal structures. Both the numerical models and the statistics are important for bridging the experimental results and the analytical solutions. We measured these rogue waves with time-lenses and observed three patterns: single-peak, twin-peaks, and triple-peaks rogue waves.

In addition, we found that scalar theories cannot explain the measured twin-peaks rogue waves and only when considering the field as a vector field we can obtain such rogue waves with high probability.

In the talk, we will present the experimental results which support our claim, we will describe the experimental measurement schemes, and present our new model for ultrafast rogue waves.

Towards Remote Lightning Manipulation by Meters-long Plasma Channels Generated by Ultra-Short-Pulse High-Intensity Lasers

Jenya Papeer, Indranuj Dey, Moti Botton, Zohar Henis, Amit D. Lad, Moniruzzaman Shaikh, Deep Sarkar, Kamalesh Jana, Sheroy Tata, Sudipta Lodh Roy, Yash M. Ved, G. Ravindra Kumar, Arie Zigler

The Hebrew University of Jerusalem, Physics Department, Israel

Remote manipulation (triggering and guiding) of lightning in atmospheric conditions of thunderstorms has been the subject of intense scientific research for decades. High power, ultrashort-pulse lasers are considered attractive in generating plasma channels in air that could serve as conductors/diverters for lightning. However, two fundamental obstacles, namely the limited length and lifetime of such plasma channels prevented their realization to this date.

During my talk, I will briefly introduce the concept of laser filamentation and the main obstacles towards lightning manipulation by filaments. Following the introduction, I will present experimental results that allow to overcome the main limitations and reveal some interesting properties of the plasma filaments generated by a high power laser. We experimentally demonstrate prolongation of plasma lifetime and extension of the length of controllable plasma channels by more than tenfold. The experimental results accompanied by simulations point to the possibility of generating controllable plasma wires with properties sufficient to guide long range electrical discharges and lightning bolts.

Design of a Multi-Bounce Öffner Triplet Pulse Stretcher for 1 µm Chirped Pulse Amplifier

Y. Shamir[1], Z. Refaeli[1,2], Siyun Chen[3] and A. Galvanauskas[3]

1. *Soreq NRC, Yavne 81800, Israel*
2. *Applied Physics Department, Hebrew University, Givat Ram, Jerusalem,*
3. *Center for Ultrafast Optical Science, College of Enmgineering, University of Michigan, Ann Arbor, Michigan, USA*

Chirped Pulse Amplifier laser systems have enabled the laser scientific and engineering communities an insight into previously unapproachable conditions: extreme light-matter experiments on a lab scale. A major enabling element is an ultrashort pulse stretching device, enabling nanoJoule seed energies amplification by factors of 10^6 and recently even by 10^{12}, mostly in big science facilities, e.g. ELI project. Here we present the design of an Öffner triplet stretcher. Among the available stretcher types, Öffner design is considered as near aberration free. Made out of four elements: grating, a concave and convex mirrors and a retroreflector, four full beam pass induces a nearly pure positive group delay dispersion, i.e. relative retardance of the higher at the expense of lower frequencies. In our dedicated design, we addressed 16 nm FWHM linewidth clean sech² modelocked laser, centered on 1053 nm, corresponding to 72 fs pulses. A 1740 line/mm gold coated ruled reflecting grating induced angular chirp of ~3.7 miliRad/nm, transformed into ~ 0.83 mm/nm spatial chirp by the spherical reflectors. By the four grating bounces, we designed total accumulated GDD of $8 \cdot 10^7$ fs², corresponding to time delay of ~2.5 ns. Additionally, an unavoidable hard spectral clip of 16 nm was taken into account as a result of the finite mirrors and grating dimensions. Our measurements indeed showed ~ 16 nm hard spectral clip centered on 1053.3 nm, and temporal stretched pulse duration of 2.1 ns. Since Silica based 'pre-amplifiers are ultimately limited by Kerr self-focusing and detrimental breakdown around 4 MW, we expect a theoretical value of ~8 miliJoule energy limit, with a more conservative conservative ~ 2 - 3 mJ uncompressed output. A near circular (0.8 circularity) output beam profile points on low grating and optics misalignments. The output stretched pulses are picked off and pre-shaped for fuure optimal post compression.

Multi-Mode Time Lens

Inbar Sibony, Avi Klein, Sara Meir, and Moti Fridman

Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Israel

We have developed a temporal imaging system that measures the dynamics of ultrafast signals in multi-mode fibers. Our system, which is based on several time-lenses and multimode multiplexer, will be used to explore nonlinear coupling between modes with a temporal resolution of 0.2 ps. Our system can shed new light on ultrafast phenomena such as multi-mode rouge wave, optical bullet and modal soliton formation.

Experimental Demonstration of Time-Resolved Imaging by Multiplexed Ptychography (TIMP)

Omri Wengrowicz, Or Peleg, Barry Loevsky, Bing Kuan Chen, Gil Ilan Haham, Oren Cohen
Department of Physics and Solid State Institute, Technion, Israel

Introduction: Frame rate is an important property of imaging systems, and imaging of ultrafast dynamical objects requires complicated ultrahigh-speed cameras. Electronic sensors enable rates <107 frames per second, and further increase is limited by storage and electronic readout speed. Time-resolved Imaging by Multiplexed-Ptychography (TIMP) was proposed as a promising approach to obtain ultrahigh-speed diffraction-limited imaging of complex-valued objects. Here we demonstrate TIMP experimentally, demultiplexing 36 complex frames from a single CCD image.

Background: Ptychography is a powerful coherent diffractive imaging scanning technique, yielding high-contrast amplitude and phase information. Recently Single-shot ptychography (SSP) was demonstrated, where multiple diffraction patterns (DPs) are recorded in a single CCD exposure, overcoming the scanning time limitation of conventional ptychography, thus allowing ultrafast measurements. To elevate SSP to TIMP, producing a movie of complex-valued dynamical objects from a single CCD snapshot, the illumination is spatio-temporally engineered to allow use of Multi-state Ptychographic Algorithm (MsPA).

Objectives: We demonstrate experimentally TIMP, reconstructing 36 complex-valued frames of a dynamical object from a single intensity pattern recorded on a single CCD exposure.

Methods: We used two spatial light modulators (SLMs) as a dynamic object, and a dynamic probes mask. In order to reconstruct multiple frames from the single input image, we use the MsPA.

Results: We encode 36 nearly-orthogonal probe beams that are sequentially launched to 36 different objects (the digits 0-9 and the letters A-Z). The CCD integrates over the whole set of images, and using MsPA we demultiplex the single intensity pattern of the CCD into 36 distinct images, reproducing the digits that we have recorded.

Conclusion: We present first experimental results for reconstructing multiple (36) frames from a single recorded diffraction intensity pattern image. This experimental demonstration paves the way to an ultra-high frame rate with diffraction-limited spatial resolution, by using adequate laser pulses with alternating encoding.

Topic: Solar Energy - Prof. David Cahen

Improving Power Conversion Efficiency of Organic Solar Cells by Integrating Grating Metasurfaces

E. Rimon[1], R. Shikler[1], R. Avrahamy[1], B. Milgrom, and M. Zohar[3]
1. *Department of Electrical and Computer Engineering, Ben Gurion University, Israel.*
2. *School of Electrical Engineering, The Jerusalem College of Technology, P.O.B 16031, Jerusalem, Israel 91160.*
3. *Department of Electrical and Electronic Engineering, Shamoon College of Engineering, P.O.B. 950, Beer Sheva, Israel 84100.*

Employing organic semiconductors in solar cells proved to be a promising technology for solar-to-electrical energy conversion [1].

One of the requirements for organic photovoltaic solar cells is absorber layers with thicknesses down to 200 nm [2]. However, thin absorber layer will suffer low power conversion efficiency (PCE). On the other hand, the advantage of thin absorber is that it possible to confine the light in the area of the absorber by using grating structure. It additional to the properties that grating structure can reduce the reflection.

In this study, we examine 3D grating embedded in selected locations in an organic solar cell. We designed and analyzed several structures for obtaining increased efficiency compare to smooth layer. We used an in-house tool based on RCWA method and using MATLAB for the simulation along with trial-and-error multi-start optimization technique.

Even though the conventional properties of grating result in narrowing the spectral width, we have obtained appropriate design for increasing the efficiency to wide spectrum that is compatible to the solar spectrum. For example, at wavelength 700 nm the absorption and the short-circuit current density was 0.035 and 0.7 $\mu A/cm^2$, respectively; where for the embedded grating structure we obtain 0.85 and 13 $\mu A/cm^2$.

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Synthesis and Characterization of Few Unit Cell Cs-Based Perovskite Nanowires and Novel Rubidium Lead Chloride Nanocrystals

Daniel Amgar, Malgorzata Wierbowska, Avigail Stern, Dvir Rotem, Danny Porath, Lioz Etgar
Weizmann Institute of Science, Israel

Perovskite nanostructures, both hybrid organo-metal and fully inorganic perovskites, gained a lot of interest in the past few years for their intriguing optical properties in the visible region.

In this work we introduce inorganic cesium lead bromide ($CsPbBr_3$) nanowires (NWs) having quantum confined dimensions corresponding to 5 unit cells. Addition of various hydrohalic acids (HX, X = Cl, Br, I) was found to highly affect the NWs' length, composition, and optical properties. The suggested mechanism determines that the addition of HX increases the acidity of the reaction solution, resulting in protonation of the oleylamine ligands from oleylamine to oleyl-ammonium cations. These cations behave similarly to Cs^+ during crystallization and occupy the cation sites in the perovskite lattice, thus blocking further growth of the NWs and cause shortening.

Furthermore, a synthesis of novel $Rb_6Pb_5Cl_{16}$ NCs, which are different from the traditional $CsPbX_3$ crystal structure, is presented with some preliminary characterizations.

Microcavity Enhanced Low-Frequency Raman Scattering from CsPbI3 at Room Temperature

Tal Ben Uliel, Laxman Gauda, Yaakov Tischler
Bar Ilan University, Chemistry Department, Israel

Raman spectroscopy is a powerful technique for identifying chemicals and characterizing materials. New laser filters, based on volume holographic gratings, make it straightforward to obtain Raman spectra much closer spectrally to the incident laser, in the range of 100 cm^{-1} to 5 cm^{-1} from the laser's wavelength. In this spectral range, Low-Frequency Raman (LFR) scattering is sensitive to the phonon dispersion relation and to the vibrational modes associated with the nanostructural dimensions of the material. The LFR spectra of different nano-structures of the same material are not identical, and therefore LFR is useful in characterizing next generation nanostructured solar materials. However, the signal strength from LFR is very weak. Here we show that introducing a material into a photonic crystal structure, in this case a 1D optical microcavity consisting of two distributed Bragg reflector (DBR) mirrors greatly enhances the LFR signal. In particular, we situated thin films of $CsPbI_3$, which in some forms are Halide Perovskites, into a microcavity prepared from stacks of ZnS and CaF_2 alternating layers. The resultant microcavities had a Quality Factor Q = 23. A TiO_2 layer with a thickness gradient was also located between the DBRs to enable tuning the cavity resonance from a wavelength of 490 nm to 545 nm. We investigated the effect of cavity tuning on LFR scattering intensity. We observed that the width of the cavity peak is sufficiently broad to resonate both the incident laser and the scattered LFR peak from the $CsPbI_3$ film. This double resonance greatly increased the light-matter interaction and hence we achieved a 47-fold increase in the LFR intensity. Our findings suggest Cavity Enhanced-LFR is a promising route for sensitive characterization of nanoscale structured solar materials. This method can also be useful for following the nano-structural changes that occur in Halide Perovskites during cell operation.

Structural Characterization and Room Temperature Low Frequency Raman Scattering from MAPbI3 Halide Perovskite Films Rigidized by Cesium Incorporation

Vinayaka H. Damle, Laxman Gouda, Shay Tirosh, Yaakov R. Tischler

Chemistry Department, Bar Ilan University, Israel

The structural instability of halide perovskites (HAP) is one of the major issues concerning commercialization of perovskite solar cells. [1] Probing this intrinsic instability is one of the major milestones and challenging tasks toward enhancing the lifespan of the material. [2-4] Here we have incorporated Cs ions into methylammonium lead iodide (MAPbI3) films and studied the thin film structural and optical properties. Incorporation of Cs into MAPbI3 leads to formation of both α-CsPbI3 and ∂-CsPbI3 phases, black and yellow, respectively, as indicated by the evolution of the optical band edge and X-ray diffraction (XRD) spectrum. At a concentration of 20% Cs ions, we observe the existence of a stable α-CsPbI3 phase.

Incorporating 59% or more Cs ions yields the yellow phase of CsPbI3, due to alloying of Cs with the MAPbI3 matrix. The structural transformations observed in absorption spectra and XRD are confirmed by low-frequency Raman spectroscopy (LFRS). The thermally induced structural fluctuations in pure MAPbI3 films are damped upon Cs incorporation, thus bringing long-range stabilized order to the perovskite structure and enabling for the first-time observation of low-frequency Raman scattering at room temperature for a HAP thin film. In addition to this, Cs incorporation rigidizes the perovskite film and sharpens all low-frequency vibrational peaks. This rigidizing effect can explain the importance of incorporating and alloying heavy elements into HAPs to bring both chemical stability and photostability. [5]

Oasis 7th Conference and Exhibition on Electro-Optics

Strain Controling Catalytic Efficiency of Water Oxidation for Nifeooh Alloy

Ester Korkus Hamal, Mayal Caspary Toroker

Technion - Israel Institute of Technology, Israel

Recently the research field of renewable energy is growing fast. There are several types of renewable energy sources and one of the significant routes among them is the hydrogen fuel that may be produced through water splitting. In my research I focused on the oxygen evolution reaction (OER) which is not favored kinetically and requires catalyst. There are some suggestions of catalytic materials such as the first row transition metal oxides (containing, for example, Ni, Fe, Co, Mn). In the battery industry a common catalyst that is being used is Nickel oxyhydroxide (NiOOH). Pure NiOOH has poor efficiency. But doped NiOOH specifically with Fe dramatically improves efficiency. The goal of the research is to explore the influence of doping on the efficiency of NiOOH in the process of water oxidation. I use Density Functional Theory +U (DFT+U) to check the dependence of the doping concentration on the efficiency of the catalyst in order to find the optimal concentration that provides the lowest OER overpotential. The dopants which I examine include Fe and Co.

A New Two-Step Method towards MAPbI3 Perovskite Films

Maayan Perez, Saar Peled, Yuval Golan

Department of Materials Engineering, Ben-Gurion University of the Negev and the Ilse Katz Institute for Nanoscale Science and Technology, Israel

Development of a new method for perovskite films with controlled morphologies can lead to more stable solar cells and with higher efficiency. The two-step method has been proved to be an effective approach to synthesize high-quality perovskite for high-performance perovskite solar cells. In this study, we present a new two-step process in which a thin layer of PbS is converted into PbI2 and subsequently into MAPbI3. Our group has previously reported on the control over PbS film morphology and its physical properties by optimizing the parameters of the chemical deposition (temperature, pH, growth duration etc.).In this work, thin films of PbS were initially deposited over GaAs substrates. The morphology was columnar which increased the density of vertical grain boundaries which can facilitate the penetration of iodine within the films. In the first conversion step, PbS films were converted into PbI2 by treating the films in solutions of polyiodide which were dissolved in a mixture of water and isopropanol. Different mixtures of water/isopropanol resulted in a controllable process, giving rise to different PbI2 morphologies. In the second step, various PbI2 films were converted into MAPbI3 by immersion in an isopropanol solution of MAI. Different MAPbI3 grain sizes were obtained depending on the initial PbI2 morphology. The degree of conversion to perovskites was found to depend on the first step of conversion; the highest conversion to perovskite resulted from PbI2 samples prepared with solutions containing 20% water. Photoluminescence measurements were carried out to confirm the quality of the film and showed that surface passivation using pyridine was necessary in order to receive photoluminescence response from the films. Moreover, we were able to enhance the signal by growing a thicker initial PbS film while keeping the same conversion parameters.

Topic: Spectroscopic and Optical Sensing - Dr. Ayala Ronen

New Method for Light Meter Calibration

Arie Amitzi, Shiran Levy
QCC Hazorea Calibration Technologies, Radiometry and Photometry, Israel

Introduction: The QTH Lamps used today for light meter calibration require a complex process of recalibration after 100 hours of use and have a limited intensity. The aim of this research is to develop an improved calibration method.

Background: This paper presents a new method for calibration of the light meter coefficient in accordance with the SI units: Ampere per lx. Our goal is to replace the traditional QTH method by using a laser beam as a light source. The new method is based on International optical metrology, the candela as the luminous intensity and the 2o Spectral Luminous Efficiency Function for Photoptic Vision, (Ref BIPM 2014, CIE 1988)

Objectives: The objective of this work is improving the calibration method to allow:

Calibration of the spectral luminous efficacy V (l) with higher accuracy
Validation of the light meter
Calibration at a high light level, 160K lx instead of 20K lx

Methods: We performed measurements to compare the traditional light meter calibration method based on the NMI (National Metrology Institute) traceable QTH light source, with the calibration using laser beam as a light source with a laser power meter that is also NMI traceable. To convert Watt to Lumens we used the following function (Ref CIE 1988)
Lumens=683∫_380^730▒F_ (E,l) V_l dl

Where:
V(λ) - Spectral luminosity function
F(E, l) Radiant energy
dl - Wavelength sampling increment

Results: Measurements in our lab showed much higher intensity levels and accuracy when the calibration was performed by using a laser beam instead of a QTH lamp. This method also enabled easy identification of calibration deviations.

Conclusion: The monochromatic calibration method at different wavelengths demonstrated improvement over the QTH method.
The light meter calibration based on monochromatic light sources instead of polychromatic increased the dynamic range, reduced calibration time and cost, and the uncertainty level

Oasis 7th Conference and Exhibition on Electro-Optics

Multi-Purpose Hyperspectral Imaging System for Sampling of Crop from a Moving Platform

Or Arad, Iftach Klapp
ARO - Volcani Center, Ben Gurion University, Israel

Introduction: A significant challenges of precision agriculture is acquiring detailed spatial information of crop status that enables response in an effective manner if any abnormalities in crop health are detected [1]. These abnormalities can be detected and measured by a hyperspectral (HS) imaging system in the 0.3-2 micron range. To date, HS agriculture survey is done mainly by airplanes, providing imaging with a spatial resolution of ~1 meter. Surveys are highly expensive due to the cost of HS system, and the relatively large platforms required to lift it, due to its weight.

In this work, we presents the development of a low cost and low weight HS scanner with a posed a significant challenge over HS system due to the prisms dispersion.

Method: The scanner was modeled [4] as sequence of geometrical surfaces centered on the optical axis [5], and a HS dataset taken by a benchmark imager [6] was reconstructed. Using that model, we present the main design aspect of the proposed system; spatial resolution, spectral transmission and their dependency on system dispersion. Analysis intend to evaluate system performance such as sampling and required radiometric corrections. In addition, a prototype of the scanning system was built, and preliminary results are presented.

Conclusions: The proposed apparatus has proved to be robust and cost-effective and is able to sample a wide FOV. A simulation of the system performance based on a high resolution HS cube suggest very high spatial resolution, 3 times higher than achievable in standard aerial survey.

Biomineral Vaterite Nanoparticles as a Platform for Targeted Drug Delivery Applications

Hani Barhum, Andrey Machnev, Alexander Goncharenko, Mikhail V. Zyuzin, Roman E. Noskov, Ivan I. Shishkin, Egor A. Gurvitz, Alexander S. Shalin, Pavel Ginzburg

Tel-Aviv University, Electrical Engineering Department, Israel

Vaterite crystals is a metastable natural occurring biomineral form of calcium carbonate. Vaterite nanoparticles recently started to attract significant attention owing to their numerous advantages in a range of biotechnological applications. Due to their natural porosity, they serve as extremely efficient fully biocompatible cargoes in drug delivery. One of the grand challenges in this field of study is to develop protocols for a controlled colloidal growth and to approach particles which are as small as 100 nm in size. Those dimensions were found to be optimal for increasing the efficiency of uptake rates in targeted cells. Fabrication of Vaterite nanoparticles with those relevant dimensions remained a challenge up until now.
Here we report on a new comprehensive methodology, which allows performing colloidal growth of vaterite particles with controllable shapes and dimensions. In particular, spherical particles of 30nm -3μm in size were demonstrated along with prolate spheroids with major axis, which can be controlled via monitoring the kinetics of the chemical reaction.

In order to monitor qualities of fabricated particles, spectroscopic methods (bright and dark field) have been developed. Monitoring of optical resonances were shown to allow the extraction of information about an internal structure of biomineral crystals.

Kinetics of cell uptake of loaded particles were also studied. In particular, the efficiency of cell uptake is demonstrated to increase when particles get smaller. Dye-loaded Vaterite capsules were investigated under confocal microscope to monitor this optimal size-capacity parameter which is a major factor in drug delivery applications. Furthermore, we demonstrate complex Vaterite-based cargoes, encompassing plasmonic nanoparticles, mixed with fluorescent agents. Those hybrid multifunctional complexes with peculiar optical and biomedical properties can be useful in high resolution bio-imaging and therapy in-situ and many other light-inspired applications.

Oasis 7th Conference and Exhibition on Electro-Optics

The Measurement of Large and Fast Strains Using Rayleigh Backscattering In Optical Fibers

Hari Datta Bhatta, Luis Costa, Andres Garcia-Ruiz, Maria R. Fernandez-Ruiz, Hugo F. Martins, Moshe Tur, Miguel Gonzalez-Herraez

School of Electrical Engineering, Tel-Aviv University, Israel
Departamento de Electronica, Universidad de Alcalá, Madrid, Spain

Structural Health Monitoring (SHM) requires the measurement of large (hundreds of microstrains) and dynamically varying (tens to hundreds of Hertz) strains along hundreds of meters of attached/embedded optical fibers, preferably in a distributed way, where each small fiber segment serves as a local sensor and a whole fiber constitutes a densely packed sensor array. While standard fiber Bragg gratings (FBGs) provide a discrete coverage of the fiber, currently available draw-tower gratings can continuously populate the whole fiber. Alas, these fibers, and their interrogators, are very expensive, having limited capabilities, ~100 Hz sampling speeds and few tens of meters range. Brillouin-based sensing can measure large and dynamic (absolute!) strains over standard single mode fibers using complex and costly setup. Rayleigh backscattering based sensors, again in standard single mode fibers, are currently available in commercial equipments having ability to measure strain (or temperature) at very high spatial resolution but with limited sampling rates and measurement range (<100 m).

Distributed Acoustic Sensing (DAS) has driven a huge interest in Rayleigh-based, phase-sensitive Optical Time Domain Reflectometry (ΦOTDR) techniques that can measure minute optical phase changes in a long fiber at sampling rates limited only by the fiber length. Using OFDR (Optical Frequency Domain Reflectometry), researchers have adapted ΦOTDR techniques to the measurement of minute strains with speeds somewhat limited by the setup in use and often involving complex coherent detection. The recently introduced chirped-pulse phase sensitive OTDR (CP-ΦOTDR) uses a standard ΦOTDR setup with the exception of replacing the standard probing pulse by a chirped one. Based on its initial success in measuring dynamic strain perturbations, we have recently extended its capabilities to the demonstration of >=1000 με (peak to peak) @ 50 Hz and >=150 με @ 400 Hz. This paper will focus on simulations that analyze issues involved in this promising technique.

Fiber Optics for Biomedical Diagnostics

Olga Bibikova, Urszula J. Zabarylo, Anastasia Surkova, Valeria Belikova, Thaddäus Hocotz, Iskander Usenov, Tatiana Sakharova, Olaf Minet, Viacheslav Artyushenko

Art Photonics GmbH, R&D, Germany
Charité-Universitätsmedizin, Germany
Research-Educational Institute of Optics and Biophotonics, Saratov National Research State University, Russia
Samara State Technical University, Russia

The latest achievements in specialty fiber optics and top trends in information technologies are shaping modern biomedicine for more advanced diagnostic technologies on early stage of disease and for minimally invasive surgeries - together with medical devices miniaturization enabling data transfer via iCloud to the enhanced databanks and use of telemedicine.

Medical fiber optics, including lab and clinical diagnostics, surgical instrumentation and endoscopy, is one of the solution, which fully qualified modern medical requirements. According to World Health Organization (WOH), cancers are one of the leading causes of morbidity and mortality worldwide. However, the current procedure for cancer diagnostics consisting of a clinical examination of the suspicious lesion, followed by biopsy and histopathology is invasive, costly, and time-consuming. Non-invasive spectroscopic investigation or "spectral histopathology" is a novel alternative for rapid cancer diagnostics and label-free cancer specification.

Our development of unique Multi-Spectral Fiber (MSF-) systems enables to test various single and combined fiber probes for 4 key spectroscopy Methods: Raman scattering, Mid IR-absorption, Diffuse NIR-reflection, and fluorescence - to select the best method (or their best combination) for a real-time detection of malignant tissue as it´s needed for cancer surgeries. Our 1st data for ex-vivo analysis of resected tissues with cancers will be presented to demonstrate the best method selection - specific for each organ and cancer type.

Moreover, spectral methods have been applied to analyse not only biopsies of health and malignant tissues, but bioliquids, such as blood and urine, of patients before and after surgery. Further multivariate data analysis of spectroscopic data, both individual techniques and their combinations, provided reliable cancer recognition with the strict demand to reach "No false negatives" in oncology diagnostics.

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Passive Optical Time-Of-Flight for Non Line-Of-Sight Localization

Jeremy Gal Boger-Lombard, Ori Katz

The Hebrew University of Jerusalem, Applied Physics Department, Israel

Optical imaging through diffusive, visually-opaque barriers, and around corners is an important challenge in many fields, ranging from defense to medical applications. Recently, novel techniques that combine time-of-flight (TOF) measurements with computational reconstruction, have allowed breakthrough imaging and tracking of objects hidden from view. These light detection and ranging (LiDAR)-based approaches, however, require active short-pulsed illumination and ultrafast time-resolved detection. Here, bringing notions from passive RADAR and passive geophysical mapping approaches, we present an optical TOF technique that allows to passively localize light sources and reflective objects through diffusive barriers and around corners. Our approach retrieves TOF information from temporal cross-correlations of scattered light, providing temporal resolution that surpasses the state-of-the-art ultrafast detectors by three orders of magnitude. We demonstrate passive localization of multiple white-light sources and reflective objects hidden from view, using a simple setup, with interesting potential for covert imaging.

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Diagnosis of Oral Cancer Based On FTIR-ATR Spectra of Salivary Exosomes - Preliminary Study

Ben Zion Dekel, Ayelet Zlotogorski-Hurvitz, Dov Malonek, Ran Yahalom, Marilena Vered
Dept. of Electrical and Computer Engineering, Ruppin Academic Center, Emek Hefer, Israel
Tel-Aviv University and Rabin Medical Center, Sheba Medical Center, Israel

Introduction: Oral cancer (OC), referring to the main variant of squamous cell carcinoma, is now assessed to have a global incidence of over 300,000 new annual cases. One of the caveats associated with oral cancer is the ability to identify early malignant changes.

Background: Tissue biopsy and light microscopy are still the gold-standard diagnostic tool. Liquid biopsy, based on different body fluids, is currently a new concept in cancer diagnostics as it can provide information at successive time points on circulating tumor cells. In this line, saliva can be used as a promising biofluid for the early identification of biomarkers for both local and systemic diseases.

Objective: To determine the FTIR spectra of salivary exosomes from oral cancer (OC) patients and healthy individuals (HI).

Methods: Whole saliva samples were collected from 21 OC patients and 13 health. Exosomes were pelleted using differential centrifugation (12,000g, 120,000g). Following the mid-IR absorbance spectra range was measured using an ATR-FTIR. Machine learning techniques, utilized to build discrimination models for the absorbance data of the measured samples, included the (PCA-LDA) and (SVM) classification.

Results: IR spectra of OC was consistently different from health at 1,072cm-1 (nucleic acids), 2,924cm-1 and 2,854cm-1(membranous lipids) and 1,543cm-1 (transmembrane proteins). The PCA-LDA discrimination model correctly classified the samples with a sensitivity of 100%, specificity of 89% and accuracy of 95% and the SVM showed a training accuracy of 100% and a cross validation accuracy of 89%.

Conclusions: We have shown for the first time the signature of FTIR-based spectrum of salivary exosomes. The present findings are important as they show that cancer exosomes can be accurately differentiated from their benign counterparts based on their infrared spectra. This may have an important role for the development of next-generation techniques for the early diagnosis of OC.

Optofluidics by the Use of Gradient Metal Nanoislands

Dimitra Gkogkou, Christoph Kratz, Norbert Esser, Dirk Janasek, Euger Speiser, Karsten Hinrichs
Leibniz-Institut für Analytische Wissenschaften - ISAS - e. V., Germany

Biosensing is a branch of sensing aiming at the identification of the smallest possible amounts of target molecules. Vibrational spectroscopies in combination with photonics, namely plasmonics, lead the advancements of the field. Essentially, metallic nanostructures are used for surface enhancing vibrational signals of molecules in the vicinity of the metal. There is a plethora of nanostructures tailored for specific optical ranges to be either used for surface enhanced Raman scattering (SERS) or surface enhanced infrared absorption (SEIRA), but there is a lack of a platform that can be tuned for both vibrational spectroscopies and hence combining the high sensitivity of the method with providing complementary information for the analyte molecule.

We present a plasmonic platform based on metal nanoislands (Ag, Au) of gradient thickness. Along the platform, the shifting plasmonic resonances provide areas with optimal enhancement for both SERS and SEIRA, allowing for parallel investigations of analyte molecules. We have integrated this platform into a microfluidic setup (optofluidics) allowing for the in-situ investigation of ultra-low volumes. The whole channel volume is 100 nl while the interaction volume is estimated to be 6 fl for Raman and 2.6 nl for IR. The plasmonic enhancement leads to high sensitivity, with detection limits in the order of 10 nM for SERS. Apart from the remarkable detection limit, this platform is used to study time dependent adsorption of molecules of the metal surface.

High Speed Fiber Bragg Grating Interrogator Enabling Ultrasonic Nondestructive Testing and Machine Condition Monitoring

Ziv Glasser, Yochay Ofer, Rita Abramov, Shmuel Sternklar

Ariel University, Israel

Introduction: Fiber Bragg grating sensors are widely used for monitoring temperature, pressure, strain and vibration in various applications. The sensing principle relays on the fact that the Bragg wavelength shifts under environmental changes. This shift is usually measured with the aid of spectral analysis techniques such as tunable lasers or diffraction elements.
In this work we propose RF phase-shift measurements as the basis for the interrogation of FBG sensors. The unique potential of this method for achieving an excellent resolution-speed tradeoff, e.g. 10 MHz speed with 10 pm spectral resolution, is demonstrated.

Method: The experimental setup consists of a superluminescent diode modulated with an RF signal of a vector network analyzer. The modulated light was directed into a sensing channel having three FBGs with different Bragg wavelengths. The reflected light was directed through a dispersion component and then to a demultiplexer which split the light spectrally to different detectors. The detected signals were then routed back to the VNA for RF phase-shift measurement.

Results: An overall sensitivity vs. speed dependence of 3.4 fm\/√Hz is demonstrated. It was shown that this technique is extremely robust and can be used for dynamic measurements as well as for quasi-static monitoring. The choice of operating point anywhere in the region between ultra-high sensitivity or ultra-high speed, can be determined by simply adjusting the RF filter bandwidth or other equivalent signal processing parameters.

Conclusion: The RF phase-shift method shows excellent performance in terms of high speed and sensitivity. Since it is based on standard telecommunication components without moving parts or reliance on interferometry, it is simple, fast, robust and inexpensive. These advantages, together with the ability to analyze cascaded FBG sensors, enabling fast and sensitive distributed measurements, opens new fields for FBG-based sensing such as ultrasonic nondestructive testing, structural health monitoring and machine condition monitoring.

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Novel Fiber-Only UHQ Micro-Resonators for Sensing Application

Gabriel Guendelman, Moran Netser, Barak Dayan

Weizmann Institute of Science, Chemical and Biological Physics, Israel

An optical fiber with gradual linear radius variation (conical shape) can host strongly localized states, called conical states [1]. The typical transmission spectra of a Nano-fiber coupled conical micro-resonator is an Airy shape one, where the nodes of spectra correspond to the spatially confined modes. In this work we propose to utilize the conical unbounded modes. These modes, when not interrupted, spiral away from the coupling point. However, when a deformation is introduced, specifically a negative slope in the radius variation, it reflects back the spiraling waves creating an effective resonator between it and the conical mode.

The spectra of such composite system consist of a comb structure overlaid with an Airy envelope. The envelope shape will depend on the cone angle and teeth's separation will depend also on the nano-taper – reflection point distance. This system might be thought of as an analogue to an external cavity diode laser. Here the "gain" medium is the injection of light through the unbounded modes and the reflection forms the external cavity.

In this work we fabricated such systems and measured the composite spectra. Although resulting from a mode confined to just a few mm of fiber or less, the low-angle spiraling propagation of the mode results in effective long round-trip lengths, leading to a very small frequency separation between the spectral teeth (~100 MHz), corresponding to effective length of a few meters, with teeth as narrow as a few MHz (quality factors of Q~[(10)]^8). In addition, we experimentally validated the suggested reflection mechanism.

Such spectrally narrow high-Q modes and the dense spectral comb-like structure can serve as a basis for highly sensitive fiber-based sensors [2][3], especially taking into account the mode is confined to the surface of the fiber and can interact evanescently with the environment.

Deflected Talbot Effect in Weakly Absorbing Medium on Waveguide with Perturbation of Cylindrical Shape

Aviad Katiyi, Alina Karabchevsky

Electro-optics and Photonics Engineering Department, Ben-Gurion University of the Negev, Israel

Introduction: Spectroscopy focuses on the interaction between light and matter. This interaction results in absorption or emission of radiation due to the change in molecular energy. Therefore, infrared spectroscopy is certainly one of the most important analytical techniques available to today's scientists. Near-infrared (NIR) radiation excites overtone and combination vibrational modes and allows direct analysis of strongly absorbing and highly scattering samples without further pretreatments.

Background: When a guided wave is transmitted through a multimode optical waveguide, it creates a wavefront replicates of periodic perturbation pattern along the propagation direction of the guided wave. This self-imaging phenomenon is caused due to a multimode interference effect that named Talbot effect after its namesake, Henry Fox Talbot. Later, in 1881, the Talbot effect was rediscovered by Lord Rayleigh and is still providing a fruitful ground for exploration.

Objectives: We explored the Talbot effect and deflected Talbot effect in a weakly absorbing medium to characterize the mechanism of this phenomenon and its possible application for molecular overtone absorption.

Methods: Through numerical simulation, we show that the Talbot effect is deflected by a nanoscale perturbation made of inclusions. Openings of inclusions on waveguide boundary were fabricated using focused ion beam (FIB) that milled on the upper boundary of the nanostrip rib waveguide. Our experimental apparatus included a broadband laser source that launched into the optical waveguide when the waveguide and the inclusions are embedded in a weakly absorbing medium. The waveguides transmittance spectra were collected using an optical spectrum analyzer.

Results: Our experimental results, while using the fabricated waveguide with inclusions, show a well-defined overtone absorption band in the near-infrared. This overtone vibration was not observed while using the optical waveguide without the inclusions.

Conclusions: We conclude that the inclusions enhance the interaction between the light and the molecular medium.

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Spectral Superresolution in a Compact FT-IR Spectrometer

Erga Lifshitz, Uri Arieli, Shahar Katz, Assaf Levanon, Michael Mrejen, Haim Suchowski

Tel-Aviv University, Condensed Matter Physics Department, Israel

The Fourier Transform Infra-Red spectrometer (FT-IR) is a widely used method to carry out optical spectroscopy. In a standard FT-IR spectrometer, the intensity of the interference pattern is gathered with respect to the optical path difference (OPD) between a stationary and a scanning arm of a michelson interferometer. Transmission or absorption spectrum of a sample is then obtained by Fourier transforming the interferogram. Therefore, the resolution of the FT-IR spectrometer is inversely related to the length of the interferogram so that high resolution FT-IR spectrometers are very large and expensive.

Here we present the super resolution FT-IR spectrometer, a novel method to improve the spectral resolution of the FT-IR by a minor alteration to the collection method. In a direct analogy to super-resolution in image compression, we enhance the resolution of FTIR spectra by folding a large interferogram. This is done by employing a tunable reference arm to fold the interferogram in steps. The interferogram is then reconstructed by our unique stitching algorithm, thus achieving the high spectral resolution of a large FT-IR spectrometer with a minimized footprint.

In this work we demonstrate a proof-of-concept of this method in simulation and experiment at different spectral ranges, source coherences and OPD scales.

The feasibility of the stitching algorithm is demonstrated by comparing the reconstructed spectrum from continuous interferograms as with folded interferograms of the same effective length. In both simulation and experiments, the spectral results of the stitched interferogram closely follows the continues interferogram. Hence, we can conclude that the stitching algorithm does not add significant error to the spectral analysis.

Furthermore, the results are similar in simulation and experiments in micrometer scale scans for coherent light, mm scale scan for incoherent light and addition of small errors in the relative OPD of the steps.

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Phase-Shift-Amplified Interferometry

Egor Liokumovitch, Moshe Ben Ayun and Shmuel Sternklar
Ariel University, Israel

Introduction: Many applications require displacement measurements down to sub-nanometer resolution. The only non-contact technology that can provide this level of resolution is optical interferometry. However, noise and nonlinearity degrades their performance. We describe a new technique, phase-shift-amplified interferometry (PAI), whose sensitivity is amplified by a factor G relative to a standard interferometer, and reduces the effect of these noise sources, allowing for shot-noise limited performance.

Background: The PAI interferometer consists of two embedded Mach-Zehnder interferometers (MZI). The inner-MZI's reference arm is phase-biased so that the signal and reference are close to π out-of-phase and the amplitude of the reference is slightly offset from the signal amplitude A by a factor ($1-\Delta A/A$). Under these conditions, an incremental phase-shift on the signal is amplified by G at the output, where $G \approx A/\Delta A$. The outer-MZI converts this amplified phase-shift into amplified intensity signal. When compared with a standard MZI, the sensitivity, defined as the normalized output intensity signal, is also improved by a factor G. We show that higher sensitivity improves the immunity of the system against noise.

Objective and Method: The PAI interferometer was constructed, and phase-amplification was measured for incremental changes of the signal phase.

Results: Various amplification factors were tested, and the results show a very good fit to theory. Amplification factor G=11 and 0.65nm displacement resolution was achieved experimentally.

Conclusions: PAI is a new technology for enhancing the sensitivity of optical interferometry. PAI is useful for overcoming RIN and improving the immunity against nonlinear and distortion effects of the detector and the ADC, as well as ADC quantization error. The effects of the RIN and ADC quantization noise are reduced by a factor of G, and the effect of the detector and post-detection nonlinearity is reduced by $G^{(2n-1)}$. Reducing these effects will allow for operation at the shot-noise limit.

Revealing Non-Mie Resonances via Dark-Field Spectroscopy in Biomineral Vaterite Nanoparticles

Andrey Machnev, Roman E. Noskov, Hani Barhom, Alexander Goncharenko, Mikhail V. Zyuzin, Ivan I. Shishkin, Egor A. Gurvitz, Alexander S. Shalin, Pavel Ginzburg
Tel-Aviv University, Israel

In order to reach subwavelength light localization, optical magnetism, generation of optical toroidal moments and other related effects, previous studies have been concentrated on the concepts of surfaces plasmonic and Mie resonances in metallic and high-index nanostructures. While demonstrating promising functionalities, these works, however, almost never addressed their relation to living organisms, which may suggest promising applications in nanobiotechnologies.

Here, we study optical resonances in vaterite nanoparticles that are induced by particle complex internal structure rather than a high refractive index or plasmonic oscillations. Being a metastable phase of calcium carbonate with comparatively low ordinary and extraordinary refractive indexes (~1.6), vaterite monocrystals can form polycrystalline spherical nanoparticles, also referred to as spherulites. We study the dark-field scattering spectra for such spherulites and observe a peculiar family of optical resonances, which cannot be classified via a commonly used Mie theory. Specifically, we distinguish contributions to the scattering from different Cartesian multipoles. Additionally, we identify modes with strong toroidal electric and magnetic dipole contributions. Our results shed light on unexplored mechanisms responsible for optical functionalities of true biological systems where vaterite plays a significant role in drug delivery, light harnessing, vestibular system etc.

Enhanced Sensitivity of Silicon-Photonics-Based Ultrasound Detection via BCB Coating

Resmi Ravi Kumar, Evgeny Hahamovich, Shai Tsesses, Yoav Hazan, Assaf Grinberg, Amir Rosenthal

Electrical Engineering, Technion-Israel Institute of Technology, Israel

In biomedical applications, ultrasound detection is conventionally performed with piezoelectric transducers. Due to its opacity and reduced sensitivity upon miniaturization, there is a need for the development of new detection methodology. Recently, ultrasound detection has been demonstrated with waveguides fabricated in silicon-on-insulator (SOI) substrates. Ultrasound detection via silicon waveguides relies on the ability of acoustic waves to modulate the effective refractive index of the guided modes. However, the low photo-elastic response of silicon and silica limited the sensitivity of conventional SOI sensors. In this study, we demonstrate that the sensitivity of silicon waveguides to ultrasound may be significantly enhanced by replacing the silica over-cladding with bisbenzocyclobutene (BCB) - a transparent polymer with a high photo-elastic coefficient. We experimentally show that the sensors' response to ultrasound in terms of the induced modulation in the effective refractive index achieved for a BCB-coated silicon waveguide with TM polarization is comparable to the values reported for polymer waveguides and an order of magnitude higher than the response achieved by an optical fiber. In addition, in our study the susceptibility of the sensors to surface acoustic waves (SAWs) and reverberations was reduced for both TE and TM modes when the BCB over-cladding was used. The use of a silicon waveguide with a polymer over-cladding may be regarded as a hybrid approach that exploits the advantages of both materials. Using this approach, optical resonators may be produced that achieve the miniaturization level offered by silicon photonics and combine it with the sensitivity values comparable to those achieved with polymer waveguides.

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Echo Spectroscopy in Multilevel Quantum-Mechanical Molecular Rotors

Dina Rosenberg, Ran Damari, Shimshon Kallush, Sharly Fleischer

Tel-Aviv University School of Chemistry, Light Matter Interaction Center, Israel

Since the first demonstration of spin echo by E. L. Hahn in the 1950's, echo spectroscopy has become a central methodology in all fronts of spectroscopy. The main motivation for echo spectroscopy is to distinguish dephasing from decoherence dynamics. In the past few years, rotational echo spectroscopy gained much interest with several works demonstrating various responses of molecular rotors to THz fields and non-resonant optical pulses.

Unlike two-level systems, multilevel rotational systems possess a unique harmonic level spacing, giving rise to periodic anisotropic angular distributions following their ultrashort laser excitation. These periodic recurrences termed 'quantum rotational revivals' persist under field-free evolution and are monitored as alignment and/or orientation events.

I will present two of our recent studies on rotational echoes:

1. Demonstration of the rephasing character of rotational echoes [JPCL 8, 5128 (2017)] - where we utilize two, time-delayed ultrashort laser pulses to rephase the rotational dynamics under strong centrifugal distortion in methyl-iodide.
2. New methodology for conducting rotational echo spectroscopy [PRL 121, 234101 (2018)] - owing to the multi-level character of molecular rotors, the echo signal depends strongly on the delay between the two interacting pulses. This dependence invokes severe difficulties for rotational echo spectroscopy and results from interferences of multiple-pathways within the rotational coherences manifold. We have found that there is an optimal intensity of the second pulse (P2) that gives rise to maximal echo amplitude, and this optimal P2 depends on delay between pulses however, remains independent of the first pulse intensity. These findings opened the possibility of echo spectroscopy by judicious control of the pulses' intensities and allowed us to extract the rotational decoherence rate. If time permits I will present additional desirable possibilities for rotational spectroscopy of dense gas media with fast decay and decoherence rates.

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Sequence-Coded Coherent Laser Range-Finder

Keren Shemer, Gil Bashan, Hagai Diamandi, Yosef London, Arik Bergman, Nadav Levanon, Avi Zadok

Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, Bar-Ilan University, Israel
School of Electrical Engineering, Faculty of Engineering, Tel-Aviv University, Israel

Optical measurements of the distance to a target are used in many civilian and military applications. Laser range-finders form the basis of light-radars (lidars), which are the sensors of choice in many autonomous vehicles. Most range-finders rely on the transmission of short, intense and isolated laser pulses and on time-of-flight measurements of reflected echoes. However, the transmission of high-peak-power pulses restricts the choice of available laser sources and may be intercepted by an adversary. Alternatively, distance can be measured by continuous transmission of modulated waveforms in conjunction with proper post-detection compression protocols. The instantaneous power of the transmitted waveform is orders of magnitude lower than those of single-pulse range-finders. Therefore, sequence-coding can be realized using low-cost semiconductor laser diodes. Effective protocols for the compression of incoherently-detected, unipolar sequences of pulses were demonstrated experimentally. However, the sensitivity of simple direct detection is restricted by additive detector noise. Furthermore, incoherent detection is insensitive to phase information, limiting the choice of sequences available. In recent years, coherent detection has been widely adopted in optical communication, and coherent receivers have become increasingly available. Optical coherent detection can now be leveraged towards additional applications such as precision reflectometry.

Here, we report a proof-of-concept laser reflectometry experiment combining pulse sequence compression and coherent detection of weak reflected echoes. Reflections from the far end of an optical fiber were used as point targets. The length of the fiber could be measured for very weak collected echoes, down to an average optical power of -83 dBm. This average power corresponds for an average energy per code symbol of 15% of the photon energy. The measurement duration was only 1.6 ms. Compared with incoherent compression of the same pulse sequences, the receiver sensitivity is improved 20-fold, and the acquisition duration is reduced by a factor of 400.

Plasma Dispersion Effect based Super-Resolved Imaging in Silicon

Moshe Sinvani, Hadar Pinhas, Omer Wagner, Maor Tiferet, Yossef Danan, Meir Danino, Zeev Zalevsky

Bar-Ilan University, Faculty of Engineering, Israel

We present a new method for shaping of a pulsed IR (λ=1550 nm) laser beam in silicon. The shaping is based on plasma dispersion effect (PDE). The shaping is done by a second pulsed pump laser beam at 532 nm which simultaneously and collinearly illuminates the silicon's surface with the IR beam. Following the PDE, and in proportion to its spatial intensity distribution, the 532 nm laser beam shapes the point spread function (PSF) by controlling the lateral transmission of the IR probe beam. The use of this probe in laser scanning microscope allows imaging and wide range of contactless electrical measurements in silicon integrated circuits (IC) being under operation e.g. for failure analysis purposes. We propose this shaping method to overcome the diffraction resolution limit in silicon microscopy on and deep under the silicon surface depending on the wavelength of the pump laser and its temporal pulse width. This approach is similar to the stimulated emission depletion (STED) concept previously introduced in scanning fluorescence microscopy.

High-Tc Superconductor Nanowire Single Photon Detector

Xinxi Xing, Shlomi Bouscher, Krishna Balasubramanian, Ronen Jacovi, Alex Hayat
Israel Institute of Technology

Introduction: We explore the possibility of utilizing the very common high temperature superconductor (HTS) material, YBCO, to realize superconductor nanowire single photon detector (SNSPD). YBCO nanowire is characterized for transport and optical response properties.

Background: Compared to previous single photon detecting technology, SNSPD demonstrates much better performance. However, present SNSPDs based on low-Tc superconducting materials, for example, NbN, require extremely cooling conditions. The possible use of high-Tc superconductors (HTS) for achieving superconducting SNSPD is challenging, but also promising. Especially copper oxide superconductors show a Tc higher than boiling point of liquid nitrogen (77K), but the difficulty still need solve in obtaining high-quality uniform films due to its complex structures and weak stability.

Objectives:

1. Develop growth and etching methods of high-quality uniform $YBa_2Cu_3O_{7+\delta}$ (YBCO) films.
2. Design SNSPD device structure and characterization experiment setup.
3. Achieve YBCO SNSPD's optical response to laser beam pulse injection.
4. Fit experiment data with SNSPD theoretical models.

Methods:

1. Several growth (PLD and selective epitaxy) and etching methods (wet etching, Gallium/Argon ion milling), are conducted to obtain high-quality uniform stable YBCO nanowire.
2. Electrical transport measurements are implemented. Various wavelength pulse beam is directly coupled into SNSPD.
3. Fitting with SNSPD theoretical models: two-temperature model, heat-flow equation and another theoretical models are fitted with experimental data.

Results: Our YBCO nanowire shows excellent superconducting properties with Tc ~86K and Ic ~ 0.75 mA, and optical response to specific injected laser pulses.

Conclusions: To characterize ultrathin YBCO films, transport experiments, including resistance vs temperature R(T) measurements and current vs voltage I-V measurement, have been studied. Our YBCO film shows excellent Tc and Ic close to that of YBCO bulk material. In addition, the special response of YBCO nanowire to laser pulses, proves that YBCO is a promising material to realize SNSPD.

Pathogen Detection Using Frequency Domain Fluorescent Lifetime Measurements

Gilad Yahav, Sivan Gershanov, Mali Salmon-Divon, Haim Ben-Zvi, Gabriel Mircus, Nitza Goldenberg-Cohen, Dror Fixler
Faculty of Engineering and Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Israel
Genomic Bioinformatics Laboratory, Department of Molecular Biology, Ariel University, Israel
The Krieger Eye Research Laboratory, Felsenstein Medical Research Center, Israel
Department of Ophthalmology, Bnai Zion Medical Center, Israel
Laboratory of microbiology, Rabin Medical Center, Israel
Sackler Faculty of Medicine, Tel-Aviv University, Israel
Ruth and Bruce Rappaport Faculty of Medicine, Technion, Israel
Faculty of Engineering and the Institute of Nanotechnology and Advanced Materials, Bar Ilan University, Israel

Inflammation of the meninges is a source of severe morbidity and therefore is an important health concerns worldwide. The conventional clinical microbiology approaches used today to identify pathogens suffer from several drawbacks and frequently provide false results. This research describes a fast method to detect the presence of pathogens using the frequency domain fluorescence lifetime (FLT) imaging microscopy system.

The study included 43 individuals divided into 4 groups of diagnosis: bacteria; viruses; controls; and negatives. All samples contained leukocytes that were extracted from the cerebrospinal fluid and were subjected to nuclear staining by 4′, 6-diamidino-2-phenylindole (DAPI) and FLT analyses based on phase and amplitude crossing point (CRPO). Using notched boxplots, we found differences in 95% probability between the first three groups through different notch ranges (NR). Pathogen samples presented a longer median FLT (3.28ns with NR of 3.24-3.32ns in bacteria and 3.18ns with NR of 3.16-3.21ns in viruses) compared to the control median FLT (2.65ns with NR of 2.63-2.67ns). Furthermore, we found that the negative group was divided into two types: a relatively normal median FLT (2.72ns with NR of 2.68-2.76ns) and a prolonged FLT (3.22ns with NR of 3.17-3.27ns).

These findings imply that the FLT measurements can differentiate between controls and pathogens by the CRPO method and that the FD-FLIM system provide a high throughput diagnostic technique that does not require a physician.