IFLA International Fiber Lasers and Applications

OASIS 7 International Conference and Exhibition on Optics and Electro-Optics

Dear Colleagues,

It gives us great pleasure to invite you to join us to the 3rd IFLA meeting (http://oasis7.org.il/ifla/) to be held on April 1 and 2, 2019 at the David Intercontinental Hotel, Tel Aviv, within the OASIS 7 conference (http://www.oasis7.org.il/).

Technological breakthroughs in specialty fibers and fiber laser technologies over the last two decades have enabled many unique applications and research topics. Advances in these optical fiber technologies were originally in telecommunication applications. The reliability, compactness, cost, and quality advantages of optical fiber technology have merited the creation of novel optical sources for industrial applications and academic research.

The meeting topics are as follows:

1. Fiber lasers applications: defence, medical, biomedical, industrial, etc.
2. High power and high energy fiber lasers, including ultrafast fiber laser sources.
3. Mid-IR fibers and sources
4. Specialty fibers and fiber based components.
5. New directions in specialty fiber designs for innovative applications.

This year we are fortunate to host many of the leading researchers in both academies and industries worldwide. A detailed program of the meeting is provided below.

We are looking forward to this exciting event and hope to see you among our guests.

Sincerely yours,
IFLA organizing committee:

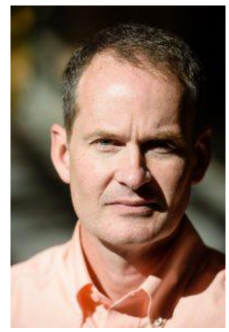
IFLA

Prof. Amiel Ishaaya, Ben-Gurion University
Dr. Zachary Sacks, Belkin Laser Ltd.
Prof. Zeev Zalevsky, Bar Ilan University
Dr. Boaz Lissak, Elbit system, ElOp electro optics division
Dr. Yoav Sintov, Soreq NRC

Materials Development for Advanced Optical Fibers

John Ballato,
Department of Materials Science and Engineering, Clemson University
Clemson, SC 29634 USA

Abstract: 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.



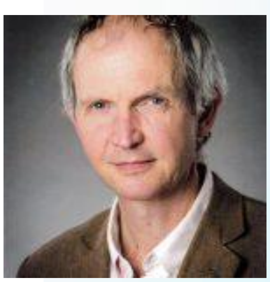
Biography: John Ballato is a Professor and Sirrine Endowed Chair in Optical Fiber at Clemson University. A world authority on optical fiber materials, Dr. Ballato is a Fellow of the American Ceramic Society (ACerS), International Society of Optical Engineering (SPIE), Optical Society of America (OSA), and Institute of Electrical and Electronics Engineers (IEEE). He also is an elected member of the World Academy of Ceramics and US National Academy of Inventors.

Silica-based hollow-core optical fibres: a new paradigm for the mid-infrared

Jonathan Knight
Department of Physics, University of Bath, UK

Abstract: Silica optical fibres have been remarkably successful. Silica is inexpensive, easily available with high purity, chemically inert, physically robust and easy to draw to fibre. 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 fibres beyond 3 microns wavelength. Instead, fibres for those longer wavelengths have previously been formed from softer glasses, with lower-frequency phonon absorption edge and consequently reduced optical attenuation. These alternative fibre 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 fibres 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 fibres 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 fibre 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 fibres will be reviewed, and their potential for further development discussed.



Biography: Jonathan Knight is Professor in the Department of Physics at the University of Bath, UK. He is interested in linear and nonlinear optics in novel optical fibres, and in particular in the opportunities offered by new forms of optical fiber based on microstructured glass. Recent results have included solarisation-free hollow-core fibres for ultraviolet wavelengths, silica-based low-loss fibres for mid-infrared wavelengths, and a 1W hollow-core fibre gas laser at 3.1 microns.

Prospects in power scaling of coherently coupled fiber lasers and amplifiers

Andreas Tünnermann, Jens Limpert
Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University Jena,
Max-Wien-Platz 1, 07743 Jena, Germany
Fraunhofer Institute for Applied Optics and Precision Engineering, Center of Excellence in Photonics
Albert-Einstein-Strasse 7, 07745 Jena, Germany

Abstract: 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.

Biography: Andreas Tünnermann received the diploma and Ph.D. degrees in physics from the University of Hannover in 1988 and 1992, respectively. His Ph.D. work was focused on nonlinear processes with emphasis on the interaction of high intensity laser sources with matter for the generation of short wavelengths lasers. In 1997 he received the habilitation and venia legendi in experimental physics for his work on ultrastable light sources for interferometric gravitational wave detectors. He was head of the department of development at the Laser Zentrum Hannover from 1992 to 1997. In the beginning of 1998 he joined the Friedrich-Schiller-University in Jena, Germany as a Professor and Director of the Institute of Applied Physics. 2001 he launched the company Guided Color Technologies GmbH. In 2003 he became the Director of the Fraunhofer Institute for Applied Optics and Precision Engineering in Jena.

Andreas Tünnermann is currently leading one of the most creative and productive research groups in modern optics and photonics world-wide. Research topics are the design and manufacturing of novel passive and active photonic devices and its application for generation, amplification, steering and switching of light – with a strong foundation in laser physics. Especially his work on high power continuous and pulsed fiber lasers operating in the visible and near infrared spectral range is highly appreciated by the laser community. Outstanding developments in photonic crystal fiber design performed in his laboratories made it possible to overcome restrictions due to nonlinear pulse distortions in the amplification fiber and revealed the full potential of rare-earth-doped fibers as a power-scalable solid-state laser concept even in the ultrashort pulse regime.

Andreas Tünnermann has been distinguished with several prizes and awards along his professional career. He received the most important German award in science and technology, provided by the German Research Foundation (DFG), the Gottfried Wilhelm Leibniz Prize. Most recently, he has been awarded with the ERC Advanced Grant of the European Community.

Unconventional high-power fiber lasers for improved wavelength coverage

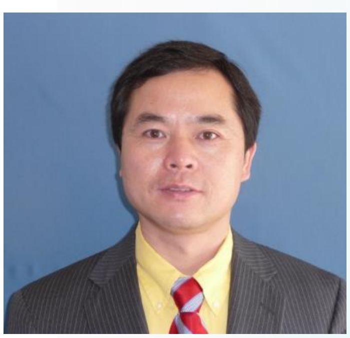
Johan Nilsson
Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ
England

Biography: Johan Nilsson is a Professor at the ORC, University of Southampton, UK, and head of the High Power Fiber Lasers research group. In 1994, he received a doctorate in Engineering Science from the Royal Institute of Technology, Sweden, for research on optical amplification. Since then, he has worked on optical amplifiers and amplification in lightwave systems, optical communications, and guided-wave lasers, first at Samsung Electronics and later at ORC, and has published over 400 scientific articles. He is a fellow of the OSA and the SPIE, and a consultant and co-founder of SPI Lasers. He is a member of the advisory board of the Journal of the Optical Society of Korea and is currently a guest editor for Optics Express and Optical Engineering. He is a former chair of the Laser Science and Engineering technical group in OSAs Science and Engineering Council and is currently program chair for the Advanced Solid State Lasers conference.

High pulse energy single frequency 1.55micron fiber amplifiers

Shibin Jiang
AdValue Photonics Inc
3440 E. Britannia Drive, Suite 190, Tucson, AZ, 85706

Abstract: There has been a significant need of developing a high energy single frequency optical pulse transmitter for LIDAR applications, especially at 1572nm for atmospheric CO_2 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.



Biography: Dr. Shibin Jiang is founder and President of AdValue Photonics Inc. and Adjunct Research Professor at College of Optical Sciences, University of Arizona. He received Ph.D. degree from Universite de Rennes 1, France. He was Co-founder and CTO of NP Photonics Inc before founding AdValue Photonics in 2008 .
Dr. Jiang holds 49 issued US patents, edited 23 proceeding books, authored more than 150 publications, and has H index of 43. He served as chairs of 26 international technical conferences including OPTO at Photonics West for SPIE and Advanced Solid State Laser Congress for OSA. He served as many award committees for OSA, SPIE and ACerS, and associate editors for 4 scientific journals. He was the chair for Glass and Optical Materials Division, The America Ceramic Society, in 2014. Currently he is a member of nominating committee of ACerS. His research activities generated more than a dozen of the world's first commercial products, which are widely used.
Dr. Jiang was awarded with the Gottardi Prize in 2005 from International Commission on Glass, 2012 R&D 100 Award, and 2014 R&D 100 Award. Dr. Jiang is a Fellow of SPIE, The America Ceramic Society, and OSA.

Mode area scaling through a multicore supermode fibre

Seongwoo Yoo
Nanyang Technological University, Singapore

Abstract: 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.

Biography: **Seongwoo Yoo** is an assistant professor at School of Electrical and Electronic Engineering in Nanyang Technological University (NTU), Singapore. He received his PhD from Gwangju Institute of Science and Technology (GIST), Korea for his study on specialty fibre design and fabrication. He joined the Optoelectronic Research Centre (ORC) at University of Southampton, UK, as a post-doctoral research fellow in 2005. Since then, his research has been centred on specialty fibre development for high power fibre lase applications. Since joining NTU, his research efforts have been focused on rare-earth doped fibres, high nonlinearity fibres and micro-structured fibres.

Image Transport through Glass-Air Disordered Optical Fiber

Axel Schülzgen,
University of Central Florida, USA

Abstract: 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.

Biography: Axel Schülzgen received his PhD in Physics from Humboldt-University of Berlin, Germany. Since 2009 he is Professor of Optics and Photonics at CREOL, The College of Optics and Photonics, at the Universi ty of Central Florida. He also holds an Adjunct Research Professor position at the College of Optical Sciences, University of Arizona. Prof. Schülzgen published over 120 papers in peer reviewed journals and holds 6 patents. He is a Fellow of the Optical Society of America.

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
Leibniz Institute of Photonic Technology (IPHT) Jena, Albert-Einstein-Str. 9, 07745 Jena, Germany

Dörte Schönfeld, Andreas Langner, Clemens Schmitt, Jaqueline Plass, Gerhard Schötz
Heraeus Quarzglas GmbH & Co. KG, Quarzstraße 8, 63450 Hanau, Germany

Abstract: 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).

Biography: Matthias Jäger received his PhD in optics from the University of Central Florida (CREOL). He was a postdoc at the ETH Zürich from 1997 to 1999. Following a two-year stay at Agilent Technologies, he joined ITF Labs in 2001 as Director Test and Measurement. Starting 2006, he worked on fiber laser development at JT Optical Engine in Jena. Since 2011, he has been leading the fiber laser group at the Leibniz Institute of Photonic Technologies. He has published five book chapters and over 100 papers and conference contributions. He is Senior Member of the OSA and member of the SPIE.

Recent Advances in Mid-Infrared Fiber Lasers

Réal Vallée
Centre d'optique photonique et laser, Université Laval, Québec, Canada

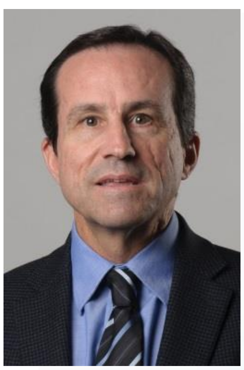
Abstract: High power silicate glass-based monolithic near-infrared fiber lasers (FLs) have revolutionized the manufacturing sector due to their superior optical as well as mechanical performances, namely in terms of beam quality, ruggedness, compactness and long-term reliability. Although they have not yet reached the same level of maturity, mid-infrared fiber lasers based on low-phonon energy glasses also hold great promise for several applications pertaining to the environment and the biomedical sectors. Now most of these applications present high requirements in terms of both CW and pulsed operation.

To date, CW laser emission from mid-IR fiber lasers at wavelength longer than 2.5 mm were mainly obtained from fluorozirconate (ZrF_4) 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 2.8 mm as well as nearly 6W near 3.5 mm were achieved. Dy^{3+} and Ho^{3+} ions have also shown very promising results recently near 3.2 mm and 3.9 mm, respectively. In the later case, fiberoptics from a new fluoride glass family, InF_3, have shown great potential for emission at longer wavelength.

Pulsed counterparts of Mid-IR fiber laser were also developed based on gain switching, leading to pulsed output in the ns range. 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. Ultrafast pulses of duration of 200-300fs were produced near 3 mm with peak power approaching 10kW. Such femtosecond FL was subsequently used to seed an Er^{3+}-doped-fiber amplifier, resulting 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.

Biography: Réal Vallée joined Université Laval in 1987 after a postdoctoral fellowship at the Laboratory for Laser Energetics at the University of Rochester. Since 2000, he has been the Director of the Centre for Optics, Photonics and Lasers (COPL), the province of Quebec network center of excellence in photonics. His research interests are in fiberoptics components (namely fiber lasers for the mid-infrared) and their applications, non-linear propagation of ultrafast pulses in fiber, inscription of waveguides and Bragg gratings with femtosecond pulses and the study of infrared glasses for integrated optics. He currently holds an NSERC-funded Industrial Research Chair in Femtosecond Photo-Inscribed Photonic Components and Devices. Professor Vallée has supervised over 75 graduate students to date, authored over 200 peer-reviewed papers in high impact journals and holds 12 patents. He is a Fellow of the Optical Society of America.



Bringing infrared fiber components to the Market

Eric Geoffrion and Mohammed Saad
Thorlabs Inc., Newton, NJ, USA

Abstract: 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.

Biography: **Mr. Eric Geoffrion** is a graduate of the École Polytechnique of the University of Montreal where he obtained his B.Ing (1984) in Biochemical Engineering. In 1992, he completed a specialized graduate diploma (DESS) from HEC Montréal.
Mr. Geoffrion began his career at IBM Bromont and then worked at EXFO where he was responsible for the development of international sales. (1992-1997). He later co-founded ITF optical technologies where he was president from 1997 to 2002. He then co-founded IRphotonics (IR Glass and fibers) with Dr. Mohammed Saad. The company was sold to Thorlabs in 2013 in order to support large US defense based program opportunities for infra-red fibers/cables. He created Thorlabs Canada after joining Thorlabs and is currently managing director . Thorlabs Canada is focused on the development and production of a range of innovative passive fiber-based optical components. Mr. Geoffrion is also involved in the Infra-red technological steering committee of Thorlabs.

Biography: Almantas Galvanauskas is a professor at the Electrical Engineering and Computer Science Department, University of Michigan. He has been working in the field of fiber lasers for more than twenty years, and has more than 200 publications, including approximately 30 patents and patent applications. He had pioneered ultrashort-pulse fiber CPA, and his work had resulted in demonstrating several record-breaking achievements in performance of fiber lasers. Prior to joining University of Michigan he spent eight years in industrial R&D at IMRA America, Inc.. His current interest spans areas from novel fiber designs to advanced fiber laser systems, including beam combining of pulsed and ultrashort pulse lasers, and new fiber laser applications such as high-intensity laser plasma produced EUV, X-ray generation, and laser driven acceleration. He is also a co-founder of Arbor Photonics, Inc., which was acquired by nLight Inc. in 2012.

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, CH 310, 1300 University Blvd., Birmingham, AL 35294, USA.

[2] IPG Photonics Corporation, Southeast Technology Center, 100 Lucerne Ln, Birmingham, Al 35211, USA.

Abstract: 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.

Biography: Dr. Sergey Mirov is an USSR-born naturalized American scholar serving as University Professor of at the University of Alabama at Birmingham (UAB). He received the M.S. degree in electronic engineering, from the Moscow Power Engineering Institute – Technical University, in 1978, and the Ph.D degree in physics in 1983 from the P. N Lebedev Physics Institute of the USSR Academy of Sciences, Moscow. He served as a staff research physicist, at P. N. Lebedev Physics Institute, and a principal research scientist and a group leader at the General Physics Institute of the USSR Academy of Sciences. His early work in USSR Academy of Sciences involved physics of color centers formation under ionizing irradiation, color center's photo chemistry, laser spectroscopy of solids and led to the development of the first room temperature operable commercial color center lasers, passive Q-switches and nonlinear filters for various types of neodymium lasers from mini lasers to powerful laser glass systems. He was awarded the USSR First National Prize for Young Scientists, in 1982, for the development of LiF color center saturable absorbers. He received Distinguished Research Awards from the General Physics Institute, in 1985 and 1989, and from the P N. Lebedev Physical Institute in 1980.

Since 1993 Dr. Mirov is a faculty member at the Department of Physics, UAB. His main fields of interest include tunable solid-state lasers, laser spectroscopy, and quantum electronics. Dr. Mirov's team is the leader in the development and investigation of novel gain media for middle-infrared tunable lasers. Their effort resulted in development of first commercial Cr2+ and Fe2+ doped ZnSe and ZnS crystals and lasers (middle infrared analogs of famous Ti-sapphire laser) with a broad range of scientific, industrial, medical, and defense related applications. In 2004 the Institute of Electrical Engineers in the United Kingdom has named Dr. Mirov and his team recipients of the Snell Premium award for the input in optoelectronics and development of Cr2+:ZnS mid-IR external cavity and microchip lasers. Dr. Mirov was also awarded Charles W. Ireland Prize for Scholarly Distinction in 2009. In 2010 IPG Photonics Corporation licensed Dr. Mirov's patents in middle-infrared laser technology and simultaneously acquired his start-up company (Photonics Innovations, Inc.). Dr. Mirov is a fellow of the Optical Society of America and National Academy of Inventors, and member of the American Physics Society and SPIE. He has authored or co-authored over four hundred scientific publications in the field of quantum electronics, has published 1 book, several book chapters, and holds twenty six patents.

Recent developments in high power industrial fiber lasers

Scott Christensen, Director of Advanced Applications
IPG Photonics, Oxford, MA, USA

Abstract: 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.

Biography: Scott Christensen received his undergraduate degree in Applied Math, Electrical Engineering, and Optical Physics from the University of WI Madison and obtained his graduate degree in Physics from the University of Colorado Boulder. Currently, Scott is the Director of Advanced Applications at IPG Photonics.

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

Benayahu Urbach
Civan Advanced Technologies, Jerusalem, Israel

Abstract: Dynamic Beam, which allows beam steering, beam focusing and beam shaping in MHz speeds can present significant advantages in cutting, welding, additive manufacturing and free space optical communication .

The Dynamic Beam is being realized by Optical Phased Array (OPA) Coherent Beam Combing (CBC) of tens of high power fiber lasers.

A few examples of the advantages of Dynamic Beam in material processing include: i) In systems based on scanning mirrors, such as 3D printers, fast beam steering combined with fast focus adjustment, can increase the scanning speed and eliminate the need for F-Theta Scan Lens; ii) Fast beam steering can provide the required wobbling effects for improved quality and speed of cutting and welding and improve welding of dis-similar materials; and iii) Fast focusing can improve the speed and quality of cutting thick materials.

Several multi KW, OPA CBC lasers will be presented. The presentation will also include an explanation of the OPA CBC technology and will present applications in Material Processions, Additive Manufacturing and Free Space Optical Communications .

Biography: Benayahu Urbach received his BsC degree in physics in 2000 and his PhD degree in physics in 2007, both from the Hebrew University of Jerusalem. His thesis research was on optical and electrical properties of composite structures of porous silicon. Between 2007 and 2009 he worked in the R&D department in Al-Cielo. Since 2009 he is working in Civan Advanced Technologies, focusing on coherent beam combining of high power laser beams**.**

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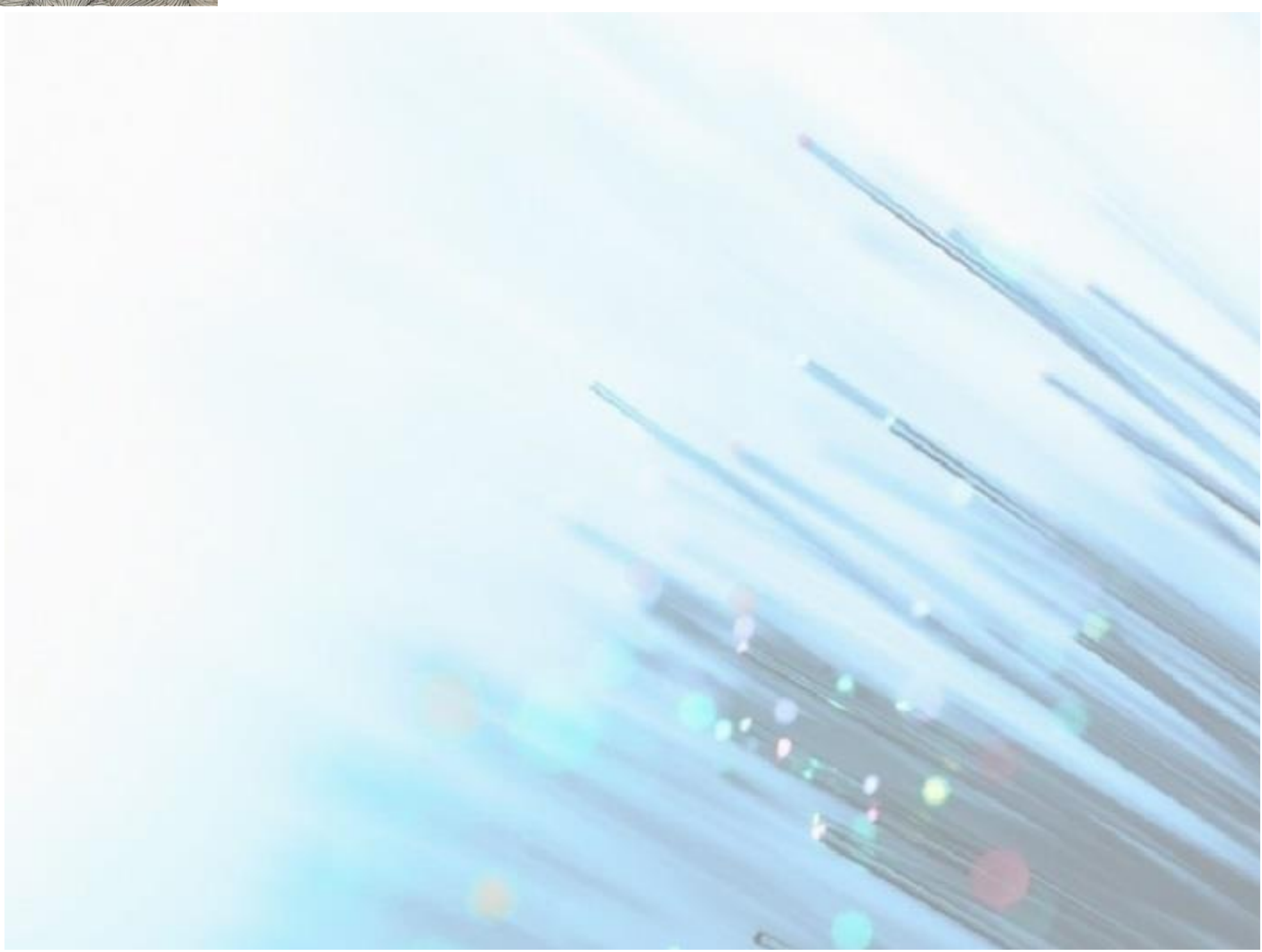
Advanced fiber laser technology for next generation airborne LiDAR applications

Doron Barness, Amir Wand and Kobi Lasri,
MKS Spectra-Physics Lasers, Israel

Abstract: Airborne LiDAR has become a mainstream technology for surface data acquisition for a variety of large-scale 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-on-demand 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-on-demand 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.

Biography: **Dr. Doron Barness** has been Director of R&D and Engineering at V-Gen Ltd., Spectra-Physics Lasers Tel-Aviv (now under MKS instruments) since July 2016, after serving as project manager and laser physicist since 2013. V-Gen is one of the leading providers of innovative fiber lasers for a wide range of industrial applications and was acquired in October 2014 by Newport Corp. Prior to joining V-Gen, Doron served as a senior physicist at Elbit Systems Electro-optics Elop since 2009. Dr. Barness graduated with a PhD degree from the Bar-Ilan University where he conducted research in the fields of Nano-magnetism, superconductivity and high speed laser imaging. Dr. Barness holds a B.Sc and M.Sc degrees in physics, also from the Bar-Ilan University.



Tailoring the spectral response in fibers by localized fs laser modifications

S. Nolte[1,2], T. A. Göbel[1], M. Heck[1], R. G. Krämer[1], C. Matzdorf[1], D. Richter[1]

1- Friedrich Schiller University, Institute of Applied Physics, Abbe Center of Photonics, Albert-Einstein-Strasse 15, 07745 Jena, Germany

2- Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Albert-Einstein-Strasse 7, 07745 Jena, Germany

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Abstract: 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.

Biography: **Stefan Nolte** is professor of laser physics at the Friedrich Schiller University in Jena, Germany, where he is heading the Ultrafast Optics group at the Institute of Applied Physics. He is also the Deputy Director of the Fraunhofer IOF, Jena.

His research focus is ultrashort pulse micromachining and materials modification for industrial and medical applications, where he has been actively engaged since the field's inception in the mid-1990s. This work has spurred the industrial use of ultrashort pulse lasers in materials processing. Apart from ablation and surface structuring, three-dimensional structuring within the volume of transparent materials is another topic.

Functionalized micro-nano-fibres and hybrid photonic crystal fibres: The role of new materials

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Abstract: 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.

Biography: Dr. Georgios Kakarantzas is Senior Researcher (Researcher B) and head of the Photonics Lab at the Theoretical and Physical Chemistry Institute (TPCI) of the National Hellenic Research Foundation since May 2008. He received his Diploma in Physics from the University of Crete in 1989 and his DPhil from the Physics Department, University of Sussex, UK in 1993. His DPhil thesis entitled “Ion Implanted Waveguides in Laser Glasses”. He worked as post-doctorate researcher at Brunel University, UK from 1993-1996, Military Service (Greek Army Signal Corps) 1996-1998, University of Bath, UK from 1998-2003 and National Technical University of Athens 2003-2005. From February 2006-May 2007 he was visiting researcher at the Max-Planck Institute for the Science of Light, Erlangen, Germany. From October 2007 – May 2008 he was Assistant Professor at the Materials Science Department, University of Patras, Greece. He has developed and studied photonic devices in planar waveguides (first Tm waveguide laser), photonic crystal fibres (first long period grating and rocking filter), tapered nano-fibres (micro-coupler) etc. He has also developed novel glasses (oxides, fluorides, chalcogenides, sol-gel) for photonic applications. His current research is mainly focused on hybrid fibre devices.

Amplifiers and lasers with active tapered double clad fibers

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Abstract: We report theoretical and experimental study of active tapered double-clad fibers (T-DCF) to be implemented as a gain media in a fiber amplifiers and lasers. We have considered most important properties and features of T-DCF in that presentation. Various amplifiers and lasers with ytterbium T-DCF are demonstrated and discussed.

Biography: **Dr. Valery Filippov** has received the Ph.D. degree in Radiophysics and Electronics from Peter the Great St. Petersburg State Polytechnic University (St. Petersburg, Russia) in 1988. He has worked at Peter the Great St. Petersburg State Polytechnic University (1983-1998, St. Petersburg, Russia), Centro de Investigaciones en Optica (1998-2002, Leon, Mexico), University of Southampton (2002-2005, UK), Liekki Corp. (2005-2007 Lohja, Finland) and Optoelectronics Research Centre (Tampere University of Technology, 2007-2016).
Dr. Filippov is founder and Research Director of Ampliconyx LLC (Tampere, Finland) since 2017 to the present. Dr. Filippov has published more than 140 peer-reviewed journal articles; he is author of six patents. The main field of scientific interests includes optical fibers, fiber sensors and fiber lasers and amplifiers.

Megawatt Fiber Oscillators

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Abstract: 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.

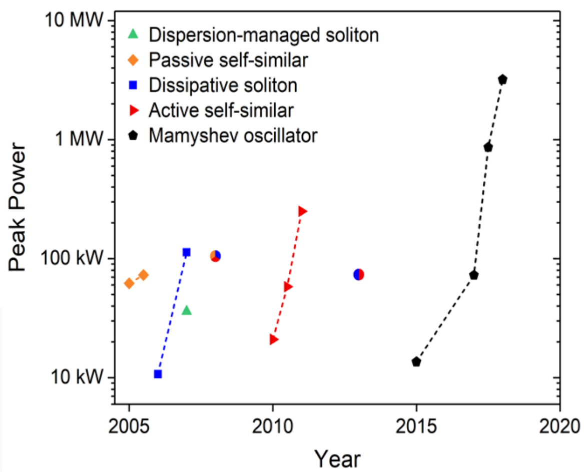

Figure 1. Peak powers achieved by femtosecond fiber lasers constructed with ordinary single-mode fiber.

Biography: Professor Frank Wise Frank Wise received a BS degree in Engineering Physics from Princeton University, an MS in Electrical Engineering from the University of California at Berkeley, and a PhD in Applied Physics from Cornell University. Before PhD studies, he worked on advanced integrated circuits at Bell Laboratories. Since receiving the PhD in 1988, he has been on the faculty in Applied Physics at Cornell.

The myths, the reality, and the unexplored potential of SESAM technology for mode-locking

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Abstract: Semiconductor saturable absorber mirrors (SESAMs) have been widely used for passive modelocking of femtosecond and picosecond lasers. Their key feature include the ability to tailor the nonlinear properties, and hence the mode-locking driving force. Thus, they offer access to customized absorption recovery time 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 on developments at 1-µm and 1.55-µm wavelength domains, where most of current volume applications are; this is in particular seen 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 vertical external cavity surface emitting lasers (VECSELs), have pushed the frontier of SESAM technology towards new material systems, a development that could be leveraged also to the next generation of fibre lasers. From this standpoint, the presentation covers recent progress of SESAM technology, in particular focused on novel approaches to tailor the absorption recovery time and developing new material systems for the absorber-mirrors 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. Finally, we discuss the development cycle for qualification of commercial-grade SESAMs touching on lifetime aspects.

Biography: Prof. Mircea Guina obtained the PhD degree in physics in 2002 at the Tampere University of Technology, Tampere, Finland. He is a professor of optoelectronics since 2008 and currently leads the Optoelectronics Research Centre team, a research group part of the Faculty of Natural Sciences and Engineering at the Tampere University. He conducts research on several major topics including molecular beam epitaxy of novel optoelectronic compounds, development of semiconductor lasers and high-efficiency solar cells, photonic integration, and use of lasers in medicine, LIDAR, and sensing. He has published more than 180 journal papers, several book chapters, has given more than 35 invited talks at major international conferences, and holds four international patents. Prof. Guina has an outstanding record in initiating and leading large-scale research projects extending from basic science to technology transfer. He is the recipient of an ERC Advanced Grant for development of high efficiency solar cell technology (AMETIST). He is also co-founder and Chairman of three start-ups related to laser technologies (Vexlum Oy, Reflekron Oy, and Picophotonics Oy). Prof. Guina is a Topical Editor for the Optics Letters journal and the Journal of European Optical Society. Recently, he has been awarded the OSA Fellow and SPIE Fellow distinctions for his work on various optoelectronics and laser technologies.

Fiber coupling to moving-, levitating- and liquid-resonators

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Abstract: One might think of the optical fiber as the primary method to convey light, and on the resonator - as a most important optical device. Together, the fiber and the resonator allow resonantly enhancing more than 99.9% of the intra-cavity light .

Here I will report on our recent experiments where we extend fiber-coupling methods to allow coupling light to moving-, levitating- and liquid-resonators. The moving resonators allow irreversible optical-refraction that supports intra-fiber 99.6% isolation efficiency. The liquid resonators enable a new type of water-wave laser where capillary waves replace atomic transitions in meditating laser emission. The levitating resonators allow quality factors exceeding a billion and finesse higher than 10 million.

Fiber coupling is now compatible with resonators made strictly of the liquid phase of matter, resonators that moves and resonators that levitates.

Biography: Tal Carmon was born in Haifa, Israel and received his B.Sc. (Cum Laude) from the Mechanical engineering Department at the Technion. Tal got his PhD in Physics from the Technion on 2003.

And continued to a Postdoc position at Caltech where he experimentally demonstrated mechanical vibrations generated by the pressure of light. On 2007, Tal Joined the University of Michigan, Ann Arbor, as an Assistant Professor and extended vibration rates of micro-resonators to above 10 GHz. In 2013, Tal got tenure at the University of Michigan and then returned to his Alma Mater at the Technion where he extends the basic principles of optics and condensed matter to water waves that are similar to the waves seen when we through a stone into a puddle. Tal is a recipient of the US Air Force Young Investigator award, the Rothschild Post Doctorate Fellowship and the Eshkol PhD Fellowship.

In-fiber speckle-based interferometry for fabric integrated, non-contact bio-sensor of vital signs

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Abstract: 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.

Biography: Zeev Zalevsky received his B.Sc. and direct Ph.D. degrees in electrical engineering from Tel-Aviv University in 1993 and 1996 respectively. Zeev is currently a full Professor in the faculty of engineering in Bar-Ilan University, Israel. His major fields of research are optical super resolution, biomedical optics, nano-photonics and electro-optical devices. Zeev has published more than 480 peer review papers, about 300 conference proceeding papers, 30 book chapters, 6 books as author and 3 as editor and more than 50 patents. He is a fellow of many large scientific societies such as SPIE, OSA, EOS, IOP, IET, IS&T and NAI. Zeev has received various scientific awards for his research activity including Krill prize, ICO prize, Juludan prize, Young investigator prize in nanoscience and nanotechnology, Lean and Maria Taubenblatt prize, The international SAOT (School for Advanced Optical Technologies) young researcher prize, Image Engineering Innovation Award, Outstanding Young Scientist Award (OYSA) of NANOSMAT, Horace Furumoto Innovations Professional – Young Investigator Award, The Asian Advanced Materials Award, SPIE Prism Award and more.

International Fiber Lasers and Applications

International Conference and Exhibition on Optics and Electro-Optics

Beam cleaning effects in multimode LD-pumped GRIN-fiber Raman laser

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Abstract: Raman fiber lasers (RFLs) are able to operate at almost any wavelength in transmission window (1-2 micron) of conventional single mode silica fibers pumped by powerful Yb-doped fiber laser. Direct pumping of multimode graded-index (GRIN) fibers by commercial high-power multimode laser diodes at 915-940 nm provides Raman lasing below 1 micron that is problematic for fiber lasers. Herewith, the quality of output beam may be greatly improved in comparison with that for laser diodes thus resulting in brightness enhancement by >20 times. Here we review physical mechanisms leading to the beam quality improvement in GRIN fibers: specific 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 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 GRIN RFL has been realized with the use of acousto-optic modulator. Output characteristics and potential applications of such laser sources are discussed.

Biography: Sergey A. Babin received MSc in physics from the Novosibirsk State University in 1983, and PhD (1990) and DSc (2003) degrees in physics and mathematics from the Institute of Automation and Electrometry SB RAS (Novosibirsk, Russia). He has been working as a head of the Fiber Optics Laboratory since 2007, and as an acting director of the Institute since 2018. He is corresponding member of Russian Academy of Sciences (RAS), member of OSA and IEEE Photonics societies, chief editor of Applied Photonics journal (in Russian). His scientific achievements include the development of the longest Raman fiber laser (300 km) in collaboration with colleagues from Aston university. He and his team proposed and demonstrated random Raman fiber lasers with record parameters (efficiency, polarization extinction ratio, tuning, etc.), as well as other novel schemes and regimes of Raman fiber lasers. The spectrum broadening in fiber lasers has been also described. Fundamental limitations for chirped pulses found and femtosecond pulses with maximum energy in an all-fiber oscillator have been generated. Their efficient Raman conversion enabling generation of femtosecond pulses at new wavelengths has been also demonstrated. Femtosecond technology of writing fiber Bragg gratings (FBGs) through the fiber coating with unique lasing and sensing characteristics has been developed. Diode-pumped Raman fiber lasers in multimode graded–index fibers with femtosecond inscribed FBGs generating near diffraction limited output beam have been demonstrated. Multiple laser and sensor systems for industrial applications (communications, biomedicine, material processing, infrastructure and energetics) have been also proposed and realized.

Robust setup for generation of high-power CW green laser

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Abstract: 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.

Fiber Optic Distributed Acoustic Sensing (DAS) data processing via Artificial Neural Networks

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Abstract: 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.

Improved sensitivity and spatial resolution in fiber Bragg gratings dynamic strain sensing system via Iterative Soft Thresholding Algorithm

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Abstract: 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

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Abstract: 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.

New Approaches in Microfiber and Nanofiber Tapering and Packaging

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Abstract: 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

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Abstract: 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.