6th Workshop on Specialty Optical Fibers and Their Applications

6-8 November 2019
Charleston, South Carolina, USA

Organizers

CLEMSON UNIVERSITY
COMSET
CENTER FOR OPTICAL MATERIALS SCIENCE + ENGINEERING TECHNOLOGIES

SPIE.

The 6th Workshop on Specialty Optical Fibers and Their Applications

Conference Program

6-8 November 2019

Charleston, South Carolina, USA

Dear colleagues, we welcome you to WSOF 2019!

It is with great pleasure that we introduce this Proceedings filled with papers from the *6th International Workshop on Specialty Optical Fibers and their Applications* (WSOF 2019). WSOF is a biennial technical workshop and exhibit focused on advances and innovations in the field of specialty optical fibers and their applications, following in the footsteps of the five previous workshops (Sao Pedro, Brazil, 2008; Oaxaca, Mexico, 2010; Sigtuna, Sweden, 2013; Hong Kong SAR, China, 2015; and Limassol, Cyprus, 2017).

The papers contained herein represent the state-of-the-art in specialty optical fibers including novel materials from which they are made and coated, their design and modeling, their fabrication, and their performance in a variety of applications. The committee members, sponsors, and authors hail from all over the world, further validating, as if there were questions, the global nature of this field. Academia, governmental laboratories and industry – large and small – are presented, as are the most well-known and acclaimed names in our field, as well as young students just beginning their careers. These facts not only capture the diversity of workshops like WSOF 2019 but also their value in creating a shared experience for all interested in specialty fiber optics in a small and familiar setting that affords one-on-one opportunities for technical discussions and fellowship.

We would be remiss in not gratefully acknowledging those who made this Proceedings, and the Conference, possible. Financially, the sponsors noted above were central to the success of WSOF 2019. Second, and no less central, were Thomas (Wade) Hawkins, Courtney Kucera, and Lindsay Grieshop (Clemson University), who provided invaluable logistical support.

John Ballato and Liang Dong, Clemson University
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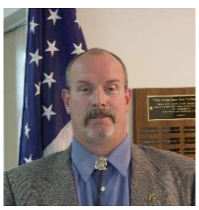
Plenary Speakers

Optical Fiber and Glasses (101)

Wednesday, November 6, 8:05 – 8:55 AM

Nicholas Borrelli, *Corning Incorporated, USA*

Nicholas Borrelli received an MS (1960) and the PhD (1963) in engineering from the University of Rochester (New York). His thesis studied the interpretation of the IR spectra of borate glasses. He started at Corning in 1962 as a research scientist. His first project involved the study of Nd:Glass Lasers. Corning was the second laboratory in the world to demonstrate laser action in glass. He subsequently worked on early aspects of laser communication, such as optical modulators and optical isolators. Dr. Borrelli also worked on projects related to the first optical fiber, which was being developed at Corning at that time. He later moved to the study of photochromic and photosensitive glass, which led to two Corning products: a polarizing glass called Polarcor™ and a Serengeti™ sunglass. Dr. Borrelli has published more than 150 technical journal articles and holds 167 U.S. Patents. He recently received the President's Award from the International Commission on Glass (ICG) given for lifetime achievement in glass science.

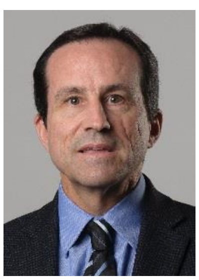


Defense Applications of High Power Fiber Lasers

Thursday, November 7, 8:00 – 8:50 AM

Mark Neice, *Directed Energy Professional Society, USA*

Mark Neice is the Executive Director of the Directed Energy Professional Society (DEPS). DEPS fosters research and development in Directed Energy, to include high-energy laser and high-power microwave technologies for national defense and civilian applications, through professional communication and education. Mr. Neice is twice retired from the federal government; the last time in December 2012, after 37 years of military and civilian service. He previously retired from the US Air Force, as a Colonel, in October 2004.



Bright Perspective for Fluoride Glass Mid-Infrared Fiber Lasers

Friday, November 8, 8:00 – 8:50 AM

Réal Vallée, *Laval University, Canada*

Réal Vallée received the Ph.D. in physics from Université Laval in 1986. He then joined the Laboratory for Laser Energetics, at the University of Rochester as a Postdoctoral Fellow. In 1989, he returned to Université Laval to begin his career as a Professor in the Department of Physics. In 2000, he was appointed Director of the Center for Optics Photonics and Lasers (COPL), a position he holds to this day. Under his leadership the COPL has grown from a Université Laval-based laboratory to a multidisciplinary strategic cluster of 42 researchers in 8 universities in Quebec. Professor Vallée contributes to this outcome having supervised over 80 graduate students so far. His research interests centre on optical fibers, optical components and their applications, visible and infrared fiber lasers, non-linear effects, short pulse propagation in fibers, waveguide and Bragg grating writing with femtosecond pulses, and the study of chalcogenide glasses for integrated optics applications. He currently holds an NSERC Industrial Research Chair in Femtosecond Photo-Inscribed Photonic Components and Devices. Professor Vallée has authored over 200 papers in peer-reviewed journals and international conferences and holds 12 patents. Since 2010, three companies have been spun off research conducted in his lab.

General Information and Special Events

Guide to Presenters

Poster Presenters

Please set up your poster in the Wraggoborough and Halston rooms after 3:30pm on Wednesday, 6 November. The poster session is from 6:00pm to 9:00pm. All posters should be taken down by their authors at the end of the poster session. Award presentations will immediately follow the poster session.

Oral Presenters

Please ensure that your talk is loaded on the Stono Ballroom computer prior to the start of your session. Speakers are expected to stay within your allocated time, leave time for questions, and respect session chairs instructions.

Special Events

Poster Session and Welcome Reception

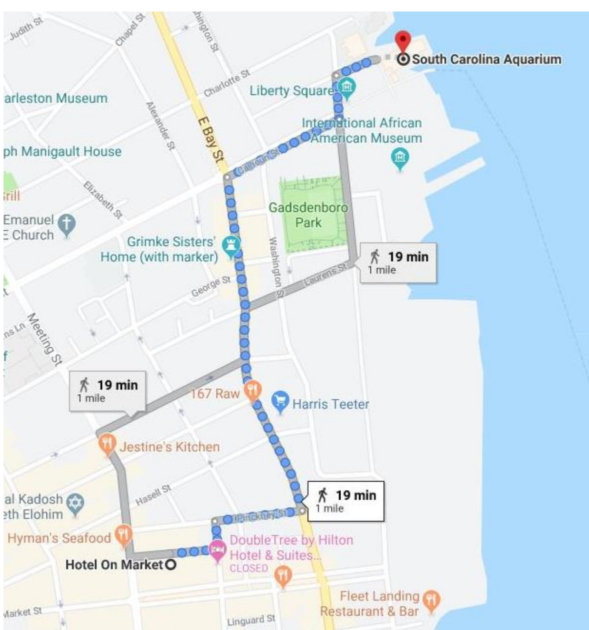
Wednesday, 6 November 2019
Time: *6:00pm – 9:00pm*
Location: *Hotel on Market (Wraggoborough and Halston Rooms)*

The Welcome Reception is combined with the Poster Session. This event is to showcase the student posters and allow time to talk with colleagues and peers. All registrants are encouraged to participate. The student award presentation will immediately follow the poster session.

Conference Banquet

Thursday, 7 November 2019
Time: *6:30pm – 9:00pm*
Location: *South Carolina Aquarium (directions below)*

The Conference Banquet is a relaxing evening of conversation, good food, and exploring the South Carolina Aquarium, which overlooks the Charleston Harbor. This event is included for all WSOF registrants. Accompanying tickets can be purchased at the registration table for $50/person.



<u>Starting point: 35 Hayne St, Charleston, SC 29401</u>
Approx. 20 min walk

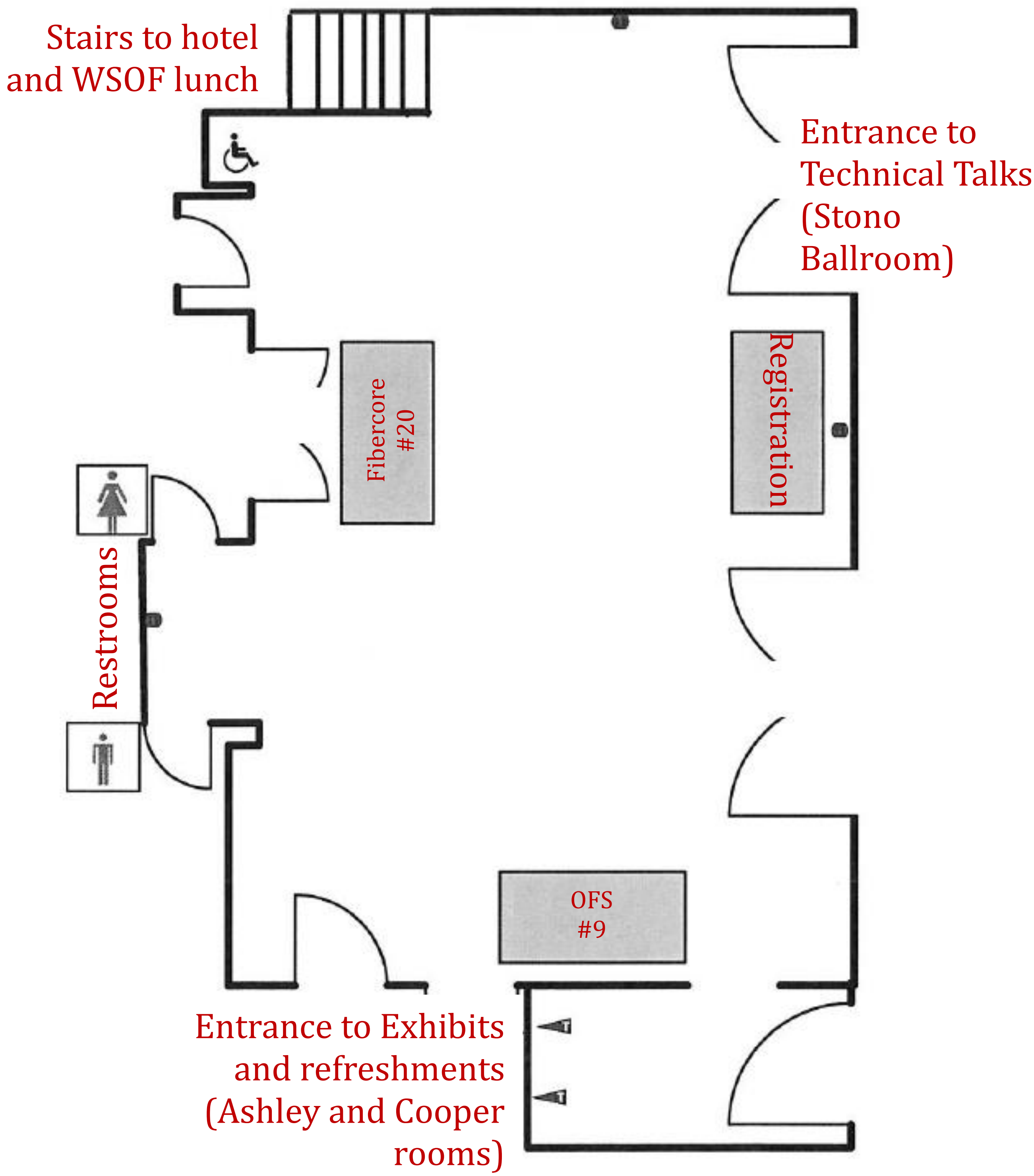
- Head east on Hayne St toward Church St – *338 ft (103 m)*
- Turn left onto Church St – *197 ft (60 m)*
- Turn right onto Pinckney St – *0.1 mi (.16 km)*
- Turn left onto E Bay St – *0.5 mi (.8 km)*
- Turn right onto Calhoun St – *0.2 mi (.32 km)*
- Turn left onto Concord St – *302 ft (92 m)*
- Turn right onto Aquarium Wharf – *302 ft (92 m)*

<u>Ending point: SC Aquarium, 100 Aquarium Wharf, Charleston SC 29401</u>

Other options besides walking are:

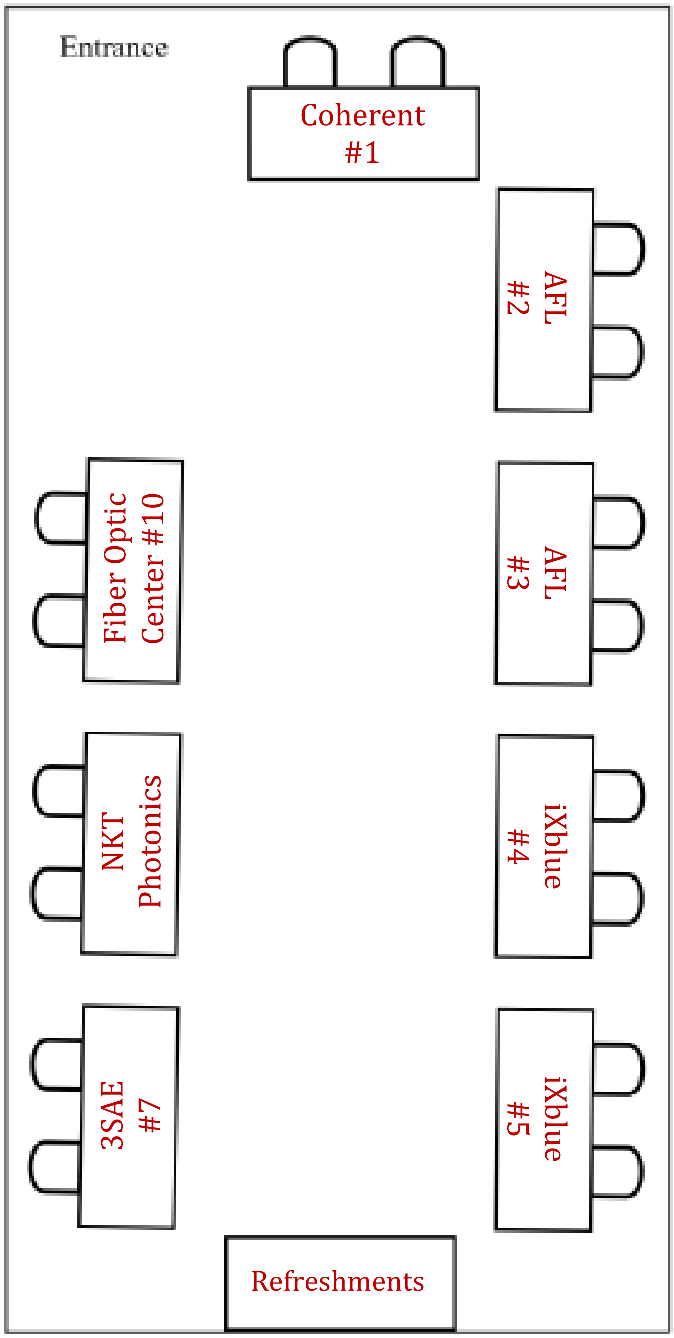
- Driving (parking is at driver's expense)
- Uber (approx. $6-$10 for 6-10 min ride)
- Lyft (approx. $6-$12 for 6-10 min ride)

Stono Foyer

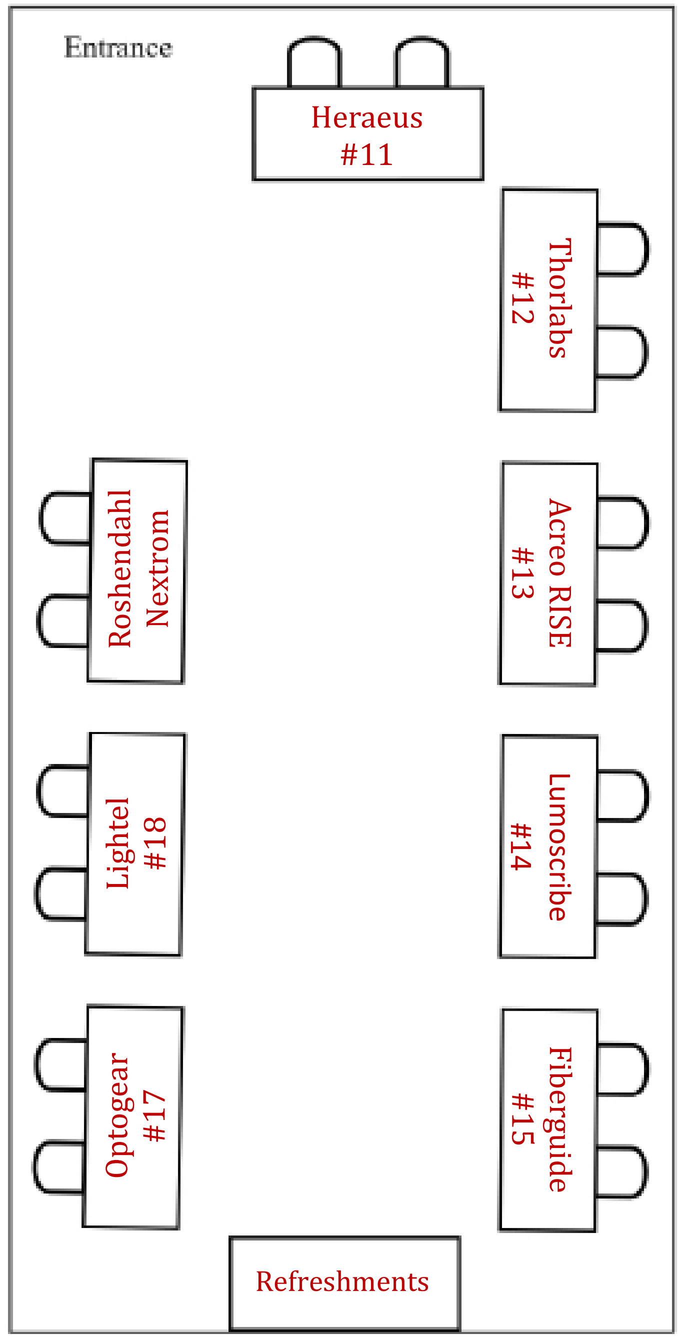

Stairs to hotel and WSOF lunch
Entrance to Technical Talks (Stono Ballroom)
Fibercore #20
Registration
Restrooms
OFS #9
Entrance to Exhibits and refreshments (Ashley and Cooper rooms)

Exhibitor

Ashley



Cooper



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www.aflglobal.com

AFL offers a wide range of Verrillon® optical fibers for harsh environments, specialty applications, polarization-maintaining and communications fibers as well as Fujikura's unique specialty fiber components and assemblies for medical, laser and harsh industrial applications. We uniquely design optical fibers and components that are widely deployed in sensing and communications applications. Additionally, AFL offers an extensive lineup of fusion splicers for specialty splicing applications, including the LAZERMaster® laser splicers, the most versatile fusion splicers in the world.

Fibercore

United Kingdom

www.fibercore.com

Founded 1982, Fibercore is a leading innovator, designer and manufacturer of specialty fiber serving customers across the world. Products include specialty fiber for the Aerospace, Defense, Telecommunications, Oil and Gas, Energy, Medical and Fiber Laser industries – the business is a global market leader. The company's operations are headquartered in Fibercore House, a custom built Southampton based facility in the UK. Fibercore has four Queen's Awards for Enterprise.

iXblue

France

www.photonics.ixblue.com

iXblue Photonics helps photonics engineers all around the world to get the most out of the light by providing high performance, innovative and reliable photonic solutions. We offer specialty fibers, bragg gratings and optical modulation solutions based on the company integrated modulators for a variety of applications including: optical communications, fiber lasers and amplifiers, fiber optics sensors, space and sciences.

OFS

United States

www.ofsoptics.com

OFS is a world-leading designer, manufacturer and provider of optical fiber, fiber optic cable, connectivity, fiber-to-the-subscriber (FTTX) and specialty photonics products. We provide reliable, cost-effective solutions for a broad range of applications including telecommunications, medicine, industrial automation, sensing, government, aerospace and defense. These products help our customers meet the needs of consumers and businesses, both today and into the future.

Headquartered in Norcross (near Atlanta) Georgia, U.S.A., OFS is a global provider with facilities in China, Denmark, Germany, Russia and the United States. OFS is part of Furukawa Electric Company, a multi-billion dollar leader in optical communications.

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Founded in 1966, Coherent, Inc. is one of the world's leading providers of lasers and laser-based technology for scientific, commercial and industrial customers. With headquarters in the heart of Silicon Valley, California, and offices spanning the globe, Coherent offers a unique and distinct product portfolio and services for scientific research, life sciences, microelectronics, and materials processing.

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www.focenter.com

Fiber Optic Center is an international leader in distributing fiber optic components, equipment and supplies and has been helping customers make the best cable assemblies in the world for over two decades. Fiber Optic Center's outstanding and personal customer service, low or no minimum purchase order values, and from-stock delivery on industry-leading products and technology make them the preferred choice for many of the world's fiber professionals. Fiber Optic Center is the industry connection to the most innovative optical products, technologies and technical experts who integrate their manufacturing knowledge and vast experience into customers' worldwide operations. @FiberOpticCntr

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NYFORS is an innovative supplier of advanced glass processing and preparation equipment for specialty optical fiber splicing operations. We supply reliable and precise solutions tailored to the individual challenges of our customers. Our systems are highly automated leading to consistent, high yield production for both high and low volume.

NYFORS currently offers the industry's only vertical CO_2 laser splicing and glass shaping, fiber end and window strippers, cleavers, recoaters, proof testers, and fiber or ferrule end face inspection interferometers. We also provide sub-micron automatic machine vision alignment systems for optical component manufacturing as well as custom solutions and work cell automation. Our product portfolio is continuously expanding to meet emerging requirements.

Rosendahl Nextrom

Finland

www.rosendahlnextrom.com/fiber-optics

Nextrom is the leading global supplier of manufacturing solutions for optical fibers and fiber optic cables. Our core competences include solutions for optical glass making, fiber drawing, fiber coating, ribbon making, proof testing and fiber optic cable production. Our technology is used for producing telecom and specialty preforms and fibers. From first contact onwards, we provide customized high quality solutions and personal support to ensure total customer satisfaction. Nextrom is a business unit of Rosendahl Nextrom GmbH.

Thorlabs

United States

www.thorlabs.com

Thorlabs has been proud to serve the photonics industry for 30 years with a broad portfolio of optomechanics, motion control, light sources, optics, instrumentation, and optical fiber. We manufacture and stock a full line of single mode, polarization maintaining, multimode, and specialty fibers. For UV to mid-IR spectral range, we manufacture single mode and multimode fluoride fibers. Custom patch cables with a variety of connectors can be ordered through our website, and most ship the same day the order is placed. Our fiber components product line includes wideband and narrowband fused fiber couplers, WDMs, and fiber optic isolators.

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Heraeus

Germany

www.heraeus.com/en/hca/fused_silica_1/home_hca.html

Heraeus Conamic is one of the technology leaders and materials specialists for the manufacture and processing of high purity fused silica and high-end ceramics. The organization excels in all key processes for producing natural fused quartz and synthetic fused silica for the semiconductor and photonics industry. Additionally, high-end materials like ceramics and composites are within our material focus. With locations around the globe, Heraeus Conamic offers fused silica and ceramic products ranging from semi-finished goods to complex system components to custom-tailored solutions. For specialty fiber applications operating from deep UV to Near IR range Heraeus provides performance fused silica products.

Exhibitors

3SAE

United States

www.3sae.com

3SAE Technologies Inc., headquartered in Franklin, Tennessee, is a company with focus and expertise in developing new fiber optic tools and technologies for optical fiber fusion splicing and related applications. The company holds multiple patents and awards related to optical fiber glass processing, fusion splicing and fiber preparation. 3SAE products are used at many of the world's leading photonics, aerospace, military research, and university facilities. These products include custom built, high-reliability optical component assemblies. Since its inception 3SAE has provided advanced fiber optic fusion splicing & fiber preparation solutions and introduced product innovations that enabled a host of new capabilities.

Fiberguide Industries

United States

www.fiberguide.com

Fiberguide Industries is a reliable, long-term, strategic partner with OEM manufacturers in providing efficient, cost-effective, practical fiber optic solutions engineered to meet their specific needs. We specialize in manufacturing large core specialty optical fiber, high temperature metalized optical fibers, and we package these fibers in a variety of assemblies / bundles used for optical power delivery and optical sensing applications. With Corporate headquarters and assembly manufacturing located in Caldwell, Idaho; fiber manufacturing located in Stirling, New Jersey; as well as a sales office and manufacturing in Shanghai, China; Fiberguide Industries is well positioned to serve the needs of our global customers.

Lightel

United States

www.lightel.com

For 20 years, Lightel has designed, manufactured, and supplied a broad range of products and services to the fiber optic industry worldwide. Starting out with coupler workstations for manufacturing fused biconic taper products, Lightel has expanded into fused fiber components (splitters, WDMs, combiners), micro-optic passive optical components (CWDMs, DWDMs, isolators, circulators), video microscopes for inspection purposes, and many other fiber optic related products. Lightel also offers in-house fiber optic design and manufacturing services and our technology innovations have resulted in many US Patents awarded. Ask about our new auto-focus fiberscope and plasma-powered multifiber stripper.

Lumoscribe

Cyprus

www.lumoscribe.com

LUMOSCRIBE LTD is an R&D company located in Cyprus that specializes in the development of custom-made optical fiber sensors and fiber lasers, while we are working on niche optical sensing solutions using Artificial Intelligence. LUMOSCRIBE LTD and Cyprus University of Technology are strategic partners, and our company has exclusive access to IP related to FBG inscription. The particular IP offers high controllability with respect to FBG inscription, which is critical for monolithic fiber lasers and optical fiber sensors in specialized materials.

Our VISION is to be a leading optical sensing and fiber laser company, providing high-value services, and intelligent sensing solutions.

NKT Photonics

Denmark

www.nktphotonics.com

NKT Photonics is the leading supplier of high-performance fiber lasers, fiber optic sensing systems, and photonic crystal fibers. Our main markets are within imaging, sensing and material processing. Our products include ultrafast lasers, supercontinuum white light lasers, low noise fiber lasers, distributed temperature sensing systems and a wide range of specialty fibers. NKT Photonics has its headquarters in Denmark with sales and service worldwide. NKT Photonics is wholly owned by NKT A/S.

Optogear

Finland

www.optogear.fi

Optogear offers equipment and technologies for photonics industry. Our products enable superior quality fiber optic products made by the world leading companies of the industry. Our flexible way of working allows us to bring new products to the market using the most advanced technologies. Modern industrial design, close co-operation with our worldwide partner network and attention to customer feedback ensure both excellent usability and exceptional performance of our products.

RISE Acreo

Sweden

www.sp.se/en/Sidor/default.aspx

RISE Acreo Fiberlab is a purpose-built facility for research, development and production of advanced optical fibers and capillaries. Visit our booth to discuss our ultrathin (25µm cladding) fibers, our processes for hermetic carbon and other specialty coatings, or other challenging fibers we can develop together. Let's also discuss fiber optic components and sensors, for example our all-fiber optofluidic systems and electrooptic fibers!

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Germany

www.fiberbridge-photonics.com

FiberBridge Photonics develops, manufactures and sells customized fused fiber components, fiber amplifier modules and fiber processing machines. For manufacturing of combiners, couplers, tapers, end caps, mode field adapters and fiber arrays FiberBridge Photonics uses industry-proven CO_2 laser technology. Our optical fiber glass processing machines enables precise and reliable fabrication of fused fiber components with single-mode, hollow-core, large-mode area, photonic crystal, multicore, soft glass, and beam delivery fibers.

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The Center for Optical Materials Science and Engineering Technologies (COMSET), formed in 2000, is an interdisciplinary unit of the College of Engineering at Clemson University. COMSET provides an organized framework with significant centralized infrastructure for researchers with common interests to collaborate in developing advanced materials, devices and systems that generate, transmit, manipulate and utilize light.

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SPIE is the international society for optics and photonics, an educational not-for-profit organization founded in 1955 to advance light-based science, engineering, and technology. The Society serves 257,000 constituents from 173 countries, offering conferences and their published proceedings, continuing education, books, journals, and the SPIE Digital Library. In 2019, SPIE will provided more than $5 million in community support including scholarships and awards, outreach and advocacy programs, travel grants, public policy, and educational resources.

Tuesday 5 November 2019	
Time	***Session***
3:00 - 5:00 PM	Registration

Wednesday 6 November 2019	
7:00 - 8:00 AM	Registration
Time	***Session***
8:00 - 8:05 AM	Opening Remarks
8:05 - 8:55 AM	Plenary - Nicholas Borrelli (Corning)
8:55 - 10:30 AM	Fiber Lasers I
10:30 - 11:00 AM	COFFEE BREAK AND EXHIBIT *(Ashley and Copper Rooms)*
11:00 - 12:30 PM	IR Fibers and Sources I
12:30 - 2:00 PM	LUNCH BREAK *(Wraggoborough and Halston Rooms)*
2:00 - 3:20 PM	Fiber Sensors I
3:20 - 3:50 PM	COFFEE BREAK AND EXHIBIT *(Ashley and Copper Rooms)*
3:50 - 5:25 PM	Fiber Devices
6:00 - 9:00 PM	**Poster Session and Welcome Reception** Poster Awards to follow *(Wraggoborough and Halston Rooms)*

Thursday 7 November 2019	
Time	***Session***
8:00 - 8:50 AM	Plenary - Mark Neice (DEPS)
8:50 - 9:40 AM	Fiber Lasers II
9:40 - 10:10 AM	COFFEE BREAK AND EXHIBIT *(Ashley and Copper Rooms)*
10:10 - 11:35 AM	Hollow-core Fibers
11:35 - 1: 05 PM	LUNCH BREAK *(Wraggoborough and Halston Rooms)*
1:05 - 3:05 PM	Fiber Fabrication I
3:05 - 3:35 PM	COFFEE BREAK AND EXHIBIT *(Ashley and Copper Rooms)*
3:35 - 5:45 PM	Fiber Fabrication II
6:30 - 9:00 PM	**Conference Banquet** *(SC Aquarium)*

Friday 8 November 2019	
Time	***Session***
8:00 - 8:50 AM	Plenary - Réal Vallée (Laval)
8:50 - 9:55 AM	IR Fibers and Sources II
9:55 - 10:25 AM	COFFEE BREAK AND EXHIBIT *(Ashley and Copper Rooms)*
10:25 - 12:05 PM	Fiber Lasers III
12:05 - 1:35 PM	LUNCH BREAK *(Wraggoborough and Halston Rooms)*
1:35 - 2:55 PM	Fiber Sensors II
2:55PM	Concluding Remarks
Conference End	

Wednesday, 6 November 2019

8:00 – 8:05 AM • Opening Remarks – John Ballato

8:05AM ***Plenary***

Optical fiber and glasses (101)

Nicholas Borrelli

Corning Incorporated

This presentation is essentially a retrospective of my 50 years of experience in the field of optical materials while working at the Corning Incorporated Research Laboratory. This time period happily coincided with the emergence of what could be termed the "optical revolution." It began with the laser then the optical fiber and subsequently to all the materials and devices that are related to the present ubiquitous optical network. A number of the topics in addition to fibers will be briefly covered such as, photonic crystal fibers, nonlinear optical glass, quantum dots and polarizing glasses.

8:55 – 10:30 AM

Session: Fiber Lasers I

Chair: Michael Messerly, Lawrence Livermore National Lab, USA

8:55AM ***Invited***

Next Generation of DC fibers enabling high performance and reliability of industrial fiber lasers beyond 1.5kW levels

Clemence Jollivet, Joshua Bradford, Mike Conroy, Adrian Carter, and Kanishka Tankala

Coherent/Nufern, 7 Airport Park Rd., East Granby, CT 06026

Stimulated Raman scattering and transverse mode instability thresholds are currently limiting the maximum output power of industrial fiber lasers around 1.5kW. To further power scale, the choice of Large-Mode-Area Yb-doped double-clad Fiber combined with pumping wavelength is critical. Design guidelines are discussed to maximize the achievable output power of single-cavity fiber oscillators and predict that up to 3 kW is achievable.

9:20AM ***Invited***

Fiber lasers and amplifiers for space lidar applications

Anthony W. Yu

NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

We present current and near-term applications of high-power fiber lasers and amplifiers for NASA science and spacecraft applications. All previously flown missions are based on matured diode pumped solid-state laser transmitters. In recent years we have been exploring the fiber-based transmitter technologies for remote sensing instruments with goals toward space deployment. For instance, due to the spectroscopic nature of trace-gas lidar, and the wavelength region of interest, a fiber-based laser transmitter with a tunable front end is a more appropriate choice. Fiber-based lasers offer a number of attractive advantages for space but since they are relatively new, challenges exist in developing instruments based on them. Our current fiber-based lasers and amplifiers portfolio include laser sounders and lidars for trace gas sensing, laser communications, astrophysics, altimetry and other applications. We discuss recent experimental progress on these systems and instrument prototypes for ongoing development efforts.

9:45AM

2 MW peak power ultrashort pulse amplification using tapered powder-sintered all-solid fibers: Fiber designs, technology, and results

Martin Leich[1], André Kalide[1], Tina Eschrich[1], Martin Lorenz[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], Yuhtat Cho[3], Andy Malinowski[3], Fabio Ghiringhelli[3], Andrew Marshall[3], Mike Durkin[3], and Matthias Jäger[1]

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We investigate various all-solid fiber designs featuring very large core-to-clad ratios and powder-sintering technology for ultrashort pulse amplification up to 2MW peak power. Using short tapered amplifiers beam qualities of M^2 ≈1.5 and better have been achieved.

10:00AM

Fabrication of vapor phase large core Yb doped preform with precise index control for the development of VLMA active fibers

Thierry Taunay[1], O. Le Goffic[1], D. Landais[1], A. Monteville[1], L. Provino[1], A. Haboucha[1], A. Barnini[2], P. Guitton[2], G. Guiraud[3], and N. Traynor[3]

[1] Photonics Bretagne, 4 rue Louis de Broglie, 22300 Lannion, France; [2] IXBLUE Photonics, Rue Paul Sabatier, 22300 Lannion, France; [3] Azur Light Systems, 11 Avenue de Canteranne,

We report on the successful fabrication of very low NA Yb doped preforms using a commercial vapor phase delivery system using chelates precursors as rare earth sources. Two preforms with low NA~0.035 were drawn to 44 µm core step index double clad PM fibers capable of operating with truly single mode regime when coiled to the proper diameter. In addition careful optimization of the glass composition with an Al_3PO_4 glass matrix enables essentially photodarkening free operation. Kilometer long uniform Yb doped PM PERFOS® fibers with mode field diameter and effective of 33 µm and 880 µm² were successfully fabricated.

10:15AM

Highly Tm^{3+} doped germanate glass and associated double clad fiber for 2 μm lasers and amplifiers

Fedia B. Slimen, Zhengqi Ren, Andrea Ventura, Juliano Grigoleto Hayashi, Jaroslaw Cimek, Nicholas White, Yongmin Jung, David Richardson, and Francesco Poletti

Optoelectronics Research Centre, University of Southampton, SO17 1BJ, UK

We report on the optimization of Tm^{3+} concentration in Tm^{3+} doped germanate single mode (SM) fibers. A record value of 8.5×10^{20} ions/cm³ (5.1 wt%) has been achieved. The fiber produced is promising for high power ultrashort fiber device applications.

10:30 – 11:00 AM • Coffee Break and Exhibit – *Ashley and Copper Rooms*

11:00 AM – 12:30 PM

Session: IR Lasers and Sources I

Chair: Francois Chenard, IRflex Corporation, USA

11:00AM ***Invited***

Soft glass microstructured optical fibers and their applications

Yasutake Ohishi

Research Center for Advanced Photon Technology, Graduate School of Engineering, Toyota Technological Institute, 2-12-1 Hisakata, Tempaku-ku, Nagoya, 468-8511, Japan

We demonstrate the mid-infrared supercontinuum generation in the normal dispersion regime by using a chalcogenide double clad fiber pumped with femtosecond pulse, and mid-infrared wavelength conversion using a chalcogenide suspended-core fiber pumped with pico-second pulse.

11:25AM ***Invited***

Progress in Mid-IR supercontinuum sources and their applications: an overview

Peter M. Moseund, Joanna Carthy, Laurent Huot, and Patrick Bowen

NKT Photonics A/S, Blokken 84 - DK-3460 Birkerød – Denmark

In this talk we will summarize the areas where mid-IR supercontinuum has been applied and demonstrated its strength since its commercial breakthrough two years ago and where we expect its application to grow in the coming years.

11:50AM ***Invited***

Optical devices based on chalcogenide fibers

Martin Rochette

Department of Electrical and Computer Engineering, McGill University, Montréal (QC), Canada, H3A 2A7

This talk features recent achievements of the Nonlinear Photonics Group at McGill University towards the fabrication of chalcogenide-based mid-infrared optical fiber components such as nonlinear gain fibers, optical fiber couplers and optical fiber filters.

12:15PM

Design of single-mode nanohole suspended-core fibers for all-normal dispersion supercontinuum generation

Matthias Jäger, Alexander Hartung, Jörg Bierlich, Adrian Lorenz, and Jens Kobelke

Leibniz-Institute of Photonic Technology, Albert-Einstein-Straße 9, 07745 Jena, Germany

Suspended-core optical fibers are designed to be all-normal dispersive and single-mode by a proper sizing of a central hole and the suspending struts. Realization strategies are discussed particularly regarding material composition and fabrication sequence and finally tested.

12:30 – 2:00 PM • Lunch Break – *Wraggoborough and Halston Rooms*

2:00 – 3:20 PM

Session: Fiber Sensors I

Chair: Paul Westbrook, OFS, USA

2:00 PM ***Invited***

Novel optical fiber for cochlear implants

Hwa-Yaw Tam[1], Zhengyong Liu[1], Dinusha Serandi Gunawardena[1], Arvind N Vadivelu[2,3], Bernard Chen[3], Denny Oetomo[2], and Stephen O'Leary[3]

[1]Photonics Research Centre, Department of Electrical Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China; [2]Department of Mechanical Engineering, University of Melbourne, Parkville, VIC 3010, Australia; [3]Department of Otolaryngology, University of Melbourne and the Royal Victorian Eye and Ear Hospital, VIC 3002, Australia

We report the application of low-bending loss fibers inscribed with fiber Bragg grating sensor arrays integrated inside a cochlear implant's electrode array for contact force measurement to reduce insertion trauma during cochlear surgery.

2:25 PM ***Invited***

Enhanced fibers for distributed sensing

Paul Westbrook[1], Ken Feder[1], Tristan Kremp[1], Hongchao Wu[1], Wing Ko[1], Roy Ortiz[1], Eric Monberg[1], and Debra Simoff[2]

[1]OFS Labs, Somerset NJ; [2]OFS, Avon, CT

We discuss the use of enhanced fibers in distributed sensing applications. Processing of fibers over lengths from 1 m to more than 1 km can increase the signal to noise ratio in many sensing applications. We discuss enhancements observed with optical frequency domain reflectometry. Applications include temperature, strain, shape and position sensing, and distributed acoustic sensing.

2:50 PM

500°C-rated optical fibers for high temperature applications

William Jacobsen, Abdel Soufiane, and John D'Urso

AFL Specialty Fibers, 15 Centennial Drive, North Grafton, MA, United States

Optical fibers for high temperature applications (> 300°C) have typically been metal-coated. These fibers suffer high attenuation (> 10 dB/km), and are limited in length. This paper describes a low-attenuation metal-coated fiber operating at temperatures up to 500°C.

3:05 PM

Carbon-coated optical fiber performance in hydrogen

William Jacobsen and Abdel Soufiane

AFL Specialty Fibers, 15 Centennial Drive, North Grafton, MA, United States

A study of the lifetime of carbon-coated optical fibers is presented. Multimode fibers are interrogated in a chamber containing hydrogen, at three different temperatures. Lifetime results are calculated. Results show that carbon is effective as a hydrogen barrier up to 150°C.

3:20 – 3:50 PM • Coffee Break and Exhibit – *Ashley and Copper Rooms*

3:50 – 5:25 PM

Session: Fiber Devices

Chair: Kyriacos Kalli, Cyprus University of Technology, Cyprus

3:50 PM ***Invited***

Photonic lanterns: Beyond telecoms

Stephanos Yerolatsitis[1], Aurélien Benoît[2], Kerrianne Harrington[1], Robert R. Thomson[2], and Tim A. Birks[1]

[1]Department of Physics, University of Bath, Claverton Down, Bath BA2 7AY, UK; [2]SUPA, Institute of Photonics and Quantum Sciences, Heriot-Watt University, Edinburgh, EH14 4AS, UK

Photonic lanterns, applied in areas such as telecommunications, astronomical and biomedical instrumentation, provide a way to bridge multimode and multicore channels. Here, we discuss the fabrication and potential uses of a six-mode mode selective photonic lantern.

4:15 PM ***Invited***

History and advancements of FBG manufacturing in specialty optical fibers and their use in sensing

Eric Linder

FBGS Technologies, GmbH (Germany)

The talk will review historic and latest advancements of FBG manufacturing in specialty optical fibers and their use in sensing technology. Furthermore we will give an outlook on future sensing applications using specialty optical fibers.

4:40 PM

Wedge-shaped fiber lenses with CO_2 laser glass ablation

Gongwen Zhu and Wenxin Zheng

AFL, 260 Parkway East, Duncan, SC, USA 29334

We present a novel method of fabricating wedge-shaped fiber lenses with CO_2 laser glass ablation. Compared with conventional method of fiber polishing, CO_2 laser glass ablation is a chemical free, contamination-free, noncontact manufacturing process which provides scratch-free microstructured fiber tips.

4:55 PM

Femtosecond laser inscribed gratings for monolithic MIR fiber lasers

Antreas Theodosiou[1,2], Jan Aubrecht[3], Nithyanandan Kanagaraj[3], Pavel Peterka[3], Pavel Honzátko[3], Andreas Stassis[4] and Kyriacos Kalli[1]

[1]Photonics & Optical Sensors Research Laboratory, Cyprus University of Technology, Nicolaou Saripolou 33, 3036, Limassol, Cyprus; [2]Lumoscribe LTD, Margatitas Liasidou 12, 8036, Paphos Cyprus; [3]Institute of Photonics and Electronics of the CAS, v.v.i., Chaberská 57, 18251 Prague, Czech Republic; [4]Department of Mechanical Engineering Cyprus University of Technology Nicolaou, Kitiou Kiprianou 45, 3041 Limassol, Cyprus

We present our recent developments regarding monolithic fibre lasers, incorporating gratings as reflectors and polarizing elements via the plane-by-plane femtosecond laser inscription method. Designs are considered for continuous and pulsed laser operation in the mid-infrared wavelength range.

5:10 PM

Fibre cladding filters through femtosecond laser inscription

Kyriacos. Kalli[1], A. Theodosiou[1], and A. Ioannou[1,2]

[1]Photonics and Optical Sensors Research Laboratory, Cyprus University of Technology, Limassol, Cyprus; [2]University of Mons, 7000, Belgium

We inscribe several in-cladding-fiber filters using the same key femtosecond laser parameters, via an “inscribe and step”, plane-by-plane (Pl-by-Pl) approach, leading to ultra-compact waveguides and Mach Zehnders (MZs) that can support functional, integrated fiber Bragg gratings (FBGs).

6:00 – 9:00 PM
Poster Session with Awards Ceremony and Welcome Reception
Wraggoborough and Halston Rooms

Poster 1

Data acquisition from a bundle of 1,000 optical fibers

David Ward

SemQuest Inc.

In existing fiber technology areas there are multi-core fibers or fiber bundles which can be used for applications such as endoscopic imaging. Those systems enable transmission of imagery from one end of the cable to the other by utilizing one optical channel for each fiber core “pixel”. In those systems, a number of imaging technologies can be utilized such as CCD or CMOS imagers in order to receive the optical information. However, when each fiber contains uncorrelated data at high bandwidth these techniques can limit the system. The bandwidth of any fiber in the system is limited to the frame rate of the imager and in addition, all pixels in the imager are sampled regardless of a fiber being present in that portion of the imaging array.

Poster 2

Fabrication of a tellurite hollow core optical fiber for mid-infrared transmission

Tong Hoang Tuan, Nobuhiko Nishiharaguchi, Takenobu Suzuki, and Yasutake Ohishi

Research Center for Advanced Photon Technology, Toyota Technological Institute, 2-12-1 Hisakata, Tempaku, Nagoya, 468-8511, Japan

We experimentally demonstrated a successful fabrication of a tellurite hollow core optical fiber with 6 non-touching air holes in the cladding to obtain low loss transmission up to 6 μm in mid-infrared region.

Poster 3

3D printed optical fiber preforms from silica contained resin

John Canning[1], Yushi Chu[1,2,4], Xinghu Fu[2,3], Yanhua Luo[2], Kevin Cook[1], Jianzhong Zhang[4], and Gang-Ding Peng[2]

[1] interdisciplinary Photonic Laboratories (iPL), Tech Lab, School of Electrical and Data Engineering, University of Technology Sydney, Sydney, NSW 2007 & 2019, Australia; [2]Photonics and Optical Communications, School of Electrical Engineering and Telecommunications, University of New South Wales, Sydney, NSW 2052, Australia; [3]The Key Laboratory for Special Fiber and Fiber Sensor of Hebei Province, School of Information Science and Engineering, Yanshan University, Qinhuangdao, 066004, China; [4]Key Lab of In-Fiber Integrated Optics of Ministry of Education, School of Science, Harbin Engineering University, Harbin, 150001, China

3D printed glass optical fiber preforms have been fabricated from silica containing resin. The fabrication process includes resin preparation, preform printing, debinding and sintering. Results demonstrate the silica concentration greatly influenced on the transmittance of resin and shape of preforms.

Poster 4

Wavelength dependence of transverse Anderson localization in disordered glass-air fiber

Axel Schülzgen[2], Paul Roth[1], Gordon K. L. Wong[1], Jian Zhao[2], Jose Enrique Antonio-Lopez[2], Rodrigo Amezcua-Correa[2], Michael H. Frosz[1], and Philip St. J. Russell[1,3]

[1]Max Planck Institute for the Science of Light, Staudtstr. 2, 91058 Erlangen, Germany; [2]CREOL, College of Optics and Photonics, University of Central Florida, Orlando, FL 32816, USA; [3]Department of Physics, University of Erlangen-Nuremberg, Staudtstr. 2, 91058 Erlangen, Germany

Wavelength-independent transverse localization of light propagating through disordered glass-air fibers is observed from 540nm to 1600nm. The effect opens the door to the transmission of color images through fibers in fluorescence imaging and endoscopy with white light illumination.

Poster 5

Noise-like pulse pumped all-fiber supercontinuum laser source

Xing Luo, Tong Hoang Tuan, Than Singh Saini, Hoa Phuoc Trung Nguyen, Takenobu Suzuki, and Yasutake Ohishi

Research Center for Advanced Photon Technology, Toyota Technological Institute, 2-12-1 Hisakata, Tempaku, Nagoya, 468-8511, Japan

Flat supercontinuum spanning from 1370nm to 2200nm with the direct pumping of a noise-like pulse mode locked fiber laser was demonstrated. The all-fiber supercontinuum source has very flat spectrum and weak residual-pump.

Poster 6

Designing silicon fiber tapers for efficient mid-IR supercontinuum

Joseph Campling, P. Horak, and A. C. Peacock

Optoelectronics Research Centre, University of Southampton, UK SO17 1BJ

We simulate supercontinuum generation for mid-infrared spectroscopy in three silicon fiber taper designs, demonstrating that a 2.1μm fiber laser input can be efficiently converted to the 3 – 4.5μm spectral range.

Poster 7

Heat mitigation via anti-Stokes fluorescence cooling in core/cladding Yb-doped fiber amplifiers

Esmaeil Mobini, Mostafa Peysokhan, and Arash Mafi

Department of Physics & Astronomy, University of New Mexico, Albuquerque, NM 87131, USA and Center for High Technology Materials, University of New Mexico, Albuquerque, NM 87106, USA

Radiation-balancing is proposed to offset the heating in a laser via anti-Stokes fluorescence cooling. Here, we report a core/cladding ion-doped fiber amplifier where the radiation-balancing can efficiently offset the generated heat in high-power operation.

Poster 8

Measuring the anti-Stokes cooling parameters of a Yb-doped ZBLAN fiber for radiation balancing

Mostafa Peysokhan, Esmaeil Mobini, and Arash Mafi

Department of Physics & Astronomy, University of New Mexico, Albuquerque, NM 87131, USA and Center for High Technology Materials, University of New Mexico, Albuquerque, NM 87106, USA

Anti-Stokes fluorescence cooling can mitigate the generated heat in fiber lasers. Performing various tests on a ytterbium-doped ZBLAN fiber, we show that the ZBLAN glass is a viable host material for implementation in radiation-balanced laser.

Poster 9

Investigation of Low-Bending-Loss Single-Mode Anti-resonant Hollow-core THz Fiber

Wei Shi, Shuai Sun, Quan Sheng, Guo Zhang, Yao Zhang and Jianquan Yao

College of Precision Instrument and Optoelectronics Engineering, Tianjin University, Tianjin 300072, China and Tianjin Institute of Modern Laser & Optics Technology, Tianjin 300384, China

An anti-resonant hollow-core THz fiber with six half-ellipse cladding tubes is demonstrated. The high order mode suppression in the hollow core fiber with half-ellipse cladding tubes is investigated. By optimizing the cladding tube, single mode and low bending loss characteristics are achieved.

Poster 10

Low-loss terahertz pulse transmission through commercially available porous tubes with PTFE

Yong Soo Lee[1], Soeun Kim[2], Inhee Maeng[2], Chul Kang[2], and Kyunghwan Oh[1]

[1]Department of Physics, Yonsei University, Seoul 03722, South Korea; [2]Intergrated Optics Laboratory, Advanced Photonics Research Institute, GIST, Gwangju 61005, South Korea

Terahertz waveguide with porous is investigated in the 0.1 - 1.0 THz frequency range. The waveguide has 17 air holes and are arranged air holes throughout the PTFE tubes in a hexagonal lattice structure without defect. We have experimentally confirmed that a terahertz signal can also be guided in a core-free waveguide and investigate the propagation characteristics of porous PTFE tubes of different lengths experimentally and numerically analyzed their optical properties using finite element method with perfectly matched layer. This porous tube with PTFE exhibit very low effective material loss than bulk material and experimentally measure high transmittance in the low frequency region.

Poster 11

Low quantum defect fiber lasers via Yb-doped fluorosilicate optical fiber

Nanjie Yu[1], Maxime Cavillon[2], Courtney Kucera[2], Thomas Hawkins[2], John Ballato[2], and Peter Dragic[1]

[1]Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, 306 N. Wright St., Urbana, Illinois 61801, USA; [2]Center for Optical Materials Science and Engineering Technologies (COMSET) and the Department of Materials Science and Engineering, Clemson University, 91 Technology Drive, Anderson, South Carolina 29625, USA

Core pumped fiber lasers exhibiting a quantum defect of 0.92%, λ =985.7nm, and best-case slope efficiency of 68.6% based on Yb-doped multicomponent fluorosilicate optical fiber are demonstrated. Power scaling through the use of a double-clad fiber in a MOPA configuration is discussed.

Poster 12

Long-term behavior of water vapor absorption in hollow core fibers

Shuichiro Rikimi[1], Yong Chen[1,2], Thomas D. Bradley[1], Marcelo A. Gouveia[2], Raymond J. Horley[2], Andrew T. Harker[2], Simon Bawn[2], Francesco Poletti[1], Marco N. Petrovich[1,2], David J. Richardson[1], and Natalie V. Wheeler[1]

[1]Optoelectronics Research Centre, University of Southampton, Southampton, United Kingdom; [2]Lumenisity Ltd, Unit 7, The Quadrangle, Premier Way, Romsey, United Kingdom

We report on the long-term behavior of water vapor absorption in 19 cell HC-PBGFs in open and spliced conditions. Two main trends were observed as a function of time: increase in absorption of water vapor after opening sealed ends and reduction of the absorption after splicing ends. Furthermore, attenuation at 1550nm was not significantly influenced by water vapor dynamics at 22°C and 85°C.

Poster 13

All-optically-driven and all-optical-fiber modulator via luminescence-quenched Yb-doped fiber

Nanjie Yu[1], Matthew Tuggle[2], Courtney Kucera[2], Thomas Wade Hawkins[2], John Ballato[2], and Peter Dragic[1]

[1]Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, 306 N. Wright St., Urbana, Illinois 61801, USA; [2]Center for Optical Materials Science and Engineering Technologies (COMSET) and the Department of Materials Science and Engineering, Clemson University, 91 Technology Drive, Anderson, South Carolina 29625, USA

An all-optically-driven and all-optical-fiber modulator based on the phase delay introduced by an optically pumped, luminescence-quenched, Yb-doped fiber microheater is presented. Results indicate that the system has the potential to achieve ~MHz modulation speeds.

Poster 14

Tunable wavelength Q-switched all-fiber laser based on two-dimensional perovskite solution

Byungjoo Kim, Seongjin Hong, and Kyunghwan Oh

Institute of Physics and Applied Physics, Yonsei University, Seoul 03722, South Korea

We experimentally demonstrate an all-fiber Q-switched laser in L-band using two-dimensional (2D) hybrid organic inorganic ($(C_6H_5C_2H_4NH_3)_2PbI_4$) perovskite solution. By adjusting an optical fiber end face micro air-gap distance, we also achieve a tunable peak wavelength blue shift of 7nm at the center wavelength of 1600.6nm using Fabry-Perot structure.

Poster 15

O-band bismuth-doped fiber amplifier and its temperature dependent performance

Yu Wang, N. K. Thipparapu, S. Wang, P. Barua, D. J. Richardson, and J. K. Sahu

Optoelectronics Research Centre, University of Southampton, University Road, Southampton, SO17 1BJ,

United Kingdom

We report temperature-dependent gain and NF of single-pass and double-pass O-band BDFA from -60 to +80°C. A maximum gain of 41dB, NF 3.8dB was achieved at -60°C for -23dB/m input-signal. The temperature-dependent-gain coefficient was -0.04dB/°C

Poster 16

Direct extrusion of hollow-core THz fiber using a 3D printer

Wanvisa Talataisong[1], Lieke D. Van Putten[1], Rand Ismaeel[1,2], Martynas Beresna[1], and Gilberto Brambilla[1]

[1]Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK; [2]National Oceanography Centre, Southampton, SO14 3ZH, UK

We report a novel fabrication technique to achieve a hollow-core antiresonant polymer optical fiber for THz guidance. The fiber can be directly extruded from a 3D printer using a modified structured nozzle in a single step procedure. The possibility to use fibers made from acrylonitrile butadiene styrene (ABS) for guiding in the THz region is assessed through the profile of the confinement loss.

Poster 17

Non-destructive tomography for the characterization of extruded optical fiber triplet 3D shape sensors

Pierre Lorre[1], Arthur Poiffaut[1], Antoine Drouin[1], Samuel Kadoury[2], and Raman Kashyap[1,3]

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This article proposes a non-destructive imaging system providing a sliced view of an extruded coated fiber triplet. It gives the relative positions of the fibers in the polymer coating with a ±1.5 µm precision. The characterization of a 3D shape sensor optical fiber triplet used for minimally invasive surgery is made using this system.

Poster 18

Spectroscopic properties of highly erbium doped fluorosilicate fiber

Guanyi Pan[1], M. Cavillon[2], T. Hawkins[2], J. Ballato[2], and P. Dragic[1]

[1]Department of Electrical and Computer Engineering, University of Illinois at UrbanaChampaign, Urbana, IL, 61822, USA; [2]Center for Optical Materials Science and Engineering Technologies (COMSET) and the Department of Materials Science and Engineering, Clemson University, Clemson, SC, 29625, USA

A highly erbium doped (up to 5 wt% Er_2O_3) optical fiber was fabricated using the molten core method (MCM), with core elemental constituents that include Sr, Al, Er, Si, O and F. Its spectroscopic and lasing properties are investigated.

Poster 19

Applications of novel metal-derived optical fibers

Matthew Tuggle[1], Thomas Hawkins[1], Nanjie Yu[2], Guanyi Pan[2], Jane Gragg[1], Courtney Kucera[1], Peter Dragic[2], and John Ballato[1]

[1]Center for Optical Materials Science and Engineering Technologies (COMSET) and the Department of Material Science and Engineering, Clemson University, Clemson SC 29625, USA; [2]Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, 306 N. Wright St., Urbana, Illinois 61801, USA

Reported herein are two amorphous, all-oxide optical fibers derived from metal precursors, each possessing unique attributes. The first is a novel erbium-doped fiber (EDF) utilized within a traditional erbium-doped fiber amplifier (EDFA). The second is a highly doped aluminosilicate core possessing a very high ytterbium concentration sufficient for luminescence quenching. While inefficient for lasing, the luminescence quenching promotes heat generation for use as a novel all-optically driven fiber microheater.

Thursday, 7 November 2019

8:00AM ***Plenary***

Defense applications of high power fiber lasers

Mark Neice

Executive Director of the Directed Energy Professional Society (DEPS), former Director, High Energy Laser Joint Technology Office

Directed energy (DE) weapons have long since been a staple across Federal Government Research & Development institutions over the past decades, and due to technological maturation a number of military DE programs are showing great promise. The current posture of DE weapons across the DoD has grown in popularity over the recent years, and many strides have been made to integrate DE as a warfighting tool in support of National security needs and the Warfighter.

8:50 – 9:40 AM

Session: Fiber Lasers II

Chair: Cesar Juregui-Misas, Friedrich Schiller University Jena, Germany

8:50AM ***Invited***

Reach extension of O-band transmission using bismuth doped fiber amplifier (BDFA)

Vitaly Mikhailov, Jiawei Luo, Man F. Yan, Yingzhi Sun, Gabriel S. Puc, Scott D. Shenk, Yuriy Dulashko, Robert S. Windeler, Paul S. Westbrook, Daryl Inniss, and David J. DiGiovanni

OFS Laboratories, 19 Schoolhouse Rd, Somerset, New-Jersey, 08873, USA

We developed a simple single-stage silica-based BDFA with 40nm gain bandwidth, 19 dB gain, 20 dBm output power, 5 dB noise figure and 20% power conversion efficiency (PCE). We demonstrated that the amplifier can be used to extend 400GBASE-LR-8 transmission distance beyond 50 km of G.652 fiber.

9:15AM ***Invited***

Recent efforts in power scaling of holmium doped fiber sources

Nikita Simakov[1], Alexander Hemming[1], Adrian Carter[2], Keiron Boyd[1], Robert Swain[3], Eric Mies[3], W. Andrew Clarkson[4], and John Haub[1]

[1]Defence Science and Technology Group, Edinburgh, South Australia 5111, Australia; [2] Coherent|Nufern, 7 Airport Park Rd, East Granby, Ct 06026 USA; [3] Sub-micron Engineering, PO Box: 509, Marlboro New Jersey 07746 USA; [4] Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK

This paper summarizes recent efforts in the development of core-pumped holmium sources. This includes the development of high power single-mode thulium-pump lasers, components optimized for core-pumping and efficiency optimization of core-pumped holmium fibers.

9:40 – 10:10 AM • Coffee Break and Exhibit – *Ashley and Copper Rooms*

10:10 – 11:35 AM

Session: Hollow Core Fibers

Chair: Yasutake Ohishi, Toyota Technological Institute, Japan

10:10AM ***Invited***

Loss reduction in hollow-core optical fiber

Ying-ying Wang[1,2], Shou-fei Gao[1,2], Wei Ding[2], and Pu Wang[1]

[1]National Center of Laser Technology, Institute of Laser Engineering, Beijing University of Technology, Beijing 100124, China; [2]Guangdong Provincial Key Laboratory of Optical Fiber Sensing and Communications, Institute of Photonics Technology, Jinan University, Guangzhou 510632, China

We review our recent progress in achieving ultralow loss hollow-core optical fiber in both the near-IR and the visible wavelengths. The loss of the green-guiding fiber strides across the Rayleigh scattering loss limit of silica glass fiber.

10:35AM

Negative curvature fibers for gas-filled fiber lasers

Jonathan Hu[1], Chengli Wei[2], Francois Chenard[3], and Curtis R. Menyuk[4]

[1]Department of Electrical and Computer Engineering, Baylor University, One Bear Place #97356, Waco, TX 76798, USA; [2]Department of Computer Science, Engineering and Physics, University of Mary Hardin-Baylor, 900 College Street, Belton, TX 76513, USA; [3]IRflex Corporation, 300 Ringgold Industrial Parkway, Danville, VA 24540, USA; [4]Department of Computer Science and Electrical Engineering, University of Maryland, 5200 Westland Blvd., Baltimore, MD 21227, USA

We find optimal structure for chalcogenide negative curvature fibers with different thicknesses and gaps between cladding tubes to yield low transmission loss at wavelengths of 1.5μm and 4.5μm simultaneously for gas-filled fiber lasers.

10:50AM

Tubular anti-resonant hollow core fiber for visible Raman spectroscopy

Ian A. Davidson, Matthew Partridge, John R. Hayes, Yong Chen, Thomas D. Bradley, Hesham Sakr, Shuichiro Rikimi, Gregory T. Jasion, Eric Numkam Fokoua, Marco Petrovich, Francesco Poletti, David J. Richardson, and Natalie V. Wheeler

Optoelectronics Research Centre, University of Southampton, SO17 1BJ, UK

We report low loss, wide bandwidth, tubular anti-resonant hollow core fibers with a low macro- and micro-bend sensitivity tailored for gas sensing using visible wavelength Raman spectroscopy. The fibers show record low bend sensitivity for anti-resonant fibers operating in this spectral region. A minimum loss of 23.6dB/km is measured at 570nm for a fiber spooled on a 30cm diameter drum for gas-filled fiber lasers.

11:05AM

Extruded chalcogenide antiresonant hollow core fiber for mid-IR laser delivery

Juliano G. Hayashi, Andrea Ventura, Gregory T. Jasion, Jaroslaw Cimek, Fedia B. Slimen, Nicholas White, Hesham Sakr, Natalie V. Wheeler, and Francesco Poletti

Optoelectronics Research Centre, University of Southampton, SO17 1BJ, UK

We report modeling and fabrication of chalcogenide antiresonant hollow core fibers aimed at laser delivery in the mid-IR (4.5-11μm). The results indicate that, with further improvements in fiber's structure, very promising performances could be achieved.

11:20AM

Non-invasive characterization of hollow-core single-ring fibers using whispering gallery mode spectroscopy

Michael H. Frosz[1], Riccardo Pennetta[1], Michael T. Enders[1], Goran Ahmed[1], and Philip St.J. Russell[1,2]

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Non-invasive whispering gallery mode spectroscopy is applied to measure the internal microstructure of a hollow-core fiber with cladding capillaries. The capillaries are measured with sub-micron accuracy in sub-cm steps along the fiber.

11:35 AM – 1:05 PM • Lunch Break – *Wraggoborough and Halston Rooms*

1:05 – 3:05 PM

Session: Fiber Fabrication I

Chair: Heike Ebendorff-Heidepriem, University of Adelaide, Australia

1:05PM ***Invited***

Microgravity fiber processing for future optical networks

Dmitry Starodubov, K. McCormick, M. Dellosa, E. Erdelyi, and L. Volfson

FOMS Inc., 3525 Del Mar Heights Road, #236, San Diego, CA 92130

The growing demand for higher capacity data links defines the need for increasing the bandwidth of optical fiber communications. Microgravity processing of challenging glass compositions with potentially lower insertion loss at longer wavelengths is explored.

1:30PM ***Invited***

Cladding shaping of optical fiber preforms via CO_2 laser machining

Peter Shardlow, R. Standish, M. N. Velazquez, J. Sahu, and W. A. Clarkson

Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK

Shaping optical fiber preforms utilizing CO_2 laser ablation is able to significantly reduce process times, improve surface qualities and facilitate fabrication of complicated cladding geometries including convex and concave surfaces.

1:55PM ***Invited***

Recent progress in graded-index plastic optical fiber

Yasuhiro Koike and Azusa Inoue

Graduate School of Science and Technology, Keio Photonics Research Institute (KPRI), Keio University, 7-1, Shin-Kawasaki, Saiwai-ku, Kawasaki, Kanagawa, 212-0032, Japan

Recently, we proposed low-noise graded-index plastic optical fiber (GI POF) utilizing distinctive mode coupling owing to microscopic polymer properties. Here we develop a low-noise GI POF to realize indoor optical wiring for next generation broadcast and communication in home and building.

2:20PM

3D printing of chalcogenide preform a novel process for the elaboration of chalcogenide microstructured optical fibers

Johann Troles[1], Julie Carcreff[1], François Chevíré[1], Elodie Galdo[1], Ronan Lebullenger[1], Antoine Gautier[1], Jean-Luc Adam[1], Laurent Brilland[2], and Gilles Renversez[3]

[1]Univ Rennes, CNRS, ISCR-UMR 6226, F-35000 Rennes, France; [2]Selenoptics, 263 Avenue Gal Leclerc, 35042 Rennes, France; [3]Aix–Marseille Univ, CNRS, Centrale Marseille, Institut Fresnel, UMR 7249, 13013 Marseille, France

The elaboration of chalcogenide microstructured optical fibers (MOFs) permits to combine the mid-infrared transmission of chalcogenide glasses up to 18 µm to the unique optical properties of MOFs due to the high degree of freedom in the design of their geometrical structure. In this context, we have shown that chalcogenide preforms can be obtained by an original additive manufacturing process, and that such as-prepared preforms can be drawn into chalcogenide optical fibers. Those results open a new way for the elaboration of chalcogenide MOFs, especially for hollow-core chalcogenide MOFs.

2:35PM

The effect of pressure on structured optical fiber drawing

Ghazal Tafti[1], John Canning[1,2], Wenyu Wang[1], Yanhua Luo[1], Kevin Cook[1,2], and Gang-Ding Peng[1]

[1]National Fibre Facility, Photonics & Optical Communication, School of Electrical Engineering and Telecommunications, University of New South Wales, Kensington, NSW 2052, Australia; [2] interdisciplinary Photonics Laboratories (iPL), School of Electrical & Data Engineering & Tech Lab, UTS and School of Chemistry, The University of Sydney, NSW 2007 & 2006 Australia

The role of internal capillary on structured optical fiber drawing is explored. A single-capillary function modified to cater for multi-capillary structural constraint within a larger single capillary draw is proposed and shown to give reasonable fits with experiment.

2:50PM

Inverse modelling of microstructured optical fiber drawing

Yvonne Stokes and Michael Chen

School of Mathematical Sciences, The University of Adelaide, Australia, 5005

Drawing of a fiber with desired structure is a difficult inverse problem, requiring determination of preform geometry and draw parameters. A mathematical model is described which enables solution of this inverse problem in a very efficient way. An excellent prediction of preform and draw parameters for a desired fiber may be obtained reducing the need for expensive experimental trials.

3:05 – 3:35 PM • Coffee Break and Exhibit – *Ashley and Copper Rooms*

3:35 – 5:45 PM
Session: Fiber Fabrication II
Chair: Dmitry Starodubov, FOMS Inc, USA

3:35 PM **Invited**

Israeli activities in specialty fibers and fiber lasers

Amiel A. Ishaaya[1] and Yoav Sintov[2]

[1]School of Electrical and Computer Engineering, Ben-Gurion University in the Negev, BeerSheva 8410501, Israel; [2]ICAP/Soreq, Yavne 81800, Israel

Within the present talk, we review the main activities that are presently taking place in Israel in the field of specialty fibers and fiber lasers. We start by presenting the objectives and infrastructure of the newly built Israel Center of Advanced Photonics (ICAP). An example of a recent ICAP activity concerning fs inscription of Fiber Bragg Gratings (FBGs) will be presented.

4:00 PM **Invited**

3D Lithography for doped and structured optical fibers

Gang-Ding Peng

Photonics and Optical Communications, School of Electrical Engineering and Telecommunications, University of New South Wales, Sydney, NSW 2052, Australia

This presentation will report on recent progress and discuss current challenges in research and development of 3D silica lithography based new fabrication technologies for future doped and structured optical fibers.

4:25 PM **Invited**

Single crystal fiber growth by laser heated pedestal growth technique

Subhabrata Bera[1,2], Paul Ohodnicki[1], Bo Liu[3,4], Michael Buric[3], and Benjamin Chorpening[3]

[1]National Energy Technology Laboratory, 626 Cochrans Mill Road, Pittsburgh, PA 15236, USA; [2]Leidos Research Support Team, 626 Cochrans Mill Road, Pittsburgh, PA 15236, USA; [3] National Energy Technology Laboratory, 3610 Collins Ferry Road, Morgantown, WV 26505, USA; [4]West Virginia University Research Co., 3610 Collins Ferry Road, Morgantown, WV 26505, USA

Single crystal (SC) fibers combine the superior material properties of crystals with the advantages of a fiber geometry, and offer have great potential in harsh environment sensing as well as high-power laser gain media. Advances in the laser heated pedestal growth of SC fibers are discussed, along with results in various passive and active fiber applications.

4:50 PM **Invited**

Titania clad fiber fatigue performance

Kevin W. Bennett, Garth W. Scannell, and G. Scott Glaesemann

Corning Research and Development Corporation, 1 Riverfront Drive, Corning NY 14831

Improvement of the mechanical reliability of fibers deployed under tight bending can be achieved through addition of TiO_2 to the outermost layer of the fiber cladding. Optimization of the layer thickness and composition can lead to performance enhancement relative to traditional silica clad fibers.

5:15 PM

Radiation-resistant nanoparticle erbium doped fibers for high power space laser communications

E. Joseph Friebele[1], Colin C. Baker[2], Ashley Burdett[3], Jasbinder S. Sanghera[2], Michael J. LuValle[4], and Stephanos Logothetis[4]

[1]KeyW Corporation, 7740 Milestone Pkwy, Suite 400, Hanover, MD 21076, USA; [2]Naval Research Laboratory, 4555 Overlook Ave. SW, Washington, DC 20375, USA; [3]University Research Foundation, 6411 Ivy Lane, Suite 110, Greenbelt MD 20770, USA; [4]Rutgers University, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019, USA

The in-situ radiation-induced degradation and recovery of the output optical power of actively pumped erbium-doped fiber amplifiers, during and after radiation exposure, has been studied to improve their radiation tolerance in the space environment. Significant progress has been made using nanoparticle doping and by incorporating specific dopants to reduce Er ion clustering and improve efficiency. Statistical kinetics modeling has been used to predict on-orbit performance.

5:30 PM

Single crystal semiconductor-core optical fiber

Seunghan Song[1,2], Wei Wu[1], Mustafa H. Balci[1], Fredrik Laurell[3], Patrick R. Cantwell[4], John Ballato[5], and Ursula Gibson[1,2,3]

[1]Department of Physics, Norwegian University of Science & Technology, Høgskoleringen 5, 7491Trondheim, Norway; [2]PoreLab, Department of Physics, Norwegian University of Science and Technology, Trondheim, Norway; [3]Department of Applied Physics, Royal Institute of Technology, Roslagstullsbacken 21, 106 91 Stockholm, Sweden; [4]Department of Mechanical Engineering, Rose-Hulman Institute of Technology, 5500 Wabash Avenue Terre Haute, IN 47803 USA; [5]Center for Optical Materials Science and Engineering Technologies (COMSET) School of Materials Science and Engineering, Clemson University, Clemson, SC 29634 USA

Semiconductor-core fibers are improved by removal of grain boundaries. We use a CO_2 laser to process silicon-based cores; an alloying element reduces both the temperature and speed required for formation of a single crystal.

6:30 – 9:00 PM

Conference Banquet

South Carolina Aquarium

Friday, 8 November 2019

8:00AM ***Plenary***

Bright perspectives for fluoride glass mid-infrared fiber lasers

Réal Vallée

Center for Optics, Photonics and Lasers, Laval University, Quebec, G1V0A6, Canada

We present the most recent achievements in terms of spectral coverage and output power from both cw and pulsed mid-IR fiber lasers with special emphasis on their basic components as well as their applications in various fields

8:50 – 9:55 AM

Session: IR Fibers and Sources II

Chair: Peter Moselund, NKT Photonics, Denmark

8:50AM ***Invited***

Chalcogenide fiber for long-wave infrared supercontinuum source

Francois Chenard, Oseas Alvarez, and Andrew Buff

IRflex Corporation, 300 Ringgold Industrial Parkway, Danville, VA 24540, USA

We explain why chalcogenide glass fibers are well suited for long-wave infrared supercontinuum source. In particular we discuss the effects of the chemical composition and the fiber properties on the supercontinuum generation.

9:15AM ***Invited***

Broadband mid-infrared supercontinuum generation in chalcogenide tapered fiber with all-normal dispersion

Shixun Dai, Nan Zhang, and Yingying Wang

Laboratory of Infrared Material and Devices, The Research Institute of Advanced Technologies, Ningbo University, Ningbo, 315211, China and Key Laboratory of Photoelectric Materials and Devices of Zhejiang Province, Ningbo, 315211, China

We report broadband supercontinuum (SC) generation in chalcogenide (ChG) tapered fibers pumped in the normal dispersion (ANDi) regime. The fibers were fabricated using the isolated stacked extrusion method. A homemade tapering platform allows us to accurately control tapering parameters. An SC generation spanning 1.4 - 7.2μm was achieved by pumping an As_2S_3 tapered fiber. To further extend the SC, a Te-based ChG tapered fiber was pumped at 5.5μm, and an SC generation covered 1.7–12.7μm with high coherence property was generated.

9:40AM

Mid-infrared supercontinuum generation in chalcogenide or heavy oxide fibers for sensing applications

Arnaud Lemière, Frédéric Désévédavy, Pierre Mathey, Grégory Gadret, Jean-Charles Jules, Christophe Aquilina, Bertrand Kibler, Pierre Béjot, Franck Billard, Olivier Faucher, and Frédéric Smektala

Laboratoire Interdisciplinaire Carnot de Bourgogne (ICB), UMR 6303 CNRS – Université Bourgogne Franche-Comté, 9 avenue Alain Savary, 21000 Dijon, France

Significant improvements have been made in the processing of non-linear glasses and optical fibers since the early 2000s in order to carry out supercontinuum generation experiments. In this work, we present recent advances achieved in our laboratory on tellurite fibers as well as on arsenic and antimony free chalcogenide fibers. We report the resulting supercontinuum spanning between 2 and 14µm for chalcogenide fibers and the result of a supercontinuum absorption spectroscopy experiment above 3µm with tellurite fibers is reported

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9:55 – 10:25 AM • Coffee Break and Exhibit – *Ashley and Copper Rooms*

10:25 AM – 12:05 PM

Session: Fiber Lasers III

Chair: Clemence Jollivet, Coherent Nufern, USA

10:25AM ***Invited***

Specialty optical fibers for generation of light with extreme properties

Alexander M. Heidt[1], Dirk-Mathys Spangenberg[1], Sönke Pilz[2], Martin Hochstrasser[2], Manuel Ryser[1], Valerio Romano[1,2], and Thomas Feurer[1]

[1]Institute of Applied Physics, University of Bern, 3012 Bern, Switzerland; [2]Bern University of Applied Sciences, ALPS, Pestalozzistrasse 20, CH-3400 Burgdorf, Switzerland

We review how specialty optical fiber technology can support the application-driven demand for light sources with increasingly extreme properties, such as extremely short pulse durations, exotic wavelength ranges, or ultra-low noise broadband coherent sources.

10:50AM

Random lasing from optical fibers with phase-separated glass cores

Srinath Jagannathan[1], Liam Ackerman[1], Wynter Chen[1], Matthew Tuggle[2], Maxime Cavillon[2], Thomas Hawkins[2], John Ballato[2], and Peter Dragic[1]

[1]Department of Electrical and Computer Engineering, University of Illinois at Urbana Champaign, 306 N. Wright St., Urbana, Illinois 61801, USA; [2]Center for Optical Materials Science and Engineering Technologies (COMSET) and the Department of Materials Science and Engineering, Clemson University, 91 Technology Drive, Anderson, South Carolina 29625, USA

Random fiber lasers incorporating optical fiber with heterogeneous, phase-separated glass cores possessing high scattering coefficients are presented. In addition to having features characteristic of random lasers, these architectures offer the possibility of azimuthally uniform (sideways) illumination.

11:05AM

Challenges in preform material preparation for laser-active fibers

Katrin Wondraczek[1], Robert Müller[1], Volker Reichel[1], Tom Trautvetter[1], and Lothar Wondraczek[2]

[1]Leibniz-IPHT Jena e.V., Albert-Einstein-Str. 9, 07745 Jena, Germany; [2] Laboratory of Glass Science, Friedrich-Schiller-University, Fraunhofer Str. 8, 07743 Jena, Germany

We present a novel approach in creating extremely uniform, actively doped core material for laser-active fibers produced by reactive powder-sintering (REPUSIL) or plasma enhanced deposition with dimensions around ⌀15 mm x 100 mm or even larger.

11:20AM

Multicore fiber amplifier based on the Talbot effect

Cesar Jauregui[1], Albrecht Steinkopff[1], and Jens Limpert[1,2,3]

[1]Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Albert-Einstein-Str. 15, 07745 Jena, Germany; [2]Helmholtz-Institute Jena, Fröbelstieg 3, 07743 Jena, Germany; [3]Fraunhofer Institute for Applied Optics and Precision Engineering, Albert-Einstein-Str. 7, 07745 Jena, Germany

We present a multicore fiber design for coherent beam combination. This fiber allows reducing the complexity of these systems since, by exploiting the Talbot effect, the beam splitting and recombination happen inside of the fiber.

11:35AM

Cleaning protocols for fabrication of fibers for kilowatt-class lasers

Michael Messerly, Michael Runkel, Diana VanBlarcom, Derrek Drachenberg, Marcus Monticelli, Gabriel Davalos, Steve Davis, Nick Schenkel, Matt Cook, Parker Crist, Jay Dawson, and Tayyab Suratwala

Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA, USA 94550

Stack-and-draw methods allow the fabrication of complex waveguide designs, including those that require control of refractive indices to the 1×10^{-4} level. Unfortunately, stacking steps can introduce power-limiting contaminants into the glass matrix. We present protocols, originally developed for cleaning and handling large optics at the National Ignition Facility, that are appropriate for fabrication of fibers for kilowatt-class lasers

11:50AM

Improved wavelength selective filtering design in a Nd doped silica fiber for E-band amplification

Leily Kiani, Paul Pax, Derrek Reggie Drachenberg, Jay Dawson, Charles Boley, Cody Mart, Victor Khitrov, Charles Yu, Robert Crist, Matthew Cook, Nick Schenkel, Michael Runkel, Michael Messerly

Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA, USA 94550

We present the design of a Nd doped silica fiber for 1400nm amplification. The waveguide design includes elements that induce core loss at selective wavelengths enabling efficient amplification of 1400nm. The effect of these elements is modeled in COMSOL in order to produce a fiber design that is applicable to telecom amplifiers.

12:05 – 1:35 PM • Lunch Break – *Wraggoborough and Halston Rooms*

1:35 – 2:55 PM

Session: Fiber Sensors II

Chair: Hwa-yaw Tam, Hong Kong Polytechnic University, Hong Kong

1:35PM ***Invited***

Optical fibers for downhole oil and gas applications

Paul F. Wysocki and Zhao Li

Baker Hughes, a GE company, 2851 Commerce St, Blacksburg, VA 24060

Optical fiber optimization for downhole applications in the oil and gas industry is discussed. Fiber coatings, packaging and glass chemistry offer unique challenges in oil wells with harsh chemicals, high pressure and temperatures up to 300°C. The use of FBGs to enhance distributed sensing in these environments is discussed.

2:00PM ***Invited***

Making optical fibers sensitive and selective to the environment via functionalization and nanostructuring

Heike Ebendorff-Heidepriem, Erik P. Schartner, Roman Kostecki, Akash Bachhuka, and Stephen C. Warren-Smith

School of Physical Sciences, Institute for Photonics and Advanced Sensing, and ARC Centre of Excellence for Nanoscale BioPhotonics, University of Adelaide, Adelaide, SA 5005, Australia

This paper presents optical fiber based approaches of sensing various physical, chemical and biological parameters. The sensitivity and selectivity for the fibers are achieved via new types of active glass, micro/nano-structures and surface functionalization.

2:25PM

Femtosecond laser inscribed bridging cladding waveguides combining single- and multi-core optical fibers for shape sensing

Kyriacos Kalli[1], A. Theodosiou[1], S. S. Stojanovic[1], A. Ioannou[1,2]

[1]Photonics and Optical Sensors Research Laboratory, Cyprus University of Technology, Limassol, Cyprus; [2]University of Mons, 7000, Belgium

We show that femtosecond laser inscribed “bridging waveguides” can couple the displaced cores of different types of optical fibers. We explore coupling between single- and four-core fiber, incorporating multiple Bragg gratings. The sensor is calibrated for bend and shape sensing.

2:40PM

Polymer end-capped fiber sensors for biomedical applications

Juan Hernández-Cordero, Ricardo Defas-Brucil, and Mildred Cano-Velázquez

Instituto de Investigaciones en Materiales, Universidad Nacional Autónoma de México, Circuito Exterior, Cd. Universitaria, México City, 04510, México

We demonstrate a simple fabrication procedure for polymer end-capped Fabry-Pérot sensors. We demonstrate the potential of these devices for biosensing, as well as for developing fiber probes for pressure and temperature measurements.

2:55 PM • Concluding Remarks – John Ballato

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