FINAL PROGRAM

SUMMER TOPICALS 2012

9-11 JULY

Photonic Next Generation Communication Systems and Novel Devices

TOPICS:

Space Division Multiplexing for Optical Systems and Networks

Co-Chairs:

Lynn Nelson, AT&T, USA

John Fini, OFS Laboratories, USA

David Richardson, University of Southampton, UK

High Power Semiconductor Lasers

Co-Chairs:

Gary Smith, MIT Lincoln Laboratory, USA

Paul Crump, Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Germany

Optical Wireless Systems and Applications

Co-Chairs:

Gee-Kung Chang, Georgia Institute of Technology, USA

Mohsen Kavehrad, Pennsylvania State University, USA

Renaissance Seattle Hotel
Seattle, Washington
USA

GENERAL CHAIR:

Kent Choquette

University of Illinois at Urbana-Champaign, USA

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Welcome to Seattle and the 2012 Photonic Society Summer Topicals

The Topical Meetings of the IEEE Photonics Society are the premier conference series for exciting new areas in photonic science, technology, and applications, creating the opportunity to learn about emerging fields and to interact with the research and technology leaders in an intimate environment. This year the meetings will be held at the Renaissance Seattle Hotel, located in downtown Seattle, WA.

The 2012 Summer Topical Meetings are focussed on "Next Generation Photonic Communication Systems and Novel Devices" The following 3 Topicals meetings will be held:

- Optical Wireless Systems and Applications
- Space Division Multiplexing for Optical Systems and Networks
- High Power Semiconductor Lasers

A unique aspect of the Topical Meetings is that Photonic Society member volunteers propose and organize these meetings. Hence I would like to thank each of the Topical Chairs and the Program Committee Members who have volunteered and invested their time organizing these conferences. I also want to thank the plenary and invited speakers for giving us their perspectives on the exciting new developments and the challenges in these three fields. Finally I would like to express my sincere appreciation to the Photonic Society Conference Staff for their professional organization and arrangements.

This topics to be discussed in this year's Summer Topicals span communication theory, semiconductor photonic device technology, military and commercial applications, and advanced optical networks. In addition to the technical presentations, hallway discussions, and coffee break conversations, I hope that you have a chance to experience and sample some of Seattle's best sights and food. Have a great time!

Kent D. Choquette
Photonics Society Topical Meetings General Chair

ACKNOWLEDGEMENT

The Conference Committee would like to thank

TRUMPF Photonics Inc.

For their support of the 2012 Summer Topicals

SUMMER TOPICALS 2012 COMMITTEES

GENERAL CHAIR

Dr. Kent D. Choquette
University of Illinois at Urbana-Champaign - Beckman Institute, Urbana, IL, USA

HIGH POWER SEMICONDUCTOR LASER

Dr. Paul Crump, **Co-Chair**
Ferdinand-Braun-Institut - Leibniz Institut für Höchstfrequenztechnik, Berlin, Germany

Dr. Gary M. Smith, **Co-Chair**
MIT Lincoln Laboratory, Lexington, MA, USA

Dr. Eugene A. Avrutin
University of York, Heslington, UK

Dr. Ryan Feeler
Northrop Grumman - , Redondo Beach, CA, USA

Dr. Hans-Dieter Hoffmann
Fraunhofer-Institut - Laser Technology, Aachen, Germany

Dr. Manoj Kanskar
nLight Corporation, Vancouver, WA, USA

Dr. Eric C. Larkins
University of Nottingham, Nottingham, UK

Dr. Norbert Lichtenstein
Oclaro Switzerland GmbH, Zurich, Switzerland

Dr. John H. Marsh
University of Glasgow, Glasgow, UK

Dr. Luke J. Mawst
University of Wisconsin-Madison, Madison, WI, USA

Dr. Uwe Strauss
Osram Opto Semiconductors GmbH, Regensburg, Germany

Dr. Georg Treusch
TRUMPF Photonics Inc., Cranbury, NJ, USA

Dr. Erik Zucker
JDS Uniphase Corporation, Milpitas, CA, USA

OPTICAL WIRELESS SYSTEMS AND APPLICATIONS

SPATIAL DIVISION MULTIPLEXING FOR OPTICAL SYSTEMS AND NETWORKS

Dr. John M. Fini, **Co-Chair**
OFS Laboratories, Norcross, GA, USA

Dr. Lynn E. Nelson, **Co-Chair**
AT&T - Labs - Research, Florham Park, NJ, USA

Dr. David J. Richardson, **Co-Chair**
University of Southampton - Optoelectronics Research Centre, Southampton, UK

Dr. Yoshinari Awaji
National Institute of Information and Communications Technology, Koganei, Tokyo, Japan

Dr. Scott R. Bickham
Corning, Inc. - Sullivan Park R&D Center, Corning, NY, USA

Dr. Mark D. Feuer
AT&T - Labs - Research, Florham Park, NJ, USA

Dr. Fatima C. G. Gunning
Tyndall National Institute, Cork, Ireland

Dr. Nobutomo Hanzawa
NTT Corporation - Access Network Service Systems Labs, Tsukuba, Japan

Dr. Joseph M. Kahn
Stanford University - Solid State Photonics Laboratory, Stanford, CA, USA

Dr. Peter Krummrich
University of Dortmund, Dortmund, Germany

Dr. Shoichiro Matsuo
Fujikura Ltd., Koto-ku, Tokyo, Japan

Dr. Francesco Poletti
University of Southampton - Optoelectronics Research Centre, Southampton, UK

Dr. Roland Ryf
Alcatel-Lucent - Bell Labs, New Providence, NJ, USA

Dr. Massimiliano Salsi
Alcatel-Lucent - Bell Labs, New Providence, NJ, USA

Dr. Takashi Sasaki
Sumitomo Electric Industries Ltd., Yokohama, Japan

Dr. William Shieh
University of Melbourne, Parkville, Victoria, Australia

Dr. Pierre Sillard
Prysmian Group, Marcoussis, France

Dr. Dirk van den Borne
Nokia Siemens Networks, Munich, Germany

Benyuan Zhu
OFS Laboratories, Somerset, NJ, USA

2012 SUMMER TOPICALS
PROGRAM – AT – A – GLANCE

	HIGH POWER SEMICONDUCTOR LASERS	OPTICAL WIRELESS SYSTEMS AND APPLICATIONS	SPACE DIVISION MULTIPLEXING FOR OPTICAL SYSTEMS AND NETWORKS
Room:	*East Room (3rd Floor)*	*South Room (3rd Floor)*	*North Room (3rd Floor)*
Monday, 9 July 2012			
8:00am – 5:00pm		REGISTRATION: Compass Foyer	
9:00am - 10:00am	**MA1:** Surface Emitting Lasers Chair: H. Hoffmann	**MB1:** Frontier of Optical Wireless Technologies I Chair: E. Chan	9:00 am – 9:15am Opening Remarks **MC1**: SMD Approaches to Increase Capacity Chair: L. Nelson
10:00am – 10:30am		COFFEE BREAK	
10:30am - 12:00pm	**MA2:** Single-Element Lasers and Bars Chair: G. Erbert	**MB2**:Frontier of Optical Wireless Technologies II Chair: E. Chan (session end at 11:45am)	**MC2**: SDM for High-Capacity Telecom Chair: D. Richardson
12:00pm – 1:30pm		LUNCH BREAK	
1:30pm - 3:00pm	**MA3:** Plenary Chair: G. Smith	**MB3**:Emerging Optical Wireless Technologies I Chair: L. Kazovsky	**MC3**: SDM Transmission Chair: F. Gunning
3:00pm – 3:30pm		COFFEE BREAK	
3:30pm - 5:00pm	**MA4**: Fiber-Coupled Laser Bars Chair: P. Crump	**MB4**: Emerging Optical Wireless Technologies II Chair: L. Kazovsky	**MC4**: DSP Technology Chair: R. Ryf
5:15pm – 6:15pm		WELCOME RECEPTION: Madison Ballroom (2nd Floor)	
Tuesday, 10 July 2012			
8:00am – 5:00pm		REGISTRATION: Compass Foyer	
Room:		*Parallel Sessions* *South Room and West Room (3rd Floor)*	
9:00am - 10:00am	**TuA1**: Laser Manufacturing Chair: N. Lichtenstein	**TuB1**: Next-Gen Optical Wireless Systems I Chair: T. Kane **TUBB1:** Optical Wireless Technologies & Applications I Chair: J. Yao	**TuC1**: Few Mode Fibers Chair: S. Brickham
10:00am – 10:30am		COFFEE BREAK	

2012 SUMMER TOPICALS
PROGRAM – AT – A – GLANCE

Tuesday, 10 July 2012 Continued			
	HIGH POWER SEMICONDUCTOR LASERS	**OPTICAL WIRELESS SYSTEMS AND APPLICATIONS**	**SPACE DIVISION MULTIPLEXING FOR OPTICAL SYSTEMS AND NETWORKS**
10:30am - 12:00pm	**TuA2**: Laser Combining Chair: L. Mawst	**TuB2**: Next-Gen Optical Wireless Systems II Chair: T. Kane **TUBB2:** Optical Wireless Technologies & Applications II Chair: J. Yao	**TuC2**: SDM in Data Com Chair: J. Fini (session end at 11:45am)
12:00pm – 1:30pm	LUNCH BREAK		
1:30pm - 3:00pm	**TuA3**: External Feedback Lasers Chair: E. Larkins	**TuB3**: Performance of Optical Wireless Systems I Chair: P. Poirier **TuBB3**: Photonics Devices and Components Design I Chair: W. Krug	**TuC3**: Mode Couplers and Mode Coupling Effects Chair: S. Matsuo **(session begin at 1:15pm)**
3:00pm – 3:30pm	COFFEE BREAK		
3:30 pm - 5:00pm	**TuA4**: Tapered and Long-Wavelength Lasers Chair: H. Koenig	**TUB4:** Performance of Optical Wireless Systems II Chair: P. Poirier **TUBB4:** Photonics Devices and Components Design II Chair: W. Krug	**TuC4**: Multicore Fibers Chair: T. Sasaki
5:00 pm - 5:30pm	**TuA5**: Special Session on EU-Funded High Power Laser Programs Chair: K. Choquette		
Wednesday, 11 July 2012			
8:00am – 5:00pm	REGISTRATION: Compass Foyer		
Room:	*East Room (3rd Floor)*	*South Room (3rd Floor)*	*North Room (3rd Floor)*
9:00am - 10:00am	**WA1:** Monolithic Power Scaling Chair: T. Fan	**WB1:** Advanced Optical Wireless Technologies I Chair: K. Ho	**WC1:** Components for FMF Systems Chair: Y.Awaji
10:00am – 10:30am	COFFEE BREAK		
10:30am - 12:00pm	**WA2**: Increasing Efficiency Chair: E. Avrutin	**WB2:** Advanced Optical Wireless Technologies II Chair: K. Ho	**WC2:** MM Fiber Amplifiers Moderator: P. Krummrich
12:00pm – 1:30pm	LUNCH BREAK		
1:30pm - 3:00pm	**WA3:** Increasing Power Chair: E. Zucker	**WB3:** Efficient Modulation and Transport System I Chair: J. Cheng	**WC3:** Novel Coupling Schemes and SDM Devices Chair: P. Sillard
3:00pm – 3:30pm	COFFEE BREAK		

2012 SUMMER TOPICALS
PROGRAM – AT – A – GLANCE

Wednesday, 11 July 2012 Continued			
3:30pm - 5:00pm	**WA4**: Improving Laser Performance Chair: P. Blood	**WB4:** Efficient Modulation and Transport Systems II Chair: J. Cheng (session end at 4:45pm)	**WC4:** Silicon Devices Chair: M. Feuer (session end at 4:45pm)

Join us 8-10 July in Hawaii for Summer Topicals 2013!
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2012 SUMMER TOPICALS
EXHIBITOR GUIDE

OptiGrate Corporation

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OptiGrate is a pioneer of commercial volume Bragg gratings and is a leading supplier of VBGs for laser line narrowing, ultra-narrow band optical filters for spectroscopy, ultra-short pulse stretchers and compressors, and other applications.

Lightel Technologies

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LIGHTEL delivers component, instrument, and equipment solutions for fiberoptics. Instruments/equipment include, the CI-1000, ViewConn™ video microscope probes, and Coupler Workstations, such as FiberForge and CW5000. Other products include fiber tapers, combiners, and passive components.

Ondax Inc.

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Ondax, Inc. is the world's largest manufacturer of commercial Volume Holographic Gratings (VHGs) and wavelength-stabilized lasers. VHGs improve laser diode performance by increasing spectral brightness, locking emission wavelength, increasing environmental stability and improving manufacturing yields.

Final Program

High Power Semiconductor Lasers

Monday, 9 July 2012

ALL SESSIONS WILL BE HELD IN EAST ROOM

9:00 AM - 10:00 AM

Session MA1: SURFACE EMITTING LASERS
Session Chair: Hans-Dieter Hoffmann, *Fraunhofer-Institut, Aachen, Germany*

MA1.1 9:00 AM - 9:30 AM (Invited)

High Power Surface Emitting Distributed Feedback (SE-DFB) Lasers, T. Garrod, D. Olson and Y. Xiao*, Alfalight, Inc., Madison, WI, USA*

High-power SE-DFB lasers have intrinsically narrow, wavelength stabilized spectra and high spatial brightness as a result of monolithic curved gratings. Performance results of high-power SE-DFB lasers in the 9xx - 15xx nm range are discussed.

MA1.2 9:30 AM - 10:00 AM (Invited)

Recent Advances in High-Power VCSEL Arrays, C. S. Wang, J. C. Geske, G. Berdin, F. Talantov, T. Cardellino, H. Garrett, D. Millenheft, V. Kumsomboone and D. Renner*, FLIR Electro-Optical Components, Ventura, CA, USA*

High power VCSEL arrays have experienced rapid growth and development. In this paper, we review the unique properties of VCSELs and present the progress that is making them very attractive for high power laser applications.

10:00 AM – 10:30 AM **COFFEE BREAK**

10:30 AM - 12:00 PM

Session MA2: SINGLE-ELEMENT LASERS AND BARS
Session Chair: Götz Erbert, *Ferdinand-Braun-Institut, Berlin, Germany*

MA2.1 10:30 AM - 11:00 AM (Invited)

Brilliance Improvement of High Power Diode Laser Systems: Status and Prospects, H.-D. Hoffmann*, Fraunhofer-Institut, Aachen, Germany*

ABSTRACT NOT AVAILABLE

MA2.2 11:00 AM - 11:30 AM (Invited)

Recent Advances in 8xx-10xx nm Devices, N. Lichtenstein*, Oclaro Switzerland GmbH, Zurich, Switzerland*

An overview on the development at Oclaro of high power laser diodes operating in the 8xx - 10xx nm range is given. We present results on laser bars and give a comparison of stabilized and non-stabilized seeders for fiber lasers.

MA2.3 11:30 AM - 12:00 PM (Invited)

High Brightness Laser Sources based upon Low Fill Factor Bars, R. N. Pathak, H. Winhold, S. Kim, Z. Xu, D. M. Grasso, P. Liang, N. Shou and D. Lee*, Coherent Inc., Santa Clara, CA, USA*

We present results from our low fill factor bars used in high brightness optical systems for pumping and material processing applications.

12:00 PM – 1:30 PM **LUNCH BREAK**

1:30 PM - 3:00 PM

Session MA3: PLENARY SESSION
Session Chair: Gary M. Smith, *MIT Lincoln Laboratory, Lexington, MA, USA*

MA3.1 1:30 PM - 2:15 PM (Plenary)

Progress in High Brilliance Lasers, G. Erbert*, Ferdinand-Braun-Institut, Berlin, Germany*

Increasing demands on brightness for laser applications is the driving force of research on high-power diode lasers. Status and current developments of monolithic und hybrid solutions for high brilliance diode laser sources will be discussed.

MA3.2 2:15 PM - 3:00 PM (Plenary)

25 Years of High-Brightness, Fiber-Coupled Semiconductor Laser Diodes, E. Zucker, *JDS Uniphase Corporation, Milpitas, CA, USA*

Fiber-coupled laser diodes continue to show dramatic progress in power and brightness. Advances in semiconductor laser power and fiber coupling performance are presented, with focus on recent designs utilizing polarization-, spatial-, and wavelength-combining techniques.

3:00 PM – 3:30 PM **COFFEE BREAK**

3:30 PM - 5:00 PM

Session MA4: FIBER-COUPLED LASER BARS
Session Chair: Paul Crump, *Ferdinand-Braun-Institut, Berlin, Germany*

MA4.1 3:30 PM - 4:00 PM (Invited)

Tailored 9xx nm Laser Bars for Fiber Coupling, H. Koenig, C. Lauer, G. Grönninger, S. Hein, A. Gomez-Iglesias, M. Furitsch, J. Maric, U. Strauss, *Osram Opto Semiconductors GmbH, Regensburg, Germany*, H. Kissel, P. Wolf and J. Biesenbach, *DILAS Diodenlaser GmbH, Mainz-Hechtsheim, Germany*

Status on low fill factor 9xx nm laser bars will be presented. Conversion efficiency peaks above 66% and slow axis divergence of less than 7° was reached up to 45W for 10%-fill factor half-bars.

MA4.2 4:00 PM - 4:30 PM (Invited)

High-Brightness, Fiber-Coupled Sources, K. Price, *nLight Corporation, Vancouver, WA, USA*

We present methods for improving diode laser brightness, fiber coupling architectures, and beam delivery methods that preserve diode brightness, resulting in improved fiber coupled diode laser modules for pumping KW-class fiber lasers.

MA4.3 4:30 PM - 5:00 PM (Invited)

High Brightness Fiber Coupled Modular Diode Laser Platform, J. Biesenbach, *DILAS Diodenlaser GmbH, Mainz-Hechtsheim, Germany*

The price for diode laser erases, reliability and power demand go up. Airborne app. require robustness at low weight and high brightness. Instead of hand made, an automated, flexible featured, power scalable platform is needed.

5:15 PM – 6:15 PM **WELCOME RECEPTION: MADISON BALLROOM (2ND FLOOR)**

Tuesday, 10 July 2012

9:00 AM - 10:00 AM

Session TuA1: LASER MANUFACTURING
Session Chair: Norbert Lichtenstein, *Oclaro, Switzerland*

TuA1.1 9:00 AM - 9:30 AM (Invited)

Aspects of Robust High-Power Semiconductor Laser Design with State-of-the-Art Performance for a Uniform and Reproducible Volume Manufacturing, A. Pietrzak, R. Huelsewede, M. Zorn, O. Hirsekorn and J. Sebastian, *Jenoptik Diode Lab GmbH, Berlin, Germany*

Diode lasers for volume production should be non-sensitive to manufacturing process variations. JENOPTIK Diode Lab presents a modal loss focused design process of GaAs-based 9xx-laser structures, which is necessary for stable volume.

TuA1.2 9:30 AM - 10:00 AM (Invited)

Low-Cost Diode Arrays for Production-Scale Fusion Energy Installations, R. Feeler, J. Junghans and J. Levy, *Northrop Grumman Cutting Edge Optronics, St. Charles, MO, USA*

A detailed investigation of the technical requirements associated with laser diode arrays used in LIFE-based fusion energy power plants. Special consideration given to issues related to scaling for manufacturing.

10:00 AM – 10:30 AM **COFFEE BREAK**

10:30 AM - 12:00 PM

Session TuA2: Laser Combining
Session Chair: Luke J. Mawst, *University of Wisconsin-Madison, Madison, WI, USA*

TuA2.1 10:30 AM - 11:30 AM (Tutorial)

High-Power, High-Brightness Laser Beam Combining, T. Y. Fan, *MIT Lincoln Laboratory, Lexington, MA, USA*

Beam combining of arrays of lasers is becoming an increasing attractive approach to generate high-power and high-brightness sources. This tutorial provides an overview on laser beam combining.

TuA2.2 11:30 AM - 11:45 AM

Coherent Beam Combining with High-Power Slab-Coupled Optical Waveguide Amplifiers, G. M. Smith, S. M. Redmond, J. P. Donnelly, L. J. Missaggia, M. K. Connors, K. J. Creedon, D. C. Mathewson, R. B. Swint, A. Sanchez-Rubio and G. W. Turner, *MIT Lincoln Laboratory, Lexington, MA, USA*

SCOWAs have produced 1.5 W of output power with a 44 mW seed. Arrays of 47 SCOWA elements have demonstrated a raw power of 57 W. Coherent beam combining of these arrays will be discussed.

TuA2.3 11:45 AM - 12:00 PM

Bar Efficiency and Beam Quality for Coarse Wavelength Multiplexing, H. An, J. Jiang, R. Robert, S. Strohmaire and G. Treusch, *TRUMPF Photonics Inc., Cranbury, NJ, USA*

We will present results from optical power conversion efficiencies as well as near field and far field study of CB packaged bars in the 900-1060nm wavelength region for coarse wavelength multiplexing application.

12:00 PM – 1:30 PM LUNCH BREAK

1:30 PM - 3:00 PM

Session TuA3: External Feedback Lasers
Session Chair: Eric C. Larkins, *University of Nottingham, Nottingham, UK*

TuA3.1 1:30 PM - 2:00 PM (Invited)

High Power Diode Lasers with External Feedback: Overview and Prospects, M. Chi and P. M. Petersen, *Technical University of Denmark, Roskilde, Denmark*

Different external-cavity feedback architectures that enhance the spatial and temporal coherence for both broad-area diode lasers and tapered diode lasers are reviewed and the most promising results in the literature are given as examples.

TuA3.2 2:00 PM - 2:30 PM (Invited)

Wavelength Locking of High-Power Diode Laser Bars by Volume Bragg Gratings, Y. Li, V. Negoita, T. Barnowski, S. Strohmaier, and G. Treusch, *TRUMPF Photonics Inc., Cranbury, NJ, USA*

Wavelength locking of high-power diode laser bars by volume Bragg gratings (VBGs) are investigated in theory and practice. Important diode laser and VBG parameters are discussed, and experimental results are presented.

TuA3.3 2:30 PM - 2:45 PM

High Power High Brightness Volume Bragg Semiconductor Lasers, L. Glebov, G. B. Venus, *University of Central Florida, Orlando, FL, USA*, K. Shavitrnuruk, *OptiGrate Corporation, Orlando, FL, USA*, I. Divliansky, *University of Central Florida, Orlando, FL, USA* and V. I. Smirnov, *OptiGrate Corporation, Orlando, FL, USA*

Development of low-loss volume Bragg gratings recorded in PTR glass and their utilization as components of external resonators of semiconductor lasers enabled dramatic increase of laser brightness without significant penalties in power and efficiency.

TuA3.4 2:45 PM - 3:00 PM

Developments of High-Power 9xx-nm Single Emitter Laser Diodes and Laser Diode Bars, T. Morita, N. Kageyama, K. Torii, T. Nagakura, M. Takauji, J. Maeda, M. Miyamoto, H. Miyajima and H. Yoshida, *Hamamatsu Photonics K.K., Hamamatsu, Shizuoka, Japan*

We will present recent results on 9xx-nm single emitters and laser diode bars. A 20 W output from the single emitter and a 200 W from the bar with low smile have been achieved.

3:00 PM – 3:30 PM COFFEE BREAK

3:30 PM - 5:00 PM

Session TuA4: Tapered and Long-Wavelength Lasers
Session Chair: Harald Koenig, *Osram Opto Semiconductors GmbH, Regensburg, Germany*

TuA4.1 3:30 PM - 4:00 PM (Invited)

Factors Influencing the Brightness and Beam Quality of Tapered Laser Diodes and Bars, J. J. Lim, S. Bull, S. Kaunga-Nyirenda, S. Sujecki, E. C. Larkins*, University of Nottingham, Nottingham, UK*, K.-H. H. Hasler and J. Fricke*, Ferdinand-Braun-Institut, Berlin, Germany*

This paper examines some of the factors affecting the brightness of high-power tapered lasers, including bleaching of the ridge waveguide and mismatch between the taper and the beam diffraction angle, which excite high-order modes.

TuA4.2 4:00 PM - 4:15 PM

Advances in High Power Laser Diodes in the 1400-1910nm Wavelength Regime, R. Lammert*,* J. Ungar, S. W. Oh*,* C. Panja and W. Hu*, Laser Operations, Sylmar, CA, USA*

We report on InGaAsP high power laser diodes recently developed at Laser Operations. Devices including 1532nm MOPAs with >3W of near diffraction limited power and 1470nm bars with 1W/A slopes using monolithically double active regions.

TuA4.3 4:15 PM - 4:30 PM

Lateral Far-Field of Multiple-Stripe High Power 1480nm Broad-Area-Lasers for Pulsed Operation, D. A. Fendler*,* M. Spiegelberg, W. Rehbein and M. Moehrle*, Fraunhofer Heinrich Hertz Institute, Berlin, Germany*

A novel 1480nm multiple stripe broad area laser structure is presented featureing a 33% lateral farfield angle reduction compared with conventional single stripe broad area lasers.

TuA4.4 4:30 PM - 4:45 PM

High-Peak Power from Optically-Pumped Mid-IR Semiconductor Lasers, A. P. Ongstad*, US Air Force Research Laboratory, Albuquerque, NM, USA*, G. C. Dente*, GCD Associates, Albuquerque, NM, USA*, M. L. Tilton, J. R. Chavez*, Boeing LTS, Inc., Albuquerque, NM, USA*, R. Kaspi*, US Air Force Research Laboratory, Albuquerque, NM, USA* and D. M. Gianardi*, Boeing LTS, Inc., Albuquerque, NM, USA*

We describe high peak-power, broad area mid-infrared semiconductor lasers. The laser structures incorporated 14 type-II quantum wells and produced near 470 W at 4.1 um when pumped with the output from a Q-switched Ho:YAG laser.

TuA4.5 4:45 PM - 5:00 PM

High Power Bragg Reflection Waveguide Diode Lasers with Twin Near-Circular Emission Spots, C. Z. Tong*, Changchun Institute of Optics, Changchun, China*

A novel semiconductor laser with two symmetrical near-circular emission spots separated at an angle of 62° was demonstrated using Bragg reflection waveguide. The low beam divergence of 5.4° and power of 2.6 W were achieved.

5:00 PM - 5:30 PM

Session TuA5: Special Session on EU-funded High Power Laser Programs
Session Chair: Kent Choquette, *University of Illinois – Urbana- Champaign, Urbana, IL, USA*

TuA5.1 5:00 PM - 5:30 PM (Invited)

EU-Funded High Power Laser Programs: Present and Future Activities, S. Kaierle, *Laser Zentrum Hannover e.V., Hannover, Germany*

ABSTRACT NOT AVAILABLE

Wednesday, 11 July 2012

9:00 AM - 10:00 AM

Session WA1: Monolithic Power Scaling
Session Chair: Tso Yee Fan, MIT Lincoln Laboratory, Lexington, MA, USA

WA1.1 9:00 AM - 10:00 AM (Tutorial)

Mode Control and Monolithic Coherent Power Scaling, L. J. Mawst and D. Botez*, University of Wisconsin-Madison, Madison, WI, USA*

Monolithic approaches for achieving coherent-power scaling of diode lasers have resulted in watt-range output powers with high beam quality. Thermal lensing effects generally limit the single-mode operational range under CW operating conditions.

10:00 AM – 10:30 AM **COFFEE BREAK**

10:30 AM - 12:00 PM

Session WA2: **INCREASING EFFICIENCY**
Session Chair: Eugene A. Avrutin, *University of York, Heslington, Yorkshire, UK*

WA2.1 10:30 AM - 11:30 AM (Tutorial)

Radiative Efficiency and High-Power Quantum Well Lasers, P. Blood, *Cardiff University, Cardiff, Wales, UK*

Optical gain in a laser diode is controlled by the internal voltage. This tutorial gives an account of the processes which contribute to the threshold current but not to stimulated emission for the lasing process.

WA2.2 11:30 AM - 12:00 PM (Invited)

Quantum Dots for High Powers and Efficiencies, D. G. Deppe, *University of Central Florida, Orlando, FL, USA*

Laser diode power conversion efficiencies tend to saturate at room temperature at ~ 70%. The fundamental limits of the laser diode efficiency are examined based on active material and compared for different active materials.

12:00 PM – 1:30 PM **LUNCH BREAK**

1:30 PM - 3:00 PM

Session WA3: **INCREASING POWER**
Session Chair: Erik Zucker, *JDS Uniphase Corporation, Milpitas, CA, USA*

WA3.1 1:30 PM - 2:00 PM (Invited)

Mechanisms and Kinetics of the Catastrophic Optical Damage (COD) of High-Power Semiconductor Lasers, J. W. Tomm, M. Hempel, *Max Born Institute, Berlin, Germany*, M. Krakowski, *Alcatel-Thales III-V Lab, Marcoussis, France* and T. Elsaesser, *Max Born Institute, Berlin, Germany*

Mechanisms relevant for the COD in GaAs-based diode lasers are reviewed. Experiments, where COD is artificially provoked, represent a main topic. The sequence of events and the kinetics down to a nanosecond timescale are addressed.

WA3.2 2:00 PM - 2:30 PM (Invited)

Carrier Accumulation in the Optical Confinement Layer, Its Effect on Power Limit in High Power and Brightness Laser Diodes, and Laser Design to Overcome This Limitation, E. A. Avrutin, *University of York, Heslington, Yorkshire, UK* and B. S. Ryvkin, *A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia*

We analyse efficiency degradation due to carrier accumulation in the optical confinement layer of high-power laser diodes. Narrow asymmetric waveguide structures are shown to reduce this limitation while enabling low built-in losses and fundamental-mode operation.

WA3.3 2:30 PM - 2:45 PM

Current Dependent Absorption in High-Power Broad Area Laser Diodes, M. Dogan, *Science Research Laboratory, Inc., Somerville, MA, USA*, R. N. Pathak, *Coherent Inc., Santa Clara, CA, USA*, T. Silverman, J. H. Jacob and K. D. Lang, *Science Research Laboratory, Inc., Somerville, MA, USA*

Current dependent absorption in broad area edge emitting lasers has been measured using laser diodes with high reflectivity (HR) output facets.

WA3.4 2:45 PM - 3:00 PM

CW and Pulsed High-Power Semiconductor Separate-Confinement Double Heterostructure Lasers, N. Pikhtin, *A.F. Ioffe Physico-Technical Institute, St. Petersburg, Russia*

The concept of high power semiconductor lasers based on separate-confinement double heterostructures with quantum wells is presented. Physical and technologic factors limiting optical output power of CW and pulsed semiconductor lasers are discussed.

3:00 PM – 3:30 PM **COFFEE BREAK**

3:30 PM - 5:00 PM

Session WA4: **IMPROVING LASER PERFORMANCE**
Session Chair: Peter Blood, *Cardiff University, Cardiff, Wales, UK*

WA4.1 3:30 PM - 4:00 PM (Invited)

Buried DFB Gratings Floating in AlGaAs with Low Oxygen Contamination Enable High Power and Efficiency DFB Lasers, C. M. Schultz, P. Crump, A. Maaßdorf, O. Brox, F. Bugge, A. Mogilatenko, H. Wenzel, S. Knigge, B. Sumpf, M. Weyers and G. Erbert, *Ferdinand-Braun-Institut, Berlin, Germany*

We report a novel design and fabrication technique for buried overgrown DFB gratings floating in AlGaAs. In-situ etching enables low oxygen contamination and results in > 60% efficient and 10W reliable high power DFB lasers.

WA4.2 4:00 PM - 4:30 PM (Invited)

Heterostructure Waveguide Design for High-Power Narrow Far-Field Laser Emission, A. Malag, M. Teodorczyk, E. Dabrowska, M. Nakielska, G. Sobczak, A. Kozlowska, J. Kalbarczyk and K. Krzyzak, *Institute of Electronic Materials Technology, Warsaw, Poland*

Semiconductor laser heterostructure waveguide design considerations are presented. Wide evanescent tails of guided mode penetrating deeply into claddings are essential for reduction of vertical divergence of an emitted beam. Symmetric and asymmetric designs are compared.

WA4.3 4:30 PM - 5:00 PM (Invited)

Diagnosing and Addressing the Limitations to Lateral Far Field Angle in High Power Broad-Area Diode Lasers, P. Crump, S. Boeldicke, C. M. Schultz, H. Ekhteraei, H. Wenzel and G. Erbert, *Ferdinand-Braun-Institut, Berlin, Germany*

We show experimentally that thermal lensing largely determines the lateral mode properties of broad-area lasers. However, additional broadening is observed at high powers, which will limit how effectively mode-filtering techniques can improve beam quality.

END OF PROGRAM

Final Program

Optical Wireless Systems and Applications

Monday, 9 July 2012

ALL SESSIONS WILL BE HELD IN SOUTH ROOM

9:00 AM - 10:00 AM

Session MB1: **FRONTIER OF OPTICAL WIRELESS TECHNOLOGIES I**
Session Chair: Eric Y. Chan, Boeing Research and Technology, Seattle, WA, USA

MB1.1 9:00 AM - 9:30 AM (Invited)

Optical Signal Processing for Millimeter-Wave Wireless Systems, T. Kawanishi*, National Institute of Information and Communications Technology, Koganei, Tokyo, Japan*

This presentation will discuss optical signal processing techniques for high-speed modulation of millimeter-wave, which can provide high-speed wireless transmission of 40Gb/s. Pure optical two-tone signals can be converted into millimeter-wave signals by using high-speed photodetectors.

MB1.2 9:30 AM - 9:45 AM

Handover in Fixed-Mobile Convergence, N. Ghazisaidi*, Ericsson USA, San Jose, CA, USA*

The concept of handover to perform inter- and intra-switching for mobile end-users in fixed-mobile convergence broadband access networks is introduced and its impact on the performance of network is evaluated.

MB1.3 9:45 AM - 10:00 AM

Physical-Layer Authentication for Poisson Channels, R. J. Drost*,* P. L. Yu, K. S. Chan and B. M. Sadler*, US Army Research Laboratory, Adelphi, MD, USA*

We present a physical-layer authentication framework for communications over a Poisson channel. Focusing on on-off keying, we discuss such aspects as the stealth, robustness, and security of the authentication approach.

10:00 AM – 10:30 AM **COFFEE BREAK**

10:30 AM - 11:45 AM

Session MB2: **FRONTIER OF OPTICAL WIRELESS TECHNOLOGIES II**
Session Chair: Eric Y. Chan, *Boeing Research and Technology, Seattle, WA, USA*

MB2.1 10:30 AM - 11:15 AM (Plenary)

Undersea Laser Communications is a "Game-Changer" for the US Navy, So How Do We Make the Promise a Reality?, G. Mooradian*, QinetiQ North America, San Diego, CA, USA*

This paper addresses the fundamental physic and architecture issues attendant to an underwater blue/green laser comm system: both all-underwater as well as through the air/sea interface. This may represent the most challenging comm propagation channel.

MB2.2 11:15 AM - 11:45 AM (Invited)

Ultra-High Capacity 60-GHz Fiber-Wireless Systems, C.-T. Lin, C.-H. Ho, T.-H. Lu, C.-Y. Wang, H.-T. Huang and F.-M. Wu*, National Chiao Tung University, Tainan City, Taiwan*

Several digital signal processing techniques and methods have been demonstrated to solve many technical challenges of 60-GHz fiber-wireless system. Using these solutions, we have experimentally demonstrated ultra-high capacity RoF systems operating at up to 50Gb/s.

12:00 PM – 1:30 PM **LUNCH BREAK**

1:30 PM - 3:00 PM

Session MB3: EMERGING OPTICAL WIRELESS TECHNOLOGIES I
Session Chair: Leonid G. Kazovsky, Stanford University, Stanford, CA, USA

MB3.1 1:30 PM - 2:00 PM (Invited)

Onboard Wireless Aerospace Applications - Challenges and Opportunties, W. P. Krug*, Boeing Company, Seattle, WA, USA*

Onboard wireless shows great promise and offers unique challenges for potential onboard communications and sensing applications.

MB3.2 2:00 PM - 2:30 PM (Invited)

Wireless Optical Links for Airplane Applications, E. Y. Chan*, Boeing Research and Technology, Seattle, WA, USA*

This paper describe the development of high quality and error free wireless optical communication links using wide dynamic range and high power small form factor (SFF) transceivers that are suitable for use in airplane platforms.

MB3.3 2:30 PM - 2:45 PM

Indoor Optical Wireless Localization System for High-Speed Personal Area Networks, K. Wang, A. Nirmalathas, C. Lim and E. Skafidas*, University of Melbourne, Melbourne, Australia*

In this paper we experimentally demonstrate an indoor optical wireless based localization system with single channel imaging receiver for personal area network applications. The results show that an accuracy of ~3.81cm can be achieved.

MB3.4 2:45 PM - 3:00 PM

A 2-D Indoor Localization System Based On Visible Light LED, M. Kavehrad and W. Zhang*, Pennsylvania State University, University Park, PA, USA*

An LED based 2-D indoor localization system is proposed. For evaluation purpose we also present computer simulations results that show for a normal room size, we can locate a target to within centimeters.

3:00 PM – 3:30 PM COFFEE BREAK

3:30 PM - 5:00 PM

Session MB4: EMERGING OPTICAL WIRELESS TECHNOLOGIES II
Session Chair: Leonid G. Kazovsky, *Stanford University, Stanford, CA, USA*

MB4.1 3:30 PM - 3:45 PM

Long-range Indoor Hybrid Localization System Design with Visible Light Communications and Wireless Network, M. Kavehrad*, Pennsylvania State University, University Park, PA, USA* and Y. U. Lee*, Hallym University, Chuncheon, Korea*

An indoor hybrid localization system is realized and experimented with, using a five-hop Zigbee wireless network and visible light communications in order to improve positioning accuracy and achieve a long-range localization.

MB4.2 3:45 PM - 4:00 PM

Comparing Wide Field-of-View Optical Receivers for Free Space Optical Communications, M. Kavehrad, P. Deng*, Pennsylvania State University, University Park, PA, USA* and X. Yuan*, Huazhong University of Science and Technology, Wuhan, Hubei, China*

We investigate the performance of wide field-of-view diversity optical receiver for free space optical communications in atmospheric strong turbulence. The proposed scheme can help to reduce scintillations and improve BER performance.

MB4.3 4:00 PM - 4:15 PM

Lasercom for High Definition Video to a Moving Platform Using Cat's Eye Modulating Retro-reflectors, P. G. Goetz, M. S. Ferraro, R. Mahon, J. L. Murphy, M. R. Suite, C. I. Moore, M. J. Vilcheck, W. S. Rabinovich and W. W. Schultz*, US Naval Research Laboratory, Washington, DC, USA*

An Ethernet boat-to-shore lasercom link was established using a cat's eye modulating retro-reflector. High-definition video and data were transferred bi-directionally at ranges of 2 – 7.7 km.

MB4.4 4:15 PM - 4:45 PM (Invited)

Emerging Technologies for Mm-wave RoF Communication, H.-C. Chien*, ZTE USA, Morristown, NJ, USA*, C. Liu, J. Liu, S.-H. Fan, Y.-T. Hsueh*, Georgia Institute of Technology, Atlanta, GA, USA*, Z. Jia*, ZTE USA, Morristown, NJ, USA*, S. He*, Zhejiang University, Hangzhou, China* and G.-K. Chang*, Georgia Institute of Technology, Atlanta, GA, USA*

We review recent experimental demonstrations on optical mm-wave generation and modulation technologies for high-speed radio-over-fiber communication, including the feasibility studies on delivering vector signals over DSB-SC optical mm-wave, duobinary modulation, and Fabry-Perot subharmonic mm-wave generator.

MB4.5 4:45 PM - 5:00 PM

Delivery of Wireless and Wired Services Using a Single-drive Mach-Zehnder Modulator for Bidirectional Radio-over-Fiber Systems, M. Zhu*, Georgia Institute of Technology, Atlanta, GA, USA*

We designed and experimentally demonstrated a cost-effective RoF system for downstream 1-Gb/s OOK/BPSK and 2-Gb/s 16QAM-OFDM signals using only one single-drive MZM by driving both RF and bias ports, and upstream 1-Gb/s OOK signal.

5:15 PM – 6:15 PM **WELCOME RECEPTION: MADISON BALLROOM (2ND FLOOR)**

Tuesday, 10 July 2012

South Room

9:00 AM - 10:00 AM

Session TuB1: NEXT-GEN OPTICAL WIRELESS SYSTEMS I
Session Chair: Timothy J. Kane, *Pennsylvania State University, University Park, PA, USA*

TuB1.1 9:00 AM - 9:15 AM

An Archipelago of High-Bandwidth Islands by Optical Wireless Systems – A Solution to the USA Wireless Airwaves Spectrum Crunch, M. Kavehrad and M. I. Chowdhury, *Pennsylvania State University, University Park, PA, USA*

We discuss the current problem of spectrum shortage and the idea of a viable solution employing indoor optical wireless links creating small high-bandwidth islands for each user effectively helping to combat this spectrum shortage [1].

TuB1.2 9:15 AM - 9:45 AM (Invited)

Multi-Carrier versus Single-Carrier Intensity Modulation Techniques for Indoor Optical Wireless Links, J. M. Kahn, *Stanford University, Stanford, CA, USA,* D. J. F. Barros, *Qualcomm Atheros, San Jose, CA, USA* and S. K. Wilson, *Santa Clara University, Santa Clara, CA, USA*

We study the performance of three direct-detection orthogonal frequency-division multiplexing techniques for combating multipath distortion in indoor optical wireless links, and compare them to unipolar M-ary pulse-amplitude modulation with minimum mean-square error decision-feedback equalization.

TuB1.3 9:45 AM - 10:00 AM

On the EVM Calculation of Clipped Optical OFDM Signals, Z. Yu, *Georgia Institute of Technology, Atlanta, GA, USA*, R. J. Baxley, *Georgia Tech Research Institute, Atlanta, GA, USA* and G. Zhou, *Georgia Institute of Technology, Atlanta, GA, USA*

Error vector magnitude (EVM) is a commonly used metric to characterize distortions. We numerically calculate the EVM of clipped optical orthogonal frequency division multiplexing (OFDM) signals and compare with lower bounds.

West Room

9:00 AM - 10:00 AM

Session TuBB1: OPTICAL WIRELESS TECHNOLOGIES & APPLICATIONS I
Session Chair: Jianping Yao, *University of Ottawa, Ottawa, ON, Canada*

TuBB1.1 9:00 AM - 9:30 AM (Invited)

Aero-Optical Effects In Free-Space Laser Communications, S. Gordeyev and E. Jumper, *University of Notre Dame, Notre Dame, IN, USA*

Physical mechanisms behind aero-optical effects and their effects on focusing a laser beam on a target, including estimation of intensity drop-outs affecting data transmission, are discussed. Several mitigation techniques to reduce aero-optical effects are discussed.

TuBB1.2 9:30 AM - 10:00 AM (Invited)

Airborne Aero-Optics Laboratory (AAOL) Flight Test Capabilities – Other Possibilities, M. Zenk, S. Gordeyev and E. Jumper, *University of Notre Dame, Notre Dame, IN, USA*

The Airborne Aero-Optics Laboratory (AAOL) seeks to make flight test a viable and affordable experimental tool to advance the scientific foundation for aero-optic effects and explore mitigation schemes involving flow control and adaptive optics.

10:00 AM - 10:30 AM COFFEE BREAK

South Room

10:30 AM - 12:00 PM

Session TuB2: NEXT-GEN OPTICAL WIRELESS SYSTEMS II
Session Chair: Timothy J. Kane, *Pennsylvania State University, University Park, PA, USA*

TuB2.1 10:30 AM - 11:00 AM (Invited)

Green Optical/Wireless Access/In-Building Networks, L. G. Kazovsky, K. M. Albeyoglu, T. Ayhan, T. Ucar, *Stanford University, Stanford, CA, USA* and D. van Veen, *Alcatel-Lucent, Murray Hill, NJ, USA*

This paper analyzes energy and power consumption of integrated

West Room

10:30 AM - 12:00 PM

Session TuBB2: OPTICAL WIRELESS TECHNOLOGIES & APPLICATIONS II
Session Chair: Jianping Yao, *University of Ottawa, Ottawa, ON, Canada*

TuBB2.1 10:30 AM - 11:00 AM (Invited)

UWB over WDM-PON, J. Yao and S. Pan, *University of Ottawa, Ottawa, ON, Canada*

An overview on UWB over WDM-PON that can simultaneously provide wireless UWB and wired baseband services is presented. Different architectures including directly multiplexing a wireless UWB

optical/wireless in-building networks, with the goal of identifying energy hogs and finding ways to reduce the overall energy consumption of such networks.

TuB2. 2 11:00 AM - 11:30 AM (Invited)

Visible Light Communications for Entertainment Networking, S. Mangold*, Disney Research Zurich, Zurich, Switzerland*

Visible light communications is a new approach for many entertainment networking scenarios. We discuss applications in theme park environments with high device densities, and introduce toy networking using LED communications with simple network protocols.

TuB2.3 11:30 AM - 12:00 PM (Invited)

OLED-based Visible Light Communications, Z. Ghassemlooy*, Northumbria University, Newcastle Upon Tyne, UK*

In this talk we introduce visible light communication and discuss challenges and techniques to improve the performance of white organic light emitting diode (OLED) based systems.

signal and a wired baseband signal are discussed.

TuBB2.2 11:00 AM - 11:30 AM (Invited)

The Use of Colloidal Quantum Dots on Focal Plane Arrays for Optical Communications, F. B. Jaworski, M. D. Jack*, Raytheon Vision Systems, Goleta, CA, USA*, M. Bawendi, J. Scherer*, Massachusetts Institute of Technology, Cambridge, MA, USA* and S. Geyer*, Stanford University, Stanford, CA, USA*

In this paper we discuss quantum dot approaches to extend the usefulness of IR focal plane arrays into another application, UV wireless communications, in order to achieve a dual-use capability for a conventional imager.

TuBB2.3 11:30 AM - 12:00 PM (Invited)

The Analysis of 7.5Gbps 40 Km FSO Experiments, Y. Ai*,* Z. Xiong, J. Chen*, Wuhan University, Wuhan, Hubei, China*, F. Zhang, Y. Liu*, Beijing Institute of Tracking and Communication Technology, Beijing, China*, S. Zhang*, Beijing Guokehuanyu Space Technology Inc., Beijing, China*, R. Dong and Y. Xiao*, Wuhan University, Wuhan, Hubei, China*

Experiments of 7.5 Gbps 40km free space laser communication were conducted in Qinghai lake Qinghai province on Aug. 2010. The relationship between the light intensity fade probability and the fade margin were analyzed.

12:00 PM - 1:30 PM LUNCH BREAK

1:30 PM - 3:00 PM

Session TuB3: Performance of Optical Wireless Systems I

Session Chair: Peter Poirier, SPAWAR Systems Center - San Diego, San Diego, CA, USA

TuB3.1 1:30 PM - 2:00 PM (Invited)

Undersea Connectivity with Optical Communications, P. Poirier and M. Lovern*, Space and Naval Warfare Systems Center - Pacific, San Diego, CA, USA*

This presentation will address the scope of performance possible for undersea optical communications and to highlight the significant component parameters essential for a variety of different undersea scenarios.

TuB3.2 2:00 PM - 2:30 PM (Invited)

An Adaptive Data Rate Controller (ADRC) for the Through Cloud, Undersea Laser Communications Channel, R. Stokes, M. Bermal, C. Griffith, R. Blair, E. Marttila and G. Mooradian*, QinetiQ North America, San Diego, CA, USA*

We present an overview of the nature of light propagation through cloud and seawater, and the communications techniques employed to achieve megabit-per-second laser communications between aircraft above the clouds and submarines at speed and depth.

TuB3.3 2:30 PM - 3:00 PM (Invited)

Aspects of Oceanic Optical Comms: From Air to Sea, T. J. Kane*, Pennsylvania State University, University Park, PA, USA*

Optical propagation through a water/air interface experiences distortion due to surface roughness, impacting optical communication as well as laser scanning systems. In situ scatter also has a detrimental impact. Potential mitigation approaches will be discussed.

1:30 PM - 3:00 PM

Session TuBB3: Photonics Devices and Components Design I

Session Chair: William P. Krug, Boeing Company, Seattle, WA, USA

TuBB3.1 1:30 PM - 2:00 PM (Invited)

Low Voltage Silicon Photonic Modulators, P. Dong*, Alcatel-Lucent, Holmdel, NJ, USA*

Silicon photonics may be a compact integration platform to implement power-efficient and high-bandwidth optical transceivers/transponders. Low-power silicon electro-optic modulators are crucial to achieve this goal. We review recently reported energy-efficient and high-speed silicon photonic modulators.

TuBB3.2 2:00 PM - 2:15 PM

High Efficiency LED Driver Design for Concurrent Data Transmission and PWM Dimming Control for Indoor Visible Light Communication, A. Mirvakili and V. J. Koomson*, Tufts University, Medford, MA, USA*

This paper presents a novel LED driver circuit architecture implemented in a 180nm silicon CMOS process to deliver concurrent illumination control, dimming control and data transmission for visible light communication systems.

TuBB3.3 2:15 PM - 2:45 PM (Invited)

Semiconductor Ultraviolet Emitters and Detectors with Potential for Wireless Communications, M. Wraback*, US Army Research Laboratory, Adelphi, MD, USA*

Progress in low cost, compact, low power consumption, semiconductor-based ultraviolet sources (LEDs and laser diodes) and avalanche photodiodes are reviewed within the context of their use for non-line-of-sight optical wireless communications.

TuBB3.4 2:45 PM - 3:00 PM

Enhanced Field of View and Speed Characteristics for Optical Wireless Devices, X. Jin, C. M. Collier, B. W. D. Veerman and J. F. Holzman*, University of British Columbia, Kelowna, Canada*

We present an integrated photoconductive photocell for multi-

directional and high-speed applications. The wide field of view and fast response of the device are theoretically and experimentally analyzed for ultimate use in free-space optical wireless systems.

3:00 PM - 3:30 PM COFFEE BREAK

3:30 PM - 5:00 PM

Session TuB4: Performance of Optical Wireless Systems II

Session Chair: Peter Poirier, SPAWAR Systems Center - San Diego, San Diego, CA, USA

TuB4.1 3:30 PM - 3:45 PM

Performance of a 10 Gbps FSO System Implementing Novel Beam Tracking and a Dynamic Buffering Modem, R. Peach, C. Visone, *Harris Corporation, Palm Bay, FL, USA*, G. Burdge, *Harris Corporation, Saint Petersburg, FL, USA*, J. Vickers, *Space Photonics Inc., Fayetteville, AR, USA*, T. Leclerc, P. Sauer, L. C. Andrews, R. L. Phillips, *University of Central Florida, Orlando, FL, USA*, J. E. Valencia and J. J. Kiriazes, *NASA, Kennedy Space Center, FL, USA*

A 10 Gbps FSO system implements beam tracking, a high dynamic range optical receiver, and a dynamic buffering packet modem. Performance was characterized at the 4.5 km Shuttle Landing Facility at Kennedy Space Center Florida.

TuB4.2 3:45 PM - 4:15 PM (Invited)

Channel Reciprocity in Single-Mode Free-Space Optical Links, R. Parenti, J. M. Roth, J. A. Greco, F. Walther, *MIT Lincoln Laboratory, Lexington, MA, USA*, and J. H. Shapiro, *Massachusetts Institute of Technology, Cambridge, MA, USA*

This article describes observations of near-unity signal correlations obtained during a recent series of single-mode lasercom experiments in which links were established between an aircraft and a ground station separated by ranges up to 80km.

TuB4.3 4:15 PM - 4:30 PM

A Method for Comparing Remote Optical Clocks over a Free-Space Link, W. C. Swann, F. R. Giorgetta, I. Coddington, E. Baumann, *National Institute of Standards and Technology, Boulder, CO, USA*, J.-D. Deschenes, *Université Laval, Quebec, Canada*, L. Sinclair, A. M. Zolot and N. R. Newbury, *National Institute of Standards and Technology, Boulder, CO, USA*

We demonstrate a method to compare optical clocks approaching 10^-17 uncertainties through the exchange of optical pulses from phase-locked frequency combs. We discuss results over a 120 m air path and prospects for longer distances.

TuB4.4 4:30 PM - 4:45 PM

Laser Visible Light Communications, T. Borogovac and T. D. C. Little, *Boston University, Boston, MA, USA*

Visible Light Communications (VLC) via lighting must overcome the slow white LED. We propose the addition of a fast red laser to improve datarate, coverage, and light quality.

TuB4.5 4:45 PM - 5:00 PM

Distributions of PAPR and Crest Factor of OFDM Signals for VLC, C. Ma, Z. Xu, *Tsinghua University, Beijing, China*, K. Cui, *University of California - Riverside, Riverside, CA, USA*, M. Yao and H. Zhang, *Tsinghua University, Beijing, China*

The distributions of peak-to-average power ratio (PAPR) and crest factor (CF) of OFDM symbols in optical wireless communication (OWC) are studied.

3:30 PM - 5:00 PM

Session TuBB4: Photonics Devices and Components Design II

Session Chair: William P. Krug, *Boeing Company, Seattle, WA, USA*

TuBB4.1 3:30 PM - 4:00 PM (Invited)

Photonic [illegible] Ladar Receivers, P. K. Kon[illegible] *Louisville, CO, USA*

WITHDRAWN

Coherent [illegible]g and sophisticated standoff sensing capabilities. These systems typically sample the optical phase and amplitude in time and space. The rapid progress of photonic integrated circuit technology has the potential to enhance coherent ladar systems by offering multi-functionality and real-time reconfiguration suitable for system deployment on compact platforms. This work reviews the utility of silica and silicon photonic integrated circuits in multi-pixel coherent ladar receivers and also reviews system applications.

TuBB4.2 4:00 PM - 4:30 PM (Invited)

Tunable RF Photonics Filters on Integrated Silicon Planar Light Waveguided Circuits, M. S. Rasras and Y.-K. Chen, *Alcatel-Lucent, Murray Hill, NJ, USA*

Planar microwave-photonics filters provide the benefits of high level of integration and significant reduction of the size and weight of RF communication link. They can further play \cf1 a critical role in these systems due to their ultra-low transmission loss and \cf0 immunity to electromagnetic interference. To demonstrate the viability of this technology, we will present the RF performance of reconfigurable high-order filters that are integrated in both silicon and low-index-contrast silica planar lightwave circuit (PLC) platforms.

TuBB4.3 4:30 PM - 5:00 PM (Invited)

Optical Wireless Integration and Mobile Backhaul Networks, N. Yoshimoto, *NTT Corporation, Yokosuka, Kanagawa, Japan*

Scalable and flexible WDM-PON is an attractive candidate for a future mobile backhaul network with high capacity and low latency, in which wavelength tuning in an OLT/ONU, and wavelength routing at the node play key roles.

Wednesday, 11 July 2012

9:00 AM - 10:00 AM

Session WB1: ADVANCED OPTICAL WIRELESS TECHNOLOGIES I
Session Chair: Keang-Po Ho, *Silicon Image, Sunnyvale, CA, USA*

WB1.1 9:00 AM - 9:30 AM (Invited)

Unlicensed 60-GHz Millimeter Wave for Multi-Gigabit Wireless Communications, K.-P. Ho, S. Emami and J. M. Gilbert*, Silicon Image, Sunnyvale, CA, USA*

A 3.8-Gb/s wireless video area network uses unlicensed 60-GHz millimeter-wave, antenna arrays, and CMOS circuits. Using beam-search techniques, the antenna arrays can steer the beam to avoid line-of-sight blockage.

WB1.2 9:30 AM - 9:45 AM

A Cost-effective Multi-gigabit 60-GHz Wireless over Optical Fiber Access System Based on a Novel Frequency Quintupling Technique, L. Zhang*, Shanghai Jiao Tong University, Shanghai, China*, S.-H. Fan, M. Zhu, C. Liu*, Georgia Institute of Technology, Atlanta, GA, USA*, X. Hu*, Shanghai Jiao Tong University, Shanghai, China*, Z. Li*, Georgia Institute of Technology, Atlanta, USA*, Y. Su*, Shanghai Jiao Tong University, Shanghai, China* and G.-K. Chang*, Georgia Institute of Technology, Atlanta, GA, USA*

We propose and demonstrate a cost-effective wireless over optical fiber access system using frequency quintupling technique. A 2.5-Gb/s OOK signal at 60-GHz is successfully transmitted through 30-km SSMF and 10-ft air link without dispersion compensation

WB1.3 9:45 AM - 10:00 AM

20-Gbaud QPSK Optical and Radio Transmission Using High-Gain Antennas for Resilient Access Networks, A. Kanno, T. Kuri*,* I. Hosako*,* T. Kawanishi*, National Institute of Information and Communications Technology, Koganei, Tokyo, Japan*, Y. Yasumura*,* Y. Yoshida and K.-I. Kitayama*, Osaka University, Suita, Osaka, Japan*

20-Gbaud QPSK transmission over 20-km SMF for optical and 7.5-m free space for 90-GHz radio is successfully demonstrated with 50-dBi Cassegrain antennas. This configuration will be feasible for kilometer-order distance transmission.

10:00 AM – 10:30 AM **COFFEE BREAK**

10:30 AM - 12:00 PM

Session WB2: ADVANCED OPTICAL WIRELESS TECHNOLOGIES II
Session Chair: Keang-Po Ho, *Silicon Image, Sunnyvale, CA, USA*

WB2.1 10:30 AM - 11:15 AM

Smart Lighting - Beyond Simple Illumination, R. F. Karlicek, Jr.*, Rensselaer Polytechnic Institute, Troy, NY, USA*

Very efficient LED lighting is entering illumination markets, but initial products are aimed largely at replacing inefficient incandescent bulbs. The full potential of electronic lighting systems - Smart Lighting - will revolutionize future illumination systems.

WB2.2 11:15 AM - 11:45 AM (Invited)

Broadband Wireless Over Fibre: For Communications and Beyond, C.-P. Liu*, University College London, London, UK*

This paper discusses latest techniques for sending MIMO signals over fibre, a new application of real-time location monitoring supported by optical fibres and an asymmetric Fabry-Perot modulator as an electrical/optical transducer in radio over fibre.

WB2.3 11:45 AM - 12:00 PM

Color Quality Control in dual use Solid State Lightingand Visible Light Communication Systems usingCoded Inverse Multiplexing, S. Muralidharan and P. S. Dutta*, Rensselaer Polytechnic Institute, Troy, NY, USA*

A coded inverse multiplexing scheme is proposed using Red-Green-Blue (RGB) LEDs for general lighting with minimal shift in correlated color temperature (~ 35 K) and visible light communication at modulation rates ~ 50 MHz.

12:00 PM – 1:30 PM **LUNCH BREAK**

1:30 PM - 3:00 PM

Session WB3: EFFICIENT MODULATION AND TRANSPORT SYSTEM I
Session Chair: Julian Cheng, *University of British Columbia, Kelowna, BC, Canada*

WB3.1 1:30 PM - 2:00 PM (Invited)

High Dynamic Range Linearized FM Photonic Link, J. M. Wyrwas and M. C. Wu*, University of California - Berkeley, Berkeley, CA, USA*

We present our work on frequency and phase modulated microwave photonic links which achieve linear demodulation using planar lightwave circuits (PLC) optical filtering and balanced detection, showing improvement in spurious free dynamic-range and signal gain.

WB3.2 2:00 PM - 2:30 PM (Invited)

Coherent IFDMA-PON: A Novel Green and Elastic Optical Access Networks, Y. Yoshida, A. Maruta and K.-I. Kitayama*, Osaka University, Suita, Osaka, Japan*

We present a novel bandwidth-elastic and power-efficient coherent PON architecture based on interleaved frequency division multiple access (IFDMA) technique and experimentally demonstrate the coherent IFDMA-PON uplink transmission via 2xONUs with free-running sources.

WB3.3 2:30 PM - 2:45 PM

Duobinary RF Envelope Detection in Coherent Optical Millimeter-Wave Systems, C. Liu, S.-H. Fan, L. Zhang, Y.-T. Hsueh, M. Zhu, A. Yi, C. Ye*, Georgia Institute of Technology, Atlanta, USA*, H.-C. Chien, J. Yu*, ZTE USA, Morristown, NJ, USA* and G.-K. Chang*, Georgia Institute of Technology, Atlanta, GA, USA*

A novel duobinary RF receiver based on envelope detection is proposed for millimeter-wave radio-over-fiber systems, which simultaneously downconverts and decodes RF duobinary signals. Duobinary signal delivery over optical-wireless link is demonstrated with proposed receiver.

WB3.4 2:45 PM - 3:00 PM

Capacity of MIMO Visible Light Communication Channels, X. Zhang*, Tsinghua University, Beijing, China*, K. Cui*, University of California - Riverside, Riverside, CA, USA*, H. Zhang and Z. Xu*, Tsinghua University, Beijing, China*

Capacity of an indoor multiple-input multiple-output (MIMO) visible light communication (VLC) channel from lighting LED arrays to an imaging receiver is investigated based on Shannon capacity theory.

3:00 PM – 3:30 PM **COFFEE BREAK**

3:30 PM - 4:45 PM

Session WB4: EFFICIENT MODULATION AND TRANSPORT SYSTEMS II
Session Chair: Julian Cheng, *University of British Columbia, Kelowna, BC, Canada*

WB4.1 3:30 PM - 4:00 PM (Invited)

Next Generation Access Systems Backhauling Using Radio-over-Fiber: a Prospective Approach, A. Haddad and M. Gagnaire*, Institut Telecom, Paris, France*

Generic Radio over Fiber Access Network federates, on the same optical infrastructure, fixed and mobile access systems. With its innovative control plane, our architecture enables radio frequencies virtualization and promotes new business models for operators.

WB4.2 4:00 PM - 4:15 PM

Subcarrier Intensity Modulated Optical Communications over K-distributed Channels, X. Song, and J. Cheng*, University of British Columbia, Kelowna, Canada*

Our analysis shows that subcarrier intensity modulation using DPSK suffers an SNR performance loss of 3.92 dB with respect to BPSK under strong atmospheric turbulence conditions.

WB4.3 4:15 PM - 4:30 PM

Optical MIMO Transmission Using A Heterodyne Receiver in K-Distributed Turbulence Channels, M. Niu, J. Cheng and J. F. Holzman*, University of British Columbia, Kelowna, BC, Canada*

Closed-form error rate expressions of heterodyne free-space optical transmission are presented for K-distributed turbulent environments. Our simplified solutions are highly accurate for practical multiple-input multiple-output system performance estimation.

WB4.4 4:30 PM - 4:45 PM

Continuous-Amplitude Modulation for Optical Wireless Channels, J. Karout*, Chalmers University of Technology, Göteborg, Sweden*, G. Kramer*, Technical University of Munich, Munich, Germany*, F. R. Kschischang*, University of Toronto, Toronto, Canada* and E. Agrell*, Chalmers University of Technology, Göteborg, Sweden*

Continuous-amplitude modulation for wireless optical channels is presented. For bandwidth measured as 99% in-band power, its spectral efficiency is 4.57 times that of the same modulation format with discontinuous amplitude for the same power requirement.

END OF PROGRAM

Final Program

Space Division Multiplexing for Optical Systems and Networks

Monday, 9 July 2012

ALL SESSIONS WILL BE HELD IN NORTH ROOM

9:00 AM – 9:15 AM **OPENING REMARKS**

9:15 AM - 10:00 AM
Session MC1: **SDM APPROACHES TO INCREASE CAPACITY**
Session Chair: Lynn E. Nelson, *AT&T, Middletown, NJ, USA*

MC1.1 9:15 AM - 10:00 AM (Plenary)

Current Capacity Limits and Activities within the EU Project MODE-GAP to Overcome Them, A. D. Ellis*, Tyndall National Institute, Cork, Ireland*

This presentation will discuss the implications of the Nonlinear Shannon Limit. We will compare technologies including new fibres for long haul transmission and techniques to expand the capacity of existing standard single mode fibers.

10:00 AM – 10:30 AM **COFFEE BREAK**

10:30 AM - 12:00 PM
Session MC2: **SDM FOR HIGH-CAPACITY TELECOM**
Session Chair: David J. Richardson, *University of Southampton, Southampton, UK*

MC2.1 10:30 AM - 11:15 AM (Plenary)

Network Capacity Scaling Through Space Division Multiplexing, P. J. Winzer*, Alcatel-Lucent, Holmdel, NJ, USA*

Space-division multiplexing (SDM) holds the promise to scalably overcome the looming optical networks capacity crunch. We will review SDM techniques using coupled and uncoupled spatial paths and assess their cost and energy scaling properties.

MC2.2 11:15 AM - 12:00 PM (Plenary)

Preparation for Ultrahigh-Capacity SDM Transmission, M. Nakazawa*, Tohoku University, Sendai, Japan*

We describe recent advances toward ultrahigh-capacity SDM with high-spectral-density transmission in multi-core fibers (MCF). In particular, our recent activities on optical Nyquist pulse TDM transmission and local mode-coupling measurement along MCF are presented in detail.

12:00 PM – 1:30 PM **LUNCH BREAK**

1:30 PM - 3:00 PM
Session MC3: **SDM TRANSMISSION**
Session Chair: Andrew Ellis, *Tyndall National Institute, Cork, Ireland*

MC3.1 1:30 PM - 2:00 PM (Invited)

Transmission in Space-Division-Multiplexed Fibers, G. Li*, University of Central Florida, Orlando, FL, USA*

Key technologies and approaches for space-division multiplexed optical transmission is reviewed.

MC3.2 2:00 PM - 2:15 PM

Mode-Multiplexed Transmission over a 184-km DGD-Compensated Few-Mode Fiber Span, R. Ryf, M. A. Mestre, S. Randel, C. Schmidt, A. H. Gnauck, R.-J. Essiambre, P. J. Winzer, R. Delbue*, Alcatel-Lucent, Holmdel, NJ, USA*, P. Pupalaikis*,* A. Sureka*, LeCroy Corporation, Chestnut Ridge, NY, USA*, Y. Sun*,* X. Jiang*,* D. W. Peckham*,* A. McCurdy and R. L. Lingle*, OFS Laboratories, Norcross, GA, USA*

We transmitted 5 wavelength channels and 6 spatial- and polarization modes over a 184-km hybrid few-mode fiber span. Low-loss three-spot mode couplers are used in combination with backward pumped distributed Raman amplification.

MC3.3 2:15 PM - 2:30 PM

Reduction of Nonlinear Impairments in Coupled-Core Multicore Optical Fibers, S. Mumtaz, G. P. Agrawal*, University of Rochester, Rochester, NY, USA* and R.-J. Essiambre*, Alcatel-Lucent, Holmdel, NJ, USA*

We present a general model for studying the non- linear effects in coupled-core multicore fibers. Our results show that interactions between the intramodal nonlinearities and linear coupling between core can improve system performance.

MC3.4 2:30 PM - 2:45 PM

Nonlinear Interference in Mode MultiplexedMulti-mode Fibers, G. Rademacher, S. Warm and K. Petermann*, Technical University Berlin, Berlin, Germany*

We present a method to study the nonlinear interference in mode multiplexed multi-mode fibers by employing a four-wave-mixing based Gaussian-Noise Signal model and investigate its effects on the OSNR.

MC3.5 2:45 PM - 3:00 PM

Birefringence Effects in Space-Division Multiplexed Fiber Transmission Systems: Generalization of Manakov equation, S. Mumtaz*, University of Rochester, Rochester, NY, USA*, R.-J. Essiambre*, Alcatel-Lucent, Holmdel, NJ, USA* and G. P. Agrawal*, University of Rochester, Rochester, NY, USA*

We derive a generalized Manakov equation for multimode fiber to study the rapidly varying birefringence effects in space-division multiplexed fiber systems and show through numerical simulations that birefringence can reduce the impact of nonlinearities.

3:00 PM – 3:30 PM **COFFEE BREAK**

3:30 PM - 5:00 PM

Session MC4: DSP TECHNOLOGY
Session Chair: Roland Ryf, *Alcatel-Lucent, USA*

MC4.1 3:30 PM - 4:00 PM (Invited)

MIMO-Based Signal Processing for Mode-Multiplexed Transmission, S. Randel, C. Schmidt, R. Ryf, R.-J. Essiambre and P. J. Winzer*, Alcatel-Lucent, Holmdel, NJ, USA*

Using MIMO signal processing, we analyze the mode-dependent loss (MDL) of a 4200-km transmission link employing mode multiplexing over a 3-core microstructured fiber. We find that the MDL has a negligible impact on capacity.

MC4.2 4:00 PM - 4:15 PM

Demonstration of Joint DSP Receivers for Spatial Superchannels, M. D. Feuer, L. E. Nelson, X. Zhou, S. L. Woodward, R. Isaac*, AT&T, Middletown, NJ, USA*, B. Zhu, T. F. Taunay, M. Fishteyn, J. M. Fini and M. F. Yan*, OFS Laboratories, Somerset, NJ, USA*

We report lab measurements of joint digital signal processing of simultaneous 112Gbps links in a 7-core fiber. Strongly-correlated phase fluctuations between the cores permit reduced processing complexity with no increase in the bit-error ratio.

MC4.3 4:15 PM - 4:30 PM

Adaptive Frequency Domain Equalization for Mode-Division Multiplexed Transmission, N. Bai and G. Li*, University of Central Florida, Orlando, FL, USA*

We propose and simulate single-carrier adaptive frequency-domain equalization (SC-FDE) for mode-division multiplexed transmission. The FDE approach reduces computational complexity significantly compared to the time-domain equalization (TDE) approach while maintaining the same performance.

MC4.4 4:30 PM - 5:00 PM (Invited)

DSP Requirements for MIMO Spatial Multiplexed Receivers, B. Inan*, Technical University of Munich, Munich, Germany*, S. L. Jansen, B. Spinnler*, Nokia Siemens Networks GmbH & Co. KG, Munich, Germany*, F. Ferreira*, Nokia Siemens Networks Portugal S.A., Amadora, Portugal*, D. van den Borne, M. Kuschnerov*, Nokia Siemens Networks GmbH & Co. KG, Munich, Germany*, A. P. Lobato*, University of Federal Armed Forces, Neubiberg, Germany*, S. Adhikari*, Christian-Albrechts University at Kiel, Kiel, Germany*, V. Sleiffer*, Eindhoven University of Technology, Eindhoven, The Netherlands* and N. Hanik*, Technical University of Munich, Munich, Germany*

OFDM requires the lowest equalizer complexity for crosstalk compensation in a mode-division-multiplexing receiver. For a 2000-km transmission distance and less than 10% OFDM- specific overhead, the modal dispersion must be below 6 ps/km for 10x10 MIMO.

5:15 PM – 6:15 PM **WELCOME RECEPTION: MADISON BALLROOM (2ND FLOOR)**

Tuesday, 10 July 2012

9:00 AM - 10:00 AM

Session TuC1: Few Mode Fibers
Session Chair: Scott R. Bickham, *Corning, Inc., Corning, NY, USA*

TuC1.1 9:00 AM - 9:30 AM (Invited)

Design and Fabrication of Weakly-Coupled Few-Modes Fibers, M. Bigot-Astruc, D. Boivin and P. Sillard, *Prysmian Group, Marcoussis, France*

We study and optimize few-mode fibers for weakly-coupled mode division multiplexed transmissions that allow to multiply the capacity of single-mode systems by more than a tenfold.

TuC1.2 9:30 AM - 9:45 AM

A Large Effective Area Few-Mode Multi-Core Fiber, K. Takenaga, Y. Sasaki, N. Guan, S. Matsuo, *Fujikura Ltd., Sakura, Chiba, Japan*, M. Kasahara, K. Saitoh and M. Koshiba, *Hokkaido University, Sapporo, Hokkaido, Japan*

A design concept of few-mode multi-core fiber is presented. A four-core fiber that supports two LP modes with large effective area (A_{eff}) larger than 110 μm^2 realizes the highest relative core multiplicity factor of 11.7.

TuC1.3 9:45 AM - 10:00 AM

Measuring Distributed Mode Scattering in Few ModeFibers with High and Low Differential Group Delay, L. Grüner-Nielsen, *OFS Denmark, Brøndby, Denmark*, J. W. Nicholson, *OFS Laboratories, Somerset, NJ, USA*, K. Jespersen, *OFS Denmark, Brøndby, Denmark*, Y. Sun, R. L. Lingle, *OFS Laboratories, Norcross, GA, USA*, D. Jakobsen and B. Palsdottir, *OFS Denmark, Brøndby, Denmark*

We present measurements of distributed mode scatteringin up to 30km long few mode fibers using spatially and spectrally resolved (S2) imaging.

10:00 AM – 10:30 AM **COFFEE BREAK**

10:30 AM - 11:45 AM

Session TuC2: SDM in Data Com
Session Chair: John M. Fini, *OFS Laboratories, Somerset, NJ, USA*

TuC2.1 10:30 AM - 11:15 AM (Plenary)

Space Division Multiplexing in Data Communications and High Performance Computing, M. Taubenblatt, *IBM Research, Yorktown Heights, NY, USA*

High performance computing systems are exponentially increasing their dependence on optical interconnects to meet their scaling BW demands. Space division multiplexing continues to play an important role to meet the requirements of these systems.

TuC2.2 11:15 AM - 11:45 AM (Invited)

Recent Progress in Weakly Coupled Multicore Fibers: >100-Tbit/s Transmission and Next Generation Data Centers and Supercomputers, T. F. Taunay, *OFS Laboratories, Somerset, NJ, USA*

Recent MCF transmission results will be reviewed including record spectral efficiency, low loss and cross-talk and MCF amplifers. In addition potential benefits of MCF for datacenter and Supercomputer applications will also be presented.

11:45 AM – 1:15 PM **LUNCH BREAK**

1:15 PM - 3:00 PM

Session TuC3: Mode Couplers and Mode Coupling Effects
Session Chair: Shoichiro Matsuo, *Fujikura Ltd., Sakura-shi, Chiba, Japan*

TuC3.1 1:15 PM - 1:45 PM (Invited)

Mode Converters and Couplers for Few-Mode Transmission, A. Li, , X. Chen, A. Al Amin and W. Shieh, *University of Melbourne, Melbourne, Victoria, Australia*

Space-division multiplexing based on few-mode fiber has been studied as a promising technique to increase capacity. In this paper we review the recent progress on the enabling mode selective components including mode converters and couplers.

TuC3.2 1:45 PM - 2:00 PM

Spot-Based Mode Coupler for Mode-Multiplexed Transmission in Few-Mode Fiber, R. Ryf, N. K. Fontaine and R.-J. Essiambre, *Alcatel-Lucent, Holmdel, NJ, USA*,

We present designs for a spot based low-loss mode coupler for few-mode fibers. A design optimized for a fiber supporting 12 spatial and polarization modes and < 3dB loss is analyzed in detail.

TuC3.3 2:00 PM - 2:15 PM

Capacity Increase in Spliced Mode-Mulitplexd Transmission Systems by Using Mode Mixers, S. Warm and K. Petermann*, Technical University Berlin, Berlin, Germany*

The capacity of MDM transmission systems may be significantly reduced by fiber splices. Using only a few additional mode scramblers along the link the influence of fiber splices to the capacity is reduced.

TuC3.4 2:15 PM - 3:00 PM (Tutorial)

Mode Coupling Effects in Mode-Division-Multiplexed Systems, J. M. Kahn*, Stanford University, Stanford, CA, USA* and K.-P. Ho*, Silicon Image, Sunnyvale, CA, USA*

Strong mode coupling is beneficial in coherent mode-division-multiplexed systems. It reduces modal delay differences, minimizing signal processing complexity, and reduces mode-dependent gain variations, maximizing capacity. With modal dispersion, it creates frequency diversity, reducing outage probability.

3:00 PM – 3:30 PM COFFEE BREAK

3:30 PM - 5:00 PM

Session TuC4: Multicore Fibers
Session Chair: Takashi Sasaki, Sumitomo Electric Industries Ltd., Yokohama, Kanagawa, Japan

TuC4.1 3:30 PM - 4:00 PM (Invited)

Multi-Core Fibers and Their Crosstalk Characteristics, T. Hayashi*,* T. Sasaki and E. Sasaoka*, Sumitomo Electric Industries Ltd., Yokohama, Kanagawa, Japan*

Inter-core crosstalk of multi-core fibers is stochastic and heavily dependent on various perturbations such as bend and twist, and of course on fiber structures. Characteristics of the crosstalk are described from theoretical and experimental results.

TuC4.2 4:00 PM - 4:15 PM

Hole-Assisted Few-Mode Multi-Core Fiber for High-Density Space-Division Multiplexing, C. Xia*,* R. A. Correa*,* N. Bai*,* E. A. Lopez, D. M. Arriojo, A. Schulzgen*,* M. C. Richardson*, University of Central Florida, Orlando, FL, USA*, J. Linares*,* C. Montero*, University of Santiago de Compostela, Santiago de Compostela, Spain*, E. Mateo*, NEC Laboratories America, Inc., Princeton, NJ, USA*, X. Zhou*, AT&T, Middletown, NJ, USA* and G. Li*, University of Central Florida, Orlando, FL, USA*

A seven-core few-mode multi-core fiber in which each core supports three spatial modes has been designed and fabricated for the first time. The hole-assisted structure allows low crosstalk transmission of 21 spatial modes per polarization.

TuC4.3 4:15 PM - 4:30 PM

19-Core Multi Core Fiber to Realize High Density Space Division Multiplexing Transmission, K. Imamura, H. Inaba, K. Mukasa and R. Sugizaki*, Furukawa Electric Co. Ltd, Ichihara, Chiba, Japan*

19-core multi core fiber which has 10 times higher core density than 250μm coated SMF was realized. Each core was located on the three layered hexagonal grid in the 200μm cladding keeping low crosstalk properties.

TuC4.4 4:30 PM - 5:00 PM (Invited)

Homogeneous and Heterogeneous Multi-core Fibers, K. Saitoh*,* M. Koshiba*, Hokkaido University, Sapporo, Hokkaido, Japan*, K. Takenaga and S. Matsuo*, Fujikura Ltd., Sakurai, Chiba, Japan*

Required coupling coefficient and propagation constant difference between neighboring cores as well as allowable outer cladding diameter and assumed bending radii range are investigated for maximizing a relative core density in homogeneous and heterogeneous MCFs.

Wednesday, 11 July 2012

9:00 AM - 10:00 AM

Session WC1: Components for FMF Systems
Session Chair: Yoshinari Awaji, *NICT, Japan*

WC1.1 9:00 AM - 9:30 AM (Invited)

All Fiber Components for Multimode SDM Systems, I. Giles*, Phoenix Photonics, South Croydon, Surrey, UK*, A. Obeysekara*, University of Southampton, Southampton, UK*, R. Chen, D. Giles*, Phoenix Photonics, South Croydon, Surrey, UK*, F. Poletti and D. J. Richardson*, University of Southampton, Southampton, UK*

Fiber based mode converters and mode splitters are important elements in the FMF mux./demux. Long Period Gratings (LPGs) have been investigated and results presented together with a technique for real time mode monitoring during manufacture.

WC1.2 9:30 AM - 9:45 AM

Stable Mode Converter for Conversion between LP01 andLP11 Using a Thermally Induced Long Period Grating, L. Grüner-Nielsen*, OFS Denmark, Brøndby, Denmark* and J. W. Nicholson*, OFS Laboratories, Somerset, NJ, USA*

A new method for making long period gratings for coupling between symmetric and asymmetric modes is presented. Good stability compared to traditionally mechanical long period gratings, high coupling efficiency and low insertion loss is demonstrated.

WC1.3 9:45 AM - 10:00 AM

Phase Plate Tolerances in a Tri-Mode Demultiplexer, R. v. Uden*,* C. Okonkwo, H. d. Waardt and A. M. J. Koonen*, Eindhoven University of Technology, Eindhoven, The Netherlands*

The tolerance in a mode-demultiplexer to rotational, longitudinal offset and phase mismatch is demonstrated to be 25 degrees, 15% of the 1/e2 radius of the LP01 mode, and 45 degrees respectively for <1dB SNR penalty.

10:00 AM – 10:30 AM COFFEE BREAK

10:30 AM - 12:00 PM

Session WC2: MM FIBER AMPLIFIERS
Session Chair: Peter Krummrich, *University of Dortmund, Dortmund, Germany*

WC2.1 10:30 AM - 11:00 AM (Invited)

Modal Gain Equalization in a Few Moded Erbium-Doped Fiber Amplifier, S.-U. Alam, Y. Jung, Z. Li, A. Dhar, J. K. Sahu*,* F. Poletti and D. J. Richardson*, University of Southampton, Southampton, UK*

We present results on broadband gain equalisation in a MM-EDFA for SDM transmission obtained by optimization of the pump launch and careful tailoring of both the fiber refractive index profile and erbium ion distribution.

WC2.2 11:00 AM - 11:15 AM

Design of Multi-Mode Erbium-Doped Fiber Amplifiers for Low Mode-Dependent Gain, D. Askarov and J. M. Kahn*, Stanford University, Stanford, CA, USA*

Erbium-doped fiber amplifiers for 12 signal modes (six spatial modes in two polarizations) are studied by numerically solving multi-mode rate equations. Mode-dependent gains are compared for different numerical apertures, index profiles and doping profiles.

WC2.3 11:15 AM - 11:30 AM

Phase-Sensitive Multimode Parametric Amplification in Parabolic-Index Waveguides, M. Vasilyev and M. Annamalai*, University of Texas at Arlington, Arlington, TX, USA*

We show that multiple spatial modes or images can be amplified by an optical parametric amplifier based on graded-index waveguide, and that the gains of various modes can be equalized by using several pump modes.

WC2.4 11:30 AM - 12:00 PM (Invited)

Gain Equalization for Few-Mode Fiber Amplifiers with More Than Two Propagating Mode Groups, E. Ip*, NEC Laboratories America, Inc., Princeton, NJ, USA*

We investigate gain equalization in few-mode fibers with more than two mode groups at the signal wavelengths, and find that a combination of pump control and optimized doping profile is required to equalize mode-dependent gain.

12:00 PM – 1:30 PM LUNCH BREAK

1:30 PM - 3:00 PM

Session WC3: NOVEL COUPLING SCHEMES AND SDM DEVICES
Session Chair: David Boivin, Prysmian Group, Marcoussis, France

WC3.1 1:30 PM - 1:45 PM

Pump Light Source for Distributed Raman Amplification in Multi-Core Fibers with PLC-integrated LD Sharing Circuit, K. Suzuki*,* H. Ono*,* T. Mizuno, Y. Hashizume and T. Takahashi*, NTT Corporation, Atsugi, Kanagawa, Japan*

We report an integrated pump source for distributed Raman amplification in multi-core fiber that utilizes a silica-based planar lightwave circuit for bundling passive components and reducing the number of fiber pigtails and LD modules.

WC3.2 1:45 PM - 2:00 PM

Optical Fiber Amplifier Employing a Bundle of Reduced Cladding Erbium-Doped Fibers for Multi-Core Fiber Transmission, K. Tsujikawa, L. Ma*, NTT Corporation, Tsukuba, Ibaraki, Japan*, K. Ichii*,* S. Matsuo*, Fujikura Ltd., Sakura, Chiba, Japan*, M. Yamada*, Osaka Prefecture University, Sakai, Japan*, N. Hanzawa*, NTT Corporation, Tsukuba, Ibaraki, Japan* and H. Ono*, NTT Corporation, Atsugi, Japan*

We propose a novel optical amplifier that employs a bundle of erbium-doped fibers for multi-core fiber transmission. We demonstrate the amplification of seven independent signals by using a bundle of EDFs with 60 um cladding.

WC3.3 2:00 PM - 2:15 PM

Free-space Coupling Optics for Multi-core Fibers, W. Klaus*, National Institute of Information and Communications Technology, Tokyo, Japan*

We describe the design of low-loss and low-crosstalk free-space coupling optics for multi-core fibers and discuss in detail its experimental evaluation.

WC3.4 2:15 PM - 2:30 PM

Low Loss Optical Connection Module for 7-Core Multi-Core Fiber and Seven Single Mode Fibers, Y. Tottori*,* T. Kobayashi and M. Watanabe*, OPTOQUEST Co., Ltd, Ageo, Saitama, Japan*

A pair of compact optical connection module is developed that connects 7-core multi-core fiber and seven single mode fibers. Insertion loss below 0.6 dB and cross talk better than -50 dB were realized.

WC3.5 2:30 PM - 2:45 PM

Mode Division Multiplexing Over 2km of OM2 Fibre Using Rotationally Optimized Mode Excitation with Fibre Coupler Demultiplexer, J. Carpenter and T. D. Wilkinson*, University of Cambridge, Cambridge, UK*

A Spatial Light Modulator and a non-specialized multimode coupler are used together to provide sufficient channel isolation and modal bandwidth for 2x12.5Gbps NRZ over 2km of standard graded-index multimode fibre without DSP.

WC3.6 2:45 PM - 3:00 PM

All Optical Degenerate Mode-Group Multiplexing Using a Mode Selective Switch, J. Carpenter*, University of Cambridge, Cambridge, UK*

A Mode Selective Switch based around an LCoS Spatial Light Modulator is demonstrated to optically demultiplex modes with the same propagation constants to the same output fibres, using a common phase mask for all channels.

3:00 PM – 3:30 PM **COFFEE BREAK**

3:30 PM - 4:45 PM

Session WC4: SILICON DEVICES
Session Chair: Mark D. Feuer, *AT&T, Middletown, NJ, USA*

WC4.1 3:30 PM - 4:00 PM (Invited)

Silicon Photonics Multicore Transceivers, T. J. Pinguet, P. M. De Dobbelaere*,* D. Foltz*,* S. Gloeckner, S. Hovey*,* Y. Liang*,* M. P. Mack*,* G. Masini, A. Mekis, M. Peterson, S. Sahni*,* J. Schramm, M. Sharp*,* D. Song, B. Welch*,* K. Yokoyama and S. Yu*, Luxtera, Carlsbad, CA, USA*

We examine how the continued increase of single channel data rates combined with spatial multiplexing enabled by multi-core fibers will lead to the aggressive scaling of the aggregate bandwidth of silicon photonics transceivers.

WC4.2 4:00 PM - 4:15 PM

Silicon Photonic Integrated Mode Multiplexer, A. M. J. Koonen*,* H. Chen, H. P. A. van den Boom and O. Raz*, Eindhoven University of Technology, Eindhoven, The Netherlands*

A novel passive integrated optical circuit for mode-multiplexing 6 channels in two-moded fiber has been designed and tested. It can outperform present bulk-optics solutions by its compactness, high coupling efficiency and excellent crosstalk suppression.

WC4.3 4:15 PM - 4:45 PM (Invited)

Silicon Photonic for Space-Division Multiplexing, C. R. Doerr*, Acacia Communications Inc., Maynard, MA, USA*

An allure of space-division multiplexing is a very high optical connection density yet it may require significant MIMO processing. Silicon photonics is well suited for handling both.

END OF PROGRAM

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