Optical Fiber Communication Conference (OFC®) and the International Conference on Integrated Optics and Optical Fiber Communication (IOOC)

OFC® '99 IOOC

TECHNICAL DIGEST SERIES

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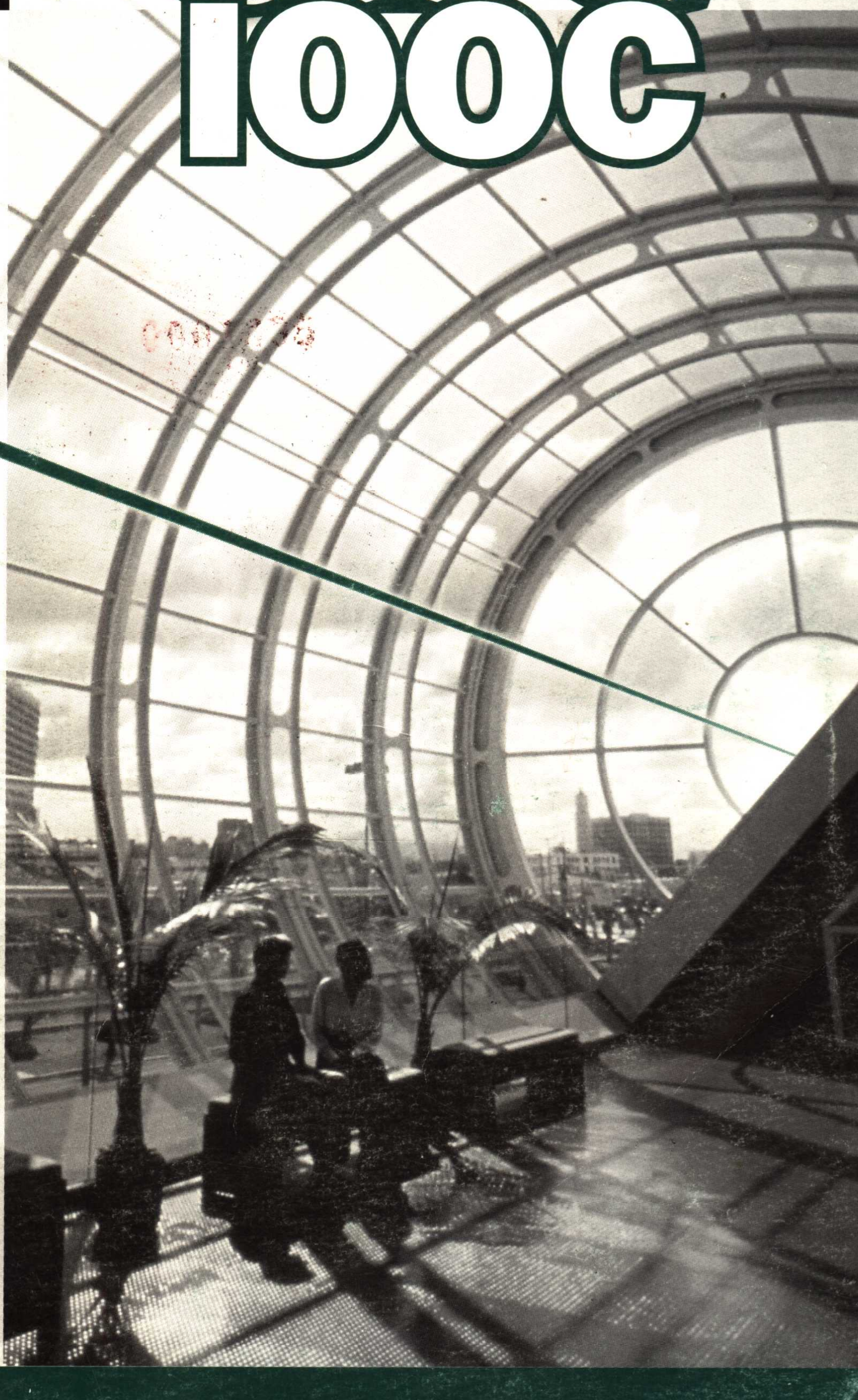

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San Diego, California

Wednesday, February 24, 1999

OFC® '99 IOOC

Optical Fiber Communication Conference and the
International Conference on Integrated Optics and Optical Fiber Communication

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San Diego, California

Technical Digest

Wednesday, February 24, 1999

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Foreword

OFC, the premiere conference on optical fiber communications, goes to San Diego, California in February 1999. This year's program spans the gamut of topics that should be of interest for both professionals and students in the lightwave community. The scope of the conference covers a wide variety of areas consisting of a technical and commercial program. The technical program includes a plenary session, short courses, workshops, tutorials, oral presentations and poster papers. This year's commercial program features an exhibit including over 300 companies spread over a 254,000 square foot exhibit hall, a Commercial Technology program, and Product Presentations.

This year, as it has every six years, the OFC conference combines with IOOC, the International Conference on Integrated Optics and Optical Fiber Communication. As a result, the conference has an increased international representation as can be seen from the makeup of the technical program committees (more than half of the members are from outside the Americas) and the paper submissions (55% of the submitted papers were from outside the Americas).

The OFC/IOOC '99 Plenary Session features two industry leaders who will provide us with two different views of the optical fiber communications industry. John Sidgmore, CEO of UUNET/WorldCom, offers the perspective of an internet service provider, and Neil Tagare, president of CTR group and leader of "Project Oxygen," speaks as a builder of an ambitious global fiber optic network. In addition, the 12th John Tyndall Award will be presented to John MacChesney of Lucent Technologies. He will receive the award for his invention and development of the MCVD process, which is one of the major techniques for the manufacture of low loss optical fibers and for high purity overcladding tubes using sol-gel techniques.

The technical program for OFC consists of invited papers and tutorials from industry leaders and contributed papers that were selected from over 600 submissions, up by 20% from last year. The technical program runs in six parallel sessions from Tuesday through Friday. There are many exciting papers in the program, covering such topics as

- Higher power, broader band optical amplifiers to support more WDM channels,
- Novel fiber and device designs, such as silica-air single-material fibers,
- Higher speed optoelectronic devices, preparing for systems past 10 Gb/sec,
- 40 Gb/sec systems experiments,
- Novel wavelength translation and bit error rate monitoring devices and applications in transparent optical networks, and
- Access network technologies to speed the deployment of fiber closer to the customers.

OFC offers unique educational opportunities. In San Diego, there will be 42 different short courses covering a wide range of optical fiber communications at all levels from basic to advanced. Short courses are offered all day Sunday and Monday, and one additional course is offered on Wednesday. These courses are taught by the top experts in their field and give attendees the opportunity to learn about related areas of optical fiber communication-related technologies.

On behalf of the entire program committee and conference staff, we look forward to sharing this exciting technology with you in San Diego.

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OFC '99 IOOC Agenda of Sessions

Category of session in parentheses (e.g. I, II, III, IV, V)

TUES., FEB. 23

	6A	6B	6C	6D	5A	1A
8:30am–10:30am	TuA • Plenary Session					
10:30am–11:00am	Exhibit Grand Opening and Coffee Break, Exhibit Hall					
11:00am–12:30pm	TuB • Fiber Laser (I)	TuC • Pump Lasers (II)	**TuD • Symposium on Undersea Systems (III)**	TuE • Access Networks (V)	TuF • Network Architecture (IV)	**TuG • Tutorial on Silicon Micromachines for Lightwave Networks (II)**
12:30pm–2:00pm	LUNCH BREAK					
2:00pm–4:00pm	TuH • Filters for WDM Systems - 1 (I)	TuI • Detectors and Receivers (II)	TuJ • Regeneration and Conversion (III)	TuK • Optical Networking (V)	TuL • Protection and Restoration (IV)	**TuM • Tutorial on Hybrid Fiber Coax System and Network Technologies (IV)**
4:00pm–4:30pm	Coffee Break, Exhibit Hall					
4:30pm–6:00pm	TuN • Filters for WDM Systems - 2 (I)	TuO • Phased-Array Services (II)	TuP • CATV Lightwave Systems(III)	TuQ • Network Implementations and Field Trials (V)	TuR • Network Performance and Degradations (IV)	**TuS • Polarization and Chromatic Dispersion Compensation (I)**
6:00pm–7:00pm	Conference Reception, Sail Area, Upper Level, San Diego Convention Center					

WED., FEB. 24

	6A	6B	6C	6D	5A	1A
8:30am–10:30am	WA • Fiber Amplifiers - 1 (I)	**WB • Symposium on Optical Crossconnects-1 (II)**	WC • Soliton Transmission (III)	WD • Wireless and Wireline Networks (IV)	WE • Polarization-Mode Dispersion (III)	**WF • Tutorial on WDM System Impairments (III)**
10:30am–1:30pm	EXHIBITS ONLY TIME LUNCH BREAK					
1:30pm–3:30pm	WG • Fiber Amplifiers - 2 (I)	WH • Lasers (II)	**WI • Symposium on Optical Crossconnects-2 (IV)**	WJ – DWDM - 1 (III)	WK • Regional and Large Scale Optical Networks (IV)	**WL • Tutorial on NRZ, RZ, or Solitons: Modulation Format, Your Choice or the Fiber's?**
4:00pm–5:30pm	WM • POSTER SESSION					

THURS., FEB. 25

	6A	6B	6C	6D	5A	1A
8:30am–10:00am	ThA • Nonlinear Fiber Devices and Technologies (I)	ThB • Arrayed-Waveguide Grating Router Devices (II)	ThC • Cross-Phase Modulation (III)	ThD • Fiber Gratings: Fundamentals (I)	ThE • Transport and Access Technologies - 1 (V)	**ThF • Tutorial on Components for Next Generation High-Speed LAN (II)**
10:00am–10:30am	Coffee Break, Exhibit Hall					
10:30am–12m	ThG • Optical Fiber Material and Processing (I)	ThH • Wavelength Add/Drop Devices (II)	ThI • 40 Gb/s Transmission (III)	ThJ • Adjustable Fiber Grating Filters (I)	ThK • Transport and Access Technologies - 2 (V)	**ThL • Tutorial on Fundamental Limitations of EDFAs in Amplified Transmission Systems**
12:00m–1:30pm	LUNCH BREAK					
1:30pm–3:30pm	ThM • Optical Packet and IP Switching (IV)	ThN • Transceivers and Packaging (II)	ThO • DWDM - 2 (III)	**ThP • Symposium on Large Optical Networking Programs (IV)**	ThQ • Nonlinear Transmission (III)	**ThR • Tutorial on Raman and Cladding-Pumped Fiber Amplifiers and Lasers (I)**
3:30pm–4:00pm	Coffee Break, Exhibit Hall					
4:00pm–5:30pm	ThS • Calibration and Measurements (I)	ThT • High-speed Modulators and Short Pulse Generation (II)	ThU • EDFA Effects (III)	ThV • Access Networks (IV)	ThW • Analog Applications (III)	**ThX • Tutorial on High-Capacity Optical Transmission System Design (V)**
5:45pm–7:00pm	POSTDEADLINE PAPER PRESENTATIONS					

FRI., FEB. 26

	6A	6B	6C	6D	5A	1A
8:30am–10:30am	FA • Dispersion Compensation with Fiber Gratings (I)	FB • Wavelength Conversion and Signal Processing (II)	FC • Wideband Amplifiers and Systems (III)	FD • Overcoming Dispersion (III)	FE • VCSELs and Novel Devices (II)	**FF • Tutorial on Protection and Restoration in Optical Networks**
10:30am–11:00am						
11:00am–12:30pm	FG • Novel Fiber Structures (I)	FH • Optical MEMS (II)	FI • OTDM (III)	FJ • Technologies for Transparent Networks (IV)	FK • Fiber Grating Applications (I)	

Room 6A

8:30am–10:30am
WA • Fiber Amplifiers 1 (Cat. I)
Douglas M. Baney, *Hewlett-Packard Laboratories, USA, Presider*

8:30am
WA1 (Invited) • Ultrabroadband optical amplifiers, Michael J. Yadlowsky, *Corning, Inc., USA.* Multiple optical amplifier technologies now exist that can be used to provide bandwidths exceeding 40 nm. Performance trade-offs as well as the economics of transmission systems and optical networks will determine the choice among these options. **(p. 2)**

9:00am
WA2 • 23-dBm output power Er/Yb codoped fiber amplifier for WDM signals in the 1575 nm to 1605 nm wavelength region, F. Di Pasquale, G. Grasso, F. Meli, G. Sacchi, S. Turolla, *Pirelli Cavi e Sistemi S.p.A., Italy.* We report, for the first time to our knowledge, theoretical and experimental results concerning a broadband and gain-flattened Er/Yb codoped double-cladding fiber amplifier, which provides up to 23-dBm output power in the wavelength region 1575 nm to 1605 nm. **(p. 4)**

9:15am
WA3 • Improvement of 157~1.61 μm band amplification efficiency recycling wasted backward ASE through the unpumped EDF section, Ju Han Lee, Uh-Chan Ryu, Namkyoo Park, *Seoul National Univ., S. Korea.* A novel structure, which utilizes detrimental backward amplified spontaneous emission (ASE) as a secondary pump source is suggested for a 1.58-μm silica-based fiber amplifier. By using the secondary pumping effect from the strong, wasted 1550-nm band ASE power in the unpumped section of the erbium-doped fiber (EDF), it was possible to achieve a considerable improvement in power conversion efficiency, increasing small signal gain by more than 4 dB. **(p. 7)**

9:30am
WA4 • Pump-induced inhomogeneity of gain spectra in conventional and extended-band EDFAs, P.N. Kean, S.J. Wilson, M. Healy, R. Di Muro, N.E. Jolley, F. Davis, *Nortel Plc, UK.* We present results on spectral gain changes resulting from small changes of pump wavelength in erbium-doped fiber amplifiers (EDFAs). While conventional-band EDFAs exhibit a significant effect with 980-nm pumping and a smaller effect with 1480 nm, it is absent for extended-band EDFAs operating around 1585 nm. **(p. 10)**

Room 6B

8:30am–10:30am
WB • Symposium on Optical Crossconnects (Cat. II)
Jay M. Wiesenfeld, *AT&T Labs–Research, USA, Presider*

8:30am
WB1 (Invited) • Hybrid PIC using PLC platform for optical network system, Tomoaki Kato, Tsuyoshi Shimoda, Takemasa Tamanuki, Jun-ichi Sasaki, *NEC Corp., Japan.* Abstract not available. **(p. 24)**

9:00am
WB2 (Invited) • Gate arrays using gain-clamped semiconductor optical amplifiers, François Dorgeuille, *Alcatel Corporate Research Centre, France.* Gate arrays using gain-clamped semiconductor optical amplifiers have been successfully implemented in optical cross-connects for wavelength-division multiplexing routing applications as well as in fast optical packet switching experiments. Recent achievements on these devices will be reviewed. **(p. 25)**

9:30am
WB3 (Invited) • Lithium niobate switch arrays for optical crossconnects, Edmond J. Murphy, *Lucent Technologies, USA.* The status of lithium niobate guided wave switches and their use in optical crossconnects will be reviewed. The talk will include recent results from the MONET program and a discussion of future applications. **(p. 28)**

Room 6C

8:30am–10:30am
WC • Soliton Transmission (Cat. III)
Curtis R. Menyuk, *University of Maryland–Baltimore County, USA, Presider*

8:30am
WC1 • 20-Gbit/s transmission of dispersion-managed solitons over 20,000 km, Gary M. Carter, Pranay Sinha, Curtis R. Menyuk, *The Laboratory for Physical Sciences and Univ. Maryland–Baltimore County, USA;* Ruomei Mu, Vladimir Grigoryan, *Univ. Maryland–Baltimore County, USA;* Thomas F. Carruthers, Michael L. Dennis, Irl N. Duling III, *Naval Research Laboratory, USA.* We have propagated 20-Gbit/s data over 20,000 km without any observed pulse-to-pulse interaction achieving an error rate $<1 \times 10^{-9}$ in a dispersion-managed soliton system. **(p. 32)**

8:45am
WC2 • The performance of a 10-Gbit/s filtered dispersion-managed soliton system with lumped amplifiers, R.-M. Mu, V.S. Grigoryan, C.R. Menyuk, G.M. Carter, J.M. Jacob, *Univ. Maryland–Baltimore County, USA.* We simulated the performance of a 10-Gbit/s filtered dispersion-managed soliton system using Monte–Carlo techniques. The predicted noise behavior was in excellent agreement with the measured data. **(p. 35)**

9:00am
WC3 • Ultra-high-speed soliton transmission in the presence of polarization-mode dispersion using in-line synchronous modulation, A. Sahara, H. Kubota, M. Nakazawa, *NTT Optical Network Systems Laboratories, Japan.* It is shown numerically that in-line synchronous modulation is especially useful for extending the transmission distance in the presence of large polarization-mode dispersion in ultra-high-speed (40 and 80 Gbit/s) optical soliton transmission systems. **(p. 38)**

9:15am
WC4 • 16,000 km 10-Gbits^{-1} soliton transmission over standard fiber by reduction of interactions through optimum amplifier positioning, S. Alleston, I. Penketh, P. Harper, A. Niculae, I. Bennion, N.J. Doran, *Aston Univ., UK.* We show that by optimizing the amplifier position in a two-stage dispersion map, the (dispersion-managed) soliton-soliton interaction can be reduced, enabling transmission of 10-Gbits^{-1} solitons over standard fiber over 16,000 km. **(p. 41)**

9:30am
WC5 • Experimental demonstration of highly tolerable dispersion-managed soliton system designed for transoceanic transmission, Gyaneshwar Chandra Gupta, Kiyoshi Fukuchi, Yoshihisa Inada, Tetsuyuki Suzaki, *NEC Corp., Japan.* Large system margins were successfully achieved in dispersion-managed soliton transmission experiments over 10,000 km at 10 Gbit/s and 20 Gbit/s with 53-km repeater spacing. Optimum system parameters were easily designed by considering pulse spacing and dispersion compensation period as primary parameters. **(p. 44)**

Room 6D

8:30am–10:30am
WD • Wireless and Wireline Networks (Cat. IV)
TBD, *Presider*

8:30am
WD1 (Invited) • Wireline and wireless access networks, T.E. Darcie, *AT&T Labs, USA.* Numerous technical and competitive forces are driving the redefinition of access networks around the world, but technology choices and economic challenges create a complex maze of options. We review the driving forces, issues, and technologies involved, drawing specific comparison between wireless (fixed and mobile) and wireline alternatives. **(p. 58)**

9:00am
WD2 (Invited) • Broadband optical-wireless systems and networks, Rolf Heidemann, Gustav Veith, *Alcatel SEL AG, Germany.* Abstract not available. **(p. 60)**

9:30am
WD3 • Capacity allocation using WDM in fiber-wireless access networks, M. Luizink, *KPN Research, The Netherlands;* C.A.M. Steenbergen, A.M.J. Koonen, *Lucent Technologies, The Netherlands.* This paper discusses the impact of fixed and flexible wavelength routing in fiber-wireless access networks. Based on the capacity required, an optimal location is identified for the dynamic wavelength router. **(p. 61)**

Room 5A

8:30am–10:30am
WE • Polarization-Mode Dispersion (Cat. III)
TBD, *Presider*

8:30am
WE1 • Limitation of optical first-order PMD compensation, Henning Bülow, *Alcatel Corporate Research Center, Germany.* A new theoretical model exhibits that first-order polarization-mode dispersion (PMD) compensation extends the maximum acceptable PMD to 0.38 times the bit period T. At 10 Gbit/s chromatic dispersion of 850 ps/nm (50 km SMF) reduces this PMD limit to 0.29 T. **(p. 74)**

8:45am
WE2 • System impairment due to PMD, C.-J. Chen, *Tyco Submarine Systems Ltd., USA.* A linear model that determines the eye closure due to polarization-mode dispersion is presented. Current 2.5-Gbit/s systems have minor impairment from PMD; however, systems with increased bit rate and/or PMD could suffer from *Q*-factor fluctuations primarily and reduced average *Q*-factor. **(p. 77)**

9:00am
WE3 • PMD impairment in return-to-zero and nonreturn-to-zero systems, R.M. Jopson, L.E. Nelson, G.J. Pendock, *Bell Labs, Lucent Technologies, USA;* A.H. Gnauck, *AT&T Labs-Research, USA.* Using 10-Gbit/s signals, amplitude modulated with either a return-to-zero (RZ) or a nonreturn-to-zero format (NRZ), we measured optically preamplified receiver sensitivity after distortion by polarization-mode dispersion (PMD). RZ modulation was found to be more resilient to PMD than NRZ modulation. **(p. 80)**

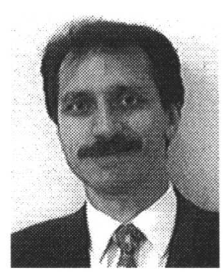
9:15am
WE4 • Measurement of the maximum speed of PMD fluctuation in installed field fiber, H. Bülow, W. Baumert, H. Schmuck, *Alcatel Corporate Research Center, Germany;* F. Mohr, T. Schulz, *FH Pforzheim—Univ. Applied Sciences, Germany;* F. Küppers, W. Weiershausen, *Deutsche Telekom, Germany.* A polarization-mode dispersion (PMD) transient recorder setup was realized enabling for the first time to our knowledge the monitoring of fast PMD fluctuation with a bandwidth of up to 1 MHz. Thirty-six hours of observation of an installed field fiber exhibits significant PMD variation within 10 ms. **(p. 83)**

9:30am
WE5 • Automatic PMD compensation in 40-Gbit/s transmission, H. Ooi, Y. Akiyama, G. Ishikawa, *Fujitsu Laboratories Ltd., Japan.* We believe we demonstrated automatic polarization-mode dispersion (PMD) compensation in 40-Gbit/s NRZ transmission for the first time. By the feedback control of an optical PMD compensator to maximize the 20-GHz intensity of received baseband signals, we more than doubled the allowable PMD from 11 to 23 ps. **(p. 86)**

Room 1A

8:30am–9:30am
WF • Tutorial on WDM System Impairments (Cat. III)
Robert Tkach, *AT&T Labs-Research, USA, Presider*

INSTRUCTOR



Fabrizio Forghieri
Pirelli Cavi e Sistemi, Italy

Optical transmission systems with capacity exceeding 100 Gbit/s per fiber are already commercially available. The combined use of high-density wavelength-division multiplexing (WDM), high per-channel bit rate and extended-bandwidth optical amplifirs is rapidly pushing the capacity of commercial systems beyond 1 Tbit/s.

The performance of WDM systems is determined by the interplay of several limiting factors: optical signal-to-noise ratio, fiber chromatic dispersion, and fiber nonlinearities.

The mechanism by which fiber propagation effects impair WDM systems will be reviewed. Practical design criteria will be discussed and applied to a terrestrial optical fiber communication system with 1 Tbit/s capacity.

Fabrizio Forghieri was born in Modena, Italy. He received the Doctor of Engineering degree in electrical engineering, summa cum laude, from the University of Pisa and the M.A. and Ph.D. degrees in electrical engineering from Princeton University.

From 1993 to 1997, he has been with AT&T Bell Laboratories at first, and then with AT&T Labs Research, working on modeling of nonlinear optical effects in fibers and WDM lightwave systems and networks.

In 1997, he joined the Lightwave Transmission Systems R&D Department of Pirelli Cavi & Sistemi, where he is currently responsible for Lightwave Systems Research. **(p. 100)**

Room 6A

WA • Fiber Amplifiers 1 (Cat. I)—Continued

9:45am
WA5 • Ultra-low-noise long-wavelength EDFA with 3.6 dB external noise figure, K.J. Cordina, N.E. Jolley, J. Mun, *Nortel Plc, UK.* A long-wavelength erbium-doped fiber amplifier (LW-EDFA) is reported showing a near-quantum-limited external noise figure as low as 3.6 dB. The amplifier configuration uses a buried optical filter and optical isolator to achieve this performance. **(p. 13)**

10:00am
WA6 • High-capacity EDFA with output power to support densely loaded channels, Paul Freeman, Dan Ratoff, Dave Mehuys, Ray Zanoni, Mark LaLiberte, *SDL, Inc., USA.* High-channel capacity is demonstrated with a 36-nm gain-flattened erbium-doped fiber amplifier (EDFA) with over 28 dBm output power. Wavelength-multiplexed and Raman-based pump sources are used to achieve the high output powers while maintaining telecom grade reliability. **(p. 16)**

10:15am
WA7 • High-power side-pumped Er/Yb codoped fiber amplifier, Lew Goldberg, Jeffrey Koplow, *Naval Research Laboratory, USA.* A high-power Er/Yb double-cladding fiber amplifier, side-pumped through a v-groove by a 100-μm-wide broad stripe laser diode exhibited 32 dBm output power, 57 dB small signal gain, a 3 dB gain compression at 28 dBm, and a 15% electrical to optical power conversion efficiency. **(p. 19)**

Room 6B

WB • Symposium on Optical Crossconnects (Cat. II)—Continued

10:00am
WB4 (Invited) • Polymeric digital optical switch using fluorinated polyimide, Tatemi Ido, *Hitachi, Ltd., Japan.* A 1 × 8 polymeric digital optical switch made using highly reliable fluorinated polyimide has been demonstrated. High-acceleration damp-heat tests show the excellent potential of this switch for use in a nonhermetic package. **(p. 29)**

Room 6C

WC • Soliton Transmission (Cat. III)—Continued

9:45am
WC6 • Long unrepeatered transmission at 10 Gbit/s using adiabatic soliton propagation, Michael L. Dennis, Walter I. Kaechele, Thomas F. Carruthers, R. Brian Jenkins, Jin U. Kang, Irl N. Duling III, *Naval Research Laboratory, USA.* We experimentally demonstrate transmission of 10-Gbit/s data over 296 km with no in-line amplification. Adiabatic propagation of picosecond solitons is used to increase the launched optical power and obtain a power budget of >62 dB. **(p. 47)**

10:00am
WC7 • Error-free 80-Gbit/s soliton transmission over transoceanic (>8,000 km) distances using fast saturable absorbers and dispersion-decreasing fiber, S. Bennett, A.J. Seeds, *Univ. College London, UK.* We present a numerical study of the use of fast saturable absorbers in conjunction with dispersion-decreasing fiber to achieve enhanced transmission of 80-Gbit/s solitons over ultralong distances (8,350 km) with an amplifier spacing of 50 km. **(p. 50)**

10:15am
WC8 • Feasibility of 1 Terabit/s (25 ch × 40 Gbit/s) global-distance, optically regenerated systems, E. Pincemin, O. Leclerc, E. Desurvire, *Alcatel Corporate Research Center, France.* The theoretical feasibility of 1 Tbit/s optically regenerated systems over 10,000 km is investigated. The role of key parameters (fiber dispersion slope, mode area, channel and regenerator spacing) on system performance is analyzed. **(p. 53)**

10:30am–1:30pm EXHIBITS ONLY TIME AND LUNCH BREAK, Exhibit Hall

Room 6D

WD • Wireless and Wireline Networks (Cat. IV)—Continued

9:45am
WD4 • Fading-free fiber-optic transport of 60-GHz optical DSB signal by using in-line phase conjugator, Ken-ichi Kitayama, Hideyuki Sotobayashi, *Ministry of Posts and Telecommunications, Japan.* Fading-free transport of 60-GHz optical DSB signal in 100-km-long non-dispersion-shifted single-mode fiber at 1550 nm by inserting a semiconductor optical amplifier phase conjugator in the midway of optical link is experimentally demonstrated for the first time to our knowledge. **(p. 64)**

10:00am
WD5 • Bidirectional passive optical network for CDMA personal communication service, H. Kim, Y.C. Chung, *Korea Advanced Institute of Science and Technology, S. Korea.* We propose and demonstrate a bidirectional passive optical network for CDMA personal communication service. This network could be implemented cost effectively by using a Fabry–Perot laser for the downlink and LEDs for the uplink. **(p. 67)**

10:15pm
WD6 • Radio-over-fiber distribution using an optical millimeter-wave/DWDM overlay, R.A. Griffin, P.M. Lane, J.J. O'Reilly, *Univ. College London, UK.* We demonstrate an optical mm-wave dense wavelength-division multiplexed (DWDM) overlay using optical suppressed-carrier modulation to simultaneously upconvert multiwavelength subcarriers to 35 GHz. Performance of the system is analyzed for radio-over-fiber distribution. **(p. 70)**

Room 5A

WE • Polarization-Mode Dispersion (Cat. III)—Continued

9:45am
WE6 • Impact of polarization hole burning effect in transoceanic WDM systems, Hidenori Taga, Noboru Edagawa, Masatoshi Suzuki, *KDD R&D Labaratories Inc., Japan.* We have investigated the impact of polarization hole burning effect in transoceanic wavelength-division multiplexing (WDM) systems experimentally. A polarization scrambler should be indispensable even in WDM transmission for wide channel separation. **(p. 89)**

10:00am
WE7 • 1.24-Gbit/s 40-km OCDM transmission by using spectral bipolar coding of broadband incoherent light, Hideyuki Sotobayashi, Ken-ichi Kitayama, *Ministry of Posts and Telecommunications, Japan.* Error-free 1.24 Gbit/s optical code division multiplexing (OCDM) transmission over 40 km by using spectral bipolar coding of spectral sliced broadband incoherent light (EDFA-ASE) has been demonstrated for the first time to our knowledge. **(p. 92)**

10:15am
WE8 • Polarization-independent all-optical clock division using a semiconductor-optical-amplifier/grating-filter switch, Hyuek Jae Lee, Hae Geun Kim, *Electronics and Telecommunications Research Institute, S. Korea.* We propose and experimentally demonstrate, for the first time to our knowledge, polarization-independent all-optical clock division (CD) of an optical pulse train at 2.88 GHz. This is achieved using a semiconductor-optical amplifir (SOA)/grating-filter switch, where the SOA acts as a spectral shifter by a self-phase modulation (SPM) and the grating filter acts as a spectral shutter. The proposed scheme is very insensitive to the polarization of input pulses and requires verylow switching energy (~102 fJ). After the all-optical CD operation, we have obtained the output pulse train at 1.44 GHz, which is half the input repetition rate, with high extinction ratio (>20 dB). **(p. 95)**

Room 1A

WF • Tutorial on WDM System Impairments (Cat. III)—Continued

10:30am–1:30pm EXHIBITS ONLY TIME AND LUNCH BREAK, Exhibit Hall

Room 6A

1:30pm–3:30pm
WG • Fiber Amplifiers 2 (Cat. I)
Bruce Nyman, *JDS Fitel Inc., USA, Presider*

1:30pm
WG1 • Effect of spectral hole burning on multichannel EDFA gain profile, Takuya Aizawa, Tetsuya Sakai, Akira Wada, Ryozo Yamauchi, *Fujikura Ltd., Japan.* We show that a spectral gain profile of a multichannel erbium-doped fiber amplifier (EDFA) changes associated with the change in multichannel location, which is well described by a summation of spectral hole burning caused by each signal channel. **(p. 102)**

1:45pm
WG2 •Analytical model describing transients within a gain-clamped EDFA, Kai Song, Richard D.T. Lauder, Malin Premaratne, *Univ. Melbourne, Australia.* We present an analytical model suitable for investigation of transient effects within a gain-clamped erbium-doped fiber amplifier (EDFA) experiencing a change to the input signal or pump power. We test the validity of assumptions made and discuss the limitations of the model presented. **(p. 105)**

2:00pm
WG3 • A new method to determine the Er-fiber gain coefficient from dynamic gain tilt technique, R. Di Muro, S.J. Wilson, N.E. Jolley, B.S. Farley, A. Robinson, J. Mun, *Nortel plc, UK.* A new method to determine the Er-fiber gain coefficient is presented using a dynamic gain tilt technique. Results demonstrate that this method is very simple, highly accurate, and especially useful for long-wavelength erbium-doped fiber amplifier. **(p. 108)**

2:15pm
WG4 • Model to predict spectral shape of a hybrid 980 nm–1480 nm pumped EDFA, M.E. Bray, T.J. Reid, K.P. Jones, M.P. Poettcker, *Nortel plc, UK.* A new model for predicting hybrid 980 nm–1480 nm pumped erbium-doped fiber amplified (EDFA) gain spectra, which agrees to better than 0.1 dB with measured results, is presented. **(p. 111)**

Room 6B

1:30pm–3:30pm
WH • Lasers (Cat. II)
Scott Burroughs, *Lasertron, USA, Presider*

1:30pm
WH1 • Wide range of operating conditions for a 1000 km–2.5 Gbit/s transmission with a new WDM optimized design of integrated laser electro-absorption modulator, H. Debrégeas-Sillard, P. Doussière, A. Bodéré, O. Legouezigou, G. Michaud, F. Gaborit, S. Gauchard, F. Brillouet, *Alcatel Corporate Research Centre, France;* Ph. Rael, *Alcatel Optronics, France.* A new wavelength-division multiplexed (WDM) optimized design of integrated electroabsorption modulator distributed feedback lasers provides a great tolerance on operating conditions and laser wavelength: 2.5 Gbit/s transmission over 1000 km is performed for $\Delta I_{laser} = 70$ mA, $\Delta T_{chip} = 20°C$, and $\Delta\lambda_{laser} = 10$ nm. **(p. 128)**

1:45pm
WH2 • 1560 nm to 1610 nm wavelength EA-modulator integrated DFB-LDs for extended-band 2.5-Gbit/s/ch and 10 Gbit/s/ch WDM systems, Yuji Furushima, Koji Kudo, Yoshiharu Muroya, Yasutaka Sakata, Yasumasa Inomoto, Kiyoshi Fukuchi, Masashige Ishizaka, Masayuki Yamaguchi, *NEC Corp., Japan.* We developed EA-modulator integrated DFB-LDs covering 1.56-µm to 1.61-µm wavelengths on a single wafer, and tested them in long-distance transmission experiments for the first time to our knowledge. Transmissions at 2.5 Gbit/s over 600 km and 10 Gbit/s over 500-ps/nm dispersion were successfully demonstrated. **(p. 131)**

2:00pm
WH3 • SMF 300-km transmission experiment by using a newly developed 10-Gbit/s lightwave transceiver with an electroabsorption modulator integrated LD, Junichi Nakagawa, Ken-ichi Uto, Kuniaki Motoshima, *Mitsubishi Electric Corp., Japan.* 10-Gbit/s lightwave transceiver with an EA/LD module has been newly developed to meet the STM-64 interface. The back-to-back receiver sensitivity of –16.8 dBm and SMF-300 km amplified transmission experiment with the power penalty of 0.6 dB have been successfully achieved. **(p. 134)**

2:15pm
WH4 (Invited) • Widely tunable semiconductor lasers, Björn Broberg, Pierre-Jean Rigole, Stefan Nilsson, Lars Andersson, Markus Renlund, *Altitun AB, Sweden.* Monolithic widely tunable lasers are reviewed, with emphasis on the grating coupled sampled reflector (GCSR) laser. Methods of controlling the lasers are discussed, leading to wavelength agile integrated wavelength-division multiplexing sources settable to any wavelength within the erbium-doped fiber amplifier window. **(p. 137)**

Room 6C

1:30pm–3:30pm
WI • Symposium on Optical Crossconnects 2 (Cat. IV)
Daniel J. Blumenthal, *University of California, Santa Barbara, USA, Presider*

1:30 pm
WI1 (Invited) • Key functional blocks of optical transport networks, A. Jourdan, F. Bruyère, D. Chiaroni, L. Berthelon, B. Lavigne, P. Bonno, J.L. Beylat, *Alcatel Corporate Research Center, France.* This paper will review the latest research achievements in the field of optical routing and switching systems, as well as the related status of enabling technologies for space and wavelength switching, as well as optical regeneration. **(p. 150)**

2:00pm
WI2 (Invited) • Large-scale photonic transport system and its supervision, Masafumi Koga, *NTT Optical Network Systems Labs, Japan.* Abstract not available. **(p. 151)**

Room 6D

1:30pm–3:30pm
WJ • DWDM 1 (Cat. III)
Ronald D. Esman, *Naval Research Laboratory, USA, Presider*

1:30pm
WJ1 (Invited) • Optical WDM space communications: the next frontier, Vincent W.S. Chan, *MIT Lincoln Laboratory, USA.* This paper will describe the technology and architecture of very high-speed optical space links that will be used in the future as a key building block for global extent satellite-based data networks. With wavelength-division multiplexing (WDM) multiplexing of >10 Gbps channels, the cost of these space systems can be very competitive with terrestrial fiber systems. **(p. 158)**

2:00pm
WJ2 • Trinal-wavelength-band WDM transmission over dispersion-shifted fiber, J. Kani, K. Hattori, M. Jinno, S. Aisawa, K. Oguchi, *NTT Optical Network Systems Laboratories, Japan;* T. Sakamoto, *NTT Optoelectronics Laboratories, Japan.* Ultrawide-band wavelength-division multiplexing transmission over a dispersion-shifted fiber utilizing the 1470-nm band, the 1550-nm band, and the 1590-nm band is demonstrated for the first time to our knowledge. **(p. 159)**

2:15pm
WJ3 • 32 × 10 Gbit/s transmission over 6150 km with 50-GHz wavelength spacing, O. Gautheron, J.B. Leroy, P. Marmier, *Alcatel, France.* The transmission of 32 wavelengths with a 50-GHz spacing and modulated at 10 Gbit/s has been demonstrated over 6150 km. The average bit error ratio of the 32 channels is 5.10^{-9}. **(p. 162)**

Room 5A

1:30pm–3:30pm
WK • Regional and Large-Scale Optical Networks (Cat. IV)
Goff R. Hill, *BT Laboratories, UK, Presider*

1:30pm
WK1 (Invited) • Optical regional access network (ORAN) project, Jane M. Simmons, Adel A.M. Saleh, *AT&T Labs-Research, USA;* Ondria J. Wasem, *Bellcore, USA;* Elisa A. Caridi, *Bell Labs, Lucent Technologies, USA;* Richard A. Barry, *Sycamore Networks, USA.* The DARPA-sponsored ORAN project is an architectural study of economically providing broadband wavelength-division multiplexing access to high-end users. The ORAN architecture is a scalable, flexible, cost-effective access network that delivers both huge bandwidth and a high degree of upgradability. **(p. 178)**

2:00pm
WK2 • Main results of the ACTS OPEN France-Belgium field trial, B. Landousies, A. Leclert, *France Telecom, France;* Ph. Bonno, A. Jourdan, *Alcatel, France;* D. Vercauteren, Y. Renard, *Belgacom S.A., Belgium.* Results of the ACTS OPEN France-Belgium are reported. Wavelength-division multiplexing transmission and routing performance has been investigated. Especially, bit-error-rate measurements were carried out in various network configurations. **(p. 181)**

2:15pm
WK3 • Optical communications research in European Community programmes, A.J.N. Houghton, B. Fabianek, G. Kalbe, *European Commission, Belgium.* This paper discusses the future directions and important changes for European Community research in optical communications, in the context of future research programmes (1999–2003), and the success and achievements of previous programmes (1994–1998). **(p. 184)**

Room 1A

1:30pm–2:30pm
WL • Tutorial on NRZ, RZ, or Solitons: Modulation Format, Your Choice or the Fibers? (Cat. III)
Mark Schtaif, *AT&T Labs-Research, USA, Presider*

INSTRUCTOR

Stephen Evangelides
Tyco Submarine Systems Ltd., USA

Since the invention of the erbium fiber amplifier made possible all-optical transmission over distances significantly longer than the length of spans between electronic regenerators, transmission line designers were confronted with a whole new design space. Parameters like dispersion, self-phase modulation, four-wave mixing, and optical noise (added as a field) became important. In the all-optical transmission line, some modulation formats, for instance FSK and PSK worked poorly, while others, like solitons, which were not appropriate with electronic regenerators, became possible. As our understanding of the transmission line has deepened, many of the standard amplitude modulation formats have been improved, thus providing greater capacity. In this time no one modulation format has proven superior for all applications. In this tutorial, we examine the available modulation schemes as they apply to long haul (undersea) and terrestrial networks.

Dr. Evangelides is a member of the Tyco Submarine Systems Ltd. research group. He received a B.A. in physics from the University of Pennsylvania and Ph.D. in Physics from MIT. He was then a post doctoral fellow at AT&T Bell Labs. Since then he has worked in his present capacity. **(p. 194)**

Room 6A	Room 6B	Room 6C

WG • Fiber Amplifiers 2 (Cat. I)—Continued

2:30pm
WG5 • 1.4 W saturated output power from a fiber Raman amplifier, S.A.E. Lewis, S.V. Chernikov, J.R. Taylor, *Imperial College, UK.* Fiber Raman amplifiers with high output power and a 50% net pump to signal conversion efficiency are reported. A 100-nm supercontinuum based upon a 10-GHz, 8-ps pulse source was generated using the strong nonlinear interaction in the amplifier. **(p. 114)**

2:45pm
WG6 • Broadband Raman amplifiers in the spectral range of 1480 nm–1620 nm, S.V. Chernikov, S.A.E. Lewis, J.R. Taylor, *Imperial College, UK.* Raman amplifiers using germano-silica fibers are demonstrated with a continuous operation bandwidth from 20 nm to more than 100 nm, 20–40 dB net gain and 4.5–7 dB noise figure. Single-, dual-, and triple-wavelength pumping are implemented in the configuration incorporating optical circulators for pump/signal multiplexing. **(p. 117)**

3:00pm
WG7 • Dy^{3+}-doped Ge-Ga-S-KBr (or CsBr) glasses for the 1.3-μm fiber amplifier materials, Jong Heo, Yong Beom Shin, *Pohang Univ. Science and Technology, S. Korea;* Hyoun Soo Kim, *Samsung Electronics Co. Ltd., S. Korea.* Addition of CsBr and KBr in Ge-Ga-S glasses doped with Dy^{3+} showed a remarkable increase in the 1.32 μm emission intensity. Lifetimes and quantum efficiency also increased to 700 μs and 100%, respectively compared to 38 μs and 17% usually found in Ge-Ga-S glasses. **(p. 120)**

3:15pm
WG8 • Efficient and low-noise operation in a gain-flattened 1580-nm band EDFA, Seo Yeon Park, Hyang Kyun Kim, *ETRI, S. Korea.* The power conversion efficiency of 35% and the noise figure of 5.1 dB are obtained in the 1580-nm band erbium-doped fiber amplifier (EDFA) composed of the first stage backward pumped at 980 nm and the second stage backward pumped at 1480 nm. **(p. 123)**

WH • Lasers (Cat. II)—Continued

2:45pm
WH5 • 1.55-μm DFB lasers with integrated spot-size converters operating at 2.5 Gbit/s with modulated power over 20 mW for 180-km transmission, B. Thédrez, J.M. Rainsant, V. Voiriot, J.L. Lafragette, L. Roux, A. Pinquier, B. Fernier, *Alcatel Corporate Research Center, France.* Low-divergence 1.55-μm distributed feedback (DFB) lasers with spot-size converter were used to demonstrate <1.5 dB penalty after 180-km transmission at a rate of 2.5 Gbit/s with peak power over 20 mW. **(p. 140)**

3:00pm
WH6 • Isolator-free 2.5-Gbit/s, 45-km transmission characteristics in partially corrugated waveguide laser diodes from –40°C to 80°C under –14 dB external optical feedback, Yidong Huang, Kazuhiro Shiba, Yoshiharu Muroya, Naofumi Suzuki, Tetsuro Okuda, *NEC Corp., Japan.* Using partially corrugated waveguide laser diodes (PC-LDs) with robust and high-yield external optical feedback resistance, isolator-free 2.5-Gbit/s, 45-km transmission was demonstrated over a wide temperature range from –40°C to +80°C under –14 dB external optical feedback. **(p. 143)**

3:15pm
WH7 • Hybrid integrated external-cavity laser without temperature-dependent mode hopping, T. Tanaka, A. Himeno, H. Takahashi, A. Kaneko, T. Hashimoto, M. Abe, Y. Yamada, Y. Inoue, N. Yoshimoto, Y. Tohmori, *NTT Optoelectronics Laboratories, Japan.* We propose a new integrated external-cavity laser, which eliminates temperature-dependent mode hopping by employing silicon between the LD and the grating. Operation without mode hopping is experimentally confirmed from 18°C to 34°C. **(p. 146)**

WI • Symposium on Optical Crossconnects 2 (Cat. IV)—Continued

2:30pm
WI3 (Invited) • Architectures for multistage crossconnects, G.W. Richards, *Lucent Technologies, Inc., USA.* Numerous issues are involved in the design of a multistage crossconnect. Many of these are concerned with technology and performance. We suggest that network control is a worthy addition to the list of design considerations. **(p. 152)**

3:00pm
WI4 (Invited) • Free-space micromachined optical switching technologies and architectures, Lih Y. Lin, *AT&T Labs–Research, USA.* As wavelength-division multiplexing transmission matures andlaunches the need for optical networking, free-space micromachined optical switches are emerging as promising candidates for the crossconnects such networks will need. We describe the promise of this new technology and the open questions it raises. **(p. 154)**

Room 6D

WJ • DWDM 1—(Cat. III)

2:30pm
WJ4 • Adaptive dispersion equalization of 8-ps pulses in 400-km transmission line by monitoring relative phase shift between spacing-fixed WDM signals, Akihide Sano, Shoichiro Kuwahara, Yutaka Miyamoto, *NTT Optical Network Systems Laboratories, Japan.* We propose an adaptive dispersion equalization system based on wavelength tuning and monitoring the relative phase shift between fixed-spacing wavelength-division multiplexing (WDM) signals. Adaptive equalization is successfully demonstrated for 40-Gbit/s (8-ps RZ pulses) 400-km transmission. **(p. 165)**

2:45pm
WJ5 • Dispersion and cross talk of optical minimum-phase filters in WDM systems, G. Lenz, L.E. Adams, *Bell Labs, Lucent Technologies, USA.* The amplitude and phase responses of optical minimum-phase filters are *uniquely* related to each other and therefore their cross talk and dispersion characteristics cannot be adjusted independently. The implications for wavelength-division multiplexed (WDM) systems will be shown experimentally and analytically. **(p. 168)**

3:00pm
WJ6 • Influence of stimulated Raman scattering on the channel power balance in bidirectional WDM transmission, P.M. Krummrich, E. Gottwald, A. Mayer, C.-J. Weiske, G. Fischer, *Seimens AG, Germany.* The influence of stimulated Raman scattering on the channel power balance in bidirectional wavelength-division multiplexing (WDM) transmission has been analyzed experimentally and numerically. Output power levels with 8 channels/direction launched at +10 dBm/ch. differ more than 0.7 dB from linear loss. **(p. 171)**

3:15pm
WJ7 • Investigation of stimulated Raman scattering limitation on WDM transmission over various types of fiber infrastructures, Sébastien Bigo, Stéphane Gauchard, Alain Bertaina, Jean-Pierre Hamaide, *Alcatel Corporate Research Centre, France.* We measure the impact of stimulated Raman scattering (SRS) on the power distribution of a 32-channel multiplex after 100-km transmission over various fiber types. The effects of fiber loss, fiber length, and channel number increase are also characterized. **(p. 174)**

Room 5A

WK • Regional and Large-Scale Optical Networks (Cat. IV)—Continued

2:30pm
WK4 • Field deployment and evaluation of 1510-nm data communication network for MONET Washington, DC network trial, H. Dai, G.K. Chang, B. Meagher, J. Young, W. Xin, S.J. Yoo, G. Ellinas, W.T. Andersen, *Bellcore, USA;* S. Spak, *Bell Atlantic, USA;* R. McFarland, *National Security Agency, USA;* P. Gary, *NASA Goddard Space Flight Center, USA;* H. Dardy, *Naval Research Labs, USA.* We report on the design and field performance evaluation of an embedded, out-of-band, 1510-nm data communication network (DCN) at OC-3c data rate for the eight-wavelength, reconfigurable MONET Washington D.C. testbed. The results of this field trial demonstrate that a multinode control and management system can depend on such a highly reliable DCN. **(p. 187)**

2:45pm
WK5 • Architecture considerations in merging multivendor WDM rings for the MONET Washington D.C. network, Georgios Ellinas, Gee-Kung Chang, William Anderson, *Bellcore, USA;* Richard Wagner, *Corning, Inc., USA.* The architecture of the MONET Washington D.C. area multivendor network resulting from merging wavelength-division multiplexing (WDM) rings was analyzed and designed. Connectivity, protection capabilities, and system interoperability were the main considerations for comparison amongst the candidate architectures. **(p. 190)**

Room 1A

WL • Tutorial on NRZ, RZ or Solitons: Modulation Format, Your Choice or the Fibers? (Cat. III)—Continued

4:00pm–5:30pm
WM • Poster Session

WM1 • Codoping effects in fibers for active applications, J. Kirchhof, S. Unger, *Institut für Physikalische Hochtechnologie e. V., Germany.* The influence of codopants on the optical and thermal properties of ytterbium- and neodymium-doped fibers for high-power applications was investigated concerning absorption, spectral and time-dependent fluorescence, loss, crystallization behavior and diffusion interplay of the dopants. **(p. 196)**

WM2 • Continuously tunable high-power fiber lasers with 11 nm tunability, J.J. Pan, Y. Shi, T. Zhu, *E-TEK Dynamics, Inc., USA.* A tunable interactive fiber laser is analyzed and experimentally demonstrated with high single-frequency output power exceeding 62 mW and 11.2 nm continuous tuning. The fiber laser has a low relative intensity noise <−165 dB/Hz and excellent environmental stabilities. **(p. 199)**

WM3 • LD-pumped 1.48-µm laser based on Yb-doped double-clad fiber and phosphorosilicate-fiber Raman converter, V.I. Karpov, E.M. Dianov, A.S. Kurkov, V.M. Paramonov, V.N. Protopopov, *Russian Academy of Sciences, Russia;* M.P. Bachynski, W.R.L. Clements, *MPB Technologies Inc., Canada.* An all-fiber 1.48-µm generator based on a LD-pumped Yb-doped double-clad laser with intracavity Raman wavelength conversion has been developed. Second-order Raman Stokes radiation was generated in a phosphorosilicate-fiber resonator formed by two pair of Bragg gratings. **(p. 202)**

WM4 • Photosensitive Yb-doped double-clad fiber for fiber lasers, A.S. Kurkov, O.I. Medvedkov, V.I. Karpov, S.A. Vasiliev, O.A. Lexin, E.M. Dianov, A.N. Gur'yanov, A.A. Laptev, A. Umnikov, N.I. Vechkanov, *Russian Academy of Sciences, Russia.* Photosensitive at 244 nm double-clad Yb-doped germanosilicate fibers have been developed. Fiber lasers based on these fibers exhibited 65% differential efficiency and 100 mW threshold at both 910 and 980 pump wavelengths. **(p. 205)**

WM5 • Terahertz, zero frequency error, tunable optical comb generator for DWDM applications, S. Bennett, B. Cai, E. Burr, O. Gough, A.J. Seeds, *Univ. College London, UK.* We report on the experimental realization of a single comb generator, based on phase modulation in an amplified fiber loop, which offers exact referencing to an arbitrary supplied reference frequency and a tunable comb-line spacing. **(p. 208)**

WM6 • Collisions in dispersion-managed soliton propagation, Y. Chen, H.A. Haus, *MIT, USA.* We study collisions in dispersion-managed pulse propagation at and near zero net dispersion. We show that the collisions can lead to group velocity changes and spectral collapse. Filters prevent spectral collapse but do not affect the velocity changes. **(p. 211)**

WM7 • Dual-cavity optical automatic gain control for EDFAs, Mark F. Krol, Yongqian Liu, James J. Watkins, David W. Lambert, *Corning, Inc., USA.* We believe we report the first demonstration of dual-cavity optical automatic gain control (OAGC). The dual-cavity technique results in improved stability of the amplifier gain spectrum under pump and signal power variations as compared to conventional OAGC. **(p. 214)**

WM8 • Reliability of fluoride fiber module for optical amplifier use, Yoshiki Nishida, Kazuo Fujiura, Koichi Hoshino, Makoto Shimizu, *NTT Optoelectronics Laboratories, Japan;* Makoto Yamada, Koichi Nakagawa, Yasutake Ohishi, *NTT Electronics Corp., Japan.* We have investigated the reliability of a fluoride fiber module with a hermetically sealed package for practical optical fiber amplifier use. We confirm that our module has long-term stability under practical environmental conditions and sufficient mechanical strength. **(p. 217)**

WM9 • Comparison between optical fiber birefringence induced by stress-anisotropy and geometric deformation, Dipak Chowdhury, David Wilcox, *Corning, Inc., USA.* A variational formulation based vector perturbation model is used to compare the contribution of stress anisotropy and geometric deformation towards optical fiber birefringence. We show that stress impacts the step-index type profiles more than the typical dispersion-shifted type profiles. **(p. 220)**

WM10 • A new signal-processing technique for interferometric fiber-optic sensors, Jianxun Fang, Henry F. Taylor, *Texas A&M Univ., USA.* A new signal-processing technique using a frequency modulated semiconductor laser maintains high accuracy even using inexpensive multimode Fabry–Perot lasers. The application of this technique is reported in temperature measurement with a fiber Fabry–Perot sensing head. **(p. 223)**

WM11 • Highly sensitive static strain fiber Bragg grating sensor using an interrogating laser locked to stable atomic lines, B. Lissak, A. Arie, M. Tur, *Tel-Aviv Univ., Israel.* Atomic absorption lines provide stable optical frequency references, which can be used to interrogate strain-induced frequency shifts of fiber Bragg gratings. High sensitivity of 1.2 nanostrain/$\sqrt{Hz}$ at 1.5 Hz is obtained using this novel technique. **(p. 226)**

WM12 • Broadband dispersion-compensating fiber module considering its attenuation spectrum behavior for WDM systems, Tomonori Kashiwada, Shinji Ishikawa, Toshiaki Okuno, Kenji Tamano, Masashi Onishi, Yoshinori Makio, *Sumitomo Electric Industries, Ltd., Japan.* Dispersion-compensating module capable of flattening dispersion spectrum of 80 km of SMF was successfully developed while realizing attenuation variance within 0.35 dB/module in 1530 nm to 1570 nm and attenuation fluctuation <0.1 dB/module in −5°C to 50°C. **(p. 229)**

WM13 • Design and manufacture of dispersion-compensating fiber for simultaneous compensation of dispersion and dispersion slope, Lars Grüner-Nielsen, Stig Nissen Knudsen, Torben Veng, Bent Edvold, C. Christian Larsen, *Lucent Technologies, Denmark.* The negative dispersion slope of dispersion-compensating fibers has been optimized by increasing the width of the depressed cladding. Simultaneous compensation and dispersion slope has been demonstrated on an actual link. **(p. 232)**

WM14 • Negative slope dispersion-compensating fibers, G.E. Berkey, M.R. Sozanki, *Corning, Inc., USA.* Two types of DC fibers are presented. The first is an improved high figure of merit (267) negative slope dispersion-compensating fiber intended for DC modules. Also presented is a type II DC fiber intended for field deployment that leads to total broadband dispersion compensation. **(p. 235)**

WM15 • Over 200 mW 980-nm pump laser diode module using optimized high-coupling lensed fiber, Yuichiro Irie, Jun Miyokawa, Akira Mugino, Takeo Shimizu, *The Furukawa Electric Co., Ltd., Japan.* The high-power 980-nm pumping laser diode module of 230 mW at king driving current was fabricated by optimizing the wedge-shape of lensed fiber to achieve 95% coupling efficiency. **(p. 238)**

WM16 • AWG-DMUX transmission characteristics improvement using grating lattice filters, Kenji Shimizu, Nobuhiro Sugano, Kazunari Harada, Teruhiko Kudou, Takeshi Ozeki, *Sophia Univ., Japan.* Synthesis methods of grating lattice filters (GLFs) with poles and zeros are derived. AWG-DMUX cross talk is improved drastically by using GLF with shaper filter characteristics and small size. **(p. 241)**

WM17 • Vertical-cavity optoelectronic transceivers for short-distance data communications links, M. Dragaš, I.H. White, R.V. Penty, J. Rorison, K.A. Williams, P.J. Heard, *Univ. Bristol, UK;* G. Parry, *Imperial College, UK.* A novel dual-purpose vertical-cavity optoelectronic component, functioning either as a laser or as an avalanche photodetector, is employed in a link as a transceiver unit allowing "ping-pong" communications. Successful system performance is demonstrated at bit rates up to 1.244 Gbit/s. **(p. 244)**

WM18 • High isolation balanced photonic microwave mixers, Yongqiang Shi, James H. Bechtel, *Tacan Corp., USA;* Wenshen Wang, *TRW Inc., USA.* An integrated photonic microwave mixer, implemented with cascaded balanced bridge Mach–Zehnder modulators, is presented. The input and local oscillator frequency components are effectively rejected at the output, as demonstrated using a lithium niobate device. **(p. 247)**

WM19 • Poling of UV-written waveguides, Jesper Arentoft, Martin Kristensen, Jörg Hübner, *Technical Univ. Denmark, Denmark;* Wei Xu, *Univ. Sydney, Australia;* Michael Bazylenko, *Univ. New South Wales, Australia.* We report poling of UV-written silica waveguides. Thermal poling induces an electro-optic coefficient of 0.05 pm/V. We also demonstrate simultaneous UV-writing and UV-poling. No measurable decay in the induced electro-optic effect was detected after nine months. **(p. 250)**

WM20 • Enhanced sensitivity in WDM optical monitoring using a MARS optical chopper, Randy Giles, Larry Stulz, Jim Walker, Rene Ruel, *Lucent Technologies, USA.* A MARS optical chopper is implemented with lock-in detection to enhance the sensitivity of a 1550-nm band wavelength-division multiplexing (WDM) optical monitor and improve its immunity of 1/f noise and dc drift. The high chopping rate, 1.02 MHz, is ideally suited for rapid-scanning optical monitors, allowing <100 μs filter time constants for high-rate data acquisition. **(p. 253)**

WM21 • Bandpass filter transfer characteristic of a complex-apodized arrayed-waveguide grating, M.C. Parker, *Fujitsu Telecom Europe Ltd. Research, UK;* S.D. Walker, *Univ. Essex, UK.* We determine a bandpass filter equivalent transfer function for a complex-apodized arrayed-waveguide grating. A combined near-parabolic phase-profile with e^{-1} Gaussian amplitude-truncation produces both a trapezoidal passband and 10 ps group delay over a 12-nm passband. **(p. 256)**

WM22 • Free-space optical interconnect at 1.25-Gbit/s/channel using adaptive alignment, Dominic J. Goodwill, David Kabal, Paparao Palacharla, *Nortel Networks, Canada.* Free-space optical backplanes have previously required precision mechanics or moving parts. An adaptive alignment technique is described, using redundant VCSEL and detector arrays for real-time mapping of parallel 1.25-Gbit/s data channels to aligned links. **(p. 259)**

WM23 • An integrated wavelength locker for waveguide DEMUXes, Emil S. Koteles, J.J. He, B. Lamontagne, L. Erickson, A. Delâge, *National Research Council of Canada, Canada.* A simple technique for precisely monitoring a reference wavelength in order to lock the wavelength channels of a waveguide demultiplexer is proposed and experimentally verified. It incorporates a differential wavelength detector monolithically integrated on the DEMUX. **(p. 262)**

WM24 • Photon statistics of NRZ signals in a high-bit-rate optically pre-amplified direct detection receiver, William S. Wong, Herman A. Haus, *MIT, USA;* John D. Moores, Jeff Korn, *MIT Lincoln Laboratory, USA.* We verify experimentally, over a dynamic range of 58 dB in the probability distribution, that the pre-amplified laser light in a lightwave receiver, rather than being Gaussian distributed, is noncentral-negative-binomial distributed. **(p. 265)**

WM25 • Wavelength-tunable add/drop filter for optical networks, R. Germann, R. Beyeler, G.L. Bona, F. Horst, B.J. Offrein, H.W.M. Salemink, *IBM Research Division, Zurich Research Laboratory, Switzerland.* A wavelength-tunable optical add/drop filter for wavelength-division multiplexing at 1550 nm was realized using planar silicon-oxynitride waveguides. The filters show low insertion loss, high isolation figures, and negligible polarization dependence. **(p. 268)**

WM26 • Spectral response apodization of Bragg-like optical filters with a novel grating chirp design, A. Lupu, A. Carenco, P. Win, H. Sik, P. Boulet, M. Carré, S. Slempkes, *France-Telecom, France.* A novel grating chirp design providing symmetric apodization without perturbing local propagation constants is successfully applied to realize codirectional grating-assisted filter. This technique is suited for apodization of Bragg grating filters and mirror spectra as well. **(p. 271)**

WM27 • Novel fiber alignment method using a partially metal-coated fiber in a silicon V-groove, Shin-Ichi Kaneko, Masaki Noda, Kimitaka Shibata, Toshitaka Aoyagi, Hiromitsu Watanabe, *Mitsubishi Electric Corp., Japan.* We propose novel fiber alignment method using a partially metal-coated fiber. Rotating the fiber in a silicon V-groove, fiber alignment can be performed. Using this method, LD modules with high coupling efficiency were obtained (average = −2.72 dB, N = 28). **(p. 274)**

WM28 • Polymeric optical waveguide with high thermal stability and its application for optical interconnection, Satoru Tomaru, Koji Enbutsu, Makoto Hikita, Michiyuki Amano, Shunichi Tohno, Saburo Imamura, *NTT Optoelectronics Laboratories, Japan.* We have realized multimode optical waveguides with low loss and high thermal stability by a simple fabrication process using UV-cured epoxy resin, and also proposed useful and low-cost waveguide film devices for optical interconnection. **(p. 277)**

WM29 • Nonlinear cross talk and SBS reduction by carrier suppression in an analog WDM optical communication system, F.S. Yang, M.E. Marhic, L.G. Kazovsky, *Stanford Univ., USA.* Nonlinear cross talk and stimulated Brillouin scattering (SBS) reduction are demonstrated in an analog wavelength-division multiplexing (WDM) optical communication system using optical carrier suppression. Cross talk reduction by 20 dB over 2 GHz is achieved. SBS is negligible without employing any frequency or phase dithering. **(p. 280)**

WM30 • Millimeter-wave optical beamforming network for phased-array antennas employing optical upconversion and wideband chirped fiber gratings, J. Marti, J.L. Corral, F. Ramos, V. Polo, J.M. Fuster, *Universidad Politecnica de Valencia, Spain.* A novel optical beamforming architecture for phased-array antennas operating at millimeter-wave frequencies is presented. Experimental results at 28 GHz have demonstrated very good performance for this technique, based on optical upconversion and wideband chirped fiber gratings. **(p. 283)**

WM31 • A high-bandwidth optical-pulse-shaping/fiber-optic distribution system for the high-energy OMEGA laser-fusion facility, Andrey V. Okishev, Mark D. Skeldon, Robert L. Keck, Richard Roides, Kenton Green, Wolf Seka, *Univ. Rochester, USA.* A high-bandwidth pulse-shaping/distribution system employing fiber-optic and integrated-optic technology has been built and implemented on the OMEGA laser-fusion facility to deliver variously shaped, 0.1-ns to 5-ns duration, nanojoule optical pulses for further amplification and frequency conversion. **(p. 286)**

WM32 • All-fiber Kerr-based wavelength converter for 1550/1300 nm conversion, Emmanuel Rossi, Lucia Marazzi, Pierpaolo Boffi, Mario Martinelli, *CoreCom, Italy.* 1550/1300 nm conversion is demonstrated using a novel all-fiber Kerr-based converter. The proposed architecture overcomes the classical interferometer limitations. Walk-off compensation is studied and performed. Simulations and experimentation up to 3 Gbit/s are presented. **(p. 289)**

WM33 • Efficient approach to estimate collision-induced timing jitter in dispersion-managed WDM RZ systems, A. Richter, *BNeD GmbH, Germany;* V.S. Grigoryan, *Univ. Maryland–Baltimore County, USA.* We developed an approach that allows us to create an efficient numerical algorithm that accurately estimates collision-induced timing jitter in wavelength-division multiplexing (WDM) RZ systems. The computational time is reduced by two orders of magnitude. **(p. 292)**

WM34 • A new linearization approach for modeling timing and amplitude jitter in dispersion-managed optical fiber communications, V.S. Grigoryan, C.R. Menyuk, *Univ. Maryland–Baltimore County, USA.* We developed a new linearization approach to calculate timing and amplitude jitter in systems with arbitrary transmission formats. Our approach yields more precise results than Monte-Carlo simulations at a fraction of the computational cost. **(p. 295)**

WM35 • Accumulation of transient power excursions in WDM networks, Yongqian Liu, Mark F. Krol, *Corning, Inc., USA.* We study transient power excursions of an all-optically gain-controlled amplifier chain. We observe that the speed of residual power excursions increase much faster with the number of amplifiers than uncontrolled networks. **(p. 298)**

WM36 • Ultrastable soliton transmission using periodic dispersion-compensated normal dispersion fibers, Kazuhiro Shimoura, Shigeyuki Seikai, *Kansai Electric Power Co., Inc., Japan.* We investigated numerically nonlinear RZ-pulse transmission through periodic dispersion-compensated normal dispersion fiber, and find that ultrastable transmission mode exists in this situation. This mode indicates better characteristics than the lines using anomalous dispersion fibers. **(p. 301)**