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

# OFC® '99 IOOC

## TECHNICAL DIGEST SERIES

POSTCONFERENCE EDITION

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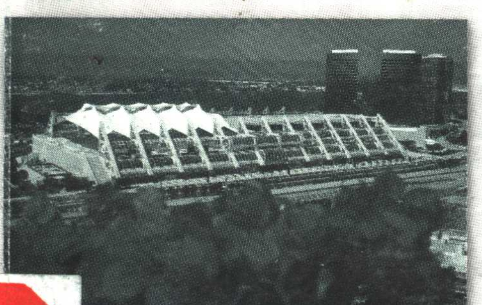



Diego Convention Center
San Diego, California

## Thursday, February 25, 1999

# OFC® '99 IOOC

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

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**February 21-26, 1999**
**San Diego Convention Center**
**San Diego, California**

# Technical Digest

## Thursday, February 25, 1999

Postconference Edition


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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<br>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–10:00am
### ThA • Nonlinear Fiber Devices and Techniques (Cat. I)
Irl N. Duling, III, *Naval Research Laboratories, USA, Presider*

**8:30am**
**ThA1 (Invited) • Ultrasensitive optical autocorrelation using two-photon absorption,** J.D. Harvey, J.M. Dudley, B.C. Thomsen, *Univ. Auckland, New Zealand;* L.P. Barry, *Dublin City Univ., Ireland.* Autocorrelation of ultrashort pulses using two-photon absorption provides a convenient and sensitive alternative to standard techniques using nonlinear crystals. We review experiments using commercially available laser diodes for ultrasensitive autocorrelation at wavelengths around 1.5 μm. **(p. 2)**

**9:00am**
**ThA2 • Cascaded nonlinearity: a simple technique to compensate Kerr effect in optical amplifiers,** S.-U. Alam, G. Biffi, A.B. Grudinin, *Univ. Southampton, UK;* G. Burdge, *Laboratory for Physical Sciences, USA.* We have experimentally demonstrated a hybrid optical amplifier comprising a periodically poled $LiNbO_3$ and an erbium-doped fiber amplifier. The use of cascaded nonlinearity inside nonlinear crystal made it possible to construct a "nonlinearity-free" optical amplifier. **(p. 5)**

**9:15am**
**ThA3 • Polarization-insensitive nonlinear optical loop mirror demultiplexer using twisted fiber,** Y. Liang, J.W. Lou, J.C. Stocker, O. Boyraz, J.K. Andersen, M.N. Islam, *Univ. Michigan, USA;* D.A. Nolan, *Corning, Inc., USA.* We reduce the polarization sensitivity of a nonlinear optical loop mirror from 5 dB to 0.5 dB by twisting fiber at 8 turns/m. Twisted fiber equates the nonlinear phase-shift terms of the parallel and orthogonal polarizations. **(p. 8)**

## Room 6B

### 8:30am–10:00am
### ThB • Arrayed-Waveguide Grating Router Devices (Cat. II)
Martin Zirngibl, *Lucent Technologies, USA, Presider*

**8:30am**
**ThB1 • High-speed 32-channel OWS using PLC hybrid integration,** F. Ebisawa, I. Ogawa, Y. Akahori, K. Takiguchi, Y. Tamura, T. Hashimoto, A. Sugita, Y. Yamada, Y. Suzaki, N. Yoshimoto, Y. Tohmori, T. Ito, K. Magari, Y. Kawaguchi, A. Himeno, K. Kato, *NTT Optoelectronics Laboratories, Japan;* S. Mino, *NTT Optical Network Systems Laboratories, Japan.* We have developed a new high-speed 32-channel optical wavelength selector (OWS) with gate drivers using PLC hybrid integration. It has excellent characteristics consisting of a low insertion loss of 2.3 dB, a low cross talk of −46 dB and the error-free optical wavelength selection of 10-Gbit/s optical signal. **(p. 18)**

**8:45am**
**ThB2 • Loss-less four-channel wavelength selector monolithically integrated on InP,** R. Mestric, M. Renaud, F. Pommereau, B. Martin, F. Gaborit, C. Janz, I. Guillemot, D. Leclerc, *Alcatel Corporate Research Centre, France.* A four-channel compact wavelength selector with 400-GHz channel spacing has been fabricated by monolithic integration on InP. Lossless operation has been achieved for all channels. Bit-error-rate performance at 2.5 Gbit/s and 10 Gbit/s has also been investigated. **(p. 21)**

**9:00am**
**ThB3 (Invited) • Waveguide-grating-router lasers for wavelength-division multiplexing,** C.R. Doerr, *Bell Laboratories, Lucent Technologies, USA.* Waveguide-grating-router lasers are multiwavelength lasers consisting of an array of semiconductor optical amplifiers integrated with a waveguide grating router. These devices can provide accurately spaced wavelengths that are inherently stable and can be produced simultaneously or fast-switched between. **(p. 24)**

## Room 6C

### 8:30am–9:45am
### ThC • Cross-Phase Modulation (Cat. III)
Andrew R. Chraplyvy, *Bell Labs, Lucent Technologies, USA, Presider*

**8:30am**
**ThC1 • Measurements of cross-phase-modulation-induced cross talk in an L-Band EDFA,** Michael Eiselt, Mark Shtaif, Robert W. Tkach, *AT&T Labs-Research, USA;* Felton A. Flood, Sergey Ten, Douglas Butler, *Corning, Inc., USA.* We measure the cross talk due to cross phase modulation in an L-band erbium-doped fiber amplifier (EDFA). The effect is larger than the one seen in C-band amplifiers and becomes the dominant effect in some wavelength-division multiplexing systems. **(p. 34)**

**8:45am**
**ThC2 • Impact of bit pattern and dispersion variation on cross-phase modulation penalty,** A.J. Lucero, S. Ten, V.L. da Silva, *Corning, Inc., USA.* Our simulations demonstrate that in wavelength-division multiplexing systems where cross phase modulation is the dominant nonlinear impairment, performance penalties depend weakly on dispersion statistical variations and have a strong bit pattern dependence. **(p. 37)**

**9:00am**
**ThC3 • Investigation of cross-phase modulation limitation on 10-Gbit/s transmission over various types of fiber infrastructures,** Sébastien Bigo, *Alcatel Corporate Research Centre, France;* Giovanni Bellotti, *Università di Parma, Italy;* Michel W. Chbat, *Alcatel Networks Systems, USA.* We measure the impact of cross phase modulation (XPM) on the transmission performance of a 2 × 2 Gbit/s multiplex. In contrast to the other investigated fiber schemes, dispersion-compensated SMF is virtually not affected by XPM down to 50-GHz channel spacing. **(p. 40)**

**9:15am**
**ThC4 • Comparison of four-wave mixing and cross-phase modulation penalties in dense WDM systems,** S. Ten, K.M. Ennser, J.M. Grochocinski, S.P. Burtsev, V.L. da Silva, *Corning, Inc., USA.* The relative impact of four-wave mixing (FWM) and cross phase modulation (XPM) is investigated by treating them as noiselike impairments. We show that XPM affects wavelength-division multiplexing (WDM) transmission more strongly than FWM for the range of fiber parameters investigated. **(p. 43)**

Room 6D

Room 5A

Room 1A

## 8:30am–9:45am
### ThD • Fiber Gratings: Fundamentals (Cat. I)
Glenn E. Kohnke, *Corning, Inc., USA*, *Presider*

**8:30am**
**ThD1 • UV-induced absorption, scattering and transition losses in UV side-written fibers,** Dietmar Johlen, Frank Knappe, Hagen Renner, Ernst Brinkmeyer, *Technische Universitaet Hamburg-Harburg, Germany.* We demonstrate that UV-illumination of hydrogen-loaded photosensitive fiber leads to considerable loss. The three contributing loss mechanisms of absorption, scattering, and field displacement losses are quantified and discussed. **(p. 50)**

**8:45am**
**ThD2 • Effect of molecular water on thermal stability of gratings in hydrogen-loaded optical fibers,** V. Grubsky, J. Feinberg, *D-STAR Technologies, Inc. and Univ. Southern California, USA;* D.S. Starodubov, *D-STAR Technologies, Inc., USA.* Photolytically generated water causes induced loss at 1.55 μm as well as decay of fiber gratings in UV-irradiated hydrogen-loaded fibers at temperatures below 350°C. These side effects can be eliminated by annealing at 500°C. **(p. 53)**

**9:00am**
**ThD3 • Thermally stable gratings in optical fibers without temperature annealing,** E. Salik, *Univ. Southern California, USA;* D.S. Starodubov, *D-STAR Technologies, Inc., USA;* V. Grubsky, J. Feinberg, *Univ. Southern California and D-STAR Technologies, Inc., USA.* Uniform UV light exposure of a fiber substantially increases the thermal stability of its Bragg grating. Both grating writing and thermal stabilization can now be performed without stripping the fiber coating. **(p. 56)**

**9:15am**
**ThD4 • The behavior of silica optical fibers exposed to very high-pressure hydrogen environments,** James F. Brennan III, Diann A. Sloan, Japhus Dent, Dwayne LaBrake, *3M Telecom Systems Division, USA.* We placed silica optical fibers into hydrogen environments of up to 30,000 psi (2,041 atm) and characterized their photosensitivity, mechanical strength, and $H_2$ diffusion rate and solubility. UV-induced index changes in the fibers were $>10^{-2}$. **(p. 59)**

## 8:30am–10:00am
### ThE • Transport and Access Technologies 1 (Cat. V)
Cliff Townsend, *Presider*

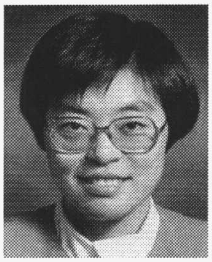
**8:30am**
**ThE1 (Invited) • ATM-PON FTTH access networks and services,** Yoichi Maeda, *NTT Access Networks Systems Labs, Japan.* Abstract not available. **(p. 66)**

**9:00am**
**ThE2 • Fault surveillance of branched optical networks using an amplifier-generated wavelength-sweeping monitoring source,** Chun-Kit Chan, *City Univ. Hong Kong;* Frank Tong, Lian-Kuan Chen, Keang-Po Ho, *Chinese Univ. Hong Kong, P.R. China;* Dennis Lam, *JDS Fitel, Inc., Canada.* We demonstrate a simple and effective fault detection scheme using an amplifier-generated wavelength sweeping source and some fiber Bragg gratings to identify the fiber fault in an optically amplified branched access network without any dedicated monitoring source. **(p. 69)**

**9:15am**
**ThE3 (Invited) • A view of next-generation optical communication systems—possible future high-capacity transport implementations,** Richard Cowper, *Nortel, Canada.* Possible implementations of next-generation high-capacity transport are presented and associated technical challenges are discussed. From the spectral efficiency of conventional modulation formats, and based on substantial system integration experience, it is estimated that a practical capacity for a single 1000-km fiber is between 2 and 5 Tbit/s, assuming a 10-THz transmission window. **(p. 72)**

## 8:30am–9:30am
### ThF • Tutorial on Components for Next-Generation High-Speed LAN
TBD, *Presider*

INSTRUCTOR



**C.J. Chang-Hasnain**
*Bandwidth Unlimited Inc., USA*

Triggered by the ever-increasing computer speed and the wide application of the Internet, the demand for higher communication bandwidth and interconnectivity is drastically increasing. Networking a group of computers in proximity to form LAN has become imperative for corporations and organizations to compete and perform.

As the volume of network traffic increases, the bandwidth demand of network backbone rises accordingly. This is clearly exhibited by the accelerated speed in market appearance of generations of Ethernet, the dominant LAN protocol, moving from 10 to 100 Mbps (mega-bits per sec) in 1995 and rapidly to 1 Gbps (giga-bits per sec) in 1998. Optical transmitters and optical fiber link have become the preferred choice to accommodate the ever-increasing bandwidth demands. In this tutorial, we will review the contenders for optical transmitters for this application and discuss the advantages and disadvantages associated with each solution. Future trends in research will be discussed.

Connie J. Chang-Hasnain is the CEO and President of Bandwidth Unlimited Inc. and Professor of Electrical Engineering and Computer Sciences at the University of California, Berkeley. Her research interests are in semiconductor optoelectronic devices and materials, and their applications. She co-authored more than 180 papers in technical journals and conferences.

Dr. Chang-Hasnain was named a Presidential Faculty Fellow by the White House, a National Young Investigator, a Packard Fellow from David and Lucille Packard Foundation, and a Sloan Research Fellow of the Alfred P. Sloan Foundation. She received the '94 LEOS Distinguished Lecturer Award. Professor Chang-Hasnain is the Program Co-Chair of '97 CLEO and General Co-Chair of '99 CLEO. She is a Director-at-Large of the OSA and a member of the US Air Force Scientific Advisory Board. Professor Chang-Hasnain is a Fellow of the IEEE and OSA. **(p. 80)**

Room 6A

## ThA • Nonlinear Fiber Devices and Techniques (Cat. I)—Continued

**9:30am**
**ThA4 • Dynamic fiber loop-mirror-filter based on pump-induced saturable gain or absorber gratings,** Steven A. Havstad, *Univ. Southern California and TRW Space and Technology Division, USA;* Baruch Fischer, *Technion, Israel;* Alan E. Willner, *Univ. Southern California, USA;* Michael G. Wickham, *TRW Space and Technology Division, USA.* We present a novel optically tunable, all-fiber narrowband filter based on saturable gain or absorber gratings in a loop mirror. The loop mirror provides built-in interferometric phase alignment between the signal and grating for optimal bandpass or notch filtering with bandwidths from the MHz to GHz regimes. **(p. 11)**

**9:45am**
**ThA5 • In-band ASE noise filtering with a dispersion-imbalanced nonlinear loop mirror,** William S. Wong, *Bell Laboratories, Lucent Technologies and MIT, USA;* Per B. Hansen, Torben N. Nielsen, *Bell Laboratories, Lucent Technologies, USA;* Mordechai Margalit, Shu Namiki, Erich P. Ippen, Hermann A. Haus, *MIT, USA.* We report removal of in-band amplified spontaneous emission (ASE) noise in a 10-Gbit/s noise-loaded RZ signal using a dispersion-imbalanced loop mirror. The resulting receiver sensitivity is improved from −37.0 dBm to −37.7 dBm. The loop mirror bias dependence of sensitivity is also investigated, and the optimal bias point is found to be where the transmissivity decreases with increasing input power. **(p. 14)**

Room 6B

## ThB • Arrayed-Waveguide Grating Router Devices (Cat. II)—Continued

**9:30am**
**ThB4 • Elimination of cross talk in the common output amplifier of a multiwavelength source by gain clamping,** D. Van Thourhout, J. De Merlier, T. Van Caenegem, L. Vanwassenhove, I. Moerman, P. Van Daele, R. Baets, *Univ. Gent - IMEC, Belgium;* C.G.P. Herben, X.J.M. Leijtens, J.W.M. van Uffelen, M.K. Smit, *Delft Univ. Technology, The Netherlands.* We realized a multiwavelength laser using a hybrid integration technology. Simultaneous laser operation of four wavelength channels could be obtained. To avoid signal cross talk, a novel approach to clamp the gain of the common amplifier is demonstrated. **(p. 27)**

**9:45am**
**ThB5 • Integrated real-time multichannel wavelength monitoring circuit using phased-array waveguide grating,** Shan Zhong, Chau-Han Lee, Xiao Lin, Xiao-Hui Yang, Yung-Jui Chen, Dennis Stone, *Univ. Maryland–Baltimore County and Joint Program for Advanced Electronic Materials, USA.* An integrated multichannel wavelength monitoring circuit using specially designed phased-array waveguide grating and detector arrays, which monitors all wavelength-division multiplexing channels in real-time (sixteen channels at 200-GHz spacing), has been demonstrated with ~0.02 nm accuracy. **(p. 30)**

Room 6C

## ThC • Cross Phase Modulation (Cat. III)—Continued

**9:30am**
**ThC5 • Cross-phase modulation distortions in multispan WDM systems,** Michael Eiselt, Mark Shtaif, Lara D. Garrett, *AT&T Labs-Research, USA.* Measurements of the cross talk due to cross phase modulation in a wavelength-division multiplexing (WDM) system on conventional single-mode fiber and on nonzero-dispersion-shifted fiber confirm theoretical results on linearity with power and inverse channel spacing. **(p. 46)**

**10:00am–10:30am COFFEE BREAK, Exhibit Hall**

## 10:30am–12:00m
## ThG • Optical Fiber Material and Processing (Cat. I)
TBD, *Presider*

**10:30am**
**ThG1 (Invited) • Specialty optical fiber,** D.J. DiGiovanni, *Lucent Technologies, USA.* Within the past decade, several fiber-based devices have achieved significant commercial success, including fiber lasers, amplifiers, filters, sensors, and gyroscopes. This discussion considers the development of the specialty fibers that enable these devices. **(p. 82)**

## 10:30am–12:00m
## ThH • Wavelength Add/Drop Devices (Cat. II)
Ray T. Chen, *University of Texas at Austin, USA, Presider*

**10:30am**
**ThH1 • Thermally tunable polymer Bragg grating OADMs,** Louay Eldada, Robert Blomquist, Mac Maxfield, Deepti Pant, George Boudoughian, Constantina Poga, Robert A. Norwood, *AlliedSignal Inc., USA.* We report the fabrication of tunable Bragg grating OADMs in polymers. They exhibit 45-dB reflection with strong sidelobe suppression and no cladding-mode coupling, and they are thermally tunable at a rate of −0.256 nm/°C. **(p. 98)**

## 10:30am–12:00m
## ThI • 40-Gbit/s Transmission (Cat. III)
Alan H. Gnauck, *AT&T Labs-Research, USA, Presider*

**10:30am**
**ThI1 • 40-Gbit/s soliton transmission field experiment over 1,020 km and its extension to 1,360 km using in-line synchronous modulation,** A. Sahara, K. Suzuki, H. Kubota, T. Komukai, E. Yamada, T. Imai, K. Tamura, M. Nakazawa, *NTT Optical Network Systems Laboratories, Japan.* We report the details of a 40-Gbit/s soliton transmission field experiment over 1,020 km, which used a dispersion-compensation technique. The transmission distance was extended to 1,360 km by installing in-line synchronous modulation. **(p. 112)**

| Room 6D | Room 5A | Room 1A |
|---|---|---|

## ThD • Fiber Gratings: Fundamentals (Cat. I)—Continued

**9:30am**
**ThD5 • Grating writing through the fiber coating using a 248-nm excimer laser,** Lu Chao, *Nanyang Technological Univ., Singapore;* Laurence Reekie, *Univ. Southampton, UK.* Fiber Bragg gratings have been written through the fiber coating using a 248-nm excimer laser for the first time to our knowledge. A standard off-the-shelf coating was used, and 92% reflectivity gratings were obtained with an index change of $2.4 \times 10^{-4}$. **(p. 62)**

## ThE • Transport and Access Technologies 1 (Cat. V)—Continued

**9:45am**
**ThE4 • Upgrading SONET rings with WDM instead of TDM: an economic analysis,** Ori Gerstel, Rajiv Ramaswami, *Tellabs.* We compare a time-division multiplexed (TDM) upgrade of a legacy SONET ring to a single higher speed ring, versus a wavelength-division multiplexed (WDM) upgrade path, in which it is possible to retain the legacy ring and add additional "virtual rings" at different wavelengths and lower speeds. The paper makes the case that the WDM option can be economically compelling. **(p. 75)**

## ThF • Tutorial on Components for Next-Generation High-Speed LAN—Continued

**10:00am–10:30am COFFEE BREAK, Exhibit Hall**

## 10:30am–12:00m
## ThJ • Adjustable Fiber Grating Filters (Cat. I)
Turan Erdogan, *University of Rochester, USA, Presider*

**10:30am**
**ThJ1 • Fast and widely tunable Bragg grating reflection filter,** Alessandro Iocco, Hans Georg Limberger, René Paul Salathé, *Swiss Federal Institute of Technology, Switzerland;* Lorna Everall, Karen Chisholm, Ian Bennion, *Aston University, UK.* A fiber Bragg grating filter device linearly tunable over 45 nm is presented. The device has a maximum tuning speed of 19 nm/ms with a wavelength setting time below 1.5 ms. **(p. 132)**

## 10:30am–12:00m
## ThK • Transport and Access Technologies 2 (Cat. V)
Laurel Clark, *AT&T Network & Computing Services, USA, Presider*

**10:30am**
**ThK1 (Invited) • Next-generation IP-based photonic transport networks,** Tom Issenhuth, *Level 3 Communications, USA.* Abstract not available. **(p. 152)**

## 10:30am–11:30am
## ThL • Tutorial on Fundamental Limitations of EDFAs in Amplified Transmission Systems (Cat. III)
Alan Eli Willner, *University of Southern California, USA, Presider*

INSTRUCTORS

**E. Desurvire**
*Alcatel CIT, France*

**B. Desthieux**
*Alcatel CIT, France*

This tutorial outlines various factors in erbium-doped fiber amplifiers (EDFAs) causing fundamental limitations in lightwave transmission systems, linear propa-

## Room 6A

### ThG • Optical Fiber Material and Processing (Cat. I)—Continued

**11:00am**
**ThG2 • Influence of drawing temperature on light-scattering properties of single-mode fibers,** P. Guenot, P. Nouchi, *Alcatel, France;* B. Poumellec, *Université Paris-Sud, France.* Light-scattering measurements on single-mode fibers show that Rayleigh scattering losses are affected very little by drawing temperature change. Drawing-induced losses are explained by an additional contribution: a small angles light-scattering phenomenon. **(p. 84)**

**11:15am**
**ThG3 • Design of dispersion-managed fiber and its FWM suppression performance,** K. Nakajima, M. Ohashi, T. Horiguchi, K. Kurokawa, Y. Miyajima, *NTT Access Network Systems Laboratories, Japan.* We describe the design and performance of a dispersion-managed fiber (DMF) whose purpose is to suppress four-wave mixing (FWM) in a wavelength-division multiplexing (WDM) system. We fabricated a 40-km-long DMF and confirmed its FWM suppression effects in a $4 \times 10$ Gbit/s WDM experiment. **(p. 87)**

**11:30am**
**ThG4 • Positive and negative thermal poling of germanosilicate fibers,** Danny Wong, Wei Xu, Simon Fleming, *Univ. Sydney, Australia;* Jesper Arentoft, *Technical Univ. Denmark, Denmark. In situ* measurements of thermal poling of germanosilicate fibers under positive and negative poling voltages show different dynamics of a linear electro-optic effect induced into fibers. The mechanism for the induced electro-optic effect is addressed. **(p. 90)**

## Room 6B

### ThH • Wavelength Add/Drop Devices (Cat. II)—Continued

**10:45am**
**ThH2 • Trimming of center wavelength of ARROW-type add/drop filter by UV irradiaiton,** S. Sato, W. Pan, S.T. Chu, Y. Kokubun, *Kanagawa Academy of Science & Technology, Japan;* S. Endo, S. Suzuki, *Yokohama National Univ., Japan.* A vertical coupler filter with a polysilane cover layer is fabricated for the trimming of the center wavelength of the filter by UV irradiaiton. A wide trimming range of 59 nm is demonstrated. **(p. 101)**

**11:00am**
**ThH3 • A multiport add/drop router using UV-induced gratings in planar waveguides,** C.K. Madsen, L.E. Adams, R.E. Scotti, A.J. Bruce, M.A. Capuzzo, L.T. Gomez, E.J. Laskowski, *Lucent Technologies, Bell Labs Innovations, USA.* A low-loss, reconfigurable add/drop multiplexer that can route channels between two fibers is presented. Hitless switching is demonstrated on a two-channel device with 10-Gbit/s signals and switching times $<500$ μs. **(p. 104)**

**11:15am**
**ThH4 • Fabrication of vertically coupled glass microring resonator channel dropping filters,** S.T. Chu, W. Pan, T. Kaneko, Y. Kokubun, *Kanagawa Academy of Science and Technology, Japan;* B.E. Little, D. Ripin, E. Ippen, *MIT, USA.* Air-clad glass microring resonators vertically coupled to buried channel waveguides are fabricated. Channel bandwidths of 3 nm, and free spectral range between 22 to 30 nm are observed for ring radii of 6 to 10 μm. **(p. 107)**

**11:30am**
**ThH5 (Invited) • AOTF and related waveguide devices for OADM systems,** Minoru Seino, *Fujitsu Labs, Japan.* Abstract not available. **(p. 110)**

## Room 6C

### ThI • 40-Gbit/s Transmission (Cat. III)—Continued

**10:45am**
**ThI2 • Impact of the polarization-mode dispersion on a field demonstration of 40-Gbit/s soliton transmission over 500 km,** F. Matera, M. Settembre, M. Tamburrini, *Fondazione UgoBordoni, Italy;* F. Favre, D. Le Guen, T. Georges, M. Henry, G. Michaud, *France Telecom CNET, France;* P. Franco, A. Schiffini, M. Romagnoli, R. Corsini, *Pirelli cavi spa, Italy;* M. Guglielmucci, S. Cascelli, *ISTC, Italy.* 40-Gbit/s single-wavelength alternate polarization soliton field experiment was performed on a dispersion-shifted fiber installed cable 500 km long. Comparison with an equivalent fiber installed in laboratory showed that the main impairment was due to the polarization-mode dispersion. **(p. 115)**

**11:00am**
**ThI3 • 40-Gbit/s transmission over 186.6 km of installed fiber using mid-span spectral inversion for dispersion compensation,** D. Nesset, A.E. Kelly, C. Gilbertas, J. Reed, R. Kashyap, A.D. Ellis, D.G. Moodie, *BT Laboratories, UK;* M.F.C. Stephens, K.A. Williams, *Univ. Bristol, UK;* S. Bouchoule, *France Telecom CNET, France.* Transmission of 40-Gbit/s data over 186.6 km of installed standard fiber has been demonstrated for the first time to our knowledge using phase conjugation by four-wave mixing in an SOA for dispersion compensation. **(p. 118)**

**11:15am**
**ThI4 • Single-wavelength 40-Gbit/s soliton field transmission experiments over 400-km fiber without in-line control,** J. Brentel, P.A. Andrekson, E. Kolltveit, B.E. Olsson, B. Bakhshi, J.Hansryd, P.O. Hedekvist, M. Karlsson, J. Li, *Chalmers Univ. Technology, Sweden.* We report single-wavelength 40-Gbit/s soliton transmission over 400-km installed fiber lines in Sweden. Both polarization-division multiplexed and parallel solitons were transmitted. The system performance is dominated by the polarization-mode dispersion. **(p. 121)**

**11:30am**
**ThI5 • 40-Gbit/s field test on an installed fiber link with high PMD and investigation of differential group delay impact on the transmission performance,** W. Weiershausen, H. Schöll, F. Küppers, R. Leppla, B. Hein, H. Burkhard, *Deutsche Telekom AG, Germany;* E. Lach, G. Veith, *Alcatel SEL AG, Germany.* 40-Gbit/s OTDM transmission over a field-installed dispersion-compensated 130-km SMF link was demonstrated successfully (BER $<10^{-12}$). The impact of high PMD (7.8 ps) in the order of the RZ pulse width (7 ps) was studied in detail. **(p. 125)**

Room 6D

Room 5A

Room 1A

## ThJ • Adjustable Fiber Grating Filters (Cat. I)—Continued

**10:45am**

**ThJ2 • Magnetically tunable fiber Bragg gratings,** S. Jin, H. Mavoori, R.P. Espindola, L.E. Adams, T.A. Strasser, *Bell Laboratories, Lucent Technologies, USA.* We believe we report the first demonstration of a broad-range (15.7 nm) tuning of fiber Bragg grating using fast, programmable, and latchable magnetic actuation. A key advantage is that the device requires no power except when shifting wavelengths. **(p. 135)**

**11:00am**

**ThJ3 • All-fiber bandpass filter with adjustable transmission,** D.S. Starodubov, *D-STAR Technologies, Inc., USA;* V. Grubsky, J. Feinberg, *D-STAR Technologies, Inc. and Univ. Southern California, USA.* A polarization-insensitive (±0.1 dB) all-fiber bandpass filter with 2-nm bandwidth and >25 dB suppression of nonresonant light uses a pair of long-period gratings and a core block. Filter transmission is adjustable over a 20-dB range. **(p. 138)**

**11:15am**

**ThJ4 • Bandwidth controllable filter using the chirped fiber Bragg gratings,** Seo Won Kwon, Hong Yoon, Sung Hee Lee, Sang Bae Lee, Sang Sam Choi, *Korea Institute of Science and Technology, S. Korea;* Jin Woo Park, *Korea Univ., S. Korea.* We demonstrated a novel bandpass filter of which bandwidth can be controlled from 0.1 nm to 2.89 nm using a pair of chirped fiber Bragg gratings and a fiber stretcher based on piezoelectric transducer. **(p. 141)**

**11:30am**

**ThJ5 • Temperature-sensitive long-period fiber gratings for wideband tunable filters,** Anatoli A. Abramov, Arturo Hale, Robert S. Windeler, Thomas A. Strasser, *Bell Laboratories, Lucent Technologies, USA.* We present a new type of long-period fiber gratings with enhanced temperature sensitivity of 80 nm/100°C via the use of specially designed polymer. New structures are presented, which should enable broadly tunable filters for communications systems. **(p. 144)**

## ThK • Transport and Access Technologies 2 (Cat. V)—Continued

**11:00am**

**ThK2 • OC-48/STS-48c IP direct on wavelength application,** R.K. Butler, M.L. Jones, W.C. Szeto, *Sprint, USA.* Synchronization, protection, restoration, and architecture are described for a direct on wavelength IP application. Interfaces for direct connection to dense wavelength-division multiplexing equipment are defined and experimental results for a 20,000-km transmission experiment are presented. **(p. 153)**

**11:15am**

**ThK3 (Invited) • Expectations and challenges in amplifier systems,** Charles Mao, *MCI Network Equipment Engineering, USA.* An intensified competition over the dense wavelength-division multiplexing market has been seen in recent years. Optical amplifier is an important element to minimize the overall system cost. This paper will look into some of the issues and reveal user options for such a system going forward. **(p. 156)**

## ThL • Tutorial on System Impairments of Optical Amplifiers (Cat. III)—Continued

gation being primarily assumed. It is divided in two parts. In the first, we recall definitions for spectral inversion and gain, noise figure, SNR and *Q*-factor, as related to optical amplifier chains; saturation-induced effects on EDFA bandwidth are also considered. The second part is concerned by practical limitations in bandwidth, noise figure and output power, and related technologies enabling their minimization (gain equalization, multiple-stage/hybrid pumping, glass hosts). Specific EDFA requirements pertaining to either terrestrial or undersea systems are emphasized.

Emmanuel Desurvire was born in 1955. He received his PhD and ScD in Physics in 1983 and 1998, respectively, from Nice University, France. He has been a Post-Doc at Stanford University during 1984–86, and then for five years a member of AT&T Bell Laboratories' technical staff at Crawford Hill, where he led the tem that investigated and developed erbium-doped fiber amplifiers. In 1991, he moved to Columbia University as Associate Professor. In 1993, he joined Alcatel-CIT in Marcoussis, France, where he is now deputy director of the Photonic Networks Unit and leads the Undersea Transmissions group. Dr. Desurvire, who is Senior Member of the IEEE, received the IEEE Distinguished Lecturer Award in 1993. For his pioneering work on erbium-doped fiber amplifiers, he was awarded the 1994 prize of the International Commission for Optics, and then the 1998 Benjamin Franklin Medal in engineering (with D.N. Payne from Southampton U.). Dr. Desurvire has authored or co-authored more than 130 technical papers and 20 patents. He is also the author of the book *"Erbium-doped fiber amplifiers: Principles and applications,"* and the Editor-in-Chief of the international journal *Optical Fiber Technology.*

Bertrand M. Desthieux was born in 1966. He received the M.S. degree in physics from Limoges University, France, in 1988, then graduated as an Engineer from Orsay's Ecole Superieure d'Optique in 1990. From 1990 to 1992, he has been with the Optoelectronics Research Center of the University of Southampton, working on high peak-power erbium-doped fiber amplifiers. He spent the following year at Fujitsu Laboratories in Kawasaki, Japan, investigating amplifier self-filtering effects in long-haul transmission. He then joined Alcatel's research laboratories in Marcoussis, France. His work and main contributions concern the optimization of EDFA's noise and passband characteristics, including co-doping effects in silica-based devices, for both submarine and terrestrial systems applications. **(p. 160)**

Room 6A

### ThG • Optical Fiber Material and Processing (Cat. I)—Continued

**11:45am**
**ThG5 • Analysis of recovery in radiation-induced loss in rare-earth-doped fibers through master curve/demarcation energy diagrams,** SriRaman Kannan, Michael LuValle, Robert Ahrens, Paul Lemaire, *Lucent Technologies, Bell Labs Innovations, USA.* Radiation-induced losses in rare-earth-doped fibers are analyzed in a novel manner. The mastercurve approach is used for analyzing stability of defects induced by radiation. This method can be applied to examine fibers for space applications. **(p. 93)**

Room 6B

### ThH • Wavelength Add/Drop Devices (Cat. II)—Continued

Room 6C

### ThI • 40-Gbit/s Transmission (Cat. III)—Continued

**11:45am**
**ThI6 • Fully electrical 40-Gbit/s TDM system prototype and its application to 160-Gbit/s WDM transmission,** Mikio Yoneyama, Yutaka Miyamoto, Taiichi Otsuji, Akira Hirano, *NTT Optical Network Systems Laboratories, Japan;* Tadao Ishibashi, *NTT System Electronics Laboratories, Japan;* Hiroshi Miyazawa, *NTT Optoelectronics Laboratories, Japan.* This paper presents a 40-Gbit/s time-division multiplexing (TDM) system prototype based on InP HEMT digital IC technologies. High-output power photodiode directly drives the digital IC and achieves high-receiver sensitivity. Four-channel 40-Gbit/s wavelength-division multiplexing (WDM) transmission is successfully performed. **(p. 128)**

**12:00m–1:30pm LUNCH BREAK**

## Room 6A

### 1:30pm–3:30pm
### ThM • Optical Packet and IP Switching (Cat. IV)
Kristian E. Stubkjaer, *Technical University of Denmark, Presider*

**1:30pm**
**ThM1 • WDM optical IP tag switching with packet-rate wavelength conversion and subcarrier multiplexed addressing,** D.J. Blumenthal, L. Rau, S. Humphries, *UC–Santa Barbara, USA;* A. Carena, V. Curri, *Politecnico di Torino, Italy.* We believe we have demonstrated for the first time wavelength-division multiplexing (WDM) all-optical IP tag switching with wavelength conversion and subcarrier multiplexed addressing. Switching over four wavelengths covering 16 nm was demonstrated with noninverting wavelength conversion of 2.5 Gbps payloads and burst mode recovery of tag/headers. **(p. 162)**

**1:45pm**
**ThM2 • Demonstration of a highly scalable 100-Gbps OTDM computer interconnect with rapid interchannel switching capability,** K.-L. Deng, R.J. Runser, P. Toliver, C. Coldwell, D. Zhou, I. Glesk, P.R. Prucnal, *Princeton Univ., USA.* We present an experimental demonstration of an error-free 100-Gbps OTDM broadcast star multiprocessor interconnect. A highly scalable novel node design provides interchannel switching speed on the order of the single-channel bit period (1.6 ns). **(p. 165)**

**2:00pm**
**ThM3 • 16 WDM optical packet routing experiment over 640 km transmission distance at data rate of 2.5 Gbit/s,** Mitsunori Fukutoku, Nori Shibata, *NTT Optical Network Systems Laboratories, Japan.* We demonstrate 1024 byte, 16 wavelength-division multiplexed (WDM) optical packet transmission experiments including a wavelength routing function over 640-km transmission distance at the data rate of 2.5 Gbit/s. The bit error rate (BER) after 640 km transmission is 10–11 with no BER floor. **(p. 168)**

## Room 6B

### 1:30pm–3:30pm
### ThN • Transceivers and Packaging (Cat. II)
Chung-en Zah, *Corning, Inc., USA, Presider*

**1:30pm**
**ThN1 • A 2.5-Gbit/s high-speed PLC module for gigabit-to-the-home system,** S. Shioiri, M. Soda, A. Goto, N. Kitamura, I. Watanabe, M. Shibutani, *NEC Corp., Japan.* A PLC module with an APD and a one-chip receiver IC was developed for use in an ultrabroadband optical access system. The module provides 2.5-Gbit/s downlink capacity and is the fastest PLC module ever reported to our knowledge. **(p. 188)**

**1:45pm**
**ThN2 • –31 dBm sensitivity of a monolithic transmit-receive-device over wide temperature range,** F. Mallécot, A. Leroy, A. Plais, Ch. Chaumont, D. Carpentier, E. Derouin, F. Gaborit, J. Jacquet, *Alcatel Corporate Research Centre, France;* H. Nakajima, *France Telecom - CNET, France;* F. Doukhan, *Alcatel Optronics, France.* High system performances (–31 dBm), over wide temperature range, were demonstrated by a monolithic in-line transmit-receive-device, designed for single-fiber bidirectional transmissions in full-duplex operation at 155 Mbit/s. **(p. 191)**

**2:00pm**
**ThN3 • Monolithically integrated 1.5 μm/1.3 μm transceiver modules for full-duplex operation,** M. Hamacher, H. Heidrich, R. Kaiser, P. Albrecht, W. Ebert, D. Franke, G. Jacumeit, S. Malchow, W. Rehbein, H. Schroeter-Janßen, R. Stenzel, *Heinrich-Hertz-Institut für Nachrichtentechnik Berlin GmbH, Germany;* P. Devoldere, M. Morin, G. Térol, J.-P. Defars, *France Telecom, France.* 1.5/1.3 μm transceiver-PICs with in-line and Y-junction architecture including a 1.3-μm wavelength-selective photodetector building block have been fabricated. The characterization of a first Y-junction module in a test bed is presented. **(p. 195)**

## Room 6C

### 1:30pm–3:30pm
### ThO • DWDM 2 (Cat. III)
Y.C. Chung, *KAIST, S. Korea, Presider*

**1:30pm**
**ThO1 (Invited) • Measurement techniques for high-speed WDM experiments,** A.R. Chraplyvy, *Bell Labs, Lucent Technologies, USA.* The recent explosive growth of fiber transmission capacity in laboratories around the world is the result of various new experimental techniques. These measurement techniques will be described and, in particular, techniques that lead to misleading experimental results will be scrutinized. **(p. 214)**

**2:00pm**
**ThO2 • 320 Gbit/s WDM transmission over 450 km of LEAF® optical fiber,** A.J. Lucero, S. Tsuda, V.L. da Silva, D.L. Butler, *Corning, Inc., USA.* We demonstrate transmission of 32 × 10 Gbit/s over 450 km of LEAF® fiber with BER ~$10^{-13}$, using the same dispersion compensation for all channels. The large effective area fiber strongly reduces all nonlinear effects, limiting the fiber-induced penalty to <1.3 dB. **(p. 215)**

| Room 6D | Room 5A | Room 1A |
|---|---|---|

### ThJ • Adjustable Fiber Grating Filters (Cat. I)—Continued

**11:45am**
**ThJ6 • Gain equalization with optimized slanted Bragg grating on adapted fiber for multichannel long-haul submarine transmission,** I. Riant, L. Gasca, P. Sansonetti, *Alcatel Corporate Research Center, France;* G. Bourret, J. Chesnoy, *Alcatel Submarine Network, France.* Slanted Bragg grating and fiber were specially designed for erbium amplifier gain flattening. Results on 11 cascaded 50-km amplified spans show 0.1 dB gain excursion per amplifier on bandwidth as wide as 17.8 nm. **(p. 147)**

### ThK • Transport and Access Technologies 2 (Cat. V)—Continued

**11:45am**
**ThK4 (Invited) • Photonics R&D programme in Germany—results of selected projects,** G. Walf, *Heinrich-Hertz-Institut für Nachrichtentechnik, Germany.* "Photonics" has been one of the main R&D programmes in information technology conducted by the German government. In April 1998, its second four-year-phase was concluded, resulting in the development of advanced technologies for broadband optical fiber systems. **(p. 157)**

**12:00m–1:30pm LUNCH BREAK**

### 1:30pm–3:30pm
### ThP • Symposium on Large Optical Networking Programs (Cat. IV)
Richard Barry, *Sycamore Networks, USA, Presider*

**1:30pm**
**ThP1 (Invited) • Photonic network research activities and testbed experiments in NTT,** Ken-ichi Sato, *NTT Optical Network Systems Labs, Japan.* This presentation will discuss the basic concept of the future photonic network. Recent advances in photonic network technology develpment will be addressed and the testbed experiments that will be conducted starting in 1999 will be reviewed. **(p. 228)**

**2:00pm**
**ThP2 (Invited) • SuperNet and NGI,** B. Hui, M. Maeda, *DARPA/ITO, USA.* The talk will cover the DARPA's role and areas of investment in the Next Generation Internet Program. Examples of individual projects will be highlighted. **(p. 231)**

### 1:30pm–3:15pm
### ThQ • Nonlinear Transmission (Cat. III)
Alexei N. Pilipetskii, *Tyco Submarine Systems Ltd., USA, Presider*

**1:30pm**
**ThQ1 • Cross-phase modulation resonances in WDM systems,** S.G. Evangelides Jr., *Tyco Submarine Systems Ltd. Labs, USA.* We present a theoretical treatment of cross-phase modulation enhancement due to the effects of periodic gain and loss in an all-optical transmission line. **(p. 240)**

**1:45pm**
**ThQ2 • Error-free propagation of 10-Gbit/s wavelength-converted RZ data over 20,000 km in a dispersion-managed system,** Pak S. Cho, Daniel Mahgerefteh, *Laboratory for Physical Sciences and Univ. Maryland–College Park, USA;* Gary M. Carter, *Univ. Maryland–Baltimore County, USA.* We performed all-optical wavelength conversion of return-to-zero data at 10 Gbit/s using a semiconductor-optical-amplifier/fiber-Bragg-grating hybrid device and propagated the converted data error-free over 20,000 km in a dispersion-managed system. **(p. 243)**

**2:00pm**
**ThQ3 • Modeling vs. experiments of 16 × 10 Gbit/s WDM chirped RZ pulse transmission over 7500 km,** Ekaterina A. Golovchenko, Neal S. Bergano, Carl R. Davidson, Alexei N. Pilipetskii, *Tyco Submarine Systems Ltd., USA.* We demonstrate a good agreement between experiments and simulations on a 16 × 10 Gbit/s wavelength-division multiplexing (WDM) transmission system over 7500 km with an average *Q*-factor >16 dB. We used a simulation technique based on careful evaluation of the key physical effects that produce system impairments. **(p. 246)**

### 1:30pm–2:30pm
### ThR • Tutorial on Raman and Cladding-Pumped Fiber Amplifiers and Lasers (Cat. I)
Bruce Nyman, *JDS Fitel Inc., USA, Presider*

INSTRUCTOR

**Andrew J. Stentz**
*Bell Laboratoires, USA*

Due to its versatility, Raman amplification is certain to play an ever increasing role in optical communication systems. In this tutorial, we will review the fundamentals of Raman amplification in optical fibers. The issues of conversion efficiency, noise, and pump sources will be discussed. The evolution of Raman amplifiers, discrete and distributed, and recent experimental results will be described.

Andrew Stentz was born in Cincinnati, Ohio in 1964. He received B.S. degrees in physics and mathematics from Xavier University in 1987 and a Ph.D. in optics from the University of Rochester in 1995. Upon graduation, he became a member of the technical staff at Bell Laboratories where he has worked on high-power fiber lasers and Raman amplifiers. **(p. 264)**

Room 6A | Room 6B | Room 6C

## ThM • Optical Packet and IP Switching (Cat. IV)—Continued

**2:15pm**
**ThM4 • All-optical packet header recognition and switching in a reconfigurable network using fiber Bragg gratings for time-to-wavelength mapping and decoding,** M.C. Cardakli, S.Lee, A.E. Willner, V. Grubsky, D. Starodubov, J. Feinberg, *Univ. Southern California, USA.* We demonstrate reconfigurable all-optical header recognition and routing of a 2.5-Gbit/s packet stream using time-to-wavelength mapping with a fiber Bragg grating array correlation decoding. We achieve penalty-free routing using a 1.6-ns guard time. This technique would be useful to enable high-speed all-optical packet switching nodes. **(p. 171)**

**2:30pm**
**ThM5 • Demonstration of sequential 100-Gbit/s word TDM packet add/drop functionality using a loop-back configuration,** J.W. Lou, Y. Liang, O. Boyraz, J.C. Stocker, M.N. Islam, *Univ. Michigan, USA.* We show sequential 100-Gbit/s packet processing by looping an all-optical packet add/drop multiplexer on itself. The packets from two different sources are routed with 17-dB contrast ratio and demultiplexed with 20-dB contrast ratio. **(p. 174)**

**2:45pm**
**ThM6 • A novel switching paradigm for bufferless WDM networks,** Myungsik Yoo, Chunming Qiao, *Univ. at Buffalo (SUNY), USA.* Optical burst switching (OBS) is proposed to efficiently support IP over wavelength-division multiplexing (WDM). We describe various OBS protocols and in particular, one that can achieve high bandwidth utilization and low blocking probability in bufferless optical networks. **(p. 177)**

**3:00pm**
**ThM7 • A new scheduling algorithm for asynchronous, variable-length IP traffic incorporating void filling,** Ljubiša Tančevski, An Ge, Gerardo Castanon, Lakshman Tamil, *Alcatel Corporate Research Center, USA.* We demonstrate that optimum switch performance can be achieved by matching the basic delay line unit in the optical buffer to the degree of self-similarity of the input traffic, in tandem with a scheduling algorithm for void filling. **(p. 180)**

**3:15pm**
**ThM8 • Latency characteristics of wavelength-switched packets in WDM multihop ring networks,** Takashi Ono, *NEC Corp., Japan;* Steven Gemelos, Ian White, Leonid G. Kazovsky, *Stanford Univ., USA.* Improvement of the latency characteristic by using a wavelength-tunable LD at each node was confirmed through numerical simulations. From these results, the required wavelength switching time was clarified to be <10 ns for 2.5 Gbit/s ATM signals. **(p. 183)**

## ThN • Transceivers and Packaging (Cat. II)—Continued

**2:15pm**
**ThN4 • LD and PD array modules assembled in a new plastic package with auto-alignment projections for silicon optical bench,** H. Mori, S. Tamura, A. Izawa, M. Iwase, *The Furukawa Electric Co., Ltd., Japan.* A plastic package with auto-alignment projections for silicon optical bench was newly developed and four-channel LD and PD array modules assembled in this package are reported. **(p. 198)**

**2:30pm**
**ThN5 • High-coupling-efficiency aspheric micro-optics integrated on a Si-V groove for a high-speed miniDIL transmitter,** K. Tatsuno, K. Yoshida, K. Fukuda, *Hitachi Ltd., Japan.* Highly efficient micro-optics mounted on a Si-V-groove in a 4.5-mm-high MiniDIL has been developed for use in a high-speed, long-haul transmitter. The optics consists of a 1.5-mm-diameter 0.55-NA aplanatic aspheric singlet and a 2-mm-diameter microisolator. The coupling from a laser diode to a single-mode fiber was 67% in the fiber alignment area of ±275 μm. **(p. 201)**

**2:45pm**
**ThN6 • Data-format-free 622-Mbit/s/ch 12-channel parallel optical transmitter and receiver,** K. Miyoshi, I. Hatakeyama, T. Nagahori, T. Shine, I. Yoneda, Y. Nukada, A. Uda, A. Kawatani, T. Watanabe, K. Akimori, J. Sasaki, *NEC Corp., Japan.* A data-format-free 622-Mbit/s/ch 12-channel optical transmitter and receiver have been developed. They provide a skewless PECL interface parallel link for 100-m transmission operating int he ambient temperature range from 0–70°C with a 3.3 V power supply. **(p. 204)**

**3:00pm**
**ThN7 • Feed-forward LD current controlled fiber-optic transmitter and PLL retimed receiver for 622 Mbps and 2.4 Gbps,** M. Yoshizawa, T. Chikuma, T. Yoshida, M. Nakano, T. Tajima, *NEC Corp., Japan.* A novel developed fiber-optic transmitter and receiver pairs for 622 Mbps and 2.4 Gbps transmission are presented. They operate over wide temperature range thanks to feed-forward APC and PLL technology. **(p. 207)**

**3:15pm**
**ThN8 • Over 20 dB of crosstalk reduction in an asymmetric bit rate optical transceiver module,** T. Akashi, K. Mori, M. Kawai, *Fujitsu Laboratories Ltd., Japan.* Over 20 dB of crosstalk reduction was achieved by the method, using transmitter bandwidth optimization. With this method, we developed a high-performance optical transceiver module for asymmetric bit rate systems. **(p. 210)**

## ThO • DWDM 2 (Cat. III)—Continued

**2:15pm**
**ThO3 (Invited) • Transmission over 360 km of 110 channels at 2.35 Gbit/s from a spectrum-sliced mode-locked laser,** L. Boivin, M. Wegmuller, M.C. Nuss, W.H. Knox, Y. Sun, A.K. Srivastava, J.W. Sulhoff, C. Wolf, *Lucent Technologies, USA.* We report the transmission over 360 km of 100 channels at 2.35 Gbit/s from a spectrum-sliced femtosecond fiber laser. Almost all transmitted channels have $Q$ factors >18.34 dB corresponding to error floors below $10^{-16}$. **(p. 218)**

**2:45pm**
**ThO4 • Seamless 32 × 10 Gbit/s transmission over 320 km of 1.55-μm dispersion-shifted fiber using wavelengths ranging from 1546 nm to 1587 nm,** H. Suzuki, N. Takachio, Y. Hamazumi, H. Masuda, S. Kawai, K. Araya, *NTT Optical Network Systems Laboratories, Japan.* This paper demonstrates 32 × 10 Gbit/s transmission over 1.55 μm dispersion-shifted fiber. The channels are seamlessly allocated from 1546 nm to 1587 nm. Wideband optical amplifiers employing distributed Raman amplification are used as in-line amplifiers. **(p. 221)**

**3:00pm**
**ThO5 (Invited) • Towards uniform channel performance in dynamic WDM systems and networks,** Alan Eli Willner, *Univ. Southern California, USA.* Several channel-degrading effects are present in dynamic reconfigurable wavelength-division multiplexing (WDM) systems and networks. These effects must be addressed by tunable methods so that signals do not fade with time. The relevant issues to be addressed include; dispersion compensation, power equalization, PMD compensation, and EDFA gain flattening and transient control. **(p. 224)**

**3:30pm–4:00pm COFFEE BREAK, Exhibit Hall**

Room 6D | Room 5A | Room 1A

## ThP • Symposium on Large Optical Networking Programs (Cat. IV)—Continued

**2:30pm**
**ThP3 (Invited) • Results of the PHOTON and MOON field trials,** Wolfgang Mader, *Siemens Austria, Austria.* The PHOTON and MOON projects prove the feasibility of all-optical networking by implementing field trial networks in Europe, demonstrating repeaterless 10-Gbit/s transmission over more than 1000 km within an eight-channel wavelength-division multiplexing grid, optical cross-connecting and management of a photonic network with three optical crossconnects and line amplifiers. **(p. 234)**

**3:00pm**
**ThP4 (Invited) • Multiwavelength optical networking in MONET Washington, D.C. Network,** Ann C. Von Lehmen, *Bellcore, USA.* This talk will describe plans and progress towards the deployment of a multiwavelength optical networking testbed in Washington, D.C. by the Multiwavelength Optical Networking Program (MONET) Consortium. **(p. 237)**

## ThQ • Nonlinear Transmission (Cat. III)—Continued

**2:15pm**
**ThQ4 • Optimal prechirping for dispersion-managed transmission of return-to-zero pulses,** Tian-Shiang Yang, William L. Kath, *Northwestern Univ., USA;* Stephen G. Evangelides Jr., *Tyco Submarine Systems Ltd., USA.* We present analytic expressions that predict the transmission dynamics of chirped return-to-zero (CRZ) pulses in dispersion-managed fibers. The theory enables us to efficiently calculate the prechirping required to optimize system performance. **(p. 249)**

**2:30pm**
**ThQ5 • Dispersion-managed RZ propagation in a circulating loop with NZ-DSF and DCF with 100-km EDFA spacing and dispersion-compensation period,** Jeff Korn, J.D. Moores, *MIT Lincoln Laboratory, USA.* Nonlinear propagation is reported for dispersion-managed 10 Gbps RZ data patterns in the net anomalous-, zero-, and normal-dispersion regimes. The maximum error-free distance achieved without controls is 8800 km with 100-km erbium-doped fiber amplifier (EDFA) spacing. **(p. 252)**

**2:45pm**
**ThQ6 • Concatenated FEC experiment over 5000 km long straight line WDM test bed,** Andrej Puc, Frank Kerfoot, Adrian Simons, David L. Wilson, *Tyco Submarine Systems Ltd., USA.* A concatenated forward error correction code yielded 10-dB coding gain in a straight line laboratory experiment over a 5000-km optically amplified test bed. We used this margin to reduce power per channel, and thus nonlinearities, allowing us to demonstrate channel spacings as close as 0.13 nm for 2.5 Gbit/s transmission. **(p. 255)**

**3:00pm**
**ThQ7 • Suppression of nonlinear waveform distortion using alternate polarization modulation for long-distance 10-Gbit/s-based WDM transmission systems,** Toshiharu Ito, Yoshihisa Inada, Kiyoshi Fukuchi, Tetuyuki Suzaki, *NEC Corp., Japan.* Alternate polarization modulation has been proposed for long-distance 10-Gbit/s-based wavelength division multiplexing (WDM) transmission systems to suppress SPM-GVD effect. In the 6000-km transmission, the allowable accumulated dispersion, which determines the available WDM bandwidth, was increased by 40% by adopting this scheme. **(p. 259)**

## ThR • Tutorial on Raman and Cladding-Pumped Fiber Amplifiers and Lasers (Cat. I)—Continued

**3:30pm–4:00pm COFFEE BREAK, Exhibit Hall**

## Room 6A

### 4:00pm–5:30pm
### ThS • Calibration and Measurements (Cat. I)
Byoung Yoon Kim, *Korea Advanced Institute of Science and Technology, S. Korea, Presider*

**4:00pm**
**ThS1 (Invited) • Wavelength standards and stabilization for WDM networks,** Masafumi Koga, *NTT Optical Network Systems Laboratories, Japan.* Abstract not available. **(p. 266)**

**4:30pm**
**ThS2 • Accurate wavelength calibration references for wavelength-division multiplexing,** Sarah L. Gilbert, William C. Swann, *NIST–Boulder, USA.* We have developed transfer standards and high-accuracy internal standards for wavelength calibration in the 1500-nm region. The Standard Reference Material transfer standards are based on the absorption of light by acetylene and hydrogen cyanide. **(p. 267)**

**4:45pm**
**ThS3 • OLCR characterization of long-period grating-induced cladding modes,** D. Varelas, A. Iocco, H.G. Limberger, R.P. Salathé, *Swiss Federal Institute of Technology, Switzerland;* S.A. Vasiliev, E.M. Dianov, O.I. Medvedkov, V.N. Protopopov, *Russian Academy of Sciences, Russia.* The group index of well-defined cladding modes has been characterized for the first time to our knowledge by optical low-coherence reflectometry (OLCR)with a precision $<10^{-4}$. Very good agreement between theoretical and experimental results has been obtained. **(p. 270)**

## Room 6B

### 4:00pm–5:30pm
### ThT • High-Speed Modulators and Short-Pulse Generation (Cat. II)
Frederick J. Leonberger, *UTP, USA, Presider*

**4:00pm**
**ThT1 • Low drive voltage, 40-GHz $LiNbO_3$ modulators,** W.K. Burns, R.P. Moeller, R.W. McElhanon, A.S. Greenblatt, *Naval Research Laboratory, USA;* M.M. Howerton, *SFA, Inc, USA.* Frequency-dependent drive voltage is reported in velocity-matched, packaged, $LiNbO_3$ interferometers with and without etched ridges. $V_\pi$'s of 7–7.5 V at 40 GHz are demonstrated, with the etched ridge device showing a 1/2–1 V advantage. **(p. 284)**

**4:15pm**
**ThT2 • An optically efficient RF modulator,** Steven A. Havstad, *Univ. Southern California and TRW Space and Technology Division, USA;* Michael G. Wickham, Donald G. Heflinger, Paul Nachman, John C. Brock, *TRW Space and Technology Division, USA.* Our RF modulator uses a novel arrangement of two low-biased Mach–Zehnder modulators within a ring laser, eliminating resonances and improving efficiency by over 7 dB relative to an externally modulated configuration. This will be useful for DC power-limited analog photonic links. **(p. 287)**

**4:30pm**
**ThT3 • 30-Gbit/s operation of a traveling-wave electroabsorption modulator,** Sheng Z. Zhang, Volkan Kaman, Adrian Keating, Yi-Jen Chiu, Patrick Abraham, John E. Bowers, *UC–Santa Barbara, USA.* Electroabsorption modulators with traveling-wave electrodes have been designed and fabricated using MOCVD grown InGaAsP/InGaAsP quantum wells. 30-Gbit/s transmission was demonstrated with a 2-μm-wide 300-μm-long device. **(p. 290)**

**4:45pm**
**ThT4 • Theoretical prediction and experimental verification of quantum well electroabsorption modulators with bandwidths exceeding 40 GHz,** M.N. Khan, G.E. Shtengel, S. Chandrasekhr, E.C. Burrows, C.A. Burrus, J. Sarathy, J.A. Grenko, J.M. Vandenberg, S.K. Sputz, M. Geva, R.W. Glew, *Lucent Technologies, Bell Laboratories, USA.* We experimentally verify the bandwidth and extinction ratio performance of electroabsorption modulators predicted from our simulation. Modulators with bandwidth exceeding 40 GHz for <2 V DC bias have been demonstrated in InGaAsP/InGaAsP multiple quantum wells. **(p. 293)**

## Room 6C

### 4:00pm–5:15pm
### ThU • EDFA Effects (Cat. III)
Per B. Hansen, *Bell Labs, Lucent Technologies, USA, Presider*

**4:00pm**
**ThU1 • Stimulated Brillouin scattering of the compensating signal in all-optical link-controlled amplifier systems,** Qian Yu, Lisong Zhou, Chongcheng Fan, *Tsinghua Univ., China.* The performance of wavelength-division multiplexed transmission systems using all-optical link control for amplifier gain stabilization can be impaired by stimulated Brillouin scattering of the compensating signal generated from ring, but not fiber Bragg grating laser structure. **(p. 304)**

**4:15pm**
**ThU2 • Fiber transmission penalties due to EDFA power transients resulting from fiber nonlinearity and ASE noise in add/drop multiplexed WDM networks,** M.I. Hayee, A.E. Willner, *Univ. Southern California, USA.* We analyze fiber transmission penalties due to erbium-doped fiber amplifier (EDFA) power transients that result from fiber nonlinearity and ASE noise in a chain of 10–20 EDFAs with as many as 32 wavelength-division multiplexing (WDM) channels. We find due to worst case power transients: (i) system performance is severely degraded (up to few 10s of dB) both in single-mode fiber and dispersion-shifted fiber, (ii) the SNR can be reduced up to 8 dB in a 32-channel system, and (iii) a control channel to suppress power/SNR transients may impose an additional penalty of up to few dBs, which increases with the bit rate. **(p. 307)**

**4:30pm**
**ThU3 (Invited) • The proper definition of noise figure of optical amplifiers,** H.A. Haus, *MIT, USA.* The noise figure definition currently in use for the characterization of optical amplifiers is critiqued. It is shown that it is inconsistent with the IEEE standard established for electronic amplifiers. A noise figure definition is proposed that is consistent with the IEEE standard and that is shown to be superior to the one currently in use. **(p. 310)**