TOPICAL MEETING ON SEMICONDUCTOR LASERS

Summaries of papers presented at the Semiconductor Lasers Topical Meeting

February 10–11, 1987

Albuquerque, New Mexico

Sponsored by the

Lasers and Electro-Optics Society of IEEE
Optical Society of America

Optical Society of America
1816 Jefferson Place, N.W.
Washington, D.C. 20036
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BALLROOM LOBBY

7:30 AM–4:00 PM REGISTRATION

BALLROOM C

8:30 AM (Invited Paper)
TuA1 Report on the Tenth IEEE International Semiconductor Laser Conference, Ivan P. Kaminow, *AT&T Laboratories.* Highlights of research topics discussed at the Tenth Biennial Semiconductor Laser Conference, held in Kanazawa, Japan in October 1986, are reviewed. (p. 2)

9:00 AM–11:00 AM
TuB, NOISE, LINEWIDTH AND STABILITY
Aram Mooradian, *MIT Lincoln Laboratory, Presider*

9:00 AM (Invited Paper)
TuB1 Phase Noise in Semiconductor Lasers and its Reduction by Optical Feedback, Charles H. Henry, *AT&T Bell Laboratories.* A general formulation of spontaneous emission noise in semiconductor lasers is presented and it is used to calculate the reduction of Lorentzian linewidth due to optical feedback. (p. 6)

9:30 AM
TuB2 Dependence of Diode Laser Linewidth on Facet Reflectivity and Output Power, F. G. Walther, D. Welford, *MIT Lincoln Laboratory.* Measurements of laser linewidth vs facet reflectivity confirm linewidth theory and indicate an increase in $1/f$ frequency noise at high injected power levels. (p. 7)

BALLROOM LOBBY

9:45 AM–10:15 AM COFFEE BREAK

BALLROOM C

10:15 AM
TuB3 Power Instability and Optical Bistability in Grating Loaded External Cavity Semiconductor Lasers, Chien-Yu Kuo, *AT&T Bell Laboratories.* Optical bistability is observed in a single frequency laser consisting of an active section and a dispersive passive section-grating loaded external cavity semiconductor laser. The laser switches between two stable power levels during tuning. Power hysteresis with respect to increasing and decreasing injection current exhibits typical hybrid optical bistability behavior. (p. 11)

10:30 AM
TuB4 Novel Optical Frequency Stabilization of Semiconductor Lasers, Dag Roar Hjelme, Alan Rolf Mickelson, *U. Colorado;* L. Hollberg, B. Dahmani, *U.S. National Bureau of Standards.* A new frequency stabilization method for semiconductor lasers based on optical feedback from a reference cavity is theoretically analyzed. Experiments demonstrate linewidths less than 50 kHz. (p. 15)

10:45 AM
TuB5 Instabilities in Long External Cavity Semiconductor Lasers due to Resonant Self-Pulsing, P. Phelan, J. O'Gorman, *Trinity College, Ireland;* J. McInerney, *U. New Mexico;* D. Heffernan, *National Institute for Higher Education, Ireland.* The self-pulsing frequency of a diode laser is observed to increase in discrete multiples of the external cavity resonance with instabilities at transition points. (p. 19)

11:00 AM–12:00 M
TuC, NOVEL DEVICES
Luis Figueroa, *University of Florida, Presider*

11:00 AM
TuC1 Interlayer-Directional Grating-Coupled III-V ARROW Structures for Integrated Optoelectronics, T. L. Koch, E. G. Burkhardt, F. G. Storz, T. J. Bridges, T. Sizer, W. T. Tsang, U. Koren, P. J. Corvini, *AT&T Bell Laboratories.* Observation of lasing action in a new III–V anti-resonant reflecting optical waveguide (ARROW) geometry has provided the first demonstration of interlayer-directional grating coupling in planar waveguides. (p. 24)

11:15 AM
TuC2 High-Power 0.83-μm Angle Stripe Superluminescent Diode, J. Niesen, P. H. Payton, C. B. Morrison, L. M. Zinkiewicz, *TRW Electro Optics Research Center.* Continuous wave operation of an angle stripe superluminescent diode has been achieved to powers as high as 30 mW. Typical spectral properties are 150-Å halfwidth with 5% Fabry-Perot modulation. (p. 27)

11:30 AM
TuC3 Low Threshold Current Density 2.2-μm GaInAsSb/AlGaAsSb Double Heterostructure Lasers, C. Caneau, J. L. Zyskind, A. G. Dentai, T. E. Glover, J. W. Sulhoff, A. K. Srivastava, M. A. Pollack, *AT&T Bell Laboratories.* GaInAsSb/AlGaAsSb injection lasers with Al-rich confinement layers and strain relieving intermediate cladding layers are reported with room temperature thresholds of 2.5 kA/cm^2. (p. 30)

11:45 AM
TuC4 Distributed Bragg Reflector Lead-Salt Diode Lasers for Operation above 77 K, Y. Shani, A. Katzir, *Tel Aviv U., Israel;* P. Norton, M. Tacke, H. Preier, *Fraunhofer Institute for Physical Metrology, F. R. Germany.* Distributed Bragg reflector double-heterostructure lasers consisting of PbSnSe and PbEuSnSe layers are discussed, operated single-mode over a range of 20 cm^{-1} at temperatures above 77 K. (p. 34)

BALLROOM C

1:30 PM–5:00 PM
TuD, GaInAsP LASERS
T. L. Koch, *AT&T Bell Laboratories, Presider*

1:30 PM (Invited Paper)
TuD1 High-Speed Buried-Heterostructure InGaAsP/InP Diode Lasers, Hajime Imai, *Fujitsu Laboratories, Ltd., Japan.* The important methods for high-bit-rate modulation—reduction of parasitic capacitance and increase in relaxation frequency—are described. (p. 40)

2:00 PM
TuD2 Universal Relationship Between Resonant Frequency and Damping Rate of 1.3-μm InGaAsP Semiconductor Lasers, R. Olshansky, P. Hill, V. Lanzisera, W. Powazinik, *GTE Laboratories, Inc.* A universal relationship between demping rate and resonant frequency is found from measurements of 1.3 μm InGaAsP lasers and explained using Yamada's model of nonlinear gain. (p. 43)

2:15 PM
TuD3 High-Speed 1.3-μm InGaAsP Buried Crescent Injection Lasers with Semi-Insulating Current Confinement Layer, W. H. Cheng, C. B. Su, K. D. Buehring, C. P. Chien, J. W. Ure, D. Perrachione, D. Renner, K. L. Hess, S. W. Zehr, *Rockwell International Corporation.* A hybrid growth technique has been used to fabricate high modulation bandwidth 1.3-μm buried crescent injection lasers with a semi-insulating blocking layer. The lasers exhibit small-signal modulation bandwidth of 5 GHz. (p. 47)

2:30 PM
TuD4 Wide-Bandwidth High-Power 1.3-μm InGaAsP Buried Crescent Lasers with Semi-Insulating Fe-Doped InP Current Blocking Layers, C. E. Zah, J. S. Osinski, S. G. Menocal, N. Tabatabaie, T. P. Lee, *Bell Communications Research, Inc.;* A. G. Dentai, C. A. Burrus, *AT&T Bell Laboratories.* By the use of Fe-doped InP as the only current blocking layer, 8.3-GHz bandwidth and 30 mW/facet output has been achieved on 1.3-μm buried crescent lasers. (p. 51)

2:45 PM
TuD5 InGaAsP/InP Planar Buried-Heterostructure Laser with Semi-Insulating InP Current Blocking Layers Grown by MOCVD, K. Wakao, K. Nakai, T. Sanada, M. Kuno, S. Yamakoshi, *Fujitsu Laboratories, Ltd., Japan.* InGaAsP/InP planar buried-heterostructure lasers with semi-insulating InP current blocking layers have been made using the selective embedding growth technique of metalorganic chemical vapor deposition. (p. 55)

BALLROOM LOBBY

3:00 PM–3:30 PM COFFEE BREAK

TUESDAY, FEBRUARY 10, 1987—*Continued*

BALLROOM C

3:30 PM (Invited Paper)
TuD6 High Power 1.3-μm Laser Diodes, E. A. Rezek, N. Adachi, D. Tran, L. Yow, *TRW-Electro Optics Research Center.* 1.3-μm double channel planar buried-heterostructure laser diodes have been fabricated which operate up to 110 mW cw. High power accelerated aging data are presented. (p. 59)

4:00 PM
TuD7 Measurement of Radiative, Auger, and Shunt Currents in 1.3-μm Buried-Heterostructure Lasers, J. LaCourse, T. Chow, R. Olshansky, W. Powazinik, *GTE Laboratories, Inc.* Improved carrier lifetime measurements permit the first accurate determination of radiative, Auger, and shunt currents as a function of bias below threshold in 1.3-μm buried-heterostructure lasers. This technique is an important diagnostic tool for identifying the cause of degradation. (p. 62)

4:15 PM
TuD8 Performance of High Reliability, Low Threshold InGaAsP Ridge Waveguide Lasers Emitting at 1.3 μm, A. A. M. Rashid, R. S. Butlin, A. P. Janssen, *STC Defence Systems, Ltd., U.K.;* T. E. Stockton, *Stantel Corporation.* The fabrication, performance, and reliability of InP/InGaAsP ridge waveguide lasers emitting at 1.3 μm is described. The structure requires only one stage of planar wafer growth and simple fabrication steps. Threshold currents are typically 25 mA with a minimum of 18 mA at 20 °C and external quantum efficiency is 20–25% per facet. Output power in the fundamental mode is maintained to > 10 mW, while total power > 100 mW cw at 20 °C has been obtained. System measurements have demonstrated that the device operates up to 2.4 Gb/s. Operating lifetimes, in excess of 25 years at 50 °C, have been predicted from over 300,000 device hours of life test, using a power law drift model. (p. 66)

4:30 PM
TuD9 Wide Temperature Range of Stable Single-Mode Operation in Optimally Designed DFB Lasers, H. Soda, K. Kihara, M. Furutsu, M. Matsuda, H. Seki, S. Ogita, H. Ishikawa, H. Imai, *Fujitsu Laboratories, Ltd., Japan.* An optimum design has been established for an asymmetric mirror structure DFB laser with high single-mode operation yield over a wide temperature range. (p. 70)

4:45 PM
TuD10 Simplified Thermal Model for Calculating the Maximum cw Output Power from a Stripe Geometry InGaAsP/InP Laser, M. Arvind, H. Hsing, Luis Figueroa, *U. Florida.* A simplified thermal model is described. Calculations made on 1.3-μm lasers shows continuous wave powers of 64-mW/facet and maximum operating temperatures of 134 °C. (p. 74)

WEDNESDAY, FEBRUARY 11, 1987

BALLROOM LOBBY

7:30 AM–4:00 PM REGISTRATION

BALLROOM C

8:30 AM–12:00 M
WA, ARRAYS, SURFACE EMITTERS, AND RELATED TECHNOLOGY
J. J. Yang, *TRW Space & Technology Group, Presider*

8:30 AM (Invited Paper)
WA1 Coherent Beam Combining of One- and Two-Dimensional Laser Arrays, James R. Leger, Gary J. Swanson, Michael Holz, *MIT Lincoln Laboratory.* Laser beam combining is demonstrated using beam superimposition as well as aperture filling techniques. Single lobed far-field patterns are produced from GaAlAs laser arrays. (p. 80)

9:00 AM
WA2 Large Monolithic 2-D Arrays of GaInAsP/InP Surface-Emitting Lasers, Z. L. Liau, J. N. Walpole, *MIT Lincoln Laboratory.* A 3 mm × 1 mm monolithic 2-D array of 112 mass-transported laser/deflectors has been fabricated with good uniformity. The total cw output is thermally limited to 670 mW. (p. 84)

9:15 AM
WA3 Monolithic 2-D Arrays of GaAlAs/GaAs Surface Emitting Lasers, J. J. Yang, S. S. Ou, M. Jansen, M. Sergant, L. Eaton, W. W. Simmons, *TRW Space & Technology Group.* A 2-D array of GaAlAs/GaAs surface emitting lasers is fabricated using the ion milling technique. Light emitting from the vertical facet of this array is deflected to a direction perpendicular to the wafer surface by 45° etched mirrors. Device performances are comparable with those of the cleaved lasers. (p. 87)

9:30 AM
WA4 Fabrication and Characterization of InP Fresnel Microlenses, V. Diadiuk, J. N. Walpole, Z. L. Liau, *MIT Lincoln Laboratory.* InP Fresnel microlens arrays have been used to collimate 1.3-μm lasers. The far-field pattern has a 1.5° FWHM main lobe, containing a near-theoretical 40% of the power. (p. 91)

9:45 AM
WA5 High-Power Laser with a Chemically Assisted Ion Beam Etched Mirror, P. Tihanyi, D. K. Wagner, H. J. Vollmer, A. J. Roza, C. M. Harding, *McDonnell Douglas Astronautics Company;* R. J. Davis, E. D. Wolf, *Cornell U.* Chemically assisted ion beam etching is used to fabricate one of the mirrors in a single quantum-well laser structure. High power cw operation is demonstrated. (p. 95)

BALLROOM LOBBY

10:00 AM–10:30 AM COFFEE BREAK

BALLROOM C

10:30 AM (Invited Paper)
WA6 Recent Progress in Surface-Emitting Lasers, K. Iga, S. Uchiyama, S. Kinoshita, F. Koyama, *Tokyo Institute of Technology, Japan.* To reduce the threshold current of surface-emitting (SE) lasers, we have tried to introduce some circular buried-heterostructures (CBH). In this paper, we present some recent results on CBH GaInAsP/InP and GaAlAs/GaAs SE lasers. (p. 99)

11:00 AM
WA7 Vertical Cavity Surface-Emitting Laser Structure in Molecular Beam Epitaxial GaAs/AlGaAs using a Multilayer Dielectric Mirror, D. H. Christensen, *Ball Aerospace Systems;* F. S. Barnes, *U. Colorado.* The device, fabricated from molecular beam epitaxial GaAs/AlGaAs, utilizes a multilayer dielectric mirror. Epilayer specifics, fabrication process and test data are reported. (p. 103)

11:15 AM
WA8 Diode Lasers with Cylindrical Mirror Facets and Reduced Beam Divergence, J. N. Walpole, Z. L. Liau, L. J. Missaggia, D. Yap, *MIT Lincoln Laboratory.* Using chemical etching and mass transport, we have monolithically integrated cylindrical lenses at one of the ends of a buried-heterostructure GaInAsP/InP laser cavity. (p. 106)

BALLROOM C

1:30 PM–5:00 PM
WB, AlGaAs LASERS
J. J. Coleman, *University of Illinois, Presider*

1:30 PM (Invited Paper)
WB1 Impurity-Induced Disordering and Laser Device Applications, R. L. Thornton, J. E. Epler, T. L. Paolo, *Xerox Palo Alto Research Center;* R. D. Burnham, *Amoco Research Center;* N. Holonyak, Jr., *U. Illinois at Urbana-Champaign.* The technology of impurity-induced disordering has been rapidly advancing. Results are presented on disordering processes as well as very encouraging device applications. (p. 112)

2:00 PM
WB2 Index-Guided AlGaAs/GaAs Visible Graded Barrier Quantum-Well Laser Diodes, C. A. Zmudzinski, L. J. Mawst, M. E. Givens, M. A. Emanuel, J. J. Coleman, *U. Illinois at Urbana-Champaign.* AlGaAs/GaAs graded barrier quantum-well laser structures have been modified by inclusion of thin AlAs barrier layers. Development into index-guided stripe laser devices is discussed. (p. 116)

2:15 PM
WB3 150-mW Quasi-cw Fundamental-Mode Operation from a Modified Twin-Channel Laser, C. B. Morrison, L. M. Zinkiewicz, A. Burghard, Dan Botez, *TRW Electro Optics Research Center.* The twin-channel laser structure has been modified to allow lasing in two well-defined coupled spots. Fundamental-mode lasing in a stable narrow beam is then achieved to 150 mW under 50% duty-cycle operation. (p. 120)

2:30 PM
WB4 High Temperature Stability of Visible Semiconductor Lasers Coupled with a Short External Cavity, Hidenori Kawanishi, Hiroshi Hayashi, Osamu Yamamoto, Nobuyuki Miyauchi, Shigeki Maei, Saburo Yamamoto, Toshiki Hijikata, *Sharp Corporation, Japan.* Highly stable single-longitudinal-mode operation of visible semiconductor lasers has been achieved. It utilizes the interferometric effect of a composite cavity. The wavelength locking range is $>46\,°C$. (p. 124)

2:45 PM
WB5 Modified Channeled Substrate Planar Lasers with Lateral Leaky-Mode Behavior, Song J. Lee, Luis Figueroa, *U. Florida.* A modified channeled substrate planar laser with lateral leaky mode is described. The modified design leads to reduced substrate radiation with improved lateral mode discrimination. (p. 128)

BALLROOM LOBBY

3:00 PM–3:30 PM COFFEE BREAK

BALLROOM C

3:30 PM (Invited Paper)
WB6 Growth of GaAs on Si Substrates by Metalorganic Chemical Vapor Deposition, Russell D. Dupuis, *AT&T Bell Laboratories.* There is increasing interest in the growth of III-V compound semiconductors on Si substrates. This paper reviews recent progress in the MOCVD growth of these heteroepitaxial materials. (p. 132)

4:00 PM
WB7 Index-Guided Single Stripe Lasers by Selective Area Growth in Metalorganic Chemical Vapor Deposition System, J. J. Yang, S. S. Ou, M. Jansen, J. Wilcox, M. Sergant, *TRW Space & Technology Group.* Index-guided single stripe lasers have been fabricated by using a one-step selective area growth technique in the metalorganic chemical vapor deposition system. The device operated with a single spatial mode for up to more than three times the threshold current. (p. 133)

WEDNESDAY, FEBRUARY 11, 1987—*Continued*

4:15 PM
WB8 High-Power Single-Quantum-Well Lasers Grown by Metalorganic Chemical Vapor Deposition, D. S. Hill, D. K. Wagner, R. G. Waters, P. L. Tihanyi, A. J. Roza, H. J. Vollmer, K. J. Bystrom, T. S. Guido, *McDonnell Douglas Astronautics Company.* The structure of graded-index separate confinement heterostructure single-quantum-well lasers has been studied experimentally to optimize high-power cw performance. (p. 137)

4:30 PM
WB9 Aging Characteristics of Graded-Index Quantum-Well Lasers Operated Junction-Up, R. G. Waters, R. K. Bertaska, S. J. Schultz, *McDonnell Douglas Astronautics Company.* The results of life testing of graded-index quantum-well semiconductor lasers operating continuous wave and mounted junction-up are reported. Degradation rates for uncoated devices grown by metalorganic chemical vapor deposition are typically 3–4 %/kh. (p. 141)

4:45 PM
WB10 Thermal Analysis of Double-Heterostructure Lasers Using Finite Elements, R. Papannareddy, W. Ferguson, J. K. Butler, *Southern Methodist U.* This paper presents numerical estimates of the temperature rise that occurs in the active layer of a zinc-diffused oxide-insulated, stripe-geometry double-heterostructure laser. (p. 145)

BALLROOM A

6:30 PM CONFERENCE BANQUET
Colonel Lawrence L. Gooch, *Kirtland Air Force Base, Speaker*

BALLROOM LOBBY

7:30 AM–4:00 PM REGISTRATION

BALLROOM C

8:30 AM–12:00 M
ThA, LINEAR PHASED ARRAYS
R. D. Burnham, *Amoco Research Center, Presider*

8:30 AM (Invited Paper)
ThA1 Phased-Locked Arrays of Semiconductor Diode Lasers, Dan Botez, *TRW Electro-Optics Research Center.* An overview of phased-locked array work is presented, with emphasis on methods for obtaining fundamental array-mode operation. (p. 150)

9:00 AM
ThA2 Single-Lobe Y-Coupled Laser Diode Arrays, D. F. Welch, P. S. Cross, D. R. Scifres, W. Streifer, *Spectra Diode Laboratories;* R. D. Burnham, *Amoco Research Center.* Y-coupled phased arrays of buried-heterostructure diode lasers have been fabricated with flared horns at the facets. The output consists predominantly of a single stable far-field lobe. (p. 154)

9:15 AM
ThA3 Generation of a Single-Lobe Radiation Pattern from a Phased-Array Laser using a Near Contact Variable-Phase-Shift Zone Plate, Suwat Thaniyavarn, William Dougherty, *TRW Electro-Optics Research Center.* A thin film zone plate readjusts the phases of individual elements of a laser diode array into an all-in-phase distribution to produce a single lobe far-field pattern. (p. 158)

9:30 AM
ThA4 In-Phase Lasing in Diffraction-Coupled Semiconductor Laser Arrays, J. Z. Wilcox, J. J. Yang, M. Jansen, S. S. Ou, M. Sergant, W. Simmons, *TRW Space & Technology Group.* Model gain analysis predicts supermode selection in diffraction-coupled arrays of diode lasers. The predictions are supported by far-field patterns of double-heterostructure and large optical cavity lasers. (p. 162)

9:45 AM
ThA5 Near-Field Phase of Diode Arrays: Measurements and Supermode Theory, Kimberley Wilson, Gregory Dente, David Depatie, *Air Force Weapons Laboratory/ARBF.* Interferometer measurements of the optical phase at the facet of ten stripe arrays are presented and contrasted with supermode theory. (p. 166)

BALLROOM LOBBY

10:00 AM–10:30 AM COFFEE BREAK

BALLROOM C

10:30 AM
ThA6 Coupled-Mode Analysis of Chirped Phased-Array Semiconductor Lasers, Marek Osinski, William Streifer, Amos Hardy, *U. New Mexico.* Improved coupled mode theory is used to analyze new geometries of phased-array semiconductor lasers with simultaneously varying channel width and spacing. Designs considered include bilinear, crosslinear, and Λ-V chirped arrays. (p. 168)

10:45 AM
ThA7 Thermal Effects in Gain-Guided Diode Laser Arrays, G. Ronald Hadley, J. P. Hohimer, A. Owyoung, *Sandia National Laboratories.* We present calculations of the effects of junction heating on both the wave profiles and the modal gains of the eigenmodes of a gain-guided diode laser array. (p. 172)

11:00 AM
ThA8 Spatial Coherence Measurements in Laser Arrays and Broad Area Configuration Lasers, J. Salzman, *Bell Communications Research, Inc.;* E. Ribak, *Jet Propulsion Laboratory.* A novel interferometer was designed for measuring the spatial coherence in broad area configuration semiconductor lasers. Measurements show a more complicated mode structure than previously reported. (p. 175)

11:15 AM
ThA9 Injection-Seeding Studies of Diode Laser Array Behavior, J. P. Hohimer, G. Ronald Hadley, A. Owyoung, *Sandia National Laboratories.* By optical injection seeding of diode laser arrays with the output from a narrowband tunable master oscillator, we are able to actively probe these devices and study their interelement coupling behavior and eigenmodes. (p. 179)