Wednesday, September 14

All talks will be held in the Zuiten (East) room

8:15-10:15 Session: High Speed Lasers

Session Co-Chairs: **Anders Larrson** *(Chalmers Univ. of Technology)*
Paul Leisher *(Rose Hulman Univ.)*

8:15 WA1 (Invited) – "Direct Modulation Laser Technology toward 50-GHz Bandwidth"

Yasuhiro Matsui[1], Richard Schatz[2], Glen Carey[1], Tsurugi Sudo[1], Charles Roxlo[1]
[1]Finisar Corp., USA, [2]Royal Institute of Technology, Sweden

A short cavity distributed reflector (DR) laser with a modulation bandwidth of 55GHz was developed using the photon-photon resonance and detuned-loading effects. The importance of the chirp parameter for the speed enhancement is discussed.

8:45 WA2 – "Extremely Low-Voltage (1.0Vpp) and 28-Gbps Uncooled Operation up to 85°C in 1.3-µm EA/DFB Lasers with High-Quality Eye Opening"

Nozomu Yasuhara, Syunya Yamauchi, Yoshihiro Tsunemi, Atsushi Nakamura, Yoriyoshi Yamaguchi, Kazuhiko Naoe, Kazuhisa Uomi
Oclaro Japan, Inc., Japan

Operation of 1.3-µm uncooled 28-Gbps EA/DFB lasers at the lowest-so-far-reported voltage was demonstrated. To achieve high-quality waveforms, the MQW structure was optimized, and a novel EA operation condition was proposed. Consequently, the lasers achieved high-quality eye openings with 1.0 Vpp up to 85°C.

9:00 WA3 – "120°C, 25.8-Gbps Operation of 1.3-µm Directly Modulated InGaAlAs-MQW DFB Lasers"

Akira Nakanishi, Takayuki Nakajima, Noriko Sasada, Shigenori Hayakawa, Yasushi Sakuma, Masaru Mukaikubo, Ryu Washino, Kazuhiko Naoe, Kouji Nakahara, Kazuhisa Uomi
Oclaro Japan, Inc., Japan

High-temperature 25.8-Gbps clear-eye-opening of a 1.3-µm directly modulated InGaAlAs-MQW DFB laser with ACPM grating was demonstrated up to 120°C for the first time. Furthermore, the eye openings showed high mask margins of more than 19% from 25 to 110°C.

9:15 WA4 – "42 nm Wide Coherent Frequency Comb Generated by a QW Based Integrated Passively Mode-Locked Laser"

Valentina Moskalenko[1], Kevin Williams[1], Jeroen Koelemeij[2], Erwin Bente[1]
[1]Eindhoven Univ. of Technology, The Netherlands, [2]Vrije Universiteit Amsterdam, The Netherlands

An experimental study of InP extended cavity passively mode-locked ring laser which generates extra wide frequency comb is presented. The bandwidth of over 40nm at -20dB level is observed. Confirmation of the coherence and measurements of the relative time delay across the comb is presented.

9:30 WA5 – "1060 nm VCSEL for up to 40 Gbit/s Data Transmission"

Ewa Simpanen[1], Johan S. Gustavsson[1], Erik Haglund[1], Emanuel Haglund[1], Anders Larsson[1], Wayne Sorin[2], Sagi Mathai[2], Michael Tan[2]
[1]Chalmers Univ. of Technology, Sweden, [2]Hewlett Packard Enterprise, USA

A GaAs-based 1060 nm VCSEL with strained InGaAs/GaAsP QWs, doped DBRs, a short optical cavity,

and multiple oxide apertures is presented. Modulation up to 40 Gbit/s at 25°C and 30 Gbit/s at 85°C is demonstrated.

9:45 WA6 – "Small-Signal Analysis of Ultra-High-Speed VCSELs"

Wissam Hamad, Stefan Wanckel, Werner Hofmann
Technical Univ. of Berlin, Germany

For ultra-high-performing VCSEL devices, a small-signal-modulation response with a shape differing from single-mode edge-emitting lasers is expected, especially if carrier reservoir splitting occurs. We derive a novel function working for all VCSELs, particularly including our latest VCSEL generation with a modulation bandwidth up to 32.7GHz.

10:00 WA7 – "Femtosecond Superradiant Emission in Semiconductor Structures: Self-Ordering and Coherent Population Gratings"

Peter P. Vasil'ev, Richard V. Penty, Ian H. White
Univ. of Cambridge, UK

An impact of transient population gratings on superradiant emission from semiconductor laser structures is studied. Strong transient modulation of e-h density dramatically affects the superradiance mechanism in semiconductor media and is able to account for observations of superluminal pulse propagation and anomalous second harmonic generation.

10:15-10:35 Coffee Break

10:35-11:50 Session: Nano Lasers

Session Co-Chairs: **Yoshiaki Nakano** *(The Univ. of Tokyo)*
Peter P. Vasil'ev *(Univ. of Cambridge)*

10:35 WB1 – "Experimental and Theoretical Investigations on the Nature of Spontaneous Emission to Lasing Transition in Near-Unity Spontaneous Emission Factor Emitters"

Weng W. Chow[1], S. Kreinberg[2], C. Schneider[3], S. Höfling[3], M. Kamp[3], S. Reitzenstein[2]
[1]Sandia National Laboratories, USA, [2]Technische Universität Berlin, Germany, [3]Universität Würzburg, Germany

We investigated lasing in high-b emitters, when the customarily-used intensity jump and linewidth narrowing are no longer trustworthy. Spectrally-resolved photoluminscence and photon autocorrelation are measured from micropillars containing quantum dots and analyzed using cavity-QED. A physically intuitive lasing criterion applicable to all lasers is proposed.

10:50 WB2 – "Optical Antenna Enhanced Spontaneous Emission Rate in Electrically Injected Nanoscale III-V LED"

Seth A. Fortuna[1], Christopher Heidelberger[2], Kevin Messer[1], Kevin Han[1], Eugene A. Fitzgerald[2], Eli Yablonovitch[1], Ming C. Wu[1]
[1]Univ. of California, Berkeley, USA, [2]Massachusetts Institute of Technology, USA

We experimentally demonstrate greater than 100-fold enhancement of the spontaneous emission rate in an electrically injected nanoscale III-V light emitting diode coupled to a cavity-backed slot antenna.

11:05 WB3 – "Nonlinear Dynamics and Enhanced Modulation Response in Optically Injected AlGaInAs/InP Microdisk Laser"

Xiu-Wen Ma, Yong-Zhen Huang, Yue-De Yang, Jin-Long Xiao, Osamu Wada
Chinese Academy of Sciences, China

Nonlinear dynamics and high speed modulation of an optically injected microdisk laser are investigated experimentally. Small signal modulation bandwidth is increased from the free-running value of 14.4 GHz to about 38 GHz and 50 GHz under the optical injection locking and period-one oscillation states, respectively.

11:20 WB4 – "Nanoisland Bandedge Lasers"

Putu Eka Pramudita, Hoon Jang, Indra Karnadi, Yong-Hee Lee
KAIST, Republic of Korea

We propose and demonstrate nanoisland bandedge lasers. We employed selective quantum-well wet-etching technique to create nanoisland array in between InP claddings of a prefabricated photonic crystal structure. We observed reduction of laser threshold as we reduced the nanoisland's sizes by increasing the wet-etching time.

11:35 WB5 – "Sub-Wavelength Metallic Laser Coupled to Silicon-on-Insulator Waveguide with Integrated Optical Feedback Stub for Q Factor Enhancement"

Kaiyin Feng, Chuanqing Yu, Masaya Nishimoto, Richard James Edward Taylor, Takuo Tanemura, Yoshiaki Nakano
The Univ. of Tokyo, Japan

We propose a novel design of sub-wavelength metallic-cavity InP/InGaAs laser with unidirectional output on a silicon-on-insulator waveguide. By engineering the length/shape of the integrated optical feedback stub, formed on non-output end of the waveguide, we improve the overall Q factor while maintaining confinement factor.

11:50-12:50 Lunch (Lunch box is served)

12:50-15:00 Anniversary WS 3

Session Co-Chairs: **Yuichi Tohmori** *(Tsurugi Photonics Foundation)*
Kent Choquette *(Univ. of Illinois)*

13:00 AWS9 (Invited) – "Forty Years of ISLC: Laser Diode Materials, Growth, Structures, and Performance"

James J. Coleman
Univ. of Texas at Dallas, USA

For more than forty years, from the 4th IEEE International Semiconductor Laser Conference in Atlanta in 1974 to the 25th edition of the Laser Conference this year in Kobe, we have had the good fortune to participate in the flagship conference of what is now a major industry. We have attended many of the conferences and enjoyed visiting beautiful places all over the world. We have helped organize many of the conferences and made lifelong friends in the process. And we have presented our work including such topics as LPE visible InGaAsP lasers, laser arrays, strained layer lasers, and selectively grown buried heterostructure lasers. In this anniversary workshop, we'll describe a few of these technical topics and share some stories about the people in our profession and the places we have visited.

13:30 AWS10 (Invited) – "Laser Diode Quantum Efficiency Revisited"

Peter Blood
Cardiff Univ., UK

The quantum efficiency, in various manifestations, has been an important figure of merit and diagnostic tool in the study of laser diodes from their earliest days, and the subject of controversy. The radiative efficiency at threshold relates the intrinsic threshold current to the external current of a real device

but is very difficult to determine independently. The external differential quantum efficiency, from the slope of the light-current characteristic, influences the output of high power lasers and its dependence upon cavity length has been used as a means to measure the internal optical mode loss.
The evolution of approaches to the interpretation of measurements of the external differential efficiency and the relation between internal and external efficiencies will be reviewed and a consistent, present-day analysis presented. The topic is intimately related to the onset of stimulated emission and Fermi level pinning above threshold. This is of importance in quantum dot lasers and solution of rate equations for carriers on dot states coupled to the wetting layer by phonon interactions within a single mode laser model will be presented to illustrate the contributions to the external differential efficiency and the inaccuracies that can arise in the determination of optical mode loss.

14:00 AWS11 (Invited) – "Thirty-Five Years of Widely-Tunable Single-Chip Lasers: A Pathway to Active PICs"

Larry A. Coldren
Univ. of California, Santa Barbara, USA

Work on monolithic tunable diode lasers began in the late 1970's and some results were being reported by a couple of groups in the early 1980's. Both coupled-cavity designs that used Vernier tuning and tunable 2 and 3-section DBR lasers were explored. By the end of this decade these concepts were combined into a 4-section 'differing multi-element mirror laser,' which a bit later was realized as the sampled-grating DBR (SGDBR) laser capable of providing outputs over 40 nm near 1550 nm. This laser used the Vernier tuning concept with different periodically blanked DBRs to provide more than a half dozen bands of tuning, each 6-7 nm in width, characteristic of DBR lasers. As such lasers involved the integration of active and passive sections with partially transmissive mirrors, they naturally provided the building blocks for more complex photonic integrated circuits, such as ones that integrated lasers with SOAs, modulators and photodiodes.
During the 1990's, as WDM communications evolved, many other monolithic widely-tunable designs also emerged and evolved. Some were similar in concept to the SGDBR, some used arrays of DFB lasers with combiners or selectors, others used widely-tunable filters, such as integrated co-directional couplers, and still others used integrated MEMs mirrors on VCSELs. By the time of the 2000-era Tech-bubble, several became the basis of start-up companies. Today, the differing multi-element mirror concept remains one of the most popular for single-chip widely-tunable lasers.

14:30 AWS12 (Invited) – "Dynamic Single Mode Laser Saw the Light of Day"

Yasuharu Suematsu
Tokyo Institute of Technology, Japan

Dynamic Single Mode (DSM) lasers were specified by characteristic features of i) operating wavelength at the lowest loss band of silica fiber, namely 1.5μm, ii) stable single mode operation, and iii) tunable wavelength. First demonstration of thermos-tunable DSM laser at wave length of 1.5μm band was made in 1980. Presently, thermo-tunable DSM laser consisted with a single mode resonator of two distributed reflectors connected by spacing of odd number multiple of a quarter wavelength, so called as phase shift DFB laser, were commonly used for most of the long distance systems, after first demonstrated in 1983 and commercial use in 1992. This phase shift DFB laser was specific by high yield of production because of the fact that the single mode resonator, as proposed in 1974, could be built in during the photoresist stage of production.
Electro-tunable DSM laser, called as wavelength tunable laser was proposed in 1980 and demonstrated in 1983. The tunable wavelength range was significantly extended by use of distributed reflector with multiple grating pitches and commercialized in the early 2000's by those who involved.

15:00-15:20 Coffee Break

15:20-16:20 Session: High Power Lasers

Session Co-Chairs: **Noriyuki Yokouchi** *(Furukawa Electric Co., Ltd.)*
Manoj Kanskar *(nLIGHT, Inc.)*

15:20 WD1 – "Assessing the Impact of Thermal Barriers on the Thermal Lens Shape in High Power Broad Area Diode Lasers"

J. Rieprich[1], Martin Winterfeldt[1], Jens Tomm[2], Paul Crump[1]
[1]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Germany, [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Germany

Measured thermal profiles on GaAs broad area diode lasers (Popt > 10 W, λ = 910 nm) were reproduced in FEM simulation, indicating an unforeseen thermal barrier between laser chip and metallization. An investigation of that barrier potentially yields design- and packaging improvements for increased radiance, since thermal lensing strongly determines in-plane beam quality.

15:35 WD2 – "Watt-Class 1550 nm Tapered Lasers with 45% Wallplug Efficiency for Free-Space Optical Communication"

Paul O. Leisher[1], Jeremy Thomas[2], Jenna Campbell[2], Isabella Gonzalez[2], Daniel Renner[2], Leif Johansson[2], Milan Mashanovitch[2]
[1]Rose-Hulman Institute of Technology, USA, [2]Freedom Photonics, LLC, USA

We report on the development of tapered diode lasers based on the InGaAsP material system and operating around 1550 nm for free-space optical communication. By combining a high efficiency epitaxial design with an innovative tapered amplifiers, a record 45% power wallplug efficiency is achieved with a maximum output >1 watt.

15:50 WD3 – "1180nm DBR-Ridge Waveguide Lasers with Strain Compensation Layers in the Active Region for Lifetime Improvement"

Katrin Paschke, Gunnar Blume, Arnim Ginolas, Julian Hofmann, David Feise, Wilfred John, Nils Werner, Frank Bugge
Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Germany

DBR ridge waveguide lasers at 1180nm were developed based on strained InGaAs quantum wells. The lasers feature a lifetime of more than 1000h at 100mW and are believed to be a key component for miniaturized SHG laser modules emitting in the yellow spectral range.

16:05 WD4 – "Studies of Limitations to Peak Power and Efficiency in Diode Lasers Using Extreme-Double-Asymmetric Vertical Designs"

Thorben Kaul, Götz Erbert, René Platz, Andre Maaßdorf, Steffen Knigge, Paul Crump
Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Germany

High power diode lasers with extreme-double-asymmetric epitaxial designs with increased confinement in the well Γ achieve high efficiency (50%) and powers (14W) at high heatsink temperature (75°C), attributed to the suppression of power saturation mechanisms. Prospects for increased performance via further increased Γ are analyzed.

All talks will be held in the Ginga room

16:20-18:20 Poster Session & Coffee Break

1. Mid Infrared Lasers

WE2 – "Molecular Beam Epitaxial Growth of 3µm Mid-Wave Infrared Laser Using InGaAsSb/AlInAsSb Quantum Well Structure"

Chunte Lu, Ron Kaspi, Tim Newell, Chi Yang, Sanh Luong, Don Gianardi
Air Force Research Laboratory, USA

We report experimental results of growth and characterization of InGaAsSb/AlInAsSb quantum well laser structure. The epitaxial structure was grown using molecular beam epitaxy system on GaSb substrate and characterized using a 2µm pump source. We observed 3.1µm laser emission at 200K and 2.98µm laser emission near 100K.

2. Silicon Photonics

WE3 – "Instability of Silicon Photonic Wavelength Tunable Laser Diodes due to the Nonlinear Optical Effect of Silicon"

Tomohiro Kita, Hirohito Yamada
Tohoku Univ., Japan

The silicon photonic wavelength tunable laser diode is a good candidate for the integrated light source. However, optical nonlinear effects easily occur due to the strong light confinement of Si photonic wire waveguides. The impact on laser operation caused by nonlinearity was discussed.

WE4 – "Hybrid Microlasers with Stable Unidirectional Emission from a Silicon Waveguide"

Shao-Shuai Sui, Yong-Zhen Huang, Ming-Ying Tang, Hai-Zhong Weng, Yue-De Yang, Jin-Long Xiao
Chinese Academy of Sciences, China

Hybrid microlasers are fabricated using wafer bonding technique. Microring laser has random competition between the travelling modes, in contrast, spiral-ring and locally deformed ring microlasers, respectively, maintain one major direction and totally unidirectional stable emission from a silicon waveguide.

3. VCSELs

WE5 – "Vertical Cavity Surface Emitting Lasers with Precise Multi-Wavelength Control"

Ryoichiro Suzuki, Hiroshi Motomura, Shunichi Satoh
RICOH Company, Ltd., Japan

We fabricated multi-wavelength VCSELs with semiconductor wavelength tuning layer (WTL) by employing a selective wet etching for varying WTL thickness. It is presented that, by inserting DBR pairs between WTL and cavity, WTL thickness can be increased to some feasible extent in typical epitaxial growth.

WE6 – "Polarization Switching and Injection Locking in 1550nm VCSELs Subject to Parallel Optical Injection"

Ana Quirce[1], Pablo Perez[2], Alexandra Popp[2], Florian Denis-le Coarer[3], Angel Valle[2], Luis Pesquera[2], Yanhua Hong[4], Hugo Thienpont[1], Krassimir Panajotov[1], Marc Sciamanna[3]
[1]Vrije Universiteit Brussel, Belgium, [2]Instituto de Fisica de Cantabria (CSIC-UC), Spain, [3]CentraleSupélec and Univ. of Lorraine, France, [4]Bangor Univ., UK

Polarization switching in a long-wavelength VCSEL under parallel optical injection is analyzed in a theoretical and experimental way. We report a novel state in which injection locking of the parallel polarization and excitation of the free-running orthogonal polarization of the VCSEL are simultaneously obtained.

WE7 – "External Mirror with Steep Reflection Phase Spectrum by Guided-Mode Resonance for Short-Cavity VECSEL"

Katsuaki Yamada[1], Kosuke Asai[1], Yeong Hwan Ko[2], Kenji Kintaka[3], Kyu Jin Lee[2], Junichi Inoue[1], Shogo Ura[1], Robert Magnusson[2]
[1]Kyoto Institute of Technology, Japan, [2]Univ. of Texas at Arlington, USA, [3]National Institute of Advanced Industrial Science and Technology, Japan

A guided-mode resonance filter on a high reflectance substrate was studied to be an external mirror of short-cavity vertical-external-cavity surface-emitting laser. Feasibility of high reflectance with steep reflection phase spectrum is one of key issues and was demonstrated for the first time.

WE8 – "Design of High Speed (> 30 GHz) 850 nm Vertical-Cavity Surface-Emitting Lasers by Efficient Theoretical Simulation Method"

Dan-Hua Hsieh[1], Michael Liu[2], Chao-Hsin Wu[3], Jian-Jang Huang[3], Gong-Ru Lin[3], Tien-Tsorng Shih[4], Wood-Hi Cheng[5], Milton Feng[2], Hao-Chung Kuo[1]
[1]National Chiao Tung Univ., Taiwan, [2]Univ. of Illinois, USA, [3]National Taiwan Univ., Taiwan, [4]National Kaohsiung Univ. of Applied Sciences, Taiwan, [5]National Chung Hsing Univ., Taiwan

Comprehensive numerical simulation is conducted for design of high speed 850 nm VCSEL, the effects of strained InGaAs/AlGaAs MQW along with multi-oxide layers are investigated. The simulated results show great agreement with the experimental performance, and the highest 3dB bandwidth of 30 GHz is achieved.

WE9 – "Temperature Characteristics of Photo Detector Integrated Transverse-Coupled-Cavity VCSELs"

Naoki Jogan[1], Junichiro Hayakawa[1], Takashi Kondo[1], Akemi Murakami[1], Jun Sakurai[1], Xiaodong Gu[2], Fumio Koyama[2]
[1]Fuji Xerox Co., Ltd., Japan, [2]Tokyo Institute of Technology, Japan

We demonstrate an ultra-compact photo-detector integrated VCSEL with laterally coupled two cavities. Output power and photo current show a similar tendency under wide temperature changes. The device could be used for monitoring the output power without a conventional photo detector mounted separately.

WE10 – "Optical Modulation of Lateral-Feeding-Designed Vertical Cavity Transistor Lasers"

Cheng-Han Wu, Yun-Hsuan Chang, Chao-Hsin Wu
National Taiwan Univ., Taiwan

We demonstrate the dual-output characteristics of the vertical cavity transistor laser with an electrical output and an optical output at 80K. Above the threshold current, the lasing wavelength is 971.7nm. The optical modulation bandwidth of 2.7 and 5GHz are obtained for current and voltage modulation.

WE11 – "Wafer fused Long-Wavelength VCSELs for Analog Photonics Applications"

Mikhail E. Belkin[1], Vladimir Iakovlev[2]
[1]Moscow State Technological Univ. (MIREA), Russia, [2]RTI Research S.A., Switzerland

The comparison of spectral, noise and linear characteristics of long wavelength (LW) wafer fused (WF) vertical surface emitting lasers (VCSEL) and short wavelength VCSELs indicates clear advantages of LW WF VCSEL for further progress in information and communication industry technology, in particular for analog applications.

WE12 – "Aspects of Direct Modulation of VCSELs"

Stewart Fryslie, Andrew Netherton, Nicholas DeNardo, Harshil Dave, Katherine Lakomy, Kent Choquette
Univ. of Illinois, USA

We compare the small signal response of 850nm oxide-confined and photonic crystal VCSELs, and show that a high bias current to threshold current ratio does not predict high bandwidth in photonic crystal VCSELs. Issued associated with increasing propagation distance for increased bandwidth-distance product are discussed.

4. High Power Lasers

WE13 – "Jet Impingement Cooling for Reliable High Efficiency Operation of 980 nm Diode Pumps at Elevated Temperatures"

Jenna Campbell[1], Paul Leisher[2], Tadej Semenic[3], Avijit Bhunia[3], Milan Mashanovitch[1], Daniel Renner[1]
[1]Freedom Photonics, LLC, USA, [2]Rose-Hulman Institute of Technology, USA, [3]Teledyne Scientific Co., USA

We report on the development of 980nm diode lasers operating with high efficiency and which show little change in performance as the liquid coolant temperature increases from 20 to 50 °C. These results are enabled by the application of a novel jet impingement cooling approach.

WE14 – "High Power Semiconductor Laser Arrays at 1120 nm"

Alexander Albrecht Reinhold[1], Marc Fischer[1], Wolfgang Zeller[1], Johannes Koeth[1], Martin Kamp[2]
[1]nanoplus Nanosystems and Technologies GmbH, Germany, [2]Universität Würzburg, Germany

Semiconductor laser arrays with a distinct number of ridge waveguides within a parallel geometry have been fabricated. Evanescently coupled supermodes with out-of-phase and in-phase characteristics are revealed by respective multi- and single-lobed farfield emission. Output powers of P=400 mW have been measured at T=10 °C.

WE15 – "Internal Optical Loss in GaAs- and InP- Based Semiconductor Lasers"

Nikita A. Pikhtin, Dmitry A. Veselov, Zinaida N. Sokolova, Sergey O. Slipchenko, Ilya S. Tarasov
Ioffe Institute, Russia

High power semiconductor lasers developed in Ioffe Institute on the base of MOCVD-grown asymmetric separate confinement double heterostructures with broadened waveguide will be discussed. Investigation results of internal optical loss and output characteristics of devices emitting in 800-1100nm and 1300-1600nm wavelength ranges will be presented.

WE16 – "Flared Oscillator Waveguide Diodes (FLOW-Diodes) Enable High Brightness Fiber-coupled Modules"

Manoj Kanskar, Ling Bao, Zhigang Chen, Dave Dawson, Marty Hemmenway
nLIGHT, Inc., USA

Broad-area lasers having narrower rear-facet width compared to front-facet have been fabricated to achieve suppression of higher order mode in the lateral direction. Consequently, slow-axis-divergence has been reduced by over two-times at current density >3kA/cm^2 making possible fiber-coupled power >200 W from 105µm -and-0.15NA beam.

WE17 – "80-GHz 1.55 mum Colliding-Pulse Mode-Locked Laser with High Pulse Power"

Pengchao Zhao, Anjin Liu, W. Zheng
Chinese Academy of Sciences, China

We demonstrate an AlGaInAs/InP 1.55 µm 80 GHz colliding-pulse mode-locked laser. The device generates pulses of 1.75 ps, with pulse energy of 0.33 pJ, and a time-bandwidth product of 0.51. With a long saturable absorber, we achieve two-fold improvement in pulse energy and peak power.

WE18 – "Dynamic Characterization of Output Power Fluctuations in FBG Stabilized 14xx-nm GaInAsP/InP Laser Modules"

Takuya Kokawa, Junji Yoshida, Noriyuki Yokouchi
Furukawa Electric Co., Ltd., Japan

Output power stability of 14xx-nm GaInAsP/InP laser module with fiber Bragg gratings (FBGs) was dynamically evaluated. Power fluctuations accompanied by wavelength jumps to gain peak were observed by single-FBG configuration. By contrast, double-FBGs configuration having same coherent reflectivity as the single-FBG showed stable output power.

5. High Speed Lasers

WE19 – "Enhanced Dynamic Response and Spectral Characteristics Improvement of Optically-Injected Widely-Tunable Laser Diodes"

Onur Duzgol, Georgios Kyritsis, Nick Zakhleniuk
Univ. of Essex, UK

Using travelling-wave model we demonstrate strong interplay between tuning and modulation performance of widely-tunable laser diodes (TLDs). Small- and large-signal dynamics of a free-running and optically-injection-locked TLD is investigated. Large TLD modulation speed enhancement and spectral characteristics improvement are obtained.

WE21 – "Highly Residual Facet Reflection Immune Electro-absorption Modulated Laser with Short Partially Corrugated Gratings"

Puspa Devi Pukhrambam, San-Liang Lee
National Taiwan Univ. of Science and Technology, Taiwan

EMLs with short partial-corrugated-grating (PCG) DFB section are designed to have good single-mode yield and immune to residual facet reflection. With 150µm long PCG of 200µm laser section, the EML can have >60% single-mode yield and maintain excellent signal quality even with 10-2 residual reflection.

WE22 – "The Analysis of Cost Effective TO-CAN Packaged 25.78 Gb/s Directly Modulated Laser"

Mizuki Shirao, Seiki Nakamura, Masaaki Shimada, Masamichi Nogami
Mitsubishi Electric Corporation, Japan

We report both numerical and experimental analysis of TO-CAN packaged 25.78Gb/s DML. Developed TO-CAN packaged 25.78Gb/s DML is successfully operated with excellent mask-margin of better than 26% against 100GBASE-LR4 mask over temperature for the first time. The TO-CAN packaged DML has ability for cost sensitive applications.

WE23 – "Tailoring of Semiconductor Laser's Frequency Response by Hybrid Modulation Scheme"

Shigeru Mieda[1], Ryuto Isshiki[1], Nobuhide Yokota[1], Wataru Kobayashi[2], Hiroshi Yasaka[1]
[1]Tohoku Univ., Japan, [2]NTT Corporation, Japan

Frequency response control of semiconductor lasers is achieved by introducing a hybrid modulation scheme. A flat response with low modulation sensitivity degradation at a high-frequency region is achieved by optimizing modulation ratio and time delay between direct current modulation and intra-cavity loss modulation signals.

WE24 – "90 Gb/s Hybrid Integrated Photoreceiver Module with High Speed 1.5 µm-Band QD-SOA"

Atsushi Matsumoto[1], Toshimasa Umezawa[1], Kouichi Akahane[1], Atsushi Kanno[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[2]
[1]National Institute of Information and Communications Technology, Japan, [2]Waseda Univ., Japan

We investigated characteristics of hybrid integrated photoreceiver with 1.5 µm-band quantum dot semiconductor optical amplifier (QD-SOA) and conventional pin-photodiode (pin-PD) as a first stage. The results indicated the photoreceiver integrated with QD-SOA and QD-PD has the potential to be operated for signals over 100 Gb/s.

6. Waveguides & Resonators

WE25 – "Rate-Equation Analysis for an Integrated Coupled-Cavity Laser with Multi-Mode Interference Anti-Phase Coupler"

Daan Lenstra
Eindhoven Univ. of Technology, The Netherlands

A rate-equation theory is derived for a laser consisting of two Fabry-Pérot cavities coupled via self-imaging in a multi-mode interference reflector. Stable single-mode anti-phase operation is demonstrated and locking ranges are calculated. The shapes of output-intensity curves agree well with measured curves.

WE26 – "Dual Output Tunable Laser Diode for Simultaneous Optical Transmission and Detection"

Mitsunobu Gotoda, Masakazu Takabayashi, Yuichiro Horiguchi, Keisuke Matsumoto, Eitaro Ishimura
Mitsubishi Electric Corporation, Japan

We demonstrate a novel tunable distributed feedback laser diode (DFB-LD) array with dual output of 13 dBm and 10 dBm, which can be used as full L-band light source for an optical transmitter and a local oscillator simultaneously in a coherent optical communication system.

WE27 – "Coupling Efficiency Improvement between Thickness-Tapered SSC-FP-LD and Horizontally Tapered SSC Si Waveguide"

Koji Nakamura, Yoshiaki Morino, Satoshi Miyamura, Daisuke Shimura, Hiroyuki Takahashi, Yosuke Onawa, Hiroki Yaegashi, Hironori Sasaki
Oki Electric Industry Co., Ltd., Japan

We developed a Fabry-Perot-laser (FP-LD) with a Spot-Size-Converter (SSC) and experimentally evaluated the coupling-efficiency between the SSC-FP-LD and a Si-waveguide with a horizontally tapered SSC. Although the addition of SSC structure in FP-LD led to the absorption loss of 0.92dB, overall coupling-efficiency was improved by 1.15dB.

WE29 – "Square Microcavity Lasers Exhibiting Dual-Transverse-Mode Lasing with Controllable Wavelength Interval"

Yue-De Yang[1], Hai-Zhong Weng[1], Jin-Long Xiao[1], Osamu Wada[2], Yong-Zhen Huang[1]
[1]Chinese Academy of Sciences, China, [2]Kobe Univ., Japan

Square microcavity lasers enabling stable, controllable dual-transverse-mode operation are demonstrated. A square microlaser with 30µm side-length showed the wavelength interval of 0.25-0.39

nm. By decreasing the cavity size to 16µm and replacing flat sidewalls with circular arcs, the wavelength interval range extended up to 7.6nm.

WE30 – "Lateral Mode Interference Observation in Emission Spectrum on Mode Selective active-Multimode Interferometer Laser Diode"

Bingzhou Hong, Takuya Kitano, Haisong Jiang , Kiichi Hamamoto
Kyushu Univ., Japan

We newly showed lateral mode interference in the emission spectrum between 0th and 1st order modes on mode selective active multi-mode-interference laser diode that leads to single wavelength emission (SMSR=25 dB).

WE31 – "Does the Reciprocity Principle Imply the Lifetimes of Counterpropagating Modes in Whistle-Geometry Ring Lasers Should Be Equal?"

Hemashilpa Kalagara, Gennady A Smolyakov, Marek Osinski
Univ. of New Mexico, USA

A key feature of whistle-geometry semiconductor ring lasers is the asymmetry between counterpropagating modes, which might be misconstrued as a violation of the Helmholtz reciprocity principle and the time-reversal symmetry of Maxwell's equations. We confirm unidirectionality of whistle-geometry configuration through rigorous three-dimensional finite-difference time-domain simulation.

WE32 – "Enhanced Coupling Strength Grating Out-Couplers in III-V Waveguides"

Gary A. Evans[1], Jerome Butler[1], Rue-Hua He[1], Jay Kirk[1], Jin Yao[2], Xuezhe Zheng[2], Ashok Krishnamoorthy[2]
[1]Southern Methodist Univ., USA, [2]Oracle, USA

A low-index liner layer and a high-index cover layer over a surface grating in a III-V waveguide increases the outcoupling efficiency by an orders of magnitude. The liner and cover layer reduces losses between waveguide components such as distributed feedback (DBR) or grating out-coupler region.

WE33 – "Rate Equation Analysis of Strongly Injection-Locked Cascaded Semiconductor Ring Lasers with Modulated Master Laser"

Fei-Hung Chu, Gennady A. Smolyakov, Marek Osinski
Univ. of New Mexico, USA

A novel method for modulation bandwidth enhancement is presented, involving strongly injection-locked cascaded whistle-geometry semiconductor ring lasers. Advantages of direct modulation of the master laser are revealed through numerical modeling.

7. Single Mode Lasers

WE34 – "Power and Wavelength Tuning Performance of Multi-Quantum-Well and Bulk Tunable Laser Diodes and Main Limiting Factors"

Georgios Kyritsis, Onur Duzgol, Nick Zakhleniuk
Univ. of Essex, UK

Performance of multi-quantum-well and bulk tunable laser diodes are investigated. It is shown that the relaxation broadening in laser active section and the intervalence band absorption in passive sections are the major limiting factors that define the output power and the achievable wavelength tuning range.

WE35 – "A Tunable Dual-Mode Operation with Three-Section Distributed Bragg Reflector Lasers"

Cheng Li[1], Hang Zhao[1], Yao Zhu[1], Yu Han[2], Yonglin Yu[1]
[1]Huazhong Univ. of Science and Technology, China, [2]Wuhan Huagong Genuine Optics Tech Co., Ltd (HG Genuine), China

A tunable dual-mode operation with three-section distributed Bragg reflector (DBR) laser is proposed for compact and low-cost microwave generation. Stable dual-mode operation with 7 nm tuning range is demonstrated.

WE36 – "The Microwave Signal Linewidth in a Monolithically Integrated Two-Section DFB Laser under Controllable Feedback"

Yao-Zhong Dong, Fu-Chun Hsiao, Yi-Chia Huang, Chien-Chung Lin
National Chiao Tung Univ., Taiwan

A controllable optical feedback system was set up to investigate the linewidth of the RF signals generated by a two-section DFB laser. A very narrow line (its width less than 100 kHz) can be detected when both sections are under the influence of optical feedback.

WE37 – "Suppression of Relative Intensity Noise in Mutually Injection Locked DFB Laser Diodes"

Bing Xiong, Xu Ke, Yi Luo, Changzheng Sun, Jian Wang, Zhibiao Hao, Yanjun Han, Lai Wang, Hongtao Li
Tsinghua Univ., China

Relative intensity noise (RIN) characteristics of mutually injection locked distributed feedback (DFB) laser diodes is investigated. RIN around the relaxation oscillation frequency in both lasers is found to be simultaneously suppressed in the mutual locking status.

WE38 – "Sub-millisecond Wavelength Switching of Tunable DFB Laser Array (TLA) with Injection Current Control"

Kenta Yamaguchi, Yudai Tatsumoto, Ryoga Kimura, Takeshi Kuboki, Kazutoshi Kato
Kyushu Univ., Japan

For the purpose of sub-millisecond wavelength switching, the feedforward-current control technique was applied to the DFB laser. At the switching from 191.2 THz to 191.0 THz, our designed controller successfully reduced the wavelength switching time of the tunable DFB laser array down to 800 μs.

WE39 – "Electrically Pumped Quantum Dot Surface Emitting Lasers with Bragg Grating Capped by ITO Cladding Layers"

Kuo-Bin Hong, Ting-Yuan Chang, Chien-Hung Pan, Chien-Hung Lin, Gray Lin, Chien-Ping Lee, Tien-Chang Lu
National Chiao Tung Univ., Taiwan

QD based Bragg gratings surface emitting lasers using ITO as transparent cladding layers were demonstrated. Measured lasing peak locates at 1298nm and threshold current density of 210 A/cm^2. The laser shows extremely small divergence surface-emitted beam and thermal redshift of 0.08 nm/K in peak wavelength.

WE40 – "Optimization of Power Spectral Density and Polarization Compensation for Coherence-Selectable ECDL"

Masaharu Hyodo[1], Akira Kawakami[2], Shingo Saito[2], Masayoshi Watanabe[3], Takahiro Kubo[4], Masaaki Adachi[4]
[1]Kanazawa Univ., Japan, [2]National Institute of Information and Communications Technology, Japan, [3]The Univ. of Electro-Communications, Japan, [4]Kanazawa Univ., Japan

Optical power-spectral density of an ECDL under coherence-selectable operation was optimized. The laser had an intracavity half-wave plate that rotates the polarization with regard to the grating for achieving the operation. It was also shown that the resultant variation in polarization can be readily

compensated.

WE41 – "GaAsP Quantum Well Tunable Single-Mode Laser with Periodically Slotted Structure"

Masahiro Uemukai, Takashi Furusawa
Osaka Univ., Japan

Tunable single-mode lasers with slotted structure were fabricated by simple process without high-resolution lithography and regrowth. By changing injection currents to the active and slotted channels discretely, wavelength tuning range of 2.6 nm was achieved with side-mode suppression ratio higher than 25 dB.

8. Quantum Dot Lasers

WE43 – "Strain Balancing of MOVPE InAs/GaAs Quantum Dots Using GaAs0.8P0.2"

Timothy Stephen Roberts[1], Benjamin Stevens[1], Edmund Clarke[1], Ian Tooley[1], Jonathan Orchard[1], Ian Farrer[1], David Childs[2], Nasser Babazadeh[2], Nobuhiko Ozaki[3], David Mowbray[1], Richard Hogg[2]
[1]The Univ. of Sheffield, UK, [2]Univ. of Glasgow, UK, [3]Wakayama Univ., Japan

MOVPE growth of stacked InAs/GaAs QDs with and without GaAs0.8P0.2 strain balancing layers has been studied. The GaAsP layers reduce the accumulated strain whilst maintaining the electrical characteristics. This should enable closer stacking of QD layers leading to higher gain and improved laser performance.

WE45 – "Dominant Role of Many-Body Effects on the Carrier Distribution Function of Quantum Dot Lasers"

Negin Peyvast[1], Kejia Zhou[1], Richard Hogg[2], David Childs[2]
[1]The Univ. of Sheffield, UK, [2]The Univ. of Glasgow, UK

The effects of quantum dot (QD) ensemble inhomogeneity, free-carrier-induced energy shift and homogeneous broadening on the carrier distribution function are studied. We show that the dominant factors determining the carrier distribution function are the free carrier effects and not the choice of carrier statistics.

WE46 – "High Characteristic Temperature for Ridge-waveguide Laser with a Highly Stacked InAs Quantum Dot Structure"

Kouichi Akahane[1], Atsushi Matsumoto[1], Toshimasa Umezawa[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[2]
[1]National Institute of Information and Communications Technology, Japan, [2]Waseda Univ., Japan

A ridge-waveguide laser with highly stacked InAs QDs based on strain compensation technique was fabricated. The threshold current of this laser was decreased to approximately 75 mA without coating the facet mirror. A high characteristic temperature of over 100 K was obtained in this laser.

9. Photonic Crystals & Nanolasers

WE48 – "Two-State-Lasing in InAs/InGaAsP/InP Quantum Dot Microcylinder Lasers"

Jin-Long Xiao[1], Zhi-Xiong Xiao[1], Yue-De Yang[1], Shuai Luo[1], Hai-Ming Ji[1], Tao Yang[1], Osamu Wada[2], Yong-Zhen Huang[1]
[1]Chinese Academy of Sciences, China, [2]Chinese Academy of Sciences and CREATE, Kobe Univ., China

InAs/InGaAsP/InP quantum dot microcylinder lasers connected with an output waveguide have been designed and fabricated. Stable, single mode lasing at two remote wavelengths corresponding to the

ground and excited states of quantum dots has been demonstrated.

WE49 – "High-Operation-Temperature Aluminum-Based SPP Nanolasers"

Yu Hsun Chou[1], Kuo-Bin Hong[1], Bo-Tsun Chou[1], Yen-Mo Wu[1], Jheng-Hong Shih[2], Yi-Cheng Chung[2], Peng-Yu Chen[1], Tzy-Rong Lin[2], Sheng-Di Lin[1], Tien-Chang Lu[1]
[1]National Chiao Tung Univ., Taiwan, [2]National Taiwan Ocean Univ., Taiwan

Metal-insulator-semiconductor structures has widely adopted in plasmonics lasers. However, we found that the insulator is not necessary if permittivity combination of laser structures is properly designed. Single-mode laser operation was demonstrate in devices without artificial insulator layers. Moreover, the operation temperature can achieve 353 K.

WE50 – "Photonic Crystal Laser with Low-Quality Factor"

Yifan Xiong, Xiuyu Zhang, Elbert He, Ryo Tezuka, Takafumi Hino, Satoshi Kasamatsu, Masato Morifuji, Hirotake Kajii, Masahiko Kondow
Osaka Univ., Japan

To investigate the optimum Quality factor for the photonic crystal laser, we fabricated and evaluated a photonic crystal laser with low Quality factor around 1000. Lasing linewidth is almost constant at 2.3 nm above the threshold. So, the laser is not a coherent light source.

WE51 – "Purcell Effect in the Gain and Spontaneous Emission of Nanolasers"

Bruno Romeira, Andrea Fiore
Eindhoven Univ. of Technology, The Netherlands

The Purcell effect strongly affects the emission in laser nanocavities. We investigate its role in the gain and spontaneous emission rate of nanopillar lasers over a wide range of cavity dimensions and emitter/cavity relative linewidths enabling the modeling of either nano-, meso- or macro-scale lasers.

WE52 – "High Power and Low Divergence Tapered Lasers with Photonic Crystal Structure"

Xiaolong Ma, Yun Liu, Pengchao Zhao, Wanhua Zheng
Chinese Academy of Sciences, China

We demonstrate 980 nm tapered lasers with photonic crystal structure. The device delivers 3 W output power under continuous wave operation and exhibits narrow vertical divergence below 16° and lateral divergence below 4° at different currents. High beam quality is also achieved.

WE53 – "Optical Characteristics of GaAs-Based High Index Contrast Photonic Crystal Lasers with Deeply-Etched Air Holes"

Kuo-Bin Hong, Chun-Chieh Yang, Tien-Chang Lu
National Chiao Tung Univ., Taiwan

We study the mode switching behavior of GaAs high index contrast photonic crystal lasers influenced by deeply-etched air holes. Higher order guiding waves could coherently couple out of photonic crystal and affect the laser output characteristics when the air filling factor increased.

WE54 – "High Efficiency Single Transverse Mode Photonic Band Crystal Lasers with High Beam Quality"

Shaoyu Zhao, Hongwei Qu, Yun Liu, Anjin Liu
Chinese Academy of Sciences, China

980nm ridge waveguide lasers based on photonic band crystal concept are designed and fabricated. The maximum power conversion efficiency is 50%. The single transverse mode output power is 430mW at 500mA with a very low vertical divergence of 11.1°.

WE55 – "Simultaneous Lasing of Exciton and Polariton in a ZnO Microcavity"

Yu Hsun Chou, Ying-Yu Lai, Tien-Chang Lu, Shing-Chung Wang
National Chiao Tung Univ., Taiwan

We have performed the condition to simultaneously triggered exciton-related polariton lasing and P-line exciton lasing in a ZnO micorcavity and verified the characteristics of their lasing behaviors. In addition, the threshold energy, linewidth, phase diagram, and angular dispersion are verified and discussed.

10. Nitride & Visible Lasers

WE56 – "Anomalous Second Harmonic Generation During Femtosecond Superradiant Emission from GaAs/AlGaAs Laser Structures"

Peter P Vasil'ev[1], Hirokazu Ohta[2], Hirofumi Kan[2], Richard V Penty[1], Ian H White[1]
[1]Univ. of Cambridge, UK, [2]Hamamatsu Photonics K.K., Japan

Anomalously strong blue SHG emission has been observed from GaAs/AlGaAs heterostructures during the generation of femtosecond superradiant pulses. The conversion efficiency is an order of magnitude greater than during standard lasing. The effect is attributed to the periodic e-h modulation and strong transient population gratings.

WE57 – "Influence of Barrier Structure on Polarization Effect in Near Ultraviolet Light-Emitting Diodes"

Yen-Kuang Kuo[1], Fang-Ming Chen[1], Jih-Yuan Chang[1], Bo-Ting Liou[2]
[1]National Changhua Univ. of Education, Taiwan, [2]Hsiuping Univ. of Science and Technology, Taiwan

Specific design of barrier in the AlGaN-based near ultraviolet light-emitting diodes is investigated numerically. Simulation results reveal that NUV LEDs with the proposed p-type/n-type barrier can reduce the polarization-induced electrostatic field, and thus enhance the spatial overlap of electron and hole wavefunctions in the wells.

WE58 – "Room-Temperature Lasing of GaN-InGaN Core-Shell Lasers in High-Order Whisper Gallery Modes"

Chia-Yen Huang, Jing-Jie Lin, Che-Yu Liu, Kuo-Bin Hong, Tsu-Chi Chang, Yu-Hao Hsiao, Tien-Chang Lu, Hao-Chung Kuo
National Chiao Tung Univ., Taiwan

Hexagon-shaped GaN-InGaN core-shell nanorods were fabricated and mechanically transferred to a SiO2 film. Lasing peaks around 368nm were observed under room-temperature under optical pumping, with a threshold pumping density 5.1 MW/cm^2. According to the cavity geometry and optical simulations, high-order whisper gallery modes were suggested.

WE59 – "Analysis and Optimization of InGaN Laser Diode with Landscape Model"

Yen-Chang Chen, Te-Jen Kung, Yuh-Renn Wu
National Taiwan Univ., Taiwan

We applied optical and electric model coupled with landscape theory to analyze InGaN LD and is matched well to the reference LD. Next, we find the key factor and made further optimization of the reference structure including different QW numbers and quantum barriers.

WE60 – "Alloy-Compositional-Fluctuation Effects on Optical Gain Characteristics in AlGaN and InGaN Quantum-Well Laser Diodes"

Atsushi A Yamaguchi[1], Takuto Minami[1], Shigeta Sakai[1], Kazunobu Kojima[2], Shigefusa F Chichibu[2]
[1]Kanazawa Institute of Technology, Japan, [2]Tohoku Univ., Japan

Optical gain characteristics have been calculated in AlGaN and InGaN quantum-well structures

considering the effects of alloy compositional fluctuation in the active layers. It is found that the difference in gain characteristics between AlGaN and InGaN lasers becomes small with increasing the degree of fluctuation.

WE61 – "The Optical Properties of GaN Microdisk on Graphene"

Hao Cyuan Jhang[1], Shyh Jer Huang[1], Jian Ting Lai[1], Cheng Wei Chou[1], Yan Kuin Su[1], Tien Chang Lu[2], Kuo Bin Hong[2], Yu Hsun Chou[2], Jian Long Ruan[3]
[1]Advanced Optoelectronic Technology Center, Taiwan, [2]National Chiao Tung Univ., Taiwan, [3]National Chung Shan Institute of Science and Technology, Taiwan

High quality GaN microdisks were obtained by metal organic chemical vapor deposition (MOCVD) growth technique on the SiO2/ Si substrate with graphene bufferlayer. The diameters are about 3 um to 10 um for the GaN grains. Finally, it is lasing from the GaN microdisk.

WE62 – "Blue Laser Diode-Based White-light Communication System with Pulse Sprayed Phosphor Conversion Film"

Dan-Hua Hsieh[1], Yi-Rou Chen[1], Tsai-Chen Wu[2], Yu-Chieh Chi[2], Gong-Ru Lin[2], Hao-Chung Kuo[1]
[1]National Chiao Tung Univ., Taiwan, [2]National Taiwan Univ., Taiwan

The effect of pulse sprayed phosphor concentration on laser diode based white-light communication with orthogonal frequency division multiplexing data format is investigated, which achieves a correlated color temperature of 5000K and a data rate of 1.2Gb/s.

WE63 – "Gallium Nitride Super-Luminescent Light Emitting Diodes for Optical Coherence Tomography Applications"

Graham R Goldberg[1], Pavlo Ivanov[1], Nobuhiko Ozaki[2], David Childs[1], Kristian Groom[3], Kenneth Kennedy[3], Richard Hogg[1]
[1]Univ. of Glasgow, UK, [2]Wakayama Univ., Japan, [3]The Univ. of Sheffield, UK

The role of biasing of absorber sections in multi-contact GaN ~400nm SLEDs is discussed. We go on to assess such devices for OCT applications. Analysis of the SLED emission spectrum allows an axial resolution of 6.0μm to be deduced in OCT applications.

18:20-19:20 Break

19:20- Banquet (Zuiten (West) room)