EPIC Members Event Report
IEEE Photonics Conference 2012

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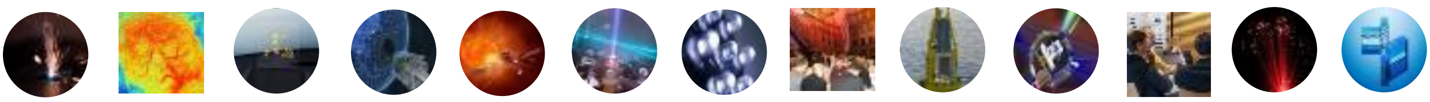
Vertically Integrated Systems

About the EPIC Members Event Reports

Initiated by the founder of EPIC Dr. Thomas Pearsall in 2003, these reports are prepared by members of EPIC to the benefit of the wider community. If you did not have a chance to attend the event but would like to know some key highlight, this report is for you. Emphasis is placed on exploring technical and business opportunities for the members of EPIC. If you are an event organizer and would like your event covered by EPIC, if you would like to volunteer for writing a report, or if you have any comments to this report, please contact info@epic-assoc.com



IEEE Photonics Conference 2012

This report briefly addresses several subjects and talks which are in the general frame of interests of the attendee. Essentially there was a continuous overlap between the subjects:

• **VCSELs**, including photonic crystal and subwavelength grating VCSELs, tunable VCSELs.

• **Quantum Dots**: quantum dot lasers and amplifiers, single quantum dot emitters, GaN-based devices, lasers on silicon, else.

• **Basic Physics**: Fundamentals of solar cells, metamaterials, subwavelength gratings, etc.

The report addresses some of these topics. There are some presentations which are addressed in more details. There is a listing of selected talks the attendee found interesting.

Plenary Talks

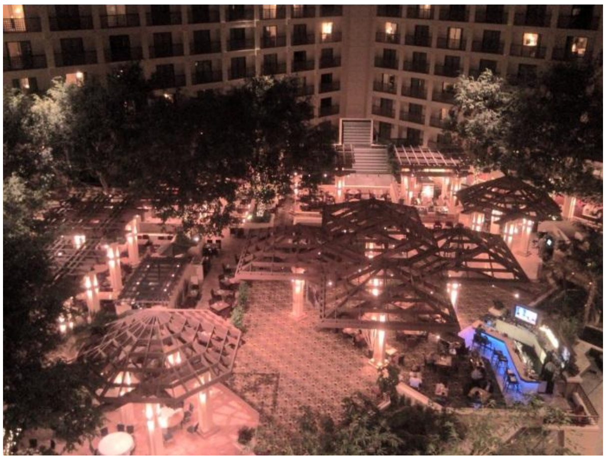
A plenary talk **"Driving VCSELs and Silicon Photonic Optical Interconnects to Brutal Area and Energy Efficiencies for Future Computing Systems"** Ashok Krishnamoorthy, Oracle Architect & Chief Technologist in Photonics. The importance of optical interconnects in the future high-performance computing systems was underlined. Once the communication bandwidth and the bandwidth density scale with Moore's law, the copper links shrink while the optical solutions at very high data rates require high cost and also power consumption. VCSEL links dominate. These links provide a significant cost and power benefit when applied at distances about 100 m and above. For distances shorter than 1 m they do not provide much benefit over electrical solutions.

Comment:

• For new standard CEI-56G-vsr (OIF) which is due in Q4 2014 the maximum length over copper on PCB is only 1 cm (@20dB loss). It looks like there will be virtually no space for copper on PCB once also the other interfaces are upgraded to the similar speed. Optical PCB is a must. As opposite on-chip communication may be still somewhat away.

• There is no laser compatible to CMOS technology. Heterogeneous coupling is required. In this sense coupling of VCSELs into the CMOS electrical interconnect layers for an optical pin application seems to be the most natural. VCSELs can be easily separated from the substrate and transferred to new locations on CMOS in a scalable way.

• 8 nm CMOS node is planned by 2015 (Intel, Nvidia). CMOS pitch sizes and the sizes of photonic components diverge rapidly. The demise (to a significant extend) of optical storage is indicative in this sense. There is no scaling in optics which deals with µm-scale distances.



View inside the hotel

View from the hotel towards the bay

Professor Eli Yablonovitch (University of California – Berkeley, CA, USA) gave a plenary talk **"The Opto-Electronic Physics that Just Broke the Efficiency Record in Solar Cells".** In the talk the record efficiency in solar cells has reached 28.8% for single junction GaAs solar cell. The main ideas: use thin films, use surface roughening and backside reflection, use materials with a high quantum efficiency, use selective contacts for electrons and holes. Thin film growth is advantageous as it allows separation of a GaAs solar cell from the substrate. The substrates then can be re-used. The thickness difference with silicon is about 10 000 times in favor of GaAs due to much higher absorption coefficient making this technology cheaper as the GaAs is not 10 000 times more expensive than silicon. Transfer of the film allows backside mirror and also option of flexible solar cells. The most efficient non-concentrating, single-junction solar cells ever built are created. P-n junction and built-in electric fields are less critical as very low gradients in the concentration are sufficient for high efficiency (a few % gradient costs a few mV of voltage only). However in this case the quantum efficiency and efficient photon recycling becomes very important. The shape of the elements for efficient trapping of the light should be ergodic (ellipse, lens shaped, but parallelogram or sphere). Lens is known to trap the light, for example. Most exciting part was a discussion on having an order in the surface roughening. Initial answer was "no" – there is no advantage over random roughness. However, once the film becomes thinner there may be some grounds to expect that non-random roughening may improve the efficiency.

Comment:

• Multijunction Ge-InGaAlAs-InGa(Al)P solar cells have reached 44% efficiency (concentrated light). It looks these may be also made bendable if the substrate separation technique used (by adding a layer into Ge substrate). May be specific ergodic shape patterning can support light concentration inside the cell.

• At the same conference a talk was presented MW2 "Inverse Electromagnetic Design for Subwavelength Light Trapping in Solar Cells", V. Ganapati, O. Miller and E. Yablonovitch, which addressed modeling of subwavelength gratings for the purposes of light concentration in solar cells.

Prof. Martin Wegener from Karlsruhe Institute of Technology, Germany gave a talk on **"3D Photonic Metamaterials and Transformation Optics".** A lot of excited opportunities arose recently due to renewed interest in advanced optical metamaterials http://en.wikipedia.org/wiki/Victor_Veselago enabled by recent breakthrough is nanotechnology. An opportunity to realize novel optical materials, create "carpets" hiding the surrounded objects and other exciting opportunities were discussed.

Topics Of Interest

Quantum Dots

There were multiple talks on quantum dot devices at the conference. The talks covered:

• Technology aspects of QDs including several talks devoted to growth of 1300 nm GaAs QD lasers on silicon and germanium substrates and capable for operation at and above room temperature

• Quantum dots for GaN-based LEDs

• Nanocrystallite core-shell QDs for advanced phosphors. This also includes GaN-laser pumped laser based on nanocrystallite QDs in a cavity for RGB applications

• Theoretical analysis of QD lasers and amplifiers evidencing that QD laser may operate at speeds much higher than those expected from small signal modulation bandwidth

• III-V and III-N QD is in microcavities and nanowires: from single QD single photon cryptography applications up to elevated temperatures to intracavity frequency conversion.

Quantum Dots for Lasers and Light- Emitting Diodes. N. N. Ledentsov, VI Systems GmbH, Berlin, Germany. Two types of quantum dots are presently broadly penetrating the markets. In one case nanocrystallites formed in host matrices are used. First quantum dots (QDs) in glass matrices were discovered by A.I. Ekimov and A.A. Onushzhenko in 1981 (http://www.jetpletters.ac.ru/ps/1030/article_15644.pdf). The size of the nanocrystallites was shown to result in the quantum size effect-induced modification of the optical absorption spectra in line with simple theoretical expectations. Later optical studies on these and also in other types of nanocrystallite QDs revealed a relatively broad homogeneous width of the resonant absorption and emission lines at low temperatures (~10 meV) and the existence of electronic QD was initially doubted. Another breakthrough came from the side of self-organized InAs-GaAs growth on GaAs when coherent islands formed by InAs deposition above the critical thickness were made responsible for the luminescence emission at long wavelengths as compared to GaAs (L. Goldstein et al, 1985). In 1991 a patent was given on "Semiconductor structure for optoelectronic components with inclusions" Jean-Michel Gerard, Claude Weisbuch US 5075742 (http://www.google.com/patents/US5075742?dq=5075742&ei=NsDQUInPKcHOtAaqg4HoCA) which is presently considered as "Fundamental Indium Gallium Nitride-based Light Emitting Device Patent" (http://www.seoulsemicon.com/en/html/company/press_view.asp?Idx=177&GotoPage=5&searchlist=&searchtxt=) and licensed to the major LED manufacturers. Nanocrystallite QDs are presently used as phosphors for GaN- LED-based applications. They allow a high color rendering index at high luminescence efficiency. When fabricated with core-shell technology they can also withstand high pump power densities and temperatures. These QDs are also believed to play a key role in the illumination market exceeding $100 billion. The first proof of electronic QD was demonstrated in August 1994 when ultranarrow luminescence lines from single InAs QDs were reported. By that date at the International Conference on the Physics of Semiconductors also efficient phonon-assisted relaxation of carriers in self-organized QDs, ground state absorption resonant to QD PL, lateral and size ordering of QDs and injection lasing was reported (see for references http://iopscience.iop.org/0268-1242/26/1/014001/pdf/0268-1242_26_1_014001.pdf). The first photopumped lasing in self-organized QDs was observed in 1993 (-"-). Further work resulted in industry-grade 1300 nm lasers on GaAs, single QD sources for cryptography, and spread of the self-organized QD technology to multiple materials systems. Recently merger of epitaxial and nanocrystal QDs resulted in InGaN laser-pumped nanocrystallite QD lasers in the red, green and blue spectral ranges.

Selected Talks

Design of Multiple Quantum Dot Semiconductor Lasers with Enhanced Modulation Capabilities using Spatially Resolved Time Dependent Model. D. Gready, Technion, Haifa, Israel

Modelling the Gain Compression Effects in Semiconductor Quantum-Dot Lasers through a New Modulation Transfer Function. C. Wang, F. Grillot and J. Even, Institut National des Sciences Appliquees de Rennes, Rennes, France.

Plasmonics for III-V Semiconductor Solar Cells. Surface plasmons supported by metal nanoparticles can be used to enhance the performance of solar-cells based on III-V semiconductors. S. Mokkapati, H. F. Lu, S. Turner, L. Fu, H. H. Tan and C. Jagadish, Australian National University, Canberra, Australia.

Low-Power Monolithic COMB Laser for Short-Reach WDM Optical Interconnects. 16+ low-noise optical comb lines with 80 GHz spacing and 0 dBm/line output power are generated by a single InAs/GaAs quantum dot (QD) Fabry-Perot laser. Electrical power consumption is reduced dramatically down to 6 mW/line. A. E. Gubenko, S. S. Mikhrin, V. Mikhrin, I. L. Krestnikov and D. A. Livshits, Innolume GmbH, Dortmund, Germany.

Relation between Small and Large Signal Modulation Capabilities in Highly Nonlinear Quantum Dot Lasers for Optical Telecommunication. D. Gready, Technion, Haifa, Israel

Stimulated Emission in Red, Green, and Blue from Colloidal Quantum Dot Films by Single Exciton Optical Gain. C. Dang, Brown University, Providence, RI, USA.

InAs Quantum Dot Photodetector Operating at 1.3 µm Grown on Silicon. I. C. Sandall, J. S. Ng, J. P. R. David, C. H. Tan, University of Sheffield, Sheffield, UK, T. Wang and H. Liu, University College London, London, UK.

Polarization-Dependent Photocurrent Enhancement in Metamaterial-integrated Quantum Dot Infrared Detectors. Y. Sharma, University of New Mexico, Albuquerque, NM, USA.

Comparison of Bulk and Quantum Dot GaAs Solar Cells. We report on the realization of a GaAs type-I quantum dot solar cell with a record 29.9 mA/cm2 short circuit current density and we compare it to a reference bulk GaAs solar cell. T. Li, J. Amirloo, J. Murray, University of Maryland, College Park, MD, USA, K. A. Sablon, J. Little, P. Uppal, US Army Research Laboratory, Adelphi, MD, USA, J. Munday and M. Dagenais, University of Maryland, College Park, MD, USA

Flexible Thin-Film Nanocrystal Quantum Dot Photodetectors on Unmodified Transparency Films
J. Wu and L. Y. Lin, University of Washington, Seattle, WA, USA

Large-Area (> 50 cm x 50 cm), Freestanding, Flexible, Optical Membranes of Cd-Free Nanocrystal Quantum Dots. E. Mutlugun, P. Hernandez Martinez, Nanyang Technological University, Singapore, C. Eroglu, Y. Coskun, T. Erdem, V. K. Sharma, E. Unal, Bilkent University, Bilkent, Ankara, Turkey, S. K. Panda, S. G. Hickey, N. Gaponik, A. Eychmüller, Technical University of Dresden, Dresden, Germany and H. V. Demir, Bilkent University, Bilkent, Ankara, Turkey.

Efficient Generation and Wavelength Conversion of Single Photons from Quantum Nanophotonic Devices. Single photon sources based on a self-assembled quantum dot in nanophotonic waveguides, gratings, and cavities are interfaced with nonlinear media and electro-optic modulators to demonstrate quantum frequency conversion and amplitude modulation of single photon states. K. Srinivasan, S. Ates, I. Agha, M. Davanço, M. T. Rakher, National Institute of Standards and Technology, Gaithersburg, MD, USA and A. Badolato, University of Rochester, Rochester, NY, USA

Intra-Cavity Frequency Doubling in Photonic Crystal Nanocavity Quantum Dot Lasers. We report visible light generation via intra-cavity frequency doubling in photonic crystal nanocavity quantum dot lasers. A strong field enhancement in the nanocavity enables the efficient conversion process, even with only a few intra-cavity photons. Y. Ota, K. Watanabe, S. Iwamoto and Y. Arakawa, University of Tokyo, Tokyo, Japan.

Deterministic Photon Cascade from Resonant Two-Photon Excitation of a Single InAs Quantum Dot. G. Weihs, H. Jayakumar, A. Predojevic, T. Huber, T. Kauten, University of Innsbruck, Innsbruck, Austria and G. S. Solomon, National Institute of Standards and Technology, Gaithersburg, MD, USA.

Blue Single Photon Emission from a Single InGaN/GaN Quantum Dot in Nanowire up to 200K
S. Deshpande, L. Zhang, T. Hill, A. Das, H. Deng and P. Bhattacharya, University of Michigan, Ann Arbor, MI, USA.

High-Quality InP/ZnS Nanocrystals with High Photometric Performance and Their Application to White Quantum Dot Light-Emitting Diodes. Full visible range covering InP/ZnS core-shell nanocrystals with high photometric performance have been prepared. Making use of these nanocrystals, we demonstrate a white quantum dot LED with a high color rendering index of 91.X. Yang, Nanyang Technological University, Singapore.

III-V Quantum Dot Lasers on Si Substrates by Wafer Bonding. We present 1.3 µm InAs/GaAs quantum dot Fabry-Perot and photonic crystal nanocavity lasers on Si substrates fabricated by wafer bonding, with thresholds of 205 A/cm2 and 2 µW, respectively, the lowest of lasers on silicon. K. Tanabe and Y. Arakawa, University of Tokyo, Tokyo, Japan.

2D and 3D Photonic Crystal Nanocavity Lasers with Quantum Dot Gain. We report our recent advanced on quantum-dot nanocavity lasers in 2D and 3D photonic crystals. A silicon-based 3D photonic crystal nanocaity laser using InAs quantum dots as active media is also discussed. S. Iwamoto, M. Nomura, A. Tandaechanurat, D. Cao and Y. Arakawa, University of Tokyo, Tokyo, Japan.

InAs/GaAs Quantum-Dot Lasers Monolithically Grown on Si Substrate. We present the studies on the development of InAs/GaAs quantum-dot lasers monolithically grown on Si for Si photonics. Room-temperature lasing near 1.3 µm has been demonstrated for the devices on Si and Ge substrates. H. Liu, A. Lee, Q. Jiang and A. J. Seeds, University College London, London, UK.

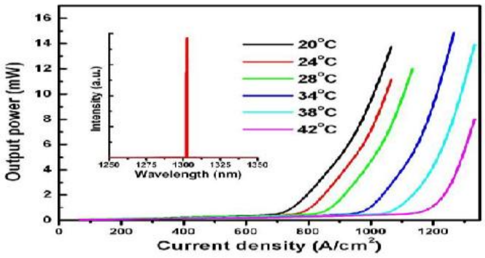


Figure 1. Light output against current characteristic for InAs/GaAs quantum-dot laser on Si substrate under pulsed condition at room temperature.

Phosphors and Quantum Dots for Solid State Lighting. L. Shea-Rohwer, Sandia National Laboratories, Albuquerque, NM, USA.

Growth of InAs Quantum Dot Laser Structures on Silicon. A. Liu, C. Zhang, A. C. Gossard and J. E. Bowers, University of California - Santa Barbara, Santa Barbara, CA, USA.

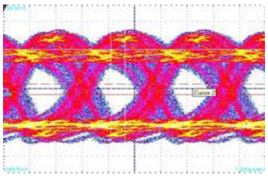
Monolithic Integration of Passive Components with High Performance Quantum Dot Lasers. P. Bhattacharya, University of Michigan, Ann Arbor, MI, USA, W. Guo, University of Michigan - Dearborn, Dearborn, MI, USA, C.-S. Lee and T. Frost, University of Michigan, Ann Arbor, MI, USA.

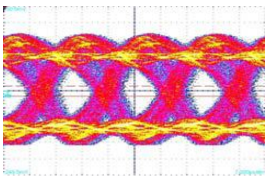
Talk On VCSELs

There was an explosion of talks related to VCSELs at this conference.

- 850 nm VCSELs and PIN-based optical up to 55 Gb/s. At 25Gb/s very good energy efficiency (25mW) is realized for the complete link even the driver circuit included positive and negative peaking to speed up VCSELs (IBM, Emcore, IBM-Finisar). At 55Gb/s the efficiency is much worse but a huge step forward is made now.
- Long wavelength VCSELs in the 1.3 – 2 µm range (Technical University of Munich, University of California at Berkeley, BeamExpress, École Polytechnique Fédérale de Lausanne, Bandwidth 10, Vertilas). These devices quickly mature and remarkable progress is made in high speed applications. With short cavity double side dielectric DBR and epitaxial selective tunnel junction approach TU Munich and Vertilas reached up to 40Gb/s bit data rates, and reasonable single mode power. Once the wafer separation techniques become scalable (solar cells, etc.) the technology becomes much more industry friendly and offers significant potential for a wide range of applications.
- Using subwavelength gratings University of California at Berkeley realized high-performance VCSELs with a high tuning speed due to the very thin membrane with subwavelength grating. Subwavelength gratings demonstrate a dramatic progress. Now also bilayer subwavelength grating with resonant cavities are introduced. The advantage of the subwavelength technology is a possibility to form 2D VCSEL arrays on a single chip for DWDM applications. This matches the needs of single mode unlimited capacity datacom transmission, particularly in combination with concepts of silicon photonics.
- Photonic crystal and subwavelength gratings

55Gb/s Directly Modulated 850nm VCSEL-Based Optical Link. D. M. Kuchta, A. V. Rylyakov, C. L. Schow, J. E. Proesel, C. Baks, *IBM.* C. Kocot, L. Graham, R. Johnson, G. Landry, E. Shaw, and J. Tatum, *Finisar.* The authors reported a directly modulated 850nm VCSEL-based Optical link operating at 55Gb/s. They claimed that this is the highest modulation rate for VCSEL-based link of any wavelength. High speed VCSEL became possible due advanced driver and amplifier electronics which includes a positive peaking at the beginning and a negative peaking at the end of the electrical pulse. 50Gb/s error free transmission with eye opening about 3.3 ps was claimed (although not directly measured at BER<1E-12). 55Gb/s was close to error free operation (even the eye opening was negligibly low).


50 Gb/s


55 Gb/s IBM/Finisar

CTU-VIS

The total link power dissipation is 1.25W =738mW Tx + 512mW Rx. The received power was at or above 0dBm (~1mW). The shift towards higher bit data rates became possible at a very high power cost for the link. At the same conference IBM and Emcore reported a low-power CMOS-driven VCSEL-based link using a 2-tap feed-forward equalizer in the transmitter driver. 850-nm linked required only 49 mW of power consumption (see below). We note, however, that recently 47Gb/s "real" error free (BER<1E-12) 850 nm VCSEL transmission was reported by Chalmers' (CTU) VCSEL coupled to VIS receiver (http://www.epic-assoc.com/sources/news/epicnewsletteroctober2012.pdf p.12). No pre-emphasis for the VCSEL driver electronics was applied. The 850nm VIS ROSA module consumed only 130 mW of power and had a transimpedance amplifier bandwidth of 35GHz. From the comparison of the eye diagrams (the figure above) one may conclude that CTU-VIS results show an even better eye opening at data bit rates close 50Gb/s (note that the jitter traces in the time domain are broader than the maximum horizontal eye opening for the IBM-Finisar case, while the situation is reversed for the CTU-VIS case). One can believe that with moderate equalization the link based on advanced VCSELs and PINs will offer further improved performance and at lower power consumption and better sensitivity. The next bit data rate standard of 56Gb/s is due in Q4 2014 when Common Electrical Interface CEI56G-VSR will be introduced (NRZ, maximum length of the electrical link over printed circuit board is 10 mm at 20dB losses) by the Optical Internetworking Forum. In discussions it was concluded that the pathway for the next generation of standards is found and that VCSELs may fulfill the tasks for the next few generations of optical links.

Single Mode Photonic Crystal Vertical Cavity Surface Emitting Lasers with Modulation Bandwidth > 13 GHz at Low Current Density. M. P. P. Tan, S. T. M. Fryslie, University of Illinois at Urbana-Champaign, Urbana, IL, USA, J. A. Lott, N. N. Ledentsov, VI Systems GmbH, Berlin, Germany and K. D. Choquette, University of Illinois at Urbana-Champaign, Urbana, IL, USA. Photonic crystal VCSELs were mostly considered for realization of single mode devices at large aperture size. However, the opportunity of the lateral mode confinement additionally allows a dramatic increase in the modulation bandwidth. In this work it was shown that in a device with implant aperture of 11 µm and at current density of only 4kA/cm^2 the modulation bandwith approaches 18GHz. To reach this bandwidth in the same structure without PC it was necessary to apply at least twice higher current densities at comparable aperture sizes. Error free transmission at 25Gb/s at record low received power of -9.5dBm without pre-emphasis in the driver circuit was demonstrated.

Recent Results on Long-Wavelength VCSELs: Device Structures, Performance and Applications. T. Gruendl, M. Mueller, C. Grasse, K. Vizbaras and M.-C Amann, Technical University of Munich, Garching, Germany. 1550 nm VCSELs with dielectric DBRs and tunnel junction formed by etching and overgrowth reach 40Gb/s error free operation range.

1310 nm Wafer Fused VCSELs - A New Generation of Uncooled 10 Gbps Telecom Lasers, A. Sirbu, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland.

A 25-Gb/s 49-mW CMOS-Driven Equalized Optical Link. A low-power CMOS-driven VCSEL-based link using a 2-tap feed-forward equalizer in the transmitter is reported at 850-nm wavelengths. Power efficiencies of 1.5, 2.0, and 3.8 pJ/b are achieved at 22.5, 25, and 28.5 Gb/s, respectively. B. G. Lee, J. E. Proesel, A. V. Rylyakov, C. Baks, IBM Research, Yorktown Heights, NY, USA, N.-Y. Li, Emcore Corporation, Albuquerque, NM, USA, C. Xie, Emcore Corporation, Newark, CA, USA, K. P. Jackson, Emcore Corporation, Albuquerque, NM, USA and C. L. Schow, IBM Research, Yorktown Heights, NY, USA.

VCSEL Bonding to Silicon and Plastic Substrates. GaAs VCSELs are transferred onto hybrid substrates using Van der Waals bonding. Arrays transferred onto Si show that transfer technique does not degrade laser characteristics and transfer onto PET demonstrate flexible VCSEL arrays. H. Jeong, J. Sulkin, R.-H. Kim, J. A. Rogers and K. D. Choquette, University of Illinois at Urbana-Champaign, Urbana, IL, USA.

On-Chip Electro-Thermal Beam Steering based on Slow-light Bragg Reflector Waveguide Laterally Integrated with VCSEL. T. Shimada, A. Matsutani and F. Koyama, Tokyo Institute of Technology, Yokohama, Kanagawa, Japan.

Electro-Thermal Tuning of Athermal 850nm VCSELs with Thermally Actuated T-shape Membrane Structure. H. Sano, N. Nakata, M. Nakahama, A. Matsutani and F. Koyama, Tokyo Institute of Technology, Yokohama, Kanagawa, Japan.

Buried Heterostructure VCSEL Using Epitaxial Mirrors. G. Zhao, Y. Zhang, D. G. Deppe, University of Central Florida, Orlando, FL, USA, K. Konthasinghe and A. Muller, University of South Florida, Tampa, FL, USA.

Tunable 1550-nm VCSEL Using High Contrast Gratings. We report monolithic, tunable 1550-nm HCGVCSELs with 26.3 nm continuous tuning. Room temperature power of 2.3 mW, 85°C power of 0.5 mW, and 10 Gb/s direct modulation over 100 km of fiber is demonstrated. Y. Rao, University of California - Berkeley, Berkeley, CA, USA, C. Chase, M. C.-Y. Huang, Bandwidth10 Inc., Newark, CA, USA, S. Khaleghi, M. R. Chitgarha, M. Ziyadi, University of Southern California, Los Angeles,CA, USA, D. Worland, Bandwidth10 Inc., Newark, CA, USA, A. E. Willner, University of Southern California, Los Angeles, CA, USA and C. J. Chang-Hasnain, University of California - Berkeley, Berkeley, CA, USA.

CMOS-Compatible VCSEL. CMOS-compatible III-V/Si vertical-cavity surface-emitting lasers (VCSELs) based on a double set of photonic crystal reflectors are demonstrated, showing single-mode continuous- wave operation at 1.55-µm with thresholds in the sub-mW range. P. Viktorovitch, C. Sciancalepore, Institut des Nanotechnologies de Lyon, Ecully, France, B. Ben Bakir, Commissariat à l'Énergie Atomique, Grenoble, France, X. Letartre, Institut des Nanotechnologies de Lyon, Ecully, France, N. Olivier, Commissariat à l'Énergie Atomique, Grenoble, France, C. Seassal, Institut des Nanotechnologies de Lyon, Ecully, France and J. Harduin, Commissariat à l'Énergie Atomique, Grenoble, France.

Beam Steering Modulation with Phased Vertical Cavity Laser Arrays. Beam steering with phased vertical cavity laser arrays is demonstrated at equipment-limited rates up to 100 MHz. The dominant phaseshifting mechanism is found to shift from thermal to carrier-induced effects with increasing modulation speed. M. Johnson, University of Illinois at Urbana-Champaign, Urbana, IL, USA, D. F. Siriani, MIT Lincoln Laboratories, Lexington, MA, USA, and K. D. Choquette, University of Illinois at Urbana- Champaign, Urbana, IL, USA.

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About VI Systems GmbH (VIS)

Founded in 2006, VIS is a fabless developer and producer of optical engines for data transmission at ultrahigh bit rates and the related electro-optic components for applications in datacommunications and access networks. The concept of the company is vertical integration to achieve qualitatively new functionality. This addresses both the design of electro-optic components and the vertical integration of them into a value chain bringing a universal optical engine, which can be further complemented by advanced coding schemes for digital and analog optical transmission.VIS is planning to reach bit rates above 100 Gb/s per channel in the near future at low cost and power consumption.

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EPIC is a membership-led not-for-profit industry association that promotes the sustainable development of organisations working in the field of photonics. Our members encompass the entire value chain from LED lighting, PV solar energy, Silicon photonics, Optical components, Lasers, Sensors, Displays, Projectors, Optic fiber, and other photonic related technologies. We foster a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement.

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