## HL 64: Focus Session: Optical interconnects - Materials, devices, and integration

Optical interconnects across optical fiber are rapidly replacing metal-based interconnects at short reach (up to 300 m) to medium reach (up to 2 km) distances in data centers, supercomputers, and at across a few meters in homes, aircraft, and automobiles. The concepts of Ubiquitous Connectivity, Big Data, and Natural/Organic User Interfaces all depend on advances in materials, devices, and integrated systems concepts for applications in optical interconnects whether across optical fiber, photonic waveguides, or free-space. Furthermore, a true paradigm shift in systems designs based on the use of optical interconnects at very short reach (< 2m) and ultrashort reach (< 2 mm) distances is underway as there are potentially huge advantages in energy efficiency, bandwidth density, purchase and operating cost, and performance. Presentations are solicited on all aspects of basic and applied research on materials, optoelectronic and photonic devices, and integrated systems for the realization of the next several generations of optical interconnects.

Organizer: James A. Lott (TU Berlin)

Time: Thursday 9:30–12:45 Location: EW 202

**Invited Talk** HL 64.1 Thu 9:30 EW 202

**Energy efficient optical interconnects for datacom and HPCs** — •Dieter Bimberg — Center of NanoPhotonics, TU Berlin

Vertical-cavity surface-emitting lasers (VCSELs) are emerging to be the decisive cost-effective, energy-efficient, and reliable light sources for short-reach (up to ~1000 m) optical interconnects in data centers and supercomputers. To viably replace copper interconnects and to advance to on-chip integrated photonics, VCSELs ideally should be able to operate at high energy efficiency, at large bit rates, and without cooling at up to 85 °C with immunity to temperature variations, which seem to be contradictions. We demonstrate that VCSELs with narrow 3-5 *m oxide apertures and ~ 15 nm shift between gain peak and maximum mirror transmission can achieve temperature-stable, energy-efficient and high-speed operation coincidently. Detailed theoretical and systematic experimental temperature- and oxide aperture-diameter-dependent characterization including static characteristics, small-signal analysis, and data transmission experiments are presented, for a variety of wavelengths. With contributions by: Connie Boldt, Günther Larisch, Hui Li, James Lott, Philip Moser, Philip Wolf, Maya Volwasen

**Invited Talk** HL 64.2 Thu 10:00 EW 202

**Plasmonic and Metallic Cavity Semiconductor Nanolasers for Ultimate Miniaturization** — •C.Z. Ning — Arizona State University, Tempe AZ, USA — Tsinghua University, Beijing, China

Miniaturization has been an eternal theme for electronics and photonics since the dawn of the semiconductor era. Size reduction of photonic devices has been driven both by the rich physics and by promising applications in future integrated nanophotonic systems. Micro cavity lasers have been topics of great interests for several decades due to their interesting photonic and quantum optical properties and their potential applications. However, further size reduction of such dielectric/semiconductor-cavity laser becomes exceedingly challenging when the wavelength becomes the eventual roadblock.

In this talk, we will present a summary overview of efforts in the last few years in developing metallic cavity or plasmonic nanolasers. Recent progress in theoretical and experimental studies will be presented, including the demonstration of the first nanolaser with a below-diffraction limit size, our recent efforts in raising the operating temperature of such nanolasers, and the eventual realization of the first room temperature subwavelength size nanolasers. Through the presentation, special emphasis will be placed on the unique features of such nanolasers that distinguish them from the conventional semiconductor lasers. We will also discuss some of attracting features that are yet to be realized experimentally. Finally, we will discuss new designs and current research towards further miniaturization and performance improvement.

**Invited Talk** HL 64.3 Thu 10:30 EW 202

**Polymer waveguides for electro-optical integration in data centers** — •Roger Dangel, Jens Hofrichter, Folkert Horst, Daniel Jubin, Antonio La Porta, Norbert Meier, Jonas Weiss, and Bert Jan Offrein — IBM Research - Zurich, Säumerstrasse 4, 8803 Rüschlikon, Switzerland

Tba

**Coffee break**

**Invited Talk** HL 64.4 Thu 11:15 EW 202

**Silicon Photonics for Optical Interconnects** — •Roel Baets — Ghent University - imec, Photonics Research Group, Ghent, Belgium

Silicon photonics is maturing very rapidly into an industrial technology platform for high datarate transceivers for optical data- and telecommunication. Nevertheless there is a rich landscape of exploratory research in this field in which new material combinations are being developed with a view of performance improvements (bandwidth, power dissiption, footprint, cost,...). Furthermore silicon photonics is also gearing towards other applications and markets, even if this means that the conventional telecom bands have to be left. In this talk some recent examples of these developments will be discussed.

**Invited Talk** HL 64.5 Thu 11:45 EW 202

**Long wavelength VCSELs for optical interconnects** — •Markus Amann — Walter Schottky Institut, TU München, 85748 Garching, Am Coulombwall 4

Wird nachgereicht

HL 64.6 Thu 12:15 EW 202

**Temperature-dependent modulation and impedance characteristics of 980 nm VCSELs** — •Hui Li[1], Philip Wolf[1], Philip Moser[1], Gunter Larisch[1], James A. Lott[1], and Dieter Bimberg[1,2] — [1]Institut für Festkörperphysik und Zentrum für Nanophotonik, Technische Universität Berlin, Hardenbergstraße 36, D-10623, Berlin, Federal Republic of Germany — [2]King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia

Multimode optical fibre interconnects based on vertical-cavity surface-emitting lasers (VCSELs) are a key enabling technology for short-reach data communication. Considering cost, long-term system sustainability, and reliability, optical interconnects must operate without extra cooling, implying the VCSELs must operate at much elevated temperatures. By introducing a -15 nm QW gain-to-cavity etalon wavelength offset, the temperature-stability, the maximum bit rate at high temperature, and the energy efficiency of our VCSELs are simultaneously improved. We present temperature stable 980 nm VCSELs capable of operating error-free at 38 Gb/s at 25 up to 85 °C without any change of working point and modulation conditions. A small-signal equivalent circuit model is fitted to measured scattering parameters to extract the circuit elements, -3 dB modulation bandwidth, D-factor, and parasitic cutoff frequency. Showing large values of -3 dB modulation bandwidth and D-factor both at room temperature and elevated temperatures, our VCSELs achieve high-speed, temperature-stable and energy-efficiency operation simultaneously, which makes these VCSELs well suited for very-short-reach and ultra-short-reach optical interconnects.

HL 64.7 Thu 12:30 EW 202

**Characterisation of Hybrid VCSEL and DFB Organic Microlasers** — •Tim Wagner, Markas Sudzius, Andreas Mischok, Hartmut Fröb, and Karl Leo — Institut für Angewandte Photophysik, Technische Universität Dresden, George-Bähr Str. 1, 01069 Dresden

Microlasers based on organic small molecules have shown great potential as coherent light sources [1,2]. Two important types of resonators being under investigation are the vertical-cavity surface-emitting laser (VCSEL) and the distributed-feedback laser (DFB). The gain medium in all structures produced is a blend of the red laser dye DCM doped by 2 wt% into the host material $Alq_3$. Although based on entirely different concepts, the two resonators exhibit comparable lasing thresholds and confinement factors.

In this work, we design a hybrid device combining both resonators in one compound structure, where second-order Bragg diffraction couples vertical modes of the VCSEL and lateral modes of the DFB. Using optical spectroscopy techniques, we analyse the emission properties and lasing characteristics to control the balance between the different mechanisms on positive optical feedback inside the composite system. Based on the results obtained, a novel structure is simulated and designed to optimise the performance of the hybridised microlaser device.

[1] I. Samuel and G. Turnbull *Chemical Reviews* **107**, 1272 (2007)
[2] A. Mischok et al. *Advanced Optical Materials* **2**, 802 (2014)