HL 23: Focus Session: Breakthroughs in wide-bandgap semiconductor laser diodes I

Recently, a number of significant breakthroughs have taken place in the area of wide-bandgap semiconductor laser diodes. The exploration of the limits of III-nitride materials, the improved understanding of the optical and electronic properties allowed to push the lasing wavelength towards the UV-B and UV-C spectral range with AlGaN-based laser diodes emitting at record short wavelength near 270 nm and 300 nm. In addition, advanced designs and fabrication technologies have led to the realization of novel devices in the blue-violet and even UV spectral range such as low-threshold VCSELs, narrow-linewidth GaN-based DFB laser diodes and photonic crystal lasers. In this focus session we will review these recent developments and discuss the future challenges and application for these devices.

Organized by Tim Wernicke, Ulrich Schwarz, and Michael Kneissl

Time: Wednesday 9:30–12:15 Location: POT 361

Invited Talk HL 23.1 Wed 9:30 POT 361

Vertical-cavity surface-emitting lasers – this is the way — •Å. Haglund[1], G. Cardinali[2], L. Persson[1], F. Hjort[1], J. Enslin[2], E. Torres[1], C. Kuhn[2], S. Graupeter[2], M. Grigoletto[2], M. A. Bergmann[1], N. Prokop[2], M. Guttmann[2], L. Sulmoni[2], N. Lobo Ploch[3], M. Cobet[2], T. Kolbe[3], J. Gustavsson[1], F. Nippert[2], I. Häusler[2], M. R. Wagner[2], J. Ciers[1], T. Wernicke[2], and M. Kneisl[2,3] — [1]Chalmers University of Technology, Göteborg, Sweden — [2]Technische Universität Berlin, Berlin — [3]FBH, Berlin

In recent years, there has been tremendous improvement in the performance of blue-emitting vertical-cavity surface-emitting lasers (VCSELs). Ultraviolet (UV)B (280-320 nm) and UVC (<280 nm) VCSELs have also been demonstrated, but so far only under optical pumping. All VCSELs require high reflectivity mirrors with an accurate cavity length control, but there is today no consensus on which is the best approach to realize this. We will summarize state of the art and then go into depth on our concept which is based upon using all-dielectric distributed Bragg reflectors where substrate removal is achieved by selective electrochemical etching. This approach has enabled the world's first UVB VCSEL at 310 nm. It also gives access to both sides of the cavity which allows for detuning postgrowth with drastically reduced lasing thresholds as well as an athermalized lasing wavelength. Thus, we believe that - this is the way - for nitride VCSELs. As a first step towards electrically injected UV VCSELs, we will demonstrate resonant cavity light emitting diodes with tunnel junctions.

Invited Talk HL 23.2 Wed 10:00 POT 361

Towards GaN-based diode lasers with narrow linewidth and high reliability — •Sven Einfeldt[1], Erik Freier[1], Ji-Hye Kang[1], Hans Wenzel[1], Anna Mogilatenko[1], Johannes Glaab[1], Asmaa Abou-Shewarib[1], Veit Hoffmann[1], Johannes Enslin[1], Martin Guttmann[1], Saad Makhladi[1], Jörg Fricke[1], Olaf Brox[1], Mathias Matalla[1], Maria Norman-Reiner[1], Christoph Stölmacker[1], Markus Weyers[1], Luca Sulmoni[2], Michael Kneissl[2], Lukas Uhlig[3], and Ulrich T. Schwarz[3] — [1]Ferdinand-Braun-Institut (FBH), Berlin, Germany — [2]Technische Universität Berlin, Institut für Festkörperphysik, Berlin, Germany — [3]Technische Universität Chemnitz, Institut für Physik, Chemnitz, Germany

Various applications require GaN-based diode lasers that not only operate in single-mode at well-defined wavelengths, but also exhibit a small linewidth and high reliability. Single-mode operation can be achieved via the distributed feedback (DFB) or distributed Bragg reflector (DBR) laser design, i.e. monolithic integration of gratings in the chip. We present here the current state of the art in fabrication technology and properties of DFB and DBR diode lasers with high-order laterally coupled surface gratings. These include continuous wave single-mode operation at room temperature with an optical power of up to 20 mW (DBR) and 70 mW (DFB), respectively, and spectral half widths of about 20 pm. We also show results of selected studies on the reliability of GaN-based lasers, in particular on the stability of the operating voltage, the evolution of spatial inhomogeneities in the current distribution in the chip, and the stability of the facets.

Invited Talk HL 23.3 Wed 10:30 POT 361

Use of wafer patterning for new functionalities of InGaN light emitters — •Anna Kafar[1,2], Ryota Ishii[3], Atsushi Sakaki[4], Kiran Saba[1], Conny Becht[5], Szymon Grzanka[1,2], Ulrich Schwarz[5], Mitsuru Funato[3], Yoichi Kawakami[3], and Piotr Perlin[1,2] — [1]Institute of High Pressure Physics PAS, Warsaw, Poland — [2]TopGaN Ltd., Warsaw, Poland — [3]Kyoto University, Kyoto, Japan — [4]Nichia Corporation, Tokushima, Japan — [5]Chemnitz University of Technology, Chemnitz, Germany

In this work we present the use of patterning of bulk GaN substrates to control the growth of InGaN layers by metalorganic vapour-phase epitaxy. We demonstrate that using local change of substrate miscut, it is possible to obtain a spatial shift of emission energy of above 25 nm. Synchrotron radiation microbeam X-ray diffraction reveals that a significant change of In content in the QWs is possible between 9% and 18%. This approach can be used for example in fabrication of micro-arrays of laser diodes with different lasing wavelength. Another application is the fabrication of superluminescent diodes with broadened emission spectra by utilizing a profile of indium content along the device waveguide. Furthermore, we use the same concept to demonstrate monolithic light-guides integrated with laser diodes on the same wafer and fabricated based on the same epitaxy. We also study the possibility to use substrate patterning in a form of micro strips and discs regions of improved quality InGaN which can be used for fabrication of the active regions of the micro LEDs and laser diodes.

30 min. break

HL 23.4 Wed 11:30 POT 361

Time-dependent intensity and wavelength dynamics of blue laser diodes with wide quantum wells — •Jannina Tepass[1], Lukas Uhlig[1], Mateusz Hajdel[2], Grzegorz Muziol[2], and Ulrich Theodor Schwarz[1] — [1]Institute of Physics, Chemnitz University of Technology, Chemnitz, Germany — [2]Institute of High Pressure Physics, Polish Academy of Sciences, Poland

In this study, thick quantum wells with two different thicknesses of 10.4 nm and 25 nm are analyzed. The very low overlap of the electron and hole wavefunction in such QWs due to the quantum confined Stark effect would indicate inefficient devices. However, it has been shown that thick QWs can be more effective and achieve high optical gain. This can be explained by the electric field screening that leads to a high overlap of the excited electron and hole states, which enable lasing. In this work, a pulsed electrical excitation scheme is used in which carrier injection at forward voltage is largely separated from carrier recombination at zero or reverse voltage. Due to this effect, the interplay between the piezoelectric field and the built-in potential on the charge carrier recombination in dependence on an external bias voltage can be observed. In particular, a sharp increase in the radiative recombination rate after the trailing edge of the driving pulse is observed, as well as a wavelength shift.

HL 23.5 Wed 11:45 POT 361

Single-mode lasing in optically pumped UVB VCSELs with circular relief structures — •Giulia Cardinali[1], Filip Hjort[2], Johannes Enslin[1], Munise Cobet[1], Michael A. Bergmann[2], Johan Gustavsson[2], Joachim Ciers[2], Tim Kolbe[3], Felix Nippert[1], Markus R. Wagner[1], Tim Wernicke[1], Åsa Haglund[2], and Michael Kneissl[1,3] — [1]Institute of Solid State Physics, Technische Universität Berlin, Berlin, Germany — [2]Department of Microtechnology and Nanoscience, Chalmers University of Technology, Gothenburg, Sweden — [3]Ferdinand-Braun-Institut (FBH), Berlin, Germany

Extending the emission wavelength of vertical-cavity surface-emitting lasers (VCSELs) in the ultraviolet (UV) range would allow advances in many applications, e.g. in medical diagnostics, material curing, and sterilization. UV VCSELs have been demonstrated only under optical pumping and they suffer from strong filamentation (i.e. spatially inhomogeneous emission), resulting in multimode lasing. In this work, we

study the emission characteristic of optically pumped UVB VCSELs with circular reliefs dry-etched on the bottom cavity. Single-mode lasing near 312 nm was achieved for VCSELs with 25 nm-deep reliefs with diameters smaller than 5 μm, when pumped up to 80 MW/cm^2. Here, the lateral size of the cavity was reduced below the dimension of one filament. VCSELs with 5 nm-deep reliefs did not show single mode lasing. 50 nm-deep structures did not lase for diameters below 6 μm. The higher thresholds in this sample are due to defect generation in the quantum-well by the dry etching, which was confirmed by time-resolved photoluminescence measurements of the carrier lifetimes.

HL 23.6 Wed 12:00 POT 361

Use of wafer patterning for new functionalities of InGaN light emitters — •Anna Kafar[1,2], Kiran Saba[1], Ryota Ishii[3], Atsushi Sakaki[4], Szymon Grzanka[1,2], Conny Becht[5], Ulrich Schwarz[5], Mitsuru Funato[3], Yoichi Kawakami[3], and Piotr Perlin[1,2] — [1]Institute of High Pressure Physics PAS, Warsaw, Poland — [2]TopGaN Ltd., Warsaw, Poland — [3]Kyoto University, Kyoto, Japan — [4]Nichia Corporation, Tokushima, Japan — [5]Chemnitz University of Technology, Chemnitz, Germany

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