HL 2: GaN: devices

Time: Monday 10:15–12:15 Location: BEY 118

HL 2.1 Mon 10:15 BEY 118

Development of InGaN-based thin disk lasers — •R. Debusmann[1], V. Hoffmann[2], W. John[2], O. Krüger[2], P. Vogt[1], M. Kneissl[1], and M. Weyers[2] — [1]Institut für Festkörperphysik, Technische Universität Berlin, EW 6-1, Hardenbergstr. 36, 10623 Berlin — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

Thin disk lasers consisting of an optically pumped vertical cavity surface emitting laser with an external cavity have gained much interest in recent years. The main reason for that is that they combine high power output of edge emitting lasers with high beam quality of surface emitting devices.

In particular for the group III-nitride material system thin disk lasers seem a promising solution for high power applications, because of the inherent problems in this material system to realize epitaxial structures with low electrical losses. Here we report on the development of InGaN thin disk lasers for emission wavelengths near 405 nm.

Besides the epitaxial heterostructure a number of fabrication steps have to be developed in order to realize such devices. We will discuss some of the developed key processes for device integration. In particular deposition of SiO_2/Ta_2O_5-DBR mirror stacks with reflectivity greater than 99.5% and substrate removal by excimer-laser liftoff in order to form the laser resonator will be discussed.

HL 2.2 Mon 10:30 BEY 118

Wavelength Dependence of Optical Gain and Laser Threshold in InGaN MQW Lasers — •Jessica Schlegel[1], Jan-Robert van Look[1], Veit Hoffmann[2], Arne Knauer[2], Patrick Vogt[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Institut für Festkörperphysik, TU-Berlin, Hardenbergstr. 36, EW6-1, 10623 Berlin — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

For InGaN quantum well (QW) laser diodes emitting in the blue and green spectral range indium contents of more than 20 % are required. To optimize the growth of InGaN QWs we have investigated the influence of the indium content on the gain characteristics and laser threshold. Optically pumped laser structures with emission wavelengths ranging between 395 nm and 450 nm were characterized. The laser heterostructures were grown by metalorganic vapor phase epitaxy (MOVPE) on (0001) sapphire substrates. The optical gain spectra were measured based on the variable stripe length method (VSLM). Laser structures with emission below 420 nm showed wavelength independent laser thresholds. A strong increase of the laser threshold and the width of the optical gain spectra was observed for longer wavelength and higher indium contents. This behaviour can be attributed to material inhomogeneities, defects and the quantum confined Stark effect (QCSE).

HL 2.3 Mon 10:45 BEY 118

Optimization of InGaN multiple quantum wells for blue lasers — •J.R. van Look[1], J. Schlegel[1], V. Hoffmann[2], A. Knauer[2], S. Einfeldt[2], M. Weyers[2], P. Vogt[1], and M. Kneissl[1,2] — [1]Institut für Festkörperphysik, TU-Berlin, Hardenbergstr. 36, 10623 Berlin — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

Group III-nitride based lasers with emission targeted at the blue and green spectral region have attracted great interest in recent years. For the optimization of these indium-rich active regions, optically pumped as well as current-injection InGaN quantum well lasers with varying indium content and well width have been investigated. The laser heterostructures were grown by metalorganic vapor phase epitaxy (MOVPE) on (0001) sapphire substrates. The resulting structures with emission wavelengths ranging from 390 nm to 480 nm have been examined. In this talk we will present theoretical as well as experimental results on the characteristics of these indium rich InGaN multi quantum well (MQWs) lasers. The effect of well width in correlation with indium content on gain characteristics and laser threshold will be discussed. For optically pumped lasers with wells containing between 15% and 20% indium we observed a significant increase of the threshold excitation density to as much as 500 kW/cm2. In device structures for blue emitters with 480 nm luminescence observed under low excitation conditions, the laser emission strongly blue-shifted to 450 nm, which can be attributed to the compensation of the quantum confined stark effect (QCSE) under high excitation conditions.

HL 2.4 Mon 11:00 BEY 118

Towards InGaN-based light emitters with superior high-current performance — •Ansgar Laubsch[1], Matthias Sabathil[1], Werner Bergbauer[1], Martin Strassburg[1], Matthias Peter[1], Hans Lugauer[1], Tobias Meyer[1], Joachim Wagner[2], Norbert Linder[1], Klaus Streubel[1], and Berthold Hahn[1] — [1]OSRAM Opto Semiconductors GmbH, Leibnizstrasse 4, 93055 Regensburg, Germany — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastrasse 72, 79108 Freiburg, Germany

The last decade has seen tremendous progress in the epitaxial growth and in advanced chip designs of light emitting diodes (LEDs) with InGaN/GaN quantum-well (QW) heterostructures. This recently enabled an efficiency for conversion of electrical to optical power of almost 60 % for a blue ThinGaN® LED at operation current. Still, the internal quantum efficiency of such devices peaks far below the operation current density and then decreases monotonously. Understanding of this mechanism is crucial to reach the ultimate limits in efficiency. We identify a QW internal high density Auger-like loss process as the culprit and model our data with a coefficient of $C = 3.5 \cdot 10^{-31}\mathrm{cm}^{-6}\mathrm{s}^{-1}$. Thick InGaN QWs and an optimized multi quantum well structure are ways to reduce the carrier density. We study the physics of recombination and carrier distribution in such structures. Consistent with simulations, both concepts exhibit reduced high current saturation. We thus conclude that regardless of the employed concept, a decrease in carrier density is central to improve the high current efficiency of InGaN based light emitters.

15 min. break

HL 2.5 Mon 11:30 BEY 118

Heterostructure design optimisation of deep (In)AlGaN ultraviolet light emitting diodes — •T. Sembdner[1], T. Kolbe[1], A. Knauer[2], V. Küller[2], S. Einfeldt[2], P. Vogt[1], M. Weyers[2], and M. Kneissl[1,2] — [1]TU Berlin, Institute of Solid State Physics, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Ultraviolet light emitting diodes (LEDs) based on III-nitride semiconductors have attracted great interest in recent years. However, due to week carrier confinement, strong piezoelectric fields and high defect densities the external quantum efficiencie of ultraviolet LEDs is still in the lower percent range.

Here we present a comparison of heterostructure design simulations and experimental results for deep ultaviolet (In)AlGaN-multiple quantum well (MQW) LEDs grown by metalorganic vapour phase epitaxy on (0001) sapphire substrates. The emission wavelength was found near 320nm for an active region comprised of (In)AlGaN quantum wells and (In)AlGaN barrier layers. For these structures the effects of the p-contact layer design, the electron blocking layer and the MQW active region on the external quantum efficiency is investigated. The latter influence is particularly important as our simulations have shown that a single quantum well LED has a higher radiative rekombination rate in comparison with a MQW LED.

HL 2.6 Mon 11:45 BEY 118

Barrier alloy composition and polarization control in nitride light emitters — •Christoph Hums, Aniko Gadanecz, Armin Dadgar, Jürgen Bläsing, Alexander Franke, Thomas Hempel, Jürgen Christen, and Alois krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

Although InGaN based light emitting diodes (LEDs) have been commercialized for general lighting applications and displays, they suffer from reduction in efficiency and a pronounced luminescence blue shift at high injection current levels. This behavior can be attributed to the strong polarization fields in c-direction of the active region and the associated quantum confined stark effect (QSCE). To reach higher external quantum efficiencies (EQE) the reduction of the polarization fields is inevitable. Most attempts in reducing the internal fields target on switching the direction of the quantum wells (QWs) from c-plane in a direction with reduced fields (e.g. a-plane). A new approach is polarization control by new barrier- and QW-materials as the ternary AlInN and the quaternary AlInGaN. We will present calculations of the internal polarization fields in the proposed structures, which allow an estimate of the needed alloy compositions. Then the growth of AlInN with high indium content will be discussed. The limits of indium incorporation, the critical layer thickness on GaN and its impact on the novel structures will be displayed.

HL 2.7 Mon 12:00 BEY 118

Phonon-assisted contributions to the Auger losses in InGaN quantum wells — •Bernhard Pasenow[1], Stephan W. Koch[1], Jörg Hader[2], and Jerome V. Moloney[2] — [1]Department of Physics and Materials Sciences Center, Philipps Universität Marburg, Renthof 5, 35032 Marburg, Germany — [2]Nonlinear Control Strategies Inc., 3542 N. Geronimo Ave., Tucson, AZ 85705 and Optical Sciences Center, University of Arizona, Tucson, Arizona 85721

The external quantum efficiency (EQE) of typical GaN-based light emitting diodes shows a maximum at very low pump currents and then decreases, often to only half that value for pump currents desired for applications. The reason for this effect is the loss of a significant fraction of the carriers pumped into the structure. One possible origin of this EQE-droop – beside some others like carrier leakage – is the carrier recombination through non-radiative Auger processes.
In our talk, we present a microscopic theory which is capable of describing non-radiative Auger losses in InGaN quantum wells. Since the calculated direct band-to-band Auger contributions are too small [1] in comparison to measurements, we focus on the phonon-assisted losses presenting details on our theoretical model, the structure of the Auger loss equations and numerical results.

[1] J. Hader, J.V. Moloney, B. Pasenow, S.W. Koch, M. Sabathil, N. Linder, and S. Lutgen, Appl. Phys. Lett. 92, 261103 (2008)