HL 45: GaN devices

Time: Thursday 9:30–11:45
Location: EW 202

HL 45.1 Thu 9:30 EW 202
Dünnschicht-LEDs auf der Basis von InGaN/GaN MQW auf Si(111)

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In broad area (Al,Ga)N laser diodes (LDs) with ridge widths larger than a few micrometers the laser mode in the waveguide builds up filaments, which influence the far field of the LD. Employing temporal and spectral resolved scanning near-field optical microscopy (SNOM) on pulsed electrically driven LDs we analyse the lateral mode profile on a nanosecond to microsecond timescale. Furthermore we are able to resolve the single Fabry-Perot modes of the laser mode correlated to the lateral position in the ridge waveguide. Different filaments have slightly different effective refractive indices and thus show up as separate longitudinal mode combs. In this way we can reconstruct the optical mode in the waveguide as a superposition of filaments, identified by their spectral fingerprint. Different samples, grown on SiC and GaN substrates, respectively, were investigated. The measurements show similar results for all samples concerning the lateral mode profile, whereas the samples grown on GaN substrate exhibit a less chaotic behaviour in the temporal and spectral regime compared to the LDs grown on SiC substrate.

HL 45.2 Thu 9:45 EW 202
External field dependent spatial resolved PL spectroscopy on InGaN/GaN heterostructures — **Clemens Verheißle**¹, **Harald Braun**¹, **Ulf M. Schäfer**¹, **Niko- laus Gmeinniewski**², **Angela Laubsch**², and **Berthold Hahn**² — ¹NW II - Physik, Universität Regensburg, Universitätstraße 31, 93053 Regensburg — ²Osram Opto Semiconductors, Leibnizstraße 4, 93055 Regensburg

The optical properties of InGaN based quantum well structures are strongly affected by internal electric fields and fluctuations of the indium content. By micro-photoluminescence of InGaN LEDs with applied bias and micro-electroluminescence we study the correlation between QW emission intensity and energy, both of which fluctuate on a micrometer length scale. Particularly interesting is the characteristic dependency of this energy-intensity correlation on the applied external electric field. For a spatially resolved measurement of the tunnel barrier we have to find a way to avoid damaging of the quantum wells by thermal stress. Combining the results of the gain measurement with a theoretical calculation of the gain spectra we determine the threshold power, carrier density and the carrier recombination times of the sample. On bulk GaN substrates we find threshold power levels as low as 20 kW/cm². Up to now we obtain optical gain up to a peak wavelength of 465 nm with losses of about 30 cm⁻¹. Our next targets are a wavelength of 480 nm as well as a further reduction of the threshold power.

HL 45.3 Thu 10:00 EW 202
Semipolar (1101) GaInN quantum wells for green light emitting diodes — **Martin Feneberg**¹, **Thomas Wunderlich**¹, **Frank Lippert**², **Peter Brückner**², **Ferdinand Scholz**², **Rolf Sauermann**¹, and **Klaus Thonke**³ — ¹Institut für Halbleiterphysik, Universität Ulm — ²Institut für Optoelektronik, Universität Ulm

Semipolar (1101) quantum wells were grown, processed and finally analyzed by electric-field-dependent photoluminescence and electroluminescence. From the PL emission energy as a function of the externally applied voltage which modifies the built-in polarization field we have determined the remaining polarization field. For this purpose, model calculations were carried out which self-consistently take full account of the tilted band structure, charge accumulation, fields in the depletion region and other relevant parameters. With these results we are able to calculate the internal quantum efficiencies of semipolar quantum wells. After carefully adjusting growth and process parameters while maintaining material quality we demonstrate first semipolar light emitting diodes operating at around 500nm.

HL 45.4 Thu 10:15 EW 202
Spectral Identification of Filaments in Broad Ridge 405 nm (Al,Ga)N Laser Diodes — **Harald Braun**¹, **Hans-Michael Solowjan**¹, **Dominik Scholz**², **Tobias Meyer**³, **Ulf Schröder**³, **Jürgen Christen**³, **Min Dadgar**³, **Lars Reimann**³, **Thomas Hempel**¹, **Oliver Schulz**¹, **Theodor Schwarz**², **Stefanie Brüningshoff**², **Alfred Lell**, and **Uwe Straßu**² — ¹NW II - Physik, Universität Regensburg — ²Osram Opto Semiconductors GmbH, Regensburg

In order to reach wavelengths longer than 450 nm an increase of the indium concentration to more than 25 % is needed. Such high indium content requires careful optimization of the growth conditions in order to avoid damaging of the quantum wells by thermal stress. Combining the results of the gain measurement with a theoretical calculation of the gain spectra we determine the threshold power, carrier density and the carrier recombination times of the sample. On bulk GaN substrates we find threshold power levels as low as 20 kW/cm². Up to now we obtain optical gain up to a peak wavelength of 465 nm with losses of about 30 cm⁻¹. Our next targets are a wavelength of 480 nm as well as a further reduction of the threshold power.

HL 45.5 Thu 10:30 EW 202
GaN/GaN quantum well laser structures emitting in the blue-green spectral range — **Daniel Drager**¹, **Uwe Rossow**¹, **Holger Jöns**¹, **David Schenk**², **Jean-Yves Duboz**², and **Andreas Hangleiter**³ — ¹Institute of Applied Physics, Technical University of Braunschweig, Germany — ²CRHEA-CNRS, Valbonne, France

Presently, GaN-based laser diodes are limited to the violet-blue region of the spectrum. Our aim is to obtain laser emission in the blue-green spectral range. In order to study GaN-based laser structures, low pressure MOVPE was used to grow such structures on a variety of substrates (freestanding GaN, GaN templates, and SiC). This allows investigations of the influence of the substrate related dislocation densities on gain, losses and carrier recombination. Our samples were investigated by optical gain spectroscopy using the variable stripe length method.

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HL 45.6 Thu 10:45 EW 202
Characteristics of (Al,In,Ga)N multiple quantum well structures for blue-green laser diodes — **Frank Höffmann**¹, **Arne Knauer**¹, **Frank Brunner**¹, **Carsten Netzkel**¹, **Markus Weyers**¹, **Günter Tränkle**¹, **Tim Kolbe**¹, **Jan Robert van Look**², and **Michael Knieser**¹,² — ¹Ferdinand-Braun-Institut für Höchstfrequenzentechnik, Gus-Girchhoff-Straße 4, 12489 Berlin — ²Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

In(Ga,In)N based laser diodes (LD) emitting in the violet spectral region are already commercially available with excellent lifetimes and high efficiencies. In order to extend the emission wavelength of these devices towards the blue and green high quality InGaN quantum well structures have to be realized. However, multiple quantum well (MQW) structures with high indium content exhibit low efficiencies, due to the large piezoelectric fields (F_{PZ}) as well as the deterioration in crystal quality. We have investigated the growth of InGaN MQW structures emitting in the blue-green wavelength region with photoluminescence and high resolution X-Ray diffraction. In our studies we were able to determine F_{PZ} quantitatively and show how F_{PZ} is influenced by the barrier composition, e.g. by adding indium to the barriers and by partially doping the barriers with silicon. By increasing the growth temperature during the barrier growth, we were able to improve the ratio of radiative to non-radiative recombination. Fi-
nally, we will discuss the effects of barrier composition and optimized growth conditions on light output and threshold current densities for LDs.


**Enabling factors for the improvement of nitride-based LED efficiency** — Ansgar Laubisch, Werner Bergbauer, Matthias Sabathil, Matthias Peter, Tobias Meyer, Georg Brüderl, Joachim Wagner, Norbert Linder, Klaus Streubel, Raimund Oberschmid, Berthold Hahn.

**Temperature and current dependent electroluminescence measurements on colour-coded Multiple Quantum Well Light Emitting Diodes** — Werner Bergbauer, Ansgar Laubisch, Matthias Peter, Tobias Meyer, Stefan Bader, Günther Benstedter, Raimund Oberschmid, and Berthold Hahn.

**As the efficiency and the luminous flux have been increased enormously in the last few years, today Light Emitting Diodes (LEDs) are even pushed to applications like general lighting and Home Cinema Projection. Still, InGaN / GaN heterostructure based LEDs suffer from loss-mechanisms like non-radiative defect and Auger recombination, carrier leakage and piezo-field induced carrier separation. To optimize the high current efficiency we evaluated the benefit of Multiple Quantum Well (MQW) compared to Single Quantum Well (SQW) LEDs. Temperature dependent electroluminescence of colour-coded structures with different Indium content in certain Quantum Wells was measured. The experiments demonstrated a strong temperature and current dependence of the MQW operation. The comparison between different LED structures showed effectively the increased LED performance of those structures which operate with a well adjusted MQW active area. Due to the enhanced carrier distribution in the high current range, these LEDs show a higher light output and additionally a reduced wavelength shift.**


**Here we present continuous wave and pulsed electroluminescence measurements of GaN-based multi quantum well LEDs with different barrier compositions. These devices were grown by metalorganic vapour phase epitaxy on (0001) sapphire substrates. The emission wavelength is approximately 375nm for an active region comprised of In_{0.03}Ga_{0.97}N quantum wells (QWs) and surrounded by GaN, Al_{0.16}Ga_{0.84}N or In_{2}Al_{0.16}Ga_{0.84}N barrier layers. We found that the blue-shift of the emission wavelength related to the piezoelectric field in the QWs and the resulting quantum confined Stark effect (QCSE) clearly depends on the barrier composition and is zero for samples with lattice matched In_{0.04}Al_{0.16}Ga_{0.80}N barrier. An InAlGaN barrier with 3.3% indium resulted in a 50-fold increase of output power compared to LEDs with GaN barriers.**