HL 35: Semiconductor Laser

Time: Wednesday 14:00–17:45 Location: BEY 154

HL 35.1 Wed 14:00 BEY 154

Crystal length dependency of the generation of the second harmonic with non-diffraction limited radiation — •Mirko Uebernickel, Gunnar Blume, Christian Fiebig, Katrin Paschke, Bernd Eppich, Reiner Güther, and Götz Erbert — Ferdinand-Braun-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Deutschland

The direct second harmonic generation (SHG) of high power, infrared semiconductor diode lasers is a possible candidate for the replacement of established visible laser systems, like Argon-Ion lasers or frequency doubled solid-state lasers. To achieve high optical output power in the visible wavelength range the length of nonlinear crystal needs to be considered. The SHG power scales linear with the length of the crystal in single path configuration for a Gaussian beam.

We determine the crystal length dependency for non-diffraction limited radiation of diode lasers in experiment and theory. Different semiconductor lasers with increasing beam propagation factor (second order moments) from 1.1 to 3 were used to examine the SHG power of four periodically poled MgO doped lithium niobate crystals with lengths of 10, 18, 22 and 50mm. It was found that the SHG power is indeed linearly dependent on the crystal length, but only if the focusing conditions are adjusted to the non-diffraction limited radiation. Theoretical calculations based on a Gauss-Shell model could verify these experimental results. The model can thus be used to predict optimised focussing conditions for SHG with non-diffraction limited beams.

HL 35.2 Wed 14:15 BEY 154

Metallorganische Gasphasenepitaxie von AlInN/GaN Bragg-Spiegeln — •Pascal Moser, Armin Dadgar, Christoph Berger, Jürgen Bläsing, Thomas Hempel und Alois Krost — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

Hochreflektierende gitterangepasste AlInN/GaN Bragg-Spiegel (DBR) für den Einsatz in Nitrid-basierten Lasern mit Vertikalresonator (VCSEL) werden präsentiert.

Die Spiegel wurden auf 2-Zoll c-achsenorientiertem Saphirsubstrat in einem AIXTRON 200/4 RF-S Reaktor gewachsen. Auf einer AlN-Nukleationsschicht wurden ca. 1500 nm GaN und anschließend 40 AlInN/GaN λ/4-Doppelschichten abgeschieden. Die jeweils 47.1 nm dicken AlInN-Schichten wurden bei 780°C unter einem Druck von 70 mbar und die 43.2 nm dicken GaN-Schichten bei 1145°C unter einem Druck von 200 mbar gewachsen. Ammoniak bei den AlInN- und Wasserstoff bei den GaN-Schichten fungierten als Trägergase. Die Rissfreiheit der Proben konnte mit Hilfe der Nomarski-Mikroskopie verifiziert werden, während zur Bestimmung der kristallinen Qualität Röntgenbeugung verwendet wurde. Darüber hinaus kam die Röntgenbeugung zur Bestimmung der Schichtdicken zum Einsatz, welche mit den aus Feldemission-Rasterelektronenmikroskopieaufnahmen ermittelten Werten verglichen wurden. Anhand von Reflektionsspektren konnten nicht nur eine hohe Reflektivität, sondern auch die ermittelten Schichtdicken durch angepasste Simulation nachgewiesen werden.

HL 35.3 Wed 14:30 BEY 154

Lasing of the direct bandgap material Ga(NAsP) pseudomophically grown on Si(001)-substrate — •Sven Liebich[1], Bernardette Kunert[2], Igor Németh[1], Steffen Zinnkann[1], Andreas Beyer[1], Rafael Fritz[1], Christoph Lange[1], Niko S. Köster[1], Daniel J. Franzbach[1], Sangam Chatterjee[1], Wolfgang W. Rühle[1], Nils C. Gerhardt[3], Nektarious Koukourakis[3], Martin Hofmann[3], Kerstin Volz[1], and Wolfgang Stolz[1] — [1]Material Sciences Center and Faculty of Physics, Philipps-University Marburg — [2]NAsPIII/V GmbH Marburg — [3]Photonics and Terahertz Technology, Ruhr-University Bochum

Photonic devices based on standard techniques used in complementary metal-oxide-semiconductor (CMOS) technology are of high interest to realize photonic integrated circuits. Silicon (Si) is the standard material but it is unsuitable for laser applications due to its indirect electronic bandgap. Therefore different strategies are pursued to realize an efficient Si-based light source i.e. the doping of crystalline Si with Erbium atoms or the use of Si nanocrystals. Our approach is the monolithic integration of the novel Ga(NAsP) laser material which can be grown nearly lattice-matched on Si. Through incorporation of Arsenic (As) and Nitrogen (N) the electronic structure can be designed in such a way that on one side the bandgap becomes direct. On the other side the lattice constant can be tuned to that of Si. Multi-quantum well structures containing the new material Ga(NAsP) were realized and results from optical pumping experiments revealed clear lasing action at low temperatures.

HL 35.4 Wed 14:45 BEY 154

Power limiting effects in 2.X μm emitting GaSb-based Diode-Lasers — •Markus Müller, Marcell Rattunde, Johannes Schmitz, Gudrun Kaufel, and Joachim Wagner — Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastrasse 72, D-79108 Freiburg, Germany

Semiconductor lasers emitting around 2 μm are of interest for a range of applications including material processing, medical diagnostics and therapy or trace gas sensing. (AlGaIn)(AsSb)-based quantum well lasers are well suited for the 1.8-2.4 μm wavelength range as they exhibit excellent lasing characteristics.

Under CW operation the output power of GaSb-based diode lasers is limited by thermal rollover due to self-heating of the active region. To suppress this thermal effect in order to explore the high-power characteristics we analyzed these lasers under pulsed mode operation using 20 ns to 2 μs long current pulses. This way we reached optical pulse power above 16 W from a single-emitter when driven with current pulses up to 100 A. Simultaneously, we performed time-resolved measurements of the lasing spectra (3 ns time frame) in order to deduce remaining self-heating effects from the shift of the lasing spectrum.

The results obtained clearly demonstrate that the high current high power performance of GaSb-based 2.X μm diode lasers is limited by self-heating effects even under short pulse operation. In contrast to GaAs-based devices emitting around 1 μm, no catastrophic optical mirror damage (COMD) is observed even at the highest power densities at the facet of 16 MW/cm^2.

HL 35.5 Wed 15:00 BEY 154

Electrically pumped organic Microcavity-GaN-Hybrid System — •Robert Brückner, Maik Langner, Daniel Kasemann, Hartmut Fröb, Vadim Lyssenko, and Karl Leo — Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Germany

We investigate a monolithic hybrid system as a step towards a small-scale electrically pumped organic solid state laser. A hybrid inorganic-organic emitting system is realized by depositing a high finesse Microcavity (MC) (21 layer DBR of TiO_2 and SiO_2, $\frac{\lambda}{2}$-layer of ALQ_3:DCM) directly on the surface of a UV-LED-Chip (CREE-XL7090). The monolithic system is characterized by negligible losses of the excitation light since no optics are involved. We obtain a high transmission from the GaN-Chip (GaN, n=2,5) to the first mirror layer (TiO_2, n=2,1). An additional DBR on the top of the MC reflects the excitation wavelength of the UV-LED (400nm), and hence the intensity of the pump light in the cavity increases. The LED is driven in pulsed mode operation (pulse duration 20ns @ 2kHz, maximum pulse current 80A) to measure the optical properties of the VCSEL device. We present first results of this hybrid system including emission at the cavity wavelength and Input-Output-characteristics.

15 min. break

HL 35.6 Wed 15:30 BEY 154

Time-resolved lasing-characteristics of external-cavity quantum-cascade (EC-QC) lasers emitting around 7.4 μm — •Borislav Hinkov, Frank Fuchs, Wolfgang Bronner, Klaus Köhler, and Joachim Wagner — Fraunhofer Institute for Applied Solid State Physics (IAF), Tullastraße 72, D-79108 Freiburg, Germany

Quantum-cascade (QC) lasers are semiconductor light sources covering the infrared spectral range from around 3 μm to 15 μm. For use in e.g. molecular fingerprint absorption spectroscopy the spectral tuning range of QC lasers can be extended significantly using external-cavity (EC) setups.

We investigated the temporal evolution of the lasing spectrum of an EC-QC laser emitting around 7.4 μm on a ns time-scale, applying 100 ns long pulses. Immediately after turn-on of the current pulse multiple-

mode lasing starts at the gain maximum of the QC laser controlled by the cavity formed by the chip facets. After a time delay of about 10 ns the QC laser begins to couple to the external cavity as seen from a change in lasing wavelength to that defined by the external grating as wavelength selective element, reaching steady-state operation after 24 ns. The characteristic time constant for the change from internal cavity modes to external cavity operation is derived to 15 ns, comparable to the photon lifetime in the external cavity of 4.5 ns.

The dynamics of this coupling process is not only of fundamental interest but also important for practical applications because most EC-QC lasers are operated in short-pulsed mode.

HL 35.7 Wed 15:45 BEY 154

The Role of Decoupled Electron and Hole Dynamics in the Turn-on Behavior of Semiconductor Quantum-Dot Lasers — •Kathy Lüdge, Ermin Malić, and Eckehard Schöll — Institut für Theoretische Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

Quantum dot (QD) injection lasers are promising candidates for high-speed data transmission applications. However, so far their performance is hindered by low cuttoff frequencies. We show that mixed e-h Auger scattering events lead to separate dynamics for holes and electrons in the device. This decoupling is essential to explain the strong damping of the relaxation oscillations of the laser in excellent agreement with the experiment. For the numerical simulations we combine a microscopic approach for calculating the non-radiative scattering times and a rate equation model for simulating the complex dynamic turn-on behavior.

HL 35.8 Wed 16:00 BEY 154

GaAs-based high power tapered amplifiers in an external cavity setup for frequency doubling — •Christian Schilling, Ralf Ostendorf, Gudrun Kaufel, Rudolf Moritz, Hans-Joachim Wagner, and Oliver Ambacher — Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastrasse 72, 79108 Freiburg, Germany

A range of future applications, especially laser TV, calls for robust and compact green laser sources. One promising approach is the conversion of infrared laser radiation generated by semiconductor laser diodes into green light by frequency doubling. Since the conversion efficiency of this nonlinear optical process depends superlinearly on the incident pump power density, the initial laser source has to provide a high output power combined with a good beam quality and a narrow line width. Frequency stabilized tapered amplifiers in an external cavity setup can meet these demands.

Thus, we have fabricated diode lasers based on the GaInAs/AlGaAs material system consisting of an index-guided ridge wave guide section and a gain-guided tapered section. The centre wavelength is around 1064 nm. A beam propagation factor of $M^2 < 2$ is measured at a maximum output power of 3.5 W. Wavelength tuning in the range from 1030 nm to 1070 nm is achieved by the use of an external diffraction grating in Littrow configuration with both laser facets anti-reflection coated. A split contact design enables us to separately adjust the currents in the ridge- and the taper section, thus allowing for a rapid modulation of the optical output power.

HL 35.9 Wed 16:15 BEY 154

Single mode emitting GaInAsSb/GaSb quantum well lasers operating in continuous wave mode at 3.02 μm — •Thomas Lehnhardt, Michael Hümmer, Karl Rössner, Mirjam Müller, Sven Höfling, and Alfred Forchel — Technische Physik, Universität Würzburg, Germany

Mid-infrared lasers have attracted significant attention for highly sensitive tunable diode laser spectroscopy of gases. We report here on room temperature continuous wave single mode GaSb based quantum well (QW) lasers emitting at record long wavelength of 3 μm.

To obtain this long wavelength several challenges stemming from the GaInAsSb/GaSb material system have to be addressed. High In-contents are needed to realize narrow band gaps for long wavelength operation. In addition, quantization effects have to be reduced to avoid severe blue shifts. Therefore, thick QWs (17 nm) have to be grown, which necessitates higher As-contents in the GaInAsSb QWs. Too high As-contents however cause type-II band alignments. Thus, a compromise has to be found to keep a sufficient confinement for holes to avoid thermal emission from the QWs. With a commonly used band structure model, we estimate for our structures a valence band offset (VBO) in the range of only 20 meV. Nevertheless, we demonstrate with this approach state-of-the art single mode emitting distributed feedback lasers emitting 3 mW output power at room temperature, being ample for gas sensing applications.

15 min. break

HL 35.10 Wed 16:45 BEY 154

Optically pumped GaSb-based semiconductor disk lasers emitting in the 2.0 - 2.8 μm wavelength range — •Rüdiger Moser, Benno Rösener, Marcel Rattunde, Christian Manz, Klaus Köhler, and Joachim Wagner — Fraunhofer-Institut für Angewandte Festkörperphysik, Tullastrasse 72, D-79108 Freiburg, Germany

Semiconductor disk lasers, also known as vertical-external-cavity surface-emitting laser (VECSEL), combine the wavelength versatility and efficiency of diode lasers with the capability of a high output power to be emitted in a nearly diffraction-limited circular beam inherent to solid-state lasers. In the wavelength range between 2 - 3 μm there is a considerable demand for compact high brightness lasers, serving e.g. medical application, material processing or long-range chemical sensing (LIDAR).
In this presentation we report on the development of high-power GaSb-based VECSELs emitting in the 2.0 - 2.8 μm range. By way of barrier pumping with fiber-coupled diode lasers at 980 nm, a maximum cw output power of e.g. 2.8 W at 2.0 μm was obtained at 20 °C heat sink temperature in multi mode operation with a typical spectral width in the range of 10 nm. The optical power conversion efficiency was 18.6 %, corresponding to a quantum efficiency of 37 %. Single longitudinal mode operation was achieved by using an intracavity birefringent quartz plate. By rotating this plate, a tuning range of 118 nm was achieved. Further, results on longer wavelength VECSEL emitting at around 2.8 μm will be presented.

HL 35.11 Wed 17:00 BEY 154

Single Mode Quantum Dot Tapered Lasers — •Pia Weinmann[1], Bjoern Lekitsch[1], Christian Zimmermann[2], Emil-Mihai Pavelescu[3], Johann-Peter Reithmaier[3], Martin Kamp[1], and Alfred Forchel[1] — [1]Technische Physik, Am Hubland, 97074 Würzburg — [2]nanoplus GmbH, Oberer Kirschberg 4, 97218 Gerbrunn — [3]INA, Universtität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel

A high output power combined with a good beam quality has made tapered lasers promising devices for applications in telecommunication, healthcare or i.e. as pump source for fibre lasers. For several applications, such as frequency doubling or pumping narrow absorption lines, a stable and spectrally narrow emission is required. We present quantum dot (QD) based tapered lasers in the 920nm and 1060nm wavelength range that fulfill these requirements. Compared to quantum well material, the shift of the emission wavelength with temperature is reduced by a factor of more than two since the decrease of the bandgap with increasing temperature can be partially balanced by the blueshift of the QD peak gain due to the increasing losses. Further stabilization of the wavelength can be achieved by including a wavelength selective distributed Bragg reflector (DBR) in the laser cavity. We have combined gain and index guided tapered lasers with etched DBR gratings, this approach allows an overgrowth free fabrication. The emission spectrum of the devices shows a very narrow spectral linewidth in combination with sidemode suppression ratios of over 40 dB. The shift of the emission wavelength with temperature is only 0.07nm/K. Output powers up to 2W are achieved with good beam quality.

HL 35.12 Wed 17:15 BEY 154

Towards green lasing: polar and nonpolar — •Alexander Daniel Dräger[1], Holger Jönen[1], Uwe Rossow[1], Heiko Bremers[1], David Schenk[2], Pierre Demolon[2], Jean-Yves Duboz[2], Brian Corbett[3], and Andreas Hangleiter[1] — [1]Institut für Angewandte Physik, TU Braunschweig, Germany — [2]CRHEA-CNRS , Valbonne, France — [3]Tyndall National Institute, Cork, Ireland

While GaInN based violet-blue laser diodes are by now commercially available in large quantities and reach high output powers and long lifetimes, a green laser based on the same material system is not yet achieved. The aim of our work is to realize a green emitting laser. Therefore we investigated laser structures grown on SiC, sapphire and GaN substrates using the variable stripe length technique for gain measurement. Here we focus on two major problems that arise for laser diodes emitting in the green spectral range: the increase of the indium composition in the quantum well to 35% and above and the decrease

of the optical confinement due to the decreased refractive index contrast between AlGaN and GaN. We present laser stuctures with high indium containing QW as well as with enhanced optical confinement.

Furthermore we grew and investigated structures on nonpolar substrates such as m-plane SiC. We compare the results of these measurements with those on similar structures grown on polar substrates and show the necessary changes to the structure for the growth on nonpolar substrates.

HL 35.13 Wed 17:30 BEY 154

Spin-relaxation measurements in VCSEL-structures at room temperature — •Hendrik Jähme[1], Mingyuan Li[1], Stephan Hövel[1], Nils C. Gerhardt[1], Martin R. Hofmann[1], A. Kroner[2], and R. Michalzik[2] — [1]Ruhr-Universität Bochum, Lehrstuhl für Photonik und Terahertztechnologie — [2]Institut für Optoelektronik, Universität Ulm

We investigate the dynamic behaviour of optically induced electron spin-relaxation in a vertical-cavity surface-emitting laser (VCSEL). As the VCSEL emits perpendicularly to the active layer, it satisfies the Faraday-geometry required for the optical selection rules. A spin-amplification has been observed in such structures [1] raising interest in the utilisation of such devices for practical spintronic applications. We use a GaAs/AlGaAs-multi-quantum-well-laser and excite a spin-polarisation of electrons by pulsed optical pumping with circularly polarised light. Additionally the structure is pumped electrically to tune the rate of polarised carriers allowing an estimation of the spin-amplification [2]. A Stokes-polarimeter and a streak-camera are used to determine the degree of light polarisation and its dynamics.

An influence of the excitation on the emitted polarisation is observed. The dynamic measurements show relaxation-processes which are faster than the carrier-recombination dynamics. In this context we see a clear temporal separation between the pulses of right and left circularly polarised light on a low ps-timescale.

We thank the DFG for support within the SFB491

[1] S. Hövel et al, Spin controlled optically pumped vertical cavity surface emitting laser. Electronic Letters 41 (2005), No. 5

[2] S. Hövel et al, Optical spin manipulation of electrically pumped vertical-cavity surface-emitting lasers. APL 92, 041118 (2008)