HL 88: Lasers

Time: Friday 10:15–13:30 Location: POT 151

HL 88.1 Fri 10:15 POT 151

Effects of Many-Body Coulomb Effects on Injection-Locked Quantum Dot Lasers — •Benjamin Lingnau[1], Kathy Lüdge[1], Eckehard Schöll[1], and Weng W. Chow[2] — [1]Institut f. Theo. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Sandia National Laboratories, Albuquerque, New Mexico 87185-1086, USA

We simulate a single-mode quantum dot semiconductor laser device under the injection of an external optical signal into the laser cavity. For a certain range of parameters, the laser will be frequency-locked to the injected signal. In the past, many-body Coulomb effects were found to influence laser dynamics[1]. With our simulations, we now investigate how many-body Coulomb effects influence the locking behavior of the device, and the parameter range for which frequency locking occurs. The theory used in the simulations is based on a semiclassical approach, where the laser field and active medium are described by the Maxwell-semiconductor-Bloch equations. Many-body Coulomb effects are described within the screened Hartree-Fock approximation. Carrier-carrier and carrier-phonon collisions are treated within the effective relaxation rate approximation. Inhomogeneous broadenening of the quantum-dot distribution is taken into account.

[1] B. Lingnau, K. Lüdge, E. Schöll, and W. W. Chow, "Many-body and nonequilibrium effects on relaxation oscillations in a quantum-dot microcavity laser", Appl. Phys. Lett. 97, 111102 (2010)

HL 88.2 Fri 10:30 POT 151

Optical Gain, Thermal Resistance and Antiguiding Factor of GaN-based Laser Diodes from UV to Green — •Wolfgang Scheibenzuber[1], Ulrich Schwarz[1], Teresa Lermer[2], Stephan Lutgen[2], and Uwe Strauss[2] — [1]Fraunhofer IAF, Tullastrasse 72, D-79108 Freiburg, Germany — [2]Osram Opto Semiconductors GmbH, Leibnizstrasse 4, D-93055 Regensburg, Germany

For highly efficient GaN-based laser diodes emitting from UV to green, suitable for projection applications or ultra short pulse generation, a detailed knowledge of the internal device properties optical gain, internal losses, thermal resistance and antiguiding factor is required. We measure these properties on state-of-the-art laser diodes emitting from UV to green. Optical gain and internal losses are determined from the modulation depth of the longitudinal modes in the electroluminescence spectrum below threshold using the Hakki-Paoli method. The measurements show an increase of the spectral width of the gain spectra towards longer laser wavelength, which is related to the larger inhomogeneous broadening and band-filling in InGaN quantum wells with high indium content. The thermal resistance of the devices is determined from the shift of the longitudinal modes above threshold. From the wavelength-shift of the longitudinal modes with increasing current at a constant device temperature we extract the charge carrier induced refractive index change and calculate the antiguiding factor of the laser diodes. All three examined samples have an antiguiding factor of 4 +- 0.5.

HL 88.3 Fri 10:45 POT 151

Implementing 330 nm UV-output by frequency doubling of a miniaturized red AlGaInP-VECSEL emitting at 660 nm — •Hermann Kahle, Thomas Schwarzbäck, Marcus Eichfelder, Wolfgang-Michael Schulz, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Vertical external cavity surface-emitting lasers (VECSELs) have emerged as an important category of power-scalable and frequency tunable semiconductor lasers. Using external cavities, optical pumping and intra-cavity optical elements, VECSELs provide the possibility of intra-cavity frequency doubling. We present a VECSEL-Chip design, based on a multi-quantum-well structure with 20 compressively-strained $GaInP$ quantum wells (QWs) grown by metal-organic vapour-phase epitaxy on $GaAs$ substrates for an operation wavelength of around 660 nm. Five QW packages are placed in $(Al_{0.55}Ga_{0.45})_{0.51}In_{0.49}P$ cladding layers, which are lattice matched to $GaAs$, in a resonant periodic gain design. Each package consists of four QWs embedded in $(Al_{0.33}Ga_{0.67})_{0.51}In_{0.49}P$ barriers. The 3 λ thick cavity is fabricated on an $Al_{0.50}Ga_{0.50}As/AlAs$ distributed Bragg reflector. By inserting a BBO-crystal into the cavity, we present an UV-emitting laser. Frequency-tuning using a birefringent filter will be presented. To improve pump photon absorption in the active region of the VECSEL-Chip, a design with 20 QWs, grouped in pairs, is also possible.

HL 88.4 Fri 11:00 POT 151

Thermal properties of high power vertical-external-cavity surface-emitting lasers — •Alexej Chernikov[1], Jens Herrmann[1], Maik Scheller[1], Martin Koch[1], Bernadette Kunert[1], Wolfgang Stolz[1], Sangam Chatterjee[1], Stephan W. Koch[1], Tsuei-Lian Wang[2], Yushi Kaneda[2], Joe M. Yarborough[2], Jörg Hader[2], and Jerome V. Moloney[2] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]College of Optical Sciences, The University of Arizona, 1630East University Boulevard, Tucson, AZ 85721, USA

Vertical-external-cavity surface-emitting lasers (VECSELs), developed in the late 90s, have received much attention in the scientific community due to the unique combination of high output power and excellent beam quality. VECSELs provide light across a broad spectral range, efficient intra-cavity frequency mixing as well as the possibility for pulsed operation. The majority of the applications rely on the high output power of the device. Since overheating generally limits the laser performance, efficient cooling concepts as well as careful choice of the pump profile are crucial. Here, we focus on the thermal properties of a high-power VECSEL. Spatially resolved temperature measurements are performed under simultaneous monitoring of the output characteristics of the device. Our results illustrate the substantial importance of three-dimensional heat transfer in the structure, limiting the VECSEL performance for large spot sizes. Finally, the heat-removal concept is optimized for a maximum output power above 70 W.

HL 88.5 Fri 11:15 POT 151

Red-emitting, highly polarized vertical-cavity surface-emitting lasers as lighting module for active microoptics — •Susanne Weidenfeld[1], Michael Wiesner[1], Marcus Eichfelder[1], Frederik Schaal[2], Christof Pruss[2], Wolfgang Osten[2], Robert Rossbach[1], Michael Jetter[1], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Institut für Technische Optik, Universität Stuttgart, Pfaffenwaldring 9, 70569 Stuttgart, Germany

AlGaInP-based vertical-cavity surface-emitting lasers (VCSELs) are attractive candidates for optical data transmission via polymer optical fibers (POF) meeting the POF's attenuation minimum at around 650 nm. For different applications the fundamental mode is desirable as well as a stable linear polarization. This is especially essential for the implementation of the VCSEL as a lighting module in a device that spatially resolved controls the polarization of incident light. With the monolithic integration of an oxide aperture, the transverse beam profile can be defined. The vertical structure of these lasers and thus the on-wafer processing offers also the opportunity to implement beam shaping optics monolithically in the surface. We present detailed analysis of the transverse beam profile and polarization characteristics of VCSELs. We demonstrate that oxide aperture sizes smaller than 6 μm are required for emission in fundamental mode and that the devices are highly linearly polarized. We further show first steps towards integrating beam shaping optics into the top mirror of the VCSEL.

HL 88.6 Fri 11:30 POT 151

Laser Diode Self-Mixing Velocimetry of Solid and Liquid Targets — •Thomas Glässer[1], Wolfgang Elsässer[1], and James O'Gorman[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstraße 7, 64289 Darmstadt — [2]previously with Eblana Photonics, Dublin (Ireland)

The laser diode self-mixing (or optical feedback) interferometry technique is a contactless measurement technique based on a very simple configuration. The setup consists only of a laser diode (LD), the focusing optics and the target to be probed. The laser beam is scattered by the target and partly back reflected into the laser cavity. This leads to a interferometric carrier and power modulation of the LD containing

information about the velocity of the target. For signal detection a monitor photodiode included in the LD package could be used.

Compared to the widely established laser doppler velocimetry (LDV), which is based on Mach Zehnder or Michelson interferometers, the self-mixing approach provides advantages in its setup size and wight and allows much easier adjustment at very low cost.

We present velocity measurements on different flowing liquids using near infrared discrete mode LDs at 1300 nm and 1550 nm.

15 min. break

HL 88.7 Fri 12:00 POT 151

Single-mode Quantum Cascade Lasers Employing a Candy-cane Shaped Fabry-Perot Cavity — Peter Q. Liu[1], •Kamil Sladek[1,2], Xiaojun Wang[3], Jen-Yu Fan[3], and Claire F. Gmachl[1] — [1]Department of Electrical Engineering, Princeton University, Princeton, NJ 08544 USA — [2]Institute of Bio- and Nanosystems (IBN-1), Jülich Aachen Research Alliance (JARA), Forschungszentrum Jülich, 52425 Jülich, Germany — [3]AdTech Optics, 18007 Cortney Court, City of Industry, CA 91748 USA

Quantum Cascade (QC) lasers are versatile mid-infrared light sources for spectroscopic molecular sensing. Most of the applications require single-mode operation of the QC lasers, which is usually achieved by either integrating distributed feedback gratings into the laser cavity or making use of an external cavity. However, both approaches require more complicated fabrication and/or coating processes. Previously we demonstrated single-mode QC lasers employing a folded FP cavity which is essentially a monolithic coupled-cavity fully compatible with simple (no Bragg gratings) ridge waveguide laser fabrication. Those lasers have single-mode performance, high throughput and relatively lower cost. Here we present an even simpler monolithic coupled-cavity design, a candy-cane shaped FP cavity, to achieve single-facet, single-mode QC lasers. It demonstrates a straightforward path to achieving single mode operation of QC lasers. Single-mode emission from QC lasers up to ~500 mA (~70%) above the threshold current is achieved in pulsed mode operation at 80 K with a SMSR of ~25dB. Mode-hop free temperature tuning of the emission wavelength is also demonstrated.

HL 88.8 Fri 12:15 POT 151

Three-section DBR lasers based on surface defined gratings for high speed telecommunication applications — •S. Afzal[1], F. Schnabel[1], W. Scholz[1], J. P. Reithmaier[1], A. Capua[2], E. Shumakher[2], G. Eisenstein[2], O. Parillaud[3], M. Krakowski[3], I. Montrosset[4], and M. Vallone[4] — [1]INA, University of Kassel. — [2]Technion, Israel. — [3]Alcatel-III-V Lab, France. — [4]Politecnico di Torino, Italy.

To combine low-cost fabrication and high-speed data communication like 100 GBit/s, multi-section DBR lasers are developed with nanoimprint compatible surface defined gratings. This laser design has the potential to enhance the modulation bandwidth by exciting a higher order optical mode, the so-called photon-photon resonance (PPR). ICP-RIE etching was used to transfer the e-beam exposed surface pattern in one step into the semiconductor. High aspect ratios of $>$ 1:15, vertical trenches with a width of about 140 nm and an etch depth of $>$ 2 um were obtained for the lateral gratings. The three-section lasers are fabricated on a MOVPE grown 1.5 um InP laser material exhibiting CW threshold currents of 94 mA for a 0.9 mm long device. A side mode suppression ratio of $>$ 50 dB could be achieved demonstrating a high enough coupling strength of the lateral gratings. The influence of different operation conditions (currents, temperature) and dependence on the grating period on threshold current and emission wavelength are studied and will be discussed. First high frequency measurements in operation conditions without PPR enhancement show a -3dB bandwidth of about 15 GHz.

HL 88.9 Fri 12:30 POT 151

2.3 μm GaSb-based semiconductor disk laser with sub-MHz linewidth — •Sebastian Kaspar, Benno Rösener, Marcel Rattunde, Tino Töpper, 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 lasers (VECSELs) can be regarded as a hybrid of classical semiconductor lasers and solid state lasers, offering an almost free choice of wavelength, high output power and diffraction-limited circular beam. VECSELs emitting in the $2-3\,\mu$m wavelength range are of special interest for a variety of applications such as materials processing and laser surgery. Other applications like spectroscopy and optical data transmission require narrow linewidth laser sources.

We report on the realization of narrow-linewidth GaSb-based VECSELs emitting in the $2.0-2.3\,\mu$m range. Single frequency emission is realized by inserting a quartz plate as birefringent filter into the external resonator for wavelength control and by optimizing the cavity for TEM_{00} mode operation. By using a high-finesse Fabry-Pérot interferometer (FPI), stable single frequency operation was verified with an output power above 200 mW. Coarse wavelength tuning of up to 118 nm is achieved by rotating the quartz plate. Modehop-free fine-tuning of the laser wavelength of over 5 GHz was possible by mounting the output coupling mirror to a piezoelectric transducer. By stabilizing the emission wavelength to the edge of a FPI transmission maximum, a linewidth of less than 400 kHz was achieved.

HL 88.10 Fri 12:45 POT 151

2.0 μm GaSb-based semiconductor disk lasers optically pumped at different wavelengths — •Tino Töpper, Benno Rösener, Marcel Rattunde, Sebastian Kasper, Christian Manz, Klaus Köhler, and Joachim Wagner — Fraunhofer IAF, 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 emitted in a nearly diffraction-limited circular beam inherent to solid-state lasers. VECSEL in the wavelength range of 2-3μm are of interest for a broad range of applications including material processing, medical therapy and trace gas sensing.

We will report on the direct comparison of two GaSb-based VECSEL structures, both with an emission wavelength of 2.0μm but with different active region designs, optimized for barrier-pumping at 1.0μm (AlGaAsSb-barriers) and 1.5μm (GaSb-barriers). Both structures were characterized in pulsed mode in order to reduce thermal heating effects. At room temperature, the power efficiency of the 1.5μm-pumped structure is 1.43-times higher than the 1.0μm-pumped structure, reflecting directly the reduced quantum deficit due to the longer pump-wavelength. Temperature dependant measurements revealed that the decrease in power efficiency and increase in threshold pump power with increasing temperature is more pronounced for the 1.5μm-pumped structure. We attribute this effect to the reduced barrier height of the latter structure and thus increased heterobarrier leakage.

HL 88.11 Fri 13:00 POT 151

Investigation of heat dissipation in Mid-Infrared quantum cascade lasers — •Stefanie Mayer, Christian Schilling, Ralf Ostendorf, Quankui Yang, Rainer Lösch, Wolfgang Bronner, and Joachim Wagner — Fraunhofer Institut für Angewandte Festkörperphysik IAF, Freiburg, Deutschland

The output power and efficiency of quantum cascade lasers (QCL) is severely limited by self-heating effects of the device during operation. Therefore, a fundamental knowledge of the heat dissipation is essential for further device optimization.

We present modelling of heat transfer processes in GaInAs/AlInAs/InP-based QCLs by finite elements analysis. The influence of different mounting techniques and of different heat spreaders on the temperature of the active region has been studied. The results indicate a significant reduction of the temperature (by about 40-50 %) inside the device by using diamond heat-spreaders and epi-down mounting due to improved heat dissipation. In addition we extended our analysis to QCL arrays and investigated thermal crosstalk between adjacent emitters of the array.

These results are confirmed by electro-optical measurements performed on QCL emitting at a wavelength of 4.7 μm. Here, an enhancement of 148.47 % in optical peak output power was observed in pulsed operation mode with 10 % duty cycle by using diamond heat-spreaders and epi-down mounting.

HL 88.12 Fri 13:15 POT 151

Spin induced polarization oscillations in vertical-cavity surface-emitting laser devices — •Mingyuan Li[1], Henning Soldat[1], Hendrik Jähme[1], Nils C. Gerhardt[1], Martin R. Hofmann[1], and Thorsten Ackemann[2] — [1]Chair of Photonics and Terahertz-Technology, Ruhr University of Bochum, Germany — [2]SUPA and Department of Physics, University of Strathclyde, Glasgow, Scotland, UK

The capabilities of spin controlled vertical-cavity surface-emitting

lasers (VCSELs) such as high-speed modulation and amplification of spin information due to the nonlinearity at threshold offer a promising method of communication with enhanced bandwidth. We investigate the polarization dynamics of electrically pumped vertical-cavity surface-emitting lasers after additional spin injection at room temperature. The experimental results demonstrate a stable polarization oscillations with a frequency in the high GHz range, which is determined by device parameters such as linear birefringence and linear dichroism. A theoretical calculation on the basis of a rate equation model is performed, in order to understand the underlying mechanism for coupling between the dynamics and device parameters. The calculation reveals a possibility to control the frequency of the oscillations by tuning the birefringence.