# HL 16 Semiconductor laser I

Time: Tuesday 11:00–13:15 Room: BEY 154

HL 16.1 Tue 11:00 BEY 154

**Spatio-Temporal Emission Dynamics of VCSELs with a Surface Grating** — •Christian Fuchs[1], Tobias Gensty[1], Joachim Kaiser[1], Johannes Michael Ostermann[2,3], Pierluigi Debernardi[3], and Wolfgang Elsässer[1] — [1]Institut für Angewandte Physik, Schloßgartenstr. 7, 64289 Darmstadt, Germany — [2]Optoelectronics Department, University of Ulm, Albert-Einstein-Allee 45, 89069 Ulm, Germany — [3]IEIIT-CNR c/o Politecnico di Torino, 10129 Torino, Italy

VCSELs are a low-cost lightsource for optical datacom applications. Because of the modal dispersion in fibers, not only spectrally single-mode, but in addition polarisation stable emission with high Orthogonal Polarisation Suppression Ratio (OPSR) at high output power is desired. We present 2D-spatially, spectrally and polarisation resolved picosecond measurements of the nearfield emission dynamics of small diameter oxide-confined VCSELs with an integrated surface grating based on a relief technique to enhance the selection of one polarisation mode [1]. The characterisation of the repetitive part of the dynamics within the turn-on process is realized with Temporally Resolved Imaging by Differential Analysis (TRIDA) providing a time resolution down to 10 ps. In addition single-shot measurements are performed to analyse the non-repetitive part of the emission dynamics. The influence of the grating parameters on the polarisation behaviour is discussed in comparison to numerical simulations.

[1] J.M. Ostermann, P. Debernardi, C. Jalics, A. Kroner, M.C. Riedl, R. Michalzik, Opt. Commun. 246, 511 (2005)

HL 16.2 Tue 11:15 BEY 154

**Gain and threshold current in quantum-wire intersubband laser structures** — •Thomas Herrle, Stephan Haneder, and Werner Wegscheider — Institut für Experimentelle und Angewandte Physik Universität Regensburg, 93040 Regensburg

In recent years quantum cascade structures with quantum-wire and quantum-dot active regions are more and more investigated. The reason for this is the theoretical prediction of a decrease of non-radiative losses in lower dimensional systems. This is experimentally confirmed by the superior performance of quantum cascade lasers in an applied magnetic field, where the lower dimensionality of the electron system is achieved by the Landau quantization [1]. In the presented work we calculate the gain and the threshold current for a quantum-wire intersubband laser structure proposed in [2], which is fabricated by the cleaved edge overgrowth technique. We report on the influence of the formation of excited states in these structures on the gain and threshold current. It turns out that these excited states have to be avoided in the sample design of such structures to end up with higher gain values in the quantum-wire structures compared to conventional quantum-well systems.

[1] C. Becker, C. Sirtori, O. Drachenko, V. Rylkov, D. Smirnov, J. Leotin, Appl. Phys. Lett. **81**, 2941 (2002).
[2] Ingo Keck, Stefan Schmult, Werner Wegscheider, Martin Rother, Andreas P. Mayer, Phys. Rev. B **67**, 125312 (2003).

HL 16.3 Tue 11:30 BEY 154

**Solutions towards high temperature AlGaInP-VCSEL** — •Marcus Eichfelder[1,2], Robert Rossbach[1,2], Heinz Schweizer[1], Michael Jetter[1,2], and Peter Michler[2] — [1]4$^{th}$ Physics Institute, University Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]5$^{th}$ Physics Institute, University Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

Vertical cavity surface emitting lasers (VCSEL) based on AlGaInP material system have attracted much interest as potential key components for low-cost optical data communication via plastic optical fibres (POF). This material system seems to fail the requirements of e.g. automotive applications (+125°C) due to the poor electron confinement and therefore they show high temperature sensitivity. We investigated the internal heating of our VCSELs by using a cylindrical heat dissipation model [1]. Out of these data we found a strong dependence of the aperture and mesa diameter and their ratio on the temperature behaviour. With this knowledge we designed new devices with an additional heat spreading layer for further heat removal. First results will be presented.

[1] W. Nakwaski, M. Osinski. Thermal resistance of top-surface-emitting vertical-cavity semiconductor lasers and monolithic two-dimensional arrays, Electron. Lett., 28, p. 572, 1992.

HL 16.4 Tue 11:45 BEY 154

**Temperature and Band gap Dependence of Carrier Recombination Processes in GaAsSb/GaAs Quantum Well Lasers** — •Konstanze Hild[1], Igor Marko[1], Shirong Jin[1], Stephen Sweeney[1], Jiang-Bo Wang[2], Shane Johnson[2], and Yong-Hang Zhang[2] — [1]Advanced Technology Institute, University of Surrey, Guildford, GU2 7XH, Surrey, United Kingdom — [2]MBE Optoelectronics group, Arizona State University, Tempe, USA

GaAs-based vertical cavity surface emitting lasers (VCSELs) emitting at 1.31 $\mu$m are of considerable importance for the development of fibre-to-the home communication systems. GaAs is the preferred substrate for VCSELs due to the strong index contrast achievable with AlGaAs Distributed Bragg Reflector (DBR) mirrors. One possible and compatible active region is GaAsSb/GaAs QWs. Lasers based upon this material have been successfully produced but remarkably little research has been undertaken to assess the carrier recombination processes occurring in this material and their temperature variation. In this study we used low temperature and high pressure techniques (to vary the band gap) to investigate edge-emitting lasers processed from wafers grown by Solid Source MBE. We find that at room temperature the device behaviour is dominated by non-radiative recombination accounting for approximately 90% of the total threshold current density. Furthermore, our pressure dependence measurements suggest that this may be attributed to thermalisation of electrons into the GaAs barriers.

HL 16.5 Tue 12:00 BEY 154

**Polarization and emission direction dependend measurements on CEO Quantum Wire Cascade Emitter Devices** — •Stephan Haneder, Thomas Herrle, Christian Gerl, Dieter Schuh, and Werner Wegscheider — Institut für Experimentelle und Angewandte Physik Universität Regensburg, 93040 Regensburg

We developed a quantum wire cascade device emitting in the Mid-Infrared spectral range by using the Cleaved Edge Overgrowth (CEO) technique [1]. Basic theoretical considerations predict a decrease of non-radiative losses in lower dimensional systems [2]. To investigate the origin of the emitted light and to analyse the electronic intersubband transitions between quantum wire states, polarization and emission direction depend measurements have been carried out. It turns out that the emitted light is TM polarized, but not TE polarized. This can be attributed to the weak confinement in the [110] direction. Temperature dependend measurements show a redshift of the intersubband transition with increasing temperature and a limitation of the performance to about 130 K. We have also performed measurements on quantum wire cascade structures equipped with a T-shaped waveguide [3].

[1] S.Schmult, I.Keck, T.Herrle, W.Wegscheider, M.Bichler, D.Schuh and G.Abstreiter, Appl. Phys. Lett. 83, 1909 (2003). [2] I.Keck, S.Schmult, W.Wegscheider, M.Rother and A.P.Mayer, Phys. Rev. B67, 125212 (2003). [3] T.Herrle, S.Schmult, M.Piendl, U.T.Schwarz and W.Wegscheider, Phys. Rev. B72, 035316 (2005).

HL 16.6 Tue 12:15 BEY 154

**Low divergence single-mode edge emitting 650 nm lasers based on longitudinal photonic bandgap crystal** — •Kristijan Posilovic[1], Thorsten Kettler[1], Leonid Ya. Karachinsky[2], Vitaly A. Shchukin[1,3], Vladimir P. Kalosha[4], Udo W. Pohl[1], Nikolai N. Ledentsov[1,3], and Dieter Bimberg[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin — [2]Ioffe Physico-Technical Institute, St.Petersburg — [3]NL Nanosemiconductor GmbH, Dortmund — [4]Department of Physics, University of Ottawa

Conventional edge-emitting lasers suffer from large vertical beam divergence due to a narrow modal spot size of the optical mode, and therefore are seriously limiting practical applications. We present a novel approach to achieve large optical spot size and low divergence. The waveguide is broadened and a one-dimensional photonic bandgap crystal is used to filter higher order modes. The structure was realised in the GaInP-AlGaInP material system grown on GaAs-substrates and processed into narrow ridge waveguide lasers using standard techniques. The devices show fundamental mode emission over a wide range of injection currents proved by near field as well as far field measurements. The lasing

wavelength remained stable at 650 nm over all injection currents. The measured vertical beam divergence is below 10° for all stripe widths investigated. A 4 micron stripe shows lateral beam divergence of 8°, resulting in a circular shaped far field emission.

HL 16.7 Tue 12:30 BEY 154

**Diode lasers for Terahertz applications** — •Carsten Brenner, Stefan Hoffmann, and Martin Hofmann — AG Optoelektronische Bauelemente und Werkstoffe, Ruhr-Universität Bochum, IC2/152, D-44780 Bochum

In recent years the research in Terahertz (THz) radiation has caused a great demand in new industrial applications. Despite this development there is no system for the generation and detection of THz radiation which is able to satisfy the necessary requirements for industrial use, as low cost and sufficient THz emission power. Our approach to close this gap is based on nonlinear processes in semiconductor lasers. We operate a semiconductor laser on two colours in an external cavity and the difference frequency in the THz regime is generated in the cavity itself [1,2]. The necessary steps to increase the THz output power to facilitate imaging applications are presented. Furthermore we discuss a new concept to detect THz radiation at room temperature involving semiconductor lasers.

[1]S. Hoffmann, M. Hofmann, E. Bründermann, M. Havenith, M. Matus, J.V. Moloney, A.S. Moskalenko, M. Kira, S.W. Koch, S. Saito and K. Sakai, Four-wave mixing and direct terahertz emission with two-color semiconductor lasers, Appl. Phys. Lett. 84, 3585 (2004)

[2]S. Hoffmann, M. Hofmann, M. Kira, ans S.W. Koch, Two-color diode lasers for generation of THz radiation, Semiconductor Science and Technology 20, 205 (2005)

HL 16.8 Tue 12:45 BEY 154

**Theory of Nonlinear Optics in Quantum Cascade Lasers** — •Carsten Weber, Fouad Banit, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We investigate nonlinear optical effects, such as Rabi flopping and pump-probe signals, in quantum cascade lasers as model systems to study multisubband semiconductor heterostructures. Nonequilibrium states are formed as an interplay of the optical excitation and different scattering processes. Here, we consider the electron-phonon interaction as well as scattering at ionized doping centers, where the influence of the resonant excitation between two subbands on further subbands can be studied.

HL 16.9 Tue 13:00 BEY 154

**Fabrication and characterization of mid-infrared $GaAs/Al_{0.45}Ga_{0.55}As$ quantum cascade lasers** — •Jan Heinrich[1], Sven Höfling[1], Jochen Seufert[2], Johannes Koeth[2], Johann Peter Reithmaier[1], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]nanoplus Nanosystems and Technologies GmbH, Oberer Kirschberg 4, 97218 Gerbrunn, Germany

Quantum cascade lasers (QCLs) emitting in the mid-infrared (MIR) have made an enormous improvement during the last 10 years. For the fabrication of the devices, we use the $GaAs/Al_xGa_{1-x}As$ material system which has the advantage of nearly perfect lattice-matched layers irrespective of the aluminium content. Moreover, the processing of $GaAs/Al_xGa_{1-x}As$ is easier to handle than for InP based samples. For MIR QCLs, an aluminium content of 45 percent has turned out to be the optimal value for samples operating at high temperatures. Special attention has to be turned on the waveguide and the doping which are essential for efficient devices. In this work we fabricated and investigated QCL designs with 45 percent aluminum content. Particularly the influence of different growth parameters was analyzed. We achieved optimized characteristics with regard to threshold current and output power of the devices by variation of growth parameters and report room temperature operation up to 360 K in pulsed mode. Furthermore, we investigated in particular the dependence of threshold current on injector doping and temperature.