HL 10: Semiconductor Lasers I

Time: Monday 9:30–12:30 Location: POT 06

HL 10.1 Mon 9:30 POT 06

Carrier dynamics in tunnel-injection quantum-dot structures — •Stephan Michael, Michael Lorke, Christian Carmesin, and Frank Jahnke — Institute of Theoretical Physics, University of Bremen, P.O. Box 330440, 28334 Bremen, Germany

For tunnel-injection (TI) quantum-dot (QD) lasers record high small signal modulation bandwidth up to 15 GHz and also high performance of 1.55 μm InAs QDs on InP-based hetero-structures (1) were reported, which shows the enormous application potential for high-speed optical communication networks. The optimal design of future TI lasers benefits from a detailed understanding of the physics and the interplay of various interaction processes involved in such TI devices. We investigated theoretically the carrier dynamics in TI structures by explicitly calculating carrier-phonon and carrier-carrier scattering processes using a material realistic model of the electronic structure based on a discretized Kane Hamiltonian. In doing so, we shed light on the underlying tunneling processes and highlight the importance of hybridized states for high scattering rates. We further specify criteria based on our microscopic calculation to engineer optimal scattering pathways necessary to obtain TI structures for high-speed laser devices.

(1) S. Bhowmick, M. Z. Baten, T. Frost, B. S. Ooi, and P. Bhattacharya, IEEE JQE **50**, NO. 1 7-14 (2014)

HL 10.2 Mon 9:45 POT 06

Simulation of monolithically integrated GaAs-AlGaAs core-shell nanowire lasers on silicon waveguides — •Jochen Bissinger, Thomas Stettner, Tobias Kostenbader, Daniel Ruhstorfer, Gregor Koblmueller, and Jonathan Finley — Walter Schottky Institut, Technische Universität München, Am Coulombwall 4, 85748 Garching

III-V semiconductor nanowire (NW) lasers monolithically integrated on silicon have attracted attention as potential on-chip light sources for optical interconnects. Their unique one-dimensional geometry is both an active gain medium and a natural Fabry-Pérot cavity. However, direct integration of NW-lasers on silicon (Si) is challenging due to the poor modal reflectivity at the NW-Si interface. Recently, we demonstrated how by patterning nano-apertures in a thick SiO_2-interlayer at the NW-Si interface, low-order mode lasing is observed with high β-factors [1]. Such schemes also enable the integration of NW lasers on silicon-on-insulator waveguides and suggest the feasibility of NW-based photonic devices.

In this contribution we simulated the optical loss of GaAs-based NW lasers and their coupling behaviour to a Si-waveguide in dependence of the different design parameters of the system. The performance of the device is found to be mainly affected by the type of lasing mode and the thicknesses of the SiO_2-interlayer and the Si-waveguide. These studies therefore serve as a guideline in the construction of optimized NW lasers on SOI waveguides for future on-chip optical interconnects.
[1] B. Mayer et al., Nano Lett., 16 (1), pp 152-156 (2016).

HL 10.3 Mon 10:00 POT 06

The impact of detuning on the performance of semiconductor disk lasers — Fan Zhang[1], Christoph Möller[1], Martin Koch[1], Stephan Koch[1], •Arash Rahimi-Iman[1], and Wolfgang Stolz[1,2] — [1]Department of Physics and Materials Sciences Center, Philipps-Universität Marburg, D-35032 Marburg, Germany — [2]NAsP III/V GmbH, Hans-Meerwein-Straße, D-35032 Marburg, Germany

After two decades of research and development, semiconductor disk lasers (SDLs), also referred to as vertical-external-cavity surface-emitting lasers (VECSELs), are recognized as advanced light sources offering a high-power output and excellent beam quality, while the lasing wavelength can be set by semiconductor bandgap engineering. In this work, we focus on an important, yet less-discussed factor, namely the detuning in SDLs. It is defined as the wavelength difference between the material gain and the longitudinal confinement factor (LCF) at room temperature. Due to device-to-device fluctuations, it is difficult to conduct direct experimental studies on the detuning. Therefore, a new approach is promoted to achieve different detunings from the same gain chip: by altering the cavity angle of a V-shaped cavity in which the VECSEL chip serves as a folding mirror. As the negative detuning is raised from -20 nm to -37 nm, a significant increment of the maximum output power by 70% is observed, while the lasing threshold is elevated from 7.4 W to 25.6 W due to the increased detuning. Yet, the modification of the intra-cavity incidence angle on the chip also leads to a shift of the emission wavelength of about 16 nm and enhances the tunability to 34 nm.

HL 10.4 Mon 10:15 POT 06

The MECSEL: A new laser concept towards AlGaInP-based direct laser emission in the orange spectral range — •Raffael Pecoroni, Hermann Kahle, Roman Bek, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen and Research Centers ScoPE and IQST, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

The new MECSEL (membrane external-cavity surface-emitting laser) concept consists of an active region without integrated DBR (distributed Bragg reflector), sandwiched in between two intra-cavity heat spreaders. The advantage now is that unusual material combinations can be used as active regions as growth restrictions due to lattice mismatch do not play a role anymore. Furthermore, no limitation of absorbing DBR layers have to be taken into account. This allows us now to reach for example the orange spectral range with an AlGaInP-based active region. Here, we include $Al_{0.33}GaInP$ quantum wells into $Al_{0.55}GaInP$-barrier layers, release wet-chemically etched the substrate and sandwich it between intra-cavity heat spreaders. First characterization measurements of the gain membranes and the operation as vertical emitting laser will be presented.

HL 10.5 Mon 10:30 POT 06

Quantum dot micropillar lasers subject to time-delayed optical feedback — •Steffen Holzinger[1], Xavier Porte[1], Benjamin Lingnau[2], Kathy Lüdge[2], Christian Schneider[3], Martin Kamp[3], Sven Höfling[3,4], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]Institut für Theoretische Physik, Technische Universität Berlin, Germany — [3]Technische Physik, Julius-Maximilians-Universität Würzburg, Germany — [4]School of Physics and Astronomy, University of St Andrews, Scotland

The chaotic dynamics of feedback-coupled semiconductor lasers have been so far mainly experimentally studied in the classical regime. Electrically pumped quantum dot micropillar lasers provide an advantageous platform for the realization of feedback experiments in the regime of few photons, where single emitter effects and high spontaneous emission noise become prominent. In these structures two linear, orthogonally polarized lasing modes compete for a common gain medium, resulting in characteristic switching dynamics above the lasing threshold. Using an external cavity, we experimentally and theoretically investigate the influence of the feedback strength, external cavity length and polarization on the optical spectrum as well as the switching dynamics of the lasing modes.

Coffee Break

HL 10.6 Mon 11:15 POT 06

Generation of high frequency oscillations independently of the external cavity length in a semiconductor laser with optical feedback — •Chi-Hak UY[1], Lionel WEICKER[1], Martin VIRTE[2], Emeric MERCIER[1], Delphine WOLFERSBERGER[1], and Marc SCIAMANNA[1] — [1]LMOPS, CentraleSupélec, 2 rue Edouard Belin 57000 Metz FRANCE — [2]Brussels Photonic Team, Department of Applied Physics and Photonics (B-PHOT TONA), Vrije Universiteit Brussels, Pleinlaan 2, 1050 Brussels, Belgium

We numerically investigate the external cavity modes generated by a semiconductor laser subject to a phase-conjugate optical feedback (PCF). We explore the effects of both the cavity length and the feedback rate on the frequency of the external cavity modes which are periodical solutions in PCF configuration. From this analysis, we observe that a short cavity does not necessarily leads to higher frequency oscillations and highlight that the key parameter for the generation of such solutions is the feedback rate. Indeed, independently of the time delay the feedback strength fixes the frequency of the solutions obtained. Finally, we investigate the Hopf bifurcations and their frequencies and deduct the frequency of the external cavity modes expected.

HL 10.7 Mon 11:30 POT 06

Mode-locking dynamics and pulse train stability of monolithic two-section quantum-well semiconductor lasers emitting at 1070 nm with different lengths and gain-to-absorber section length ratios — •Christoph Weber[1], Andreas Klehr[2], Andrea Knigge[2], and Stefan Breuer[1] — [1]Institute of Applied Physics, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

We experimentally investigate the mode-locking (ML) dynamics of passively mode-locked multi-section multi quantum well narrow ridge waveguide semiconductor lasers emitting at a peak wavelength of 1070 nm. ML stability is quantified by pulse train timing jitter (TJ) as well as the relative amplitude jitter (AJ) in dependence on laser biasing by gain injection current and absorber reverse bias voltage. Initial results on pulse train stability analysis have been presented in C. Weber et al., Proc. SPIE, 9892-77, 2016, and on mode-locking stability of a quantum well laser in C. Weber et al., Proc IEEE Internat. Conf. on Transparent Optical Networks, We.P.29, 2016. In this contribution, lasers with different total cavity lengths and absorber to gain section length ratios are studied and regimes of stable and unstable emission are identified by stability analysis, and studies on average and peak optical power, pulse width and pulse repetition rate, enabling a direct comparison of ML regimes.

HL 10.8 Mon 11:45 POT 06

k-space engineering of laser modes in organic microcavities with photonic lattices — •Mona Kliem, Andreas Mischok, Hartmut Fröb, and Karl Leo — Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP), Technische Universität Dresden, 01062 Dresden

Microcavities (MCs) offer a flexible playground to study photon and polariton dispersion in a tunable potential landscape. In vertical MCs, confined photons exhibit a parabolic dispersion relation and in turn behave similarly to other parabolic particles such as free electrons, albeit with an approx. 10^{-5} times smaller effective mass, leading to very low condensation and/or lasing thresholds. By adding a silver layer inside of an organic MC, we observe the formation of Tamm-plasmon-polariton states, shifting the cavity potential to lower energies. Consequently, patterning this thin silver layer enables us to manipulate the potential landscape and create periodic photonic lattices in 2D and 3D, exhibiting Bloch-like band structures in both k_x and k_y direction. The silver layer is photolithographically structured on top of a distributed Bragg reflector (DBR) to achieve micron-scale stripe-, hole- and dot-like patterns, arranged in square and hexagonal arrays before finishing the sample with a $\lambda/2$ active layer and top DBR. We study the effect of these photonic lattices on the full in-plane MC dispersion via tomographic micro-photoluminescence measurements and observe novel lasing modes at band edges of the resulting energy diagram. By choosing the right design parameters of the silver pattern we are able to directly engineer and control the lasing performance of our MCs.

HL 10.9 Mon 12:00 POT 06

Intensity and Wavefront Analysis of Multimode Semiconductor Lasers — •Inga-Maria Eichentopf and Martin Reufer — Hochschule Ruhr West, Institut Naturwissenschaften, Mülheim an der Ruhr, Germany

To analyse the beam characteristics of laser sources wavefront measurements using a Shack-Hartmann Sensor became an established way for nearly Gaussian beams. The aim of our research is to transfer this method to broad area semiconductor lasers. The multimode lasers we utilize in our studies are based on the material system of GaAs emitting light in the near infrared. For this type of laser the number and structure of optical modes is affected by electrical as well as thermal effects inside the laser resonator. Thereby the changes in modal composition can be detected instantaneously through the deformation of the wavefront. For our investigations we use a so called Gaussian telescope setup to magnify the cross section of the laser beam and to increase the length of spatial transition from optical near to far field. This approach is used to analyze the emission evolution of high power laser diodes which emit a multitude of optical modes.

HL 10.10 Mon 12:15 POT 06

Analysis of ultra-low threshold lasing from a nanobeam laser with a quantum-well gain material — •Frederik Lohof[1], Stephan Jagsch[2], Noelia Vico Triviño[3], Gordon Callsen[2], Stefan Kalinowski[2], Ian Rousseau[3], Jean-François Carlin[3], Raphaël Butté[3], Axel Hoffmann[2], Nicolas Grandjean[3], Frank Jahnke[2], Stephan Reitzenstein[1], and Christopher Gies[1] — [1]Institute for Theoretical Physics, University of Bremen, Germany — [2]Institute of Solid State Physics, Technische Universität Berlin, Germany — [3]Institute of Physics, École Polytechnique Féderal de Lusanne, Switzerland

The ongoing quest for miniaturization of laser structures is a driving factor in applied semiconductor physics. Cavities with large Q factors and low mode volume strongly funnel the emission into the laser mode, thereby approaching the thresholdless regime ($\beta \approx 1$). A recent addition are nanobeam cavities that offer great potential for silicon-integrated nanophotonics and on-chip structures. For such a design we develop and evaluate a quantum-mechanical laser theory that facilitates quantitative predictions of the emission output and the autocorrelation function $g^{(2)}$. Our device uses a quantum-well gain material. While typical QW edge-emitting lasers operate with $\beta < 10^{-3}$, the nanobeam cavity exhibits high β and vanishing threshold in the emission output, in which case $g^{(2)}$ has become an established tool to identify lasing. Building on a formalism employed for high-Q quantum-dot nanolasers, we calculate $g^{(2)}$ for a QW gain material to reveal the laser transition and to evaluate device characterisitics.