HL 5: Semiconductor Lasers

Time: Monday 9:30–12:30 Location: EW 202

HL 5.1 Mon 9:30 EW 202

Emitter-emitter correlation mediated by collective modes in coupled cavity arrays — •Mawussey Segnon[1], Isa Grothe[1], Paul Gartner[2], and Christopher Gies[1] — [1]Institute for Theoretical Physics, University of Bremen, P.O. Box 330 440, 28334 Bremen, Germany — [2]National Institute of Materials Physics, P.O. Box MG-7, Bucharest-Magurele, Romania

Coupled cavity arrays are an interesting physical architecture, in which the optical coupling between their building blocks allows one to explore some exotic states of photons including the Mott insulator and the fractional quantum Hall effect. In the present work, we numerically investigate the physics of superradiance in coupled cavity systems. To this end, we use the Jaynes-Cummings-Hubbard Hamiltonian, where each cavity contains a single two-level quantum dot interacting with the confined local mode and contiguous cavities are mutually coupled by photon hopping. A diagonalization of the photonic part of the system Hamiltonian yields collective modes. We find parameter regimes, in which the exchange of photons via each of these collective modes leads to a radiactive coupling of the intercavity emitters.

HL 5.2 Mon 9:45 EW 202

Influence of spontaneous emission on the coherence properties of high-β semiconductor nanolasers — •Frederik Lohof[1], Roy Barzel[1], Paul Gartner[2], and Christopher Gies[1] — [1]Institute for Theoretical Physics, University of Bremen, Bremen, Germany — [2]National Institute of Material Physics, Bucharest-Magurele, Romania

Nanolasers, often operating in the high-β regime, are one of the prime applications of cavity-QED promising ultra-low thresholds and driving research in the field of green photonics. However, in such lasers spontaneous emission can play a central role even above the threshold, thereby influencing the coherence properties of the emitted light. In this context, we revisit the lasing criterion in terms of the degree of coherence of the emission inprinted in the two photon correlation function $g^{(2)}$. Using theoretical models we demonstrate that there are new regimes of cavity-QED lasing, realized e.g. in nanolasers with extended gain material, for which the coherence is reached at higher pump powers than required to observe the laser intensity jump, normally associated with the laser threshold. We present results from a photonic crystal nanobeam cavity laser with nitride-based quantum well gain material, operating in the mentioned new regime where $g^{(2)}$ becomes essential to identify lasing in the system.

HL 5.3 Mon 10:00 EW 202

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

For many applications of semiconductor lasers like high precision engraving, cutting and additive manufacturing a constant beam quality during processing is essential. But even if the intensity distribution is perfectly Gaussian for a certain set of laser parameters, blur effects can occur due to a slight shift of working conditions during the process. To forecast a loss of beam quality the analysis of the wavefront structure of the processing laser over the typical diode current range can be a helpful tool to choose a suitable parameter window or to correct the beam parameters using optical elements like deformable mirrors. In our research we use a Shack-Hartmann Sensor to record the wavefront and intensity distribution of single and multimode semiconductor lasers based on GaAs composites emitting at wavelengths in the near infrared. Over the parameter range electrical as well as thermal effects inside the laser resonator strongly influence the modal composition of the intensity distribution causing a deformation of the wavefront. To determine the impact of these effects a Gaussian telescope setup is used to detect the wavefront structure during the spatial and current depending evolution of the beam. This approach shall be used to forecast the beam stability.

HL 5.4 Mon 10:15 EW 202

Carrier dynamics and modulation properties in tunnel-injection based quantum-dot structures — •Michael Lorke, Stephan Michael, and Frank Jahnke — Institute für theoretische Physik, Universität Bremen

For tunnel-injection (TI) quantum-dot (QD) lasers record high small signal modulation bandwidth and improved performance of 1.55 μm InAs QDs on InP-based hetero-structures (1) were reported, which underscores their application potential for high-speed optical communication networks. We present a theoretical analysis of TI laser devices by combining material realistic electronic structure calculations with a many-body description of the carrier dynamics and the modulation properties. Based on these investigations, we give design guidelines to optimize the modulation bandwidth and turn-on delay.

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

HL 5.5 Mon 10:30 EW 202

Switching behaviour of bimodal micro lasers with optical injection — •David Schicke[1], Christoph Redlich[1], Benjamin Lingnau[1], Elisabeth Schlottmann[2], Felix Krüger[2], Xavier Porte[2], Sören Kreinberg[2], Kathy Lüdge[1], and Stephan Reitzenstein[2] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Institut für Festkörperphysik, Technische Universität Berlin

The dynamics of micropillar laser devices have been a topic of increased interest in the semiconductor laser community over the last years. Because of unavoidable structural asymmetries in such a micro laser, the device can emit in two possible orthogonal linearly polarized modes. Far from the threshold pump current, one of these modes becomes the dominant mode and suppresses the other, weak, mode. However, because of the high noise level present in the laser temporal switching is possible, i.e. the weaker mode becomes the strong, lasing, mode.

We present numerical simulations using a semiclassical rate equation approach to describe the emission dynamics of a bimodal laser subject to external optical injection and compare to recent experimental results. We find that the switching dynamics can be controlled by a proper choice of the injection parameters and investigate the underlying bifurcation scenarios by modeling the noise as a deterministic variable.

HL 5.6 Mon 10:45 EW 202

Repetition rate transitions and timing stability improvement in monolithic multi-section semiconductor lasers — •Martin Birkholz[1], Julien Javaloyes[2], Oleg Nikiforov[1], Christoph Weber[1], Luke F. Lester[3], and Stefan Breuer[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]Departamento de Física, Universitat de les Illes Balears, 07122 Palma de Mallorca, Spain — [3]Bradley Department of Electrical and Computer Engineer- ing, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA

Passively mode-locked lasers (PMLLs) are compact photonic sources delivering high repetition rate (RR) pulse trains and picosecond short optical pulses. An excellent stability of the generated optical pulse train is crucially important towards their application in optical sampling, in optical time division multiplexing or as photonic clocks. In this contribution, we study numerically the optical pulse train stability improvement and transitions to higher harmonic RRs in a monolithic semiconductor laser with interdigitated absorber placement by the simulation tool FreeTWM (http://onl.uib.eu/softwares). The laser under investigation is 4 mm long, corresponding to a fundamental RR of 10 GHz, and consists of 2 gain and 2 absorber sections. By using numerical continuation transitions from fundamental mode locking to higher harmonic mode locking occur. Associated with these transitions is an improved timing stability. Experimental studies on timing stability and RR transitions confirm the simulated results.

15 min. break.

HL 5.7 Mon 11:15 EW 202

Nonlinear lensing in a vertical-external-cavity surface-emitting laser — •Christian Kriso, Tasnim Munshi, Sascha Kress, Mohib Alvi, Wolfgang Stolz, Martin Koch, and Arash Rahimi-Iman — Philipps-Universität Marburg, 35032 Marburg, Germany

Passively mode-locked semiconductor disk lasers (SDLs), also known as vertical-external-cavity surface-emitting lasers (VECSELs), present a cost-efficient and wavelength-flexible alternative to conventional solid-state lasers. However, most mode-locked SDLs rely on the use of an additional saturable absorber element setting constraints on compactness and peak powers. Recently, a new, saturable-absorber-free mode-locking technique has shown promising results in terms of pulse duration and peak power. The underlying mechanism is assumed to be Kerr-lens mode-locking but the observation of self-mode-locking behavior is still not well understood. In order to gain a deeper understanding of nonlinear lensing in a VECSEL chip, we investigate the influence of optical pumping and the operation wavelength on the measured nonlinear refractive index via z-scan measurements close to real operation conditions.

HL 5.8 Mon 11:30 EW 202

Remarkable laser emission around 630nm via a vertical cavity surface emitting laser (VCSEL) based on InP quantum dot layers — •Isabel Reis, Mona Stadler, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart

VCSELs in the AlGaInP material system are ideal candidates to realize a miniaturized optical device for laser emission around 630 nm capable to integrate. Such a development will be a suitable alternative to the best-known and successful emitter at 633nm, the HeNe laser. Furthermore, the realization of single-mode VCSELs comes with the ability of easy fiber coupling and array fabrication. We have carried out devices with an emission wavelength at 630 nm by combining structural design and adjusted growth parameters. Particular attention was devoted to the active region, which consists either of stacked InP quantum dot (QD) layers or quantum wells (QW) within a barrier and cladding layer of Al0.33GaInP and Al0.55GaInP, respectively. The advantage of QD based VCSEL compared to QW based devices is the decreased threshold current with less temperature dependency, an improved gain and tunability of the emission wavelength. The results of specific examples emitting around 630 nm will be presented, in both their designs and experimental behavior. Especially, the output power in the continuous wave and pulsed operation, the lasing characteristics and spectra of our processed VCSEL are measured and evaluated.

HL 5.9 Mon 11:45 EW 202

Controlling switching dynamics in quantum-dot micropillar lasers with time-delayed optical feedback — •Steffen Holzinger[1], Christoph Redlich[2], Benjamin Lingnau[2], Marco Schmidt[1], Martin von Helversen[1], Jörn Beyer[3], Christian Schneider[4], Martin Kamp[4], Sven Höfling[4,5], Kathy Lüdge[2], Xavier Porte[1], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]Institut für Theoretische Physik, Technische Universität Berlin, Germany — [3]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [4]Technische Physik, Julius-Maximilians-Universität Würzburg, Germany — [5]School of Physics and Astronomy, University of St Andrews, Scotland

Electrically pumped quantum-dot micropillar lasers provide a platform for the realization of delay-coupled experiments in the field of quantum optics, 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. We experimentally and theoretically investigate the influence of the feedback on the optical spectrum as well as the switching dynamics of the lasing modes. By directly measuring the photon number distribution with a transition edge sensor detector, we characterize the effects of feedback on the stability of the modes.

HL 5.10 Mon 12:00 EW 202

Injection forced Polarization Switching in Bimodal Quantum Dot Micropillar Lasers — •Elisabeth Schlottmann[1], Felix Krüger[1], Benjamin Lingnau[2], David Schicke[2], Steffen Holzinger[1], Christian Schneider[3], Martin Kamp[3], Sven Höfling[3], Xavier Porte[1], Kathy Lüdge[2], 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

Quantum Dot Micropillar lasers are fascinating devices that show an enhanced spontaneous emission in the lasing mode (high β-factor) and a correspondingly low laser threshold. Moreover, the fundamental laser mode is splitted into two orthogonally polarized modes. As they share the gain medium, gain competition leads to stable laser emission in either one of the modes or stochastic polarization switching (C. Redlich et al. New J. Phys. 18, 63011 (2016)).

Here, we tailor polarization switching in a QD-micropillar laser via optical injection into the non-lasing mode. For low injection powers, a non-switching micropillar laser strongly fluctuates. Increased injection power stabilizes the intrinsically non-lasing mode and pushes it to lasing with simultaneous suppression of the other mode. These effects are characterized with high-resolution spectral and correlation measurements.

HL 5.11 Mon 12:15 EW 202

Fabrication of spectrally homogeneous microlaser arrays as a nanophotonic hardware for reservoir computing — •Tobias Heuser[1], Jan Grosse[1], Arsenty Kaganskiy[1], James Lott[1], Daniel Brunner[2], Ingo Fischer[3], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universiät Berlin, D-10623 Berlin, Germany — [2]FEMTO-ST, 15B Avenue des Montboucons, 25030 Besançon, France — [3]IFISC (UIB-CSIC), Campus Universitat de les Illes Balear, E-07122 Palma de Mallorca, Spain

Reservoir computing is a powerful machine learning concept for a new kind of data processing which is inspired by the neurons in the brain. In this concept an interacting network of nodes, called the reservoir, is evaluated by a trained readout for applications like fast pattern recognition. To further improve the performance of this concept, a photonic hardware implementation is of particular interest. Here, we report on developements of our fabrication process to realize large 2D arrays of microlasers, namely quantum dot micropillars and VCSELs, which will serve as a nonlinear network via diffractive optical coupling [1]. For this spectral alignment of the involved lasers is crucial. To achieve this with a spectral homogeneity better than 200μeV throughout the array of up to 900 lasers, shifts of the emission energy, which are related to the material growth, are compensated by electrical tuning or by precisely adjusting the radius of the fabricated micropillars [2].

References:
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