HL 3: Semiconductor lasers and Photonic crystals

Time: Monday 9:30–12:00 Location: H33

HL 3.1 Mon 9:30 H33

High-speed InP-based 1.55 μm quantum dot lasers with and without tunnel injection quantum wells — •Sven Bauer[1], Vitalii Sichkovskyi[1], Ori Eyal[2], Gadi Eisenstein[2], and Johann Peter Reithmaier[1] — [1]Technische Physik, Institute of Nanostructure Technologies and Analytics (INA), CINSaT, University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Andrew and Erna Viterbi Department of Electrical Engineering, Technion, Haifa 32000, Israel

The performance of directly modulated quantum dot (QD) lasers, used for 1.55 μm telecommunication, is limited by the intraband carrier relaxation time. To improve it, one might use a so-called tunnel injection (TI) scheme. Carriers are captured and relax in a quantum well (QW) and tunnel through a thin barrier for recombination into the QDs. After a careful optimization process, the coupled QW-QD structures, consisting of an InGaAs QW, a thin InAlGaAs barrier, both lattice matched to InP, and InAs QDs, were implemented in a high-speed laser design. A corresponding QD reference laser was grown as well. The structure specific static parameters were extracted from the power current characteristics of the processed broad area lasers. Furthermore, the effect of different rapid thermal annealing temperatures was investigated. The small signal modulation properties of ridge waveguide lasers were measured and significant differences could be evaluated for both laser types. Large signal modulation experiments revealed a high modulation rate for both laser types.

HL 3.2 Mon 9:45 H33

Do TMD Nanolasers Benefit From a High β-Factor? — •Frederik Lohof[1], Alexander Steinhoff[1], Matthias Florian[1], Daniel Erben[1], Michael Lorke[1], Roy Barzel[1], Paul Gartner[2], Frank Jahnke[1], and Christopher Gies[1] — [1]Institute for Theoretical Physics, University of Bremen — [2]National Institute of Materials Physics, CIFRA, Bucharest-Măgurele, Romania

The realization of high-β lasers is one of the prime applications of cavity- QED promising ultra-low thresholds, integrability and reduced power consump- tion. Recently also monolayers of transition metal dichalcogenide (TMD) have been reported to be used as gain medium in high-β nanolasers. In my talk I will present first results from material realistic gain calculations of highly excited TMD monolayers and specify requirements to achieve lasing with the four commonly used TMD semiconductors. Combining the results with a rate equation theory I will discuss consequences for experimentally accessible laser characteristics. In cavity-enhanced nanolasers with limited amount of gain, spontaneous emission has been shown to play a central role even above the threshold. In using a simplified approach, I will discuss the prospects of low-threshold high- beta lasing in TMD based nanolasers. Extended rate equations are used to access the photon autocorrelation function, revealing an offset between the laser threshold in the input-output curve and the transition to coherent emission. Furture experimental measurements should provide insight into the validity of our theoretical prediction.

HL 3.3 Mon 10:00 H33

Characterization of the nonlinear optical properties of a semiconductor disk laser — •Christian Kriso[1], Sascha Kress[1], Tasnim Munshi[1], Marius Grossmann[2], Roman Bek[2], Michael Jetter[2], Peter Michler[2], Wolfgang Stolz[1], Martin Koch[1], and Arash Rahimi-Iman[1] — [1]Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, D-35032 Marburg, Germany — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, D-70569 Stuttgart, Germany

The quest for pulsed laser sources with steadily higher peak powers and shorter pulse durations is subject of ongoing research efforts. Semiconductor disk lasers or vertical-external-cavity surface-emitting-lasers (VECSELs) are a particularly attractive laser platform for this purpose, since they combine the wavelength flexibility typical for semiconductor lasers, the beam qualities known from solid-state lasers and the desired potential mass producibility for applications like frequency combs or multi-photon imaging.

Besides conventional passive mode-locking of VECSELs with semiconductor-saturable-absorber mirrors (SESAMs), a new mode-locking phenomenon has been observed in these lasers in the absence of such SESAMs. Based on the assumption that Kerr-lensing in the VECSEL chip might explain "self-mode-locked" operation, we systematically characterize the nonlinear refractive index of a gain chip and discuss the impact of the gain chip's microcavity on possible Kerr-lens mode-locking of VECSELs.

HL 3.4 Mon 10:15 H33

A theoretical model for the generation of non-equidistant pulses in passively mode-locked VECSELs — •Jan Hausen[1], Stefan Meinecke[1], Benjamin Lingnau[1,2], and Kathy Lüdge[1] — [1]Institute for theoretical Physics, TU Berlin, Hardenbergstrasse 36, 10623 Berlin — [2]Physics Department, University College Cork, College Rd, Cork, Irland

Embedding the active sections of a passively mode-locked laser, i.e. gain and absorber medium, in an external cavity with a V-shaped geometry can greatly enhance their performance in terms of pulse width and power. However, multi-pulse solutions with non-equidistant interpulse spacing (pulse clusters) emerge in these devices and limit their performance. We derive a system of multi-delay differential equations, which is simple enough to allow for large numeric parameter studies as well as a bifurcation analysis to understand the underlying bifurcation scenarios. We find that by tuning the cavity geometry different mode-locking behaviour can be favoured e.g. fundamental, higher harmonic or pulse cluster mode-locking. Furthermore, our investigations show that by increasing the cavity geometry stable regions of higher order pulse clusters develop from cusps of saddle-node bifurcation and stabilizing torus bifurcations.

HL 3.5 Mon 10:30 H33

Investigation of Red-Emitting Mode-Locked VECSELs — •Philipp Tatar-Mathes, Marius Grossmann, 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

Since the first realization of mode-locked vertical external-cavity surface-emitting lasers (VECSELs) in 2000, huge development especially in the infrared spectral range was initiated. These systems generate ultrashort pulses with high output powers and a near diffraction-limited beam profile, beneficial properties over a wide wavelength range. Semiconductor structures with an active region containing GaInP/AlGaInP quantum wells, grown on top of AlAs/AlGaAs DBR demonstrate as well excellent performances of VECSELs but in the visible spectral range [1].

We present a VECSEL configuration with emission in the red spectral range from a cavity optimized for high average powers and GHz repetition rates. We interpret the measurements in light of the recently demonstrated self-mode-locking [2] which allows the absence of a SESAM. Therefore, intrinsic nonsaturable losses can be overcome. Our current research focus is capturing the dynamics of pulsed laser emission by investigation of its temporal evolution and frequency spectra with a high bandwidth oscilloscope and performing second harmonic intensity autocorrelations to determine its properties on ultrashort-timescales. [1] Bek et al., Opt. Express 2015; [2] Bek et al., APL. 2017

15 min. break

HL 3.6 Mon 11:00 H33

Dynamics of two coupled semiconductor mode-locked lasers — •Jakob Eberhardt, Stefan Meinecke, and Kathy Lüdge — Institut für Theoretische Physik, TU Berlin, Hardenbergstr 36, 10623 Berlin

Passively mode-locked semiconductor lasers are an inexpensive source of short optical pulses at high repetition rates. Networks of mode-locked lasers have received interest due to applications in data communication and metrology and as a possible implementation of novel analog computing schemes [1]. We numerically investigate the dynamics of the simplest network setup, namely two mutually coupled lasers, using a system of delay differential equations [2]. For two non-identical passively mode-locked lasers, we study the stability and synchronisation behaviour of the two lasers in dependence of the laser and coupling parameters and predict regions of stable synchronised mode locking and regions of leap frogging, where the two lasers alternatingly emit pulses at the fundamental repetition frequency.

[1] Mesaritakis, C. , Kapsalis, A., Bogris, A. and Syvridis, D. , Sci. Rep. 6, 39317 (2016).

[2] Vladimirov, A. G. and Turaev, D. V. , Phys. Rev. A 72, 3, 033808 (2005).

HL 3.7 Mon 11:15 H33

Fabrication of spectrally homogeneous microlaser arrays as a nanophotonic hardware for reservoir computing — •Tobias Heuser[1], Jan Grosse[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), 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 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 our new developements in the fabrication process and lasing performance of large 2D arrays of microlasers, namely quantum dot micropillars and VCSELs. These arrays 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 are compensated by electrical tuning or by precisely adjusting the radius of the fabricated micropillars [2, 3].

References

[1] D.Brunner, I.Fischer, Opt. Lett. 40, 3854-3857 (2015)

[2] S.Reitzenstein, A.Forchel, J.Phys.D.Appl.Phys. 43, 033001 (2010)

[3] T.Heuser et al., APL Photonics 3, 116103 (2018)

HL 3.8 Mon 11:30 H33

Bragg grating cavities embedded into nano-photonic waveguides for Purcell enhanced quantum dot emission — •Stephanie Bauer, Stefan Hepp, Florian Hornung, Mario Schwartz, Simone Luca Portalupi, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, Allmandring 3, Universität Stuttgart, 70569 Stuttgart, Germany

Quantum photonic integrated circuits are a promising platform for quantum information technologies. In contrast to silicon based systems, photonic circuits on a III-V semiconductor platform bear the advantage of the direct implementation of quantum dots with their outstanding properties as single photon sources.

The widely used ridge waveguides offer a scalable and low loss routing of quantum dot light on a photonic chip. However, the coupling efficiency of directly integrated emitters is quite poor.

Here we present a method to increase the coupling efficiency between the quantum dots and waveguides via the utilization of a Bragg grating cavity that can be directly integrated into the waveguide. High Q-factors of fabricated cavities in combination with a stable resonance wavelength of ± 0.11 nm over the full fabricated chip show the potential of this design. Furthermore we show the Purcell enhanced quantum dot emission up to a factor of $F_p = 3.5 \pm 0.5$ which can be increased up to a factor of 20 according to FTDT simulations.

HL 3.9 Mon 11:45 H33

Twisted light - new perspectives for solid state optical spectroscopy — •Florian Büscher[1,2], Dirk Wulferding[1,2], and Peter Lemmens[1,2] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]LENA, TU-BS, Braunschweig, Germany

Conventionally polarized light possesses zero orbital angular momentum. Using spatially modulated filters (”q-plates”) [1,2] we probe the response of certain magnetic model systems to a finite orbital angular momentum, so-called twisted light [3]. We search for such effects in electronic and phononic Raman scattering and demonstrate initial results. Work supported by QUANOMET NL-4 and DFG LE967/16-1. [1] Marrucci, et al., PRL 96, 163905 (2006). [2] Slussarenko, et al., Opt. Express 19, 4085 (2011). [3] Schmiegelow, et al., Nat. Commun. 7, 12998 (2016).