HL 81: Semiconductor lasers II

Time: Friday 9:30–11:45 Location: POT 81

Invited Talk HL 81.1 Fri 9:30 POT 81

Ultrafast Spin-Lasers — Markus Lindemann[1], Natalie Jung[1], Tobias Pusch[2], Gaofeng Xu[3], Pascal Stadler[1], Igor Zutic[3], Rainer Michalzik[2], Martin R. Hofmann[1], and •Nils C. Gerhardt[1] — [1]Photonics and Terahertz Technology, Ruhr-University Bochum, 44780 Bochum, Germany — [2]Institute of Functional Nanosystems, Ulm University, 89081 Ulm, Germany — [3]Department of Physics, University at Buffalo, State University of New York, Buffalo, New York 14260, USA

Current-driven intensity modulated semiconductor lasers are key devices for optical transmitters in short-distance data transmission, but their modulation bandwidth is usually limited to values below 50 GHz. By exploiting the coupling between carrier spin and light polarization in semiconductor spin-lasers, the modulation frequencies in such lasers can be increased to values above 200 GHz [1]. These high frequencies are achievable by increasing the resonance frequency of the coupled spin-photon system using strong birefringence in the laser cavity. Birefringent spin-lasers are capable to provide polarization modulation bandwidths and digital data transmission rates of more than 240 GHz and 240 Gbit/s respectively [1]. In contrast to intensity modulation in conventional lasers, polarization modulation in spin-lasers is largely independent of the pumping level. This makes spin-lasers perfect candidates for future ultrafast communication systems with extraordinarily low power consumption.

[1] M. Lindemann et al., Nature 568, 212 (2019).

HL 81.2 Fri 10:00 POT 81

Fabrication of spectrally homogeneous microlaser arrays as a nanophotonic hardware for reservoir computing — •Tobias Heuser[1], Jan Grosse[1], Daniel Brunner[2], 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

Reservoir computing is a powerful machine learning concept for a new kind of neural inspired data processing. 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 newest developements in the fabrication process, lasing performance and polarisation characteristics of large 2D arrays of microlasers, specifically quantum dot micropillars [1]. These arrays will serve as a nonlinear network via diffractive optical coupling [2]. 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 precisely adjusting the radius of the fabricated micropillars based on the local sample emission[3, 4].

References

[1] S.Reitzenstein, A.Forchel, J.Phys.D.Appl.Phys. 43, 033001 (2010)
[2] D.Brunner, I.Fischer, Opt. Lett. 40, 3854-3857 (2015)
[3] T.Heuser et al., APL Photonics 3, 116103 (2018)
[4] T.Heuser et al., IEEE JSTQ 26, 1, (2020)

HL 81.3 Fri 10:15 POT 81

Dynamic instabilities in gain-folded mode-locked VECSELs — •Marius Grossmann[1], Roman Bek[2], Michael Jetter[1], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and Research Center SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Twenty-One Semiconductors, Kiefernweg 4, 72654 Neckartenzlingen, Germany

Since the first demonstration of mode-locked vertical external-cavity surface-emitting lasers (VECSELs) using semiconductor saturable absorbers (SESAMs) in the year 2000, these lasers have shown to provide a diffraction-limited beam quality as well as high output powers across multiple emission wavelengths. These ultrashort pulse lasers offer interesting dynamics, which are often linked to semiconductor properties and can be influenced by the exact cavity design. A cavity geometry often used is the z-shaped cavity, which provides further flexibilities concerning mode area ratios, cavity lengths and additional intra-cavity elements like etalons and nonlinear crystals.

We present the mode-locked emission characteristics of a red-emitting SESAM mode-locked VECSEL with an average output power up to 2 mW. We put the focus on the temporal dynamics recorded upon wavelength tuning of the pulsed emission and discuss the emission dynamics based on numerical modelling.

15 min. break

HL 81.4 Fri 10:45 POT 81

Dynamical properties of quantum dot lasers with and without p-doping and tunneling injection quantum wells in the active region — •Sven Bauer[1], Vitalii Sichkovskyi[1], Florian Schnabel[1], Anna Sengül[1], Ori Eyal[2], Igor Khanonkin[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]Electrical Engineering Department and Russell Berrie Nanotechnology Institute, 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 as well as thermally broadened hole distribution effects. These properties could be improved by using a so-called tunnel injection (TI) scheme or the introduction of p-type doping into the active region of a high-speed laser design. Conventional QD lasers are directly compared to QD lasers with TI, p-type doping and both. The QD density and uniformity are nominally the same for all devices. Small signal modulation measurements yielded higher bandwidths for the QD lasers in comparison to the TI QD lasers. P-type doping greatly improved the performance of TI QD lasers and more refined doping profiles are promising to further enhance the modulation properties. Large signal modulation measurements showed a maximum data rate of more than 25 Gbit/s for both laser types, which is already suitable for telecom applications.

HL 81.5 Fri 11:00 POT 81

Wave front analysis of monolithic passively mode locked semiconductor quantum well lasers — •Clemens Adler[1], Christoph Weber[2], Inga-Maria Eichentopf[1], Andreas Klehr[3], Andrea Knigge[3], Stefan Breuer[2], and Martin Reufer[1] — [1]Hochschule Ruhr West, Institute of Natural Sciences, Duisburger Str. 100, 45479 Mülheim an der Ruhr — [2]Institute of Applied Physics, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [3]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

Mode-locked semiconductor diode lasers are well established photon sources. Their temperature and charge carrier distributions within the active layer depends on the injection conditions and are expected to change with the process of mode locking. Higher optical modes are supported by the resonator potentially impacting the modal composition and emitted laser beam properties. We experimentally study the bias dependent modal composition of a passively mode-locked quantum well laser emitting at 1070 nm [1]. A Shack-Hartmann sensor detects the local gradients of the Poynting vector of the laser beam. Deviations in the wave front are identified by decomposition into Zernike polynomials [2]. Our near and far field measurement results suggest a dependence of the wave front properties on the laser operation mode.

[1] Weber et al, IEEE J. Quantum Electron. 54 (3), 2000609 (2018)
[2] Schäfer et al, Applied Optics 41, 2809 (2002)

HL 81.6 Fri 11:15 POT 81

Nonlinear lensing in optically-pumped semiconductor disk lasers — Christian Kriso[1], Sascha Kress[1], Tasnim Munshi[1], Marius Grossmann[2], Roman Bek[3], 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, Renthof 5, D-35032 Marburg, Germany — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integraed Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart — [3]Twenty-One Semiconductors GmbH, Kiefernweg 4, 72654 Neckartenzlingen

Semiconductor disk lasers or vertical-external-cavity surface-emitting-lasers (VECSELs) have been highlighted in recent years as promising sources for ultrashort pulses. Particularly, saturable-absorber-free "self-mode-locked" operation of VECSELs has raised considerable attention. The origin of this phenomenon is still not well-enough understood to effectively utilize it for future mode-locking device concepts. Currently, nonlinear lensing in the VECSEL chip itself, which has been indicated to be sufficiently strong to enable Kerr-lens-like mode-locking, is suspected to be one driving mechanism behind self-mode-locking [Kriso et al., *Opt. Express* (2019)]. Here, we summarize a systematical characterization of the effective nonlinear refractive index and nonlinear absorption coefficient of an optically-pumped gain chip, having probed the complex, effective third-order susceptibility of the chip for excited charge-carrier densities similar to that of laser operation [Kriso et al., *Phot. Tech. Lett.* (in press)].

HL 81.7 Fri 11:30 POT 81

Pulse generation and emission dynamics of Fabry-Pérot multisection passively mode-locked lasers on an InP photonic integrated circuit — •Abishek Vibhaker[1], Christoph Weber[1], Dominik Auth[1], Luke F. Lester[2], and Stefan Breuer[1] — [1]Institute of Applied Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]Bradley Department of Electrical and Computer Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 24061, USA

Passively mode-locked lasers on photonic integrated circuits based on InP material are low footprint light sources emitting picosecond short pulses in the C- or L-band for telecommunication applications. Recent investigations on photonic integrated circuit symmetric ring structures [Lo et al, Optics Letters 44 (14), 3566 (2019)] are now followed by investigations on multimode interference reflectors based Fabry-Perot cavity designs consisting of gain and saturable absorber sections for short pulse generation at high repetition rates. Multiple designs are realized to study the optical frequency comb generation and the pulse train stability in terms of timing jitter and amplitude stability.