HL 51: Semiconductor lasers I

Time: Wednesday 15:00–18:00 Location: POT 51

HL 51.1 Wed 15:00 POT 51

Direct Band-Gap Emission from Hexagonal SiGe: Towards a SiGe Nanolaser — •Claudia Rödl, Jens Renè Suckert, Jürgen Furthmüller, Friedhelm Bechstedt, and Silvana Botti — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Incorporation of microelectronics and optoelectronics is expected to revolutionize various fields of technology, such as communication, sensing, and imaging. A Si-compatible nanolaser would be the key to achieve integrated silicon photonics. However, Si as well as Ge in their diamond-structure equilibrium phases are known to be optically inactive due to the indirect nature of their band gaps. The hexagonal allotropes of Si and Ge in the lonsdaleite phase, which can now be grown in good quality, may overcome this limitation. Hexagonal Si is still indirect, whereas hexagonal Ge is a direct semiconductor. Unfortunately, the dipole matrix elements of the lowest optical transitions are almost zero. Here, we show that it is possible to enhance the optical oscillator strengths of hexagonal Ge by applying tensile uniaxial strain or alloying it with Si. Upon structural modification, the two lowest conduction bands change order and the lowest optical transitions become strongly dipole active. We compare our results to recent data from our experimental collaborators. Using first-principles density-functional theory with hybrid functionals and the MBJLDA meta-GGA, we calculate structural and electronic properties and show how the absorption and emission spectra are affected by strain and alloying, respectively.

HL 51.2 Wed 15:15 POT 51

Thresholdless transition to coherent emission at telecom wavelength from metallic cavity nanolasers — •Frederik Lohof[1], Sören Kreinberg[2], Kaisa Laiho[2], William Hayenga[3], Paweł Holewa[2], Mercedeh Khajavikhan[3], Stephan Reitzenstein[2], and Christopher Gies[1] — [1]Institute for Theoretical Physics, University of Bremen — [2]Institute for Solid State Physics, Technical University Berlin — [3]CREOL, Univerity of Central Florida

The miniaturization of semiconductor nanolasers has created an avenue to (near) thresholdless devices with small footprints for applications in photonics and quantum information. In this regime, the onset of coherent emission, i.e. the threshold, must be determined from a change in the photon statistics of the emission, as output intensity and linewidth provide ambiguous information. We present results from theoretical and experimental studies of telecom wavelength, thresholdless coaxial nanolasers using metallic cavities. These cavities allow to confine light on length scales below the diffraction limit, leading to high field intensities and large light-matter interactions. Our theoretical modeling gives access to time-resolved photoluminescence and fingerprints of the emission's photon statistics, given by photon-correlation functions. In modeling of the experimentally obtained data, we demonstrate a clear onset of coherent emission at finite pump powers. Our combination of experimental and theoretical techniques results in a comprehensive picture of the device dynamics, verifying its lasing operation and providing directions for future experimental designs of nanolasers.

HL 51.3 Wed 15:30 POT 51

Characteristics of red MECSEL with a quantum dot active region — •Ana Ćutuk[1], Roman Bek[2], Michael Jetter[1], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integraed Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Twenty-One Semiconductors GmbH, Kiefernweg 4, 72654 Neckartenzlingen

Quantum dots (QDs) as active region for a laser are very attractive due to their promising properties e.g. higher differential gain, lower threshold, better temperature stability and wavelength versatility. We choose a membrane approach as it is realized by a membrane external-cavity surface-emitting laser (MECSEL) for improved thermal budget. Therefore we realized a semiconductor membrane structure consisting of an AlGaInP/InP QD active region deposited on GaAs substrate in the Stranski-Krastanow growth mode by metal-organic vapor-phase epitaxy (MOVPE) with emission in the red spectral range. Our usual processing technique implies a membrane release from the substrate with capillary bonding between two heat spreaders. However, the internal strain makes this approach rather difficult, which is why also wafer-bonding of the semiconductor structure to one heat spreader and further processing of the membrane including bonding the second heat spreader was performed. In this contribution we present our newest results on the QD-based MECSEL. Ongoing characterization includes comparison of the two bonding approaches in terms of laser output in order to learn more about the influence of the internal strain.

HL 51.4 Wed 15:45 POT 51

Miniaturized lasers for picosecond ultrasonics — •Michal Kobecki — Experimentelle Physik 2, Technische Universität Dortmund, D-44221 Dortmund, Germany

There is a great desire to extend ultrasonic techniques for imaging and characterization of nanoobjects. This may be achieved by picosecond ultrasonics, where using ultrafast lasers it is possible to generate and detect acoustic wave with the frequencies up to terahertz and wavelength down to nanometers. In our work we present the picosecond ultrasonics setup based on miniaturezed mode-locked semiconductor lasers, which are appropriate to obtain necessary power, pulse duration and repetition rate.

Project was focused on generation and detection of the strain pulses in thin metal films (Al,Pt,Cr,Au) deposited on GaAs substrates. The used mode locked laser diode (MLLD) based on AlGaInAs/InP quantum-well active media was manufactured at Glasgow University. Invastigated device emits 1-ps duration laser pulses with repetition rate of 20 GHz and average power of 50mW at 930nm wavelength.In experiments we have used standard pump-probe scheme. Detected signal reflects an ultra-short strain pulse generated in a film and its echo arriving back to the surface. Observed signals are in perfect agreement with the data obtained by means of conventional set-ups, which gives motivation for further development in the field and pursuing more ambitious goals.

HL 51.5 Wed 16:00 POT 51

Monolithic passively mode-locked quantum well lasers — •Christoph Weber[1], Andreas Klehr[2], Andrea Knigge[2], and Stefan Breuer[1] — [1]Institute of Applied Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

Monolithic passively mode-locked quantum well lasers emitting at wavelength around 1070 nm are ideal sources of picosecond short optical pulses at high repetition rates for novel data transmission systems or multi-photon imaging applications. For 2 mm long narrow ridge waveguide lasers with an absorber to total length ratio of 10 % emission of 2 ps short optical pulses with high pulse train stability has been reported [Weber et al, IEEE J. Quantum Electron. 54 (3), 2000609 (2018)]. In this contribution we study monolithic semiconductor lasers with different lengths, different absorber to total length ratios and different ridge widths and gain material based on InAs/InGaAs quantum wells. We analyze the pulse generation and the pulse train timing stability in dependence on the different laser cavity designs.

30 min. break

HL 51.6 Wed 16:45 POT 51

Optical and quantum optical characterization of silver-coated InP-based nanolasers on silicon — •Aris Koulas-Simos[1], Kaisa Laiho[1], Jianxing Zhang[2], Cun-Zheng Ning[2], and Stephan Reitzenstein[1] — [1]Institute of Solid State Physics, Technische Universität Berlin, Berlin Germany — [2]Tsinghua University, Department of Electronic Engineering, Beijing, China

A nanolaser is an optical laser device with a design close to the size limit of the cubic light wavelength. In comparison to conventional lasers, nanolasers possess very low-threshold powers for few-photon operation and may exhibit even a "thresholdless" input-output behavior thanks to the high β-factors close to unity, where the β-factor describes the coupling efficiency of the spontaneous emission to the lasing mode. Here, we investigate at first the conventional optical properties such as the LL-curve and the linewidth narrowing of silver-coated bulk InP nanolasers emitting at telecom wavelengths. More importantly, to confirm lasing of a device, the knowledge of the photon statistics is required. We verify that by observing the transition from thermal to coherent emission in excitation-dependent second order correlation measurements.

HL 51.7 Wed 17:00 POT 51

Development towards AlGaInP based electrically pumped VECSELs for the red spectral range — •Michael Zimmer, Zhihua Huang, 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.

In recent years, electrically pumped vertical external-cavity surface-emitting lasers (EP-VECSELs) have been studied extensively due to their potential for miniaturization and integration applications. Based on their good beam quality and compact device size EP-VECSELs are excellent candidates for a new generation of light sources. However, in the red wavelength regime EP-VECSELs have not been realized yet. Here we present the design of an AlGaInP based EP-VECSEL aiming at an emission around 670 nm. To realize an EP-VECSEL, a homogeneous charge carrier distribution within the active region of the device and the avoidance of heat at the same place need to be targeted. Thus, we apply a combination of bottom disk contacts and a thick current spreading layer for current confinement. Growth of our proposed EP-VECSEL structure takes place by metal-organic vapor-phase epitaxy (MOVPE) on a GaAs substrate. For device fabrication, a flip-chip process including dry and wet chemical etching steps as well as the complete removal of the GaAs substrate is performed. Electroluminescence profile measurements indicate promising results of an enlarged emission area with quasi-homogenous current density distribution and tens of micrometers in diameter.

HL 51.8 Wed 17:15 POT 51

Scalable networks of quantum dot micropillar lasers — Louis Andreoli[1], Javier Porte[1], Maxime Jacquot[1], Stephan Reitzenstein[2], Laurent Larger[1], and •Daniel Brunner[1] — [1]Institut FEMTO-ST, Université Bourgogne Franche-Comté CNRS UMR 6174, Besançon, France — [2]Technische Universität Berlin, Berlin, Germany

Large scale networks of semiconductor lasers are a long shought after technology. Since the demonstration of semiconductor lasers they have been heavily involved in investigating nonlinear dynamics and chaos. However, scalable networks with the potential for hosting 100s of such lasers have never been achieved. We will demonstrate individual and addressable single mode pumping of densely packed, homogenized arrays of quantum dot micropillar lasers. We are able to pump more than 50 devices and realize all-optical nearest neighbor coupling. It is the first time such large semiconductor laser networks have been demonstrated, and our concept is scalable in principle until over 100.000 lasers. Our experiment opens new avenus for fundamental nonlinear dynamics experiments and high profile applications such as novel neuromorphic computing concepts and material processing.

HL 51.9 Wed 17:30 POT 51

Stabilization of an optical frequency comb interband cascade laser at 3.3 micrometer by time-delayed optical self-injection — •Dominik Auth[1], Mahmood Bagheri[2], Clifford Frez[2], Chadwick L. Canedy[3], Igor Vurgaftman[3], Jerry R. Meyer[3], and Stefan Breuer[1] — [1]Institute of Applied Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, USA — [3]Naval Research Laboratory, Washington, DC, 20375, USA

Interband cascade lasers emitting optical frequency combs in the mid-wave infrared at wavelengths around 3.3 micrometer are promising sources for applications like dual comb spectroscopy probing strong fundamental absorption lines of numerous chemical and biological agents [Bagheri et. al. Sci. Rep. 8(1) (2018), 3322]. In this contribution, the intermode beat frequency (IBF) tuning range and IBF line width of an 4 mm long optical frequency comb interband cascade laser subject to single cavity optical self-injection is investigated experimentally and by modelling [Drzewietzki et al., Opt. Express 21 (2013), 16142].

HL 51.10 Wed 17:45 POT 51

Lasing of an artificial, topological defect in a 1D, linear Su-Schrieffer-Heeger chain — •Philipp Gagel[1], Tristan Harder[1], Monika Emmerling[1], Sebastian Klembt[1], Christian Schneider[1], and Sven Höfling[1,2] — [1]Technische Physik and Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, Julius-Maximilians-Universität Würzburg, Würzburg, Germany — [2]SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, UK

The concept of topology has been adapted to categorize states of matter by topological invariants: Quantities which persist under adiabatic deformation. One of the various distinct features is the appearance of edge- and corner states between areas with different topological invariants, that are immune to external perturbations. Here we demonstrate lasing from an artificially created topological defect in a one-dimensional, linear Su-Schrieffer-Heeger chain of coupled photonic cavities by non-resonant optical pumping. The stability against distortions in combination with the intrinsic energy gap of the system provides a source for stable single mode lasing that is well suited for the next generation of optoelectronic devices, which can potentially be operated under electrical pumping and at ambient conditions.