HL 86: Semiconductor Lasers

Time: Thursday 15:00–17:45 Location: EW 015

HL 86.1 Thu 15:00 EW 015

Many-Body Effects in Optically Injected Quantum-Dot Lasers — •Benjamin Lingnau[1], Kathy Lüdge[1], Weng W. Chow[2], and Eckehard Schöll[1] — [1]Institut f. Theo. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623Berlin, Germany — [2]Sandia National Laboratories, Albuquerque, New Mexico 87185-1086, USA

We investigate the reaction of a quantum-dot (QD) laser to external optical injection. The QD laser device is described using a semiclassical approach, based on the semiconductor-Bloch and Maxwell's equations, describing the material-light interaction in a quantum-mechanical framework and the electric field dynamics classically. The optical QD transition is modeled using a finite spectral width, accounting for inhomogeneities of the QDs. Carrier-carrier and carrier-phonon scattering of charge carriers in bulk, quantum well (QW) and QD states are considered within the relaxation rate approximation, where the QD-QW scattering rate exhibits a strongly nonlinear dependence on the QW charge carrier density. Furthermore, many-body Coulomb interactions, leading to renormalizations of the single-particle energies, are taken into account within the screened Hartree-Fock approximation.

When subjecting the laser to external optical injection, the dynamical shift of the band-gap energy due to the Coulomb interactions gives rise to modifications in the locking behavior of the laser, which can not be explained with simpler free-carrier models.

HL 86.2 Thu 15:15 EW 015

Absorption Spectra and Modulation Response of a Quantum Dot Laser Device With Integrated Electro-Optic Modulator — •Miriam Wegert, Kathy Lüdge und Eckehard Schöll — TU Berlin, Institut für Theoretische Physik, Berlin, Germany

In this work we theoretically study the influence of modulator voltage, optical input and band structure on the absorption spectrum and the small-signal modulation response of a quantum dot (QD) electrooptic modulator (EOM) and investigate the dynamics of a laser device with integrated EOM.

Our theoretical model is based upon semiconductor Bloch equations which describe the coupled polarization and population dynamics and a traveling wave field equation. The impact of the quantum confined Stark effect, a red shift of the wavelength of the optical transition and a decrease of the oscillator strength through the shift of the energy levels and the distortion of the wave functions when a voltage is applied to the modulator, is included in the model.

Our simulations show that it is crucial both to include the QD excited state and to distinguish between electrons and holes to describe the absorption recovery properly. The absorption recovery time can be optimized by tuning the energy spacing. That makes a laser device with integrated EOM an excellent candidate for switching applications in an optical communication system. The simulated absorption spectra as well as the small-signal modulation response are in good agreement with experimental results.

HL 86.3 Thu 15:30 EW 015

Influences on random laser modes in dependence of their localization strength — •Janos Sartor, Daniel Schneider, Felix Eilers, and Heinz Kalt — Karlsruher Institut für Technologie (KIT) Karlsruhe

In a strongly scattering medium that provides optical gain, laser activity can be observed without an external resonator. In a so called random laser the coherent feedback is provided by multiple scattering. Optically pumped ZnO powders with a grain size in the order of the emitted wavelength provide optical gain and strong scattering at the same time and can therefore be used to examine random lasing activity. In our work we want to discuss important influences on the lasing properties like the temperature or the mean free path of light, which can be controlled by using powders with different grain sizes. When the mean free path is close to the limit where localization of light can occur, two different kinds of modes can be observed. Either modes that extend over large areas of the sample or strongly localized ones. We use samples of reduced size to reduce the strong fluctuations usually found for random lasers in order to be able to examine the behavior of single lasing modes. They behave different under influences like sample size or excitation density.

HL 86.4 Thu 15:45 EW 015

MBE-grown InAs/InP-based quantum dot lasers with high modal gain at 1.55 μ emission wavelength — •Christian Gilfert[1], Vitalii Ivanov[1], Johann Peter Reithmaier[1], David Gready[2], and Gadi Eisenstein[2] — [1]Technische Physik, Institute of Nanostructure Technologies and Analytics, Universität Kassel, 34132 Kassel, Germany — [2]Technion - Israel Institute of Technology, Haifa 32000, Israel

Self-organized InAs/InP(100) quantum dot systems are promising candidates for future telecommunication applications at 1.55 μm. Several groups have reported on a variety of nano species ranging from quantum wires over elongated quantum dashes to quantum dots in this material system. Quantum dots are, however, the preferred choice due to their 0-dimensional confinement. A recently developed growth method allows engineering the shape of the growing species by molecular beam epitaxy. Quantum dot like ensembles exhibiting much smaller photoluminescence line widths than comparable dash structures are achieved. Diode lasers, in which stacks of such structures are used as active region, emit around 1550 nm with good internal characteristics. In particular, a high modal gain of 10 cm^{-1} per active layer. Consequently, ridge waveguide lasers with 4 active layers could be operated down to cavity lengths as short as 340 μm at room temperature. The threshold current was measured to 35 mA and a cw output power of 16 mW was obtained. Such short cavities are a prerequisite for directly modulated high-speed lasers.

HL 86.5 Thu 16:00 EW 015

Room temperature, continuous wave lasing in microcylinder and microring quantum dot laser diodes — Ferdinand Albert[1], Fabian Langer[1], Thomas Schlereth[1], Maciej Michal Pieczarka[1], Sven Höfling[1], Stephan Reitzenstein[1,2], and •Martin Kamp[1] — [1]Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Present address: Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany

Whispering gallery mode (WGM) optical resonators made of semiconductors have a wide range of applications, ranging from cavity quantum electrodynamics studies to integrated planar photonic circuits. Most of these resonators investigated so far were based on suspended microdisks supported by a pedestal with a smaller diameter. However, this geometry puts severe limitations to electrical current injection and heat removal from the resonator. Better geometries as far as these parameters are concerned are microcylinders or microrings.

We've achieved room temperature, continuous wave operation of laser diodes based these structures. The active region consists of six layers of InGaAs quantum dots (emission wavelength around 1.3μm) embedded in a quantum well. Current injection in the active part of the device is improved in ring resonators, leading to a reduction of the lasing thresholds to a few mA. This geometry also suppresses whispering gallery modes with a high radial order, thus simplifying the lasing spectra. Under these conditions, single-mode and two-color lasing can be obtained simply by adjusting the injected current.

Coffee Break (15 min)

HL 86.6 Thu 16:30 EW 015

Interband Cascade Lasers Operating in cw-Mode at Room Temperature — •Robert Weih, Adam Bauer, Alfred Forchel, Sven Höfling, and Martin Kamp — Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Within the last years, interband cascade lasers (ICLs) have become the most promising devices to cover the mid-infrared wavelength range between 3 and 4 μm. They are able to deliver large optical output powers of several hundred milliwatts while consuming less power than quantum cascade lasers (QCLs). Like in traditional diode lasers, amplification of light in ICLs is based on interband transitions. However, the unique band alignments in the GaSb material system - in particular the broken gap of a InAs/GaSb junction - allow a recycling of carriers via a tunnel process. This enables cascaded active regions like in QCLs. The ICLs in this work were grown by molecular beam epitaxy

and characterized via temperature dependent electro-optical measurements. In order to lower the threshold current density, design variations concerning the active region and the waveguide structure were made. Changing the composition and thickness of the GaInSb hole quantum well significantly increases the spatial overlap of the wavefunctions involved in the optical transition. This results in a higher recombination probability and hence decreases the threshold current. Furthermore, optical losses could be reduced by increasing the lower cladding thickness from 1.9 μm to 3.4 μm. Laser structures incorporating these optimizations were able to operate up to 20°C in cw mode. The latest structures showed threshold currents as low as $400 A/cm^2$.

HL 86.7 Thu 16:45 EW 015

Quantum dot microlasers with external feedback — •Ferdinand Albert[1], Caspar Hopfmann[1,2], Christian Schneider[1], Sven Höfling[1], Lukas Worschech[1], Martin Kamp[1], Wolfgang Kinzel[3], Alfred Forchel[1], Stephan Reitzenstein[1,2], and Ido Kanter[4] — [1]Technische Physik, Universität Würzburg, Germany — [2]Present address: Institute of Solid State Physics, Technische Universität Berlin, Germany — [3]Institute for Theoretical Physics, Universität Würzburg, Germany — [4]Department of Physics, Bar-Ilan University, Ramat-Gan, 52900 Israel

Advances in semiconductor nanotechnology have triggered considerable research and development of photonic devices on the nanoscale, which feature specific emission characteristics that are related to the quantum nature of the involved emitters. In this work we address the unexplored field of lasing in microcavities with self-feedback close to the quantum limit. A finite fraction of the emission of an electrically driven quantum dot micropillar laser is reflected back into the microcavity by an external mirror. This self-feedback results in a dramatic change in the photon statistics, where the second order photon autocorrelation function at times zero, $g^{(2)}(0)$, exhibits super-thermal values up to 3.51±0.06. This unique type of strong photon bunching fundamentally differs from $g^{(2)}(0) = 2$ and $g^{(2)}(0) = 1$ expected for thermal and coherent light, respectively. It occurs simultaneously with a revival of the bunching signal with a round trip time of the external cavity and is as such indicative of random intensity fluctuations associated with the spiked emission of light at the nW level.

HL 86.8 Thu 17:00 EW 015

Exceeding 100 mW UV laser emission around 330 nm via intracavity frequency doubling of a tunable red AlGaInP-VECSEL — •Hermann Kahle, Thomas Schwarzbäck, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen and Research Center SCoPE, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

The wide range of applications in biophotonics, television technologies, spectroscopy and lithography made the vertical external cavity surface-emitting laser (VECSEL) an important category of power scalable lasers. The possibility of bandgap engineering, inserting frequency selective and converting elements into the open laser cavity and laser emission in the fundamental Gaussian mode leads to ongoing growth of the area of applications for VECSELs. We present an intra cavity frequency doubled VECSEL with emission wavelength around 330 nm, a maximum tuning range of more than 7 nm and output powers exceeding 100 mW. Frequency doubling is realized with a beta barium borate crystal, while a birefringent filter, placed inside the laser cavity under Brewster's angle, is used for frequency tuning. The laser-chip is realized by a 55 $\lambda/4$ pairs $Al_{0.50}Ga_{0.50}As$/AlAs Bragg mirror on a GaAs substrate, followed by a n-λ cavity multi quantum well structure consisting of 20 compressively strained GaInP quantum wells in an $Al_xGa_{1-x}InP$ separate confinement heterostructure for an emission wavelength of around 660 nm. We show results of different arrangements of the quantum wells and investigate further innovative approaches for the active region.

HL 86.9 Thu 17:15 EW 015

Investigation of the 2-color emission from a vertical-external-cavity surface-emitting laser — •Matthias Wichmann[1], Alexej Chernikov[1], Mohammad Khaled Shakfa[1], Stephan W. Koch[1], Martin Koch[1], Maik Scheller[2], and Jerome V. Moloney[2] — [1]Department of Physics and Materials Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]College of Optical Sciences, University of Arizona, 1630 E University Boulevard, Tucson, AZ, 85721, USA

Vertical-external-cavity surface-emitting lasers (VECSELs) combine an excellent output beam quality and high power operation. Furthermore, the external cavity makes the VECSEL ideally suited for intra-cavity frequency conversion. Recently, a high power, room temperature continuous wave terahertz source was demonstrated based on difference frequency generation within a nonlinear crystal that was placed inside a VECSEL cavity. For this kind of application, a stable two color operation is mandatory. Here, we present systematic measurements on the time dynamics of the two-color emission from a VECSEL using a streak camera. With this, time- and frequency resolved "snapshots" of the VECSEL emission are acquired and analyzed with respect to correlation and relative stability. By varying the pump power, different operation regimes could be realized. The results show that the VECSEL can be operated in a broad stable regime with both colors emitting simultaneously. Near the lasing threshold and the thermal roll-over, a breakdown of stability is observed.

HL 86.10 Thu 17:30 EW 015

Green II-VI-based electron beam pumped vertical-cavity surface-emitting laser — •Thorsten Klein[1], Sebastian Klembt[1], Vladimir I. Kozlovsky[2], Michael D. Tiberi[3], and Carsten Kruse[1] — [1]Institute of Solid State Physics, University of Bremen, Germany — [2]P.N. Lebedev Physical Institute, Moscow, Russia — [3]Principia Lightworks, Inc., Woodland Hills, USA

Laser light sources for projection applications have distinct advantages over the commonly used light sources. The color gamut of an RGB laser light based display is closer to the range of the human visual system, and the operating lifetime is significantly extended. Optical coupling is simple due to the small divergence angle of vertical-cavity surface-emitting laser (VCSEL). Color filters are not needed, leading to an improvement in power efficiency. Moreover, UV and IR emission is eliminated. An electron beam pumped VCSEL (eVCSEL) based on II-VI semiconductors has been developed for emission in the green spectral region. The structure was grown using molecular beam epitaxy on (001)-GaAs substrates misoriented 10° towards the (111)A crystal plane. The 10.5 fold bottom DBR consists of a MgS-ZnCdSe-superlattice as low index material and ZnSSe as high index material. The cavity contains 20 ZnCdSSe-QWs in ZnSSe barriers, the 4 fold dielectric top DBR consists of SiO_2/Ta_2O_5. Structural characterization was carried out by HRXRD, SEM and TEM. Luminescence properties were investigated by CL and PL. Room temperature lasing was achieved at 522 nm. The output power is about 2.5 - 3 W using 45 keV of acceleration voltage and 1.5 mA of current for the electron beam.