Dynamic Properties of Quantum Dot Semiconductor Optical Amplifiers — •NIELS MAIER, MIHAIAN WIEGAND, KATHY LÜDGE, and ECKERHAARD SCHÖLL — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We investigate the dynamic properties of quantum dot semiconductor optical amplifiers (QD-SOAs) on the basis of Bloch equations for the coupled interband polarization and carrier dynamics of the QDs along with a travelling wave field equation for the electric field within the device. The model includes microscopically calculated Coulomb scattering rates in the dynamic equations for the carrier populations of the quantum dots.

Pump-probe simulations using ultrashort input pulses (∼150 fs) give insight into the (ultra-)fast gain recovery dynamics of QD-SOAs, whereas the propagation dynamics of ultrashort input pulses reveals coherent effects such as pulse breakup.

Quantum Dot Based Electro Absorption Waveguide Modulator — •MIRKO STUBERNAUCH, CHRISTIAN MEUER, GERRIT FIOGL, and DIETER BIMBERG — Institut für Festkörperphysik, Technische Universität Berlin, EW 5-2, Hardenbergstr. 36, 10623 Berlin, Germany

InAs quantum dot (QD) based electro absorption ridge waveguide modulators (EAM) having different length and layer number are fabricated and tested. The operation wavelength of the devices is around 1.3 μm and the fast change of electro absorption is induced by the Quantum Confined Stark Effect (QCES). Transmission spectra simulations based on kp-calculations including charge carrier Coulomb interaction predict a QCS shift of 20 nm and an extinction ratio of maximum 35 dB at 10 V reverse bias. These results are compared to experimentally achieved values for maximum absorption edge shift of 15 nm at an applied field of 240 kV/cm, corresponding to 9 V reverse voltage. Transmission power measurements show the highest extinction ratio of 18 dB reached so far for QD devices at a wavelength of 1315 nm.

First dynamic scattering parameter measurements using a completely calibrated network analyzer show a maximum 3dB bandwidth of 17 GHz at a wavelength of 1310 nm with an applied reverse bias of 1.5 V. These are promising results for monolithic integration with single mode emitting lasers, e.g. distributed feedback lasers.

Effects of 1st order Coulomb Interaction on the Turn-on Dynamics of Quantum Dot Lasers — •BENJAMIN LINGNAU1, KATHY LUDGE1, ECKERHAARD SCHÖLL1, and WENG CHOW2 — 1Institut für Theophysik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany, 2Sandia National Laboratories, Albuquerque, New Mexico 87185-1086, USA

We investigate the influence of many-body effects and nonequilibrium effects on the turn-on dynamics of a quantum dot laser. The interplay of bandgap renormalization, population hole-burning and inhomogeneous broadening is crucial for understanding the dynamics of the turn-on process and gives rise to modifications in relaxation oscillation behaviour. The theory used in the simulations is based on a semiclassical approach, where the laser field and active medium are described by the Maxwell-semiconductor-Bloch equations. Many-body Coulomb effects are described in the screened Hartree-Fock approximation. Carrier-carrier and carrier-phonon collisions are treated within the effective relaxation rate approximation. Inhomogeneous broadening of the quantum-dot distribution is taken into account. Many-body effects were found to have a large effect on the turn-on dynamics of the laser device and especially on the relaxation oscillations after turn-on. We observe a noticeable increase in oscillation frequency and a stronger damping due to the bandgap renormalization. Furthermore, when changing the width of the inhomogeneously broadened quantum dot distribution, increasing frequencies and more pronounced oscillations for smaller broadening widths are observed.

Characterization of red VCSELs via S-Parameter Analysis — •HENDRIK NIEDERBRACHT1, MARCUS EICHEFELDER1, WOLFGANG VOGEL2, MICHAEL WIESNER1, SANDRA KLINGER2, ROBERT ROSSBACH1, MICHAEL JETTER1, MANFRED BERUTH2, and PIETER MICHLER1 — 1Institut für Halbleiteroptik und Funktionelle Grenzflächen, 70550 Stuttgart, Germany — 2Institut für Elektrische und Informationstechnik, Fachbereich Elektrotechnik und Informationstechnik, Universität Stuttgart

The future optical data transmission via Polymer Optical Fibre needs devices which are able to achieve high modulation frequencies. The ideal candidates for this task are vertical-cavity surface-emitting laser (VCSEL) due to their splendid properties. In this presentation we show small signal modulation measurements examined by the method of scattering (S)-parameter analysis to characterize 660 nm AlGaInP-based VCSELs. Based on S11 measurements and an equivalent circuit model for the VCSEL geometry, device values are revealed. First steps of optimization are shown, allowing a higher modulation frequency, mainly by reducing parasitic pad capacitance. The area surrounding the mesa was reduced and the spatial distance between p- and n-contacts was increased by a thick layer of high dielectric material. The intrinsic response is evaluated through the simulated low pass and the measurement of the S21-parameter. The difference between single and multiple apertures for current confinement reducing intrinsic capacitance is also part of the presentation.

Monolithic electro-optically modulated vertical cavity surface emitting laser — •DIJAN ARSENIJEVIC1, GERRIT FIOGL, and DIETER BIMBERG — Institut für Festkörperphysik, Technische Universität Berlin, EW 5-2, Hardenbergstr. 36, 10623 Berlin, Germany

The quantum dot mode-locked lasers presented here are processed into ridge waveguide structure from material grown by molecular beam epitaxy and contain 15 stacks of InGaAs/GaAs quantum dots emitting at 1.3 μm. To enhance temperature stability the material is p-doped. The lasers having an overall length of 1 mm are separated into two sections (900 μm gain, 100 μm absorber). For hybrid mode-locking in addition to the DC-biasing of these two sections a RF signal was applied to the absorber. The emitted optical pulses for varying frequency and power of the RF source as well as different heat sink temperatures are analyzed by auto-correlation and electrical spectra measurements. The pulse width ranges from below 2 ps to about 8 ps. Although no change in pulse width is found by switching the operation mode from passive to hybrid mode-locking a decrease in optical timing jitter is observed. The maximum locking range for one operating point is 30 MHz and in addition can be linked to the widths of the pulses. The dependence of the locking range on the RF power is found to be linear. Interestingly the region of hybrid mode locking is asymmetric compared to the passive mode-locking frequency.

Monolithic electro-optically modulated vertical cavity surface emitting laser — •HGOUDA HABIBI1, JYONG WANG2, STEPHEN A. PAOLINI3, and DIETER BIMBERG1 — 1Institut für Festkörperphysik, Technische Universität Berlin, EW 5-2, Hardenbergstr. 36, 10623 Berlin, Germany

The steadily growing data traffic requires high speed and low-cost laser diodes. Conventional current modulated vertical cavity surface emitting lasers (VCSEL) are limited in their bit rate due to a quadratic increase in the current density with the bit rate. Monolithically integrated electro-opto-modulator (EOM) VCSEL promise to overcome this problem. In this work we demonstrate a GaAs-based 850 nm EOM-VCSEL. The VCSEL is driven continuously while the pulsed light output is generated by reflectivity modulation of the top DBR through an embedded EOM section. A low modulation voltage (∼2 V) is needed to reach -3 dB extinction ratio enabling the use of such EOM-VCSELs with low power consumption CMOS drivers. Excellent output stability at a significant extinction ratio is demonstrated up to 85°C. A similar extinction ratio was revealed in large-signal modulation experiments at frequencies presently up to 3 GHz. Thus the first high bit rate data transmission by an EOM-VCSEL is demonstrated.

Time: Thursday 9:30–12:45

Location: H13

Thursday

Technische Physik, Institute of Nanostructure Technology and Physical Chemistry, INF, Universität Kassel, Kassel, Germany — Technische Physik, Institute of Nanostructure Technology and Physical Chemistry, INF, Universität Kassel, Kassel, Germany

Amir Capua

Tobias Korn

Time-resolved studies of a rolled-up semiconductor laser with a width of 10 GHz with an extrapolated max. bandwidth of about 40 GHz. The temperature on the threshold current and emission wavelength will be down to 8 mA by pumping the grating section at 50 mA (total device formed lateral to the ridge in 1st and 2nd order with a trench width by low-cost large volume nanoimprint lithography. The gratings are lithogaphically defined on the sample surface by e-beam lithography, but could be easily adapted to aspect ratios of > 1:15. The gratings are lithogaphically defined on InGaN quantum wells (QWs) for an operation wavelength of around 665 nm. Five QW packages are placed in (AlO:Ga:Gao.45)5.1Ino.49P cladding layers in a resonant periodic gain design. Each package consists of four QWs embedded in (AlO:Ga:Gao.67)5.0Ino.41P barriers, respectively. The 33A cavity is fabricated on an AlO:Ga:Gao.50As/AIAs distributed Bragg reflector. By bonding an intra-cavity diamond heatspreader on the chip, continuous-wave operation exceeding 1 W output power is achieved.

We show key parameters like power transfer characteristics, beam profile and spectra of the laser. The measurement of the beam propagation factor is also presented.

Tobias Kipp

Andrea Stemmann

Thomas Schwarzbäck

Sohaib Afzal

Petri Melanen

HL 48.11 Thu 12:15 H13

Tuning the emission wavelength of interband cascade lasers in the 3-4 μm spectral range — M. Dallner, A. Baur, F. Lang, M. Motyka, G. Gheorghe, K. Krzyzstof Ryczko, J. M. H. W. InGaN based greenish separate confinement heterostructures

— J. Ebeling, T. Aschenbrenner, C. Tessarek, S. Figge, and D. Hommel

Institut für Festkörperphysik, Universität Bremen

For opto-electronic applications green laser diodes (LDs) are of great interest. The fabrication of such GaN-based light emitting diodes (LEDs) and LDs however faced different problems ranging from the lack of adequate homoepitaxial substrates to the miscibility gap of InGaN. Recently [1,2] there have been reports of laser diodes based on InGaN quantum wells (QWs) with typically 42 nm wall thickness and about 2.4 μm radius. Constructive interference after a round trip leads to the formation of ring modes. In axial direction a special modulation of the wall thickness, similar to a ridge waveguide, confines the modes on a length of about 1.4 μm. A GaAs quantum well as optical gain material is excited nearly resonantly by sub-picosecond laser pulses. Time-resolved studies on this novel kind of semiconductor laser reveal particularly fast turn-on times and short pulse emission above the threshold, as well as single-mode lasing. We present non-equilibrium quantum transport in 3D nanostructures — P. Greck, C. Schindler, and P. Vogl

Technische Universität München, Germany

We present non-equilibrium Green's function (NEGF) calculations based on the extension of the standard Büttiker Probe model [1]. Büttiker Probes provide a phenomenological method to model incoherent scattering very efficiently. However, any effects of discrete energy coupling (e.g. by optical phonons) are not captured due to the simple structure of the model. Therefore, devices relying on resonant phonon effects such as THz quantum cascade lasers (QCLs) calls for more sophisticated models for the scattering self energies. While the self-consistent Born approximation provides the required accuracy, it is extremely costly in terms of computational resources, especially for 3D nanostructures. We have extended the standard Büttiker Probe model in a way that accurately accounts for optical phonon scattering without losing the computational efficiency and simplicity of the Büttiker Probe model. The method allows one to control the scattering mechanisms individually. This renders realistic quantum transport calculations of 3D nanostructures feasible. We present detailed calculations of mid-infrared quantum cascade structures and compare the results with experimental data as well as with full NEGF results [2].


HL 48.12 Thu 12:30 H13

Efficient modeling of non-equilibrium quantum transport in 3D nanostructures — P. Greck, C. Schindler, and P. Vogl

Technische Universität München, Germany

We present non-equilibrium Green's function (NEGF) calculations based on the extension of the standard Büttiker Probe model [1]. Büttiker Probes provide a phenomenological method to model incoherent scattering very efficiently. However, any effects of discrete energy coupling (e.g. by optical phonons) are not captured due to the simple structure of the model. Therefore, devices relying on resonant phonon effects such as THz quantum cascade lasers (QCLs) call for more sophisticated models for the scattering self energies. While the self-consistent Born approximation provides the required accuracy, it is extremely costly in terms of computational resources, especially for 3D nanostructures. We have extended the standard Büttiker Probe model in a way that accurately accounts for optical phonon scattering without losing the computational efficiency and simplicity of the Büttiker Probe model. The method allows one to control the scattering mechanisms individually. This renders realistic quantum transport calculations of 3D nanostructures feasible. We present detailed calculations of mid-infrared quantum cascade structures and compare the results with experimental data as well as with full NEGF results [2].


HL 48.10 Thu 12:00 H13

Exceeding 1 W output power of a red AlGaNP-VECSEL emitting at 665 nm — T. Schwarzbäck, M. Eichfelder, W. Scholz, R. Roßbach, M. Jetter, and P. Michler

Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Vertical external cavity surface-emitting lasers (VECSELs) have emerged recently as an important category of power-scalable semiconductor lasers where high optical output power and near-diffraction-limited beam quality with a TEM00 Gaussian beam profile. We present a VECSEL system based on a multi-quantum-well structure with 20 compressively-strained GaP quantum wells (QWs) for an operation wavelength of around 665 nm. Five QW packages are placed in (AlO:Ga:Gao.45)5.1Ino.49P cladding layers in a resonant periodic gain design. Each package consists of four QWs embedded in (AlO:Ga:Gao.67)5.0Ino.41P barriers, respectively. The 33A cavity is fabricated on an AlO:Ga:Gao.50As/AIAs distributed Bragg reflector. By bonding an intra-cavity diamond heatspreader on the chip, continuous-wave operation exceeding 1 W output power is achieved.

We show key parameters like power transfer characteristics, beam profile and spectra of the laser. The measurement of the beam propagation factor is also presented.

HL 48.11 Thu 12:15 H13

Tuning the emission wavelength of interband cascade lasers in the 3-4 μm spectral range — M. Dallner, A. Baur, F. Lang, M. Motyka, G. Gheorghe, K. Krzyzstof Ryczko, J. M. H. W.