HL 9: Semiconductor Laser II

Time: Monday 14:45–17:15 Location: H13

HL 9.1 Mon 14:45 H13

Nichtgleichgewichtsrechnungen in Halbleiterlaserstrukturen
— •Eckhard Kühn[1], Angela Thränhardt[1], Sangam Chatterjee[1], Christoph Lange[1], Peter Brick[2], Wolfgang Diehl[2], Swantje Horst[1], Kristian Hantke[1], Wendel Wohlleben[3], Marcus Motzkus[3], Wolfgang Stolz[1], Wolfgang Rühle[1] und Stephan Koch[1] — [1]Fachbereich Physik, Philipps Universität Marburg, Deutschland — [2]Osram Semiconductors, Regensburg, Deutschland — [3]Fachbereich Chemie, Philipps Universität Marburg, Deutschland

Wir präsentieren ein mikroskopisches Modell zur Beschreibung von Nichtgleichgewichtsladungsträgerverteilungen in Halbleiterquantenfilmlaserstrukturen. In optisch gepumpten Systemen wie z.B. Halbleiterscheibenlasern erzeugt der anregende Laserstrahl eine Verteilung von Ladungsträgern, die keine thermische Gleichgewichtsverteilung darstellt. Erst durch stoßinduzierte Relaxationsprozesse kann sich eine Fermiverteilung einstellen. Unser Modell beschreibt die Erzeugung und Relaxation von Ladungsträgern im Quantenfilm unter Berücksichtigung des Pauli-Prinzips auf Basis der halbklassischen Maxwell-Halbleiter Bloch Gleichungen.

Die resultierenden dynamischen Prozesse finden auf unterschiedlichen Zeitskalen statt. Auf die Thermalisation innerhalb der einzelnen Bänder folgt ein Regime mit deutlich verschiedenen Ladungsträger- und Gittertemperaturen. Die daraus abgeleitete zeitliche Entwicklung der Gittererwärmung zeigt gute Übereinstimmung mit dem Experiment. Thermische Effekte wie das Überrollen eines VECSELs lassen sich qualitativ gut reproduzieren.

HL 9.2 Mon 15:00 H13

Non-equilibrium quantum transport theory for quantum cascade lasers
— •Tillmann Kubis and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

We present fully self-consistent non-equilibrium Green's function (NEGF) calculations of various quantum cascade laser structures (QCL) including all relevant coherent and incoherent scattering mechanisms. We have developed an implementation of the NEGF formalism that takes into account acoustic and polar-optical phonon scattering as well as impurity and interface roughness scattering within the self-consistent Born approximation. The complete momentum and energy dependence of all scattering mechanisms is accounted for. This is known to have a significant influence on all QCL device characteristics yet has been neglected in previous work. The electron-electron scattering is incorporated self-consistently within the Hartree approximation. The coupling between the lesser and the retarded Green's function is fully taken into account. In this way, all scattering states, transition probabilities between them, and their occupancies are calculated self-consistently instead of semi-classically. Our calculations yield I-V characteristics and optical gain that agree nicely with experiment. In spite of realistic dephasing, we observe multi-barrier tunneling and coherent formation of occupation inversion. Incoherent scattering mechanisms appear to assist tunneling but reduce the optical gain significantly.

HL 9.3 Mon 15:15 H13

Dynamic behavior of 1050nm semiconductor disk lasers
— •Wolfgang Diehl[1,3], Sangam Chatterjee[2], Swantje Horst[2], Kristian Hantke[2], Wolfgang Rühle[2], Michael Furitsch[1], Stefan Illek[1], Ines Pietzonka[1], Johann Luft[1], Wolfgang Stolz[3], and Peter Brick[1] — [1]Osram Opto Semiconductors, Leibnizstr. 4, D-93055 Regensburg, Germany — [2]Faculty of Physics and Material Science Center, Philipps-Universität Marburg, Renthof 5, D-33032 Marburg, Germany — [3]Philipps-University Marburg, Hans Meerwein Str., D-35032 Marburg, Germany

We have investigated the lasing dynamics of semiconductor disk lasers emitting at 1050nm. Pulse durations of 500ns and 5000ns were used for excitation pump wavelength of 808nm for barrier pumping and 940nm for direct well pumping. Without resonator due to the high pump densities of up to 10kW/cmˆ2 high order transitions in the QW as well as band filling effects can be observed. With a resonator present, the photoluminescence overshoots and is subsequently clamped on a time scale of 40ns to 80ns depending on the pump power. This behavior can be explained with rate-equation modell using microscopically calculated gain and luminescence spectra.

HL 9.4 Mon 15:30 H13

Coulomb effects on luminescence spectra and radiative recombination times
— •Walter Hoyer, Mackillo Kira, and Stephan W. Koch — Department of Physics and Material Sciences Center, Philipps-University, Renthof 5, 35032 Marburg, Germany

Semiconductor laser structures are of great technological importance while they also offer a unique possibility to study fundamental properties of light-matter interaction. Typically, lasers operate at room temperature or above such that appreciable phonon scattering has to be considered for a realistic description. At the same time, phase-space filling and Coulomb effects such as screening or Auger recombination are important for laser systems, and strong internal electric fields can furthermore complicate the analysis.

Here, a microscopic theory based on Bloch electrons and holes in a two-band approximation is applied in order to compute absorption and luminescence spectra for GaAs-type quantum wells at room temperature. Special focus is set to investigate the effect of Coulomb interaction on the linewidth of the luminescence spectra and on the radiative recombination rates. Since spontaneous emission provides an unavoidable loss mechanism, precise knowledge is important in order to correctly predict laser threshhold densities. Density dependent recombination rates are computed and contrasted with the common assumption of a quadratic increase with density. It is found that even for densities clearly beyond the transparency point a free-carrier model is insufficient for a correct estimate of the radiative recombination rates.

HL 9.5 Mon 15:45 H13

High modal gain and low threshold temperature dependence of InGaAlAs quantum dot lasers with increased dot density
— •Thomas Schlereth, Christian Schneider, Wolfgang Kaiser, Sven Höfling, and Alfred Forchel — Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

The growth, morphology and spectral properties of $In_xGa_{1-x}As$ and $In_xGa_{1-x-y}Al_yAs$ quantum dots (QDs) were studied. The emission wavelength of the QDs can be tuned in a wide range by varying the In and Al content. Furthermore, an increase in Al concentration results in an enhancement of dot density and a decrease of dot size. This phenomenon can be explained by the lower migration ability of Al compared to In.

By adjusting the In and Al content, lasers with different dot species (InGaAs and InGaAlAs), and different dot densities (factor of ∼2.5), yet similar emission wavelengths (∼920 nm) have been realized. Both laser samples exhibit high internal quantum efficiencies and low internal absorptions of 0.83 and $\sim 2\mathrm{cm}^{-1}$ for the InGaAs and 0.79 and $\sim 1\ \mathrm{cm}^{-1}$ for the InGaAlAs sample. The sample containing InGaAlAs QDs, however, shows a factor of ∼1.6 higher modal gain ($\sim 63\ \mathrm{cm}^{-1}$), and a lower threshold current density, which we attribute mainly to the higher dot density. Characteristic temperatures as high as 174 K for the Al-containing QD laser and 144 K for the InGaAs QD laser were found between 15°C and 85°C.

HL 9.6 Mon 16:00 H13

Low threshold high efficiency InAs/InGaAlAs/InP ∼1.55 µm quantum dash-in-a-well lasers
— •Sebastian Hein, André Somers, Sven Höfling, and Alfred Forchel — Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

In this work the dash-in-a-well (DWELL) design was used to improve the basic characteristics of InP-based quantum dash lasers. By embedding self-assembled InAs QDashes in a quantum well threshold current densities could be reduced due to an enhanced carrier capture of the QDashes. However the well layers reduce the energy barrier and hence lower the energy levels of the QDashes resulting in a longer emission wavelength. Though the QDash emission wavelength can be tuned over a wide range by varying the thickness of the QDash layers, the critical layer thickness for the formation of QDashes poses a lower limit to adjustment. Employing an adapted $InAs/In_{0.53}Ga_{0.37}Al_{0.10}As/In_{0.53}Ga_{0.23}Al_{0.24}As$ DWELL design, threshold current densities could be significantly reduced while maintaining an emission wavelength near 1.55 µm. Cavity length de-

pendent measurements of as-grown devices lead to an extrapolated transparency current density of 165 A/cm^2 per dash layer and a very high internal differential efficiency of 0.89. With 0.6 mm long devices a very high external differential efficiency of 0.20 W/A per facet was achieved.

HL 9.7 Mon 16:15 H13

Optical characterisation of Ga(AsSb) heterostructures — •Christina Bückers, Gunnar Blume, Angela Thränhardt, Christoph Schlichenmaier, Peter J. Klar, Gerhard Weiser, and Stephan W. Koch — Fachbereich Physik und Wissenschaftliches Zentrum für Materialwissenschaften, Philipps-Universiät Marburg

Ga(AsSb)/GaAs is one of the most promising material systems for room temperature VCSEL (vertical cavity surface emitting laser) operation at 1.3μm or even longer wavelengths. To enable emission in the desired regime Sb fractions of about 30-40% are required. An unresolved question remains the band alignment of Ga(AsSb) embedded between GaAs: While holes are certainly localised in the Ga(AsSb) layer, the confinement of the electrons is controversially discussed. This has major implications for the lasing performance.

In order to characterise the band alignment, Ga(AsSb)/GaAs quantum well structures are investigated. The lineshape of electroabsorption (EA) spectra is analysed by microscopic theory which offers an accurate determination of the conduction band offset between different layers: The calculations demonstrate that the offset is the most sensitive parameter for the lineshape of the EA spectra. Comparison of theoretical and measured spectra indicates a type II band alignment between Ga(AsSb) and GaAs with a conduction band offset of 40±20meV. Furthermore, information about the internal electric field in the quantum well region can be extracted.

HL 9.8 Mon 16:30 H13

Optische Eigenschaften von (GaIn)(NAs) und Ga(AsSb) - ein Vergleich — •Angela Thränhardt[1], Christina Bückers[1], Christoph Schlichenmaier[1], Stephan W. Koch[1], Jörg Hader[2] und Jerome V. Moloney[2] — [1]Philipps-Universität Marburg, Fachbereich Physik, Renthof 5, 35032 Marburg — [2]Arizona Center for Mathematical Sciences, The University of Arizona, Tucson, AZ 85721, USA

Der Wellenlängenbereich von 1.3mum bis 1.55 mum ist wegen des dort angesiedelten Dispersions- und Absorptionsminimums von Glasfasern ein für Laseranwendungen hochinteressantes Regime. Insbesondere GaAs-basierte Materialsysteme ermöglichen eine einfache Realisierung von oberflächenemittierenden Lasern. Zwei Kandidaten, die sich hier anbieten, sind die verdünnten Nitride sowie Ga(AsSb). In diesem Beitrag wird gezeigt, dass die optischen Eigenschaften beider Materialsysteme mikroskopisch realistisch modellierbar sind, und ein detaillierter Vergleich im Bezug auf typische Lasereigenschaften wie Gewinn und Linienbreitenfaktor präsentiert.

HL 9.9 Mon 16:45 H13

Charging Effects in Electrically Pumped Semiconductor Quantum Wells — •Ada Becker, Walter Hoyer, Mackillo Kira, and Stephan W. Koch — Department of Physics and Material Sciences, Philipps-University, Renthof 5. 35037 Marburg, Germany

In electrically pumped quantum-well lasers, population inversion results from the capture of barrier electrons and holes into the active region. In principle, unequal electron and hole masses lead to different in-scattering rates of charge carriers implying charging inside the quantum well. However, typical experiments do not show significant charging-induced effects.

A microscopic theory for barrier and quantum-well charge carriers is presented to explain the absence of a net charge by the screening effect of the barrier electrons. It is shown that their dynamics almost completely compensates the charging of the quantum well. Furthermore, a collective oscillation with the plasma frequency is predicted, which may give rise to terahertz emission.

HL 9.10 Mon 17:00 H13

coherence properties of high-β semiconductor micropillar lasers — •Serkan Ates[1], Sven Ulrich[1], Stephan Reitzenstein[2], Andreas Löffler[2], Alfred Forchel[2], and Peter Michler[1] — [1]Institut für Strahlenphysik, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

We will present our latest results of low temperature (T = 4 K) microphotoluminescence (μ-PL), first-order field correlation $g^{(1)}(\tau)$, and second-order field correlation $g^{(2)}(\tau)$ measurements on high-β (≤ 0.12) semiconductor micropillar lasers with (InGa)As/GaAs quantum dots (QDs) as a gain material. A first identification of an onset of lasing was observed from μ-PL measurements which yield a smooth transition from spontaneous into stimulated emission in the input-output intensity characteristics. Based on these results, power-dependent $g^{(1)}(\tau)$ measurements have been performed by Michelson interferometry to investigate the coherence properties of the emission throughout the transition regime. While the visibility of the emission's self interference yield a Gaussian behavior below the smooth lasing onset with a coherence time of $\tau_c \approx 30$ ps, we observed a gradual change to a Lorentzian profile around the transition region. With increasing excitation, our measurements reveal a strong increase in τ_c (x10) of the emission which therefore reflects the change of emission characteristics from thermal to (mainly) stimulated (coherent) light. This observation was approved by $g^{(2)}(\tau)$ correlation measurements which showed a strong reduction of intensity fluctuations above the transition regime.