HL 97: Semiconductor laser II: Microcavities and quantum-dot laser

Time: Thursday 15:30–17:15 Location: POT 051

HL 97.1 Thu 15:30 POT 051

Direct Net Gain Measurements in Organic Microcavities — •Christian Tzschaschel, Markas Sudzius, Andreas Mischok, Hartmut Fröb, and Karl Leo — Institut für Angewandte Photophysik, Technische Universität Dresden, Georg-Bähr Str. 1, 01069 Dresden

A profound knowledge of absorption and net gain coefficients of the active material is crucial for designing microcavity lasers. An extremely high degree of optical confinement in such systems modifies the spontaneous emission properties of the gain medium. Standard gain measurement techniques, such as the variable stripe length method, are thus rendered unreliable and hardly applicable.

In this work, a novel technique is presented. It allows direct measurements of both net gain and absorption coefficients of optically pumped organic microcavities. The method involves an in-depth analysis of the line shape of the cavity mode, which is then compared to transfer-matrix simulations. The use of wedge-shaped cavities provides tunable devices and allows for a detailed analysis of spectral net gain properties. The method is applied to organic microcavity structures consisting of a highly fluorescent laser dye (DCM), doped into a matrix material (Alq_3) and sandwiched between distributed Bragg reflectors. For this system, gain coefficients as high as $750\,\mathrm{cm}^{-1}$ have been extracted at optical pumping close to the lasing threshold.

HL 97.2 Thu 15:45 POT 051

Bloch-like Photonic States in Laterally Structured Organic Microcavities — •Andreas Mischok[1], Robert Brückner[1], Alexander A. Zakhidov[2], Vadim G. Lyssenko[1], Hartmut Fröb[1], and Karl Leo[1] — [1]Institut für Angewandte Photophysik, TU Dresden, George-Bähr Str. 1, 01069 Dresden, Germany — [2]Fraunhofer COMEDD, Maria-Reiche-Str. 2, 01109 Dresden, Germany

Organic microcavities offer broad spectral coverage and low lasing thresholds with comparably simple preparation techniques. In this work, a highly fluorescent laser dye (DCM) is doped into a matrix material (Alq3) and sandwiched between distributed Bragg reflectors, creating a high-quality cavity emitting around 590-680nm. Introducing an almost non-absorptive SiO2 layer next to the cavity, we are able to shape the photonic landscape in the cavity by micron-scale lateral structuring via photolithography. Periodic stripes in this layer create a periodic array of photonic potential wells, evoking memories of the crystal potential observed for electrons in solid state materials. This structuring creates a mode spectrum showing great similarity to Bloch states, reproducing confined modes below the confining potential and extended modes exhibiting mini-bands and mini-bandgaps above. Numerical simulations and analytical calculations provide further insight into the device as an easily accessible model for quantum mechanical effects in macroscopic systems. Lasing can be observed in a multitude of confined states - tunable by modifying the optical excitation patterns.

HL 97.3 Thu 16:00 POT 051

Jitter Reduction by Optical Feedback of Passively Mode-locked Quantum-Dot Lasers — •Marc Spiegelberg[1], Dejan Arsenijević[1], Moritz Kleinert[2], and Dieter Bimberg[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Berlin, Germany — [2]Fraunhofer Heinrich Hertz Institut, Berlin, Germany

Monolithically integrated two-section quantum-dot mode-locked lasers (MLL) providing optical pulse trains at several tens of Gigahertz are ideal candidates for applications in optical communication systems, e.g. as an optical clock or as a transmitter. Low jitter of the pulse comb is at least as crucial as repetition rates of or beyond 40GHz. The integrated jitter of passively MLLs is of the order of a few picoseconds. For hybrid mode-locking, a standard technique to reduce the jitter, an external electrical signal source is necessary, which is costly. Optical self-feedback (OFB), where a part of the MLL light is injected back into the device, is used here as a simple and effective way to reduce the jitter and to tune the repetition frequency of the MLL at the same time. For the first time, five different regimes of OFB are identified, depending on the OFB parameters: overall fiber length, feedback strength and the relative delay between emitted and injected pulses. But only one, the resonant regime, yield a jitter reduction of 94.2% down to 219fs. In this regime the repetition frequency of the MLL shows a linear dependence on the delay and can be tuned within 6.5MHz.

HL 97.4 Thu 16:15 POT 051

Timing jitter reduction in a mode-locked laser subject to optical feedback — •Lina Jaurigue[1], Christian Otto[1,2], Eckehard Schöll[1], and Kathy Lüdge[1] — [1]Institut f. Theo. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Potsdam Institute for Climate Impact Research, Telegrafenberg A26, 14412 Potsdam, Germany

Passively mode-locked (ML) lasers have a relatively large timing jitter due to the absence of an external reference clock. We investigate the effect of optical feedback (FB) on the timing stability of a passively ML laser. To model the ML laser we use a set of three coupled delay differential equations (DDE) describing a ring cavity, consisting of a gain section and a saturable absorber section. Optical FB is modeled by coupling the ring cavity to an external cavity. In the absence of FB the free running laser produces ultra-short pulses which have an internal cavity round trip time of $T_{ISI,0}$. When FB is added there is a second important time scale, the external cavity round-trip time τ. FB is resonant when $pT_{ISI,0} = q\tau$, where p and q are integers. Through resonant FB the timing jitter of the ML laser can be reduced and it has been shown that longer external cavities lead to a greater reduction in the timing jitter. This is, however, not always the case. For example, with non-zero α-factors (linewidth enhancement factors) resonant FB can give rise to destabilized pulse streams. For non-resonant FB the timing jitter is dramatically increased.

HL 97.5 Thu 16:30 POT 051

Excited state lasing and ground state quenching in quantum dot lasers: An analytical approach — •Andre Röhm, Benjamin Lingnau, Eckehard Schöll, and Kathy Lüdge — Institut f. Theo. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623Berlin, Germany

We theoretically investigate semiconductor quantum dot (QD) lasers and their transition from ground state (GS) lasing to two-state lasing as well as the physical mechanisms behind GS quenching. The QD laser device is described by a rate-equation approach based on the semiconductor-Bloch equations, and the electric field dynamics by Maxwell's equations. We compare our numerical simulations with an analytical approach. Based on that we are able to predict regions of GS as well as excited state (ES) lasing as a function of the different energy gaps between GS and ES for electrons and holes. Different ground state quenching mechanisms are studied in the framework of this analytical approach. Key parameters and their impact on the two-state lasing properties of the QD laser are discussed, which allows to predict the different lasing regimes for a wide range of possible QD sets. Furthermore, the influence of doping is investigated.

The GS quenching can be mainly attributed to a charge carrier asymmetry in the quantum dots which increases with pump current. This critical electron to hole ratio can be influenced by temperature, gain and GS-ES energy separation.

HL 97.6 Thu 16:45 POT 051

1.55 μm InAs/InP(100) Based Quantum Dot Lasers for High-Speed Optical Communication — Vitalii Ivanov[1], •Vitalii Sichkovskyi[1], Florian Schnabel[1], Anna Rippien[1], David Gready[2], Gadi Eisenstein[2], and Johann Peter Reithmaier[1] — [1]Institute of Nanostructure Technologies and Analytics, CINSaT, University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany — [2]2Department of Electrical Engineering, Technion, Haifa 32000, Israel

Self-organized InAs/InP quantum dot systems are promising candidates for telecommunication applications at 1.55 μm. Here we report on the latest development of high-speed directly modulated 1.55 μm lasers utilizing recently developed high-density round-shaped InAs quantum dots (QDs) as active material. The laser structures were specially optimized for high-speed operation using a unique spatially resolved model. In particular, the waveguide thickness is significantly reduced down to 100 nm on each side of the active region in order to minimize the carrier transport time. Static and dynamic properties of ridge waveguide lasers with ridge widths of 2 μm and relatively short cavity lengths of 275 μm to 350 μm were investigated. Due to the high modal gain of 70 cm-1 for lasers consisting of 6 QDs layers in the active region, 275 μm long devices are lasing at ground state up to 50 °C. Such lasers exhibit new record values in direct digital modulation of 22 GBit/s with a clear open eye.

HL 97.7 Thu 17:00 POT 051

InAs/InP based quantum dots laser with high gain at 1.55 μm emission wavelength — •Saddam Banyoudeh[1], Johann Peter Reithmaier[1], Christian Gilfert[1], Vitalii Ivanov[1], Vitalii Sichkovskyi[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

The Self-organized InAs/InP(100) quantum dot (QD) systems are promising canidates for the future telecommunication applications at 1.55 μm. Here we report on the recent advances in the performance of 1.55 μm QD laser, which allow to digital modulation at 22GBit/s with a 3 dB on/off ratio .The strong impact of different parameters on the dynamic proparties of directed modulated laser related to the QD material itself and the the laser design were investigated. The grown laser structure by molecular beam epitaxy consists of 100 nm waveguide layers composed of In0.528Al0.238Ga0.234As in which the InAs QD layers QD laser embedded. The cladding is formed by a 300 nm In0.523Al0.477As layer, 200 nm InP buffer layer and the InPsubstrate on the n-side while 300 nm thick In0.523Al0.477As and 1.7 μm InP layers are deposited for the p-cladding, re-spectively. A highly p-doped 200 nm thick In.532Ga.468Aslayer serves as p-contact. As active region a stacked QD are used, which emit around 1.55 μm with a high internal modal gain of 10 cm-1 per active layer.