HL 7: Semiconductor Lasers

Time: Tuesday 10:00–11:30 Location: H4

Invited Talk HL 7.1 Tue 10:00 H4

Ultrafast Spin-Lasers — Natalie Jung[1], Markus Lindemann[1], Tobias Pusch[2], Rainer Michalzik[2], Martin R. Hofmann[1], and •Nils C. Gerhardt[1] — [1]Photonics and Terahertz Technology, Ruhr-University Bochum, 44780 Bochum, Germany — [2]Institute of Functional Nanosystems, Ulm University, 89081 Ulm, Germany

Current-driven intensity-modulated semiconductor lasers are key optical sources for short-distance data transmission, but their modulation bandwidth is usually limited to values below 50 GHz. By exploiting the coupling between carrier spin and light polarization in semiconductor spin-lasers, the modulation frequencies can be increased to values above 200 GHz [1]. These high frequencies are achievable by increasing the resonance frequency of the coupled spin-photon system using strong birefringence in the laser cavity. Birefringent spin-lasers are capable to provide polarization modulation bandwidths and digital data transmission rates of more than 240 GHz and 240 Gbit/s respectively [1]. In contrast to intensity modulation in conventional lasers, polarization modulation in spin-lasers is largely independent of the pumping level and less sensitive to temperature increase [2]. This makes spin-lasers perfect candidates for future ultrafast communication systems as well as for many other emerging applications such as radio-over-fiber [3], neuromorphic computing [4] or THz generation [5].

[1] M. Lindemann et al., Nature 568, 212 (2019). [2] M. Lindemann et al., AIP Adv. 10, 035211 (2020). [3] N. Yokota et al., IEEE Photon. Technol. Lett. 33, 297 (2021). [4] K. Harkhoe et al., Appl. Sci. 11, 4232 (2021). [5] M. Drong et al., Phys. Rev. Appl. 15, 014041 (2021).

HL 7.2 Tue 10:30 H4

Extraction of silver permittivity at cryogenic temperatures through the optical characterization of Ag-coated plasmonic nanolasers — •Georgios Sinatkas[1,2], Aris Koulas-Simos[2], Jianxing Zhang[3], Jia-Lu Xu[3], Cun-Zheng Ning[3,4], and Stephan Reitzenstein[2] — [1]School of Physics, Aristotle University of Thessaloniki, 54124, Greece — [2]Institut für Festköperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany — [3]Department of Electronic Engineering, Tsinghua University, Beijing, 100084, China — [4]School of Electrical, Computer and Energy Engineering, Arizona State University, Tempe, AZ 85287, USA

Plasmonic nanolasers hold great promise for compact, low threshold opto-electronic devices [1, 2]. For the development and design of such lasers, often operating at cryogenic temperatures, it is important to know the temperature dependence of the involved materials with high accuracy. Here, we report the extraction of silver permittivity in the range 10 K–230 K by performing temperature-dependent μPL measurements in conjunction with numeric simulations on silver-coated nanolasers in the near-infrared regime. By mapping the changes in Q-factor, measured at transparency, into silver-loss variations, we extract the imaginary part of silver permittivity, estimating an order of magnitude shift in the examined temperature range. This data is missing from the literature and it could be useful for theoretically validating experimental observations and evaluating thermal effects.

[1] S. I. Azzam et al., *Light: Science & Applications* **9**(1) (2020).
[2] S. Kreinberg et al., *Laser Photonics Rev.* **14**(12), 2000065 (2020).

HL 7.3 Tue 10:45 H4

Linewidth transition at the laser threshold of quantum-well nanolasers — •J. Buchgeister[1], M. L. Drechsler[1], F. Lohof[1], C. Gies[1], F. Jahnke[1], A. Koulas-Simos[2], K. Laiho[2], G. Sinatkas[2], S. Reitzenstein[2], T. Zhang[4], J. Xu[4], C.-Z. Ning[3,4], and W. W. Chow[5] — [1]Universität Bremen, Germany — [2]Technische Universität Berlin, Germany — [3]Arizona State University, USA — [4]Tsinghua University, China — [5]Sandia National Laboratories, USA

Semiconductor nanolasers as small-scale sources of coherent light have become increasingly important for applications in the data and medical industry for their size, power-efficiency, and modulation speed. Determining the presence of lasing, however, is challenging due to the near-thresholdless behaviour of ultra-efficient devices, which requires going beyond input-output characteristics. The research presented here focuses on a quantum-optical study of a silver-coated InGaAsP nanolaser, accompanied by a full quantum-mechanical semiconductor laser theory; this gives access to the time-resolved single-photon and zero-time-delay two-photon correlation function that holds information about the photon statistics, allowing to identify the onset of coherent emission with confidence. Our theoretical model can match the experimentally obtained data using a single set of realistic parameters that holds not just in a stationary regime, but also when focusing on the temporal dynamics for the investigation of the coherence time. This procedure presents a comprehensive strategy for the identification of lasing while being extensible to those gain materials requiring a more pronounced focus on quantum-material aspects, like TMDCs.

HL 7.4 Tue 11:00 H4

Electro-optical switching of a topological polariton laser — •Philipp Gagel[1], Tristan H. Harder[1], Simon Betzold[1], Oleg A. Egorov[2], Johannes Beierlein[1], Holger Suchomel[1], Monika Emmerling[1], Adriana Wolf[1], Ulf Peschel[2], Sven Höfling[1], Christian Schneider[3], and Sebastian Klembt[1] — [1]Technische Physik, Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Institute of Condensed Matter Theory and Solid State Optics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, D-07743, Germany — [3]Institute of Physics, University of Oldenburg, D-26129 Oldenburg, Germany

Here we implement a topological domain boundary defect in an orbital Su-Schrieffer-Heeger geometry by etching coupled pillars into an AlGaAs based microcavity. We show exciton-polariton lasing from the topologically non-trivial domain boundary defect in the bandgap of the P-bands under optical excitation. A gold back and top contact is used to apply a reverse bias to the structure allowing to tune the exciton-polariton detuning due to a shift in the energetic position of the exciton based on the quantum confined Stark effect. This way, we demonstrate control of the energetic position polariton condensation and lasing takes place. Furthermore, we show that this effect can be used to switch the polariton lasing from the topological defect on and off. These findings are an important step towards the realization of an electrically driven, topological polariton laser.

HL 7.5 Tue 11:15 H4

Investigation of the bimodal behavior of microlasers with a two-channel photon number-resolving transition edge sensor system — •Marco Schmidt[1,2], Isa Hedda Grothe[3], Sergej Neumeier[3], Lucas Bremer[1], Martin von Helversen[1], Wenera Zent[1], Boris Melcher[3], Jörn Beyer[2], Christian Schneider[4,5], Sven Höfling[4], Jan Wiersig[3], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin — [2]Physikalisch-Technische Bundesanstalt, Abbestraße 2-12, 10587 Berlin — [3]Institut für Physik, Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg — [4]Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg — [5]Universität Oldenburg, 26129 Oldenburg

A two-channel photon-number-resolving (PNR) transition-edge sensor (TES) is used to measure the photon-number distribution of a bimodal quantum-dot micropillar laser [1]. The TES system simultaneously detect light emission of two orthogonal components of the fundamental emission mode of the bimodal microlaser. The applied cross-correlation scheme provides an unprecedented access to the joint PNR and allows an insight into the photon statistics and dynamics of the coupled mode components. Especially, the measurements reveal an optical bi-stability of the anti-correlated mode components, which can be interpreted as a temporal hopping between emission with coherent and thermal-like emission statistics. Our studies clearly demonstrate the great advantage of investigating nanophotonic devices via TESs.

[1] M. Schmidt et al, Phys. Rev. Res. 3, 013263 (2021)