HL 62: 2D Semiconductors and van der Waals Heterostructures VII

The session covers the physics of quantum emitters and defects in 2D materials and their heterostructures. Note, the session starts directly after the session "2D Semiconductors and van der Waals Heterostructures VI".

Time: Friday 11:45–13:00 Location: H15

HL 62.1 Fri 11:45 H15

Deterministic Purcell enhancement of single photon emission from a WSe_2 monolayer quantum emitter — •Ivan Solovev[1], Victor Mitryakhin[1], Sven Stephan[1,2], Jens-Christian Drawer[1], Lukas Lackner[1], Seth Tongay[3], Kenji Watanabe[4], Takashi Taniguchi[5], Martin Esmann[1], and Christian Schneider[1] — [1]Institute for Physics, Carl von Ossietzky University of Oldenburg, Oldenburg, Germany — [2]University of Applied Sciences Emden/Leer, Emden, Germany — [3]Materials Science and Engineering, School for Engineering of Matter, Transport and Energy, Arizona State University, Tempe, Arizona, USA — [4]Research Center for Functional Materials, National Institute for Materials Science, Tsukuba, Japan — [5]International Center for Materials Nanoarchitectonics, National Institute for Materials Science, Tsukuba, Japan

Bright and easily fabricated quantum emitters in two-dimensional semiconductors have emerged as a promising platform for scalable quantum communication [1,2]. Here, we show, how their performance can be markedly elevated by integrating a monolayer into a versatile open plano-concave Fabry-Pérot microcavity. We managed to modulate radiative decay rate of a zero-phonon line by tuning a high Q-factor cavity. Reached five-fold shortening of the lifetime opens the route towards higher rates of quantum key distribution and generation of indistinguishable single photons in 2D semiconductors.

[1] J.C. Drawer et al., Nano Lett. 23 (18), 8683 (2023). [2] T. Gao et al. npj 2D Mater Appl 7, 4 (2023).

HL 62.2 Fri 12:00 H15

Deterministic generation of single-photon emitters in 2D materials by in-situ electron beam lithography — •Shachi Machchhar, Bhabani Sankar Sahoo, Yuhui Yang, Imad Limame, Chirag Chandrakant Palekar, and Stephan Reitzenstein — Technische Universität Berlin, Berlin, Germany

The development of on-demand sources of single photons with high indistinguishability represents a crucial step in the creation of photonic quantum systems, such as those required for the construction of large-scale quantum networks for the secure transfer of data. One potential avenue for the realization of such sources in a scalable and cost-effective manner is the exploitation of defect centres in transition metal dichalcogenides (TMDCs). The fabrication of these defect centres in TMDC monolayers can be achieved through the introduction of strain, ion implantation, and the structuring or patterning of the substrate. In this study, we employ cathodoluminescence (CL) spectroscopy at cryogenic temperatures to probe hBN-encapsulated WSe* and utilise in-situ electron beam lithography (iEBL) to structure predetermined patterns on the emission active region. This nanopatterning of the monolayer facilitates the deterministic generation of single-photon emitters (SPEs) with distinct quantum optical properties. Furthermore, we demonstrate the single-photon nature of these SPEs through second-order correlation measurements on the MLs. Additionally, we study the temperature dependence of such SPEs generated in various patterned geometries.

HL 62.3 Fri 12:15 H15

Generation of luminescent defects in hBN by focused helium ion beam irradiation — •Amedeo Carbone[1,2], Martijn Wubs[1], Alexander W. Holleitner[2], Christoph Kastl[2], Alexander Huck[3], and Nicolas Stenger[1] — [1]Department of Electrical and Photonics Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark — [2]Walter Schottky Institute, Physik Department, Technical University of Munich, Am Coulombwall 4, 85748 Garching, Germany — [3]Center for Macroscopic Quantum States (bigQ), Department of Physics, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

Among the luminescent centres in hBN, which have recently gained attention because of their brightness and exceptional quantum properties at room temperature, the charged boron vacancy (V_B^-) defect stands out for its magnetic properties, which have significant applications in quantum sensing schemes [1]. In the present work [2] we irradiate hBN flakes with a focused helium ion beam to generate V_B^- defects, conduct optical and magnetically resolved characterization, and apply a theoretical model [3] to infer the generated density of charged emitters. These results are further compared to the estimated vacancy density from Molecular Dynamics simulations. Our work provides a systematic study of the defect generation efficiency by comparing different irradiation doses.

[1] Gottscholl, A. et al., *Nat. Mater.* 19, 540-545 (2020), [2] Carbone, A. et al., *in preparation*, [3] Udvarhelyi, P. et al., *npj Comp. Mat.* 9, 150 (2023).

HL 62.4 Fri 12:30 H15

Impact of low-energy ion-irradiation induced defects on optical and vibrational properties of molybdenum disulfide — •Philipp Kraus, Eileen Schneider, Tobias Dierke, Stefan Wolff, Yuri Koval, and Janina Maultzsch — Chair of Experimental Physics, FAU Erlangen-Nürnberg, Erlangen

We present the controlled creation of vacancies in 2D materials, in particular graphene and molybdenum disulfide (MoS_2), by low-energy ion-irradiation. With Raman spectroscopy on exfoliated graphene flakes before and after irradiation, we determined the defect density to calibrate the ion dose of our setup. Then, we irradiated MoS_2 monolayers, grown via chemical vapor deposition (CVD), and determined the impact of the ion-induced defects on Raman and photoluminescence (PL) spectra. These results are additionally compared with density functional theory (DFT) calculations.

HL 62.5 Fri 12:45 H15

Composition- and strain-dependent quantum dot states in transition metal dichalcogenide nanobubbles — •Stefan Velja, Jannis Krumland, and Caterina Cocchi — Carl von Ossietzky Universität Oldenburg

Mechanical deformations in transition metal dichalcogenide monolayers can appear both spontaneously and artificially, giving rise to peculiar nanostructures, such as nanobubbles, or nanowrinkles. These systems have been observed to harbor localized states in the gap region, a known prerequisite for single-photon emission. While recent theoretical studies have attempted to explain these phenomena on selected systems [1,2], a detailed analysis concomitantly examining the role of the chemical constituents and the amount of applied strain is essential to gain full insight. In this work, we investigate the electronic properties of MX_2 nanobubbles (M=Mo, W and X=S, Se) characterized by varying levels of local strain. For materials composed of lighter elements, localized states appear in the gap region when the deforming force reaches the order of 0.01 a.u./atom. A thorough analysis of these states sets the stage for predicting and interpreting the optical fingerprints of these nanostructures.

[1] Krumland et al., *ACS Photonics* **11**, 586 (2024)
[2] Velja et al., *Nanoscale* **16**, 7134 (2024)