# DS 47: Focussed Session: Physics and Application of Emergent 2D-semiconductors and their Heterostructures II (Joint session of DS and HL, organized by DS)

Atomically thin two-dimensional materials have advanced to the point where they are becoming highly appealing for the study of novel quantum physics and for constructing emergent photonic, electronic and photochemical devices using tailored 2D-heterostructures. The most prominent monolayer 2D material, graphene, has a bandstructure in its pristine form without an electronic bandgap. In contrast, monolayers of transition metal dichalcogenides (TMDCs) tend to be direct gap semiconductors with a bandgap in the visible to near-infrared spectral range. Moreover, the two-dimensional nature of these monolayered semiconductors give rise to very strong excitonic effects, even at ambient conditions and their strong light-matter interactions and spin-valley properties make them highly interesting for e.g. opto-valleytronics and novel coherent light sources. Intriguingly, TMDC crystals can host strongly localized excitons, which result in the possibility to emit quantum light. In this symposium the current status and prospects of the very rapidly evolving field of TMDC research will be summarised including materials properties and synthesis and the exploration of phenomena such as quantum light emission, coherent laser action, spinor excitonics and cavity quantum electrodynamics.

Organizers: Sven Höfling (U Würzburg), Christian Schneider (U Würzburg) and Jonathan Finley (WSI München)

Time: Thursday 15:00–17:00 Location: H8

**Topical Talk** DS 47.1 Thu 15:00 H8

**Bright and dark excitons in transition metal dichalcogenide monolayers** — Cedric Robert[1], Gang Wang[1], Aslihan Suslu[2], Bin Chen[2], Sije Yang[2], Sarah Alamdari[2], Iann Gerber[1], Thierry Amand[1], Sef Tongay[2], Bernhard Urbaszek[1], and •Xavier Marie[1] — [1]Universite de Toulouse, INSA-CNRS-UPS, LPCNO, 135 avenue de Rangueil, 31077 Toulouse cedex, France — [2]School for Engineering of Matter, Transport and Energy, Arizona State University, Tempe, AZ 85287, USA

Highly crystalline Mo(1-x)WxSe2 has been synthetized to show engineering of the direct optical bandgap and the spin-orbit (SO) coupling in ternary alloy monolayers. We have investigated the impact of the tuning of the SO splitting on the optical and polarization properties. In particular, we have measured the effect of tuning of the conduction band SO splitting on the bright versus dark exciton state population i.e. photoluminescence (PL) intensity. We show that the MoSe2 PL intensity decreases as a function of temperature by an order of magnitude, whereas for WSe2 we measure surprisingly an order of magnitude increase over the same temperature range (T=4-300K). The ternary material shows a trend between these two extreme behaviors [1]. These results are interpreted on the basis of the reversal of the sign of the spin-orbit splitting in the CB for MoSe2 and WSe2 leading to different temperature dependences of the emission yield. The additional role of the electron-hole exchange interaction on the bright/dark exciton states splitting will also be discussed on the basis of ab-initio calculations. [1] G. Wang, et al, Nature Com. 6, 10110 (2015)

**Topical Talk** DS 47.2 Thu 15:30 H8

**Exciton fine structure in transition-metal dichalcogenides monolayers** — •Mikhail Glazov — Ioffe Institute, St.-Petersburg, Russia

Strong spin-orbit interaction in transition-metal dichalcogenides monolayers (TMDCs) such as $MoS_2$ or $WSe_2$ results in the spin-valley locking effect: The states of electrons and holes in $\mathbf{K}_\pm$ valleys of the Brillouin zone are spin-split. This makes spin and valley dynamics of charge carriers and their complexes, neutral and charged excitons, in TMCDs non-trivial and interesting. In my talk, an overview of recent theoretical results on exciton and trion fine structure in TMDCs is given. It is shown that the spin/valley dynamics of bright exciton doublet is governed by the long-range exchange interaction between an electron and a hole. The latter provides efficient spin depolarization mechanism of excitons. The developed theory is illustrated by comparison with recent experimental results on time-resolved polarized photoluminescence and Kerr-rotation spectroscopy.

**Topical Talk** DS 47.3 Thu 16:00 H8

**Photonics and polaritonics with van der Waals heterostructures** — •Alexander Tartakovskii — Department of Physics and Astronomy, University of Sheffield, Sheffield, S3 7RH, UK

Monolayer films of van der Waals crystals of transition metal dichalcogenides (TMDCs) are direct band gap semiconductors exhibiting excitons with very large binding energies and small Bohr radii, leading to a high oscillator strength of the exciton optical transition. Together with graphene as transparent electrode and hexagonal boron nitride (hBN) as an insulator, TMDC monolayers can be used to produce so-called van der Waals heterostructures. Here we use this approach to make electrically pumped light-emitting quantum wells (LEQWs) and single-photon emitters. We combine this new technology with optical microcavities to demonstrate control of the emitter spectral properties and directionality, making first steps towards electrically injected TMDC lasers. By embedding MoSe2/hBN structures in tuneable microcavities, we enter the regime of the strong light-matter interaction and observe formation of exciton-polaritons. We demonstrate that the magnitude of the characteristic anti-crossing between the cavity modes and the TMDC excitons can be enhanced by embedding a multiple-QW structure, containing two TMDC monolayers separated by an hBN barrier. This work opens a new avenue in the use of van der Waals crystals and heterostructures with a potential for polariton devices operating at room temperature.

**Topical Talk** DS 47.4 Thu 16:30 H8

**van der Waals Epitaxy of 2D materials** — •Sefaattin Tongay — Arizona State University, USA

Van der Waals (vdW) epitaxy is a common technique used for production of 2D materials systems. Owing to their chemically passivated surfaces, vdW epitaxy does require any lattice match and a number of 2D transition metal dischalcogenide (TMDCs) and post-transition metal chalcogenides (PTMCs) can be deposited onto various oxide surfaces. Since the underlying substrate and 2D materials weakly interact with each other, vdW epitaxy anticipated to produce 2D systems with material properties closely similar to that of exfoliated ones. This talk will focus on how underlying substrates influence the material properties through interation with 2D layered materials, and introduce colossal band renormalization in some unique systems.