Optics of Deterministically Induced Localized Excitons in Monolayer MoS_2

Julian Klein

Walter Schottky Institut und Physik Department, Technische Universität München, Am Coulombwall 4, 85748 Garching, Germany

Nanosystems Initiative Munich (NIM), Schellingstr. 4, 80799 Munich

Atomically thin transition metal dichalcogenides represent a vast playground for studying Coulomb bound electron-hole complexes. While most of the focus has been devoted to the investigation of delocalized excitons my talk will shed some light on recent advances in the deterministic generation and spectroscopic study of single localized excitons in monolayers of MoS_2.

In this talk, I will show a systematic study of the impact of disorder on the optical properties and intervalley scattering of monolayer MoS_2 [1]. Using a helium ion microscope, defects are locally induced in the 2D crystal lattice. Optical spectroscopy reveals significant shifts of both first order Raman modes E' and A_1, which are well understood in the framework of a phonon confinement model, where increasing disorder links the ion dose to the inter-defect distance. Micro-photoluminescence measurements at T=10K show how a broad (~50 meV) defect-related luminescence band emerges that is red-shifted by ~180 meV with respect to the 2D neutral exciton. Remarkably, embedding monolayer MoS_2 into hBN, strongly reduces the linewidth of the delocalized excitons (<5meV), approaching the homogeneous limit yielding unprecedented clean optical spectra [2, 3]. In combination with helium ion irradiation, this approach enables to controllably realize single optical active emission centres in MoS_2, which show clear indications of quantum dot-like behaviour emitting in a spectral window of 100-220 meV below the neutral 2D exciton [4].

These results demonstrate the potential of helium ion irradiation as a tool to deterministically engineer the optical properties of 2D semiconductors at the nanoscale, gain new insights into disorder and valley depolarization processes and, moreover, represent a new route to realize localized excitons that could be harnessed as potential optically active quantum emitters in transition metal dichalcogenides.

[1] J. Klein *et al*. 2D Mater. **5**, 011007 (2018)

[2] J. Wierzbowski and J. Klein *et al.* Sci. Rep. **7**, 12383 (2017)

[3] M. Florian *et al.* Nano Letters **18**, 2725 (2018)

[4] J. Klein *et al.* to be submitted (2018)