Positioned generation of luminescence defects in 2D materials by helium ion beams

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Single spin defects in 2D transition-metal dichalcogenides are natural spin-photon interfaces for quantum applications. The creation of such point-defects in bulk crystals lacks either lateral or vertical precision. We overcome this disadvantage by irradiating atomically thin materials by a focused He-ion beam. Here we report on deterministic generation of optically active defects with a helium ion microscope in monolayer MoS_2. In photoluminescence (PL) measurements on the irradiated sites we measure sharp emission lines ~200 meV below the optical bandgap of MoS_2. [1] The He-ion beam dose can be decreased to create single emission lines at each irradiated spot with a yield of ~20%. These single emission lines emit single photons, which could be unambiguously proven in second-order correlation measurements. [2] In high-field magneto-photoluminescence we attribute the emission lines to single sulfur vacancies by combining experiment and ab-initio calculations. In the experiment, we reveal the lifting of spin-degeneracy of the involved defect bands even at zero magnetic field. These results highlight that defects in 2D semiconductors may be utilized for quantum technologies. [3]

[1] J. Klein et al.; Site-selectively generated photon emitters in monolayer MoS_2 via local helium ion irradiation, Nature Comm. 10 (**2019**), 2755
[2] J. Klein, L. Sigl et al.; Engineering the Luminescence and Generation of Individual Defect Emitters in Atomically Thin MoS_2; ACS Photonics 8 (**2021**), 2
[3] A. Hötger et al.; Spin-defect characteristics of single sulfur vacancies in monolayer MoS_2; arXiv:2205.10286 (**2022**)

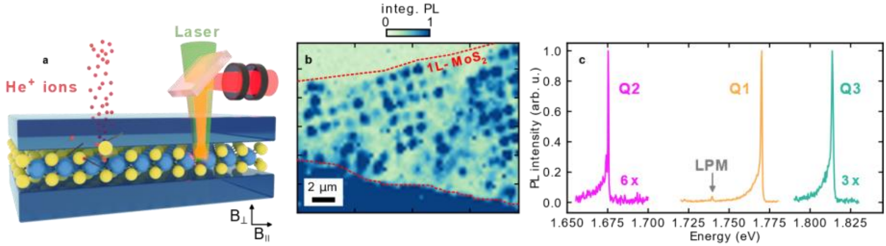

Fig. 1: a) Sketch of the He-ion irradiation and the magneto-optical measurement on the generated defect center. b) False color map of the defect luminescence showing the irradiated array pattern. c) Typical photoluminescence spectra of three different emission bands showing similar asymmetric line shapes.