Exploring ultrafast magnetic processes of low-dimensional ferromagnets using EXTREMAG

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P. S. Keatley,[a] M. Dąbrowski,[a] and R. J. Hicken,[a]
a: University of Exeter, Exeter, UK;

The Exeter Time Resolved Magnetism (EXTREMAG) Facility is an ultrafast magneto-optics user facility at the University of Exeter. Recently users have applied EXTREMAG's variable temperature and high magnetic field environments to exemplar studies of flakes of low, or 2-dimensional (2D) materials and van der Waals heterostructures (vdWh). Low temperature magnetometry and domain imaging on a $MoSe_2/CrBr_3$ vdWh using a wide field Kerr microscope allowed its magneto-photoluminescence to be understood in terms of the magnetic state of the $CrBr_3$ [1]. Combining the microscope with an ultrafast laser pump allowed all-optical switching to be studied in the CrI_3/WSe_2 [2] and $Cr_2Ge_2Te_6$ [3] vdVh where toggle switching of the magnetic state was observed. In the time domain, beam-scanning Kerr microscopy allows microscale imaging on sub-ps timescales in a superconducting magnet. In $Cr_2Ge_2Te_6$ this enabled time-resolved domain imaging and the measurement of ultrafast demagnetisation and subsequent variation in relaxation timescales for different flake thickness [4]. Finally, imaging of h-BN flakes in photoluminescence using a scanning Kerr microscope with microwave probe station opens opportunities to study the high frequency properties of devices containing such low-dimensional materials, e.g. [5]. Since the first user experiments in 2019, EXTREMAG has nurtured a growing overlap of its unique capabilities with the expertise of users exploring low dimensional magnetism. With EXTREMAG's growing use to study these materials, we will continue to develop the capability to probe ultrafast dynamic processes in these exciting materials where quantum effects may emerge.

[1] T.P. Lyons et al. Nature Communications 11, 6021 (2020).

[2] M. Dąbrowski et al. Nature Communications 13, 5976 (2022).

[3] M. Khela et al. Nature Communications, 14, 1378 (2023).

[4] M. Dąbrowski et al. Nature Communications, 16, 2797 (2025).

[5] S. Baber et al. Nano Letters 22, 461 (2022).

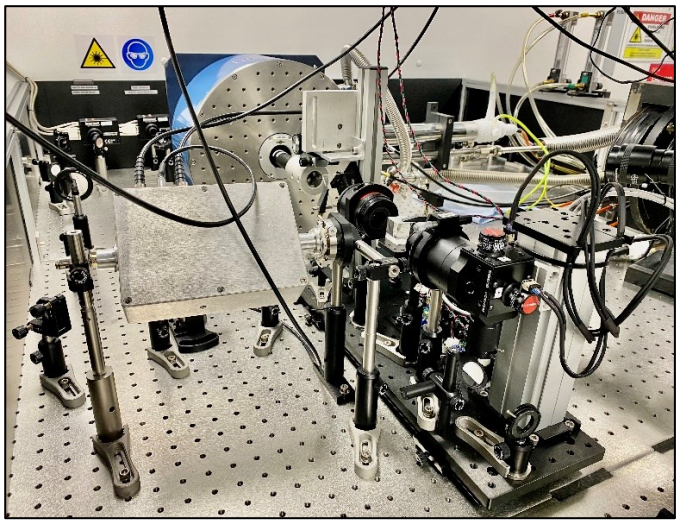

Fig. 1. The all-optical pump, beam-scanning probe Kerr microscope, for sub-ps imaging of ultrafast magnetic processes. The microscope is equipped with a super-conducting magnet for high vacuum, variable temperature (~6-300 K), and high magnetic field (~3 T) sample environments. This instrument has been developed for sub-micron magneto-optical imaging of microscale 2D flakes and van der Waals heterostructures.