Control and understanding of magnon transport in insulating antiferromagnets

A. Ross[1, 2]

[1] *Institute of Physics, Johannes Gutenberg-University Mainz, 55128 Mainz, Germany*

[2] *Graduate School of Excellence Materials Science in Mainz, 55128, Mainz, Germany*

With THz spin dynamics, unrivalled stability against magnetic field perturbations, and a lack of stray fields enabling large packing densities, antiferromagnetic (AFM) materials are positioned to become key in future low power spintronic devices. In this talk I will focus on functionalising the magnon transport properties of the insulating AFM α-Fe_2O_3 for magnonic applications. Not only does this material benefit from an ultra-low damping magnetic damping [1], but it has a controllable magnetic ordering [2,3] and shows topologically non-trivial skyrmionic domain structures.
First, I will highlight that long distance magnon transport can be achieved in non-local spin-transport devices, making use of circularly-polarised magnon modes excited by an electrical, interfacial spin-bias with spin diffusion lengths of up to 9 μm in single crystals [4]. Then, as single crystals are undesirable for devices, we explore high-quality thin film α-Fe_2O_3 of different crystalline orientations. We find that long distance transport of circularly-polarised magnons is possible in these films with intrinsic spin diffusion lengths of hundreds of nanometres [5], orders of magnitude larger than previously reported for thin film AFMs. This key result demonstrates that even in thin films, this material benefits from low magnetic damping. I will introduce how the efficiency of the transport mechanisms can be tuned by field cycling of the domain structure and the relative orientations of the magnetic field and magnetic anisotropies. The manner by which the AFM domain structure leads to frequency dependent decay lengths will also be discussed.
Finally, the observation of the transport of circularly polarised magnons relies on stabilising the AFM easy-axis phase of α-Fe_2O_3 at temperatures below the Morin transition (260 K). At room temperature the magnon modes adopt a linearly polarisation and become unable to transport angular momentum. Despite this, I demonstrate that room temperature magnon transport is indeed possible through a superposition of differently polarised magnon modes that dephase [1,6]. In parallel, I will show that a high magnetic symmetry is not necessary for efficient magnon transport. The dilute substitution of ferric ions with Zn drastically alters the magnetic anisotropy, lowering the magnetic symmetry of the system [6]. Even in this low-symmetry system, magnon transport is still seen over micrometres, where the non-local resistance displays a periodic beating with magnetic field due to the magnon Hanle effect.

References:

[1] R. Lebrun, **A. Ross** *et al.*, *Nat. Commun.* **11**, 6332 (2020)
[2] R. Lebrun, **A. Ross** *et al.*, *Commun. Phys.* **2**, 50 (2019)
[3] **A. Ross** *et al.*, *Phys. Rev. B* **102**, 094415 (2020)
[4] R. Lebrun, **A. Ross** *et al.*, *Nature* **561**, 222 (2018)
[5] **A. Ross** *et al.*, *Nano Lett.* **20**, 306 (2020)
[6] **A. Ross** *et al.*, *Appl. Phys. Lett.* **117**, 242405 (2020)