Disrupting Magnons Using Ferroelectric Domains

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Summary: This PhD project has been funded as part of a large research consortium (with core funding from a £6.6M EPSRC Programme Grant called CAMIE) involving the University of Leeds, Imperial College London and QUB. The consortium has ~7 PDRAs and more than 10 PhD students, all working on different aspects of coupling between functional materials. The aim is to explore coupling and interfacial emergent behaviour, as part of a push towards finding new ways of transferring or processed information with ultralow energy loss. It should be emphasised that the research is essentially blue-skies in nature. The QUB research will primarily focus on the way in which uncompensated bound charge at ferroelectric surfaces (and associated locally intense electric fields) affect magnetically active systems. This specific PhD will focus on the effect that bound charges at interfaces can have on magnons (magnetic spin waves).

Background and Context: A magnetic field is the Lorentz Transform of an electrostatic field. Hence, moving charges interact with magnetic fields (the Lorentz Force). By the same token, in the laboratory frame of reference, moving spins experience magnetic fields resulting from stationary charge. “Magnons” (or waves in magnetic spin orientations) will hence see a magnetic influence from electrostatic fields.

This Project: In this project we seek to move spins by generating magnons in Yttrium Iron Garnet (YIG). We intend to image these magnon spin waves, using a nitrogen-vacancy microscope (which can image spatial variations in magnetic field, with exquisite resolution) and observe the manner in which magnons can be scattered and their propagation controlled. This has been done, to some extent, in previous work by Zhou *et al.* [1] (see figure 1 below). However, uniquely, we seek to explore the manner in which local variations in the bound charge at the surface of an underlying ferroelectric material can influence magnon propagation. This in itself is new. However, since domains in ferroelectrics can be actively controlled by local switching, a further development of the research would be to see how changing the interfacial bound charges might be used to control magnon propagation “live”. Magnon-based logic might hence be realized. The project will involve: imaging magnons using a nitrogen-vacancy microscope; creating and imaging ferroelectric domains; and correlating domain patterns and magnon behaviour. It will be mainly experimental, but some finite element modelling will probably be useful.

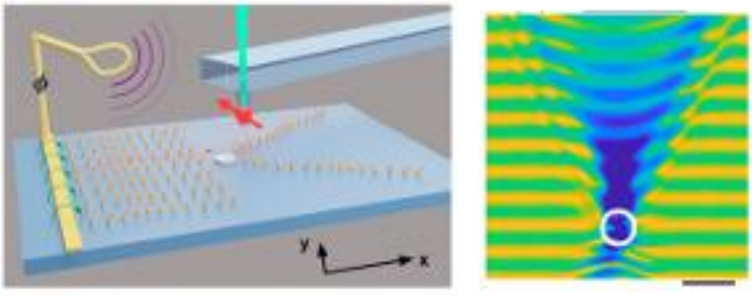

Figure 1: Adapted from [1]: Magnetic spins can be disrupted by pulsed Oersted fields, creating waves in the magnetic spin orientations (magnons). Magnons can be imaged using nitrogen-vacancy scanning probe techniques (see left-hand schematic). The dot in the schematic is a scattering centre which causes magnon scattering and interference, imaged directly (right hand panel).

References:

[1] TX Zhou et al. PNAS **118** 2019473118 (2021)