Spin-Steered Magnonics

C. Gonzalez-Ballestero[1,2]
Toeno van der Sar[3], O. Romero-Isart[1,2]
[1]*Institute for Quantum Optics and Quantum Information, A-6020 Innsbruck, Austria*
[2]*Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria*
[3]*Kavli Institute of Nanoscience, Delft University of Technology, 2628 CJ Delft, The Netherlands*
*carlos.gonzalez-ballestero@uibk.ac.at

Current information technologies based on electronics are near a saturation point, as transistor miniaturization becomes increasingly challenging. Satisfying the demand for faster and more powerful computing requires to develop new technological platforms to replace electronics in the next few decades. Spin waves, namely magnetization waves propagating in magnetic materials, are major candidates for future information carrying and processing [1]. Their useful properties, such as nonlinearity, tuneable spectra, and the absence of Joule heating, has already enabled a first generation of fast and low-power-consumption spin wave (magnonic) devices [2]. Although way ahead of most competing technologies, these devices are far from performing at the level of current electronics. The main obstacle is the lack of an efficient and flexible way to tailor spin wave propagation.

We propose a novel way to control the propagation of spin waves, namely to couple them to a large ensemble of solid-state paramagnetic spins such as NV centres. The collective back-action of this ensemble, enabled by magnetic dipole interaction, depends on the internal state of the spins, which can be externally tuned. This enables controlling spin wave propagation, in analogy with the dispersion engineering of optical light using atomic ensembles (e.g. slow light).

In our work [3], we develop a quantum theory describing the effective spin wave dynamics in the presence of a spin ensemble, and apply it to a thin magnetic film, a usual experimental configuration [4]. We predict strong modifications of the spin wave propagation properties induced by the spin ensemble, including enhancement and full suppression of their propagation length. These modifications are fully tunable through an externally applied field, and can be turned on and off by optically pumping the spin ensemble. We show that our proposal is experimentally feasible in current experimental platforms. The flexibility of this platform, evidenced by our results, can be enhanced in multiple ways with state of the art techniques. This could enable a new generation of fast, flexible, reconfigurable, and easy to fabricate *spin-steered magnonic devices*.

REFERENCES

[1] A. Mahmoud et al. (2020) *Introduction to spin wave computing*, J. Appl. Phys **128**, 161101
[2] A. V. Chumak et al. (2015) *Magnon spintronics*, Nat Physics **11**, 453
[3] C. Gonzalez-Ballestero et al. (2020) Towards a quantum interface between spin waves and paramagnetic spin baths, arXiv: 2012.00540
[4] I. Bertelli et al. (2020) Magnetic resonance imaging of spin-wave transport and interference in a magnetic insulator, Sci. Adv. 6, eabd3556