Magnonics for Unconventional Computing Devices

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Spin waves (elementary excitations of magnetically ordered materials) boast extreme nonlinearity and modest loss while having micrometre to nanometre wavelengths at GHz frequencies. This presents a unique path towards miniature and powerful yet energy efficient devices for unconventional computing. In this project, you will seek to combine two inherently energy-efficient technology paradigms: (i) magnonics (using spin waves to process signals and data) and (ii) neuromorphic computing (using large-scale integrated systems and analog circuits to solve data-driven problems in a brain-like manner). Going well beyond existing paradigms, we will use nanoscale chiral magnonic resonators [1] as building blocks of artificial neural networks. The power of the networks will be demonstrated by creating magnonics versions of field programmable gate arrays, reservoir computers, and recurrent neural networks. The ultimate efficiency of the devices will be achieved by (a) maximising their magnetic nonlinearity (via spin wave power focusing within chiral magnonic resonators of minimal intrinsic loss); (b) using epitaxial yttrium iron garnet (YIG), which has the lowest known magnetic damping allowed by physics, for thin film magnonic media and resonators; and (c) using wireless delivery of power (minimising Ohmic loss in interconnects). Sensitive to the resonators' micromagnetic states, such artificial neural networks will be conveniently programmable and trainable within existing paradigms of magnetic data storage. The latter includes magnetic random-access memory (MRAM), which is already compatible with CMOS, while compatibility with other technology paradigms of spintronics will also be sought, explored, and exploited.

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1. V. V. Kruglyak, "Chiral magnonic resonators: Rediscovering the basic magnetic chirality in magnonics", Appl. Phys. Lett. **119**, 200502 (2021).