

Designing an experimentally feasible two-dimensional magnonic crystal for the demonstration of topologically protected spin waves

Contemporary information processing and transmission technologies heavily rely on electronics, utilizing electrical charges as carriers of information. While electronics offers numerous benefits, it also faces significant drawbacks that impede further technological advancements. Limitations in circuit miniaturization and the generation of Joule heat during charge transmission in conductors are among the challenges associated with electronics. Hence, it becomes crucial to explore alternative technologies that can complement or potentially replace existing electronic systems. In this context, magnonics emerges as a promising field of physics dedicated to the study of spin-wave propagation, aiming to develop alternative solutions to address these limitations in electronics.

Spin, one of the properties of elementary particles alongside mass and charge, plays a crucial role in the magnetic properties of matter. Stemming from quantum physics, spin represents the momentum of a particle. In ferromagnetic materials, the spins align in a way that minimizes the system's energy, resulting in a state of equilibrium and a non-zero magnetic moment even without an external magnetic field. If one of the spins in the material is perturbed from its equilibrium position, such as by a change in the magnetic field, it begins to precess around its original state. Through interactions like dipole and exchange interactions, the precessing spin transfers its motion to neighboring spins, giving rise to a propagating disturbance known as a spin wave.

Spin waves exhibit unique characteristics that distinguish them from electromagnetic waves used in photonics and broader microwave technologies. They possess considerably shorter wavelengths compared to electromagnetic waves at the same frequencies. Furthermore, spin waves do not carry charge or mass, resulting in lower energy requirements for transmitting information compared to electric charges. Like other waves, spin waves can be described in terms of amplitude, wavelength, and phase. Incorporating spin waves into functional magnonic devices entails finding methods to manipulate their parameters akin to other established wave-based devices.

Our project will focus on designing topologically protected spin waves that have advantageous properties, including robustness, low dissipation, nanoscale operation, high-speed processing, and the ability to tailor material properties for integration with other technologies. One way to create these special spin waves is the create a two dimensional patterns in thin ferromagnetic films. To achieve this goal, we will first develop the tools to analyze them and then look at two promising categories of materials that can exhibit the magnonic properties we are looking for. Finally, we will put together all of our findings to design and verify two-dimensional magnonic crystals that demonstrate topologically protected spin waves

Our project marks an initial stride in the development of novel magnonic devices that leverage topologically protected spin waves. These devices have the potential to serve as building blocks for advanced information transmission and processing systems, offering significantly lower energy consumption compared to existing electronic systems. As a result, our project has the potential to contribute to the advancement of technology aimed at reducing energy consumption in the field of information technologies.