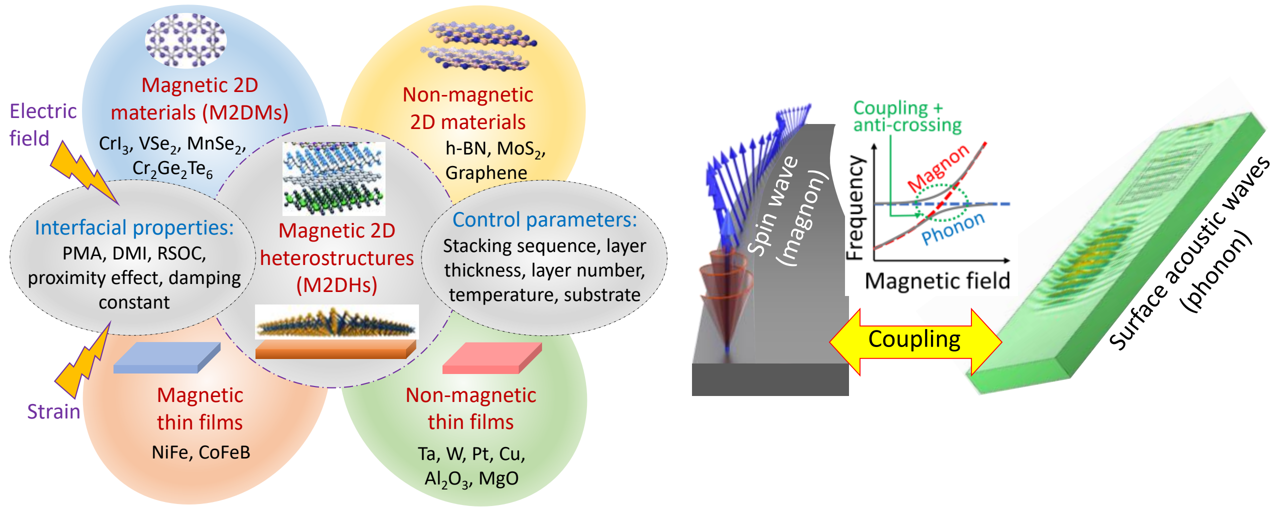
MAGNON-PHONON COUPLING IN MAGNETIC 2D HETEROSTRUCTURES IN PRESENCE AND ABSENCE OF SKYRMION LATTICE

There is a growing demand for the smaller, smarter, faster and energetically efficient miniaturized high frequency microwave devices. To fulfil these requirements an alternative technology, beyond the present CMOS technology, is urgently required. The wave-or quasiparticle-based information and computation technology was found to be one of the most potential alternatives for non-Boolean logic operations. In this regard, the spin waves (SWs), collective precessional motion of ordered magnetic spins and surface acoustic waves (SAWs), collective oscillatory motion of lattices have emerged as two potential alternatives. These waves are associated with two quasiparticles: magnons and phonons, respectively.



A cartoon describes a short overview of the project

The magnon properties can be easily controlled and reconfigured by material, geometrical and external parameters. To further improve the functionality of magnonic devices by removing all the limitations, magnons must be coupled with other quasiparticle such as phonons. One of the major challenges is to enhance the coupling coefficient to ensure back and forth information exchange with high efficiency. Also, the selection of suitable material system with rich and externally controllable properties is equally important. In this regard magnetic 2D materials (M2DMs) and magnetic 2D heterostructures (M2DHs) with various fascinating interfacial and magnetic properties have emerged. The properties of coherent magnons, phonons in M2DHs has not been explored so far. In particular, the synergy of magnon-phonon coupling and the optimization of coupling strength by playing with the properties of M2DHs have never been reported before. Additionally, the presence of another quasiparticle, *skyrmions*, nanoscale topological chiral spin structures, can enrich the physics and add more ingredients to control magnon-phonon coupling. Here we take the challenge to investigate, control, optimize magnon-phonon coupling phenomena in magnetic M2DHs in the absence and presence of skyrmions with an aim to develop hybrid magnonic devices which will eventually surpass the speed, efficiency, functionality and integration density of the present CMOS technology.

In this proposal we would like to employ M2DHs as the testbeds for the experimental study of magnon-phonon coupling including theoretical understanding of underlying physics. In particular, we would like to address four key questions in this proposal: (1) Can we efficiently tune the properties of magnons and phonons by playing with the interfacial, physical, magnetic properties of M2DHs? (2) Is it possible to achieve ultra-strong magnon-phonon coupling? If yes, what is the route and what are the key ingredients? (3) Is it possible to achieve high degree of non-reciprocity in magnons, phonons and magnon-phonon coupling? If yes, then how? (4) What are the advantages of skrymion lattices as a magnonic crystals and whether magnon-phonon coupling can be improved in presence of skyrmions or not?

The M2DMs will be made by mechanical exfoliation and chemical vapor deposition method and the devices afterwards will be fabricated by conventional nanolithography techniques. M2DHs will be prepared by hybridizing M2DMs with various magnetic, nonmagnetic 2D materials and non-2D thin films. Various interfacial properties, magnetic, elastic behaviour of M2DHs will be investigated as a function of layer thickness, layer sequence, temperature, strain, electric field. The electrically or thermally excited magnons, phonons and magnon-phonon coupling phenomena will be investigated by Brillouin light spectroscopy for various temperatures. The complementary vector network analyzer ferromagnetic resonance (VNA-FMR) technique will be utilized to study magnon, phonon properties. We will investigate the influence of M2DHs properties on magnons, phonons and skyrmion characters. Skyrmions will be observed by Lorentz-TEM, MOKE microscope. To theoretically understand the underlying physics behind various interfacial phenomena we will adapt advance analytical and computational approaches. We will employ numerical and semi-analytical approaches to analyze the properties of magnons, phonons, skyrmions and their coupling phenomena.

The scientific results will be published in high-quality international journals and disseminated through conference presentations. The young researchers involved in the program will receive extensive training in research and exposure to international research, and culture through international visits.