Long-range dynamic interaction between insulating ferromagnetic films mediated by phonons

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PhD may follow: Yes

Summary :

The proposed research project inserts itself in the emerging field of insulator spintronics whose vision is to fully replace the moving electrical charge with the friction-free propagation of the spin degree of freedom using electrical insulators. In this novel paradigm, low damping magnetic insulators are good spin-conductors by allowing the long-range propagation of the spin information trough spin-waves.Â In this project we shall investigate the ability to transfer orbital angular momentum using circularly polarized acoustic-waves. The project shall focus on Yttrium Iron GarnetÂ (YIG) thin films grown on Gadolinium Gallium Garnet (GGG) substrate because i) of the strong magneto-elastic constant in YIG, which should allow efficient interconversion of magnetic energy into acoustic; ii) of the small acoustic impedance mismatch between YIG and GGG; and iii) of the ultra-low acoustic damping in garnets (better than quartz). The target here is to demonstrate dynamical exchange coupling mediated by phonons between between two spatially separated YIG layers intercalated by a non-magnetic dielectric GGG spacer. This will be measured by performing frequency and time-domain spectroscopic studies on YIG thin films prepared by liquid phase epitaxy, which consists of having two almost identical YIG layers of variable thickness on both side of a GGG substrate. We believe that these progresses on hybrid transducers exploiting the magneto-elastic coupling could be beneficial for the development of the future microwave analog front-end technology (e.g. delay lines and filters) used in the wireless industry. The efficiency of this interconversion process could help removing the high frequency limitations of piezo transducers found in acoustic devices.
This training could lead to a PhD thesis (financing secured).

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Full description :

The emerging field of insulator spintronics is attracting a lot of attention. Its long-term vision is to replace the moving electrical charge with the friction-free propagation of the spin signal using electrical insulator media. This novel information platform promises higher energy efficiency and higher fidelity, while remaining adaptive and miniaturized.

The research on pure spin conductors has so far concentrated on the exploitation of coherent and incoherent spin-waves, or their quanta magnons, propagating inside magnetic insulators with characteristic frequencies ranging from GHz to THz and wavelengths from Âµm to nm. For this research effort, which falls into the field of magnonics, the ideal material is Yttrium Iron Garnet (YIG), a material known for its record low magnetic damping coefficient. YIG samples are available in the form of epitaxial thin film grown on Gadolinium Gallium Garnet (GGG) substrate. The current state of the art is the exploitation of spin-orbit effects (spin torque, spin-charge conversion, etc) with the aim to excite, detect and control magnons. A recent accomplishment was the demonstration that their decay time can be controlled electrically by injecting a dc current (~mA) into an adjacent platinum (Pt) layer, a metal with strong spin-orbit coupling, that could potentially lead to the magnetization auto-oscillation of a coherent mode at radio-frequencies (rf).

But a crucial function still missing in this toolbox for electrical insulators is the ability to transfer the corresponding angular momentum information across a non-magnetic (NM) dielectric spacer, which is key to the operation of spintronics devices. The spacer is required to decouple from the multilayer stack a free magnetic layer, whose orientation can be controlled by transport. The spin conductance of the spacer is captured by the characteristic decay length of the spin signal in the non-magnetic material. In metals, this quantity is called the spin diffusion length whose value lays in the sub-micron range. Currently the longest spin diffusion length has been reported in graphene, which lays in the micron range. In this paper we propose to investigate a novel and original channel to efficiently transfer angular momentum between two distinct YIG layers separated by GGG using circularly polarized phonons. The concept relies on the magneto-elastic coupling Î© between the Larmor precession of the magnetization and the corresponding circular elastic deformation of the lattice (see FIG1), which can carry orbital angular momentum. There are 3 reasons that make such proposition very promising: i) the magneto-elastic coupling in YIG is known to allow efficient energy transfer from spin-waves (SWs) to acoustic-waves (AWs), ii) AWs excited in YIG should be transferred efficiently into GGG due to small impedance mismatch, iii) acoustic waves in GGG have amongst the lowest damping in nature (the ultra-sonic attenuation coefficient of garnets is ten times smaller than quartz) and the expected decay length of circularly polarized phonons in GGG is expected to be in the millimetric range.

This will be measured by performing frequency and time-domain spectroscopic studies on YIG thin films prepared by liquid phase epitaxy, which consists of having two almost identical YIG layers of variable thickness on both side of a GGG substrate. We believe that these progresses on hybrid transducers exploiting the magneto-elastic coupling could be beneficial for the development of the future microwave analog front-end technology (e.g. delay lines and filters) used in the wireless industry. The efficiency of this interconversion process could help removing the high frequency limitations of piezo transducers found in acoustic devices. Among the targeted applications are the development of a new generation of microwave analog front-end functions (e.g. delay lines and filters), which can enhance the potential of CMOS based electronics by complementing the deficiencies of the digital signal processing, in particular in terms of sensitivity or dynamical range, while remaining compatible with the long-term evolution of wireless telecom standards, which foresees an increase of the carrier frequency well above 5 GHz.

Requested skills :

The candidate must have solid knowledge in solid state physics. 'Parcours nanoscience' organized by Univ. Grenoble Alpes is the perfect academic preparation.