Exchange spin waves as probe and tool

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Spin waves, the collective excitations of the spin lattice of a magnetic material and their quanta, magnons, show a large variety of linear and nonlinear phenomena which makes them an interesting data carrier for novel computing concepts [1]. They constitute a flow of spin angular momentum which opens a new research direction: magnon spintronics, a sub-field of spintronics, in which information is transferred and processed using magnons.

Two important key parameters of an efficient magnonic logic are the speed of information processing and the footprint of the device. For both, the use of short-waved spin waves dominated by the exchange interaction is of paramount importance since they offer high group velocities and a scalability of the devices to the nanoscale.

However, the measurement of the exchange constant A_{ex} is still a challenge in ultrathin films. In my presentation, I will first address how to extract the exchange stiffness $D = 2A_{ex}/M$ and the resulting group velocity $v \propto D$ from Brillouin light scattering spectroscopy measurements of thermal spin-wave spectra in a series of ultrathin ferromagnetic films with adjacent heavy metals. We compare our results to measurements of the exchange constant using Bloch's law. Our analysis shows that the traditional Bloch law $M(T) \propto T^{3/2}$ is not valid anymore due to the two-dimensional character of the spin-wave band structure. By using appropriate 2D formulations [2], we illustrate the influence of the changed dimensionality on the magnetization $M(T)$ and the resulting impact on the evaluation of the exchange constant A_{ex} via temperature dependent measurements.

In a second part, I will discuss how the exchange stiffness D can be increased to create novel systems with faster exchange spin waves. For this purpose, I present measurements of spin-wave dispersion relations in different insulating ferrimagnets including Gadolinium and substituted Yttrium Iron Garnets. We could show that the exchange stiffness in ferrimagnets close to compensation significantly exceeds the values obtained in metallic ferromagnets. In addition, we found first evidence of additional interfacial exchange contributions in insulator-heavy metal bilayers which further increase the exchange stiffness and with this also the speed of the hosted spin waves.

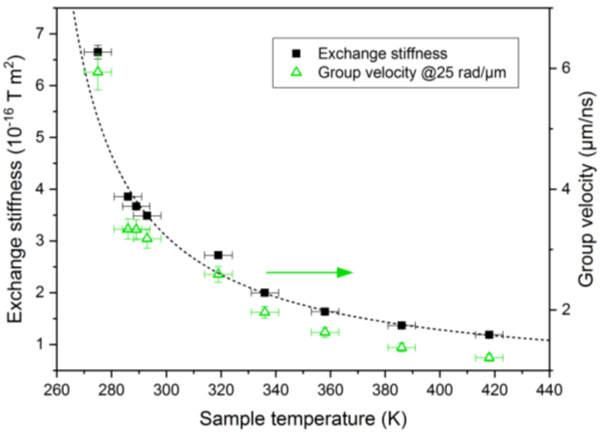

Fig. 1: Exchange stiffness and spin-wave group velocity in Gadolinium Iron Garnet as a function of temperature. Close to the compensation point, the exchange stiffness significantly exceeds the values obtained in metallic ferromagnets.

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Reference(s):

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