Centre de Nanosciences et de Nanotechnologies

Séminaire

Mardi 15 mai
11 heures
Salle 44 (Pierre Grivet) du C2N site Orsay

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”Auto-generators of sinusoidal and pulsed THz-frequency signals based on antiferromagnetic dielectrics driven by spin current”

Abstract
Antiferromagnets (AFM) are seen as materials for novel THz-frequency signal processing devices [1,2]. In contrast to the devices based on ferromagnets (FM), the AFM-based devices do not require any external bias magnetic field. Also, the ultrafast magnetization dynamics of the AFM devices is determined by the strong internal exchange field that exists in AFM materials, and keeps their magnetic sublattices anti-parallel to each other. This exchange field determines the high natural frequencies of the AFM resonance, lying in the sub-THz to THz frequency range. Thus, it is tempting to use AFM as active layers in THz-frequency spin-torque nano-oscillators, where the output electromagnetic signal is received using the inverse spin-Hall effect (ISHE) in the NiO/Pt layered structure [3]. Unfortunately, the amplitude of the generated THz-frequency signal is such an AFM oscillator decreases with the increase of frequency, making the generation process less efficient.

To meet this challenge, we propose a design of a THz-frequency signal generator based on a the AFM/Pt layered structure where the magnetization vectors of the AFM sub-lattices are canted inside the easy plane by the Dzyaloshinskii-Moriya interaction (DMI), resulting in the formation of a small net magnetization mDMI (e.g. Hematite (Fe2O3)). The perpendicularly polarized spin current, created by a driving DC current in the Pt layer, tilts the DMI-canted AFM sublattices out of the easy plane, thus exposing them to strong internal exchange magnetic field of the AFM. The sublattice magnetizations, along with the small net magnetization vector mDMI of the canted AFM, start to rotate about the hard anisotropy axis of the AFM with the THz frequency proportional to the injected spin current and the AFM exchange field. The rotation of the small net magnetization mDMI results in the THz-frequency dipolar radiation that can be directly received by an adjacent (e.g. dielectric) resonator.

We demonstrate theoretically that the radiation frequencies in the range f = 0.05 - 2 THz are possible at the experimentally reachable magnitudes of the driving current density, and evaluate the power of the signal radiated into different types of resonators, showing that this power increases with the increase of frequency and could reach several when a dielectric resonator with a typical quality factor of Q= 750 is used.

[1] T. Jungwirth *et al.*, Nature Nanotechnology **11**, 231 (2016).
[2] O. Gomonay *et al.*, Phys. Status Solidi RRL **11**, 1700022 (2017).
[3] R. Khymyn *et al.*, Scientific Reports **7**, 43705 (2017).