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Electrical excitation of magnetic spin waves in nanoheterostructures

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1. Introduction

Spintronic effect of electric-controlled local spin dynamics under the spin current-induced torque in magnetic nanostructures is the basis for the controlled excitation of the coherent spin waves of given amplitude and phase. The electrically insulating magnetic materials provide their exceptionally low magnetic damping and relative large distances of propagation. The coherent ratio, frequency damping and relative large distances of propagation. The coherent ratio, frequency origin of the spin polarization and spin torque exerting on the localized spin that results in the spin wave propagation. The electric-induced spin torque can be exhibited as the spin transfer torque related to conve-sation of electric current into spin polarized current [1], the spin-orbit torque related to the spin Hall effect of current conversation into spin current and spin-orbit torque related to the electric field-induced surface spin polarization in the effective Rashba field [2]. The latter results in the voltage controlled magnetic anisotropy (VCMA) which is characterized as an efficient mechanism for low-energy excitation and propagation of coherent spin waves with given amplitude and phase [3]. In the case of antiferromagnetic nanostructures, VCMA-induced spin waves possess low description of the electric controlled excitation and propagation of spin waves is based on first-principle density functional theory in a tight-binding model realized with second quantization accounting for features of electron and magnetic structures and interface exchange interactions.

2. Methods

The microscopic description of the electric-controlled magnetization dynamics in the multilayer magnetic nanostructures is based on the modified for magnetic system theory of non-equilibrium Green functions with the real-time propagation of the embedded Kadanof-Baym equations. In tight-binding approximation this forms an effective approach for study electromagnetic effects in in the investigated magnetic systems. For the case of considered magnetic two-layer CoFe/MgO the microscopic approach is based on the generalized Heisenberg model which includes surface interface in-plane magnetic anisotropy and interface spin-orbit interaction spin-orbit Rashba interaction describing of converting an external magnetic field into an effective internal magnetic field inducing controlled changing the surface magnetic anisotropy. It can be accompanied by spin dynamics and parametric selective excitation of coherent spin waves.

3. Results

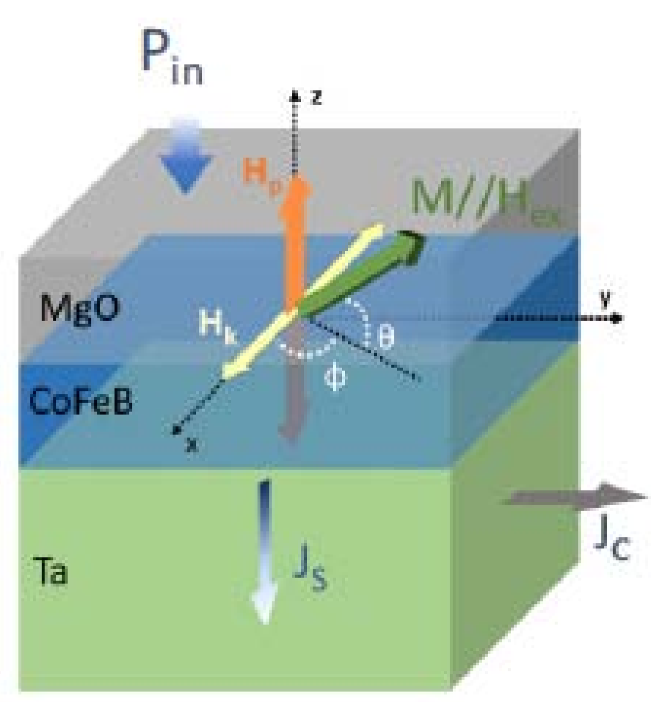

Fig.1. Schematic showing the orientation of the perpendicular magnetic anisotropy field *Hp* and in-plane magnetic anisotorpy field *Hk*. Magnetzation *M* is taken parallel to magnetic field *Hex* applied at an elevation angle *ϑ* and azimuthal angle *φ*.

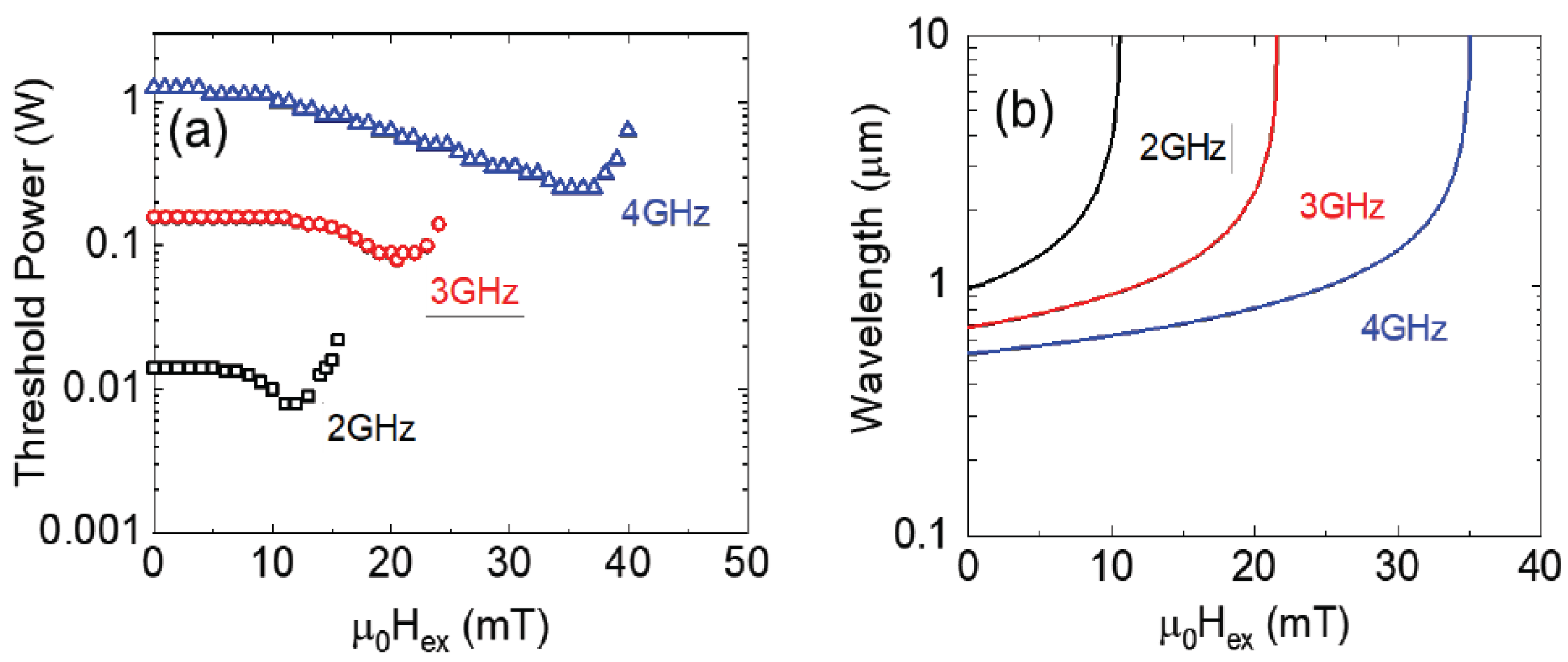

Fig.2. (a) Threshold power of parametric excitation modes as function of *Hex* for *f=2-4 GHz.* (b) Corresponding wave-lengths as function of *Hex.*

In Fig.1 A microwave voltage is applied at the CoFeB/MgO junction using an input power *Pin.* Spin current *Js* is pumped and then conver-ted into charge current *Jc* due a spin Hall effectof the Ta layer. The torque arising from VCMA of both *Hp* and *Hk* is described by the equation (1).

$$\tau_{VCMA} \propto \begin{bmatrix} -(\partial H_p/\partial V)V_{rf}\sin\varphi\sin\theta\cos\theta \\ (\partial H_p/\partial V-\partial H_k/\partial V)V_{rf}\sin\theta\cos\theta \\ (\partial H_p/\partial V)V_{rf}\sin\varphi\sin\theta\cos^2\theta \end{bmatrix} \quad (1)$$

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3. References

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