Manipulation of Dzyaloshinskii-Moriya interaction in Co/Pt multilayers with strain

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Interfacial Dzyaloshinskii-Moriya interaction (DMI) is experimentally investigated in Pt/Co/Pt multilayer films under strain. A strong variation (from 0.1 to 0.8 mJ/m^2) of the DMI constant is demonstrated at $\pm 0.1\%$ in-plane uniaxial deformation of the films. The anisotropic strain induces strong DMI anisotropy. The DMI constant perpendicular to the strain direction changes sign while the constant along the strain direction does not. Estimates are made showing that DMI manipulation with an electric field can be realized in hybrid ferroelectric/ferromagnetic systems. So, the observed effect opens the way to manipulate the DMI and eventually skyrmions with a voltage via a strain-mediated magneto-electric coupling.

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Skyrmions in magnetic thin films with perpendicular anistropy are non-trivial magnetic textures [1] promising various applications such as memory and logics. Therefore, manipulating (creating, annihilating and moving) the skyrmions is an urge but still challenging quest of the modern spintronics [2–5]. So far, several approaches were used. Electrical current based techniques utilizing spin torque [6–8] and spin-orbit torque [9 and 10] allow to control the skyrmions but require a high current density and therefore, have low energy efficiency. A lot of groups work on electric field based approaches where the heat losses are minimized. One of the most actively studied approaches is based on voltage controlled magnetic anisotropy [11–15]. Since a skyrmion stability is defined by the competition of the magnetic anisotropy and the Dzyaloshinskii-Moriya interaction (DMI), tuning of one of these contributions opens the way to control the skyrmions. So far, people were focused on the variation of the magnetic anisotropy via a strain-mediated magnetoelectric coupling [16] or a charge-mediated magnetoelectric effect [17].

In the present work we experimentally demonstrate that the DMI can be also controlled with a strain. Previously, people studied strain dependence of the DMI in bulk crystals [18–20]. Here, we show that in heavy metal/ferromagnet (Co/Pt) multilayer structures the interfacial DMI coefficient can be tuned in a wide range by applying strain. The uniaxial strain modifies the average DMI constant and also introduces anisotropy to the DMI. Moreover, the DMI of different sign for different directions appears due to the uniaxial strain.

Strains in magnetic films can be induced mechanically (via bending for example) or with an electric field in hybrid ferromagnetic (FM)/ferroelectric(FE) systems. In our work we use the mechanical mean to create the strain. At that, the deformations used in our experiments can be easily induced by an electric field in a ferroelectric (such as PMN-PT). This opens the way to control the DMI (and therefore skyrmions) in heavy metal(HM)/FM systems with voltage.

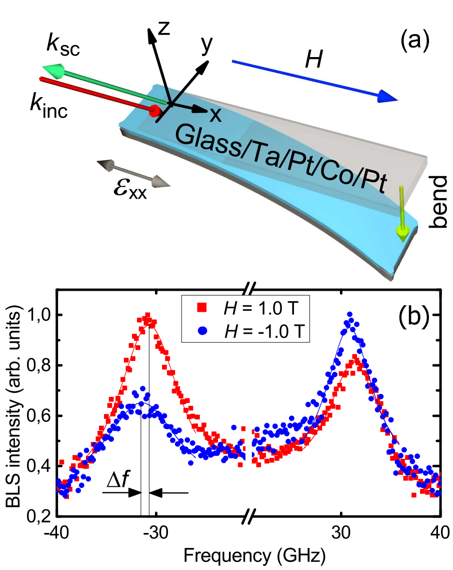

FIG. 1. (a) Experimental geometry. The sample (Glass/Ta/Pt/Co/Pt) is bent and has in-plane strain, ε_{xx}. BLS experiments are performed in the Damon-Eshbach geometry. The laser beam with the incident wavevector $\mathbf{k}_{\rm inc}$ (red arrow) laying in the (y,z)-plane irradiates the sample. The multilayers film scatters the light back into the direction $\mathbf{k}_{\rm sc} = -\mathbf{k}_{\rm inc}$ (green arrow). A magnetic field H is applied perpendicular to the incidence plane. (b) Typical BLS spectrum of Glass/Ta/Pt/Co/Pt without a strain at $H = 1$ T (squares) and $H = -1$ T (circles). Solid lines are Lorentzian fits. Δf is the frequency shift between the Stokes and anti-Stokes peaks.

Note that voltage based tuning of the DMI due to a charge accumulation was demonstrated in a Pt/Co/TaO multilayers in Ref. [21]. The DMI in this system appears at the insulator/FM boundary rather than at the HM/FM interface. Therefore, the DMI in this system is much weaker (of order of 0.1 mJ/m^2) than in HM/FM