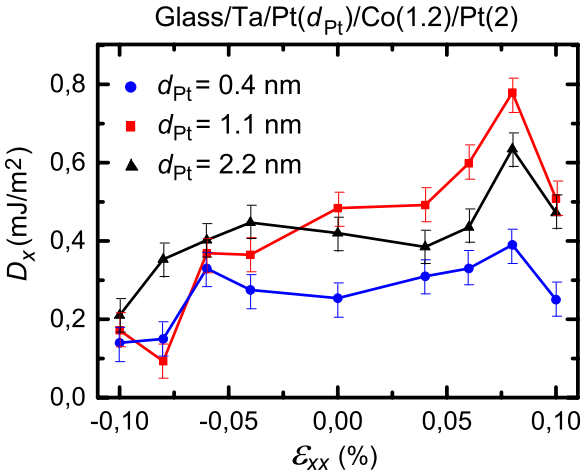

FIG. 3. The DMI constant measured along the x-direction (D_x) as a function of applied strain (ε_{xx}). See the linear least-square fits in the Supplementary materials.

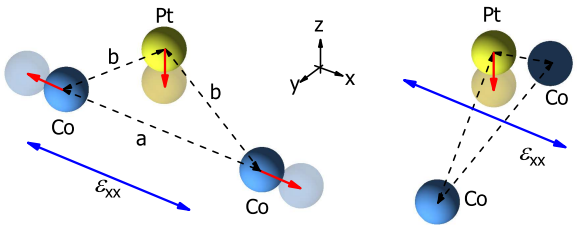

FIG. 4. Displacement of Co and Pt ions due to xx tensile strain ε_{xx}. a is the distance between the Co ions. b is the distance between the Pt and Co ions. Left panel shows the ion triangle oriented along the x-axis. Right panel shows the triangle oriented perpendicular to the strain axis.

2.2 nm is shown in Fig. 3 as a function of strain, ε_{xx}. The samples with $d_{\rm Pt} = 0.4$ and 2.2 nm show weak variation of the DMI. The sample with $d_{\rm Pt} = 1.1$ nm demonstrates rather strong change of the DMI constant D_x from 0.1 to 0.8 mJ/m^2 which is 8 times variation. Note that $D_x = 0.8$ mJ/m^2 is the DMI constant high enough for stabilization of skyrmions in Co/Pt systems [2] while 0.1 mJ/m^2 is too low for skyrmion formation. Therefore, one can e ectively control the skyrmions using the strain induced DMI modulation.

The microscopic reason for the DMI strain dependence can be understood on the base the theoretical model by Fert and Levy [29]. According to this model the DMI is mediated by conducting electrons hopping between magnetic ions through heavy metal ions. Since the interaction appears due to the conduction electrons, it has oscillating character and is described by the expression

$$W_{\rm DMI} \sim \sin(k_{\rm F}(a+2b) + \pi Z_{\rm d}/10)\sin(2\theta)/(ab^2), \quad (2)$$

where $k_{\rm F}$ is the Fermi momentum, a is the distance between magnetic (Co) ions (see Fig. 4), b is the distance between magnetic and heavy metal (Pt) ions, $Z_{\rm d}$ is the number of d-electrons, and θ is the angle made by vectors connecting heavy metal ion and two magnetic ions.

The in-plane strain produced by bending changes the distances a and b. For example, the tensile strain along the x-axis increases a but decreases the height of Pt ion (see left panel in Fig. 4). The height reduces according to the Poisson law. This modifies the DMI constant. Eq. (2) gives non-monotonic behaviour of the DMI constant as a function of distances. This probably is the reason for the non monotonic behaviour of the DMI constant at a high strain.

Note however, that the proposed consideration does not explain the dependence of the DMI strain variation on the Pt layer thickness. At first the model includes only one neighbouring Pt layer, while all other layers may contribute. Another factor is that $d_{\rm Pt}$ influences the lattice constant a in the Pt layer closest to the Co film.

Since the strain induced in our samples is anisotropic, one can expect that the DMI is also anisotropic. This is demonstrated in Fig. 5 where the behaviour of the DMI coefficient for two different directions is shown for the sample with $d_{\rm Pt} = 1.1$ nm. The uniaxial deformation changes the DMI coefficient for both directions. For the tensile strain $D_x \approx D_y$ but for the compressive strain there is a strong anisotropy of the DMI coefficient $D_x \neq D_y$.

The DMI anisotropy can be also understood from the crude consideration on the base of Eq. (2). When the deformation is applied along x-axis the DMI constant along this direction is modified due to variation of both a and b (see left panel in Fig. 4). At that the DMI constant in the y-direction is defined by ion triangles along y-axis. These triangles are modified in a different way (see right panel in Fig. 4). The distance between magnetic ions a is not changed, while the height of the Pt ion reduces. So, variation of the DMI constant in this direction is different.

What is even more interesting is that at strong compressive strain the y-component of the DMI changes the sign while the x-component does not. In Ref. [30] authors simulate the magnetic skyrmions in the situation with different sign of the DMI along different directions. They show that the skyrmion with an anti-vortex domain wall (see inset in Fig. 5) can be realized in this case. So, the strained Co/Pt films can be a good candidates for studying such “antivortex” skyrmions.

Usually, the interface induced DMI in the thin film is described by the expression $-D(\mathbf{m}\cdot[[\mathbf{z}\times\nabla]\times m])$, where D is the DMI constant, $\mathbf{m}$ is the normalized magnetization vector and $\mathbf{z}$ is the interface normal. This expression describes the system isotropic in the film plane. In our study we use uniaxial strain inducing the anisotropic DMI. The interaction energy $W_{\rm DMI}$ can be described by