

RESEARCH ARTICLE

A strategy for fast and precise control of polarity and chirality in magnetic vortices

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Supporting Information

1. Energy evolution during the magnetic structure relaxation process under out-of-plane magnetic field of 170 mT

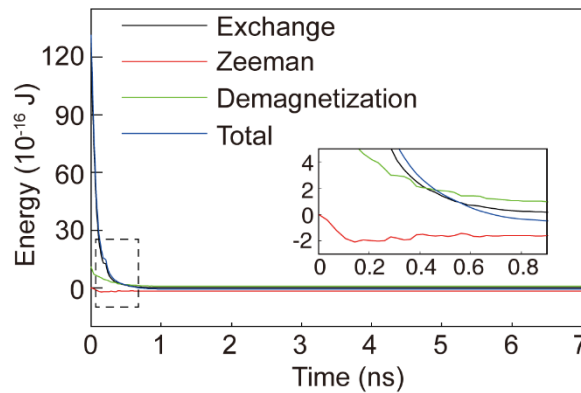


Fig. S1 Energy evolution during the magnetic structure relaxation process under an out-of-plane magnetic field of 170 mT. Inset is the zoom of the area indicated by the dashed rectangular.

2. Magnetic structure evolution under the time-varying magnetic field

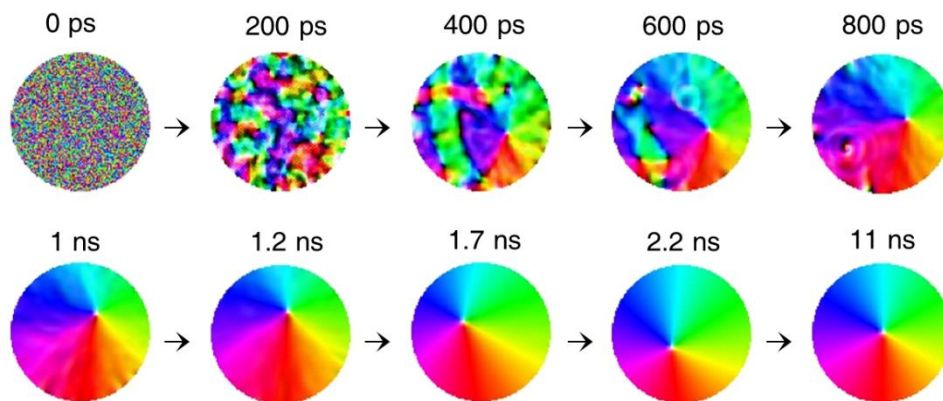


Fig. S2 In the presence of a 170 mT out-of-plane magnetic field with a duration of ~0.1 ns, the relaxation process of the magnetic vortex slows to ~11 ns.

3. Polarity control serves as an example of threshold variations under different conditions

To determine whether the threshold is related to the sample size and magnetic parameters, simulations were conducted. Due to computational resource limitations, the simulations take polarity control as an example. 20 simulations were performed under each selected condition. Additionally, a control group was simulated with a diameter of 500 nm, a thickness of 30 nm, $A = 13$ pJ/m, and $M_s = 800$ kA/m. The results for the diameter of a 700 nm nanodisk are shown in Fig. S3, indicating the polarity controllability reaches 100% under the magnetic field of 110 mT.

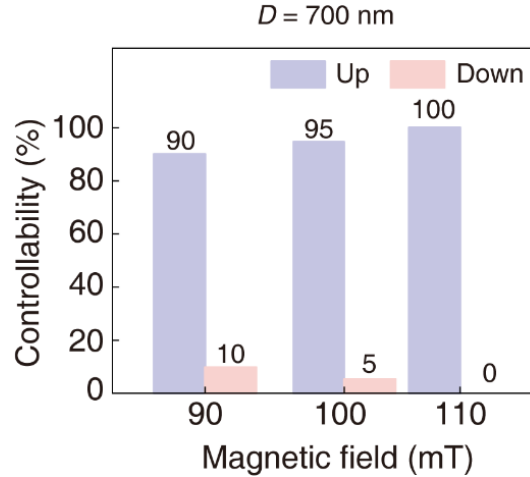


Fig. S3 Polarity controllability in a Py disk with a diameter of 700 nm, for which the controllability reaches 100% under the out-of-plane magnetic field of ~ 110 mT.

For a Py disk, the key magnetic parameters are the A and the M_s . When the A increases, the interactions between spins in the magnetic material increase, leading to the formation of more stable magnetic domain walls. Thus, a higher magnetic field should be required for the polarity control. To investigate the relationship between these magnetic parameters and the critical magnetic fields for the polarity controllability, we have performed micromagnetic simulations with different magnetic parameters. Each condition was simulated by 20 times. As shown in Fig. S4(a), when $A = 26$ pJ/m and $M_s = 800$ kA/m, the polarity controllabilities under the out-of-plane magnetic field of 90 mT, 100 mT, and 110 mT are 80%, 80% and 90%, respectively. While with the magnetic parameters of $A = 13$ pJ/m and $M_s = 1000$ kA/m, the polarity control rates under the out-of-plane magnetic field of 90 mT, 100 mT, and 110 mT are 85%, 95% and 95%, respectively, as shown in Fig. S4(b). Therefore, comparing with the simulation result in the main text ($A = 13$ pJ/m and $M_s = 800$ kA/m), it can be found that the threshold of the magnetic field increases with both of the magnetic constants A and M_s .

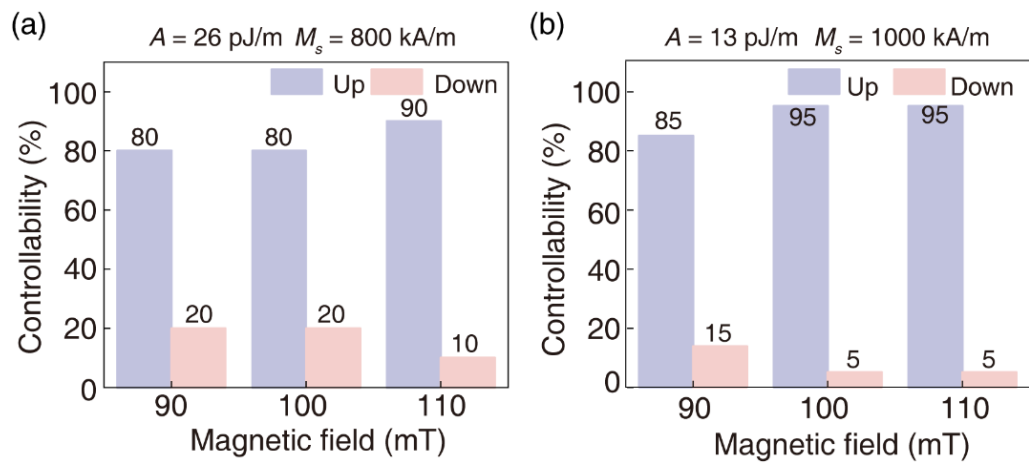


Fig. S4 Threshold for polarity control under different magnetic parameters. (a) Polarity controllability for $A = 26 \text{ pJ/m}$, $M_s = 800 \text{ kA/m}$. (b) Polarity controllability for $A = 13 \text{ pJ/m}$, $M_s = 1000 \text{ kA/m}$.