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Reproducible control of the magnetic vortex chirality on a nanosecond timescale[1]

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Magnetic vortices are curling magnetization structures which represent the lowest energy state in sub-micron size magnetic disks or polygons. The vortex core, a singularity at the vortex center, features magnetization pointing either up or down perpendicular to the disk plane. The binary character of the chirality of the curl and the polarity of the vortex core leads to four possible stable magnetization configurations that can be utilized in a multi-bit memory cell. Both the vortex polarity and chirality are stable against static magnetic fields. It has been shown that when excited with ultrafast magnetic field or current stimuli, the core polarity can be reversed on a 100 ps timescale. We demonstrate ultrafast switching of vortex chirality using nanosecond magnetic field pulses by imaging the process with full-field x-ray transmission microscopy. The dynamic reversal process is controlled by far-from-equilibrium gyrotropic precession of the vortex core and the reversal is achieved at significantly reduced field amplitudes when compared to quasi-static switching. Controlled switching of the chirality requires removing the vortex core out of the disk and then reforming the vortex with opposite chirality. This can be achieved by using a static magnetic field and exploiting a geometric asymmetry in the object. However, scaling this process down in time, using nanosecond and shorter magnetic field pulses, necessarily introduces complex magnetization dynamics that might prevent efficient and reproducible switching of the vortex chirality. We show that these issues can be overcome by selecting magnetic disks of an appropriate geometry along with the field pulse parameters. Finally we discuss that faster switching rates can be achieved by scaling down the disk size.

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