Soft X-ray Microscopy Observation of Dipolar-interaction Induced Magnetic-vortex Gyration

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1. Introduction

The well-known magnetic vortex structure is now of revived interest in the field of nanomagnetism. Especially ultrafast vortex-core (VC) switching and VC oscillation are at the center of current researches [1-3] due to their potential applications to future information storage and nano-oscillator devices, respectively. In order to increase the storage density and the oscillator signals, it is necessary to reduce interdistance between neighboring dots in a vortex-state dot array. When the neighboring dots are close enough [4], vortex dynamics in an isolated single dot can be affected by the dynamics of the next neighboring dots. Here, we report on real-time and real-space soft x-ray microscopy imaging of dipolar-interaction induced vortex gyrations in physically disconnected vortex-state dots.

2. Experiments

The sample studied is shown in Fig. 1(a). Each pair has two Permalloy (Py) disks which are separated physically at a different edge-to-edge distance, as indicated. In order to excite only one vortex-state dot in each pair, the single Cu strip electrode was deposited on top of only the right Py disk in each pair. The sample was prepared onto on a 150 nm thick Si3N4 membrane using e-beam lithography, thermal evaporation, and lift off technique for soft x-ray transmission through the sample. Real-time soft x-ray microscopy imaging of VC gyrations in both dots in each pair was carried out using a full-field magnetic transmission soft x-ray microscope (MTXM) of 70 ps temporal and 20 nm spatial resolutions on beamline 6.1.2 at Advanced Light Source (Berkeley, California, USA), on the basis of a stroboscopic pump-and-probe technique [see Fig. 1(b)]. To study dipolar interaction between two different vortex-state dots, local field pulses were repetitively applied along the x-axis with a 328 ns interval. The full field images were obtained at every time step of 1.67 ns.

3. Results and Discussion

VC orbital motions were observed in both disks although external fields were applied only to the right disk of each pair. According to the rotation senses of both gyrations and image contrasts, we found the same chirality and opposite polarization. In this initial state, the two vortices showed anti-phase motion in the x axis and in-phase motion in the y axis. The results obtained from this experiment are in good agreements with the simulation and analytical calculations of the same vortex state [4]. The degree of the exchange rate of energy or signal between the two is determined by the relative displacement of vortex gyrations.

4. Conclusion

Dynamics of two vortices in physically disconnected Py dots was experimentally observed with a time-resolved MTXM. Vortex gyrations can be induced by dipolar interaction between physically disconnected dots. Energy and information signal between them can be transferred efficiently with low energy dissipation through dipolar-induced vortex gyration.

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5. Reference

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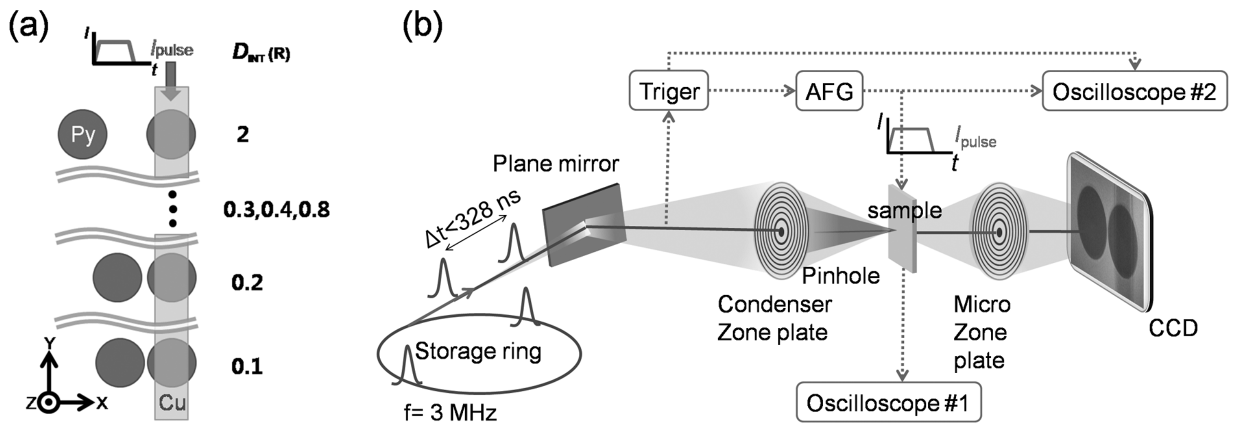

Fig 1. (a) Schematic illustration of the sample studied. Each Py disk has 1.2 µm radius (R) and 50 nm thickness. The Cu strip electrode of 1.5 µm width and 75 nm thickness was deposited on to top of one dot of each pair. (b) Experimental setup for real-time microscopy imaging of vortex-core gyrations.