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Imaging Magnetic Vortices Dynamics Using Lorentz Electron Microscopy with GHz Excitations[1]

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Magnetic vortices in thin films are naturally formed spiral spin configurations with a core polarization pointing out of the film plane. They typically represent ground states with high structural and thermal stability as well as four different chirality-polarity combinations, offering great promise in the development of spin-based devices. For applications to spin oscillators, non-volatile memory and logic devices, the fundamental understanding and precise control of vortex excitations and dynamic switching behavior are essential. The compact dimensionality and fast spin dynamics set grand challenges for direct imaging technologies. Recently, we have developed a unique method to directly visualize the dynamic magnetic vortex motion using advanced Lorentz electron microscopy combined with GHz electronic excitations. It enables us to map the orbit of a magnetic vortex core in a permalloy square with <5nm resolution and to reveal subtle changes of the gyrotropic motion as the vortex is driven through resonance [1]. Further, in multilayer spin-valve disks, we probed the strongly coupled coaxial vortex motion in the dipolar- and indirect exchange-coupled regimes and unraveled the underlying coherence and modality [2]. Our approach is complementary to X-ray magnetic circular dichroism and is of general interest to the magnetism community as it paves a way to study fundamental spin phenomena with unprecedented resolution and accuracy. Collaborations with S.D. Pollard, J.F. Pulecio, D.A. Arena and K.S. Buchanan are acknowledged.

[1] S. D. Pollard, L. Huang, K. S. Buchanan, D. A. Arena & Y. Zhu, Direct dynamic imaging of non-adiabatic spin torque effects, Nat. Commun. 3, 1028 (2012).
[2] J. F. Pulecio, P. Warnicke, S. D. Pollard, D. A. Arena & Y. Zhu, Coherence and modality of driven interlayer-coupled magnetic vortices, Nat. Commun. 5, 3760 (2014).

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