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691 – A New Type of Domain and Interacting Bloch-lines in a Dzyaloshinskii-Moriya Multilayer Thin Film

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Lorentz phase microscopy (LPM) is a powerful tool to study nanoscale magnetic order [1–3], with the capacity to probe local spin configurations at the sub-5nm length scales, and has been used to visualize Bloch-lines (BLs) and non-Q=1 topological defects previously [4]. LPM contrast is the result of a phase shift in the electron wave as it passes through a magnetic field where the contrast at the domain wall is proportional to the component of the curl of the magnetization along the beam propagation direction and can be approximated according to eq.(2) in Garlow et al. [5]. Beyond Fresnel imaging, electron phase retrieval techniques, specifically using the transport-of-intensity equation (TIE), are well-suited to quantitatively map the local magnetic induction with nanometer resolution. Though phase retrieval is generally regarded as qualitative due to the addition of a small nonzero constant, q0, to solve the TIE through Fourier methods and to filter out low frequency noise, with careful image acquisition and analysis, quantitative information can be obtained [6–9].

Bloch-lines (BLs) play a key role in determining the static and dynamic behavior of chiral domain walls and skyrmions in multilayer films with a significant Dzyaloshinskii-Moriya interaction (DMI) [10,11]. Here, we reveal a new spin texture, termed a type-II domain wall pair, that can be stabilized in DMI multilayer thin films through the formation of BLs and apply our previously developed method [5] to quantify complex chiral structures with phase imaging. For a type-II domain wall pair, the Bloch component of each complementary domain wall has opposite chirality, whereas a type-I domain wall pair is comprised of a continuous Bloch component that may have either right- or left-handed chirality. We find that type-II domain wall pairs preferentially form through bifurcation of a type-I domain wall pair and requires the formation of BLs. We establish the prevalence and evolution of type-II domain regions and show that BL pairs can form a strong interaction through their stray fields. Finally, we demonstrate that at high applied fields type-II domain wall pairs can lead to the formation of mixed-character skyrmions with a Bloch component that can be of either left- or right-handed chirality [12].

References

[1] S. R. Herd and P. Chaudhari, Phys. Status Solidi **18**, 603 (1973).

[2] P. J. Grundy and S. R. Herd, Phys. Status Solidi **20**, 295 (1973).

[3] S. R. Herd, Phys. Status Solidi **38**, 305 (1976).

[4] A. K. Nayak, V. Kumar, T. Ma, P. Werner, E. Pippel, R. Sahoo, F. Damay, U. K. Rößler, C. Felser, and S. S. P. Parkin, Nature **548**, 561 (2017).

[5] J. A. Garlow, S. D. Pollard, M. Beleggia, T. Dutta, H. Yang, and Y. Zhu, Phys. Rev. Lett. **122**, 237201 (2019).

[6] M. Beleggia, M. A. Schofield, V. V. Volkov, and Y. Zhu, Ultramicroscopy **102**, 37 (2004).

[7] M. Mitome, K. Ishizuka, and Y. Bando, J. Electron Microsc. **59**, 33 (2010).

[8] C. T. Koch and A. Lubk, Ultramicroscopy **110**, 460 (2010).

[9] C. T. Koch, Micron **63**, 69 (2014).

[10] I. Lemesh and G. S. D. Beach, Phys. Rev. Appl. **12**, 044031 (2019).

[11] V. Krizakova, J. P. Garcia, J. Vogel, N. Rougemaille, D. de S. Chaves, S. Pizzini, and A. Thiaville, Phys. Rev. B **100**, 214404 (2019).

[12] J. A. Garlow, S. D. Pollard, M. Beleggia, T. Dutta, H. Yang, and Y. Zhu, submitted.