Comment on "Three-Dimensional, Spin-Resolved Structure of Magnetic Vortex and Antivortex States in Patterned Co Films Using Scanning Ion Microscopy with Polarization Analysis"

In a recent Letter, Li and Rau [1] presented a new method, scanning ion microscopy with polarization analysis (SIMPA), where a focused beam of Ga^+ ions (25 keV) is scanned across the surface and a spin analysis of the emitted electrons allows an imaging of all magnetization components. As any experimental method, SIMPA may be subject to artifacts, such as the existence of wide tails or an increased effective probe width due to convolution with the sample damage function, all possibly giving rise to inaccurate results. The data of Ref. [1] obtained on Co disks (diameter d) which exhibit a vortex state with a perpendicularly magnetized vortex core showed a surprisingly large core width $d_{vc} \approx 2\ \mu$m (Fig. 2 of Ref. [1]). By defining a quantity called the "relative core width," d_{vc}/d, good agreement with previous experimental and theoretical studies was claimed. Here we show that (i) d_{vc} is on the order of 10 nm rather than μm and that (ii) d_{vc} is essentially independent of d. Although we are not able to identify the responsible mechanisms, these facts evidence that these SIMPA images are affected by artifacts.

The width of the vortex core is a long-standing issue [2] first solved by a variational approach [3] showing that $d_{vc} = 2\sqrt{A/K_{ms}}$ in the thin film limit, where A is the exchange stiffness and $K_{ms} = \mu_0 M_{sat}^2/2$ is the magnetostatic energy density with the saturation magnetization M_{sat}. Recent numerical techniques using different codes give consistent results [4,5]. As shown in Table I the magnetocrystalline anisotropy energy density K_c can be neglected when estimating d_{vc} since—for any material shown here—it never exceeds 50% of K_{ms} (in Ref. [1] this fact is reflected by the parameter $Q < 1$). Insertion into the above equation results in $d_{vc} = 7$–16 nm; i.e., d_{vc} for different ferromagnetic materials is very similar. Note that d_{vc} is determined entirely by microscopic properties of the ferromagnet reflecting the competition of the short range magnetic exchange interaction and the local stray field. In contrast to the discussion of Ref. [1], d_{vc} does not scale with the particle size. This is also verified by the micromagnetic calculation of Fig. 1, where a finite-element mesh with variable cell size and material parameters of polycrystalline ($K_c = 0$) Co have been used [5].

TABLE I. Properties of ferromagnets (from Ref. [6]).

Material	A [J/m]	K_{ms} [J/m^3]	K_c [J/m^3]	d_{vc} [nm]
Fe	2.1×10^{-11}	1.82×10^6	4.8×10^4	6.8
Co	3.0×10^{-11}	1.23×10^6	5.2×10^5	9.9
Ni	9×10^{-12}	1.51×10^5	-5.7×10^3	15.4
Permalloy	1.3×10^{-11}	4.65×10^5	0	10.6

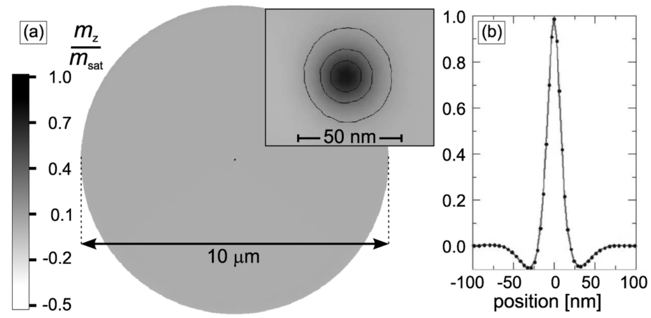

FIG. 1. (a) Calculated gray-scale plot and (b) line profile of m_z in the central region of a 30 nm thick polycrystalline Co disk ($d = 10\ \mu$m). Inset: magnified region around the vortex core which appears as a tiny black dot in (a) [10].

The width [7–9] and the shape of magnetic vortex cores [8] has been determined by high-resolution magnetic imaging techniques like spin-polarized scanning tunneling microscopy and (scanning) transmission electron microscopy ($d_{vc} \approx 20$ nm in Co [7] and 9 nm in Fe [8] and permalloy [9]). The shape of a vortex core was found to be in good agreement with numerical solutions [6] including a circular region with reversed magnetization around the vortex core [8].

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Received 23 October 2006; published 14 January 2008
DOI: 10.1103/PhysRevLett.100.029703
PACS numbers: 75.60.Ch, 07.78.+s, 75.70.Rf

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[10] The simulations shown in Fig. 1 were performed by R. Hertel (Jülich Research Center), with the micromagnetic finite-element program that was used in Ref. [5].

