Vortex head-to-head domain walls and their formation in onion-state ring elements

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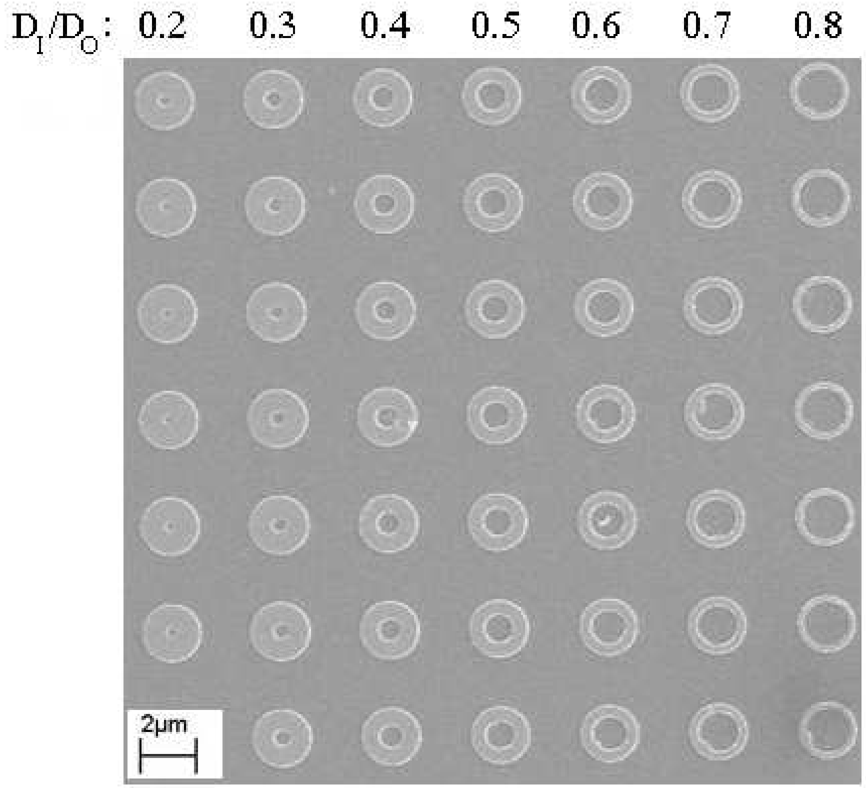
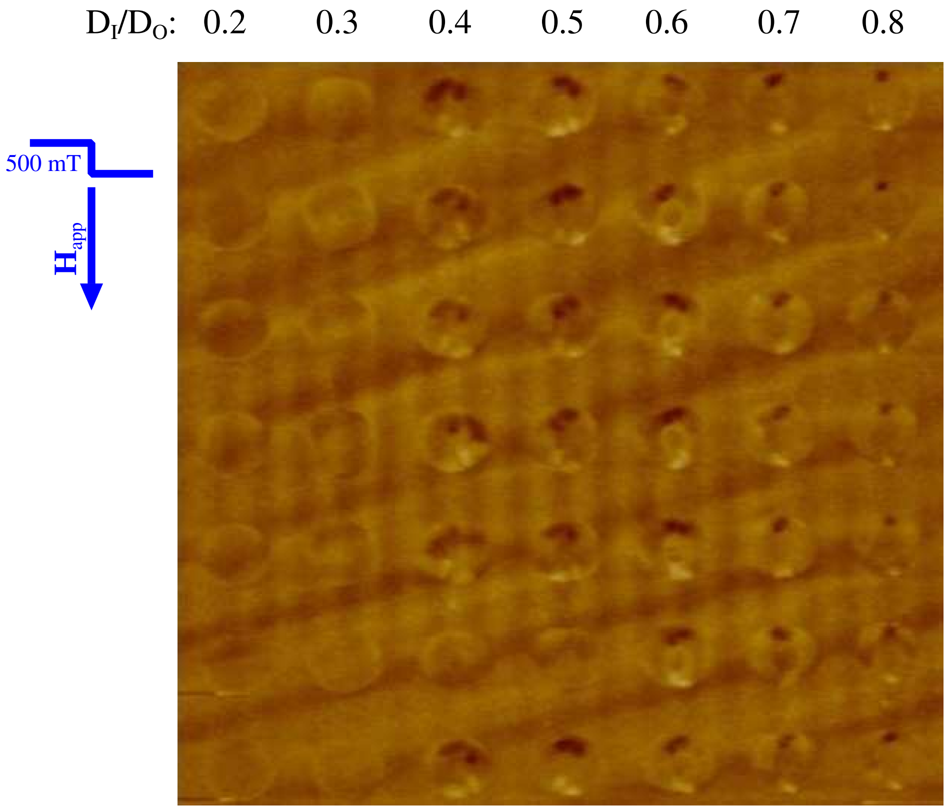
SEM image



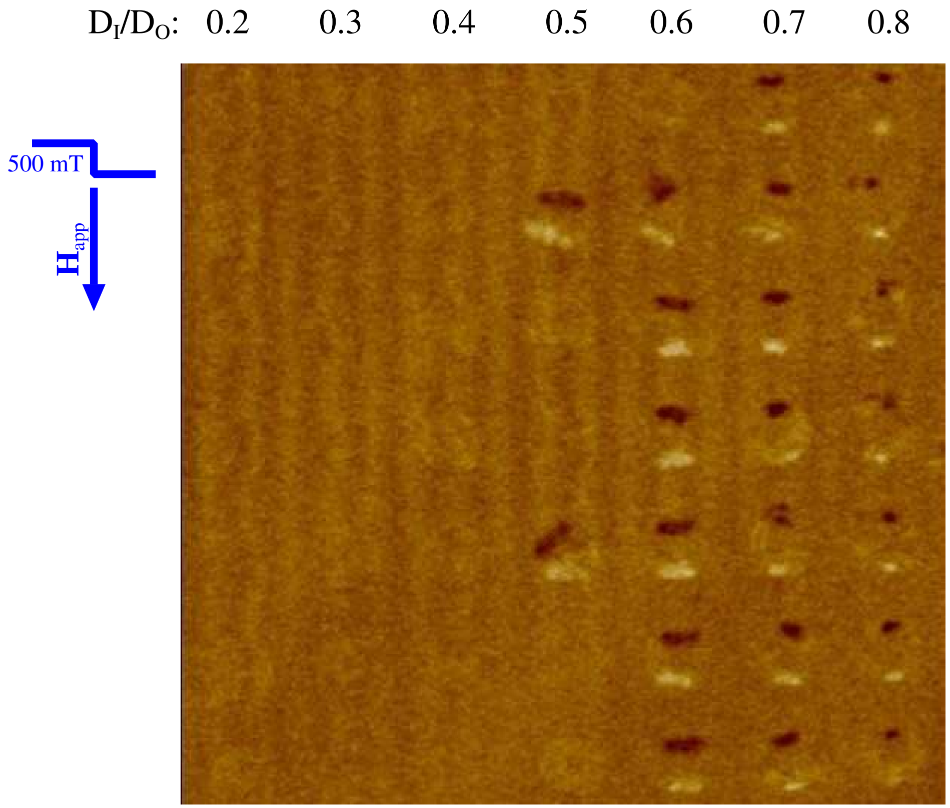
Array of $Ni_{80}Fe_{20}$ ring elements,
D_O = 2 μm, t = 40 nm.

MFM image



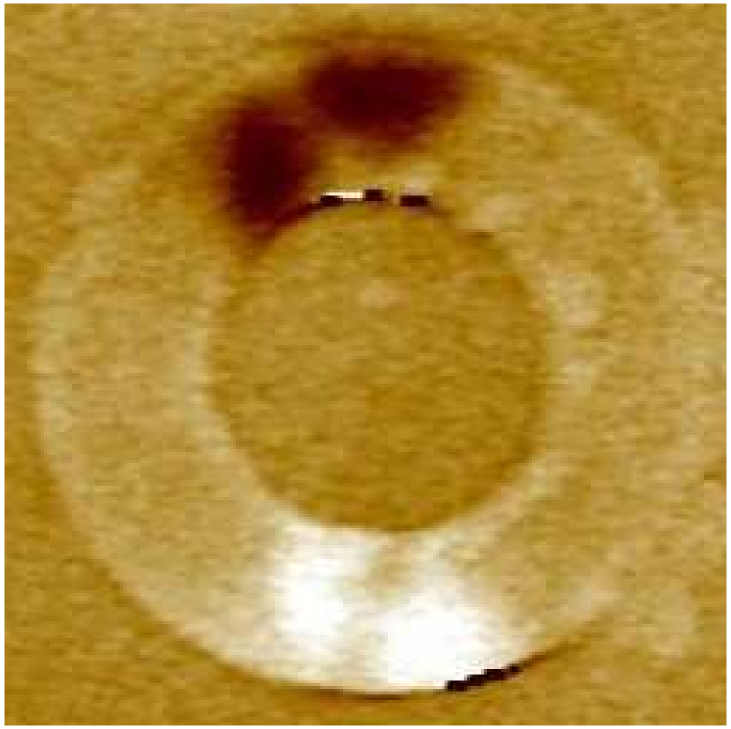
D_O = 2 μm, t = 40 nm

MFM image

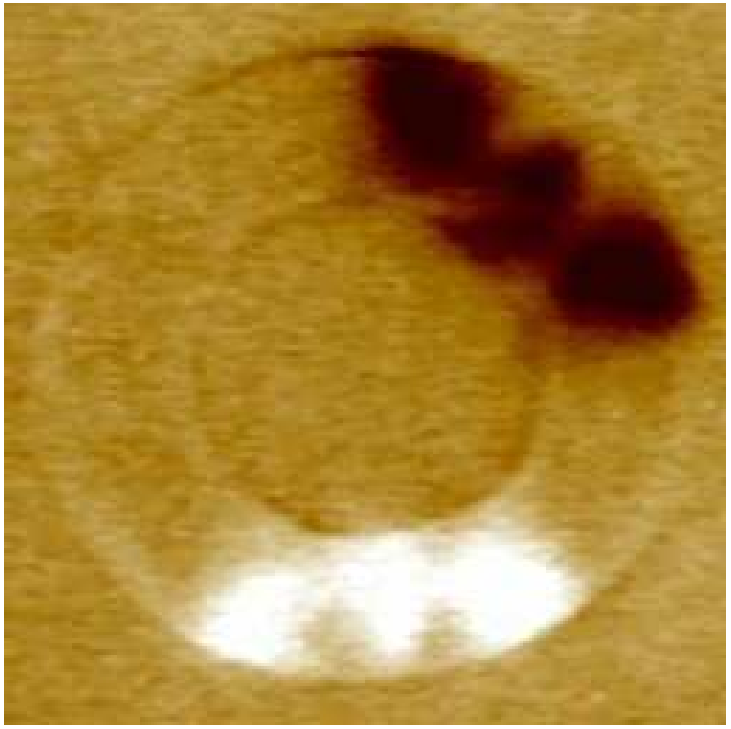


D_O = 2 μm, t = 65 nm

MFM detail, $D_{\mathrm{I/O}}$=0.6

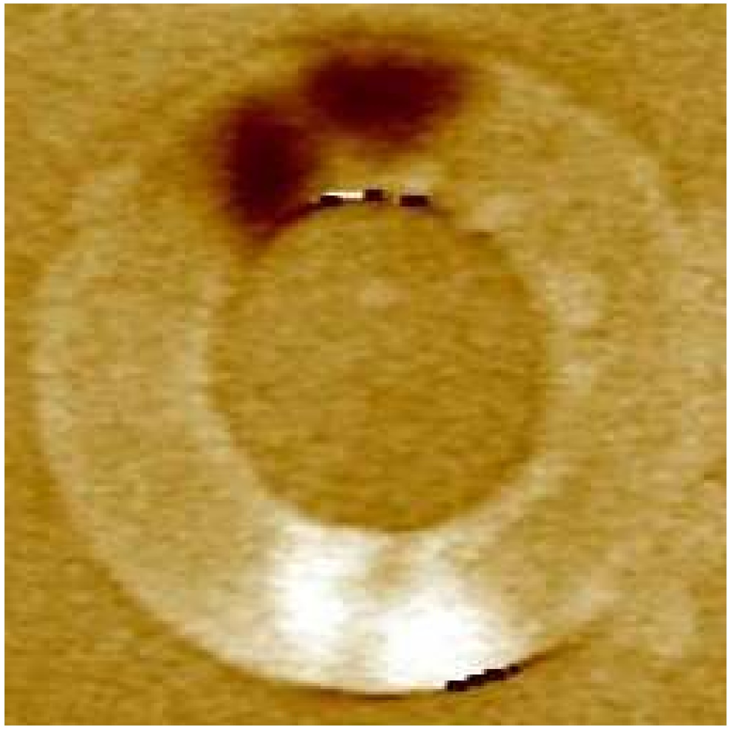


t = 40 nm

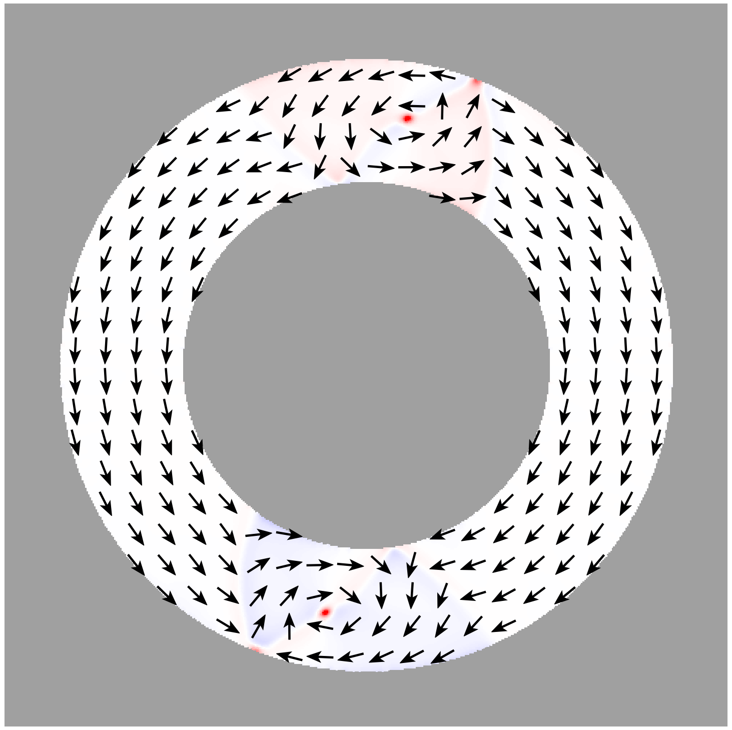


t = 65 nm

$D_{\mathrm{I/O}}$=0.6, t=40 nm

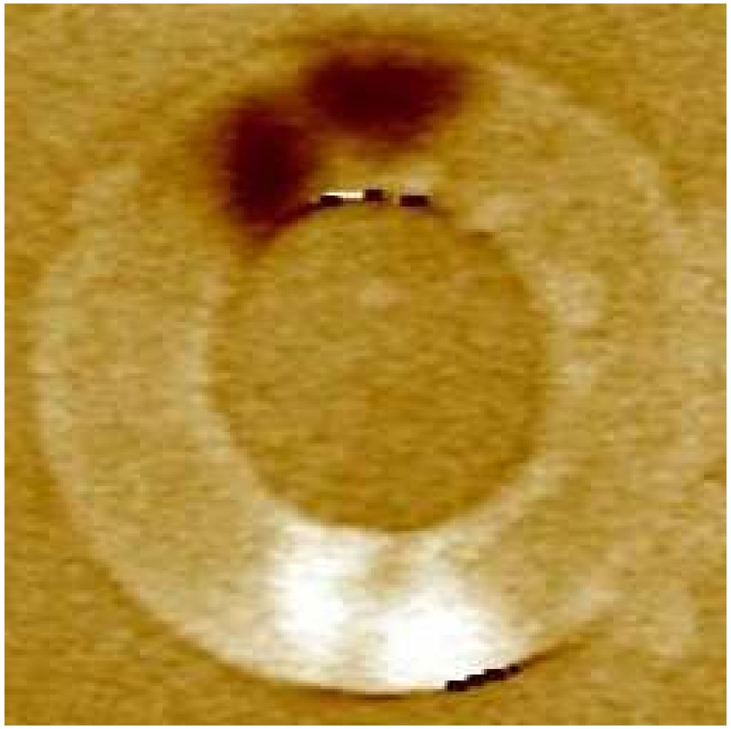


MFM image

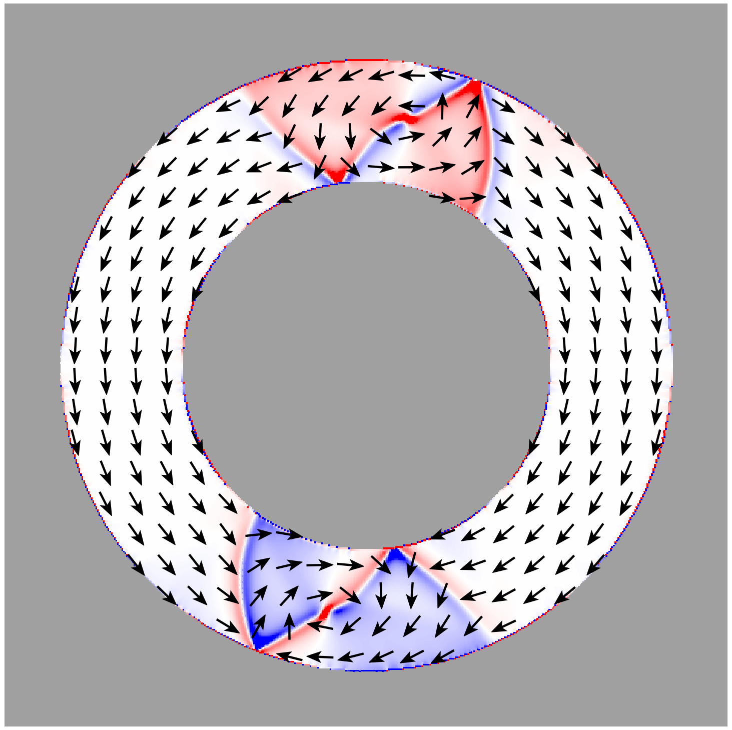


Simulation, M_z

$D_{\mathrm{I/O}}$=0.6, t=40 nm

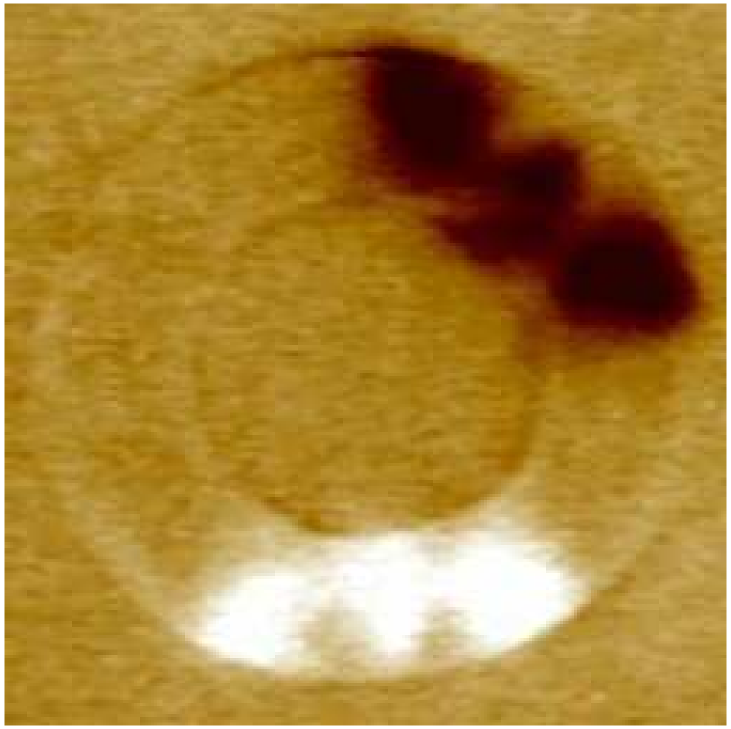


MFM image

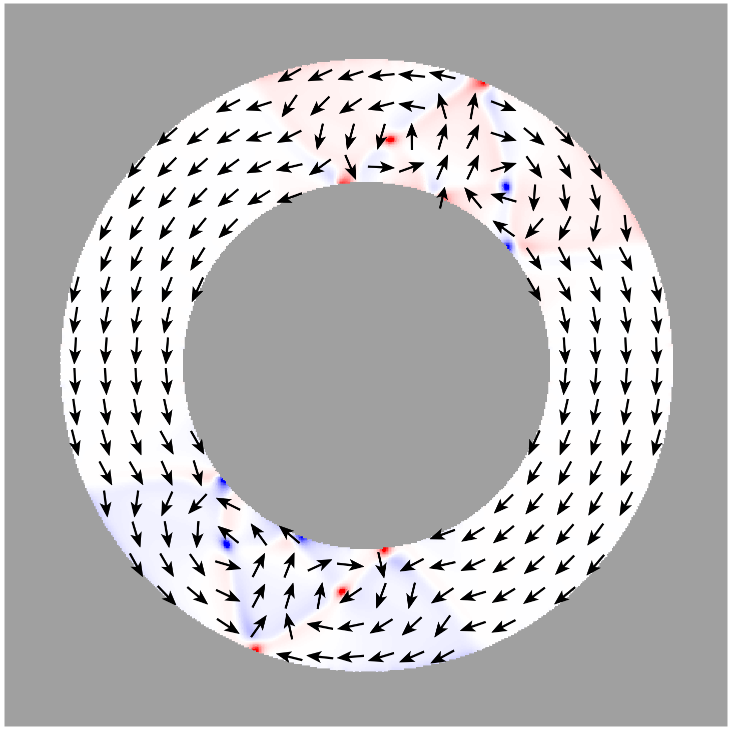


Simulation, $\nabla \cdot M$

$D_{\mathrm{I/O}}$=0.6, *t*=65 nm

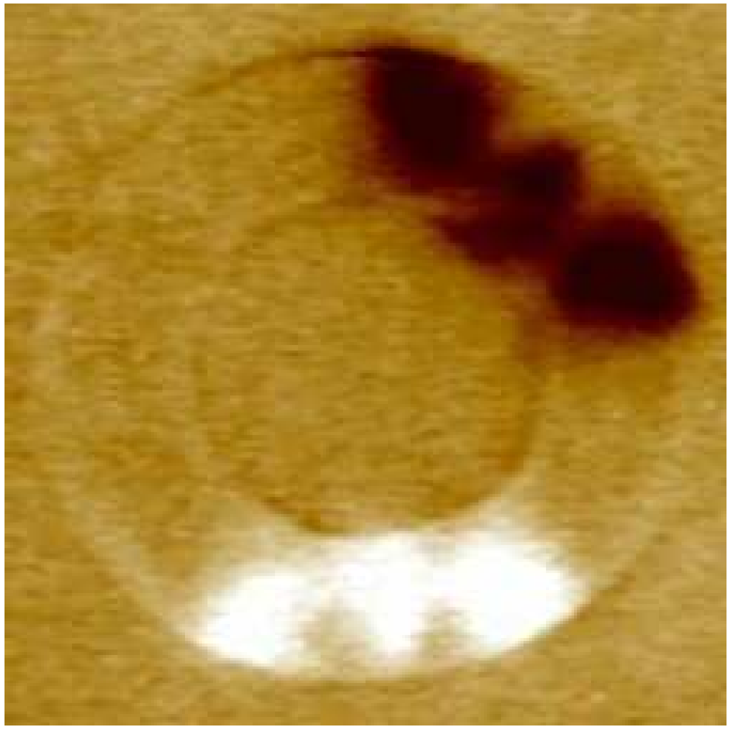


MFM image

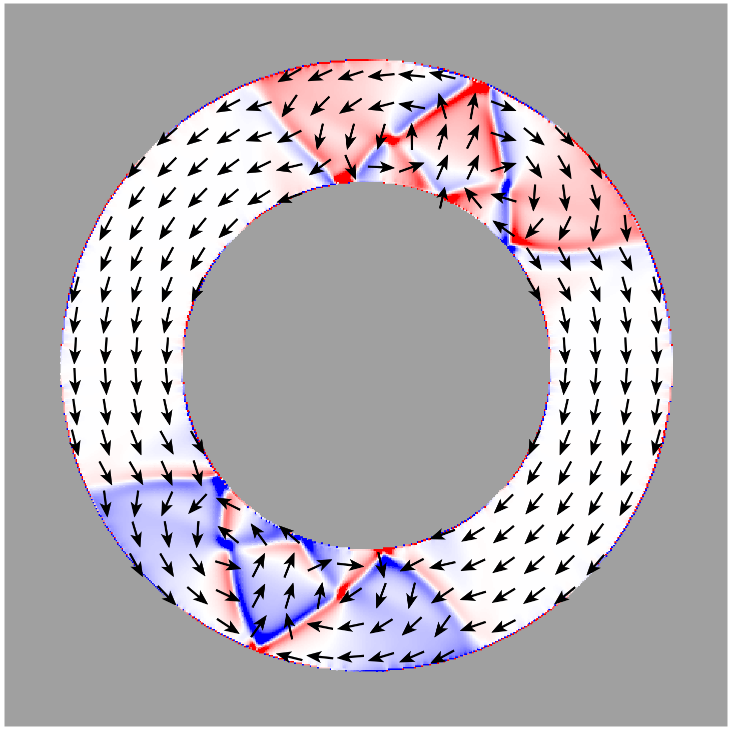


Simulation, M_z

$D_{\mathrm{I/O}}$=0.6, t=65 nm

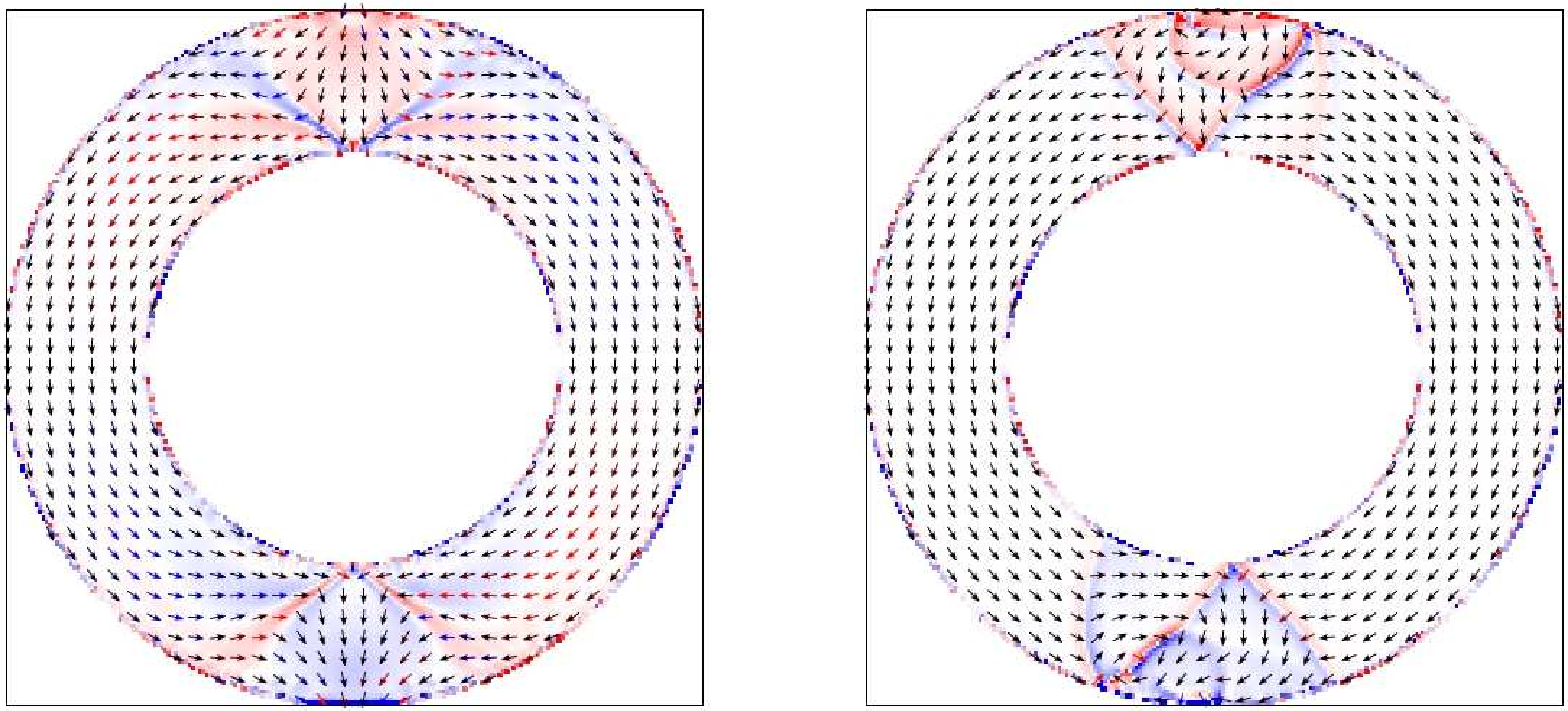


MFM image



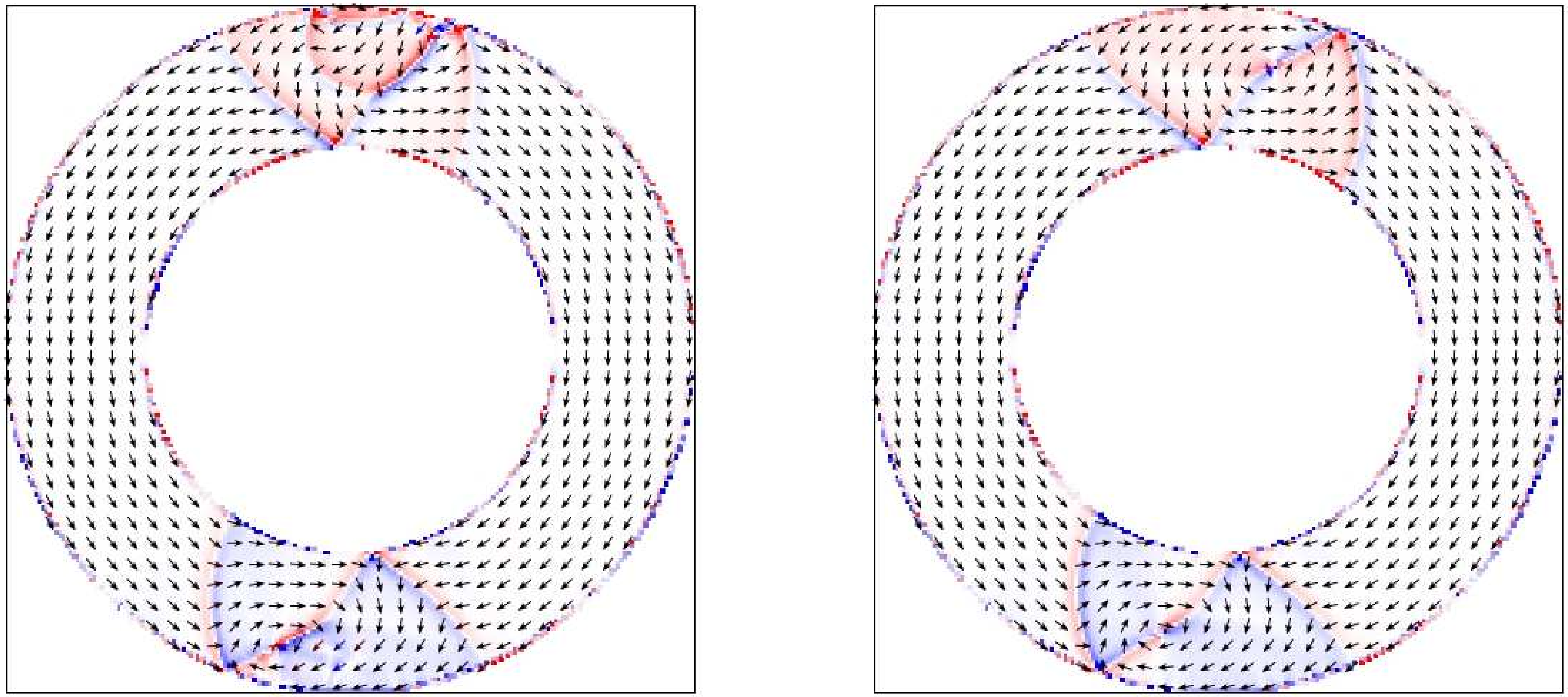
Simulation, $\nabla \cdot M$

Wall formation, t=40 nm



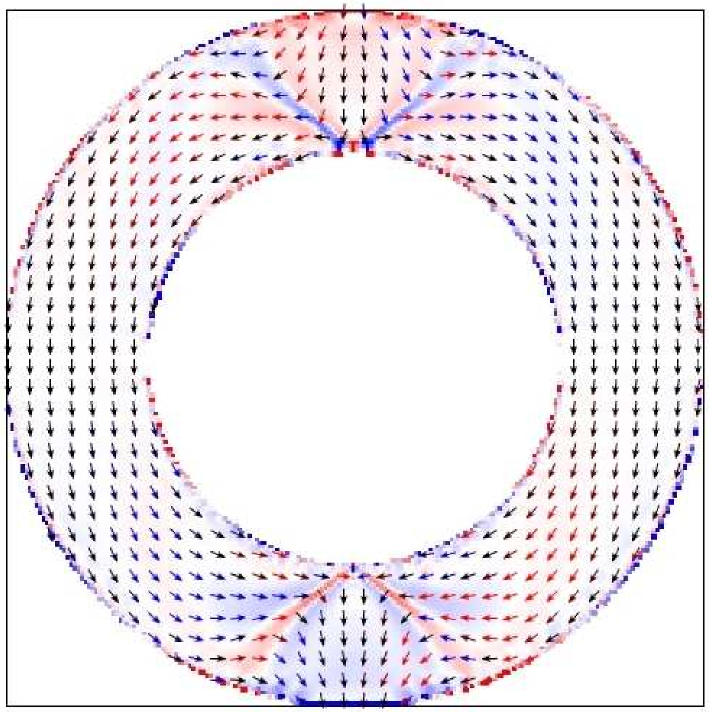
time = 100 ps　　　　600 ps

Wall formation, t=40 nm

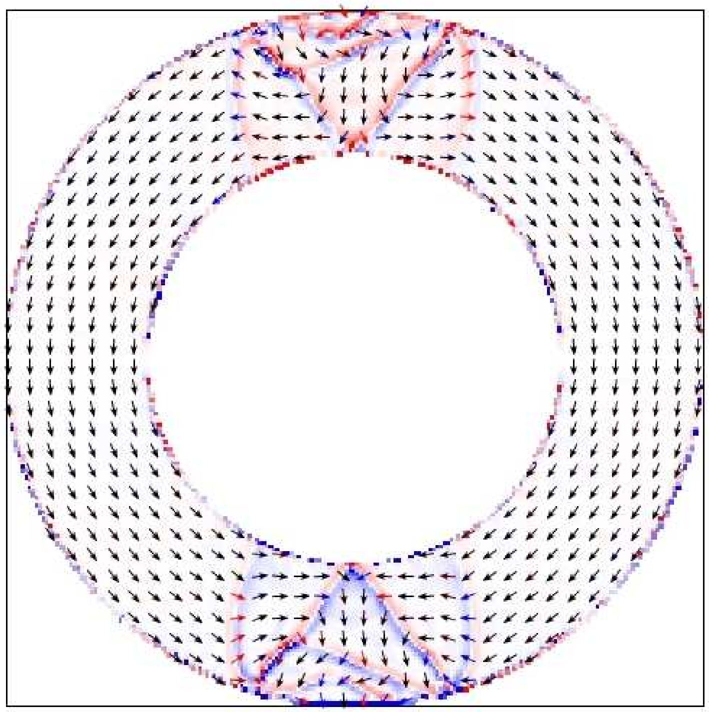


time = 1000 ps | 1600 ps

Wall formation, t=65 nm

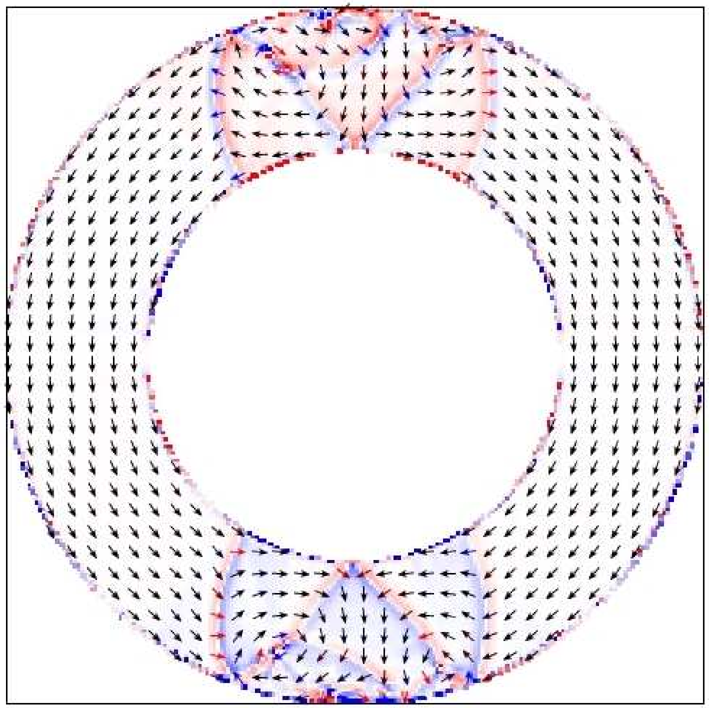


time = 100 ps

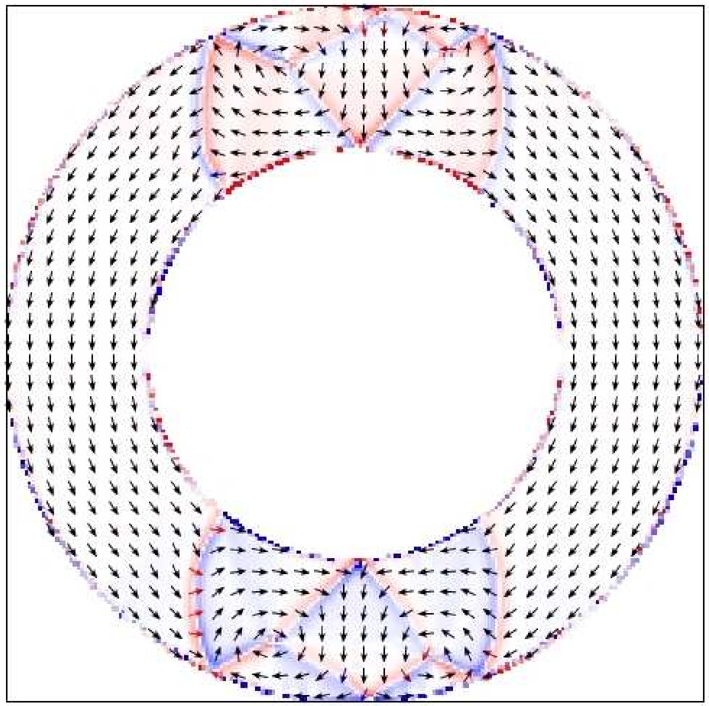


300 ps

Wall formation, t=65 nm

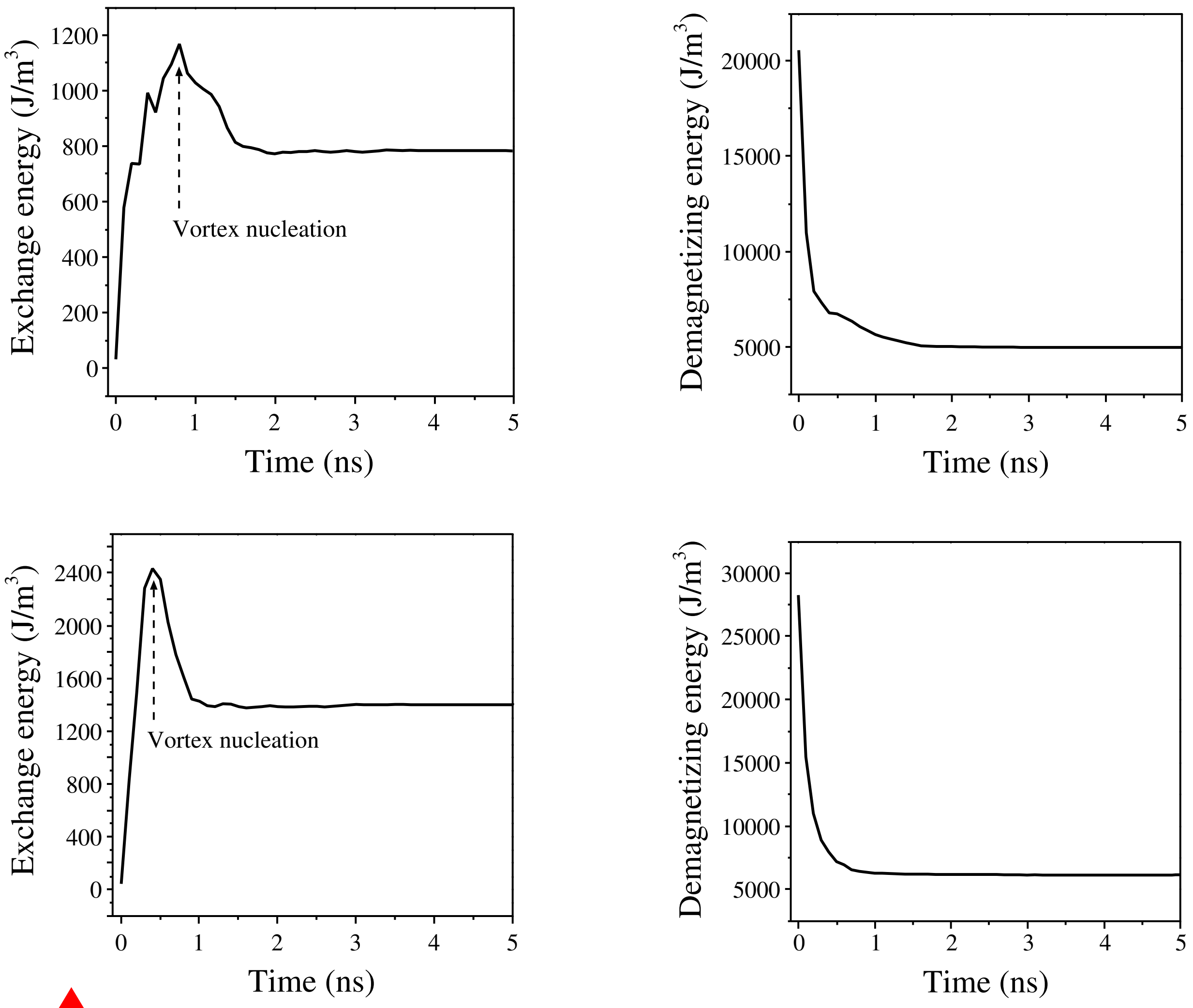


time = 500 ps



900 ps

Wall formation



Energy comparisons

t (nm)	$D_{I/O}$	One Vortex Wall Exch	One Vortex Wall Demag	One Vortex Wall Total	Two Vortex Wall Exch	Two Vortex Wall Demag	Two Vortex Wall Total
40	0.4	896	4729	5625	1221	3806	5028
	0.5	894	4770	5664	1241	4056	5297
	0.6	921	4796	5718	1306	4190	5496
	0.8	1122	5071	6193	1653	4622	6275
55	0.6	1071	5871	6942	1437	5054	6490
65	0.6	-	-	-	1567	5500	7067
	0.7	1484	6128	7612	1667	5533	7200
	0.8	1561	6179	7740	1840	5698	7538

Energy units: J/m^3

Similar effects reported for transverse/single-vortex transition:

- M. Kläui, C.A.F. Vaz, J.A.C. Bland, L.J. Heyderman, F. Nolting, A. Pavlovska, E. Bauer, S. Cherifi, S. Heun, A. Locatelli, "Head-to-head domain-wall phase diagram in mesoscopic ring magnets," *Applied Physics Letters*, **85**, 5637-5639 (2004).
- M. Kläui, M. Laufenberg, U. Rüdiger, F. Nolting, L. Heyderman, H. Ehrke, R. Dunin-Borkowski, C.A.F. Vaz, J.A.C. Bland, S. Cherifi, E. Bauer, P.-O. Jubert, R. Allenspach, "Intermag 2005, ED07 Geometrically confined Domain Walls," April 2005.

Summary

- Good agreement between MFM and micromagnetics for $Ni_{80}Fe_{20}$ ring elements.
- Single-vortex head-to-head walls observed in 40 nm elements.
- Double-vortex head-to-head walls observed in 65 nm elements.
- Micromagnetics indicate double-vortex wall has lower energy in 40 nm element, but is inaccessible.
- Nucleation event evident in micromagnetic simulations as spike in exchange energy.