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Magnetic twists: Micromagnetic simulations to describe polarised neutron reflectometry data

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Magnetic thin films are important for computing technologies, where atomic-scale control of magnetic properties is required. Here, we present a 1D micromagnetic simulator (microM-ref1D) for thin film magnets with twisted magnetization profiles. Importantly, it is integrated with the Ref1D software for polarized neutron reflectometry fitting to accurately extract magnetic parameters.

Using this new software approach, we show that exchange interactions and other atomic-level magnetic parameters can be probed using neutron reflectometry. Mechanical rotation of a film in an applied magnetic field can be used to manipulate magnetization at the nanoscale, to wind a variety of distinctive 1D magnetic structures: exchange springs, propellers and solitons. Each of these structures can be identified by its unique finger print in the Q-dependent neutron spin flip signal of the reflection pattern.

A proof-of-concept experiment using the Platypus polarised reflectometer at the ACNS was conducted to explore the magnetic winding in the ferromagnetic/antiferromagnetic $Ni_{80}Fe_{20}/Fe_2O_3$ thin film system.[1] After field-cooling and rotation, the presence of a non-collinear component in the spin structure was detected using neutron spin flip analysis. The data is described well using the 1D micromagnetic model for the twist.[2]

The 1D micromagnetic simulation is general and can be widely applied in polarised neutron reflectometry fitting to constrain complex models of planar magnets. The aim is to also incorporate simulations into RefNx software at ANSTO.

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[1] D. L. Cortie et al. Phys. Rev. B 86, 054408 (2012).
[2] B. McGrath, K. L. Livesey & R. E. Camley, Phys. Rev. B 111, 094422 (2025).

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