

Experimental report

14/09/2026

Proposal: 5-53-311

Council: 4/2021

Title: Defect-induced Dzyaloshinskii-Moriya interaction in iron oxide nanoparticles

Research area: Physics

This proposal is a new proposal

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Samples: Fe₂O₃
Fe₂O₃/Fe₃O₄
FeO-Fe₃O₄

Instrument	Requested days	Allocated days	From	To
D33	5	5	08/09/2021	13/09/2021

Abstract:

Magnetic nanoparticles possess unique tunable properties and can be manipulated by external magnetic fields, which make them ideal candidates for various applications. Recently, we proposed defect-engineering of iron oxide nanoparticles as a new research avenue to optimize the particle properties for life science applications.

For defect-rich bulk ferromagnets, we could already show the generic relevance of the defect-induced Dzyaloshinskii-Moriya interaction (DMI), suggesting a potential for the creation of local incommensurate spin textures. To verify the existence of nonuniform spin textures we performed half-polarized SANS measurements, that is, SANS POL while applying a symmetry-breaking magnetic field.

In this experiment we want to use SANS POL to investigate if the structural defects within iron oxide nanoparticles also cause DMI which would show up as chiral terms in the residual SANS POL cross section. We will mainly investigate defect-rich particle systems. These particles excel at magnetic hyperthermia, and we are confident that the high density of structural defects causes incommensurate spin textures within the particles, similar to defect-rich bulk ferromagnets.

Defect-induced Dzyaloshinskii-Moriya interaction in iron oxide nanoparticles

Magnetic nanoparticles possess unique tunable properties and can be manipulated by external magnetic fields, which make them ideal candidates for various applications. Recently, we proposed defect-engineering of iron oxide nanoparticles as a new research avenue to optimize the particle properties for life science applications. The objective of this experiment was to use SANSPOLE to investigate if the structural defects within iron oxide nanoparticles cause Dzyaloshinskii-Moriya interaction which would show up as chiral terms in the residual SANSPOLE cross section. We therefore mainly investigate defect-rich particle systems, i.e. iron oxide nanoflowers. These particles are known to excel at magnetic hyperthermia, and we are confident that the high density of structural defects causes inconsumerate spin textures within the particles, similar to defect-rich bulk ferromagnets.

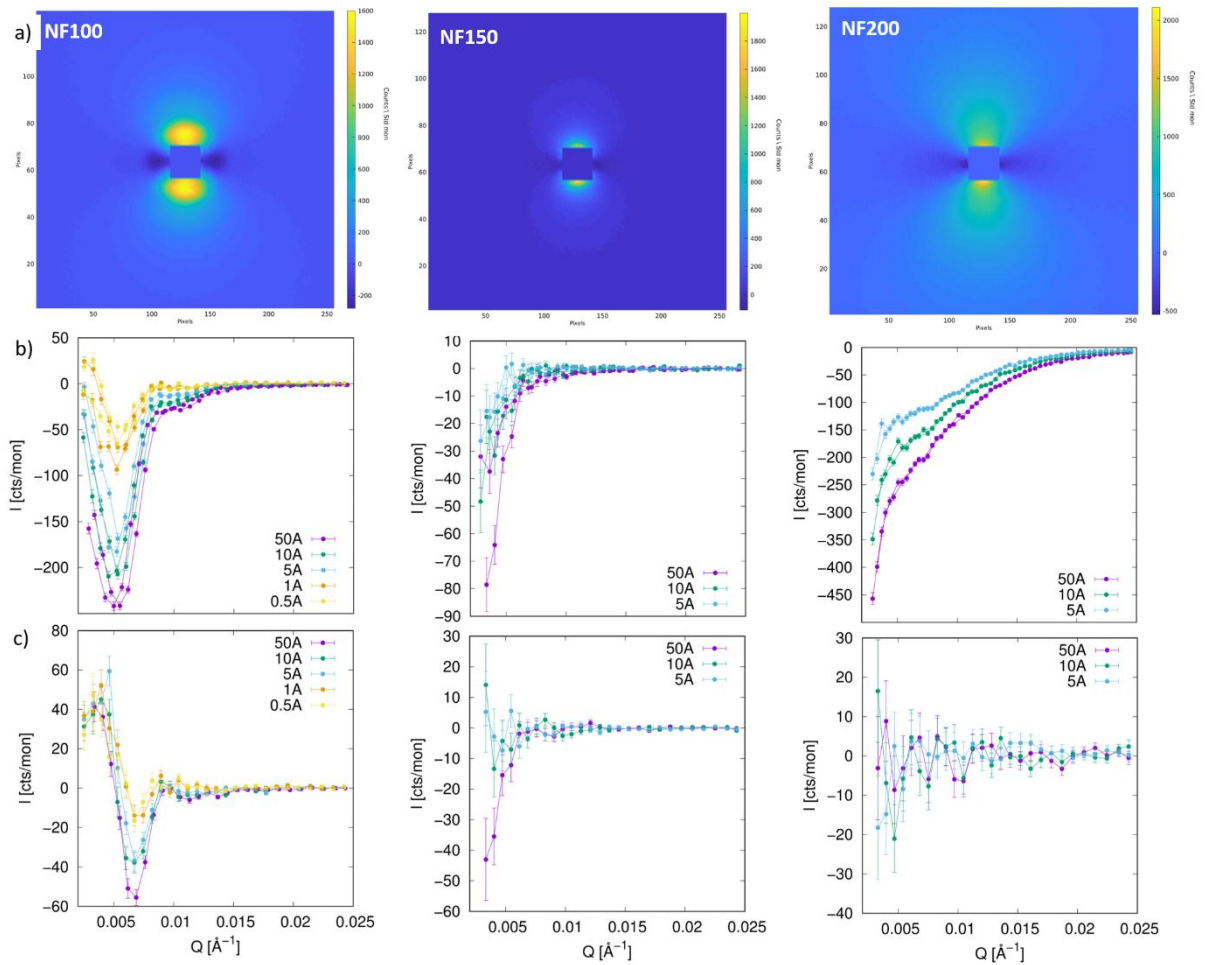


Figure 1: a) polarized SANS intensities for NF100, NF150, and NF200. The difference between spin up (I^+) and spin down (I^-) scattering intensities in a magnetic field applied horizontally is shown. b) Integrated scattering differences in the horizontal direction for different applied magnetic fields (given as current of the electromagnet, 50A corr. to ca. 1 T). Data is shown as integrated to the left- and right-hand side of the beam center. c) Spin asymmetry derived as the difference between the left- and right-hand side data shown in (b).

Polarized SANS was measured on three different nanoflowers samples with different dimensions, NF100, NF150, and NF200 (corresponding to average nanoflower sizes of 100-200 nm). Fig. 1a shows the detector images for the difference between both spin channels, ($I^+ - I^-$). For all samples, there is a clear negative intensity difference visible in the horizontal direction, i.e. parallel to the applied magnetic field. Non-zero intensity difference in the field direction is a signature of either spin misalignment or chiral magnetism.

We observe that the modulus of the intensity difference increases with applied field (Fig. 1b). This behavior is in contrast to what we expect for classical spin misalignment, e.g. for disordered spins near surfaces or interfaces that gradually align with an applied magnetic field of increasing magnitude. We therefore attribute the origin for the observed spin asymmetry to chiral spin structures. This is supported by the slight asymmetry between the intensity difference on the left- and right-hand sides of the beam center that we observe for NF100 and NF150 (Fig. 1c), another signature of chiral spin structures.

Further evaluation of the data is ongoing.