Imaging topological defects in a non-collinear antiferromagnet

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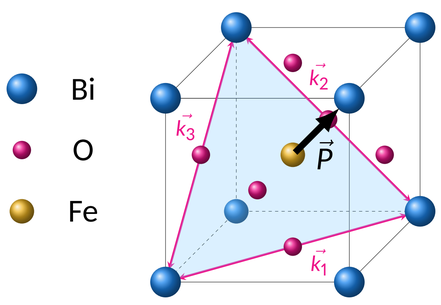
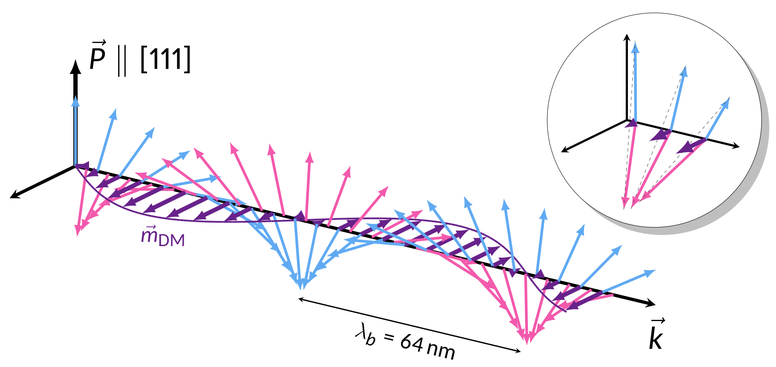
A. Finco *et al. Phys. Rev. Lett.* 128 (2022), 187201

The cycloid in multiferroic $BiFeO_3$

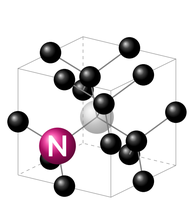




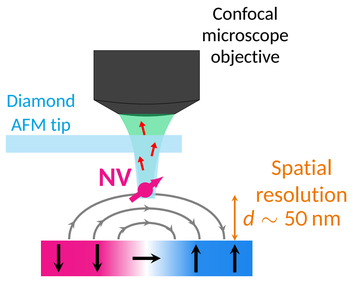
- Magnetoelectric coupling
  → *antiferromagnetic cycloid* → **compensated!**
- Dzyaloshinskii-Moriya interaction
  → *spin density wave* → **stray field!**

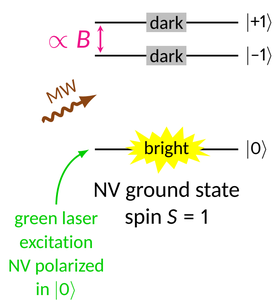
M. Ramazanoglu *et al. Phys. Rev. Lett.* 107 (2011), 207206

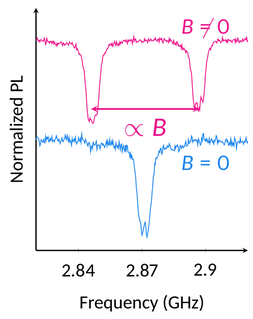
Scanning NV center magnetometry



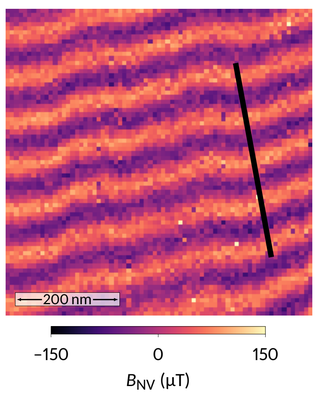
Nitrogen-Vacancy defect in diamond

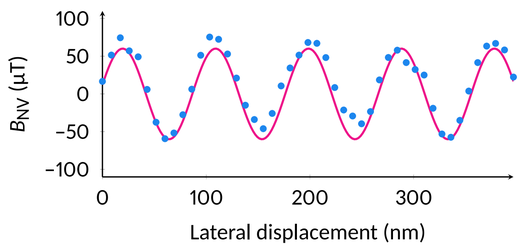






Quantitative analysis of the cycloid

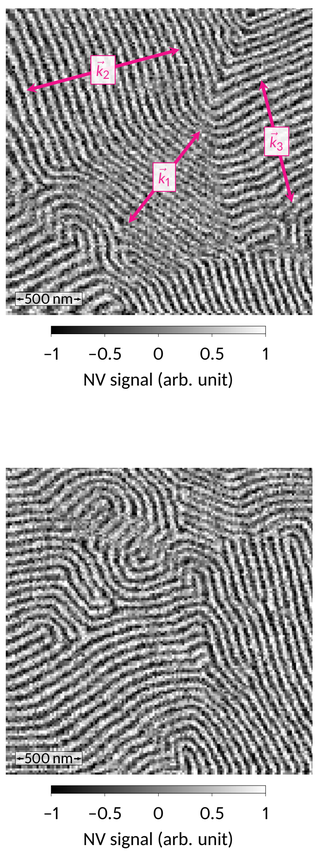


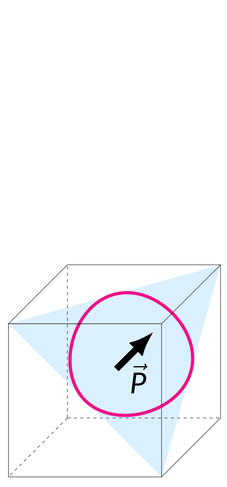


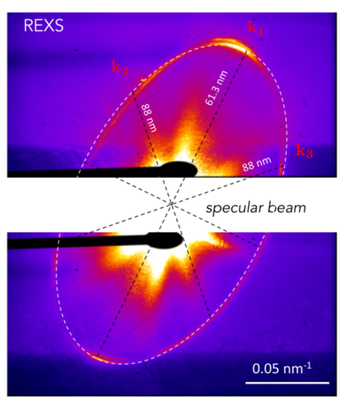
$$\begin{cases} B_x = 0 \\ B_y = -\dfrac{\mathcal{A}}{\sqrt{2}}\,(\mathrm{Re}\{\mathcal{S}\} - \mathrm{Im}\{\mathcal{S}\}) \\ B_z = \sqrt{2}\,\mathcal{A}\,\mathrm{Re}\{\mathcal{S}\} \end{cases} \quad \text{with} \quad \begin{cases} A = \dfrac{\mu_0 m_{DM}}{\sqrt{3}\,a^3}\sinh\left(\dfrac{ka}{2\sqrt{2}}\right) \\ S = e^{-kz/\sqrt{2}}e^{ik(y-z)/\sqrt{2}}\,\dfrac{1-e^{-kt(1+i)/\sqrt{2}}}{1-e^{-ka(1+i)/\sqrt{2}}} \end{cases}$$

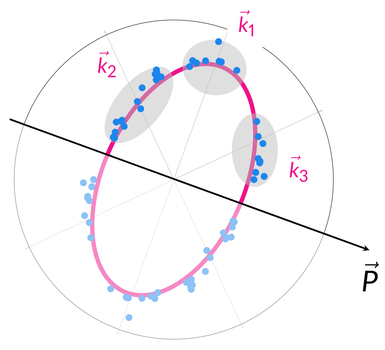
$m_{DM} = 0.09 \pm 0.03\ \mu_B$

Rotation of the cycloid wavevector in bulk crystals







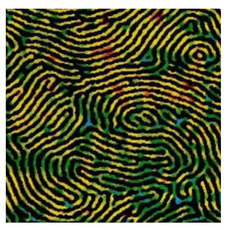


Surface effect? Only $\vec{k}_1$ seen by neutrons

D. Lebeugle *et al. Phys. Rev. Lett.* 100 (2008), 227602

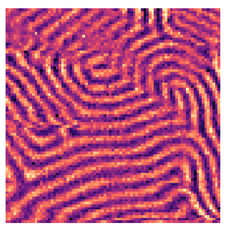
Topological defects in lamellar systems

Block copolymer
Period 40 nm



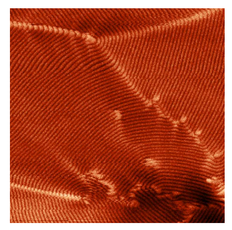
T. A. Witten. *Phys. Today* 43 (1990), 21

$BiFeO_3$ magnetic cycloid
Period 64 nm



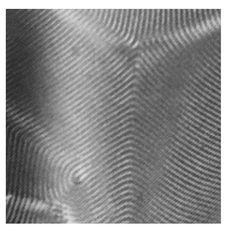
A. Finco *et al. Phys. Rev. Lett.* 128 (2022), 187201

FeGe magnetic helix
Period 70 nm



P. Schönherr *et al. Nat. Phys.* 14 (2018), 465

Liquid crystals
Period 800 nm



Y. Bouligand. *Dislocations in solids* (1983)

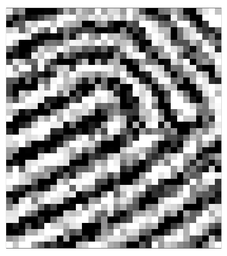
Ferrimagnetic garnet
Period 8 μm

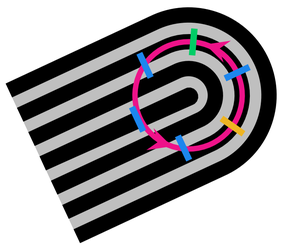
M. Seul *et al. Phys. Rev. A* 46 (1992), 7519

Fluid diffusion
Period 250 μm

Q. Ouyang *et al. Chaos* 1 (1991), 411

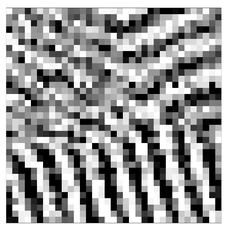
Identification of topological defects in bulk $BiFeO_3$

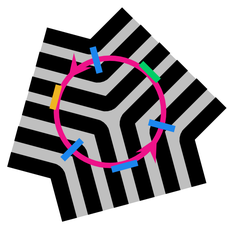




+π-disclination

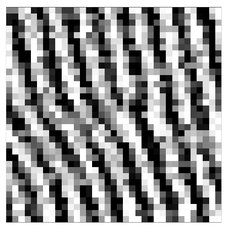
winding number +½

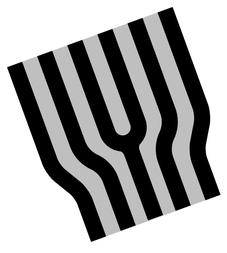




−π-disclination

winding number −½





Edge dislocation

Combination of +π- and −π-disclinations

winding number 0

Topological description of defects

General ordered medium	Lamellar system
Order parameter	Wavevector $\vec{k}$ of the periodic modulation
non-uniform, smoothly varying in space	with a rotating direction

except at singular regions of lower dimensionality → **topological defects**

N. D. Mermin. *Rev. Mod. Phys.* 51 (1979), 591

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