TECHNISCHE UNIVERSITÄT DRESDEN

SFB 1143

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Spin-spiral structure in $ZnCr_2Se_4$ across the whole field-temperature phase diagram

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Material properties

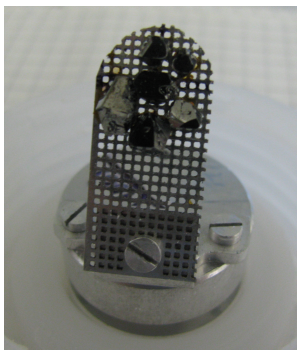


Fig. 1. Co-aligned single crystal mosaic of $ZnCr_2Se_4$.

- Magnetically frustrated spinel.
- Magnetic Cr^{3+} ions.
- Incommensurate spin spiral order.
- Curie temperature: $T_C = 21\,\mathrm{K}$.
- Propagation vector: $k_h = 0.28\,\text{Å}^{-1}$.
- Helical pitch: $\lambda_h = 22.4\,\text{Å}$.

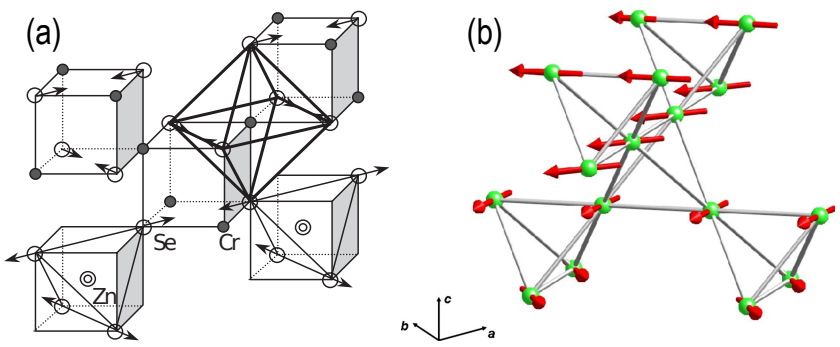
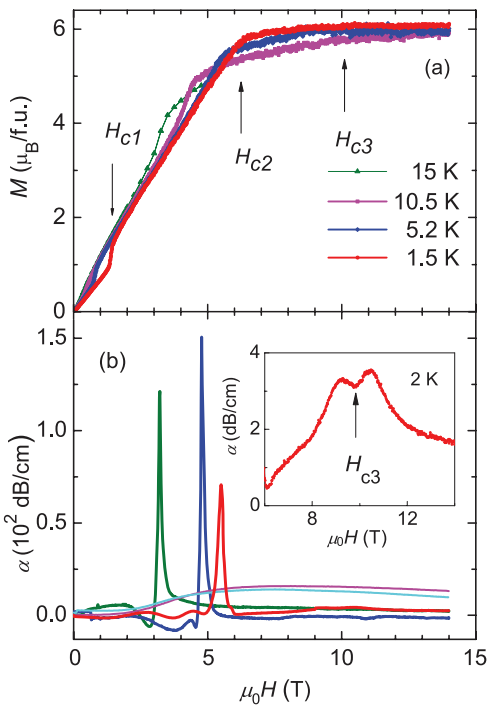


Fig. 2. (a) Spinel structure of $ZnCr_2Se_4$ [1]. Arrows indicate displacements of Se^{2-} ions in the orthorhombic phase below about 21 K (T_C). (b) Schematic representation of the magnetic structure of $ZnCr_2Se_4$ (only the Cr atoms displayed) [4].

Motivation



Sound velocity and magnetization measurements (Fig. 3) indicate the presence of a high-field phase between 6 and 10 T (green color in Fig. 8). It has been attributed to a "spin-nematic" phase [3], yet its true microscopic nature has not been understood. This motivated us to perform SANS measurements to check if long-range magnetic order is present in this phase.

Fig. 3. (a) Relative change of the attenuation α vs magnetic field at different temperatures in $ZnCr_2Se_4$. (b) Magnetization curves at different temperatures for $ZnCr_2Se_4$ measured along the ⟨001⟩ axis [3].

[1] M. Hidaka *et al.*, phys. stat. sol. (b) **236**, 9 (2003).
[2] A. Cameron, PhD thesis, University of Birmingham (2013).
[3] V. Felea *et al.*, Phys. Rev. B **86**, 104420 (2012).
[4] F. Yokaichiya *et al.*, Phys. Rev. B **79**, 064423 (2009).

Experiment

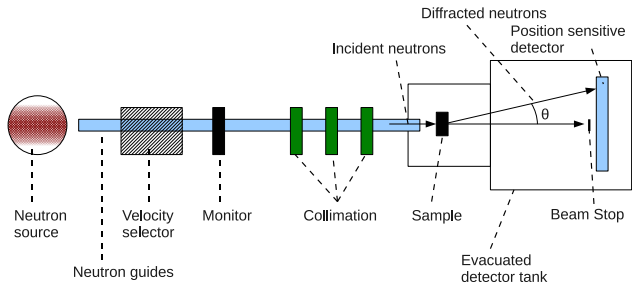


Fig. 4. Schematic of a SANS instrument [2].

Small angle neutron scattering (SANS) at the SANS-I diffractometer, PSI, Switzerland.

Sample mass: ∼ 1 g, mounted on an Al plate.

11 T cryomagnet with 2 K base temperature.

Magnetic field parallel to either (001) or (110), perpendicular to the neutron beam.

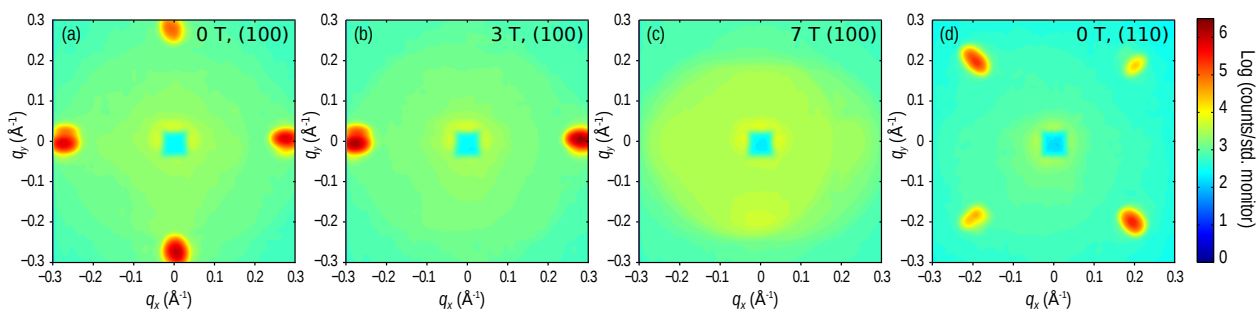


Fig. 5. Magnetic-field dependence of the low-temperature magnetic neutron diffraction patterns in $ZnCr_2Se_4$. Typical neutron diffraction patterns are shown from each of the distinct phases and orientations observed during the experiment. The data demonstrate two phase transitions across B_{C1} and B_{C2} which are shown on phase diagram (Fig. 8).

Data analysis

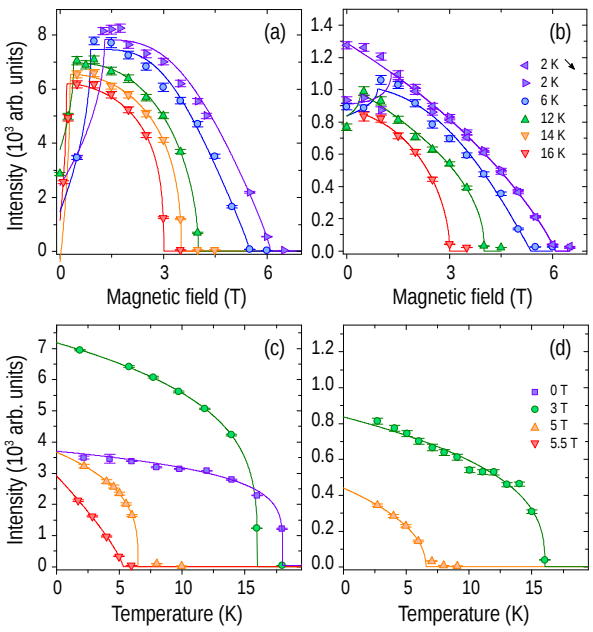


Fig. 6. Magnetic-field and temperature dependence of the magnetic Bragg intensity in $ZnCr_2Se_4$, obtained by fitting the neutron-diffraction data.

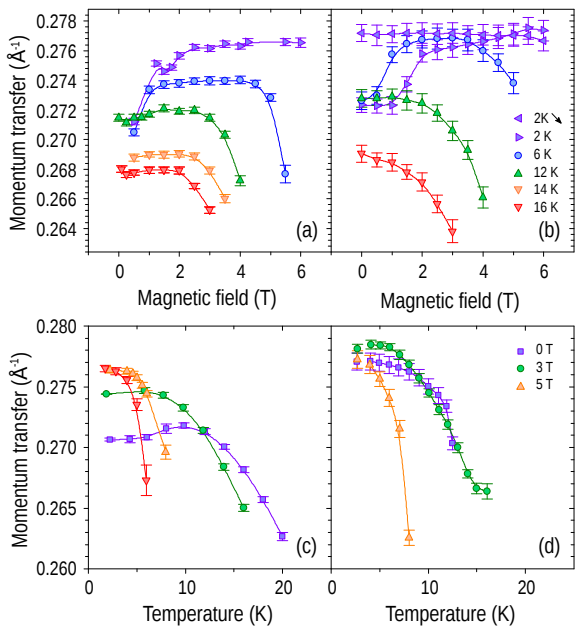


Fig. 7. Magnetic-field and temperature dependence of the magnetic propagation vector in $ZnCr_2Se_4$, obtained by fitting the neutron-diffraction data.

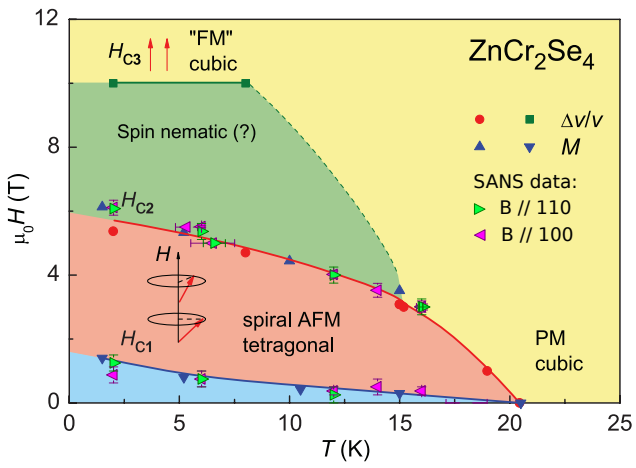


Fig. 8. Phase diagram of $ZnCr_2Se_4$ from a combination of ultrasound and magnetization measurements, reproduced from Ref. [3], onto which we have superimposed transition points from our SANS data.

Conclusions

- Magnetic Bragg peaks corresponding to long-range helical order are found below H_{C2}.
- The field H_{C1} corresponds to domain selection between different directions of the spin spiral.
- No anisotropy of H_{C1} or H_{C2} was observed for the two measured field directions.
- No incommensurate magnetic peaks were seen in the high-field ("spin-nematic") phase.
- We observed a weak dependence of the propagation vector (helical pitch) on magnetic field and temperature that does not exceed 5%.