Experimental report

03/06/2025

Proposal: 5-41-1234 **Council:** 4/2023

Title: Multiferroic properties of the vortex-antivortex phase of DMI-magnet Ba2CuGe2O7

Research area: Physics

This proposal is a new proposal

Main proposer: Peter werner WILD

Experimental team: Peter werner WILD
Korbinian FELLNER

Local contacts: Eric RESSOUCHE

Samples: Ba2CuGe2O7

Instrument	Requested days	Allocated days	From	To
D23	4	3	04/09/2023	07/09/2023

Abstract:

Ba2CuGe2O7 is an insulator, characterised by a quasi-2D structure with Dzyaloshinskii¿Moriya-interactions (DMI). At low temperature, it shows a wealth of non-trivial spin structures. Besides a cycloidal and an AF cone phase, an AF square and rectangular vortex phase is stabilized in a pocket around 2.2T for fields along the tetragonal c-axis. Recent measurements indicate a finite linewidth in Q and E of the incommensurate peaks in that phase. To investigate the multiferroic properties of Ba2CuGe2O7 in the vortex phase, we want to apply an electric field along the 1,1,0 direction. Theory describes a distortion from the square vortex phase to the rectangular phase. Moreover, an E-field aligned along the c-axis of the crystal should lead to population changes in the degenerate domains with propagation vector along k = (±1, 1, 0) in the cycloidal phase.

Multiferroic properties of the vortex-antivortex phase of DMI-magnet $Ba_2CuGe_2O_7$

P. Wild[1], K. Fellner[1], M. Dembski-Villalta[1], M. Garst[2], S. Mühlbauer[1]
[1]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München
[2]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie (KIT)

$Ba_2CuGe_2O_7$ *is a quasi-2D insulator with a proposed AF vortex-antivortex phase in a small pocket of the phase diagram. Following previous neutron scattering experiments, this experiment aimed for a more detailed view on the multiferroic character of the phase.*

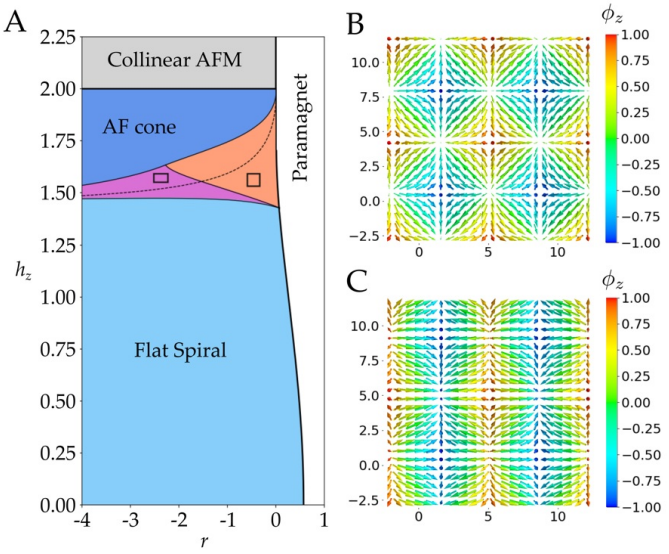

Figure 1: (A) Theoretical phase diagram of $Ba_2CuGe_2O_7$ for magnetic field along the c-axis. (B,C) Proposed spin structure of the square and rectangular AF vortex phase. [1]

A material that is interesting in regards of unconventional magnetic phase transitions and multiferroicity is $Ba_2CuGe_2O_7$, featuring a quasi-2D structure with Dzyaloshinskii–Moriya interactions (DMI). $Ba_2CuGe_2O_7$ is an insulator characterized by a tetragonal, non-centrosymmetric space group ($P\bar{4}2_1m$) with lattice parameters $a = 8.466\,\text{Å}$ and $c = 5.445\,\text{Å}$. The main features of the magnetic structure are due to the Cu^{2+} ions in a square arrangement in the tetragonal (a,b) plane with dominant nearest-neighbor AF exchange along the diagonal in the (a,b) plane and much weaker FM exchange between planes, leading to a quasi-2D behaviour. The phase diagram of $Ba_2CuGe_2O_7$ has been theoretically described in great detail [2]. Recently it has been updated [1] using a model additionally accounting for the anisotropy and bond alternating DMI component Dz, which causes weak ferromagnetism (FM) and in result, a tilting of the AF cycloid plane. The model allows for two new phases, positioned between the soliton lattice and the AF cone phase: an AF square and rectangular vortex phase is stabilized in a pocket around 2.2 T for fields along the tetragonal c-axis. Fig. 1 shows the proposed phase diagram with the spin arrangement of the square and rectangular vortex phase. Theory describes a significant impact of any in-plane magnetic and electric field components on the structure of the vortex phase.

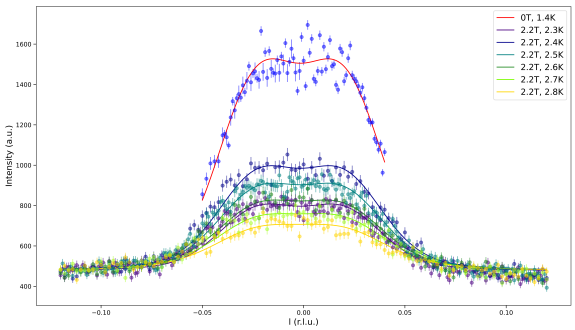

Figure 2: Scans over l of the magnetic satellites in the proposed vortex-antivortex phase for different temperatures.

In the experiment at D23, the aspect of main interest was the evolution of the satellite peaks when applying an electrical field across the sample. Unfortunately, no stable electrical field could be applied, so we investigated the correlations in the l-directions instead. Figure 2 shows typical scans made along l for different temperatures in the vortex phase. These seem to mark the quasi-2D n ature of the material as reason for the fluctuating behaviour of the vortex texture.

[1] B. Wolba. PhD thesis, KIT, 2021.
[2] J. Chovan et al. *Phys. Rev. B*, 65:064433, 3 2002.

Work performed at D23 (ILL), Proposal 5-41-1234 & CRG-3128