Experimental report

22/11/2016

Proposal: 5-51-508 **Council:** 4/2015

Title: Spin susceptibility in the possibly topological superconductor CuxBi2Se3

Research area: Physics

This proposal is a new proposal

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Samples: CuxBi2Se3

Instrument	Requested days	Allocated days	From	To
D3 High field >1T	10	8	23/11/2015	01/12/2015

Abstract:

CuxBi2Se3 is possibly a topological superconductor with spin-triplet pairing. If that is the case the electronic spin susceptibility should be anisotropic. Here we propose to study the electronic spin susceptibility in CuxBi2Se3 as function of temperature in high magnetic fields applied along different in-plane directions.

Spin susceptibility in the possibly topological superconductor $Cu_xBi_2Se_3$

The concept of topological insulators [1] can be extended to so-called topological superconductors which are fully gapped in the bulk and exhibit gapless surface Andreev bound states [3]. Fu and Berg [3] develop a sufficient criterion for a topological superconductor based on the symmetry, and propose that $Cu_xBi_2Se_3$ is an odd-parity topological superconductor, in which the conducting electrons exhibit triplet pairing. $Cu_xBi_2Se_3$ is a strongly two-dimensional material consisting of double layers of $BiSe_3$-octahedrons, which are weakly coupled through van der Waals interaction and which are intercalated by Cu, see figure 1a. However, the material is very fragile and must be handled with great care. The crystal used in our experiment was provided by the group of Prof. Ando.

The natural prove of triplet pairing is the study of the magnetic moment of the Cooper pairs. However, due to the superconducting screening of magnetic fields, the magnetic moment of the electron pairs cannot be measured by macroscopic magnetometer measurement. Therefore, microscopic measurements are needed to provide the experimental evidence of the triplet pairing. So far, Knight shift NMR-measurements exist, which show strong anisotropy in the in-plane directions with respect to the layered structure [6]. For several directions the Knight shift stays constant upon entering the superconducting state, which is taken as direct evidence for triplet pairing, because singlet pairing induces a full suppression of magnetic moment along all directions.

We studied the magnetic moments of the conducting electrons via polarized neutron diffraction using a single crystal of $5.5\,\mathrm{mm}^3$ volume. After a first search on a large set of Bragg reflections, significant flipping ratios could be detected at low temperature and large magnetic field for a few (hkl) values. Figure 1b shows the temperature and field dependent magnetic scattering length of the (1 0 10) and equivalent reflections, calculated via $F_\mathrm{M} = (R-1)\cdot F_\mathrm{N}/(2\cdot(P_+ + P_-))$ [2], wherein R is the flipping ratio, F_N the nuclear structure factor of Bi_2Se_3, and $P_+ = P_- = 94\%$ the efficiency of the neutron polarization. At 8T and 50mK the magnetization can be determined with a satisfactory precision. Upon entering the superconducting state by lowering the magnetic field at T=50mK we find a linear dependence and no effect of the superconducting phase, which can be interpreted as evidence for persisting moments and thus triplet pairing. However, we find a sofar unexplainable temperature dependence of the magnetic signal. Upon heating at constant field of 8T the magnetic signal is already lost at 500mK. The origin of this low-temperature moment remains therefore elusive. At 2.5T no statistically significant data could be obtained within reasonable measuring time.

One might argue, that the low temperature signal arises from polarized nuclear magnetic moments. However, the nuclear magnetic scattering, calculated with the temperature and field dependent Brillouin function for 8 T and 50 mK [5], is far below the experimental value. We must conclude that some sizeable moment appears in $Cu_xBi_2Se_3$ only at low temperature, which is supported by recent specific heat experiments finding a significant low-temperature contribution below 500mK (L. Anderssen, private communication).

While the magnetic field dependence of the determined magnetic moment at 50 mK agrees with a triplet pairing, further measurements are needed in order to clarify the origin of the signal and to characterize its interplay with superconductivity in $Cu_xBi_2Se_3$.

References

[1] Y. Ando. Topological insulator materials. *Journal of the Physical Society of Japan*, **82**:102001, 2016.

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[3] L. Fu and E. Berg. Odd-parity topological superconductors: Theory and application to $Cu_xBi_2Se_3$. *Physical Review Letters*, **105**:097001, 2010.

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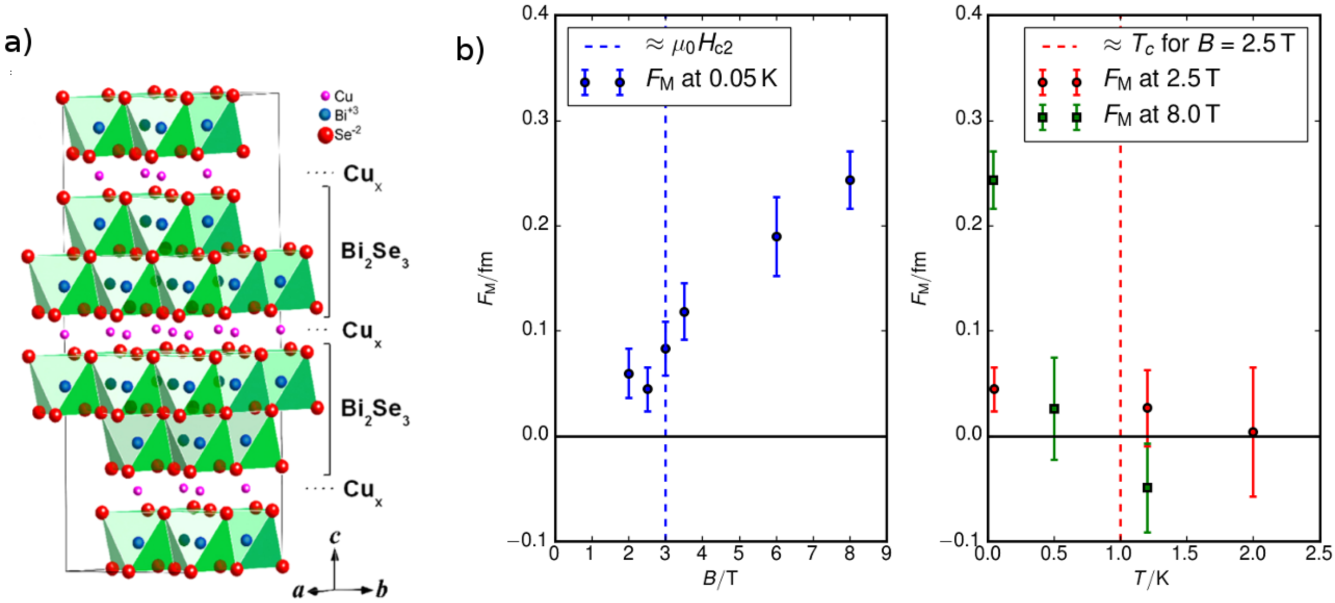

Figure 1: **a)** Layerd structure of $Cu_xBi_2Se_3$. The Cu is supposed to be intercalated [4]. **b)** The magnetic structure factor obtained at (1 0 10) at different temperatures and magnetic fields. The dotted lines show the second critical field and the critical temperature in the left and right panel, respectively. The magnetic component causing the finite flipping ratios cannot be explained through nuclear magnetic moments.