SUPPLEMENTAL MATERIAL

Muon spin rotation study of the topological superconductor $Sr_xBi_2Se_3$

H. Leng[1], D. Cherian[1], Y. K. Huang[1], J.-C. Orain[2], A. Amato[2] and A. de Visser[1]

[1]*Van der Waals - Zeeman Institute, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands*
[2]*Laboratory for Muon-Spin Spectroscopy, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland*

Frequency shift in the superconducting state

Fitting the asymmetry spectra to the one- or two-component muon depolarization functions (manuscript eqs. 1 and 4) as presented in section III of the manuscript is a standard and frequently used method to determine the damping due to the vortex lattice and the superconducting volume fraction. Another way is to directly compare the frequencies in the normal and superconducting state and the corresponding amplitudes of the Fast Fourier Transform (FFT). However, since the frequency shifts are small (< 1.1 %) and the FFTs of the asymmetry spectra relatively broad we cannot resolve the frequencies for the superconducting and normal phase. Nonetheless, a clear frequency shift is detected as reported in figure S1. Here we have fitted the asymmetry spectra $A(t)$ to the one-component depolarization function (eq.1)

$$A(t) = A_{tot} \exp(-\frac{1}{2}\sigma_{TF}^2 t^2)\cos(2\pi\nu t + \phi) \quad ,$$

where A_{tot} is the experimental asymmetry, σ_{TF} is the Gaussian damping rate, $\nu = \gamma_\mu B_\mu/2\pi$ is the muon precession frequency, B_μ is the average field sensed by the muon ensemble and ϕ is a phase factor. For the ordered vortex lattice (x = 0.15; FC 10 mT; $B \parallel a$) we observe a small diamagnetic shift of the order of -0.3 % (panel a). For the disorder vortex lattice the total shift amounts to -0.6 % (x = 0.18; FC 10 mT; TF = 14.5 mT; $B \parallel a$; panel b) and 1.1 % (x = 0.18, FC 0.4 T; TF = 10 mT, $B \parallel c$, panel c). Note the sign of the shift relates to the field history: negative for FC 10 mT (panel a) and for FC 10 mT $\rightarrow$ 0 T $\rightarrow$ 14.5 mT (panel b), and positive for FC 0.4 T $\rightarrow$ 10 mT (panel c). The latter shift is positive, because the field is reduced from a large positive value and thus the data are taken in the positive quadrant of the $M(H)$ hysteresis loop.

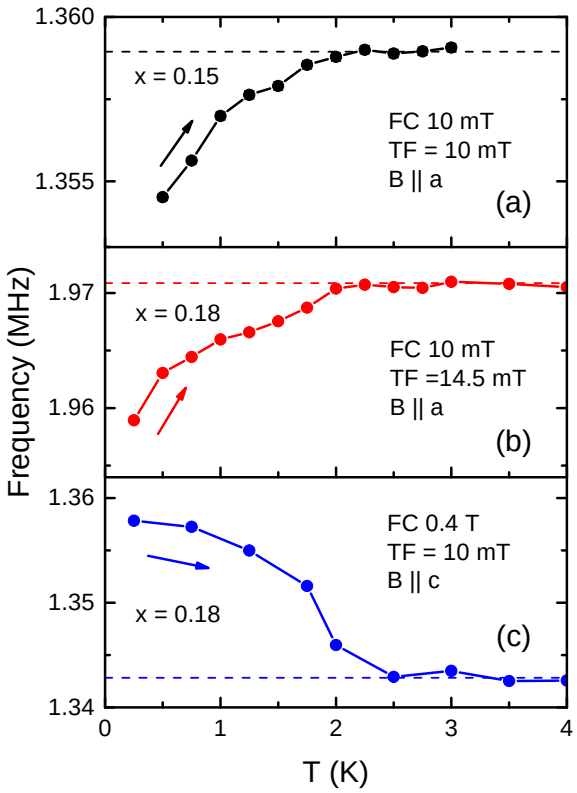

Fig. S1 Observed frequency shifts in the superconducting phase of the asymmetry signal of $Sr_xBi_2Se_3$ crystals obtained by fitting the spectra to a one-component muon depolarization (see above). The arrows indicate the data are taken with increasing temperature.