Understanding the Field-Induced Superconducting Phases of FeSe

Schoenemann R. (Maglab); Zheng, W. (Maglab and FSU, Physics); Chiu, Y.-C. (Maglab and FSU, Physics); Chen, K.W. (Maglab and FSU, Physics); Chen, T. (Rice U. Physics); Dai, P.C. (Rice U. Physics) Balicas. L. (Maglab and FSU, Physics).

Introduction

FeSe is a unique member of the family of iron-based superconductors, not only because of the high values of Tc in FeSe monolayer, but also because in bulk FeSe superconductivity emerges inside a nematic phase without competing with long-range magnetic order. Near T_c, the superconducting order necessarily has $s + d$ symmetry, because nematic order would couple linearly the *s*-wave and *d*-wave harmonics of the superconducting order parameter [1].

Experimental

We measured torque magnetometry via the use of micro-piezolevers down to ^{3}He temperatures in SCM2.

Results and Discussion

Figure 1 displays the magnetic torque t as a function of the magnetic field $\mu_0 H$ for a FeSe single crystal, for fields slightly tilted with respect to the *c*-axis and for two temperatures. We observe sharp changes in slope within the irreversible region, which are more noticeable in the derivative of the torque, and which are difficult to reconcile with conventional vortex pinning mechanisms. These might correspond to the additional superconducting phases reported by Ref. [2] although their temperature dependence is quite distinct.

Conclusions

Although we do detect anomalies in the torque, these do not follow the phase diagram reported in Ref. [2]. In addition, we detect again an anomalous reversal in the sign of the irreversibity which in the past was interpreted by us as evidence for time-reversal symmetry breaking within the superconducting state [4], and might support the predictions of Ref. [1]. More needs to be done to map this phase diagram as a function of angle and temperature, and in particular, to correlate it with geometry of the Fermi surface as it is affected by the application of an external field.

Acknowledgements

The National High Magnetic Field Laboratory is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida. L.B. acknowledges support from DOE-BES through award DE-SC0002613.

References

[1] J. Kang *et al*., Phys. Rev. B **98**, 064508 (2018).
[2] S. Kasahara *et al.*, PNAS **111**, 16309 (2014).
[3] K. W. Song *et al*., Phys. Rev. B **97**, 224520 (2018).
[4] G. Li *et al*., Phys. Rev. B **88**, 134517 (2013); ibid **87**, 024512 (2013).

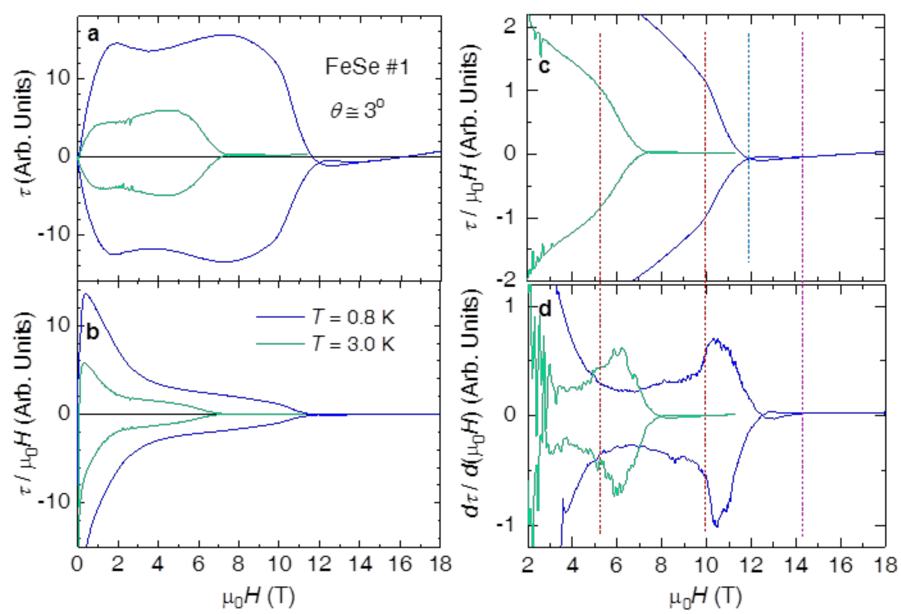

Fig. 1 **a**, Magnetic torque τ for a FeSe single-crystal as a function of the magnetic field applied nearly along its c-axis, and for two temperatures. **b**, τ normalized by the magnetic field. **c**, same as in but in a limited field range. Red vertical lines indicate changes in slope of τ, blue line a change in the sign of the irreversibility, and magenta line the irreversibility field. **d**, Derivative of the torque normalized by the field, exposing the anomalies