Evolution of the Fermi Surface of the Nematic Superconductors FeSe$_{1-x}$S$_x$

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Introduction

Nematic electronic order is believed to play an important role in understanding superconductivity in iron-based and copper oxide superconductors. FeSe is an ideal system to study this interplay as the nematic phase below 87K is manifested via a strong distortion of the Fermi surface, which has been linked to the lifting of the orbital degeneracy of the Fe $d_{xz}/d_{yz}$ bands and the development of $d_{xy}$ orbital anisotropy [1,3]. Another peculiarity of FeSe is the strong disparity in band renormalization between the degenerate $d_{xz}/d_{yz}$ bands compared with a much stronger effect for the $d_{xy}$ band, as determined from angle resolved photoemission spectroscopy (ARPES) at high temperatures [1]. Chemical pressure may mimic the behaviour of applied hydrostatic pressure by bringing the FeSe layers closer together, potentially increasing the bandwidth and suppressing the electronic correlations. Thus, isoelectronic substitution in superconducting FeSe$_{1-x}$S$_x$ is an alternative tuning parameter which may provide new insight into the interplay of the nematic order found in the parent compound, and the induced magnetic order and enhanced superconductivity found under physical pressure.

Experimental

We have performed magneto-transport measurements on different crystals of FeSe$_{1-x}$S$_x$ as a function of temperature down to 0.4K and different orientations in magnetic field up to 45T, as shown in Fig.1.

Summary of our results

We have investigated the evolution of the complex Fermi surfaces and electronic interactions across the nematic phase transition in single crystals of FeSe$_{1-x}$S$_x$ using Shubnikov-de Haas oscillations in high magnetic fields up to 45T in the low temperature regime. The unusually small and strongly elongated Fermi surface of FeSe [1,4,5] increases monotonically with chemical pressure, $x$, due to the suppression of the in-plane anisotropy except for the smallest orbit which suffers a Lifshitz-like transition once nematicity disappears, as shown in Fig.1d [6]. Even outside the nematic phase the Fermi surface continues to increase, in stark contrast to the reconstructed Fermi surface detected in FeSe under applied external pressure [2]. We detect signatures of orbital-dependent quasiparticle mass renomalization suppressed for those orbits with dominant $d_{xz}/d_{yz}$ character, but unusually enhanced for those orbits with dominant $d_{xy}$ character [6]. The lack of enhanced superconductivity outside the nematic phase in FeSe$_{1-x}$S$_x$ suggests that nematicity may not play the essential role in enhancing Tc in these systems.

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References


Fig. 1 Quantum oscillations in superconducting single crystals of FeSe$_{1-x}$S$_x$. a, The in-plane resistance $R_{xx}(B)$ as a function of magnetic field $B$ for different compositions, $x$. b, The oscillatory part of the resistivity obtained by removing a polynomial background from the raw data in a) at the lowest measured temperature. c, Phase diagram and d, the evolution of the Fermi surface across the nematic phase of FeSe$_{1-x}$S$_x$. 