Experimental report

22/11/2015

Proposal: **4-01-1335** **Council:** 4/2014

Title: Magnetic resonance mode in superconducting FeSe single crystals

Research area: Physics

This proposal is a new proposal

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Samples: FeSe

Instrument	Requested days	Allocated days	From	To
IN12	7	0		
IN20	0	7	15/12/2014	21/12/2014

Abstract:

Measurements of the resonance peak can provide important information on the pairing state of an unconventional superconductor. The iron selenide FeSe superconductor (Tc=9 K), being simplest with respect to its crystal structure, is the most unusual compound among the large family of iron based high temperature superconductors. In single layer FeSe thin films grown on SrTiO3 (STO) substrate by molecular beam epitaxy (MBE), both Scanning Tunnelling Spectroscopy (STS) and angle-resolved photoemission spectroscopy (ARPES) experiments have shown that the band structure and the magnitude of the superconducting gap are very different from those of FeAs based superconductors. Because there is no hole pockets near the zone center, the naive Fermi surface nesting scenario seems not applicable here. In order to shed more light on the pairing state of FeSe superconductor and its related compounds, we propose to study spin fluctuation and its relationship with superconductivity in single crystalline FeSe.

Experimental Report of Proposal 4-01-1335

Magnetic resonance mode in superconducting FeSe single crystals

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The distinctive features of FeSe has attracted great research interests. While the parent compounds of iron-pnictides exhibit stripe antiferromagnetic order which is pre-empted by a nematic order, FeSe displays a nematic phase transition at T_s= 90 K but does not show an antiferromagnetic order therefore casting doubt on the spin-fluctuation-driven superconductivity and nematicity scenario [1].

The FeSe single crystalline sample were aligned in the (H, K, 0) scattering plane within ~ 3 degrees mosaicity for the measurements. We define the wave vector Q at (q_x, q_y, q_z) as (h, k, l) = ($q_x a/2\pi$, $q_y b/2\ \pi$, $q_z c/2\ \pi$) reciprocal lattice units (r.l.u.) in the orthorhombic unit cell. A focusing Si(111) was used as monochromator and a pyrolytic graphite [(PG)(002)] was used as the analyzer.

We first did Q-scans at 4 meV below and above T_c to study the momentum for the spin fluctuations in FeSe. Strong spin fluctuations were observed around Q = (1, 0, 0) which is associated with the stripe antiferromagnetism (Fig. 1). The peak intensity is drastically enhanced when entering the superconducting state which is reminiscent of a spin resonant mode observed in other iron-based superconductors.

Figure 2 shows the energy dependence of the spin fluctuations at different temperatures. A sharp resonant mode is observed at ~ 4meV in the superconducting state suggesting a spin-fluctuation-driven s+-wave paring mechanism in FeSe. Previous NMR results suggested the absence of spin fluctuations above T_s in FeSe [2, 3]. However, our INS results reveal that there are substantial spin fluctuations above T_s (Fig. 2). To investigate the impact of nematicity on the spin fluctuations, we measured the temperature dependence of the spin fluctuation at 2.5 meV. The result shows that the scattering is drastically enhanced when entering the nematic phase and is clearly coupled to the development of the nematic phase (Fig. 3). Therefore our data suggest that the nematic phase in FeSe is driven by spin fluctuations.

In summary, we have observed substantial stripe spin fluctuations in FeSe in both the nematic and tetragonal phase. The strong coupling between the stripe spin fluctuations, nematicity and superconductivity in FeSe indicates that both the superconductivity and nematicity have a spin-fluctuation origin.

Reference

[1] T. M. McQueen et al., Phys. Rev. Lett. 103, 057002 (2014)

[2] A. E. Bohmer et al., Phys. Rev. Lett. 114, 027001 (2011)

[3] S.-H. Baek et al., Nature Mater. 14, 210-214 (2010)

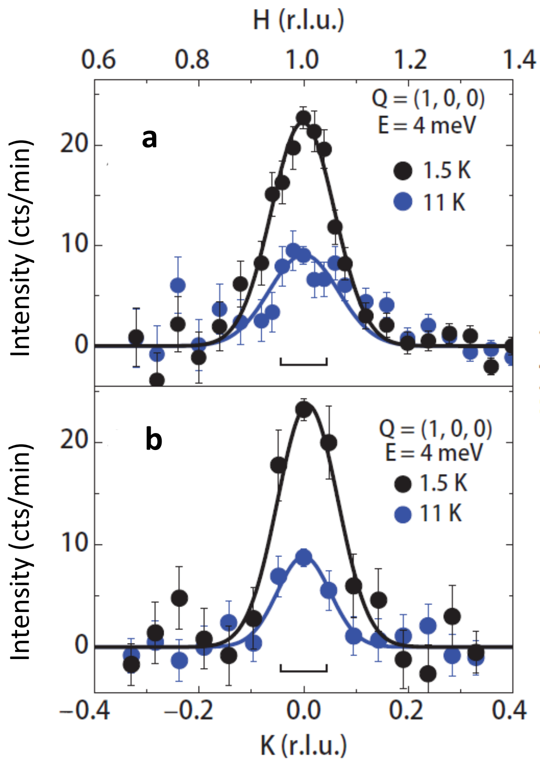

Figure 1. Spin fluctuations in FeSe at 4 meV below and above T_c. **a**. Longitudinal scan near (1, 0, 0) at 4 meV below and above T_c. **b**. Rocking scan near (1, 0, 0) at 4 meV below and above T_c.

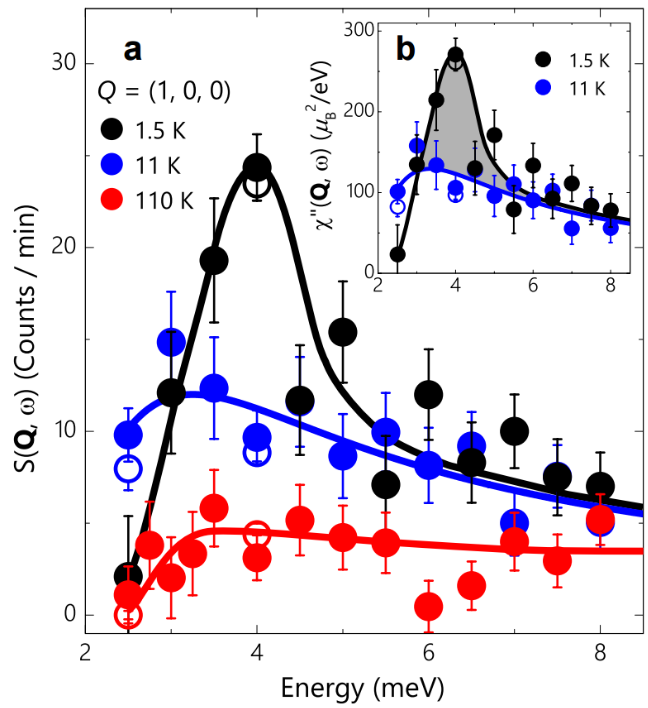

Figure 2. Energy dependence of stripe spin fluctuation in FeSe at different temperatures. The inset are the calculated dynamic susceptibilities normalized into absolute unit. The vertical error bars indicate one standard deviation. The solid lines are guides to the eye.

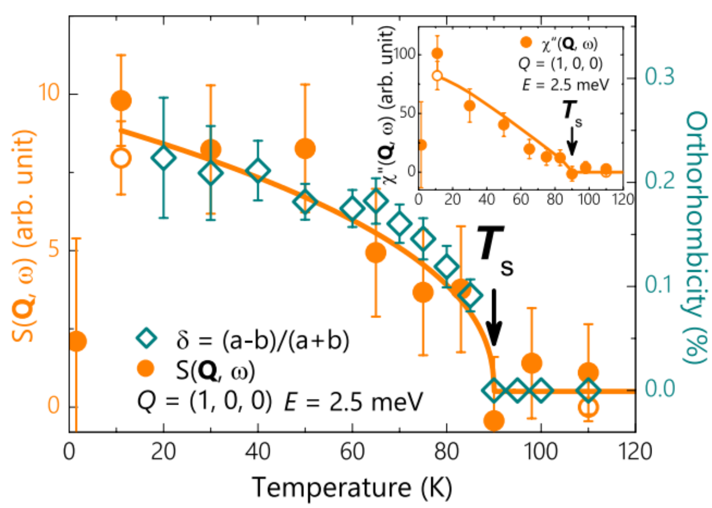

Figure 3. Temperature dependence of spin fluctuations in FeSe. The orthorhombicity is adapted from the X-ray diffraction data in ref. 1. The inset shows the temperature evolution of the dynamic susceptibility.