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Probing the superconducting gap structure and nematicity by angle-resolved specific heat

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Abstract:
The gap structures of some unconventional superconductors such high-T_c cuprates, iron based superconductors, and heavy-fermion materials contain nodes or gap minima, which are directly related to their pairing mechanism. On the other hand, the electronic nematic phases, which break the rotational symmetry, e.g. the 2-fold electronic system observed in the tetragonal FeSe, have been proposed in many unconventional superconductors. The relation between nematicity and superconductivity is a major unsolved problem in condensed matter physics. To study the gap structure and nematicity, a space-resolved technique is required. The angle-resolved specific heat (ARSH) measurement not only has the space-resolution, but also probes the quasi-partial in bulk, which is ideal for studying both the superconducting gap structure and the nematicity.

In this seminar, I will introduce the study of gap structure and nematicity by ARSH measurements based on three examples. The first one is the FeSe, which attracts much attention due to its intriguing properties including the unexpected high T_c (over 60 K) in the monolayer thin film, a nematic state without long-range magnetic order, and a crossover from BCS to BEC. Our ARSH study on the high-quality FeSe reveals a small gap with two vertical-line nodes or gap minima along the k_z–direction [1]. Such symmetry-unprotected nodes or gap minima are found to be smeared out by a small amount of disorder, and the gap becomes isotropic in the sample of lower quality. Our study reveals that the reported controversy on the gap structure of FeSe is due to the disorder-sensitive nodelike small gap [2]. The second example is the $Sr_xBi_2Se_3$, which is a topological superconductor with T_c ~ 3.2 K. By ARSH measurements, we report bulk quasi-particle evidence of nematicity in the topological superconductor $Sr_xBi_2Se_3$. The specific heat exhibits a clear 2-fold symmetry despite the 3-fold symmetric lattice. Most importantly, the 2-fold symmetry appears in the normal state above T_c. Such results highlight the interrelation between nematicity and unconventional superconductivity [3]. The last example is the $PbTaSe_2$, which is reported to be a topological nodal-line semimetal with T_c ~ 3.7 K. Our ARSH results combined with the angle-dependent measurements of resistivity and point-contact found out the nematic superconductivity on the topological surface state of $PbTaSe_2$ despite its isotropic bulk gap structure [4].

[1] Y. Sun *et al*., Phys. Rev. B **96**, 220505(R) (2017)
[2] Y. Sun *et al*., Phys. Rev. B **98**, 064505 (2018)
[3] Y. Sun *et al*., Phys. Rev. Lett. *in press* (arXiv:1902.08903)
[4] T. Le, Y. Sun *et al*., arXiv:1905.11177 (2019)

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