Non-saturating lower critical field of the multiband superconductor $PrOs_4Sb_{12}$ with broken time-reversal symmetry

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Topological superconductivity is a highly interesting unconventional state of matter that provides a natural platform for realizing Majorana edge modes being central to various proposals for quantum computation. Among various scenarios, chiral superconductivity is a long-sought topological state that spontaneously breaks time-reversal symmetry through the development of Cooper pairing with finite angular momentum. However, despite intensive theoretical studies and huge experimental efforts, no material has been proven definitively to be a chiral superconductor.

The heavy-fermion and multiband superconductor $PrOs_4Sb_{12}$, for which a μSR study and polar Kerr effect measurements showed evidence of broken time-reversal symmetry below the critical temperature $T_c \simeq 1.85$ K, is a leading candidate to display chiral superconductivity. Based on measurements of the temperature dependence of the lower critical field $H_{c1}(T)$, we have recently proposed a multiband and multisymmetric scenario, in which a superconducting condensate is composed of a sign-changing smaller gap and a large isotropic s-wave gap [1].

To develop a detailed understanding of multicomponent superconductivity in $PrOs_4Sb_{12}$, we have extended measurements of $H_{c1}(T)$ down to temperatures as low as 7 mK utilizing a 2DEG Hall magnetometry. We observe a sudden increase in $H_{c1}(T)$ deep in a superconducting state, indicative of a rare case of two nearly decoupled bands. Furthermore, a non-saturating and concave behavior of $H_{c1}(T)$ below about 0.45 K, clearly points at a sing-changing symmetry of the smaller gap. Equally remarkable is a high sensitivity of this characteristic to electron irradiation. Even small concentration of artificial atomic defects is a tuning parameter changing unusual superconducting properties of $PrOs_4Sb_{12}$. We observe the saturated dependence of $H_{c1}(T)$ and a strong suppression of its enhancement. This is in contrast to the two-band isotropic s-wave homologue $LaRu_4As_{12}$ which shows that atomic defects in this case change both gaps similarly. The above-mentioned observations indicate that impurities apparently destroy a sign-changing order parameter in $PrOs_4Sb_{12}$, which superconductivity will be discussed in the context of a putative chiral spin-triplet pairing state.

References:

[1] J. Juraszek *et al.*, Phys. Rev. Lett. **124**, 027001 (2020).