UNUSUALLY HIGH UPPER CRITICAL FIELD IN THE SUPERCONDUCTING KOs_2O_6 PYROCHLORE: A CONSEQUENCE OF BROKEN INVERSION SYMMETRY

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Introduction

Superconductivity in β-pyrochlore oxides with relatively high transition temperatures T_c and distinctly odd behaviors in the normal state, suggests new physics, perhaps explicitly connected to this structure. The coexistence of strong electron correlations that prefer an anisotropic order parameter and strong electron-phonon coupling that favors a fully gapped *s*-wave ground state may render the workings of superconducting pairing in KOs_2O_6 rather uncommon. Experimentally, the situation seems contradictory: μSR measurements suggest anisotropic gap functions with nodes, in sharp contrast to the nodeless gap in a sister compound $RbOs_2O_6$, while low-temperature thermal conductivity is consistent with a fully gapped state. Indeed, there has been much speculation about possible (unconventional) modes of pair-breaking in KOs_2O_6 at low temperatures. Here we show [1,2] that in this pyrochlore system, missing spatial inversion symmetry can uniquely control the pair-breaking process, leading to unconventional behavior of the upper critical field without an unconventional pairing mechanism found in some heavy fermion systems (e.g. $CePt_3Si$) that also lack inversion symmetry.

Experimental

We have mapped the entire temperature dependence of the upper critical field H_{c2} in the highest T_c (= 9.6 K) pyrochlore KOs_2O_6 from resistivity and magnetic measurements in high (up to 50 T) magnetic fields, see data in Fig. 1. By both techniques we find H_{c2} (T = 0 K) not only uncommonly high, but also the approach to it unconventionally temperature-linear all the way below T_c.

Results and Discussion

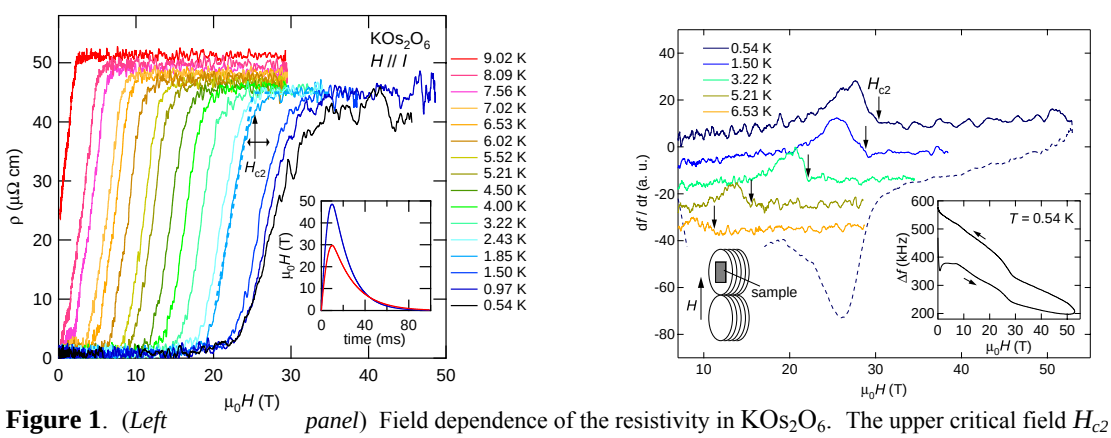

Figure 1. (*Left panel*) Field dependence of the resistivity in KOs_2O_6. The upper critical field H_{c2} is determined in the usual way from the field at which ρ(H) is fully restored to its normal-state value. Inset: Typical field-pulse profiles used. (*Right panel*) Time derivative of the frequency shift of the tunnel diode oscillator containing the KOs_2O_6 sample. The high-field end point of the peak in df/dt corresponds to the field where the whole sample becomes normal, and hence it is the value of the upper critical field. The full up- (dashed line) and down-field cycle is shown for T = 0.54 K, for which the frequency shift Δf vs. field is also displayed in the inset.

Conclusions

We conclude that depairing at the upper limiting field is enforced by the orbital degrees of freedom, without interferences from the Pauli limit hugely enhanced by the broken spatial symmetry, and that the superconducting pairing mainly occurs on the closed Fermi surfaces. Our finding of orbitally limited H_{c2} is compatible with the fully gapped superconductivity.

References

[1] Shibauchi, T., Krusin-Elbaum, L., Kasahara, Y., Shimono, Y., Matsuda, Y., McDonald, R.D., Mielke, C.H., Yonezawa, S., Hiroi, Z., Arai, M., Kita, T., Blatter, G, and Sigrist, M., Phys. Rev. B. **74**, 220506(**Rapids**) (2006).
[2] Shibauchi, T., Krusin-Elbaum, L., Kasahara, Y., Shimono, Y., Matsuda, Y., McDonald, R.D., Mielke, C.H., Yonezawa, S., Hiroi, Z., Arai, M., Kita, T., Blatter, G, and Sigrist, J. Phys. **51**, 295, (2006).