Reentrant superconductivity induced by strong magnetic field in uranium based heavy-fermion compound URhGe

Y. Tokunaga[1), H. Sakai[1), T. Hattori[1), S. Kambe[1), D.Aoki[2,3), H. Mayaffre[4),
S. Krämer[4), M.-H. Julien[4), C. Berthier[4), M. Horvatić[4), and S. Araki[2,5)
1): R. G. for Materials Physics for Heavy Element Systems, ASRC, JAEA
2): CEA-Grenoble 3): Tohoku Univ. 4): LNCMI-CNRS 5): Okayama Univ.

Ferromagnetism is incompatible in general with superconductivity (SC) with singlet spin pairs, since a strong exchange field in ferromagnetic state forces the spin pairs to align in the same direction. In contrast, fluctuation of ferromagnetic moments has been supposed to create a binding force between quasi-particles with triplet spin, in the same manner as in the mechanism of superfluid pairing in ^{3}He. Such an unconventional spin-triplet state, mediated by ferromagnetic fluctuations, is now expected to be realized in a family of uranium based compounds, UGe_2, URhGe and UCoGe, so far the only fully established examples of ferromagnetic superconductors in which uniform SC is realized deep inside the ferromagnetic states.

The field-induced re-entrant superconductivity (RSC) discovered in URhGe [1] highlights the close interplay between SC and ferromagnetism in these exotic superconductors. Applied magnetic fields along the *b*-crystal axis first suppress the SC around 2 T, but then re-induce it between 10 and 13.5 T (Fig.1) [2]. At a similar field of H_R～12 T, the ferromagnetic moments (which are parallel to the *c* crystal axis in zero field) are forced to be aligned along the field direction; the transition is thus reminiscent of the textbook example of a quantum phase transition in a transverse Ising chain. The phase diagram of URhGe thus implies the existence of novel SC mechanism associated with the quantum phase transition, and the understanding of it will increase the possibility for developing new SC devices controlled by strong magnetic fields.

To elucidate the mechanism of the RSC, we have prepared a 10% Co-doped URhGe single crystal and performed Co nuclear magnetic resonance (NMR) experiments. Figure 2 shows the contour plot of the transverse NMR relaxation rate, $1/T_2$, measured at 1.6 K, which reveals how ferromagnetic quantum fluctuations are developed in the proximity of quantum critical point (H_R) in the plane (H_b, H_c) of the magnetic field components [3]. In the same figure, we also show the region where the RSC has been observed by resistivity measurements in a single crystal of URhGe [4]. We can see that the RSC appears almost in the same limited region as that where we have observed the strong quantum fluctuations in the (H_b, H_c) plane. This close overlap between RSC and the quantum fluctuations provide strong evidence that the pairing mechanism of RSC is mediated by these fluctuations in this system [3].

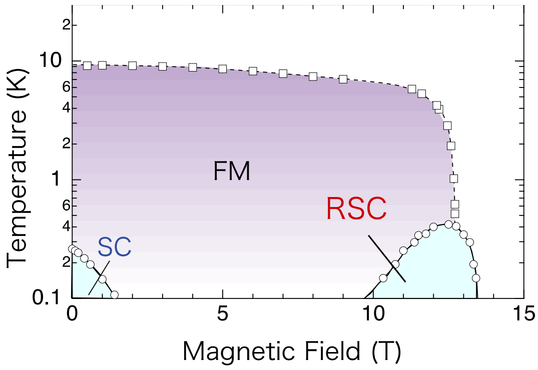

Fig.1 Temperature-field phase diagram of URhGe under the magnetic field applied along the *b*-crystal axis.

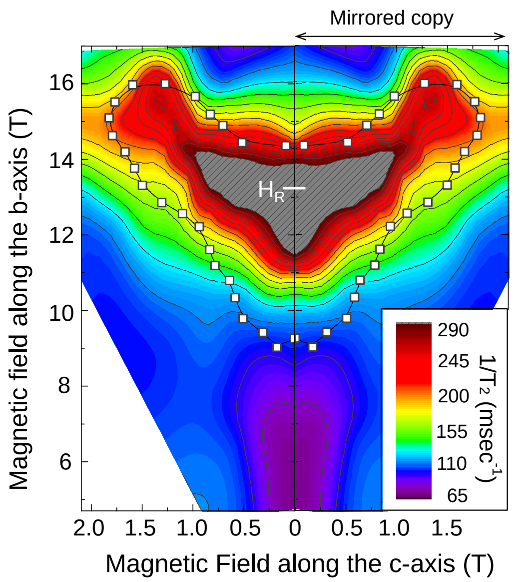

Fig.2 Map of the magnetic fluctuations amplitude in the (H_b,H_c) plane around H_R [3]. The open squares indicate the region where RSC has been observed at T=40 mK in a single crystal of URhGe [4]. Since URhGe has a lower H_R (12 T) than $URh_{0.9}Co_{0.1}Ge$ (13.4 T), the data for URhGe are plotted here with the field values scaled proportionally to the corresponding H_R values.

References

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