OBSERVATION OF THE SUPERCONDUCTING GAP IN THE FIELD-INDUCED SUPERCONDUCTING STATE OF λ-$(BETS)_2FeCl_4$ BY MULTI-FREQUENCY ESR SPECTROSCOPY

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Introduction

From the discovery of the field-induced superconducting (FISC) state in an organic conductor λ-$(BETS)_2FeCl_4$ [1], this material has attracted much attention, and the FICS state has been investigated by various techniques [2,3]. However, the direct observation of the superconducting gap has not been achieved yet. From the resistivity measurements, the FISC state of this material appears between 17 and 42 T at low temperatures and the center of the FISC phase is 33 T when the magnetic field is applied to the *ac*-plane precisely. The highest transition temperature of the FISC transition is ~5 K at 33 T [3]. One of the methods to observed the superconducting gap directly is an optical spectroscopy measurement. However, the observation of the FISC gap of this material may be difficult by the conventional spectroscopy measurements in a magnetic field because the FISC state appears in limited high-field region (i.e., 17-42 T), which is close to the limit of the conventional superconducting magnets. Moreover, the superconducting gap estimated from the transition temperature (~5 K) corresponds to ~3.5 cm^{-1} (105 GHz) which is beyond the limit of the conventional FIR spectrometer. On the other hand, the usual electron spin resonance (ESR) scans the magnetic field at the constant frequency. However, if we make the ESR measurements at the multi frequency, we will get the same information as the usual optical spectroscopy measurements in a magnetic field. We define this technique as the "multi-frequency ESR spectroscopy". Furthermore, the photon energies used usually for the ESR measurements match with the energies of superconducting gap in the present system; i.e., ~3.5 cm^{-1}. Therefore, the multi-frequency ESR spectroscopy using the high-field resistive magnets up to 33 T in NHMFL would provide the direct information of the FISC gap of λ-$(BETS)_2FeCl_4$.

Experimental, Results and Discussion

The experiment was performed using the resistive magnets (up to 25 T and 33 T) and the backward wave oscillators (BWOs) at the NHMFL. The frequencies used in the experiment were about 180-700 GHz, and the temperature was 1.4 K. To apply the magnetic field along the *c*-axis precisely, the newly developed rotational ESR probe was used in the experiment and several single crystals were mounted in the probe. Fig. 1 shows the magnetic field dependence of the transmission for various frequencies at 1.4 K. The magnetic field was applied along the *c*-axis. The large transmission changes at ~8 T corresponding to the insulator-metal (IM) transition of this material were observed for each frequencies. Moreover, the hump structures, which is located at the lower field of the IM transition, are enhanced as the frequencies increase. However, the origin of the hump structure observed in the high frequency region is not clear at the moment. On the other hand, the transmission change corresponding to the superconducting transition at high magnetic field was not observed. One of the possible origins of the non-observation of the FISC transition is a slight deviation of the field direction from the *c*-axis. Therefore, in the next measurements, the electrical resistivity should be measured simultaneously with the transmission measurement to confirm the FISC transition at high fields. Moreover, high frequency BWO's should be stabilized at high field because the transmission changes at high field observed in Fig. 1 is not intrinsic.

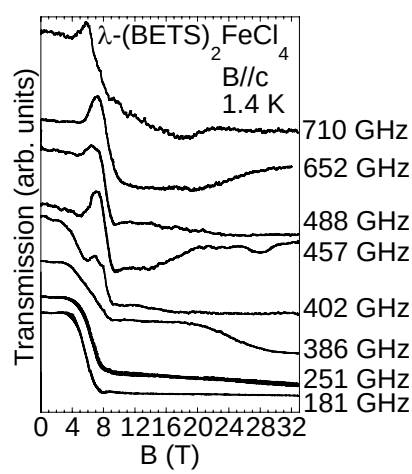

Fig. 1. Magnetic field dependence of the transmission for various frequencies.

References

[1] Uji, S., *et al*., Nature, **410**, 908-910 (2001).
[2] Uji, S., *et al*., Phys. Rev. Lett. **97**, 157001 (2006).
[3] Balicas, L., *et al*., Phys. Rev. Lett. **87**, 067002(2001).