High Magnetic Field ESR Study of Field Induced Antiferromagnetic Ordering in $CsFeBr_3$ at Low Temperature

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Abstract

The triangular antiferromagnet $CsFeBr_3$, which has the spin singlet ground state due to the large single ion anisotropy of Fe^{2+} ions, shows the field-induced magnetic ordering for B//c. Submillimeter and millimeter wave ESR measurements of $CsFeBr_3$ have been performed at 2K. Several absorption lines were observed below the ordering field 5T which is in the paramagnetic region. Temperature dependence of ESR absorption lines for paramagnetic region shows the decrease of intensity as the temperature is increased. It suggests that the observed ESR absorption lines come from the ground state. Changes of the ESR modes at 2K were observed at the field corresponding to the antiferromagnetic gap of 2.89T. The results are discussed in connection with the theory of the gap system.

Key words: field induced magnetic order; $CsFeBr_3$; high field ESR; spin gap

The hexagonal ABX_3 type antiferromagnets show various quantum phenomena, for example the spin frustration, quantum-fluctuation-induced transition of $CsCuCl_3$ and the field-induced antiferromagnetic ordering. $CsFeBr_3$ has hexagonal $P6_3/mmc$ space group and 1D antiferromagnetic chain along c-axis, which forms triangular lattice coupled antiferromagnetically in the c-plane. Low temperature magnetic properties of $CsFeBr_3$ can be described by the pseudo spin S=1. The energy level of $CsFeBr_3$ for B//c splits into the spin singlet $S_z = 0$ ground state and doublet $S_z = \pm 1$ states in zero magnetic field by a large uniaxial anisotropy D which was estimated to be 21.4K [1] or 29.8K [2]. B. Dorner *et al.* [1] and D. Visser *et al.* [2] estimated the intra-chain exchange interaction $J_0^{\parallel} = 3.2K, 4.9K$ and $J_0^{\perp} = 3.2K, 4.4K$, and inter-chain exchange interaction $J_1^{\parallel} = 0.32K, 0.48K$ and $J_1^{\perp} = 0.32K, 4.3K$, respectively. Y. Tanaka *et al.* investigated the field dependence of the magnetic susceptibility, the specific heat and the temperature dependence of the magnetization in detail, and revealed novel B-T phase diagram which has the field-induced antiferromagnetic ordering above $B_{AF} = 5T$ [3]. The gap field B_g, which corresponds to the excitation gap, was estimated to be $B_g = 2.89T$ at T=0K. Therefore, we performed submillimeter and millimeter wave ESR measurements of single crystal $CsFeBr_3$ to reveal electronic states at low temperature.

Single crystal synthesis of $CsFeBr_3$ is described in reference [3]. The ESR measurements are performed by the transmission method using a bulk InSb detector [4]. The millimeter and the submillimeter wave ESR measurements are performed using pulsed magnetic field up to 16T. The observed temperature region is from 1.8K to 80K. Gunn oscillators are used in the frequency region from 60GHz to 160GHz. BWO is also used in the frequency region from 180GHz to 360GHz.

Fig. 1 shows the temperature dependence of ESR spectra observed at 60GHz for B//c. A sharp absorption lines is DPPH signal which is the field marker of g=2. Several absorption lines were observed below 10K. Intensity of these absorption lines decreases as

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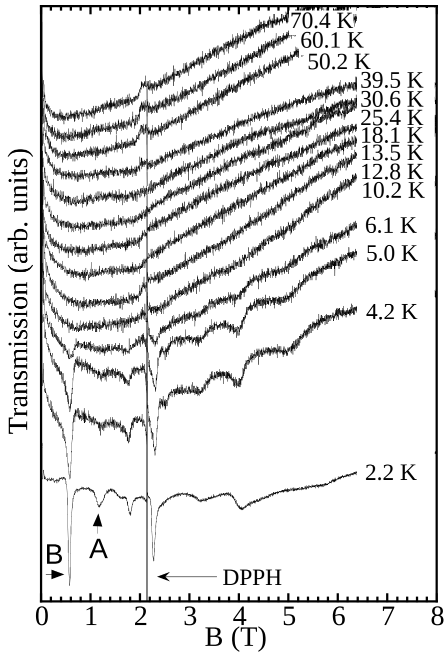

Fig. 1. Temperature dependence of ESR spectra observed at 60GHz for B//c.

the temperature is increased. It suggests that the observed ESR absorption lines come from the ground state. The characteristic features of ESR spectra for 60GHz is two intensive absorption lines A and B and other weak absorption lines. Fig. 2 shows the frequency field diagram of B//c at 2K. From the B-T diagram, the phase boundary of the antiferromagnetic ordering at 2K is $B_{AF} = 5T$, below which is paramagnetic. Mode A changes at the gap field $B_g = 2.89T$. From the linear fitting, the mode A below B_g has a slope of g=2.9 and the gap at zero field is 90GHz, which corresponds approximately to the gap field B_g. A slope of mode A changes to g=6.1 above B_g. It is about 2 times as larger than the slope below B_g. Recently theorists discussed about the ESR modes of S=1/2 and S=1 gapped spin chains system in the high field critical phase [5–7]. They suggest that there exist two ESR modes above and below B_c, where the gap becomes zero. The slope of the modes above B_c becomes twice as large of that below B_c. The behavior of the mode A corresponds to the theoretical proposal. On the other hand, the mode B has no anomaly at the critical fields B_g and B_{AF}. From the linear fitting, the mode B has a slope of g=1.8 and the gap at the zero field is 50GHz. It suggests the existence of the smaller gap than the zero field gap of B_g. The existence of the mode B does not agree with the theoretical proposal. The origin of the mode B remains as a future problem.

Distinct ESR modes were observed below B_{AF}. The mode A can be interpreted by the theory of ESR mode

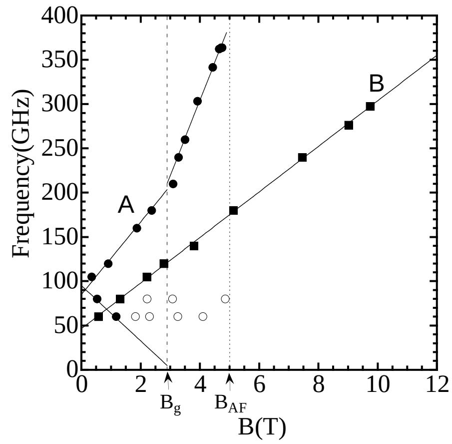

Fig. 2. Frequency field diagram of B//c at 2K. Solid lines are linear fitting lines.

in S=1 gapped spin system. However, the existence of the mode B remains as a future problem. For the observation of the field induced ordering mode, higher frequency and higher field ESR measurements are required.

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