| MLF Experimental Report | 提出日 Date of Report |
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| 課題番号 Project No.<br>2017A0005<br>実験課題名 Title of experiment<br>Magnetic excitations in the new-structure Fe-based superconducting material $EuRbFe_4As_4$<br>実験責任者名 Name of principal investigator<br>Kazuki Iida<br>所属 Affiliation<br>CROSS | 装置責任者 Name of responsible person<br>Ryoichi Kajimoto<br>装置名 Name of Instrument/（BL No.）<br>4SEASONS (BL01)<br>実施日 Date of Experiment<br>2017/4/28 – 2017/5/2 |

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

Polycrystalline $EuRbFe_4As_4$ (approximately 4 g).

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

Very recently, new-structure-type iron-based superconducting materials $AeAFe_4As_4$ (*Ae* = Ca, Sr, Eu and *A* = K, Rb, Cs) were reported, one of which is $EuRbFe_4As_4$. $EuRbFe_4As_4$ shows bulk superconductivity below $T_c$ = 36.5 K. $BaFe_2As_2$ is a non-superconducting parent material with antiferromagnetic transition at $T_N$ = 143 K, and upon $K^+$ substitution at $Ba^{2+}$ site, $(Ba_{0.5}K_{0.5})Fe_2As_2$ shows superconductivity below $T_c$ ~ 38 K. Similar to $BaFe_2As_2$, $EuFe_2As_2$ is also a non-superconducting parent material with antiferromagnetic transition at $T_N$ = 190 K. As in $(Ba_{0.5}K_{0.5})Fe_2As_2$, $Rb^+$ substitution at $Eu^{2+}$ site in $EuFe_2As_2$ gives rise to hole doping, resulting in superconductivity in $EuRbFe_4As_4$. Furthermore, Eu sublattice in $EuRbFe_4As_4$ shows ferromagnetic order below $T_C$ = 15 K. However, no inelastic neutron scattering measurement has been performed on $EuRbFe_4As_4$. Therefore, the neutron resonance and ferromagnetic spin wave excitation as well as interplay between superconductivity and ferromagnetism in $EuRbFe_4As_4$ has been investigated using 4SEASONS.

2. 実験方法及び結果（つづき） Experimental method and results (continued)

About 3.94 g polycrystalline $EuRbFe_4As_4$ was sealed in aluminum can whose thickness was 1 mm. Assuming the packing factor, we estimated that the effective thickness of the sample is 0.5 mm. Given $E_i$ = 70 meV, about half of neutrons are absorbed by the sample in the elastic channel. Time-of-flight neutron scattering measurements were preformed using incident neutron energies of 11.3, 15.6, 22.9, 37.1, and 70.1 meV with Fermi chopper frequency of 300 Hz. The measurements were performed at $T$ = 10.5, 25.0, and 41.0 K. Note that 10.5 K $< T_C$, $T_C <$ 25 K $< T_c$, and 41.0 K $> T_c$.

To emphasize the magnetic signals, we made two different subtractions: (1) 25.0 K − 41.0 K for the neutron-resonance mode （Fig. 1) and (2) 10.5 K − 25.0 K for the spin wave excitations （Fig. 2). As seen in Fig. 1, there are magnetic resonance at $E_{res}$ = 15 meV and $Q \sim 1.1$ Å$^{-1}$ (see the red arrow in Fig. 1). Note that $E_{res} \sim 5k_B T_c$ , which is the reasonable value for the iron-based superconductors. On the other hand, below $T_C$, the ferromagnetic spin wave excitations were observed as shown in Fig. 2. This spin wave spectrum can be understood by the ferromagnetic spin structure of the Eu site. Although Eu is strong neutron absorber, we have succeeded in observing in two important features (neutron resonance mode and ferromagnetic excitation) in the new iron-based superconducting material $EuRbFe_4As_4$. We are now analyzing the data in more detail.

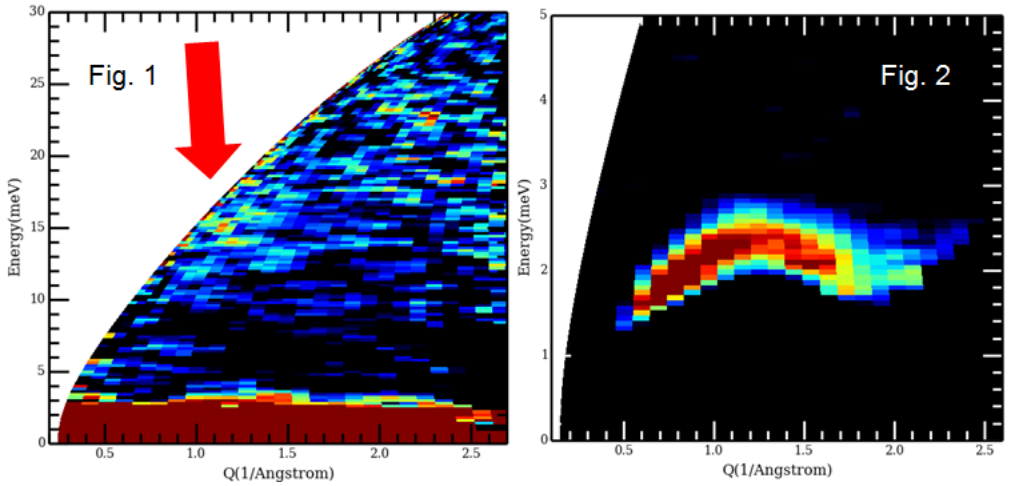


Figure 1. Subtracted $I(Q, \hbar\omega)$ spectra (25.0 K − 41.0 K) with $E_i$ = 37.1 meV. (b) Subtracted $I(Q, \hbar\omega)$ spectra (10.5 K − 25.0 K) with $E_i$ = 11.3 meV.