MLF Experimental Report	提出日 Date of Report 2010.4.13
課題番号 Project No. 2009B0029 実験課題名 Title of experiment High field magnetic structure of single crystal multiferroic $BiFeO_3$ 実験責任者名 Name of principal investigator Je-Geun Park 所属 Affiliation Department of Physics & Astronomy, Seoul National Univ., Korea	装置責任者 Name of responsible person Fujio Maekawa 装置名 Name of Instrument/（BL No.） BL10 実施日 Date of Experiment 2010.1.17.10:00-2010.1.22.10:00

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.

$BiFeO_3$ single crystal

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.

The purpose of our experiment was to conduct neutron diffraction under very high magnetic fields and to investigate the mechanism of room temperature multiferroic $BiFeO_3$ compounds.

In the 2009B, the beam intensity has been around 100 kW, which is 5 times stronger than before. And there were two major achievements in the present run. (1) We have succeeded in the neutron diffraction up to 40 T on the standard sample of NaCl. (2) We have examined the magnetic structure of multiferroic compound $BiFeO_3$. The former established the feasibility of neutron diffraction experiments under very strong magnetic fields. And then we carried out the high field neutron diffraction experiment on room temperature multiferroic $BiFeO_3$.

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

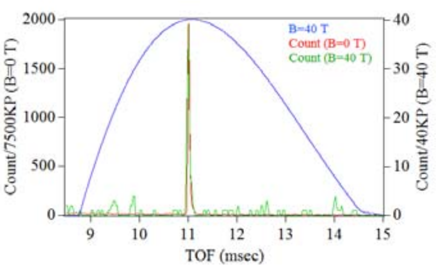

Fig. 1 Comparison of TOF spectrum in 40 T with zero field spectrum.

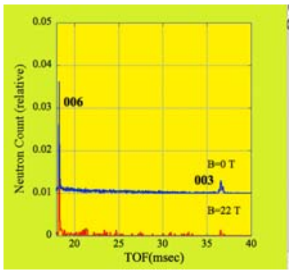

Fig. 2 TOF spectrum Of $BiFeO_3$.

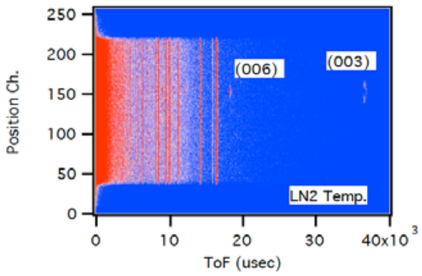

Fig. 3 Two dimensional plot of TOF and positional pattern of $BiFeO_3$.

Figure 1 shows the TOF spectrum of [400] nuclear Bragg peak of NaCl single crystal as the standard. The proton beam power was 100 kW, and basically there was no visible difference in TOF spectra between 0 and 40 T. It indicates that the performance of the system was maintained even in such high magnetic fields. The number of the shots was 40 and it took about 8 hours in total. We could achieve a sufficient S/N ratio with in 20 shots, and thus the diffraction experiments can be made at 40 T in several hours with the beam power of 100 kW. If we scale it to 500 kW, then a few shots are enough for data accumulation with reasonable statistics. Therefore, if necessary much more detailed experiments will become practical. This demonstrates that neutron diffraction up to 40 T has been established at J-PARC, a great achievement among neutron facilities worldwide.

As the next step, we have measured the magnetic diffraction of multiferroic compound $BiFeO_3$. This compound shows a metamagnetic transition around 20 T, and the aim of the proposal was to determine the magnetic structure in the high magnetic field phase. Figure 2 shows the TOF spectra taken at 0 and 22 T while Figure 3 shows the two-dimensional image spanning over the TOF and positions (scattering angles). As one can see in Fig.3, the (003) peak splits in both TOF and angular axes for the incommensurate magnetic structure. This small splitting can be measured by the high resolution TOF spectrum. To achieve the high resolution, the sample was set for the backscattering configuration with the solenoid coil. In this configuration, the scattering vector is parallel to the magnetic field. Because of the orientational factor of the magnetic diffraction, the measured intensity was due to the magnetic moments perpendicular to the scattering vector. Namely, the finite intensity in the backscattering configuration indicates that the magnetic moments lie perpendicular to the magnetic field. This result then excludes the one of two possible models and supports the model with a spin flop like state. However, the limited count for the small sample volume prevents us from checking the change of the propagation vector under high magnetic fields. Presently, we cannot tell for sure whether there is IC splitting around (003) peak or not. A further experimental study is needed to clarify this point.

In conclusion, in 2009B, we have established the 40 T neutron diffraction system by using pulsed magnetic fields. It shows the usefulness in determining the magnetic structure of multiferroic compound under high magnetic fields.