MLF Experimental Report	提出日 Date of Report 2009.5.28
課題番号 Project No. 2008A0018 実験課題名 Title of experiment High Magnetic Field Neutron Diffractions in Frustrated Multi-ferroics 実験責任者名 Name of principal investigator Hiroyuki Nojiri 所属 Affiliation Institute for Materials Research, Tohoku University	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 2009.1.27.10:00–2009.1.27.22:00 2009.2.19.22:00–2009.2.24.9:00

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.

$TbMnO_3$ 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 is to conduct neutron diffraction in very high magnetic field above 40 T and to investigate the mechanism of multi-ferroic compounds such as $TbMnO_3$. For this purpose, we made the first measurement combining the real neutron beam and pulsed magnetic fields up to 35 T in this beam time. We have succeeded in generating pulsed magnetic field safely and steadily in the real condition. However, the statistics of the data was totally insufficient. One of the major reasons is the weak beam intensity during 2008B period and the reconsideration of the experimental plan was essential to get some scientific result in the present intensity of user neutron beam.

Figure 1 shows the test result of the pulsed magnet developed for the J-PARC experiment and we have succeeded in generating 55 T with this magnet. The magnet is solenoid type and the open angle for scattering is 30 degree. The magnet is inserted into the original cryostat called "donut", with which a wide angle path of neutron can be obtained putting the liquid nitrogen bath with a hole inside the He bath of sample cooling.

Figure 2 shows the example of TOF spectrum at the one PSD pixel and the generated pulsed magnetic field waveform. The rising time to the maximum field is about 2.5 msec and the total width is about 30 msec. The time period of the half maximum is about 6 msec.

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

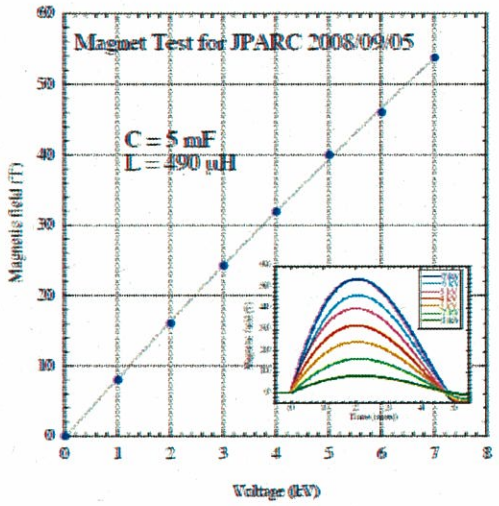

Fig. 1 Test result of the pulsed magnet for neutron diffraction at J-PARC.

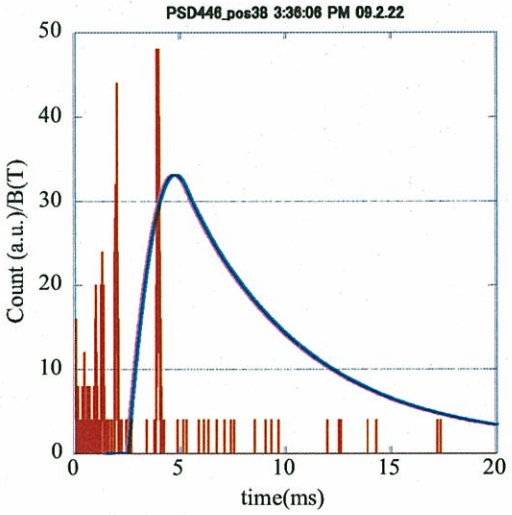

Fig. 2 Example of TOF spectrum and pulsed magentic field wave form.

In the TOF spectrum, series of peaks are observed in a few msec time-window. The pulsed magnetic field generation is synchronized with the neutron beam and the delay time of the starting field generation can be controlled precisely. If the peak of the pulsed magnetic field is set to coincide with the one of TOF peaks, the field variation in the peak is less than 0.2 %. We can set the magnetic fields of other peaks for different values by adjusting the delay. By analyzing the peaks at different times/magnetic fields, we can know the field variation of magnetic structure and the wave vector, though the points are discrete in magnetic field axis. The present data clearly demonstrates that the neutron diffraction in such strong magnetic field is possible by using the pulsed magnetic fields. In this sense, it is the very important step for our final goal.

On the other hand, there is a serious problem in applying the technique to other experiments. Namely, the weak intensity of beam is the serious limiting factor for the practical experiment. In Fig. 2, the data is taken for the strong nuclear peak and the measurement for the magnetic peak was very difficult in the limited beam time. We estimated that the time required for one TOF spectrum is more than 10 days with the present beam intensity. It means that the much stronger beam is needed to complete the measurement of $TbMnO_3$. It is also expected that a high magnetic field neutron diffraction above 40 T can be made under the beam intensity of about 5 times stronger than the present or by measuring the 5 times stronger Bragg peak of other materials.

In conclusion, we have established the technique of neutron diffraction in pulsed magnetic fields of 35 T at J-PARC and it can be extended up to 40 T or higher without difficulty. The planed experiment for $TbMnO_3$ was turned out to be difficult at this stage of neutron beam. A modified reasonable experimental plan for other target material will be performed in the 2009A beam time.