MLF Experimental Report	提出日 Date of Report 2015.6.14
課題番号 Project No. 2014B0126 実験課題名 Title of experiment Successive magnetic phase transition accompanying switch in magnetic anisotropy of $DyFe_2Zn_{20}$ 実験責任者名 Name of principal investigator Kazuaki Iwasa 所属 Affiliation Department of Physics, Tohoku University	装置責任者 Name of responsible person Shuki Torii 装置名 Name of Instrument/（BL No.） BL08 実施日 Date of Experiment 2015.3.13 – 2015.3.15

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.

$DyFe_2Zn_{20}$: powder sample （1.48 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.

We carried out neutron diffraction experiments in order to determine the crystal and magnetic structures of $DyFe_2Zn_{20}$, which exhibits successive magnetic phase transitions at 52 and 25 K （Y. Isikawa *et al.*: J. Korean Phys. Soc. 63 (2013) 644). Below 52 K, a ferromagnetic correlation without a magnetic anisotropy was found in the magnetization measurements. On the other hand, strong magnetic anisotropy appears suddenly below 25 K. Magnetic moments are expected to originate from 4*f* electrons of the Dy ions and 3*d* electrons of the Fe ions. A scenario of the successive ordering is that the Fe 3*d* spins order at 52 K, and Dy 4*f* magnetic moments are forced to align under the internal magnetic field from the Fe spin ordering. The less anisotropy is hypothesized to originate from small crystalline-electric-field (CEF) splitting of Dy ions due to high-symmetry cage structure of the Zn atoms, which surround the Dy ions. Below 25 K, the strong anisotropy is dominated only by the CEF ground state of Dy. Such combination of *d*-*f* interaction and anisotropy owing to the CEF splitting is a key for understanding of this successive magnetic transition of $DyFe_2Zn_{20}$. In order to examine this scenario, we measured neutron diffraction to extract the magnetic ordered structures.

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

A powder sample of $DyFe_2Zn_{20}$ was prepared by crashing a block of a single crystal synthesized by the Zn-self-flux method at The University of Toyama. The sample of 1.48 g in weight was sealed inside a vanadium cell of 6 mm in diameter, and this was installed in a closed-cycle helium cryostat to cool the sample down to 6 K in order to investigate the lowest-temperature phase. We measured three sets of diffraction patterns at 6, 35, and 65 K. Figure 1 shows selected diffraction patterns at the back-scattering detectors as a function of the neutron time-of-flight. The data measured at 65 K, shown by the red circles connected by a broke line, is for analysis of crystal structure, which has not been determined yet. A black solid line shows a result of the Rietvelt analysis using the software Z-Rietvelt, although the parameters of crystal structure are not shown here. It is consistent with the cubic Fd-3m structure for the isostructural 1-2-20 series. Some of the reflections in the data measured at 6 and 35 K, shown by the blue triangles and the green diamonds, respectively, exhibit an intensity increment compared to that at 65 K. This result indicates that the magnetic structure possess the same periodicity as that of the crystal structure (cubic Fd-3m with a = 14.04 Å). Although the structural analysis has not been finalized yet, the diffraction pattern can be reproduced by combination of the ordered magnetic moments of Dy and Fe. Based on the symmetrical consideration, the magnetic moments at the Dy sites should be collinear, whereas those at the Fe sites can be canted from the direction of the Dy moments. We can proceed to further analysis of the magnetic structures at 6 and 35 K using the obtained crystal structure parameters at 65 K.

We have measured magnetic excitation spectra of this material as a function of temperature by using the disk-chopper spectrometer BL14 AMATERAS. Combining the data obtained in the present diffraction measurement, we will be able to solve the roles of the CEF splitting of Dy 4*f* electrons and the *d*–*f* exchange interaction between the Dy and Fe magnetic moments to the characteristic magnetic behavior of $DyFe_2Zn_{20}$.

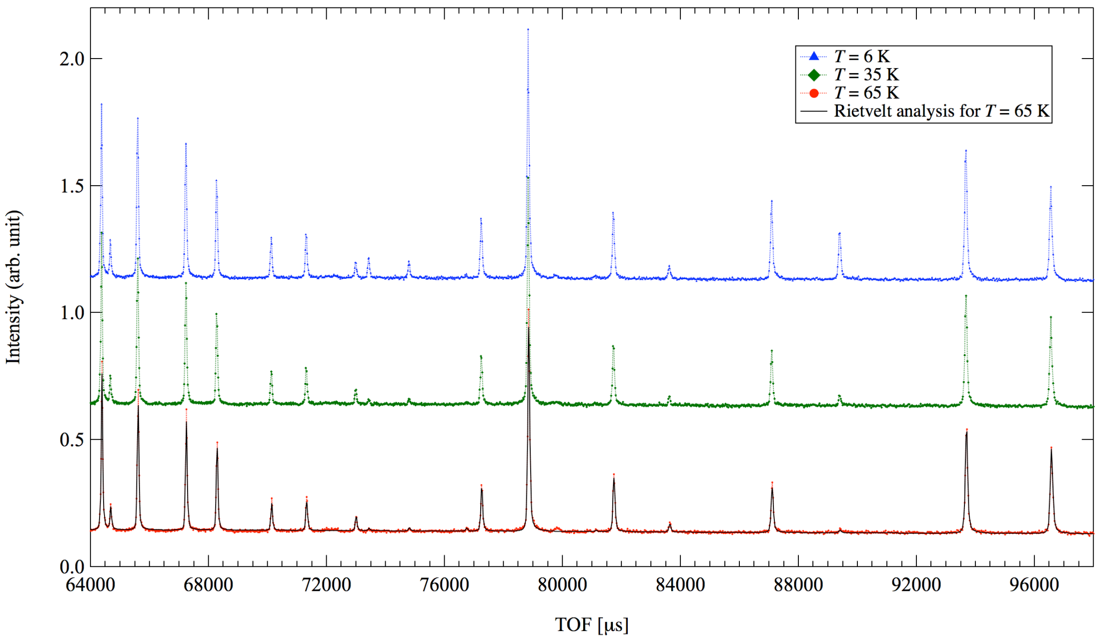

Fig. 1 Neutron diffraction patterns of $DyFe_2Zn_{20}$ measured at 6, 35, and 65 K, by using the high-resolution difractometer BL08.