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Possibility to Atomic Imaging using Mössbauer Holography

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Introduction

The holographic method introduced by Gabor[1] has been widely used since the advent of coherent laser light. Moreover, using x-rays or electrons, this method is becoming a powerful tool to reproduce an atomic arrangement. When the Mössbauer effect is used, it can be more useful method to reproduce element-specific atomic arrangement.[2] In addition, the distinction by the hyperfine interaction makes it possible to reproduce site-specific atomic arrangement.[3] It is also notable that visibility of Mössbauer holography can be much higher than the x-ray one. In spite of these advantages, Mössbauer holography has not been used until quite recent. It is partly because Mössbauer holography experiments using a radioactive source require as long time as several months. However, the synchrotron radiation can be an alternative source to excite Mössbauer nuclei to improve these experiments. Since the synchrotron radiation has the advantages such as photon flux and polarized property, this can be more practical. However, the Mössbauer experiment using synchrotron radiation, that is nuclear resonant scattering, has some differences with the conventional Mössbauer experiment. First, nuclear resonant scattering is normally carried out in timing method instead of energy scan. Second, several different processes with nuclear excitement are included in the measurement of nuclear resonant time spectrum. These features make the holographic process complex. Therefore, it is important to make an attempt to evaluate the possibility of the experimental technique of the Mössbauer holography using synchrotron radiation.

Experiment

The experiment was carried out at the undulator beamline of PFAR-NE3A. The experimental set up is shown in Fig. 1. The x-rays were monochromatized by a water-cooled C (1 1 1) pre-monochromator and a nested Si (4 2 2) and Si (12 2 2) high-resolution monochromator. The 14.4 keV x-rays with the resonant energy of ^{57}Fe was led through a slit of 2 mm x 1 mm onto ^{57}Fe-contained single-crystal sample. The nuclear resonant scattering from the sample was measured with a set of multi-element avalanche photodiode (APD) detector every time changing the incident angle to the sample plane and in-plane angle of the sample. The holographic interference signal was generated "inversely" by reference wave of nuclear resonance from direct x-ray and object wave of nuclear resonance scattered via adjacent nucleus.

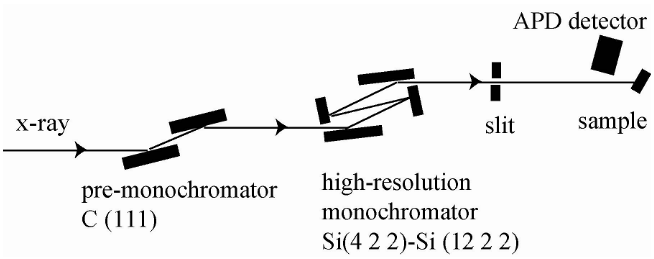

Fig. 1. Experimental setup.

Results and Discussion

The photon flux on the sample at this experimental setup was roughly evaluated to be 5x10^7 photons/s for 14.4 keV. When using a ^{57}Fe-enriched hematite sample, typical count rate for the delayed nuclear resonant signal was a few counts/s. That made several hundred counts for each point of the angle by the measurement for a few days. The experimental results suggest that the obtained data set seems to contain the holographic information. However, the data statistics should be at least several thousand counts to make an analysis to reproduce the atomic arrangement. The count rate will be increased by the improvement of the experimental setup such as a detector. Therefore, this result suggests that the measurement is not impossible by this method with some achievable improvements.

References

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