Generation of arbitrary X-ray polarization by rotatable four-quadrant diamond phase-retarder system

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Introduction

We are now aiming at developing an optical system that can generate arbitrary X-ray polarization from horizontal linear X-ray polarization.

Perfect crystals show birefringence near the Bragg conditions and are used as X-ray phase retarders. The X-ray two-quadrant phase-retarder system we developed is composed of two transmission-type X-ray phase retarders and can compensate for off-axis aberration (phase-shift inhomogeneity due to angular divergence of incident X-rays)[1]. We also developed the X-ray four-quadrant phase-retarder system composed of four transmission-type X-ray phase retarders. The scattering planes of four phase-retarder diamond crystals are set to incline by 45°, 135°, 225°, and 315°, respectively, with respect to the direction of incident polarization. It can compensate for both off-axis and chromatic aberrations[2].

In our optical system, X-ray four-quadrant phase retarders are mounted on a χ-circle goniometer so that they can be rotated all together around the X-ray beam. Each phase retarder placed on tangential bar-type goniometers is rotatable around diameter of the χ-circle. The system occupies 27 cm in the beam path.

Here we report on generation of 45° oblique linear polarization by the use of the rotatable four-quadrant diamond phase-retarder system.

Experimental

Horizontal linear polarization was converted into 45° oblique linear polarization along two different paths on the Poincaré sphere shown in Fig 1 and the results were evaluated and compared by an X-ray polarimeter composed of a polarizer and an analyzer. Intensities of rocking curves were measured at intervals of 20° of analyzer angle and each measuring time was 100 sec.

Path 1: Incident horizontal polarization was converted into clockwise circular polarization in the first stage, and was then converted into 45° oblique linear polarization in the second stage. The above two conversions were made by two sets of two-quadrant phase retarders. One placed in the downstream is rotatable, while one in the upper-stream is not.

Path 2: Incident X-ray was converted into 45° oblique linear polarization by using a rotatable four-quadrant phase-retarder system with the χ-angle set to be 22.5°.

Results and Discussion

Fig. 2 shows the experimental results with the polarimeter. The degree and azimuth angle of polarization were 0.952 and 55.8°, respectively, in the case of path 1, whereas they are 0.973 and 47.3°, respectively, in the case of path 2.

The azimuth angle of polarization obtained along the path 1 was different by 10° from the targeted value. There are two possible reasons conceivable for the error. Firstly, the phase shift given by the upstream two-quadrant phase retarder was smaller than intended. Secondly, the rotation axis of the down-stream two-quadrant phase retarder was slightly misaligned.

In the case of path 2, approximately 45° oblique linear polarization was obtained. The degree of polarization was also higher in the case of path 2 than path 1. This may be due to 1) compensation for chromatic aberrations by the use of four-quadrant phase-retarder system as a single component and 2) shorter path length of conversion on the Poincaré sphere.

In this experiment, we could generate 45° oblique linear polarization from horizontal linear polarization by using the X-ray four-quadrant phase-retarder. We are going to increase the accuracy in converting the polarization, and to generate arbitrary polarization including elliptically polarized X-ray, and to apply the system to experiments in which a switching between arbitrary polarizations is required.

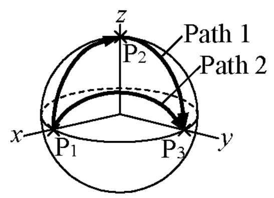

Figure 1
Polarization conversion paths on the Poincaré sphere. P_1: horizontal linear polarization. P_2: clockwise circular polarization. P_3: 45° oblique linear polarization.

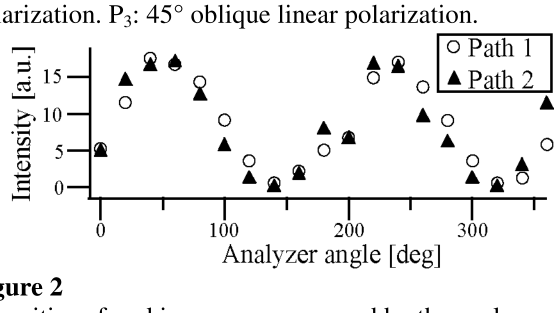

Figure 2
Intensities of rocking curves measured by the analyzer.

Reference

[1] K. Okitsu *et al.*, J. Synchrotron Rad., **8**, 33 - 37 (2001).
[2] K. Okitsu *et al.*, Acta Cryst., **A58**, 146 - 154 (2002).

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