Generation of circularly-polarized soft x-ray by segmented cross undulator at SPring-8 BL07LSU

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Introduction

Polarization is one of the most important characteristics of synchrotron radiation (SR). Especially, circularly-polarized SR provides new possibilities to study magnetic properties of materials using x-ray magnetic circular dichroism (XMCD) effects.

A soft x-ray beamline BL07LSU at SPring-8 is designed to achieve high energy resolution ($E/\Delta E>10{,}000$) and high photon flux ($>10^{12}$ photons/s/0.01% BW) in the photon energy range of 250-2000 eV with controllable polarization [1]. SR with linear (horizontal or vertical) or circular polarizations is generated by a newly-developed insertion devise (ID) called segmented figure-8 cross undulator. This ID is 27 m-long and consists of eight undulator segments and seven phase shifters. The horizontal and vertical segments (four segments for each type) are placed alternately, and the phase shifters located between the segments adjust the relative phase of light emitted from each segment, thus control the polarization of light.

Here we report the generation of circularly-polarized soft x-ray by segmented cross undulator at SPring-8 BL07LSU and XMCD measurements to evaluate the degree of circular polarization. In this report the simplest configuration of ID (one pair of horizontal and vertical segments and one phase shifter) was adopted to generate circularly-polarized soft x-ray.

Results and discussion

To generate circularly-polarized SR, the phase shifter is adjusted by a soft x-ray polarimeter based on a multilayer analyzer [2]. The degree of polarization is derived by measuring a reflectivity curve of a multilayer analyzer as a function of azimuth angle. The reflectivity of multilayer analyzer at the fixed azimuth angle will vary with the degree of polarization. Figure 1 shows a reflectivity of soft x-ray ($h\nu$= 720 eV) by a multilayer analyzer at the fixed azimuth angle of 45° as a function of phase shift. The center energy of horizontal and vertical undulator segments was tuned at 720 eV, and the gap of phase shifter was scanned from 80 to 31 mm. The multilayer analyzer was the W/B_4C multilayer mirror with 100 periods of 1.19 nm nominal periodic distance. SR with a phase shift of $(n+1/2)\pi$, $(2n)\pi$, $(2n+1)\pi$ has the polarization of circular, 45° linear, 135° linear, respectively. The optimization of phase shifter was carried out over the 2*p* absorption edge of Fe (700-740 eV) with 10 eV step in order to generate circularly-polarized SR in this energy region.

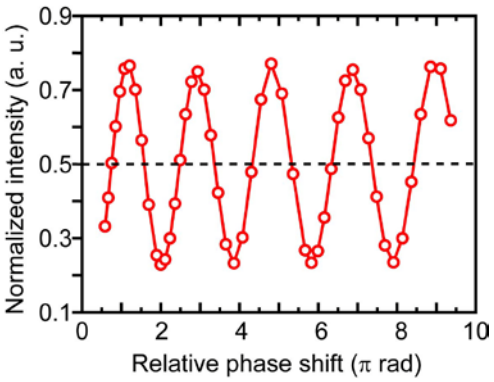

Figure 1: Normalized reflectivity of multilayer analyzer at $h\nu$= 720 eV. The azimuth angle of multilayer analyzer was fixed at 45°. The relative phase shift has an offset of -0.342 π rad.

To confirm the generation of circularly-polarized SR, we have measured Fe 2*p* XMCD spectra of a ferrimagnetic Gd-Fe-Co sample (Figure 2). The sample was mounted on an Nd-Fe-B permanent magnet (B~ 0.33 T) at room temperature. The Fe 2*p* x-ray absorption spectra

(XAS) were measured with a total electron yield (TEY) in a normal incidence of SR. In the TEY XAS measurements, the drain current of a sample was normalized by that of a post-focusing mirror. Note that both ID (undulator and phase shifter) and grating were scanned during XAS measurements. The observed XMCD spectrum indicates the generation of circularly-polarized soft x-ray at Fe 2*p* edges.

The degree of circular polarization will be evaluated quantitatively by comparing the present XMCD spectrum with that measured on the same sample with the well-characterized SR (i.e., SPring-8 BL25SU). Figure 3 shows a photon flux and Stokes parameters calculated by SPECTRA [3] for (a) two ID's and (b) eight ID's (hν= 720 eV). The degree of circular polarization is improved from two ID's (s3=+0.586) studied in this report to eight ID's (+0.795). In addition, it should be noticed that the higher degree of circular polarization is available at the higher energy side of ID spectrum; -0.914 at hν= 733 eV and +0.795 at hν= 718 eV for eight ID's. Therefore, the generation of circularly-polarized soft x-ray with eight ID segments at the off-center energies will be next goal in the future ID commissioning.

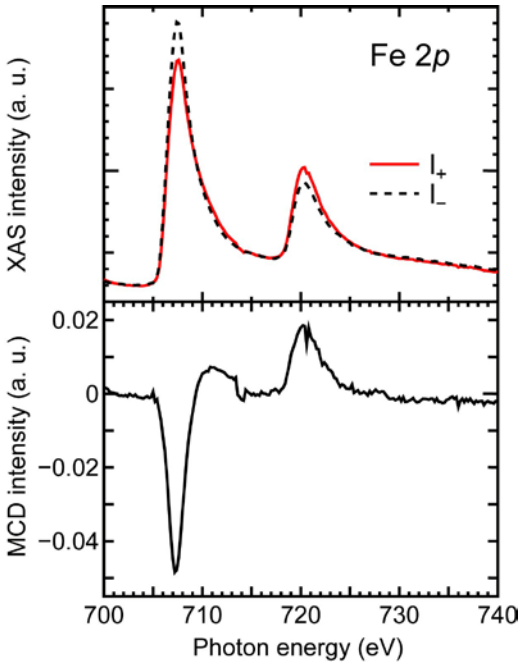

Figure 2: Fe 2*p* XAS and XMCD spectra of Gd-Fe-Co measured at SPring-8 BL07LSU. XAS intensities I_+ and I_- represent the cases where the photon spin is parallel and antiparallel to the direction of magnetic field. MCD intensity is defined as $I_{MCD} = I_+ - I_-$.

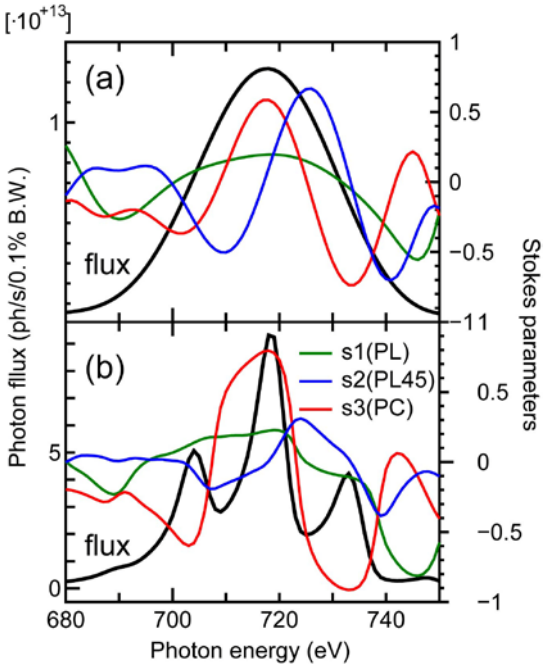

Figure 3: Calculated photon flux and Stokes parameters for (a) two ID's and (b) eight ID's: s1 (linear polarization), s2 (45° linear polarization), s3 (circular polarization). Each undulator segment has a center energy of 720 eV. The opening of front end slit is set to be 0.5x0.5 mm^2.

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References

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