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The elliptically polarized undulator beamlines at BESSY II

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Abstract

During 1998/99 three beamlines of the UE56-PGM type were built at BESSY-II to meet the increased need for synchrotron radiation of tuneable, i.e. linear to fully circular, polarization. We report on the results of characterization measurements, which were focused on spectral resolution, photon flux and polarization properties.

The spectral resolution for all three beamlines exceeds $E/\Delta E = 100\,000$ at 64.1 eV as obtained from absorption spectra of doubly excited He. The flux measurements resulted in values that closely follow the theoretical prediction of up to 1×10^{14} photons/(s 100 mA 0.1%) at 160 eV. The degree of polarization turned out to be close to 100% with circular and linear content, each of up to 100% depending on the undulator shift value, as predicted by theory. We also give first results on the double beam mode in which both undulator modules produce horizontally separated beams. This mode was used for fast switching of the polarization, utilizing a motorized chopper in the beamline. © 2001 Published by Elsevier Science B.V.

Keywords: Variable polarization; Soft X-ray monochromator

1. Introduction

During 1998/99 three beamlines of the UE56-PGM type were built at BESSY-II to meet the increased need for synchrotron radiation of tuneable, i.e. linear circular, polarization. Each beamline is located on a dual Sasaki type elliptical polarizing undulators [1,2] and are based on a plane grating monochromator design which works with collimated light and employs only one set of optical elements for steering and monochromatizing the beams from the double undulators [3].

The beamlines have been characterized with respect to photon flux, spectral resolution and polarization characteristics. In addition, first tests of the double beam mode were conducted. These results will be discussed in the following section.

2. Photon flux

The photon flux was measured using a GaAsP photodiode. For these measurements, the input

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aperture, placed at 13 m after the source point, was set to 4 mm×4 mm and the exit slit was kept at 200 μm. The fix-focus constant, c_{ff}, was set to 2.25 for the 1200 l/mm grating, and 1.6 for the 400 l/mm grating. Only on undulator module was used and set to circular mode in the first harmonic and to elliptical mode in the third and fifth harmonic. The photon flux measured at various energies is shown in Fig. 1 along with ray trace results [3]. The earlier calculations on photon flux, carried out for the whole beamline, where corrected introducing the effective microroughness of 1.3 nm (RMS), which results in good matching between calculations and measurements, as is evident from Fig. 1.

3. Spectral resolution

The spectral resolution at various photon energies was determined by measuring the absorption spectra of several gases using a home-made gas ionization chamber. Absorption spectra of N_2, Kr, Ar, Ne, SF_6, and He were measured. All gases, except for He, do not show the limits of the monochromator due to their large lifetime broadening.

Therefore, we concentrated on the $N=2$ series of doubly excited helium at about 64 eV. In Fig. 2 (a) an overview spectrum of this series with blow-up insets is shown where resonances up the 35 are resolved. The 2p3d feature, with theoretical line-width of 3 μeV [4] was measured in detail (b) to study the resolution limits. Here, a spectral resolution of up to 570 μeV was obtained, which corresponds to an $E/\Delta E$ of 112 000, if the Doppler broadening is taken into account.

4. Polarization analysis

The polarization analysis was done with the BESSY soft X-ray polarimeter using phase retarding transmission- and linear-polarizing reflection multilayers [5]. Fig. 3 (a) shows experimental results (symbols) for S_1 and S_3 as function of the undulator-shift values, obtained with a set of Mo/Si multilayers for the first undulator harmonic

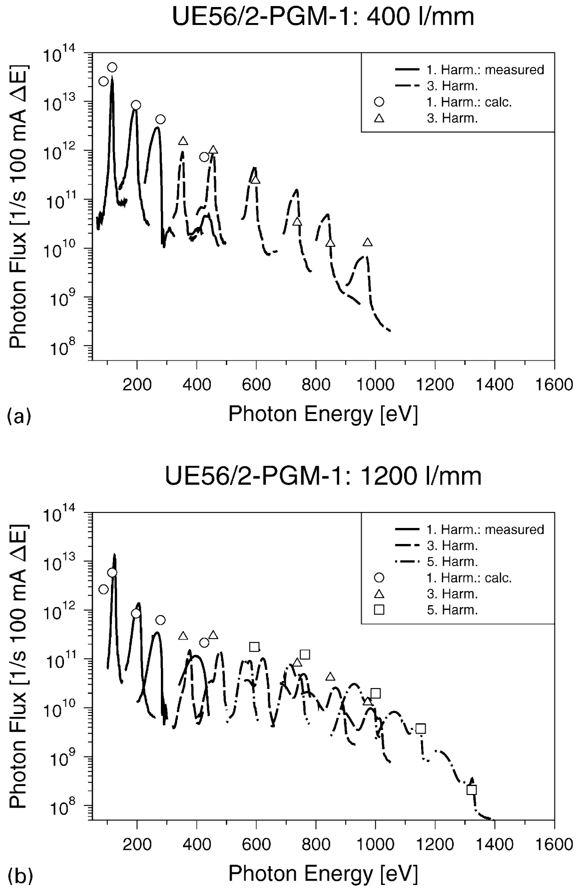

Fig. 1. Comparison of the measured photon flux (symbols) with theoretical predictions (lines) for the 400 l/mm grating (a) and the 1200 l/mm grating (b).

at 98 eV. The measurements agree well with the calculations (lines) performed as described by Walker [6] and demonstrate the full tuneability from linear (horizontal/vertical) to left- or right-handed circular polarization. Measurements were performed for additional photon energies with the transmission and reflection multilayers Cr/C (275 eV) and Cr/Sc (399 eV, 572 eV). For energies above 600 eV, linear polarization analysis was performed using a W/B4C reflection multilayer operating close to the Brewster angle. The degree of circular polarization was calculated via $S_3 = \sqrt{1 - S_1^2}$ assuming no unpolarized light. This

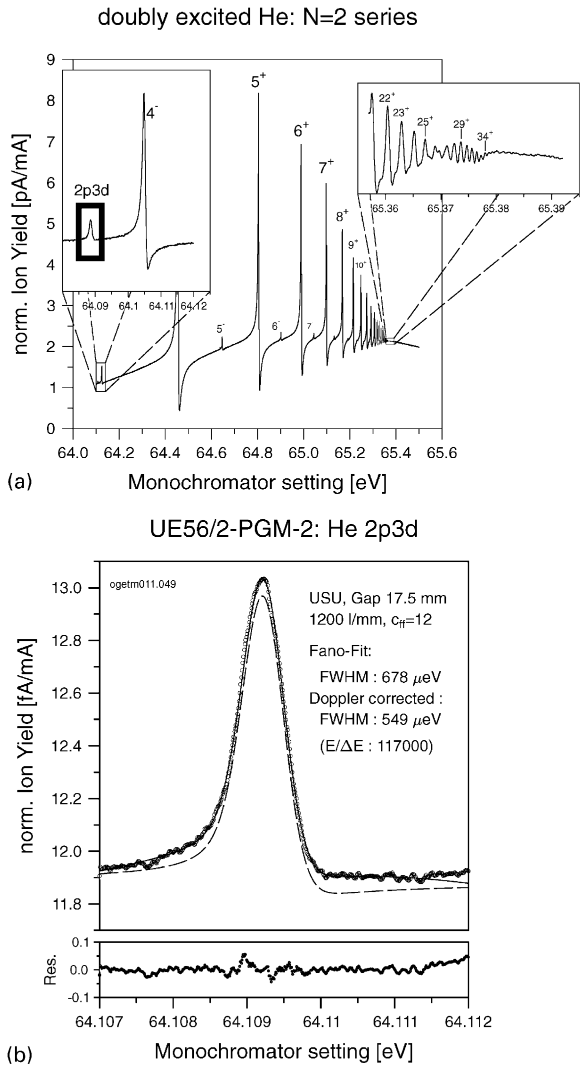

Fig. 2. (a) Autoionization spectrum of doubly excited helium. The principle series was resolved up to the 35 resonance. The inset shows the very sharp 2p3d feature. (b) Detailed measurement of the 2p3d peak, showing a Doppler-broadened FWHM of 690 μeV.

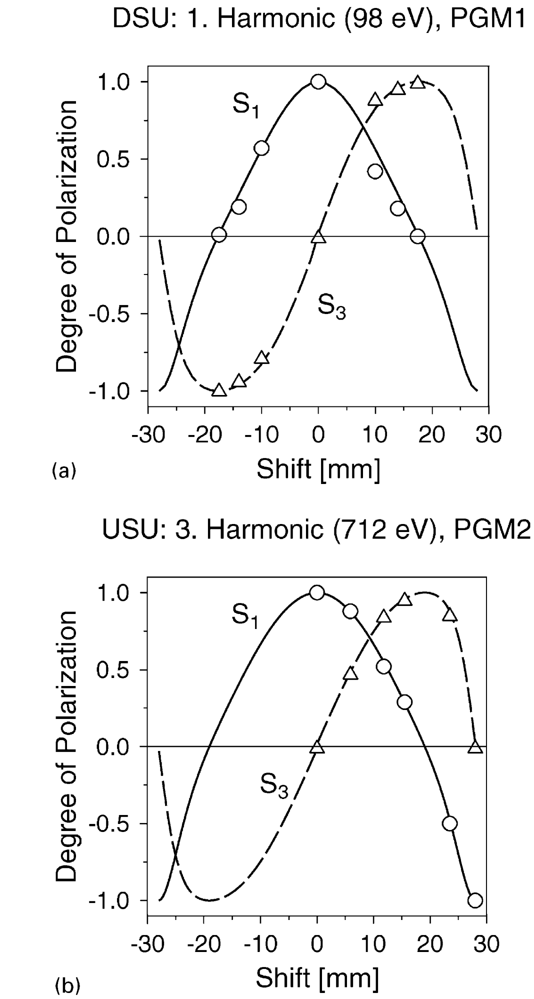

Fig. 3. Degree of circular polarization S_3 and linear polarization S_1 as a function of undulator's longitudinal shift for 98 eV (a) in first undulator harmonic, and for 712 eV (b) in the third harmonic. Symbols: measured values; lines: calculations.

is shown in Fig. 3(b) for the third harmonic at 712 eV. With these data the MCD-detectors were calibrated which exploit the magnetic circular dichroism of magnetized 50 nm thick Fe, Co and Fe-Ni films in the range between 700 and 850 eV [7].

5. Double beam tests

First tests of the double beam mode were conducted in which a magnetic structure before, between, and after the undulator modules provides a horizontal separation of the beams of up to 500 μrad. These tests included optimization of the horizontal, vertical, and energetical match of the two beams at the sample position.

The energetical match was found by N_2 absorption spectra, which turned out to be below

10 meV after adjusting the rotation about the normal of the first mirror. The vertical match was adjusted by rotating the refocusing mirror about the normal. Finally, the horizontal match was optimized by changing the deflection angles of the first mirror and focusing mirror. Subsequent measurements of the intensity distribution by a photo electron emission microscope revealed a match of better than 10% in the contrast function. With these adjustments in place, MCD-measurements were performed at the iron edge with the chopper running at up to 130 Hz.

6. Conclusion

These commissioning results of the PGM beamlines for circularly polarized radiation demonstrate the flexibility of this design wherein not only the helicity of the circular polarization can be switched, but any state of the polarization is available: from horizontal linear to vertical linear and any in between elliptical state. This flexibility is not limited to the polarization, since the new generation PGM allows to switch between various operational modes for e.g. very high spectral resolution, high flux or higher order suppression. The first tests of the double beam mode demonstrate that the design of these beamlines will provide a stable source of monochromatized synchrotron radiation with fast switching of the polarization. Still, further optimization work is necessary to reduce the intensity variations on the sample below 3%.

References

[1] S. Sasaki et al., Jpn. J. Appl. Phys. 31 (1992) L1794.
[2] J. Bahrdt, Nucl. Instr. and Meth. A 467–468 (2001), these proceedings.
[3] K.J.S. Sawhney et al., Nucl. Instr. and Meth. A 390 (1997) 395.
[4] M. Domke et al., Phys. Rev. Lett. 69 (1992) 1171.
[5] F. Schäfers et al., Appl. Opt. 38 (1999) 4074.
[6] R. Walker, Synchrotrone Trieste Internal Report, ST/M-97/2, 1997.
[7] M.R. Weiss, et al., Proceedings of the Synchrotron Radiation Instrumentation (SRI99) AIP, New York, 2000, pp. 134–137.