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A HIGH FLUX NORMAL INCIDENCE MONOCHROMATOR FOR CIRCULARLY POLARIZED SYNCHROTRON RADIATION

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Design and performance of a 6.3 m normal incidence UHV-monochromator (see fig. 1) of the Gillieson type for synchrotron radiation are described. The monochromator will be used for simultaneously spin polarization and emission angle-resolved photoelectron spectroscopy; it combines a high photon flux and a high degree of circular polarization of the monochromatized radiation with a moderate resolution.

Special features of the design of the monochromator are the following:

– Apertures movable in vertical direction allow the selection of left-handed or right-handed circular polarization (off-plane radiation).

– Apertures movable in horizontal direction may be closed to improve the resolution (since no entrance slit is used).

– The spherical mirror is adjustable to refocus the beam onto the exit slit after each injection.

– Two different gratings interchangeable under vacuum are used to cover the wavelength range from the visible to the VUV.

– The wavelength scan is performed by a simultaneous rotation and, to maintain focusing, an independent translation of the grating; both as well as the motion of the vertical apertures are controlled by a minicomputer.

– The monochromator has two exit slits, which will be used for studies of atomic and molecular photoionization (in connection with a differential pumping stage) and for surface photoemission studies, respectively.

The monochromator was built by Chelsea Instruments Ltd., London U.K. (electronic hard and software), by Bird and Tole Ltd., High Wycombe U.K. (mechanical precision equipment) and by Vacuum Generators Ltd., Hastings U.K. (vacuum vessel) and is now connected with a beam line at BESSY, Berlin.

Technical data for the monochromator is listed in table 1.

The resolution of the monochromator has been measured using grating 1 (1200 lines/mm) in connection with a sodium D-lines resonance light source and a real entrance slit (width 1 mm). For a 0.5 mm opened exit slit the resolution measured by scanning the wavelength scale of the monochromator and detecting the light

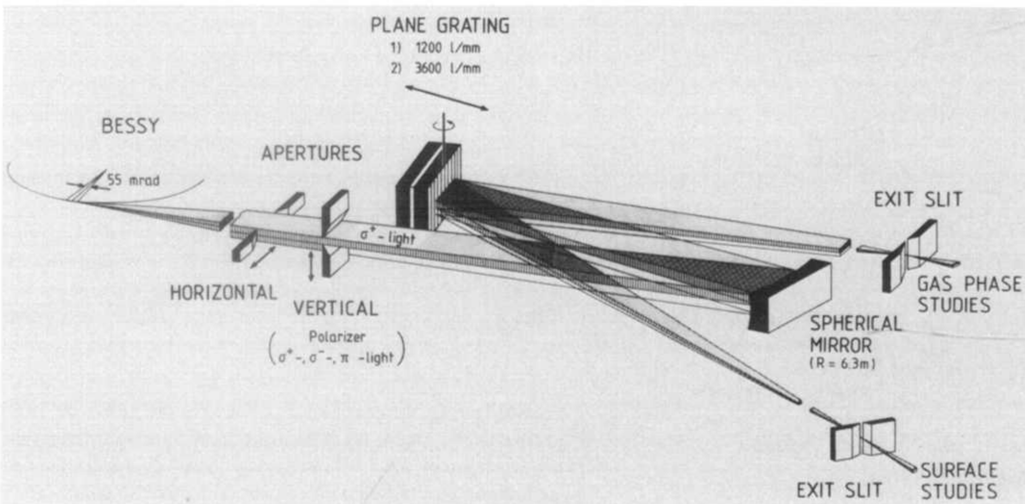

Fig. 1. Set-up of the Gillieson-type monochromator.

Table 1
Technical details of the monochromator

Spherical mirror (radius 6.3 m)	$365 \times 80 \times 65$ mm^3 Al + Os coated
Acceptance	54 mrad horizontal 10 mrad vertical
Plane grating	$260 \times 140 \times 60$ mm^3
1) 1200 lines/mm MgF_2 + Al coated	wavelength range 100–675 nm
2) 3600 lines/mm Os coated	wavelength range 35–130 nm
Dispersion	1) 5.4 mm/nm 2) 16.2 mm/nm
Absolute resolution expected for electron beam and exit slit widths of 1 mm	1) 0.33 nm 2) 0.12 nm
Expected circular polarization	90%
VUV-intensity expected behind the exit slit (electron current 500 mA wavelength range and bandwidth as in 2 above)	$> 10^{11}$ photons/s

intensity behind the exit slit is shown in fig. 2, lower and upper part, for horizontal apertures accepting 12 mrad and 54 mrad light divergence, respectively. The resolution values measured shown in fig. 2 are in agreement with the corresponding expected data mentioned above.

The vacuum in the monochromator has been measured to be in the 10^{-9} mbar after the monochromator was installed at the BESSY beamline and was baked out, after the optical components were built in and during the full beamline and the monochromator is in operation with synchrotron radiation.

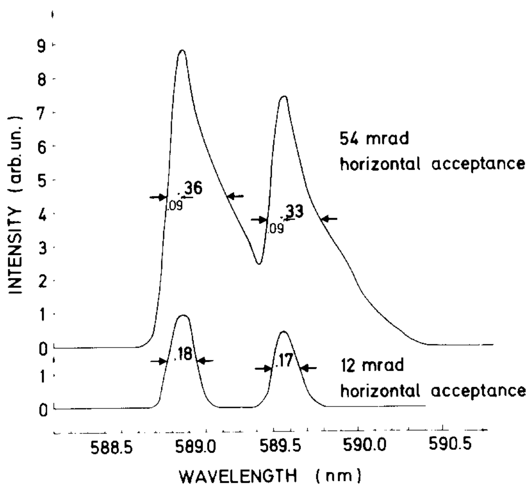

Fig. 2. Resolution of the monochromator measured using a sodium D-lines light source.

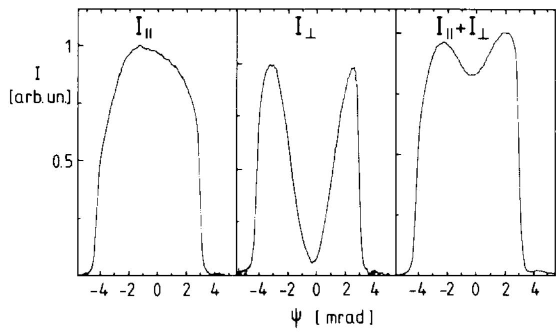

Fig. 3. Intensity dependence of the radiation components polarized horizontally ($I_{\parallel}$) and vertically ($I_{\perp}$) upon the vertical angle ψ (± 0.25 mrad) the radiation is emitted with respect to the BESSY plane. The intensities $I_{\parallel}$, $I_{\perp}$ and their sum have been measured behind the monochromator exit slit at a wavelength of 450 ± 0.2 nm.

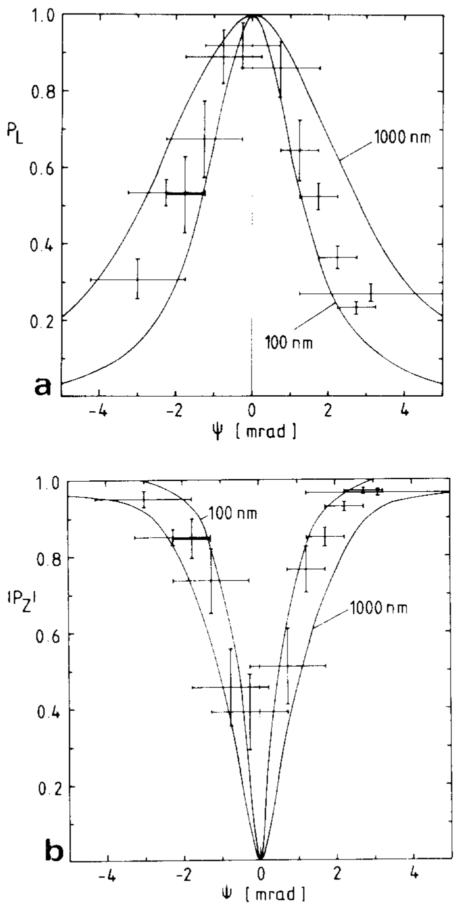

Fig. 4. (a) Degree of linear and (b) circular polarization, P_L and P_Z respectively, measured behind the monochromator exit slit at a wavelength of 300 ± 0.2 nm as function of the vertical angle ψ the radiation is emitted with respect to the BESSY plane. The experimental results are compared with calculated curves for 100 nm and 1000 nm wavelength (BESSY handbook, 1979).

We have also measured the degrees of linear and circular polarization P_L and P_Z of the monochromatized radiation behind the exit slit by use of grating 1 (1200 lines/mm) in the near UV and visible spectral range. The measurements have been performed by use of a conventional Glan prism and a quarter wave plate and a photodiode as the analyzer and the detector, respectively. By moving both vertical apertures simultaneously thus forming a horizontal slit of a width corresponding to 0.5 mrad, intensity profiles of the BESSY radiation have been measured. Fig. 3 shows the components $I_\parallel$ and $I_\perp$ of the radiation emitted, whose electric field vector oscillates parallel and perpendicular with respect to the orbital plane of the storage ring, and the total intensity; they are functions of the vertical angle ψ the radiation with a wavelength of 450 nm is emitted with respect to the orbital plane of BESSY ($\psi = 0$). The shapes and the halfwidths of the profiles are in good agreement with the expected calculated values although the actual position of the orbital plane which may change slightly after each injection seems to be a little bit too low.

Figs. 4(a) and (b) show the degree of linear and circular polarization P_L and P_Z as function of the vertical angle ψ the radiation is emitted with respect to the BESSY plane. We have measured by use of the quarter wave plate, that the radiation behind the monochromator exit slit is completely polarized, i.e. $P = \sqrt{(P_L^2 + P_Z^2)} = 1$, and that the circular polarization is right-handed and left-handed for light emitted into directions above and below the plane, respectively. The experimental results, obtained at a wavelength of 300 nm are shown in fig. 4 as error crosses, where the horizontal error bars are connected with the slit width of the vertical apertures and the vertical error bars determine the experimental uncertainty. The comparison with the calculated curves for wavelengths of 100 nm and 1000 nm based upon the Schwinger theory shows a quantitative agreement.

The experimental results discussed in this paper which are in good agreement with the calculated and expected values show that BESSY is indeed a good source of polarized radiation and that the monochromator described is well qualified for its application to monochromatize the circularly polarized radiation without a larger depolarization effect.

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