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LETTER TO THE EDITOR

Polarised photoelectrons produced at xenon atoms by circularly polarised synchrotron radiation

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Abstract. Circularly polarised synchrotron radiation is used for producing spin polarised photoelectrons at xenon atoms. After a brief description of the apparatus the dependence of the electron polarisation on the photon energy is presented and compared with a theoretical prediction.

Experimental studies of the polarisation of photoelectrons that are produced by circularly polarised radiation are hampered by the fact that most atoms have their ionisation thresholds in the VUV where conventional methods for producing circularly polarised radiation of high intensity break down. Such experiments can, however, be performed with the radiation emitted by a synchrotron into directions above and below the plane of the electron beam, since this radiation contains a large fraction of circular polarisation. The experiment described in the present letter has been made with the 2·5 GeV synchrotron at Bonn.

A schematic diagram of the apparatus is shown in figure 1. A 10 m normal-incidence monochromator with a plane holographic grating (4960 lines/mm) and a concave mirror which produces an image of the electron beam in the exit slit has been built. The radiation coming from the electron beam (within an accepted horizontal angle of 20 mrad) is cut off in the vertical direction by an aperture which is able to move up and down for selecting radiation of left- or right-circular polarisation. The resolution of the monochromator depends on the size of the electron beam and of the exit slit: the bandwidth of the radiation coming through the 1·5 mm exit slit has been measured to be 0·05 nm using a second VUV monochromator for calibration. The 10 m monochromator covers a wavelength range of 40 to 180 nm.

The intensity of the polarised radiation behind the exit slit has been estimated from the photoelectron intensities measured to be more than 2×10^9 photons/s for wavelengths between 50 and 120 nm at a synchrotron current of 40 mA and an energy of 800 MeV. The radiation passes through the atomic beam and is analysed by a rotatable linear analyser (successive reflection from four gold mirrors under angles of 60°) shown in figure 1. The measured wavelength dependence of the circular polarisation (Heinzmann 1977) of the radiation emitted into an angular range from 1 to 3·5 mrad vertical with respect to the synchrotron plane is shown in figure 2. Because the analyser cannot distinguish between circular and unpolarised radiation, in an additional measurement the fraction of the unpolarised background radiation has been measured to be smaller than 1%. In this measurement an additional MgF_2 quarter-wave plate described by Heinzmann (1977) has been used to transform the elliptical polarisation into a linear one which is analysed by the four-mirror arrangement. By this measurement the analysing power of the analyser has also been determined to be higher than 99%.

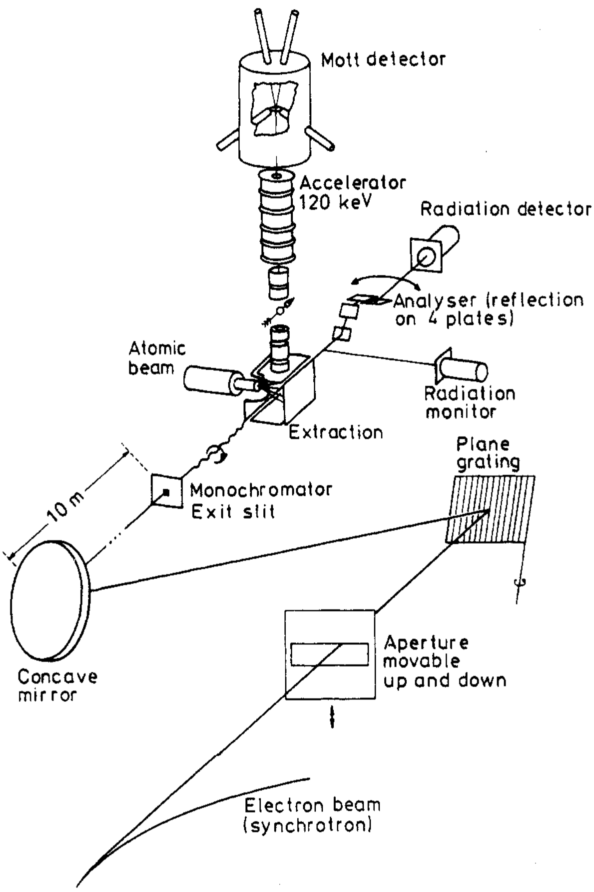

Figure 1. Schematic diagram of the apparatus.

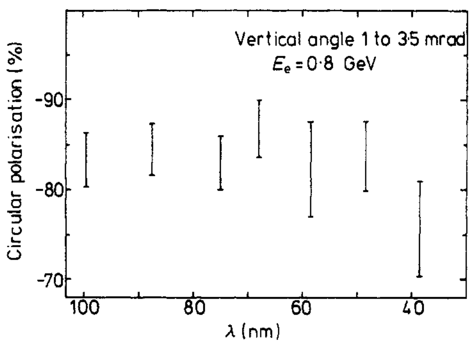

Figure 2. Measured degree of circular polarisation of radiation emitted into an angular range from 1 to 3·5 mrad vertical with respect to the synchrotron plane.

The photoelectrons produced were extracted by an electric field described by Heinzmann (1978), focused by electron optical components and accelerated to 120 keV for polarisation analysis in a Mott detector (Kessler 1976, Heinzmann 1978).

The experimental results are shown in figure 3. The pronounced resonance structure to be seen in the upper part is due to autoionisation processes between the first and the second ionisation threshold (102·2 nm and 92·2 nm) which correspond to the states $^2P_{3/2}$ and $^2P_{1/2}$ of the residual xenon ion. The full curve in the upper part of figure 3, which represents the photoelectron intensity measured with our apparatus, indicates that the used bandwidth of 0·05 nm suffices to make visible the structure even of the narrow resonances. The electron intensity is not exactly proportional to the photoionisation cross section, because light and atomic-beam intensity were not strictly constant in time. Nevertheless the positions of the peaks and the structures observed are in good agreement with the cross section measured by Huffman *et al* (1963) and Saile (1976).

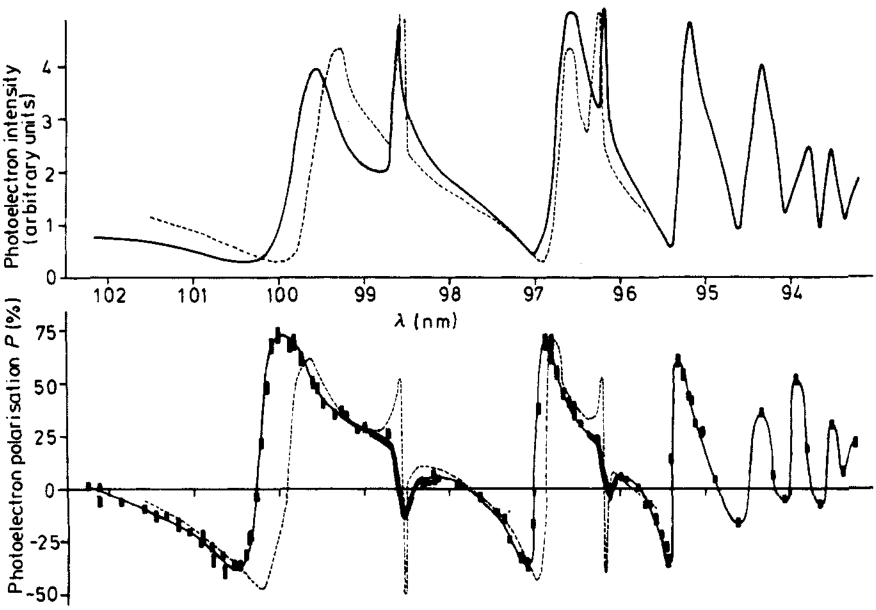

Figure 3. Photoionisation of xenon atoms in the autoionisation range. Upper part: cross section, photoelectron intensity; lower part: spin polarisation of photoelectrons; full curve: experimental results; broken curve: theoretical prediction by Lee (1974).

In the lower part of figure 3 the measured polarisation data are shown as black rectangles; they are connected by a full curve to guide the eye. The base of each rectangle is the bandwidth of the radiation used and the height represents the error bar of the polarisation including the uncertainties of light-polarisation and spin-polarisation analysis (single statistical error). The measured spin polarisation shows a pronounced resonance structure as predicted by Lee (1974) (broken curve). There are some discrepancies between Lee's prediction and our measured values in the positions of the broad resonances, e.g. at 100 nm, which can also be seen in the cross section and the angular distribution parameter β measured by Samson and Gardner (1973). It may be worth noting here that cross section, angular distribution and spin polarisation measurements complement each other as pointed out by Lee (1974); the assumption of Kabachnik and Sazhina (1976) that the autoionisation processes are fully parametrised by the cross section and the angular distribution alone is only valid for some simple cases (isolated resonance, no spin–orbit interaction) and thus not for xenon atoms (Geiger 1977, Heinzmann 1979).

The shapes of the narrow polarisation resonances are shown in figure 4 using a broader wavelength scale. Figure 5 shows the measured spin polarisation beyond the second threshold between 92 and 45 nm where the cross section drops monotonously

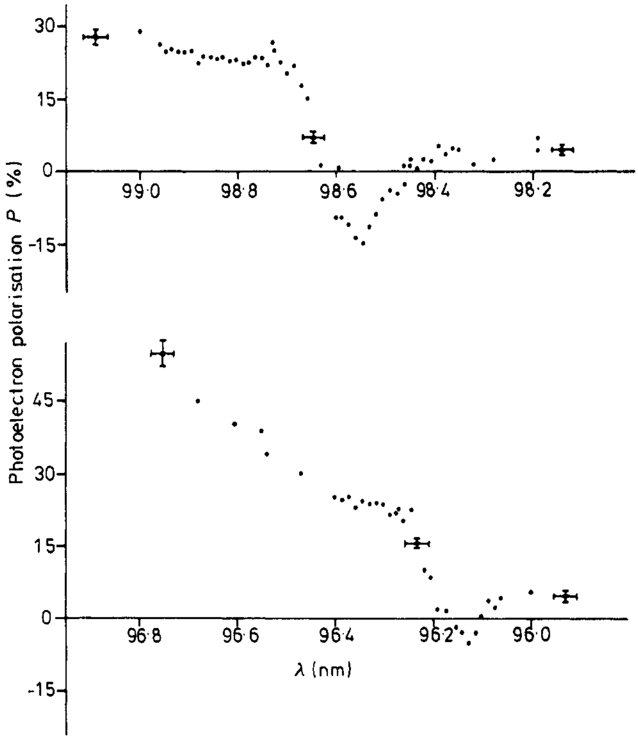

Figure 4. Measured spin polarisation at the narrow resonances. Typical error bars are indicated at a few points only.

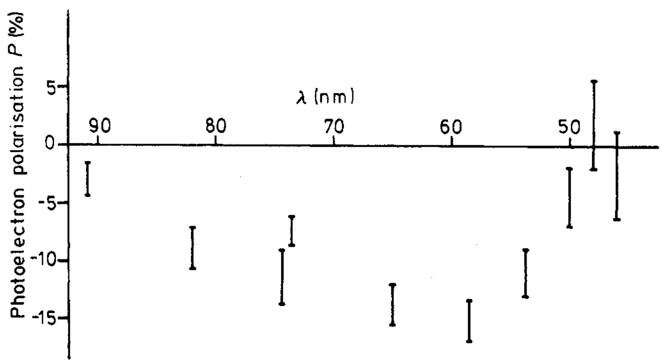

Figure 5. Measured spin polarisation beyond the second ionisation threshold.

(Huffman *et al* 1963). Here photoelectrons corresponding to the two residual ionic states were obtained so that the results are mean values for both kinds of electrons which have polarisations of opposite sign as pointed out by Cherepkov (1974). The fact that the mean polarisation is different from zero shows that spin–orbit interaction in the continuum has an appreciable influence (Fano 1969, Cherepkov 1974). The present data are being used to determine the parameters by which the photoionisation process is described on the basis of the multichannel quantum defect theory (Heinzmann 1979).

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