INVESTIGATION ON DOUBLE CRYSTAL ARRANGEMENTS FOR X-RAY PLASMA SPECTROSCOPY

U. Schumacher, H.W. Morsi*, H. Röhr

Max-Planck Institut für Plasmaphysik, EURATOM Association,
D-8046 Garching bei München, Fed. Rep. of Germany

Abstract

For the application of double crystal monochromators to X-ray plasma spectroscopy several investigations of important components were performed. Results are given for the measurements of the spatial dependence of double crystal reflectivities (for optimum photon throughput) and rocking curve widths of suitable crystals (which determine the spectral resolution), for the experimental determination of the dispersion and resolution of the swivelled double crystal device (for continuous spatial scan application), for the test of the gridded collimators, and for the development of the absolutely calibrated large-area X-ray source.

1. Introduction

The application of double crystal monochromators (with flat crystals) for the spectroscopy of fusion plasmas as proposed for JET [1] is attractive, because it offers a fast continuous scan over a wide spectral range and hence the deduction of important plasma properties from absolute line intensities and spectral line profiles. Since for the double crystal monochromator in parallel mode the detector location is fixed for all wavelengths, the instrument can be effectively shielded against neutrons and hard X-rays (see fig. 1). If the crystal which is nearer to the plasma is allowed to rotate additionally around the axis parallel to the beam between both crystals one obtains a continuous spatial scan of one spectral line within a relatively short time interval [1].

2. Measurements of crystal properties

For maximum throughput of the double crystal monochromator the Bragg reflection condition must hold simultaneously for both crystals with high reflectance homogeneity over the crystal surfaces. For commercially available crystals there are limitations due to misorientations within large natural crystals (as LiF220) or by lattice bending and anisotropies of inadequately surface-treated perfect crystals [2]. In the soft X-ray wavelength range from about 0.1 to 2.5 nm several crystals offer high flexibility of the double crystal monochromator with respect to spectral resolution, photon throughput and mechanical accuracy. These properties can be optimized by appropriate surface treating. An example of the spatial dependence of double crystal reflectivity of the natural crystal topaz (303) is given in fig. 2.

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* presently at JET, Abingdon, Oxfordshire, England

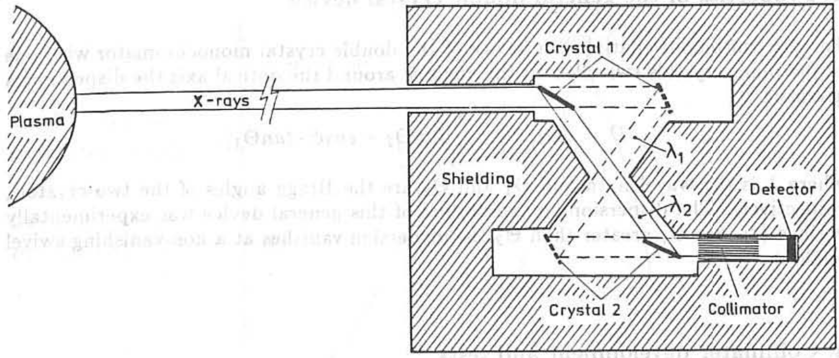
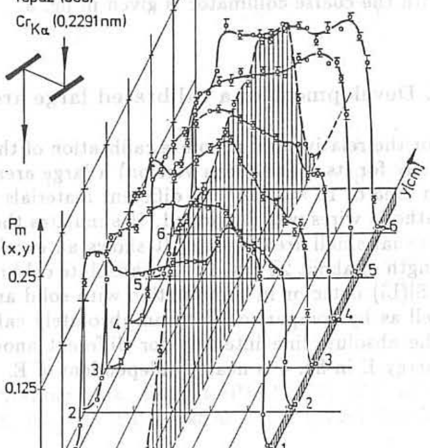


Fig. 1. Shielded double crystal monochromator scheme

Fig. 2. Spatial dependence of double crystal reflectivity of topaz (303) [2]



3. Properties of the general double crystal device

For the continuous spatial scan device of the double crystal monochromator with one of the plane crystals swivelled by the angle Ψ around the optical axis the dispersion is given by

$$D = d\Theta_2/d\lambda = \frac{1}{\lambda}[tan\Theta_2 - cos\psi \cdot tan\Theta_1],$$

where λ is the wavelength and Θ_1 and Θ_2 are the Bragg angles of the two crystals, respectively. The dispersion and resolution of this general device was experimentally verified [3]. For Θ_1 greater than Θ_2 the dispersion vanishes at a non-vanishing swivel angle ψ.

4. Collimator development and tests

In order to reach a certain spectral resolution with the double crystal monochromator (in its non-dispersive mode as given in fig. 1), which is necessary for spectral line separation and line profile measurements, two different grid collimators were developed and tested, a coarse collimator with a resolution of about 600 and a fine collimator with about 5000 resolution. The alignment of the fine grids in a double-T frame is performed by a combination of a Moiré-pattern observation with a precise alignment telescope [4]. An example of the CuK_α spectrum of the double crystal device of fig. 1 with the coarse collimator is given in fig. 3.

5. Development of a calibrated large area X-ray source

For the relative and absolute calibration of the double-crystal monochromators (especially for its spatial-scan version) a large area X-ray source with a massive anode (of an area of $10 \times 30cm^2$) of different materials and 5 parallel, thin Au-coated tungsten cathode wires was developed. It simulates the large plasma X-ray source better than a usual small area source. It shows an excellent homogeneity of its emission over a length of about 24 cm [4]. The absolute calibration was done by photon counting with a Si(Li) detector in combination with solid angle and aperture area determination as well as by comparison with an absolutely calibrated ^{55}Fe source (emitting MnK_α). The absolute line intensity for different anode materials plotted versus the photon energy E in fig. 4 is nearly independent of E.

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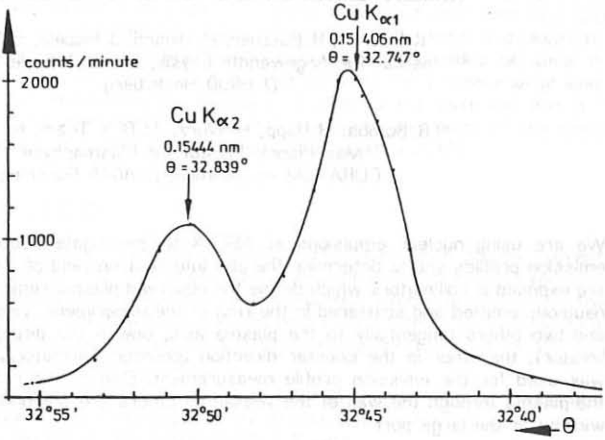

Fig. 3. Example of a Cu K_α spectrum obtained with the double crystal monochromator

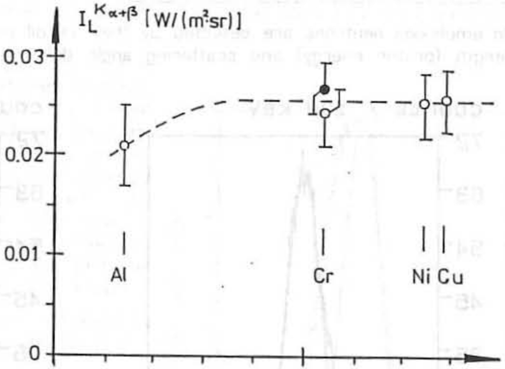

Fig. 4. Absolute K_α line intensities for different anode materials of the large area X-ray source versus the photon energy E

References

/1/ W. Engelhardt et al., MPI für Plasmaphysik, Report IPP 1/212, IPP III/81, Garching 1982; C. Andelfinger, et al., Reports IPP 1/225 and IPP 1/226, Garching 1984.

/2/ U. Schumacher, Nucl. Instr. and Meth. in Phys. Res. A251, 564 (1986).

/3/ U. Schumacher, to be published.

/4/ J. Fink, H.W. Morsi, H. Röhr, U. Schumacher, Report IPP 1/240 (1987).