FLUORESCENCE EXCITATION OF ULTRA- SOFT X-RAY EMISSION SPECTRA USING SYNCHROTRON RADIATION

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Résumé. — Nous avons utilisé le rayonnement synchrotron du synchrotron à électrons DESY de 7,5 GeV pour tenter d'exciter la fluorescence des spectres d'émission des rayons X ultramous. Nous avons pu réduire le bruit de fond très intense produit par le rayonnement diffusé de courte longueur d'onde suffisamment pour pouvoir observer les bandes d'émission *K* du carbone (45 Å), du bore (67 Å) et du beryllium (114 Å). Les résultats sont comparés aux données obtenues par excitation électronique.

Abstract. — Attemps have been made to use the synchrotron radiation of the 7.5 GeV electron synchrotron DESY for the fluorescence excitation of ultra-soft X-ray emission spectra. The very intense background produced by the scattered radiation of short wavelengths could be reduced so that it was possible to observe the *K* emission bands of carbon (45 Å), boron (67 Å) and beryllium (114 Å). The results are compared with data obtained by electron excitation.

Introduction. — In studies of ultra-soft X-ray emission spectra one is compelled so far to use primary excitation for reasons of intensity, if high resolution is required. However, many substances cannot be investigated with this kind of excitation, because they decompose under the influence of the electron bombardment. Distortions by chemical conversion must be expected particularly in the region of ultra-soft X-rays, since only a very thin surface layer of the substance contributes to the intensity of the emitted radiation.

Fluorescence excitation of ultra-soft X-ray emission spectra should be possible with the synchrotron radiation which has higher intensity between 20 and 200 Å than any other known continuous radiation. In the following we report on attempts to excite ultra-soft X-ray emission bands using the synchrotron radiation of the Deutsches Elektronen-Synchrotron DESY, Hamburg.

Experimental arrangement. — The measurements were performed using a 2 m grazing incidence concave grating spectrometer [1] with photoelectric registration. Blazed gratings with 1 200 and 2 400 lines/mm were used. The resolution was 0.15 Å. The detector is a continuous dynode electron multiplier with thin layers of carbon as dynodes [2]. The spectra were recorded by scanning in steps. Because of the fluctuations in intensity of the synchrotron radiation a monitor system was used.

A great experimental problem is the strong scattered radiation of short wavelengths which is due to the fact that the continuum of the synchrotron radiation extends into the region of hard X-rays if the accelerator works at energies above 3 GeV (Fig. 1). In the course

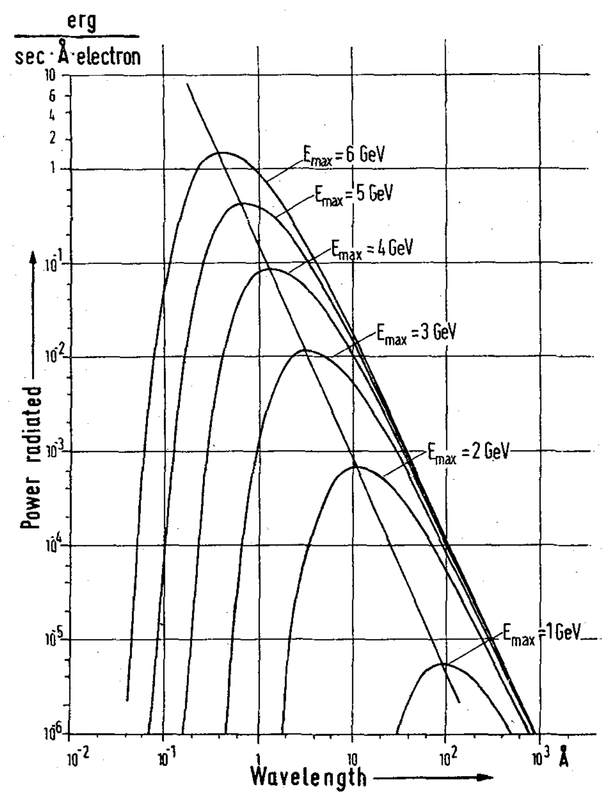

FIG. 1. — Power radiated as a function of wavelength, after ref. [3].

of the experiments the synchrotron was frequently operated at energies up to 7.5 GeV. As can be extrapolated from the curves in figure 1 the power radiated at 7.5 GeV has a maximum at about 0.2 Å and an intensity at this wavelength which is by a factor of 10^4 higher than at 40 Å.

The very intense background due to the scattered radiation could be reduced to less than 100 counts/min — if the synchrotron is operated at 6 to 7.5 GeV and about 10 mA — by careful shielding of the sample and the detector, and by an electronic gate opening the monitor and counting channel only during the acceleration time necessary to give the electrons an energy of 4.5 GeV.

Results and discussion. — The results of preliminary measurements of the *K*-emission band of carbon (graphite), boron, and beryllium are shown in figures 2-4. The position of the detector was changed automatically every 5 min ; the intensities measured at each point are plotted as circles. In the case of carbon the synchrotron was operated at 4.0 GeV and 4.5 mA, in the case of boron and beryllium at 6.5 GeV and 10 mA. — For comparison the emission bands obtained by primary excitation [4], [5] are shown as solid lines, the curves being normalized in height to give good matching.

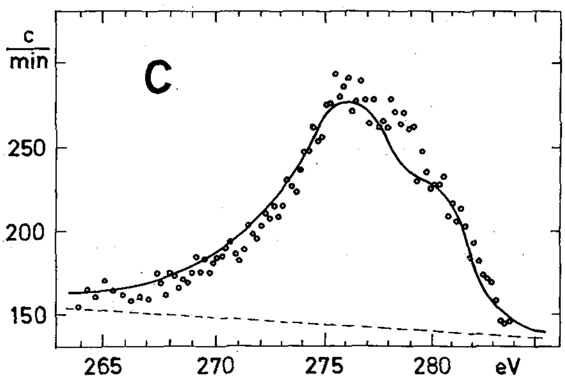

FIG. 2. — C *K*-emission band of graphite ; circles : fluorescence excitation, solid line : primary excitation.

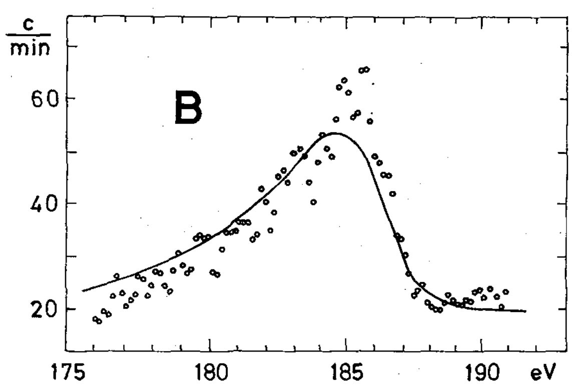

FIG. 3. — B *K*-emission band of boron ; circles : fluorescence excitation (cryst. B), solid line : primary excitation (evaporated B), after ref. [4].

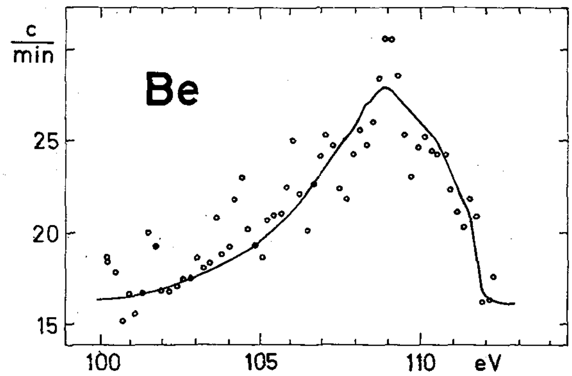

FIG. 4. — Be *K*-emission band of metallic beryllium ; circles : fluorescence excitation, solid line : primary excitation, after ref. [5].

Due to the low counting rates, the statistics are rather poor, especially in the case of boron and beryllium ; however, the pronounced asymmetry of the intensity distribution of both emission bands is established.

The decrease of the intensity of the bands from graphite to beryllium is partly due to the decreasing fluorescence yield, mainly however to the fact that the intensity of the synchrotron radiation rapidly decreases with increasing wavelength. One has to remember that only radiation of wavelengths somewhat shorter than the wavelength of the absorption edge contributes effectively to the fluorescence excitation.

It should be emphasized that the experiments were performed under conditions — high electron energies, low currents — which were not very favourable. As figure 1 shows an increase of the electron energy above 3 GeV increases the intensity of the synchrotron radiation in the wavelength region above 10 Å only very little, but much so in the region of the hard X-rays giving rise to the disturbing background. Optimal conditions would be energies of about 3 GeV and currents as high as possible.

The experiences made in the course of these experiments have shown, that improvements in several directions are possible. Recently two spherical mirrors were mounted symmetrically to the synchrotron beam to focus the radiation onto the sample, the average angle of reflection being 88.5°. A gain in intensity of the emission bands by a factor of about 10 was obtained. Changes in the spectroscopic arrangement will bring a further increase of intensity.

A decisive progress can be expected when the new linear accelerator for injection into the synchrotron and the storage ring of DESY will be in operation.

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DISCUSSION

M. DAS GUPTA. — Is it advisable to increase the size of the sample to gain in intensity. Self absorption at glancing angle will be large.

M. FESER. — The effective size of the sample is 0.2 mm × 1 cm.

M. WIECH. — It seems not opportune to enlargen the size of the specimen and to take off the radiation under investigation at a very small angle because the intensity again will be decreased by self absorption.