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Second order reflection from crystals used in soft X-ray spectroscopy

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Abstract. In this note the ratio of the second to the first order reflection is determined for the KAP and PbSt crystals, for wavelengths corresponding to the Al K-line emission. The source of the radiation was a low-voltage stabilized X-ray tube. The X-rays were detected with a Bragg spectrometer equipped with a proportional counter detector. The signal measured by the proportional counter was subsequently pulse height analyzed.

Key words: soft X-ray • plasma spectroscopy • PbSt • KAP

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Introduction

One of the typical problems in the optical spectroscopy is the second order reflection by the diffraction gratings. In order to avoid these unwanted signals optical filters are usually applied.

In the X-ray spectroscopy this problem is usually ignored as it is usually assumed that higher order reflections are negligible. In many cases one can also assume that the radiation in the lower wavelength (higher energy) is not emitted by the laboratory source or that the intensity of this radiation is very low.

In the case when the detector of the X-ray radiation utilized in the spectroscopic system is energy sensitive, the high energy (second order component) can be subtracted by the analysis of the pulse height spectrum.

However, in high temperature fusion plasma the high energy electromagnetic radiation can be of a very high intensity – either as a result of plasma processes or a result of interaction of the plasma heating systems with the plasma. In such cases the fluxes of short electromagnetic radiation can be so large that they may change the dynamic properties and the dynamic range of the detector.

For soft X-ray spectroscopy the organic crystals – such as acid phtalate (KAP, TlAP) or lead stearate (PbSt) – are commonly used [1, 2].

Experimental setup

In order to perform the tests, the Bragg (flat crystal) spectrometer (former C/O monitor for the W7-AS) combined with a low-voltage X-ray tube was used

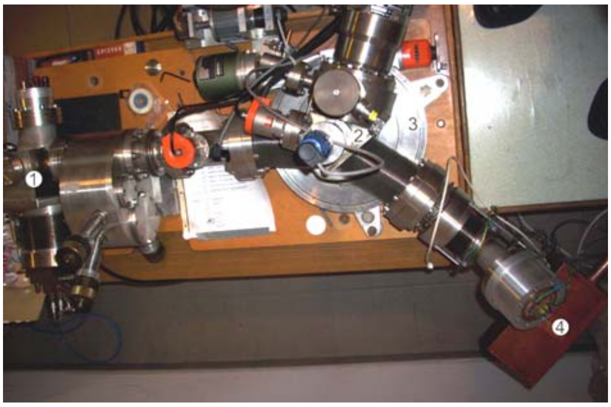

Fig. 1. The experimental setup: 1) an X-ray tube; 2) a crystal housing; 3) a goniometer; 4) a detector (proportional counter).

(Fig. 1). The special construction of the anode of the X-ray tube allowed for an easy switch between three different anodes, and this in turn allowed to observe intense X-ray radiation associated with the K and L transitions in the elements present in the material of anodes. The spectrometer was equipped with a standard proportional counter associated with a typical signal processing system consisting of the following elements: a preamplifier, a shaping amplifier, a discriminator and a counter. In order to improve the quality of the measurements, after the initial amplification the signal was simultaneously analyzed using a digital pulse processor working in the pulse height analyzer mode.

Pulse height spectra

The energy resolution of the proportional counter is rather poor, usually close to 30%. The spectral resolution of the system is determined mainly by the applied crystal and its properties as well as by the angular resolution of the system.

In order to study the second order reflection, measurements were performed by setting the spectrometer for the Bragg angle relevant for the first, and then for the second order of reflection of the selected line (see Table 1). The pulse height spectra were determined by measuring the reflected radiation during the time interval of 300 s. Pulses corresponding to the line under study (Fig. 2) were integrated (in pulse height domain), which allowed for a reconstruction of spectra, such as those presented in Fig. 3. The total intensity of the radiation was determined by the integration of the signal within the range of the pulse height corresponding to the X-ray line under study. The X-ray tube current was 1 mA.

For inorganic crystals such as Si and Ge the signals registered at angles corresponding to the sec-

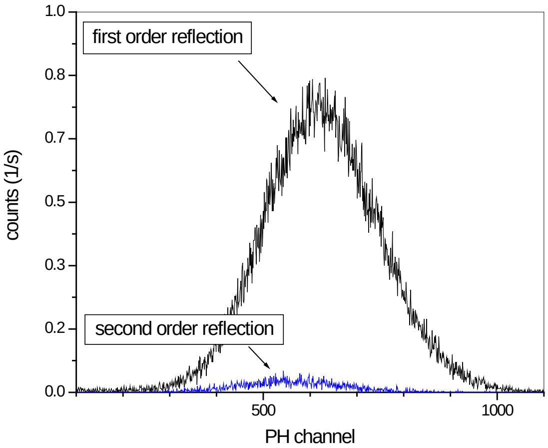

Fig. 2. A sample of the pulse height spectra.

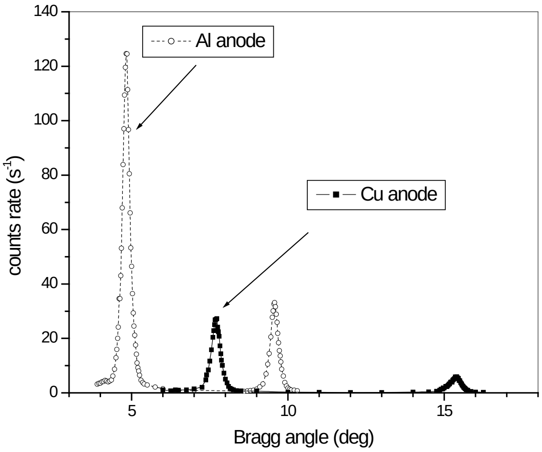

Fig. 3. A sample of the Bragg spectra.

Table 1. Lines of X-ray characteristic

Anode	Line	Energy [eV]	Wavelength [nm]
Al	$K_{\alpha1}$	1486.70	0.8340
Al	$K_{\alpha2}$	1486.27	0.8342
Cu	$K_{\alpha1}$	8047.78	0.1541
Cu	$K_{\alpha2}$	8027.83	0.1544
Cu	K_{β}	8905.29	0.1392
Cu	$L_{\alpha1,\alpha2}$	929.70	1.3336
Cu	L_{β}	949.80	1.3054

Table 2. The ratios of the registered signals

	Al K-line (1.5 keV; 0.8 nm)	Cu L-line (0.9 keV; 1.3 nm)
KAP (2d = 2.7 nm)	0.030 ± 0.002	–
PbSt (2d = 10.0 nm)	0.260 ± 0.020	0.28 ± 0.02

ond order of reflection were negligible. For organic crystals such as KAP and PbSt a much more intense signal was registered. The determined ratios of the signals are listed in Table 2.

Summary and conclusions

The obtained results are in agreement with the data presented in [1, 3, 4]. This investigation was devoted to the determination of the ratio of the second to first order reflection. It turned out that the accuracy of the obtained result is quite satisfactory and it is much better than for the results reported in e.g. [1]. By applying the pulse height analysis one can improve the accuracy by selecting only the pulses associated with the line under study.

The obtained results show that in the soft X-ray spectroscopic measurements of high-temperature plasmas, performed with the use of organic crystals as dispersive elements, one needs to take into account the effect of the second order interference. This observation should be important for the design of diagnostic systems as well as for the interpretation of the obtained results. This effect can be especially important for spectrometers equipped with proportional counters fixed at their positions, but with lengths sufficiently large to record the radiation reflected at different wavelengths, such as e.g. Bragg-rotor spectrometer (KS6) being used at JET.

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