The Yoneda effect in the region of ultrasoft x-ray emission

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(Submitted 25 July 1990; resubmitted 25 August 1990)
Pis'ma Zh. Eksp. Teor. Fiz. **52**, No. 7, 1005–1007 (10 October 1990)

The presence of the Yoneda effect in the region of ultrasoft x-ray emission has been verified experimentally. The angular distribution of the scattered radiation of the various wavelengths of a hexagonal boron nitride has been studied at various grazing incidence angles.

The anomalous scattering of x-rays (the Yoneda effect) was initially observed by Yoneda[1] and has until now been studied both experimentally[2–4] and theoretically.[3,5–7] It should be emphasized that all experimental studies were carried out in the region of hard radiation.

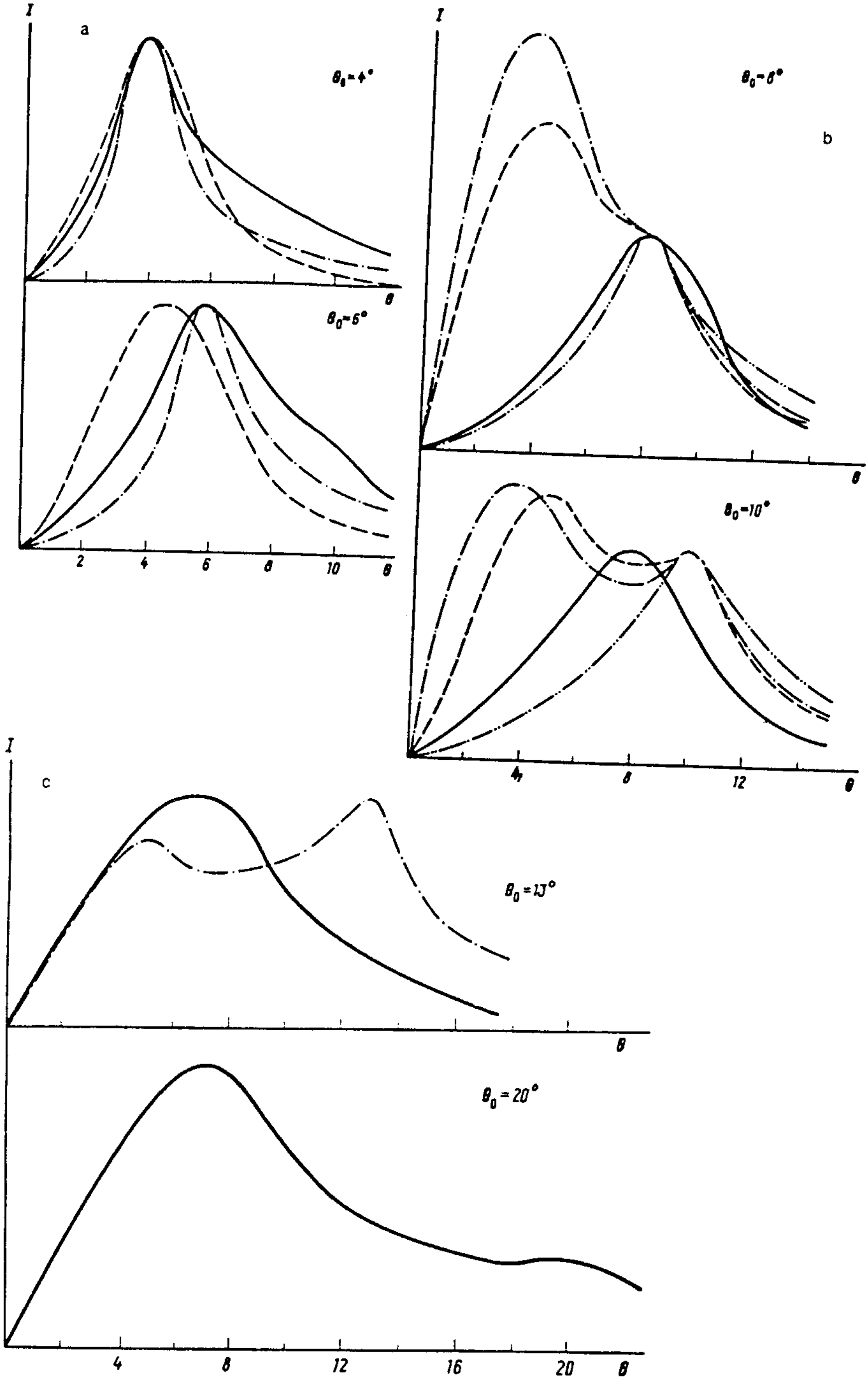

FIG. 1. The angular distribution of scattered radiation for $BN_{\rm hex}$. Dot–dashed line—$\lambda = 57.0$ Å; dashed line—$\lambda = 67.6$ Å; solid line—$\lambda = 104.5$ Å; undulating line—$\lambda = 161.6$ Å.

The Yoneda effect involves the appearance of an additional maximum in the angular distribution of scattered radiation (the scattering indicatrix) at grazing angles θ_0 of the incident radiation greater than the critical angle θ_c of the total external reflection. The angular position of this maximum is near the critical angle θ_c.

In the present experimental study we have attempted to detect the Yoneda effect in the region of ultrasoft x-ray emission. We studied the angular distribution of the scattering of a pyrolytic BN_{hex}. The measurements were carried out in a special chamber which was attached to an RSM-500 x-ray spectrometer-monochromator,[8] in which the bremsstrahlung from the tungsten anode of the x-ray tube was used. As the radiation detector we used a VEU-6 channel multiplier with a cesium photocathode, in front of which we established a 1.6-mm-wide gap which provided an angular resolution of 2.4°. We studied the angular distribution of scattered radiation from a face cut out parallel to the **c** axis of the crystal.

Figure 1 shows the angular distributions of scattered radiation obtained for grazing incidence angles $\theta_0 = 4$, 6, 8, 10, 13, and 20° and wavelengths $\lambda = 57.0$, 67.6, 104.5, and 161.6 Å. For clarity, all the angular distributions of scattered radiation were normalized to the intensity of the specular component of the reflection. As can be seen from the figure, the angular position of the maximum of the scattering indicatrix, which was obtained for a grazing incidence angle $\theta_0 = 4°$, corresponds to the specular reflection for all the wavelengths studied. An increase in the grazing incidence angle θ_0 leads to a gradual shift of the scattering indicatrix peak toward smaller angles (for $\lambda = 67.6$ Å, for example, the shift is observed at $\theta_0 = 6°$ and for $\lambda = 104.5$ Å it is observed at $\theta_0 = 10°$) and then to a splitting of the peak into two peaks. The angular position of one of the two peaks strictly corresponds to the reflection in the specular direction. The results which we obtained will be analyzed in detail in future papers. We will note, however, the principal characteristic features which we observed.

1. The anomalous scattering peak is situated at lower angles relative to the specular reflection angle.

2. The angular position of the anomalous scattering peak, virtually independent of the incidence angle, depends on the wavelength.

3. An increase in the incidence angle θ_0 leads to a transfer of the scattering intensity from the anomalous scattering peak to the specular reflection peak.

The systematic features we have observed prove that the Yoneda effect exists in the region of ultrasoft x-ray emission.

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Translated by S. J. Amoretty