

Investigation of Characteristics of EUV Backward Transition Radiation generated by 5.7 MeV Electrons in Mono- and Multilayer Targets

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INTRODUCTION

Transverse beam profile imaging based on the backward transition radiation (BTR) in the visible region is widely used in the modern accelerators. However, the recent results obtained at linear X-ray free electron lasers such as LCLS (USA), FLASH (Germany) and SACLA (Japan) showed that BTR based imaging in the visible region may fail due to a microbunching during the beam acceleration. The microbunched structure radiates coherently that makes the standard diagnostics impossible.

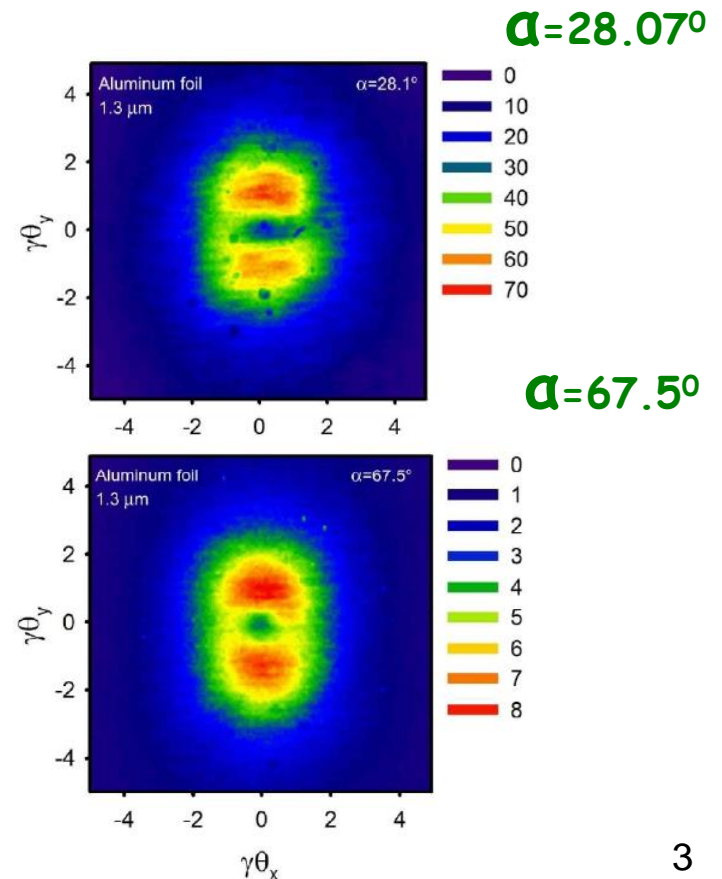
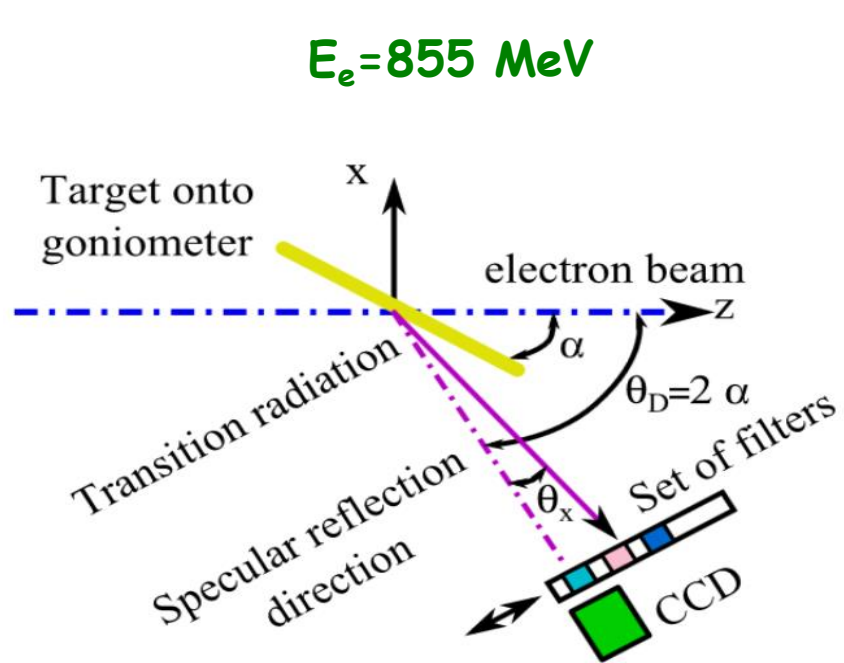
In order to overcome such a problem it was proposed to use BTR in the EUV region.

INTRODUCTION

Experiment with direct measure EUV BTR for beam diagnostic aims

L.G. Sukhikh, S.Yu. Gogolev, and A.P. Potylitsyn, Nucl. Instrum. Methods Phys. Res., Sect. A 623(1) (2010) 567

L.G. Sukhikh, D. Krambrich, G. Kube, W. Lauth, Yu.A. Popov, and A.P. Potylitsyn, SPIE Optics and Optoelectronics proceedings 8076, Prague, Czech Republic, p. 80760G-1 (2011).



INTRODUCTION

Next step - the experiment with using optic of multilayer spherical mirror to get image of electron beam

"BEAM PROFILE IMAGING BASED ON BACKWARD TRANSITION RADIATION IN THE EXTREME ULTRAVIOLET REGION" L.G. Sukhikh, S. Bajt, G. Kube, Yu.A. Popov, A.P. Potylitsyn

This paper about the results of the first beam profile imaging experiments using BTR in the EUV region.

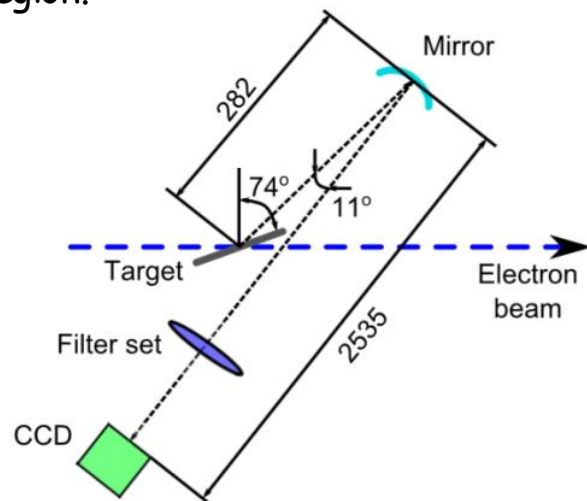
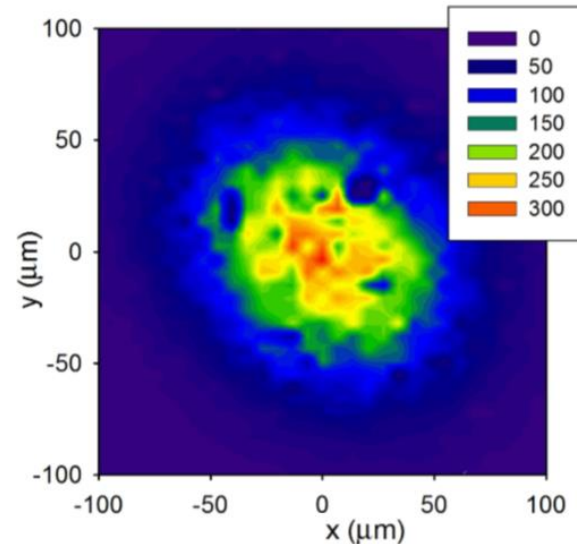


Figure 1: Experimental setup.



Beam image obtained in the EUV region.

$\alpha = 16^\circ$

One of the problems that appear for EUV BTR is a rather low light output that comes from the low reflection coefficients of the mono substance layer (monolayer) targets with increase indecent angle.

Therefore one of the ways to solve the problem is to change the monolayer target for the multilayer structure with appropriate spatial period that has better reflection coefficients at the geometries of interest.

Observation of PXR from multilayer X-Ray mirror in X-ray region

Indeed, now there are several experimental works, but for X-ray region, which was shown that the periodical structure of multilayer X-ray mirror can generate the quasi monochromatic X-ray radiation.

1. V. V. Kaplin, S. R. Uglov, V.N. Zabaev, M. A. Piestrup, C. K. Gary, and M. J. Fuller, "Observation of bright monochromatic x-rays generated by relativistic electrons in a multilayer mirror" Appl. Phys. Lett. 76, 3647-3649 (2000).

2 . V.V. Kaplin, V.V.Sohoreva, S. R. Uglov, A.A. Voronin, M. A. Piestrup, C. K. Gary, M. Fuller. // Nucl. Inst. and Meth. in Phys. Res. B. -2009. -V. 267. -C.777.

The properties this radiation similar on the parametric X-ray radiation (PXR) for crystals.

In this report we present the first results of observation experimental investigation of generation by multilayer target the radiation in the EUV region with 5.7 MeV electron beam.

Search of parametric radiation from EUV multilayer mirror

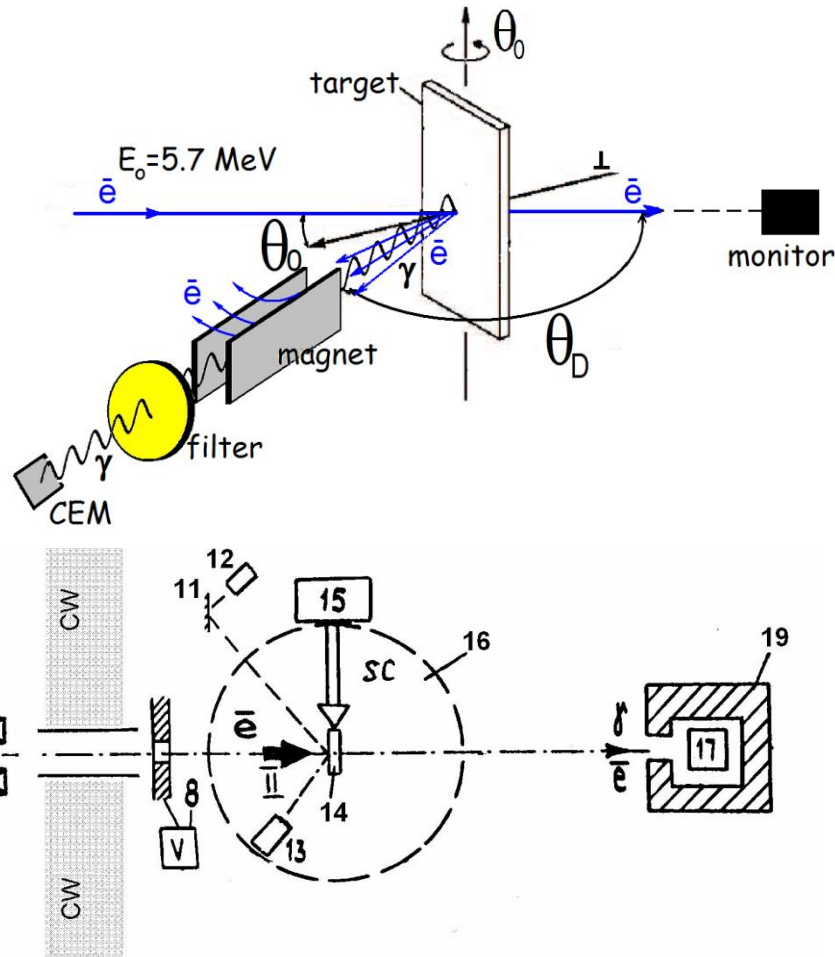
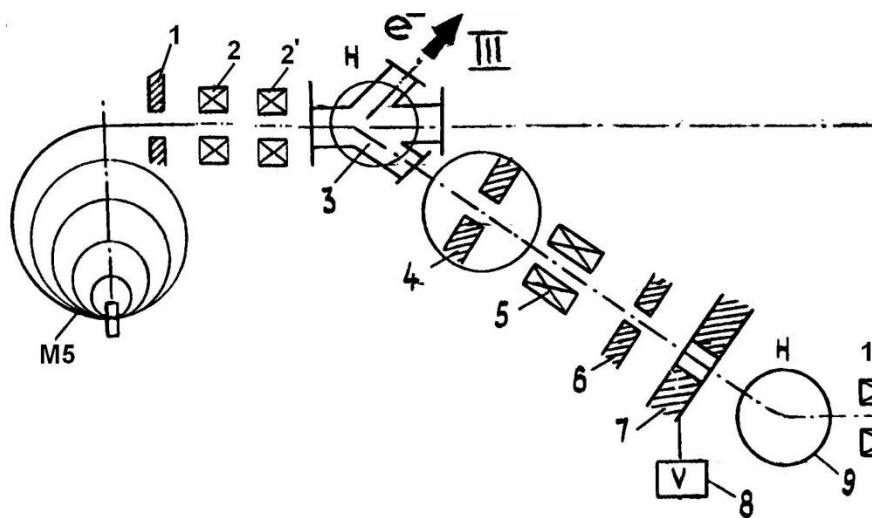
Experimental setup based on microtron M-5

Electron energy - 5.7 MeV

Repetition - 25 Hz,

Pulse duration - 0.4 μ s

Current on target - 4nC per pulse



Targets, Chamber and Detector

Multilayer target:

50 pairs of Mo/Si layers

$d = 11.32 \text{ nm}$

$d_{\text{Mo}} = 3.4 \text{ nm}$, $d_{\text{Si}} = 7.92 \text{ nm}$

Substrate is Si with $t = 530 \mu\text{m}$

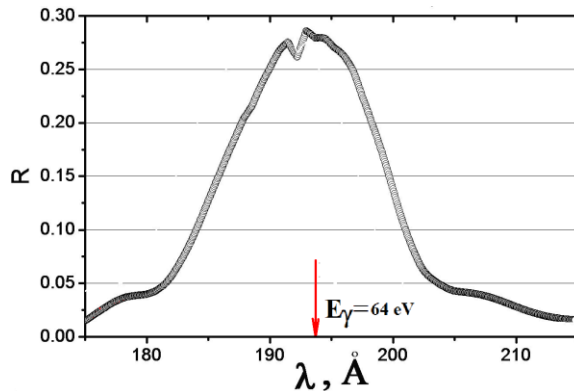
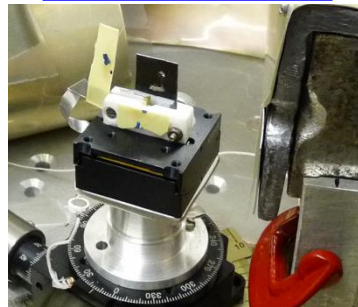


Fig.1. Reflectivity $-R$ of Mo/Si target for $\theta_0 = 22.5^\circ$

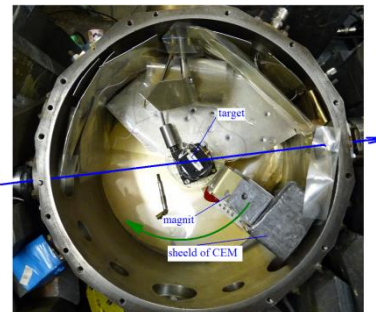
Single layer target:

Single Mo layer with $t = 50 \text{ nm}$
on Si substrate with $t = 680 \mu\text{m}$

Goniometer



Experimental chamber



Detector VUV

Channel electron multiplier (CEM)
Model - "SEM-6"

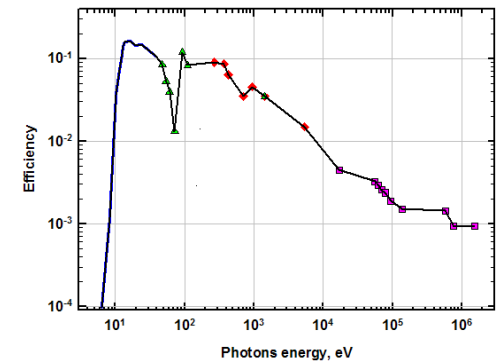


Fig. 2. Efficiency of CEM (VEU-6) detector [Ainbund M R and Polenov B V "Secondary electron multipliers and their use"]

ANGULAR DISTRIBUTIONS OF BACKWARD TRANSITION RADIATION (BTR)

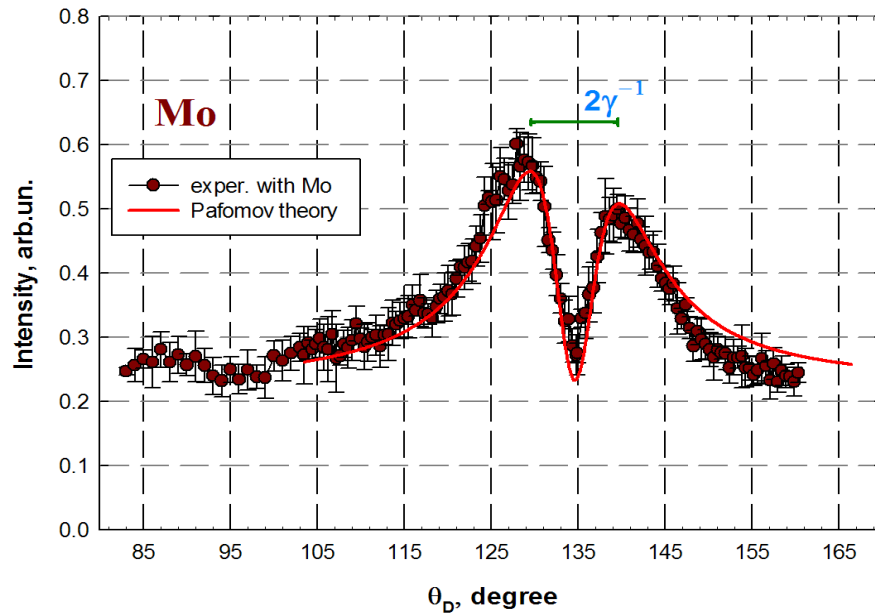


Fig.1. The angular distribution of radiation for silicon wafer coated with molybdenum and incidence angle $\theta_0=22.5^\circ$

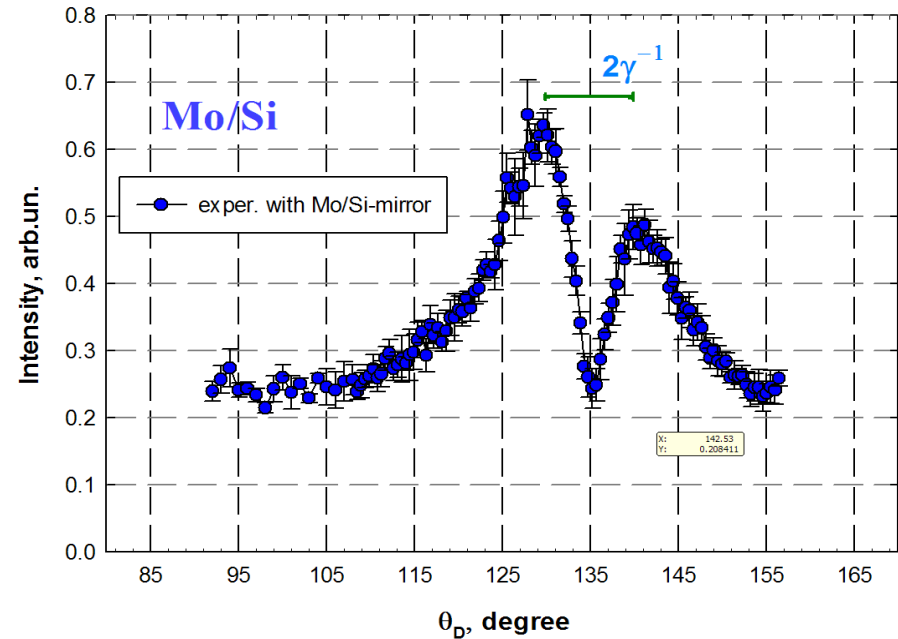


Fig.2. The angular distribution of the radiation for the multilayer Mo/Si structure and incidence angle $\theta_0=22.5^\circ$

On overcoming BTR contribution by thin Al filter

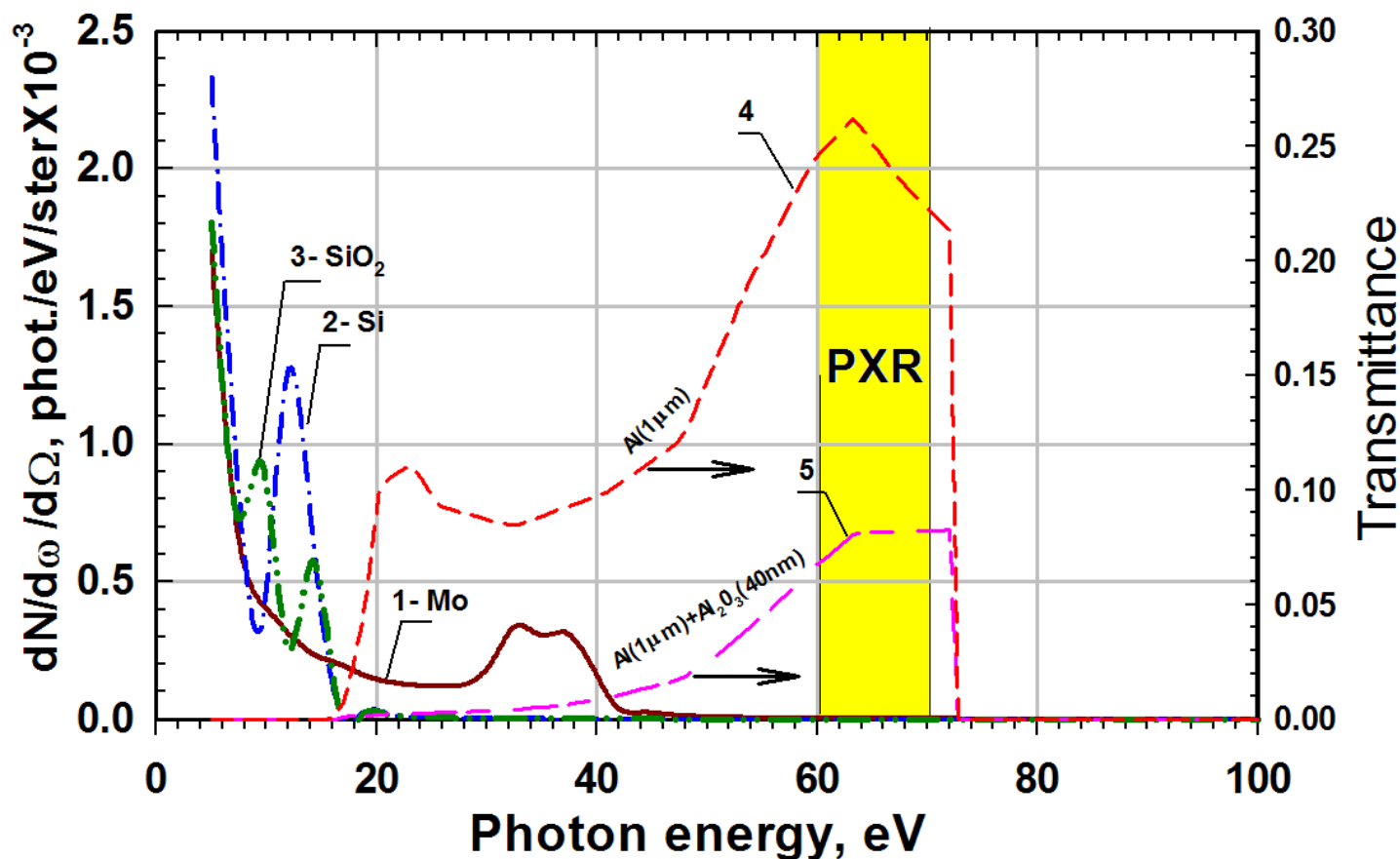


Fig.2. The spectral angular density BTR at the maximum of the angular distribution (marked by arrow in Fig. 1) for tree substance: Mo-line 1, Si - line 2, SiO₂ - Line 3. The curve 4 and 5 the transmittance of Al foil with thickness of 1 μm without and with Al₂O₃ ($t_{\text{Al}_2\text{O}_3} = 40\text{nm}$), -PXR region

The scans of angular distribution of radiation after passing through of 1 μ m Al foil

Observation Parametric radiation from X-ray mirror

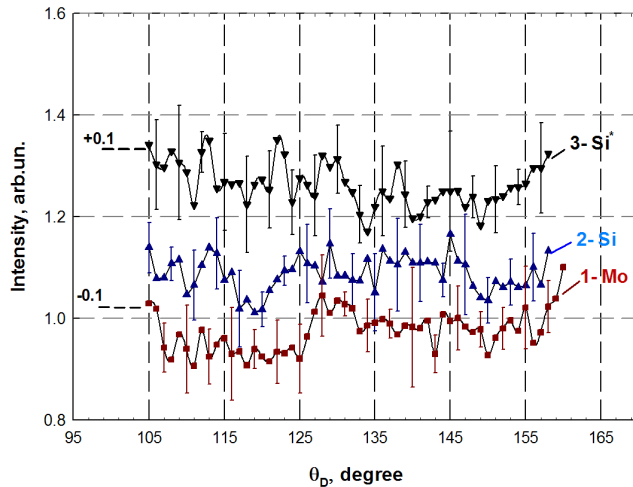


Fig. 1. The angular distribution of radiation from uniform targets after passing through of 1 μ m Al foil: 1-Molybdenum target, 2- polished Si, 3- unpolished Si

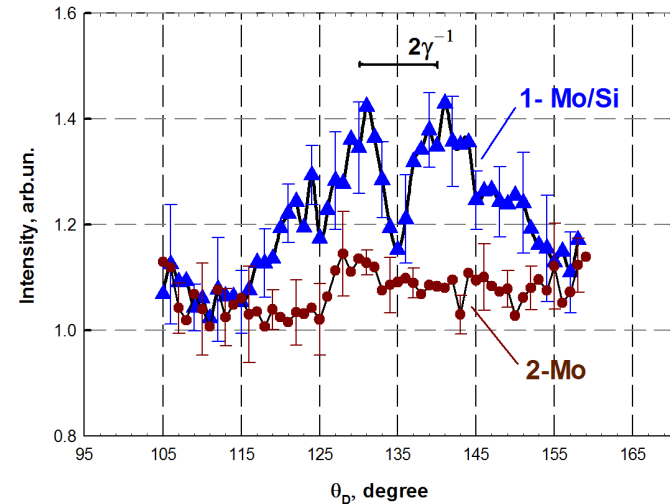


Fig.2. The angular distribution of radiation after passing through of 1 μ m Al foil:
1- radiation from multilayer Mo/Si mirror,
2- radiation from uniform Molybdenum target

HOW MUCH ?

Now we have not experimental data about the detector efficiency and transmittance of sample Al filter.

But if to take in to account the detector efficiency SEM-6 from book [1] and to calculate data transmittance of 1 μm Al filter[2] then the estimate of angular density of PX is about - $dN/d\Omega = 5.3 \times 10^{-4}$ ph./ster/e.

The angular density of PR from Nasonov's theory[3] is- $dN/d\Omega = 4.6 \times 10^{-4}$ ph./ster/e.

1. Ainbund M R and Polenov B V "Secondary electron multipliers and their use".
2. www.esrf.fr/computing/expg/subgroups/theory/DABAX/dabax.html.
3. Nasonov N., Kaplin V., Uglov S., Piestrup M., Gary C. // Phys. Rev. - 2003. - E 68. - P. 036504.

Conclusion

1. The experimental investigation of the radiation generated by electrons with an energy of 5.7 MeV in multilayer structures shown that the periodic structure of the target generated an additional contribution to the total intensity.
2. This value is in good agreement with calculations based on the Nasonov's theory. But it is necessary to measure detector efficiency.