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Experimental study of Z-pinch radiation spectra at the Angara-5-1 facility

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Abstract. The results of measuring the energy, power and spectrum of the soft X-ray radiation (SXR) pulse at the Angara-5-1 facility in the photon energy range of 0.02 – 2 kV are presented. A comparison of the SXR emitted in axial and radial directions is presented.

This paper presents the results of measuring the energy, power and spectrum of the soft X-ray radiation (SXR) pulse in the photon energy range of 0.02 – 2 kV, observed in the powerful Z-pinch in axial and radial directions. The data was obtained by analyzing the implosions of cylinders (1.2 cm in diameter and 1.6 cm high) composed of 6 μm-diameter tungsten wires with linear mass of 220 μg/cm at the Angara-5-1 facility in the range of the discharge current of 2.2 – 3 MA.

Two sets of vacuum X-ray diode (VXRD) sensors were used to measure temporal profile of the SXR radiation power as well as to reconstruct spectral features of powerful Z-pinch radiation in axial and radial direction. The radial set consisted of 4 VXRDs placed behind various filters while the axial one consisted of 3 VXRDs behind the same filters. Spectral range of each VXRD sensor was determined by quantum efficiency curve of the photocathode used and by spectral dependence of transmission factor of the set of filters made from different materials [1].

The spectral characteristics of the SXR radiation source during implosion of the Z-pinch based on the tungsten (wolfram) cylindrical wire liners (W-CWL) also was studied using the diffraction grazing incidence spectrometer (DGIS) with the off-Rowland circle registration scheme of spectrum registration. Figure 1 shows the optical scheme of the DGIS:

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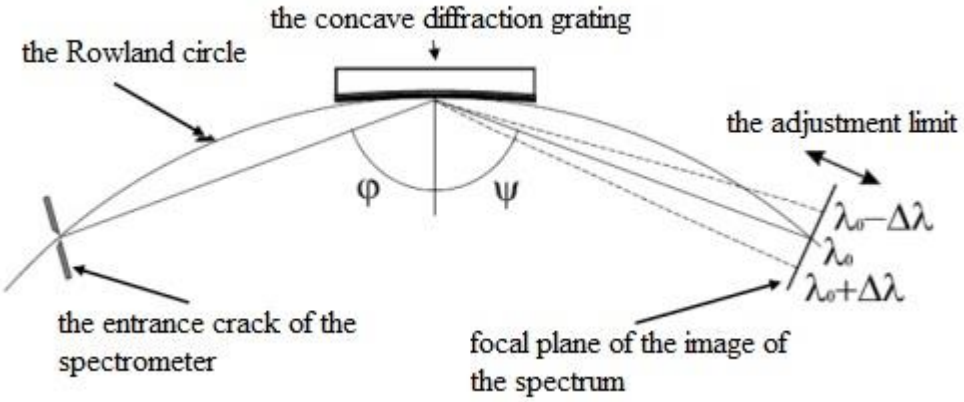

Figure 1. Optical scheme of the diffraction grazing incidence spectrometer (DGIS) with the off-Rowland circle scheme of spectrum registration (φ- angle of incidence of the studied X-ray flux on the concave diffraction grating; ψ- the diffraction angle of the x-rays of a wavelength λ_0; $\Delta\lambda$ - the wavelength range of the spectrum registration.

The high power and spectral brightness of the SXR radiation source makes it possible to register the spectra with a spatial resolution on the UV-4 X-ray film using the DGIS located inside the vacuum chamber at a distance of 1.5 m from the source. To reduce the detector illumination background signal we provided a shielding of the spectrometer and detector elements using the collimators and the lead shields of 1 - 2.5 cm thickness.

Experimental data on the temporal profiles of the SXR radiation pulse power, during implosion of the W-CWL, in the following ranges of photon energy, 20 - 70 eV, 70 - 300 eV, 300 - 1500 eV, as well as the spectrum-integrated power, were recorded by the sets of the VXRD sets) in the radial and axial directions of observation. These data allow to solve the inverse problem of recovering the spectral power of the SXR radiation at any time instant [2].

Figure 2 shows the dependence of an average spectral energy density (SED) of the SXR radiation of the W-CWL Z-pinch on the energy of photon emitted in the radial and axial directions.

These dependencies show that the radiation of the Z-pinch plasma for the given load (W-CWL: 12 mm diameter multiwire array of the forty W 6 μm diameter wires) in the radial direction is harder than that in the axial one. I.e., in the radial direction the main part of energy is emitted in the range of 70 – 300 eV, whereas in the axial direction the energy is distributed more uniformly, in the ranges of 20 - 70 eV and 70 – 300 eV.

Thus, the intensity distribution of the cylindrical Z-pinch source of the SXR-radiation is isotropic in height and azimuthal angle, and spectrum of the radiation in the axial direction corresponds to a softer spectrum compared to that in the radial direction.

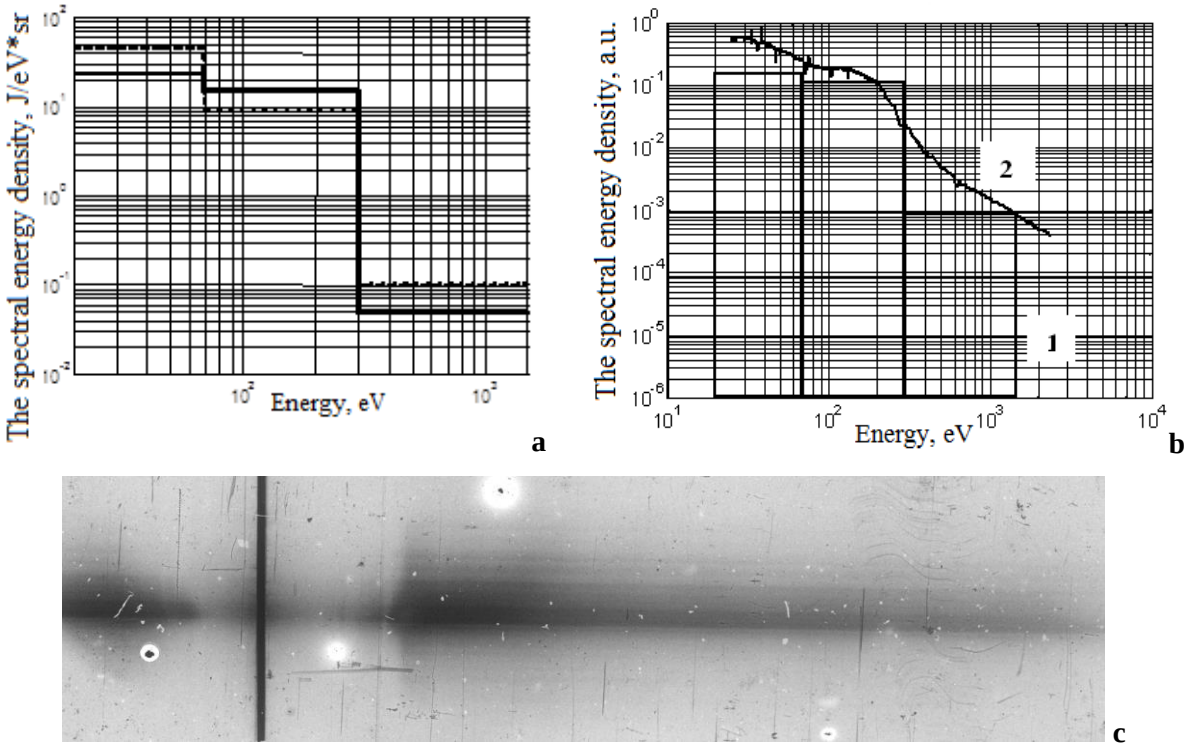

Figure 2. (a) Dependence of the average SED of the SXR radiation, emitted by the W-CWL Z-pinch in the radial and axial directions, on the photon energy (solid line - SED^{avg}_{radial}; dashed line - SED^{avg}_{axial}); (b) Comparison of the SED of the SXR radiation from the central region of the Z-pinch in the radial direction, evaluated with different methods (1 - SED data from VXRD, 2 - SED data from DGIS); (c) An image of the spectrum of the SXR radiation of tungsten cylindrical pinch with a spatial resolution along its radius for a shot 5274.

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References

[1] http://henke.lbl.gov/optical_constants/index.html
[2] Branitskii A V and Oleinik G M 2000 Reconstruction of the Parameters of a Soft X-radiation Spectrum from Signals of Vacuum X-ray Diodes *Instruments and Experimental Techniques* **43** 486
[3] Mitrofanov K N, Grabovski E V, Gritsuk A N, Laukhin Ya N, Aleksandrov V V, Oleinik G M, Medovshchikov S F and Shevel'ko A P 2013 Specific features of the structure of the Z-pinch emitting region formed during the implosion of a foam-wire load at the ANGARA-5-1 facility *Plasma Physics Reports* **39** 62