

NON-THERMAL RADIATION FROM Z-PINCH STABLE CORONA

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1. Introduction

Studies of the stable corona and the non-thermal intensive emission from the thicker wires due to discharge of a small Z-pinch type, are subject of papers [1] - [4]. Papers [1] and [2] deal with the visual diagnostics of the plasma corona of the carbon fiber with diameter 6 and 20 μm , situated in discharge with the current 20 kA and quarter period 1 μs . In [3] is described the stable corona with a helical and toroidal current tube giving rise an emission in the interval of 14-21 nm wavelength around the graphite rod with diameter 2 mm. Observed small Z-pinch operated at 20 kA. The same device as in [3] served to observe [4] XUV diagnostics of the carbon fiber with diameter 20 and 100 μm . Energy emission, app.60%, took place in non-thermal window 17-35 nm with calculated temperature 10 eV and emitted lines exhibited recombination character. Papers [1] - [4] indicated that sufficiently high diameter of the wires appears to be a stabilizing factor. For high diameter wires a rest of the wires in solid state is preserved in the central axis. Let us note, that the X-ray emission of the plasma corona of wire at higher current is considered in [5,6]. The present paper deals with diagnostics of the stable corona and non-thermal radiation from observations carried on MA Z-pinch at RRC Kurchatov Institute in Moscow.

1. Experimental results

For our experiments we have used the pulse power generator Stand-300 [7, 8] at the current of 2 - 3 MA with a rise time of 100 ns. Wires with the diameter of 110 μm served as a load.

The copper fibers with a diameter of 110 μm and a length of 5-8 mm were studied using current with maximum of 1.3 - 2.7 MA. The velocity of the enhancement of the corona radius (of $1-2 \times 10^4 \text{ ms}^{-1}$) was estimated from the streak camera pictures in visible lights during the first 150 ns after the current beginning (down part of the Fig. 2). The soft X-ray radiation was detected by a vacuum diode filtered with 2 foils, each of 1.5 μm mylar $\text{C}_{10}\text{H}_8\text{O}_4$ aluminized with 60nm of Al. This radiation began 100 - 120 ns after the start of the current and its total duration was ~ 50 ns. It had 2-3 local maxima with a FWHM of 10-20 ns, and total energy tens of J (Fig. 2, trace 3).

Integral X-ray exposure was done using obscure chamber with a pinhole of 100 μm and with 2 foils (each 12 μm of mylar and 100 nm of Al). In the pictures of the obscure chamber, the interesting structures, helical (Fig.1) or like the part of a spiral and rings (Fig 2) with diameter 0.5-1.5 mm, were imagined. The thickness of these structures varied between 0.1-0.4 mm. Some rings are covered by a cloud of exploding plasma.

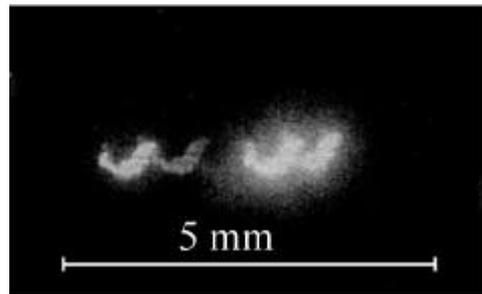


Fig. 1: Shot No. 1905981. X-ray obscure picture filtered with foil (aluminized mylar 1,5 μm)

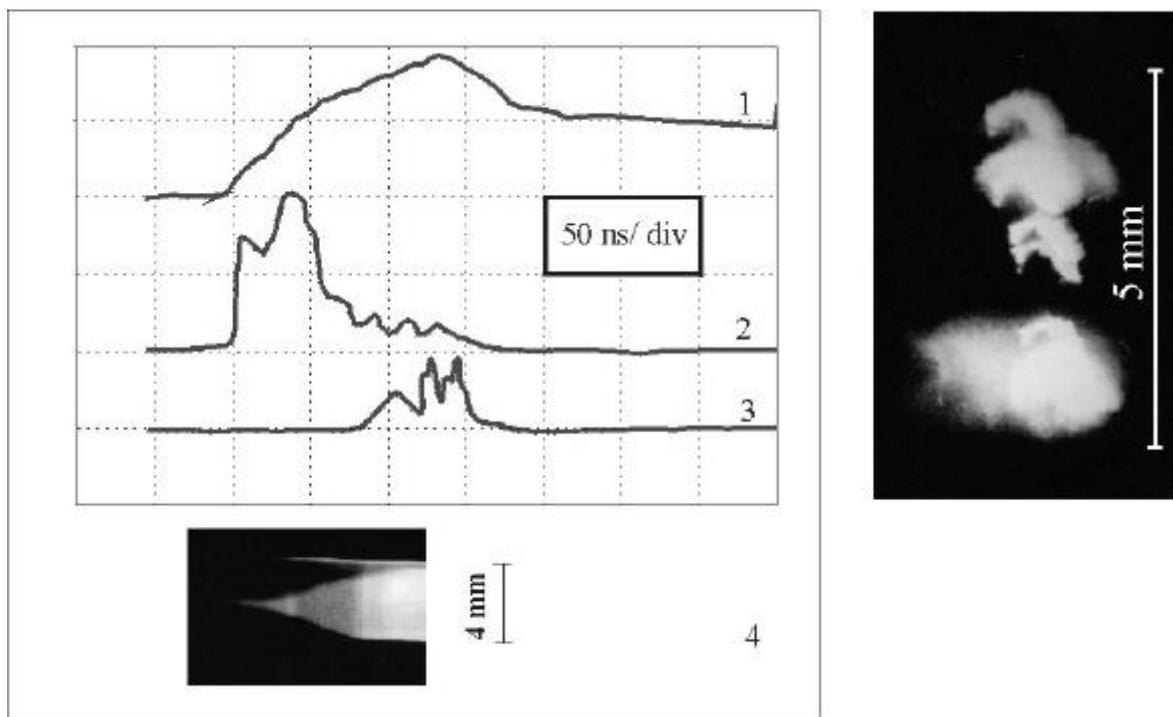


Fig. 2: Shot No.22059801. Left: traces 1 - current, 2 - voltage, 3 - X - ray filtered with 2 foils, aluminized mylar 1,5 μm , 4 - image from streak camera. Right: X-ray obscure picture filtered with foil (aluminized mylar 1,5 μm).

Helical structures in Fig.1 are imaged by the obscure chamber with 100 μm pinhole filtered with foils (24 μm of mylar $\text{C}_{10}\text{H}_8\text{O}_4$ and 120 nm Al) for shot with the current maximum of 1.3 MA. These helical structures emitted X-ray with a photon energy higher than 0.7 keV, In Fig. 2 (left) are oscillograms of the current, voltage, signal of the vacuum-diode and streak camera picture. In Fig. 2 (right) are the structures of emitted X-ray having an energy higher than 0.7 keV. They are imaged by the obscure chamber with 100 μm pinhole filtered with foils (24 μm of mylar $\text{C}_{10}\text{H}_8\text{O}_4$ and 120 nm Al). In Fig.3 are the spectra of lines and a continuum of energy higher than 0.7 keV.They are shown for a shot of Fig. 2.

The time-integrated spectra were taken on x-ray film DEF with an average spectral resolution of 2000. There is a rather coarse spatial resolution along the discharge column. The spectrum emitted in the shot of Fig.1 was weak and was not exposed. The spectral lines numerated in Fig.3 were identified by using the dispersion relation of the spectrograph and the tabulated wavelengths [9]. The most of the lines belong to the Cu ions with charge of 27 (lines No.1, 3), 25 (14), 23 (16), 21 (5, 6), 20 (8, 9, 15, 19, 20, 21, 25, 26) and 19 (7, 10, 11, 12, 13, 24, 27, 28). The lines of the Cu He-like resonance group (peaks 1, 3 in Fig. 3) are dispersed in the third and fifth spectroscopic order, the other lines correspond to the first order.

The drop in intensity of the CuK_α line (peaks 2, 4 in Fig. 3) mostly excited excited by hot electrons in the cold dense material. This does not indicate the absence of the solid wire core but the modification of the wire.

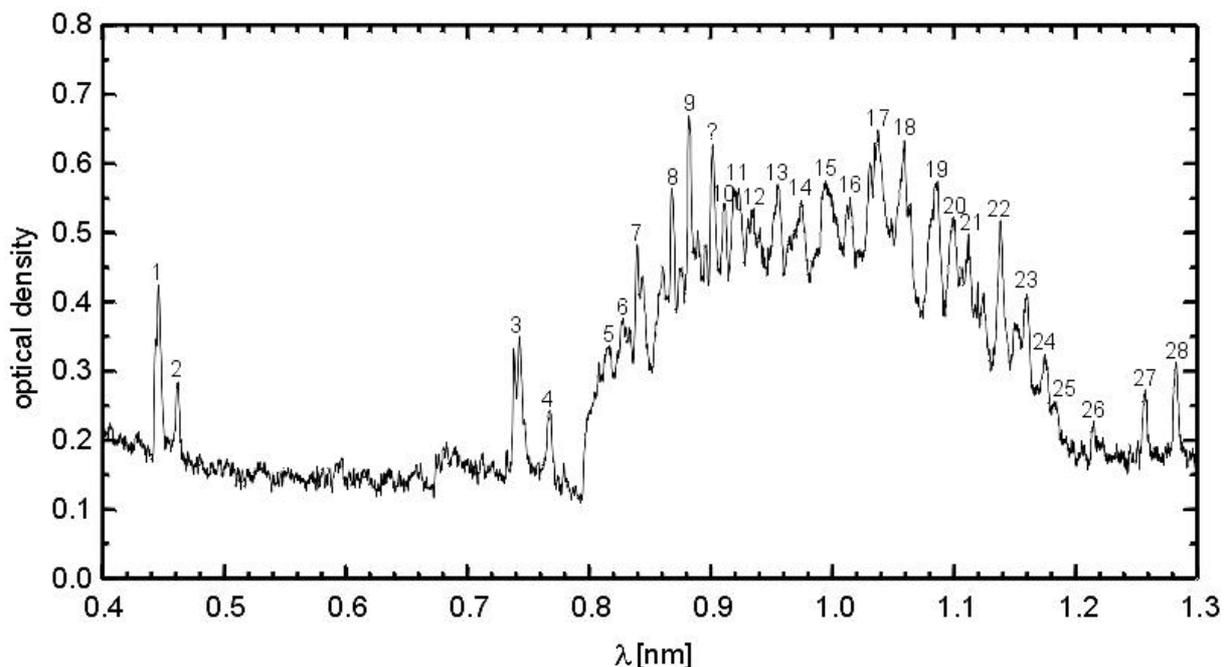


Fig. 3: Spectrum from the discharge No. 22059801 (Fig. 2)

3. Discussion and conclusion

The radiation emitted during the pinch phase of the standard exploding wire discharges consists of two clearly distinguishable components: (i) the equilibrium emission from the

whole volume of the plasma column with temperature ~ 100 eV representing the bulk of radiated energy; (ii) the shorter wavelength emission, from unstable hot spots, representing only a few percentage of energy. In our experimental configuration, however, X-ray emission, in the wavelength range 0.8-1.2 nm (1-1.5 keV) takes place from *the toroidal and helical structures and not from hot spots*.

The observed non-thermal emission of the wire plasma corona with a stabilizing factor of a central solid state core, might provide an effective source of harder X-ray radiation and also it could serve for continual pumping of inverse population in recombination lasing schemes [10].

Formation of helical and toroidal current tubes may result from radial explosion of the plasma from corona, across the azimuthal magnetic field. The non-homogeneous plasma moving perpendicularly to the magnetic lines may satisfy conditions for the dynamo effect. The generated non-thermal radiation seems to be due to: (i) an electric field, induced by variation of the inductance of the helical magnetic fields; (ii) an acceleration of the electrons by this electric field in the helical tubes, so that electrons have sufficient energy to ionize K and L shells of Cu lines.

Acknowledgement

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