

GENERATION OF VUV-RADIATION OF A ROD CORONA FROM A SMALL MAGNETIC PINCH

¹P. Kubeš, J. ¹Kravárik, ¹A. Ortiz -Tapia, L. ²Karpinski, ³L. Aschke, ⁴Ž. Andreić, ³H-J. Kunze

¹*FEE Czech Technical University, Technická 2, 16627 Prague 6, Czech Republic*

²*Institute of Plasma Physics and Laser Microfusion, P.O.Box 49 00-908 Warsaw, Poland*

³*Institut für Experimentalphysik V, Ruhr-Universität, 44780 Bochum, Germany*

⁴*Ruder Bosković Institute, Bijenička 54, 10 000 Zagreb, Croatia*

The authors report the formation of a helical dense current tube around the graphite rod and an intensive generation of non-thermal radiation of 13-21 nm wavelength. VUV and visible spectral and a laser schlieren diagnostics were used for the discharge load from graphite, for a pencil of 1 cm length and 2 mm of diameter between two copper conical electrodes. The electric discharge was initiated by a small capacitor bank of 20 kV voltage and 1 μ F capacitance. The current reached its maximum at 40 kA during 360 ns after the increase of the current.

For the detection of radiation, PIN diodes, sensitive to XUV-ray wavelength with 1 ns temporal resolution, were used in the axial direction along the length of the rod and in the radial direction perpendicular towards the axis of the rod. The detection of an axial radiation was enabled due to a 5 mm diameter hole in the center of the electrode near the detector. For the visual schlieren and the differential interferometer diagnostics two 3-ns beams, optically separated from one laser pulse, were used with a time delay of 12 and 55 ns or for perpendicular image in two radial directions. The plasma corona was observed side-on with a VUV flat-field spectrograph [1,2] based on a Hitachi flat-field grating [3]. The visible spectral region of 400 – 600 nm was observed by a ISP-51 spectrograph .

The emission and explosion of the corona of the carbon fiber of 20 μ m diameter with the inner layer in solid phase, were reported from a previous device with a non-regular, random and weak radiation intensity [4]. The shorter increase of the current from 1 to 0.36 μ s and the greater diameter of the rod caused the ten-times energy enhancement of XUV radiation to 0.1 J (power 500 kW), the increase of the probability of this emission from random to stable regime (from 30% to 100%) of the discharges, and it enabled the usage of the VUV spectrograph.

The emission started 55 – 80 ns after the increase of the current, reached its maximum at 380 ns (at current maximum) and finished at 600 – 1000 ns with FWHM of 90 – 450 ns and with a mean value of 230 ns. The radial radiation had similar behavior as in the axial direction. When an oscilloscope signal had its local maximum, then its position in the radial and axial direction was the same, but the ratio of their intensities could not be the same. The intensity of the visible wavelength was lower than 10% of the total intensity. The 0.8 μm thick Al foil applied in front of the PIN reduced the emission intensity to 10 – 20 %. The 1.5 μm mylar foil reduces the radiation maximally to 2%.

The diagnostics by VUV spectrograph proved the line character of the dominant emission in the region 13-21 nm. The intensities of these lines were dependent on the discharge current but the line ratios were temporary independent during an emission of few hundreds ns. An example of the spectra with the signed wavelength and ion determination is illustrated in Fig. 1.

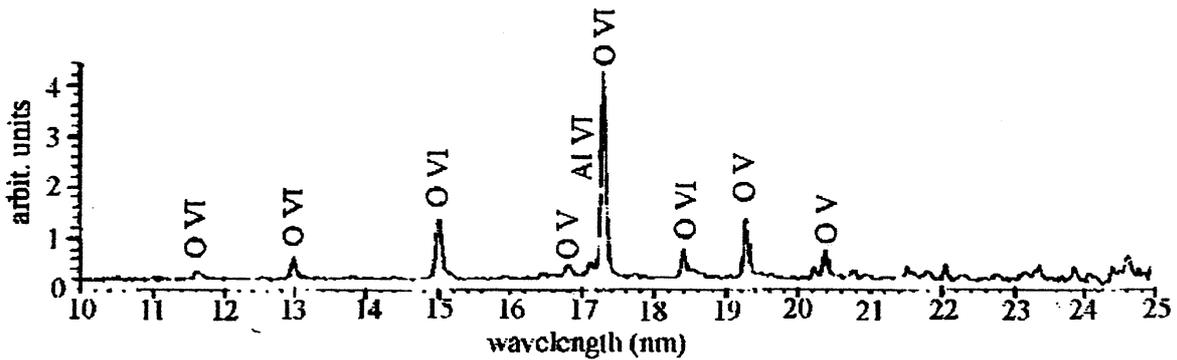


Fig.1: Shot No. 619. Spectrum of the dominating emission of plasma corona

The plasma corona and its temporal evolution generated around the solid graphite rod showed some interesting features. The width of the corona evaluated from the visual diagnostics was dependent on the sensitivity of the schlieren method. For a deflection angle $\alpha > 3$ mrad, the corona width of 200 μm was regularly spread around the rod with electron densities higher than $2 \times 10^{25} \text{ m}^{-3}$. For a deflection angle $\alpha > 1.5$ mrad⁻³ (the electron densities higher than 10^{25} m^{-3}) the width increased to 500 μm and in the schlieren pictures the radial explosions from the corona were observable to 1 mm distance from the rod. For a lower deflection angle $\alpha > 0.75$ mrad⁻³ (with electron densities higher than $5 \times 10^{24} \text{ m}^{-3}$) the local explosions extended to a distance of 2-3 mm from the rod. It implied the local explosion of the plasma from the corona. The velocities of the radial plasma explosions, higher than 10^5 m/s, were evaluated.

At visualization of the corona, by Wollaston interferometry, a helical form of these plasma explosions was observed. Along the length of the rod the 3-6 winds are imagined with an axial width of $\sim 0.5 - 1$ mm and a pitch of $\sim 1 - 2$ mm . The axial velocity of the variation of positions of the winds was evaluated till $2-4 \times 10^4$ m/s. In some pictures the connection of neighbor winds and the formation of a toroidal ring around the rod can be seen (Fig.2).

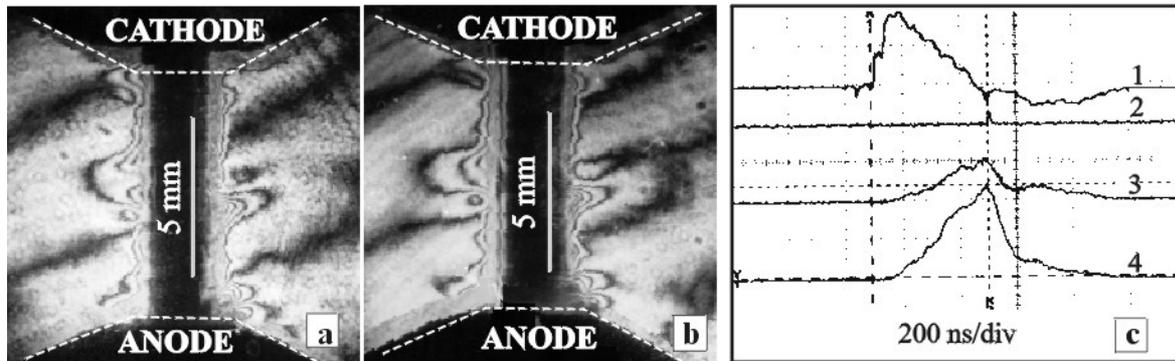


Fig. 2: Shot No. 215-98. Plasma channel at VUV maximum, 412 ns (a) and 424 ns (b) after increase of the current. Oscillogram (c): trace 1- current derivative, 2 - temporal position of (a), 3 - axial and 4 - radial PIN diode signals.

The velocity of connection was evaluated as $\sim 10^5$ m/s . The time of connection correlates with the local maximum of VUV emission. The orientation of the helical form is random, sometimes right and sometimes left. This conclusion was induced by the comparison of two pictures of diagnostic beams from two perpendicular radial directions. During the discharge, the main part of the rod remained in solid phase. The number of evaporated particles (3×10^{18}) was evaluated by measuring the volume of the graphite rod after the discharge. For one evacuation of the chamber it is possible to realize a few hundred of discharges with one rod and this form of the load enables high repeating frequency of experiments. The number of particles present in the plasma corona reached the value of $\sim 10^{17}$. The number of photons with an energy value of 50 – 100 eV ($2 - 4 \times 10^{15}$) was evaluated from the absolute measurement of the intensity of the emitted radiation. Similar behavior (tube formation and non-thermal radiation as the graphite rod) was observed in the plasma corona of a plastic rod with spray-painted Al, Cu and Ag coating .

From these experimental results it is possible to induce some considerations and conclusions.

The interval of emitted wavelength was determined from the combination of results of the Al and mylar filters and from the measured dependence of the intensity of the reflected

emission on the angle of incidence. The Al foil absorbed less than 90% of the 0 – 2.7 nm and 17 – 60 nm wavelength, whereas the mylar foil did the same for the 0 – 2.4 nm and 5 – 11 nm wavelength. For the observed absorption it is possible to suppose that the dominant emission in the Al-L window is between 17 – 60 nm. From the results of the incidence reflection spectroscopy it is possible to exclude the wavelengths above 30 nm [6]. The emitted lines belong to OV and OVI ions. The lines of CV and CVI ions were not confirmed. The visual lines are produced by CII and OII ions at the 1-2 eV corona temperature.

On the surface of the plasma corona of the thick rod of the 2 mm diameter is formed. The reason for helical current tube formation could be a radial explosion of the plasma from the plasma corona across the azimuthal magnetic field. At conditions, when the non-homogeneous plasma is moving perpendicular to the magnetic lines may be fulfill the conditions for dynamo effect. A non-thermal radiation could be generated by electric field induced by variation of the inductance of the helical magnetic fields and acceleration of the electrons in the helical tubes to energies sufficient for ionization of OII and CII ions to OV and OVI but not sufficient for CVI ions.

Acknowledgements

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