

Temporal profile analysis of selected spectral lines of Nitrogen filled capillary discharge plasma

M. Tamas¹, L. Pina¹, J. Blazej¹, A. Jancarek¹, S. Palinek¹, P. Vrba², M. Vrbova¹

¹ Czech Technical University, Prague, Czech Republic

² Institute of Plasma Physics of Academy of Sciences, Prague, Czech Republic

We are reporting spectroscopy studies of Nitrogen filled capillary discharge. Identification procedure of spectra was done with use of extreme ultraviolet (EUV) grazing incidence spectrometer with torroidal grating and the cooled EUV-sensitive CCD camera in role of planar detector. The time-resolved spectroscopy was done by pin-diode detector placed behind EUV monochromator for selected intensive lines. The source of radiation and the object under study is a pinching discharge in alumina capillary filled by Nitrogen, where stimulated emission in 13.4 nm wavelength region is expected. The results of temporal profile analysis were used both for collecting input values for magneto-hydrodynamics plasma modeling and for confident pinch effect identification. Finally, the modeling results are used for experiment conditions optimization.

1. Experimental setup

The experimental setup presented is located at L'Aquila University, Italy [1]. Alumina capillary with the length $L = 150$ mm and diameter $d = 4$ mm is filled with nitrogen. High voltage of $U_{\max} = 240$ kV is discharged to the capillary. The passing current has form of damped sinus with maximum current value of $I_{\max} = 32$ kA and with quasiperiod $T = 220$ ns. The shape of the current pulse is measured by means of a Rogowski coil

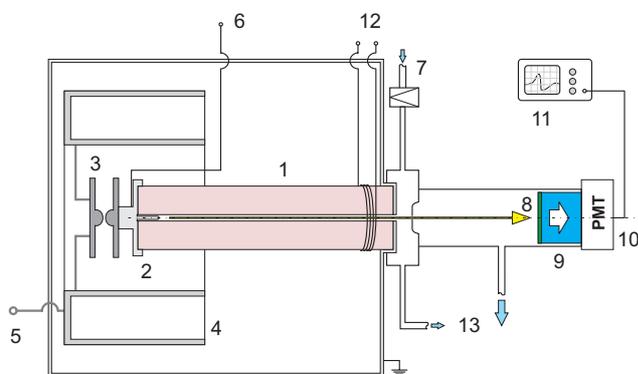


Figure 1: Experimental setup: 1- Alumina capillary, 2- Electrode, 3- Spark gap, 4- Capacitor, 5- High voltage, 6- Preionization, 7- Gas inflow, 8- Scintillator, 9- Lightguide, 10- Photomultiplier, 11- Oscilloscope, 12- Rogowski coil, 13- Vacuum pumping

The X-UV radiation emitted from the capillary passes through a monochromator with planar grating with 800 l/mm and is converted to visible radiation by fast scintillator (response time is in order of ten nanoseconds).

The spectrum of the emitted radiation is known from previous measurements [2]. The goal of the experiment is to

detect the time evolution of radiation intensity at different wavelengths belonging to certain lines that were identified in the spectra. The three most intense lines in discharge spectrum were chosen, their wavelengths being 13.05 nm, 15 nm and 17.25 nm (Figure 2). The pressure of nitrogen in the capillary is varied from 0.5 mbar to 9 mbar. Signals from photomultiplier and Rogowski coil are registered simultaneously in the oscilloscope.

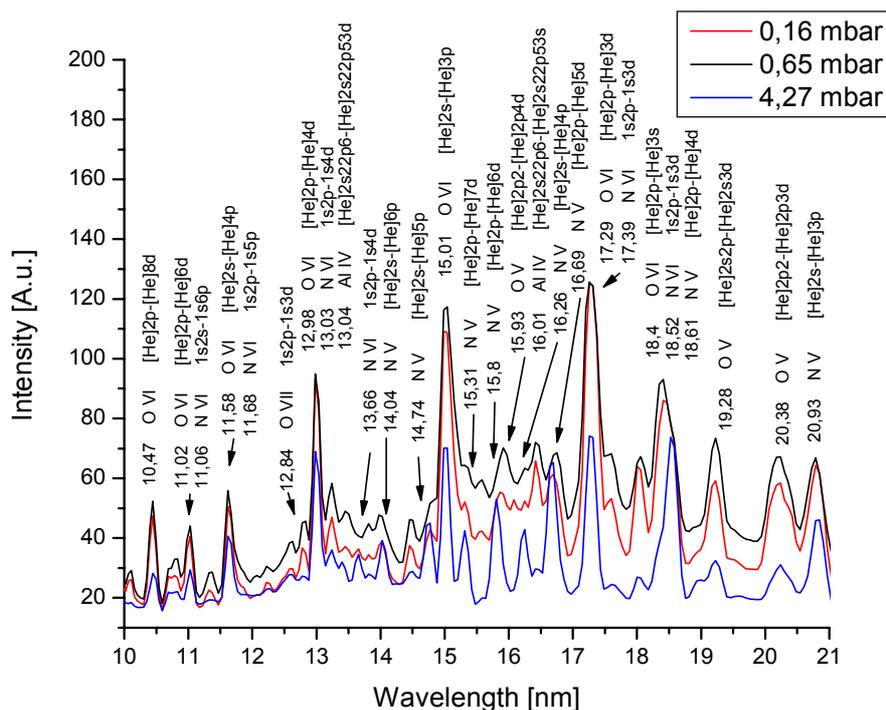


Figure 2: The time integrated spectrum of the radiation emitted by the capillary discharge in nitrogen at various pre-fill pressures.

2. Measured results

Monochromator spectral resolution is approximately 0.2 nm. The time evolution of the X-UV signal (Figure 3) shows the maxima around the quarter period and the end of the first period of the discharge current. The signal intensity is proportional to the population densities of the identified ions i.e. N VI and O VI.

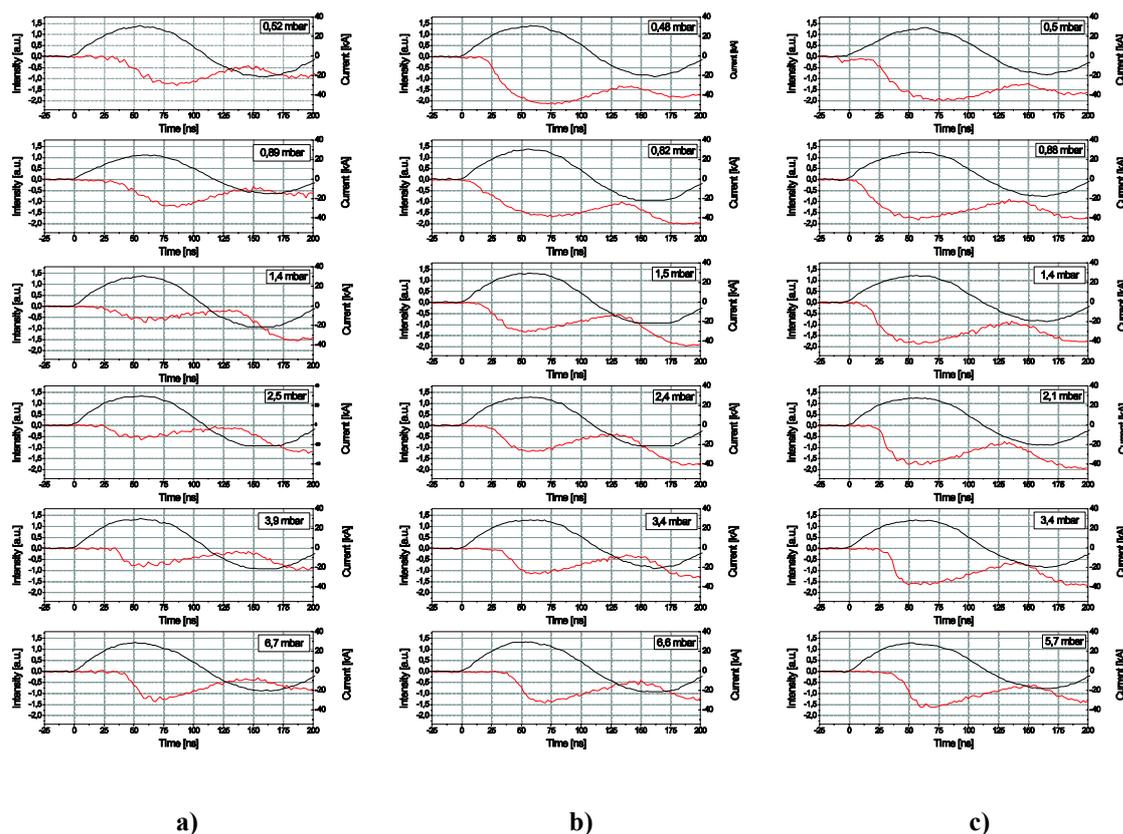


Figure 3: Time evolution of current profile (black) and signal intensity (red) at three wavelengths a) 13 nm, b) 15 nm and c) 17,25 nm corresponding to the three most intense spectral lines identified in the time integrated spectrum of capillary discharge at various pressures of pre-filled nitrogen.

3. Computer simulations

To describe the processes inside the capillary during the discharge, two steps are used. MHD calculations- the spatial and time dependencies of plasma density, plasma electron and ion temperatures and electron density in a nitrogen-filled alumina capillary discharge are evaluated by means of the code NPINCH [3]. Kinetics evaluations- the time dependencies of ionization fractions and energy level populations for lithium-, helium- and hydrogen-like nitrogen ions on the capillary

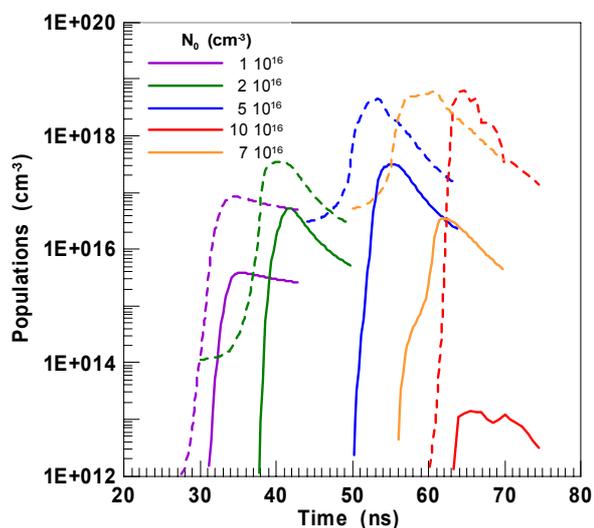


Figure 4: Time dependencies of hydrogen like ion densities (full lines) and helium like ion densities (dashed lines) for various nitrogen initial atom densities at the axis of the capillary.

axis are evaluated by means of the kinetic code FLY used as a post-processor [4]. From the simulations we are able to obtain the time dependencies of densities of different ionization

stages at the axis of the capillary. Figure 4 shows population densities of hydrogen- and helium-like nitrogen ions in the discharge dependent on initial atom density [5]. The helium-like nitrogen is predicted to be present in the measurements based on the identification of the capillary discharge spectra

4. Conclusion

The time evolution of the X-UV signal of the three most intense lines in the time integrated discharge spectrum was measured. Results of the computer simulations were presented. Comparing the time evolution of X-UV signal and simulations of helium- like nitrogen populations simulated within the first period of the discharge current we see good correspondence. More detailed study of the structure of the X-UV signal is hindered by the response time of the scintillator. The results confirm the computer simulation as a valid model for pinching discharge in gas filled capillary.

Acknowledgement

This research has been supported by the research framework MSM6840770022, section 3 of Ministry of Education of Czech Republic, grant CTU0708114 and experimental data has been obtained thanks to support of grant 1P04LA235.

References

- [1] A. Ritucci et al., *Europhys. Lett.*, Vol. 63 (5) (2003) pp. 694-700
- [2] M.Tamas et al., 33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.30I, P-2.005 (2006)
- [3] N. A. Bobrova et al.: *Plasma Physics Reports.*, Vol. 22, (1996), pp. 387-402
- [4] R. W. Lee and J. T. Larsen: *J.Q.S.R.T.* , Vol. 56, (1996), pp. 535-556
- [5] A. Jancarek et al.: *Czech. J. Phys.*, Vol. 56, (2006), pp. B250-B254