Spectral characterization of pulsed plasma discharges at the Chilean Nuclear Energy Commission (CCHEN)

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Research in pulsed electrical discharges at the Chilean Nuclear Energy Commission (CCHEN) currently focuses in a couple of device types: Plasma Focus discharges and Wire array discharges. Plasma Focus devices available at CCHEN have stored energies that range from 0.1 J (nanofoco) to the hundreds of kilojoules (SPEED 2), which enable the study of a wide range of physical phenomena. This work presents results obtained in PF-400J (176-539 J, 880 nF, 20-35 kV, quarter period ˜300 ns) [1] and PF-2kJ (1.6-3.6 kJ, 8000nF, 20-30 kV, ~ 960 ns time to peak current, dI/dt~ 2.7×10^{11}A/s) discharges. Spectroscopic observations were made by means of a 0.5m Czerny-Turner imaging spectrometer attached to a 20 ns integration time ICCD VIS camera. Spatial resolution was obtained by using a telescopic system that enabled the observation of a small volume of the sheath. Gas impurities (Neon, Nitrogen, Argon, and Krypton) were added in different concentrations (2 and 5%) to the background gas to be able to observe the ionization evolution of the plasma sheath when moving in the inter-electrode space. Ionization degrees up to N V were observed in Nitrogen and up to Kr II/III when Krypton was used.

Wire array experiments (X-pinch) with a small current amplitude were carried out in the Multipurpose device (1.2µF, 345J, 47.5nH, T/4=500ns and Z=0.2Ω in short circuit). With a wire load and 24 kV of charging voltage, currents up to 122 kA were observed with a 500 ns quarter period. Spectral observations were done with a 1 m grazing incidence off-Rowland Circle spectrometer, were light emitted from the discharge was focused into the entrance slit with an adjustable curvature grazing incidence cylindrical mirror. A 4-strip MCP detector allowed the acquisition of spectra at different moments of the current pulse, with a time integration of 10 ns. Aluminum and Copper wires were used in different shots, enabling the observation of the ionization degree evolution from the plasma during the current pulse progression. Preliminary results show the appearance of Cu XVII to Cu XXII at the beginning of the current pulse. Aluminum shows emission from Al V to Al IX ions. Characterization of the X-ray emission with a convex KAP crystal spectrometer from the hot spots generated by these plasmas is underway.

*Work supported by CONICYT-PAI Inserción 791100020, FONDECYT Iniciación 11121587, CONICYT-PIA Anillo ACT 1115 and FONDECYT Regular 1120801.

[1] "Neutron emission from a fast plasma focus of 400 Joules", Silva P, Moreno J, Soto L, Birstein L, Mayer R E and Kies W, App. Phys. Lett. 83 3269–3271 (2003)

Spectroscopic observations of homogenous microcapillary plasma columns heated by ultrafast current pulses*

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Homogeneous plasma columns with ionization levels typical of MA discharges were created by rapidly heating gas-filled 520-µm-diameter channels with ns rise time current pulses of only 40 kA [1]. These current pulses allow the generation of unique experimental conditions, producing large aspect ratio (>300:1 length-to-diameter) plasma columns capable of ionizing pure Xenon up to Ni-like levels Xe^{28+} and Xenon impurities to levels up to the Zn-like state, Xe^{30+}. The use of Neon as the discharge gas enabled the ionization of Aluminum and Silicon (from injected SiH_4) to levels up to H-like and He-like. Axially acquired spectra show the unusual dominance of the intercombination line over the resonance line of He-like Al by nearly an order of magnitude, caused by differences in opacities in the axial and radial directions. These plasma columns could enable the development of sub-10nm x-ray lasers in Xenon discharges, where spectral transitions of Ni-like Xenon from the $3d^9 4d$ (3/2, 3/2)J=0 to the $3d^9 4p$(5/2, 3/2)J=1 and to $3d^9 4p$(3/2, 1/2)J=1 are observed.

*This work was supported by NSF Plasma Physics grant No. PHY1004295. G. A. acknowledges the support by CONICYT-PAI Inserción 791100020, FONDECYT Iniciación 11121587 and CONICYT-PIA Anillo ACT 1115.

References

[1] G. Avaria, M. Grisham, J. Li, F. G. Tomasel, V. N. Shlyaptsev, M. Busquet, M. Woolston, and J. J. Rocca, Phys. Rev. Lett., Accepted (In press).