Cryoplasma in Helium at 4.5 K under different pressures.

R. Rincon[(*)2], H.V. Nguyen [1], N. Bonifaci [1], F Aitken[1], V. M. Atrazhev [3], K. van Haeften[4] and J. Eloranta[5]

[1] *Laboratoire G2Elab CNRS & Joseph Fourier University. 25 rue des Martyrs, 38042 Grenoble, France*
[2] *Grupo de Espectroscopía de Plasmas (GEP) University of Cordoba, Cordoba, Spain*
[3] *Joint Institute for High Temperatures, RAS, Moscow, 125412*
[4] *Department of physics and Astronomy, University of Leicester, UK*
[5] *Department of Chemistry and Biochemistry, University of Northridge, USA*
(*) f32rilir@uco.es

Gaseous and liquid Helium at 4.5 K and pressure (0.1 - 0.2) MPa was excited using a corona discharge for both negative and positive high voltages. The light emitted from the ionization zone of the discharge was analyzed. Asymmetric shape of an atomic line 706 nm was recorded. Blue wing of the line recorded in negative corona was more intensive than its red wing. In positive corona, red wing of the line was more intense than blue wing. Spectral shift of the line was small for the range of applied pressure. The line shape was the same for lines observed in gaseous and liquid Helium for conditions closed to the boiling pressure at 4.5 K

Emission spectroscopy is a powerful tool to obtain information about the important parameters that characterize non-equilibrium discharge plasma at both low and high pressures. Spectroscopic observations of the light emitted by ionization gases can be used to determine conditions surrounding the emitted atoms or molecules. An ionization zone near a tip electrode is a source of a light emitted by the corona. Excited atoms interact with environment and features of their spectra give information about density and temperature of a gas in the ionization zone.

Spectroscopic studies of the excitations in liquid helium by corona discharge have been exposed in the literature [1-3]. In liquid helium the excited He^* and He^*_2 species have been established to reside inside voids with a radius ranging from (7 – 15) Å ("bubble states"), which are slightly smaller than for a solvated electron in the liquid (18.5 Å). Such structures are the result of the repulsive Pauli exchange interaction between the Rydberg electron and the surrounding closed shell helium atoms.

In a gas, the "impact" interaction of radiator with surrounding atoms determines the symmetric Lorentzian profile of spectral lines with shift and width are proportional to the gas density. The shift sign ("red shift" for the shift toward longer wavelengths and "blue shift" for the shift toward shorter wavelengths) depends on character of radiator-perturbator interaction. The blue shift corresponds to significant repulsion. Well known measurements showed the blue shift of the line 706 nm (3^3S-2^3P transition) in low density He gas [2]. The measurements were made using discharge in low pressure gas (< 10 Torr) and gave the symmetric Lorentzian profile of the line

The corona discharge in cryogenic helium under pressures (0.1 -0.2) MPa allows us to observe lines of He I in conditions where liquid and dense gas were realised. Experiments have been carried out in gaseous and liquid He at the fixed temperature 4.5 K and different pressures in the cell from 0.1 MPa up to 0.2 MPa. The range of pressure gave gaseous He for P < 0.129 MPa and liquid He for P > 0.129 MPa, where 0.129 MPa is the boiling pressure for 4.5 K.

Light emitted from the region close to the point electrode was analyzed by a spectrograph through a sapphire window. The direction of an observation was oriented perpendicularly to the cathode-anode direction The spectrograph (Acton Research Corporation of 300 mm focal length) was equipped with 3 plane gratings: one with 150 gr./mm and two with 1200 gr./mm that were blazed at 750 nm and 300 nm, respectively. The 2D-CCDTKB-UV/AR detector is located directly in the exit plane of the spectrograph. Its dimensions are 12.3x12.3 mm with 512x512 pixels of 24x24 µm for each pixel. In order to reduce the dark current, the detector was cooled to a temperature of 153 K (dark current < 1 e/pixel/hour at 153 K). In our conditions, the instrumental broadening measured by recording profiles of argon lines from a low pressure discharge lamp is $\Delta\lambda_{instr}$ = 0.1 nm for a 1200 grooves/mm grating. The light emitted from the corona region was collected and spectra in the range 500 - 1080 nm were recorded. Most of atomic lines and molecular bands were identified. These lines correspond to

radiative transitions between excited states of He* atoms and He_2* excimer molecules. The atomic line 706 nm (3^3S-2^3P transition) of the helium spectrum is considered in the report.

Figure 1 shows the profile of the line observed in cryogenic gaseous He at 4.5 K and the pressure less than the boiling pressure. The lines are non-symmetric ones and intensities of their wings depend on a polarity of corona discharge. The line has blue wing for negative corona.

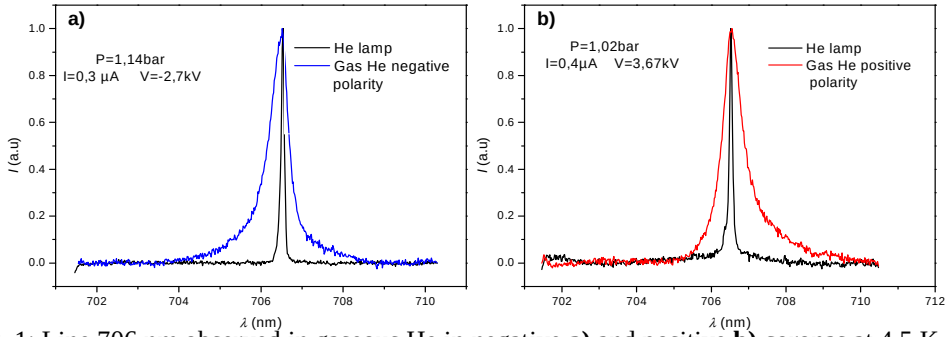

Fig. 1: Line 706 nm observed in gaseous He in negative **a)** and positive **b)** coronas at 4.5 K.

Figure 2 shows the profile of the line observed in a liquid He at 4.5 K and the pressure exceeded than the boiling pressure. The lines are non-symmetric ones and intensities of their wings depend on a polarity of corona discharge. The line has blue wing for negative corona.

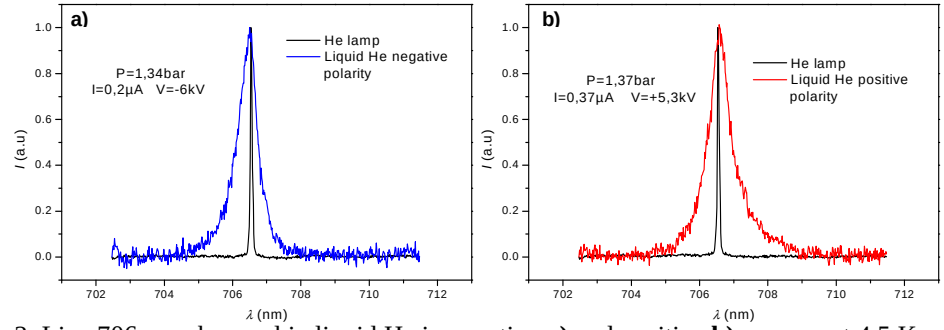

Fig. 2: Line 706 nm observed in liquid He in negative **a)** and positive **b)** coronas at 4.5 K.

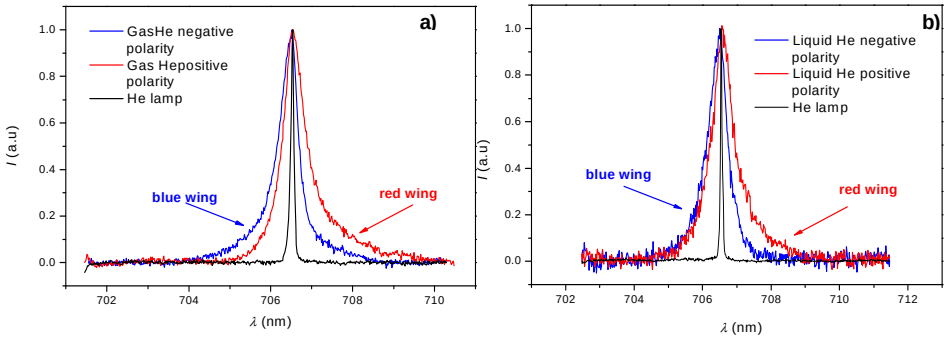

Fig. 3: Comparison of line 706 nm profiles observed in gas **a)** and liquid **b)** at 4.5 K in coronas of different polarity.

The qualitative features of atomic spectra observed in cryogenic gas and liquid in coronas of different polarity are represented in Fig. 3. The blue wing is typical for negative corona and the red wind was observed in positive corona for cryogenic conditions. Note that high temperature spectra have a blue wing as a rule.

V. M. A. thanks the foundation RFBR for support, grant 12-08-91052.
R.R. thanks to the Ministry of Science and Innovation (Spain) for support, grant EEBB-2011-43289.

References

[1] W. Qine et *al*. *Jpn. J. Appl. Phys*, **36** (1997) 4474
[2] Z. –L. Li et *al*. *IEEE Trans. Dielectrics Electrical Insulation*, **16** (2009) 742
[3] Z. –L. Li et *al*. *Fizika Nizkikh Temperatur*, **37** (2011) 1