VUV SPECTROSCOPY OF THE He II – LYMAN SERIES FOR ELECTRON DENSITY ESTIMATION

Laboratory for Plasma Spectroscopy and Lasers

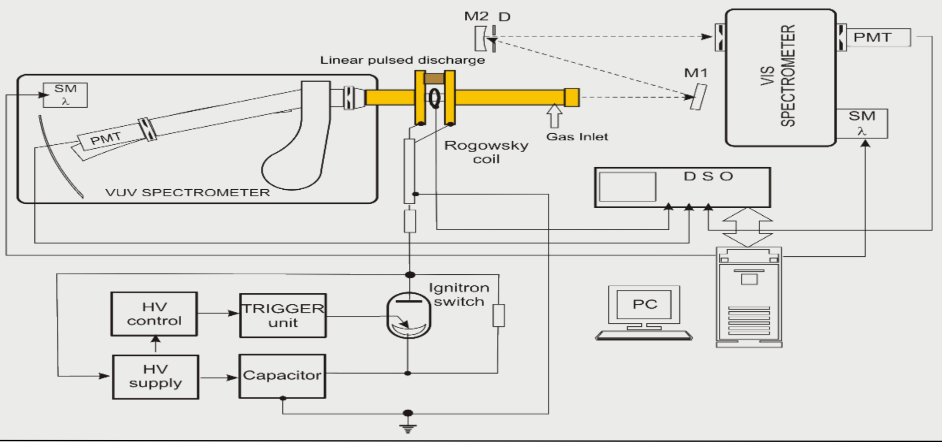
I. Traparić[1,2] and M. Ivković[2]

[1] Faculty of Physics, University of Belgrade, Studentski trg 12, Belgrade, Serbia
[2] Institute of Physics, University of Belgrade, Pregrevica 118, Belgrade, Serbia

Abstract

We report the use of the spectral line shapes of the Lyman series of ionized helium for diagnostics of high temperature plasmas. As a light source the low pressure pulsed arc was used. Electron density was determined from width of the He II Pashen alpha line and parameters of the He I 447.1 nm line, while electron temperature was determined from Boltzmann plot of the He II lines. The use of the Inglis-Teller relation on merging of spectral lines along series, condition for partial local thermodynamic equilibrium and Vidal theory of line merging were tested as methods for electron density estimation.

EXPERIMENTAL SETUP



Used plasma source was low pressure arc, whose inner diameter is 10 mm and distance between electrodes is 130 mm.

Light emission was obtained by discharing a capacitor previously charged to 5 μF. Light image was projected onto the enterance slit of 1 m Cherny-Turner spectrometer equiped with PMT as light detector using reflective mirror M1 and focusing mirror M2 (f = 2 m).

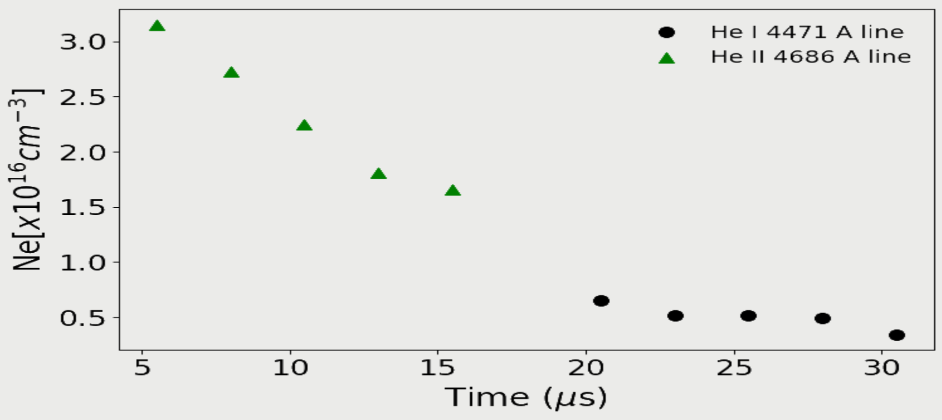
The other side of light source is mounted on grazing incidence VUV spectrometer, whose operation is based on the theory of Rowland circe. Radius of grating is 2.2 m, and PMT is also used as light detector.

PLASMA DIAGNOSTICS

Plasma diagnostics was performed using two methods: the width of He II Pashen alpha line (468.6 nm) and the distance between forbidden and allowed component of He I 447.1 nm line.

To estimate electron density from He II Pashen alpha the following formula was used (Buscher et al, 1996):

$$N_e = 3.58 \cdot 10^{17} \omega[nm]^{1.204}$$

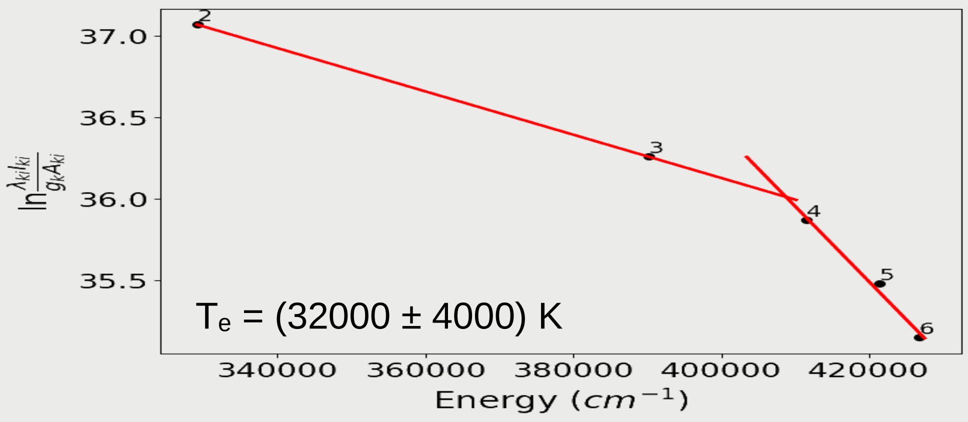


Temporal evolution of electron density

For electron density determination from He I 447.1 nm line, the formula proposed by Ivković et al. (Ivković et al., 2010) was used:

$$\log_{10}(N_e) = 21.5 + \log_{10}\left(\left(\frac{s}{0.1479}\right)^{b(T_e)} - 1\right),\quad b(T_e) = 1.46 + \frac{8380}{T_e^{1.2}}$$

Electron temperature was calculated from the slope of Boltzmann plot of the higher members of Lyman series.



Boltzmann plot of the He II Lyman series

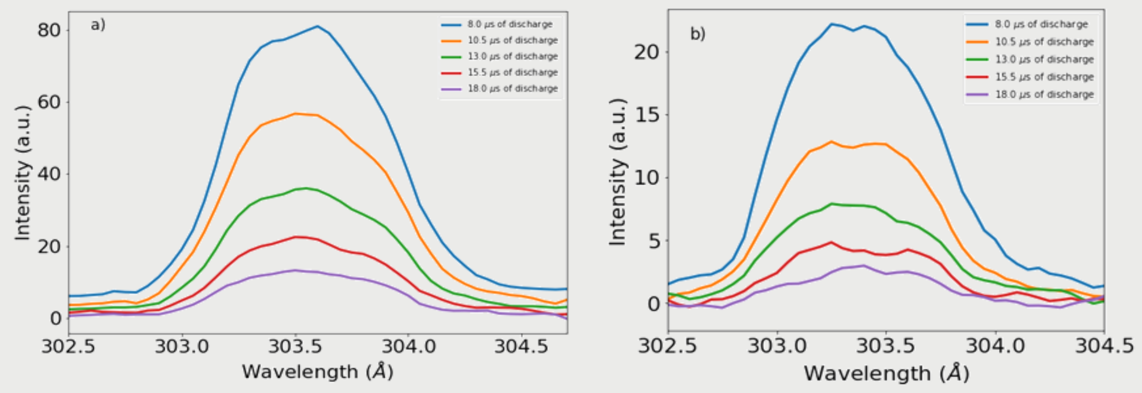
RESULTS

Three methods that are based on the higher members of the series were tested. The first method was Inglis – Teller relation (Inglis and Teller, 1939):

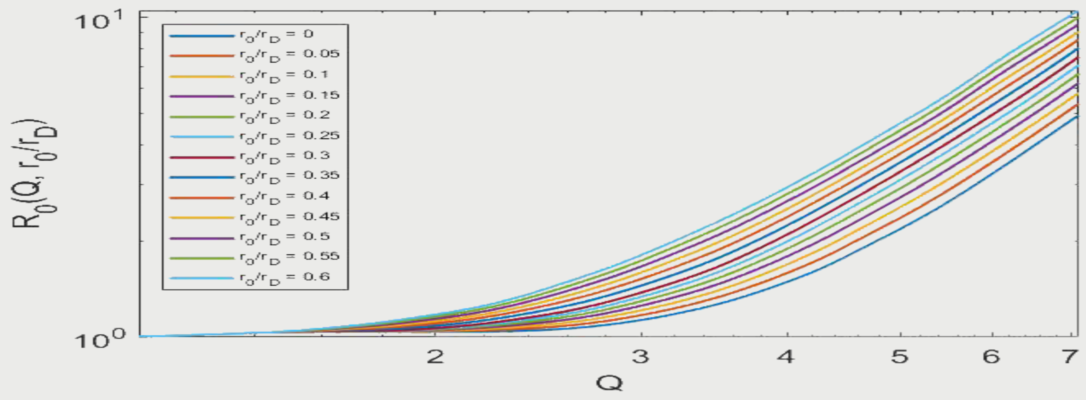
$$\log_{10}(N_i + N_e\,[cm^{-3}]) = 23.26 - 7.5 n_{max} + 4.5 \log_{10} Z$$

The second method is based on Griem PLTE criteria (Griem, 1963) and usage of effective quantum number n* (see Konjević et al., 2009):

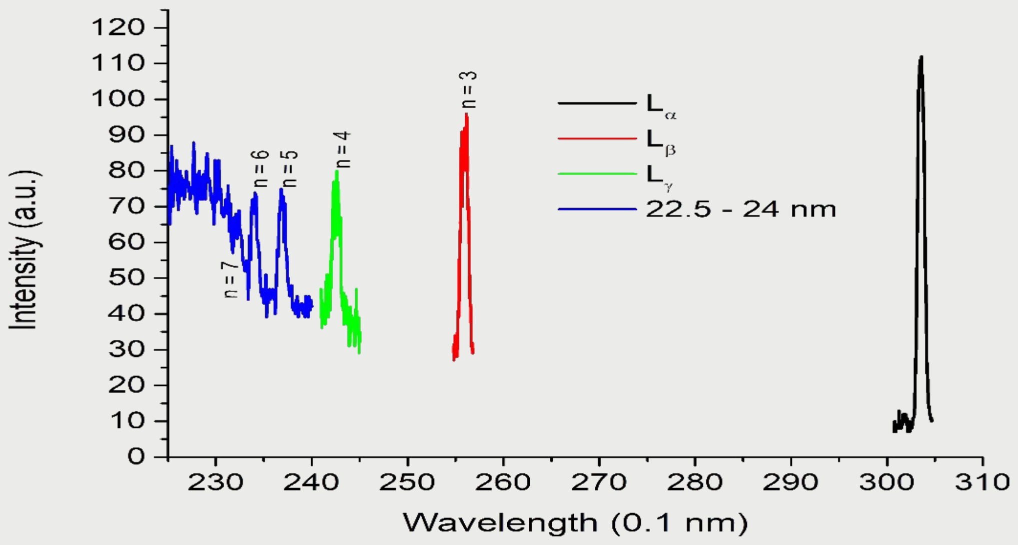
$$N_e(cm^{-3}) \geq 7.4 \cdot 10^{18} \frac{Z}{n^{*\,17/2}} \sqrt{\frac{k_B T_e}{E_H}}$$



Lyman alpha profile at 3mbar and a) 7 kV b) 6 kV



Interpolation of function $R_0(Q, \frac{r_0}{r_D})$ for different values of parameter $\frac{r_0}{r_D}$. In this case this parameter is equal to 0.3.



Lyman series of He II at 3 mbar and 7 kV

Third method was the method proposed by Vidal (Vidal, 1966). Method has three steps. In first, the ratio of maxima and minima of spectral line R(n) and parameter $\frac{r_0}{r_D} = 0.0898\frac{N_e^{1/6}}{T_e^{1/2}}$ were calculated. After that for given theoretical dependency of R(Q, $\frac{r_0}{r_D}$) of Q, the value of Q was obtained, using R(Q, $\frac{r_0}{r_D}$) = R(n). Finally, using the formula below, electron density N_e was determined:

$$N_e = \frac{1}{2}\left(\frac{1.07 \cdot 10^{16}[cm^{-2}]Z^3}{Qn^5\left(1 - \frac{\delta}{n}\right)^3}\right)^{\frac{3}{2}}$$

Here, δ is Rydberg correction, and according to the author, this correction can be neglected in the case of large n. Results of electron density calculations are given in the table below.

Method	Electron density [10^{16} cm^{-3}]
He II Pashen alpha	3.16
IT relation, n_{max} = 7	4.17
Griem PLTE criteria, n* = 3.8	0.13
Vidal formula, n = 5 and Q = 3.47	3.92

CONCLUSION

From above results it is clear that IT relation yields good results when compared to He II Pashen alpha line. Even better results gives Vidal formula. On the other side, estimated electron density from Griem PLTE criteria is three times lower than one obtained from IT relation, He II Pashen alpha or Vidal formula

So it is shown in this paper that tehnique which involves estimation of effective quantum number n* from the intersection of two Boltzmann plots is expected to give good results at densities below 10^{16} cm^{-3}, while the others can be used for electron density determination of the odrer of 10^{16} cm^{-3}.

REFERENCES

Busher S., Glenzer S. and Kunze H.J., 1996, *J.Phys. B, At.Mol.Opt.Phys.* **29**, 4107
Griem H. R., 1963: *Phys. Rev.* **131**, 1170.
Inglis D. and Teller E., 1939, *Astrophys.J.* **90**, 439.
Ivković M. et al., 2010: *Spectrochimica Acta B* **65**, 234.
Konjević N., Jovićević S., Ivković M., 2009, *Physics of plasmas* **16**, 103501.
Vidal C.R., 1966, *JQSRT* **6**, 575.

30th SPIG, August 24-28, Šabac, Serbia