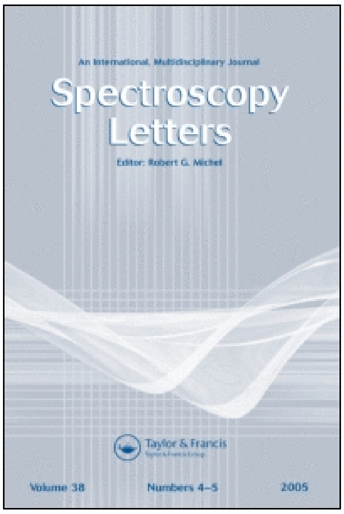

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Spectroscopic Investigation of a Double Discharge Pulsed Electron Beam Generator

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Spectroscopic Investigation of a Double Discharge Pulsed Electron Beam Generator

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ABSTRACT The wide range of applications of the plasma-based electron beam generator make it necessary to diagnose the device with a noninterfering method. The results of experimental and modeling studies of neutral helium and hydrogen beta spectral lines emitted from the double discharge pulsed electron beam generator are presented in this paper. Neutral helium lines emitted from the plasma in the pressure range 0.1–0.4 torr are studied and compared with results of the collisional radiative model. The duration of the electron beam is shorter than 100 ns, and the peak current intensity is of order amperes. The full width at half maximum of the H_β spectral line is used for the determination of the plasma electron density, found as $3.16 \times 10^{21}\,m^{-3}$ at 0.3 torr, and good agreement is obtained by comparing with the full computer simulation method.

KEYWORDS collisional radiative model, electron beam generator, emission spectroscopy, hydrogen beta line

INTRODUCTION

The double discharge pulsed electron beam generator (DDPEBG) is a device generating an intense electron beam of high peak current with a short pulse duration. These characteristics are making the DDPEBG extremely useful for practical applications such as synthesizing carbon nanotubes,[1] biosensors,[2] microprocessing,[3] radiation effects on superconducting bulk and thin films,[4] X-ray generation, and high-power laser preionization. This is why good diagnostics of the device is very important.

As a noninterfering method, the spectroscopic diagnostic technique has been used to investigate and determine fundamental plasma parameters such as electron temperature and density for several decades.[5] Usually, this is done by recording the various types of emission from the plasma and using one or more plasma models to interpret the measurements in terms of electron temperature and density. In this study, two simulation methods are used to investigate the plasma produced in the course of producing the electron beam.

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The DDPEBG has been investigated by emission spectroscopy.[6–8] Neutral helium spectral lines emitted between 400 and 700 nm were recorded and investigated by a developed collisional radiative model (CRM) for temperature determination. The details of the device, the spectroscopic measurements, and the CRM code have been described in detail previously.[7,8]

The FWHM of the H_β line is used for the measurement of the electron density. Comparisons with line profiles obtained by a full computer simulation method (FCSM)[9] for the H_β line are also presented.

RESULTS AND DISCUSSION

In the DDPEBG discharge system, once the electron beam channel is developed, the beam creates the necessary supplementary ionization, and a cylindrical pinch is established.

The experimental results can be divided into two main parts; the first part deals with the derivation of the electron temperature and the electron density of the experimental He I lines with the simulation by the collisional radiative model (CRM). The second part deals with the determination of the electron density using the FWHM of the H_β line, as well as comparison of experimental H_β line profile with the profiles obtained by FCSM code. The experimental results were carried out for a pressure range from 0.1 to 0.4 torr.

For the first part, Fig. 1 shows the recorded spectrum from 400 nm to 700 nm using a 300 lines/mm grating to see at a glance the emitted visible spectrum. The recorded spectrum mainly consists of He I spectral lines and the H_β line, where hydrogen was present as an impurity, approximately 1% in the helium gas. For better resolution of the He I spectral lines, the 1200 lines/mm grating is used. The emitted He I lines are recorded in the spectral range from 456.0 nm to 506.0 nm as shown in Fig. 2.

For the calculation of spectral lines intensities emitted from neutral helium using the CRM code, 108 excited levels are considered,[10] and the simulation procedure was described previously.[8] The simulation result gives the electron temperature and density by comparing the simulated intensities with the experimental ones. Good agreement between the simulated spectrum and the experimental one is shown in Fig. 2. The resulting electron temperature and density are 2.5 eV and $3.1 \times 10^{21}\,m^{-3}$, respectively, at the pressure of 0.3 torr.

The FWHM of the H_β line (shown in Fig. 3) is used for the determination of the electron density of the DDPEBG plasma. In the figure, the solid line shows the experimental line profile of the H_β, and the dashed line indicates the same line from the numerical code of the FCSM at 2.5 eV and $3.16 \times 10^{21}\,m^{-3}$ electron temperature and density, respectively. To obtain the pure Stark width experimentally, deconvolution procedure takes place after subtracting the contribution originating from Doppler and instrumental broadening as given in Ref. [11]. At the end,

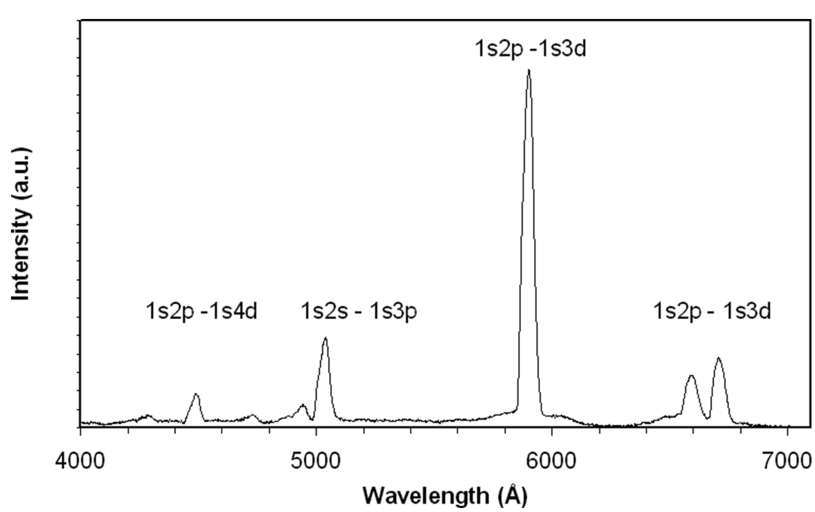

FIGURE 1 **Helium spectral line recorded side-on, from 400 nm to 700 nm at a pressure of 0.3 torr.**

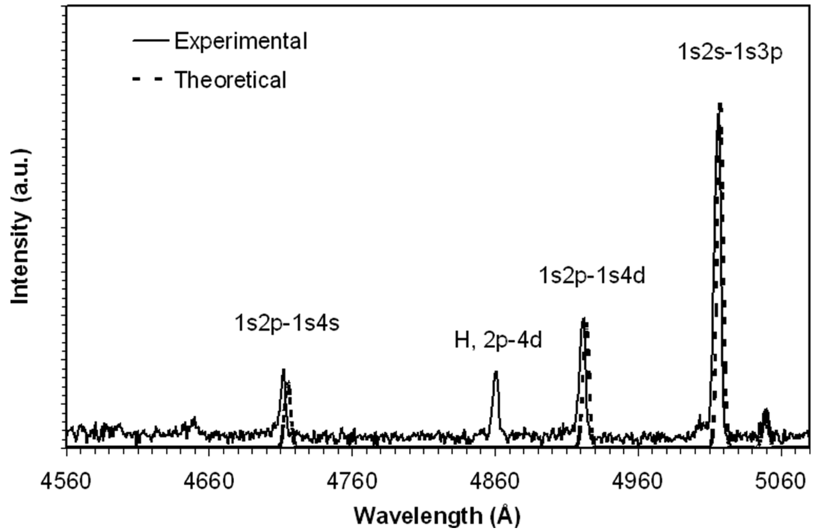

FIGURE 2 Experimental He I spectral lines (solid line) and simulated spectrum by CRM (dots) for a $T_e = 2.5$ eV and $N_e = 3.1 \times 10^{21}$ m^{-3} at a pressure of 0.3 torr.

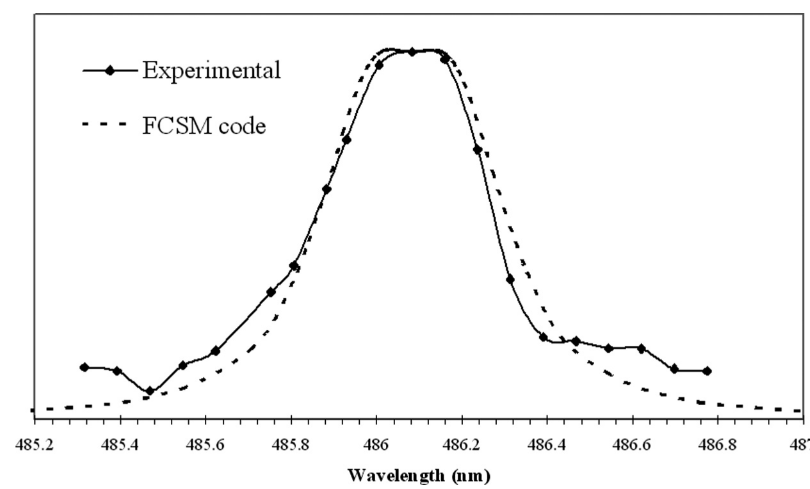

FIGURE 3 Experimental H_β spectral line (solid line) and the simulated profile by FCSM model (dots) at $T_e = 2.5$ eV and $N_e = 3.16 \times 10^{21}$ m^{-3}.

TABLE 1 FWHM (Å) of H_β line at Various Electron Densities and Electron Temperatures Calculated with the FCSM Code

T_e (eV) N_e (x $\times 10^{21}$ m^{-3})	1.5	2.0	2.5
1.0	2.14	2.17	2.20
1.77	3.21	3.30	3.14
3.16	4.67	4.65	4.73
5.62	7.05	7.09	6.79

the pure Stark FWHM is obtained experimentally as $4.48 \pm 0.46\,\text{Å}$. The pure Stark FWHM is used in Eq. (1) to derive the electron density.

$$N_e = 1.09 \times 10^{22} (\Delta\lambda_{1/2})^{1.458}\,\mathrm{m}^{-3} \tag{1}$$

where the full half width $\Delta\lambda_{1/2}$ is in nm. This equation is valid for the temperature range 1 eV to 4 eV and electron densities from 10^{20} m^{-3} to 10^{24} m^{-3}.[12] The electron density from Eq. (1) for the calculated Stark FWHM is $3.38\ (\pm 0.5) \times 10^{21}\,\mathrm{m}^{-3}$. The obtained electron density conformed well with the CRM results.

Table 1 presents recent results of the FWHM of H_β spectral line derived by the FCSM code for various electron density and temperature. A good agreement between the line profile derived by FCSM and the experimental one is also obtained, as shown in Fig. 3.

CONCLUSIONS

Two different methods are involved for the measurement of electron density and temperature of the DDPEBG device. Both methods are in good agreement. The obtained value of the electron density and temperature are 2.0×10^{21} to $3.38 \times 10^{21}\,\mathrm{m}^{-3}$ and 2.0–2.8 eV, respectively, for a pressure range 0.1–0.4 torr. The well-resolved observed spectra prove that the experimental setup and the radiation detection are suitable to perform interesting spectroscopic studies, too.

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