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A spectroscopic diagnostic of the electron density in a corona discharge

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Abstract. Spectral lines of hydrogen observed in a corona discharge are investigated. The corona discharge has been performed at the vicinity of a tip electrode under high voltage. The shape of the H-α and H-β lines is dominated by the Stark broadening due to the plasma microfield. Using a computer simulation method, we examine the sensitivity of the line shapes to the electron density. Our results indicate the possibility of a density diagnostic based on passive spectroscopy.

1. Introduction

Corona discharges of helium have been performed in an experiment devoted to the investigations of the dielectric properties of insulators in the context of electrical engineering. Here, we report on the analysis of hydrogen Balmer lines, which are strongly sensitive to the electron density and which have been observed in discharges at the room temperature. We show that a diagnostic of the electron density can be performed from an analysis of the width of these spectral lines. This work, which serves as a preliminary step, will be completed with further analyses of helium corona discharges that will be performed at low temperatures (a few K) with liquid helium.

2. Presentation of the experiment

The experimental setup consists of a point-plane electrode system placed inside a helium cryostat. The point electrode is negatively polarized by a stabilized high voltage DC power supply (Spellman RHSR/20PN60). The current-voltage characteristics were measured by using a Tektronix TDS540 oscilloscope and a Keithley 610C ammeter. The corona discharge in this geometry is axially symmetric and it appears as a luminous spherical region (ionization region) localized near the point electrode against the dark background. The measured intensity of the radiation is averaged over the observed lines and the exposure time. A liquid N_2 cooled 2D-CCDTKB-UV/AR detector is located directly in the exit plane of the spectrograph. The noise level of the CCD detector is determined only by the read-out noise as the dark current of the camera is less than 1 e/pixel/h at 153 K. The wavelength and intensity response of the detection system was calibrated by using low pressure helium and tungsten ribbon lamps. The line broadening due to the instrument response (1200g/mm grating) was estimated from the helium lines of a helium lamp as $\Delta\lambda_{ins} < 0.10$ nm.

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3. An analysis of hydrogen lines observed at 300 K

As a preliminary step, we report here on an analysis of hydrogen lines that have been observed in helium discharges at the room temperature. The atomic hydrogen is present in traces and its emission is sufficiently strong so as to yield intense lines, especially in the H-α and H-β transitions. The discharges were carried out at pressures from 1 to 12 bar, with a current of 100 μA. In order to simplify the interpretation of spectra, we focus on the lowest pressure values (namely, between 1 and 2 bar) because the H-α and H-β lines overlap with nearby atomic lines and molecular bands at higher pressures. Furthermore, we focus on the H-β line because its spectral profile is cleaner than that of H-α.

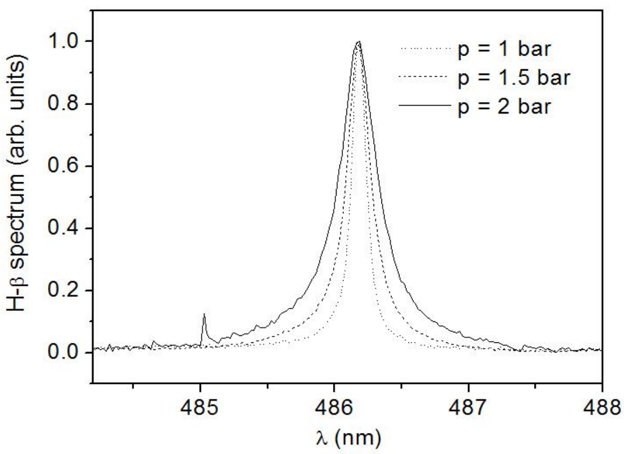

Figure 1. Plot of H-β observed in a helium corona discharge at room temperature, for different pressure values. The line width increases with the pressure. This trend is also observed on other lines.

Figure 1 shows a plot of the H-β line observed at 1, 1.5, and 2 bar. The line width increases with the pressure. An analysis using a van der Waals broadening model [1,2] indicates that this effect is not the dominant line broadening one. The instrumental broadening is also not dominant. We have examined the role of the Stark effect related to the plasma microfield. A computer simulation method [3] has been applied to the H-β line at the same pressure values as above. The He^+ ion microfield evolution is simulated from a quasiparticle model and the line broadening is calculated from a numerical integration of the time-dependent Schrödinger equation. The contribution of the electrons is evaluated using a collision operator. In our calculations, we have used the Griem-Kolb-Shen model [4] assuming an electron temperature of 10^4 K and leaving the electron density as an adjustable parameter. The ion temperature has been assumed equal to the atomic (300 K) temperature. Our calculations indicate that the Stark broadening is mainly due to the ions. Figure 2 shows an example of adjustment performed using the simulation method at p = 1 bar. A value of 10^{15} cm^{-3} has been obtained for the electron density. Our calculations at p = 1.5 bar and 2 bar yield higher values for the electron density (2×10^{15} cm^{-3} and 3×10^{15} cm^{-3}, respectively), which indicates an increase trend in terms of the pressure. This result is preliminary and will be completed with further analyses.

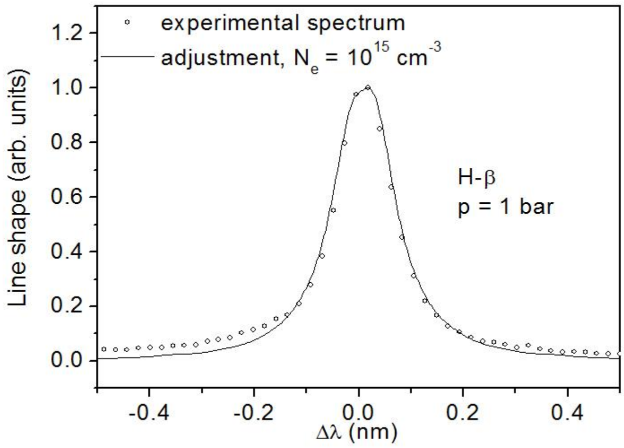

Figure 2. The plasma microfield yields an additional broadening, which can serve as a probe of the density. Here, the Stark broadening has been evaluated using a computer simulation method [3].

4. Conclusion

We have analyzed spectral profiles of hydrogen lines in helium corona discharges by means of a computer simulation method. An application to 1, 1.5, and 2 bar gas pressures indicates that the plasma microfield yields a visible Stark broadening, which can serve as a probe for the electron density. This result is a preliminary step in foregoing investigations of liquid corona discharges. New experiments, with liquid helium, are planned and will be analyzed using spectroscopic techniques.

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