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THE STARK WIDTH OF THE He II PASCHEN - α LINE

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1. INTRODUCTION

Stark parameters of the some neutral and ionized helium lines are often used for electron density measurements in plasmas (Griem, 1964; 1997). The accuracy of N_e determination achieved in this way often reaches the one obtained by using H_β line. The one most frequently used for diagnostic purposes between He II lines is P_α 468.6 nm line. Its FWHM width ranges from a few angstroms for density around $10^{23} m^{-3}$ to about 80 Å for $N_e \approx 4 \cdot 10^{24} m^{-3}$. Excellent overall agreement which was found between measured (Pittman and Fleurier, 1986; Büscher et al., 1996) and calculated (Griem, 1961) FWHM widths is the basis for the application of this line for plasma diagnostics. The Pittman and Fleurier (1986) relation:

$$N_e = 2.04(\Delta\lambda_{FWHM})^{1.21}$$

obtained from the best fit of experimental data is widely used in diagnostic purposes.

The experimental data for FWHM from about two dozen of papers Büscher et al., (1996) cover the broad range of electron density from $2 \cdot 10^{22} m^{-3}$ up to about $4 \cdot 10^{24} m^{-3}$. However, in the middle of this range there exists only a few measurements published, we have turned our attention to this density region in order to fill in the data gap.

2. EXPERIMENT

The experimental setup for plasma production and techniques of measurements of plasma parameters are described in details in (Ćirković et al., 1982; Vujičić, 1984). The apparatus (Fig. 1) consisted of a TEA CO_2 laser which produced a 10.6 μm light pulse consisting of a intense peak taking one-third of the energy with 80 ns FWHM, followed by a 2 μs tail. The total energy of the pulse was 12 J.

The bras axicon mirror coated by nickel, which formed one end of the steel chamber filled by He gas at 70 kPa, concentrates the laser power along axicon focal line. The breakdown arises at the maximum of the laser pulse along the focal line, so that cylindrical plasma, about 35 mm in length and 6 to 10 mm in diameter is formed. The photon drag detectors (FDD) were used for monitoring the incident and transmitted laser pulse shapes. In that way it was possible to monitor continuously shot-to-shot reproducibility of the laser and a regularity of the breakdown inside the chamber. The sharp maximum of photon drag signal is also used as a trigger signal for the oscilloscope and high speed camera (not shown in Fig. 1). The plasma was observed radially through the side windows. Transverse scanning (scanning perpendicular to the major axis) of the plasma is achieved by placing a thick plane-parallel plate (PP) between the condensing lens and spectrometer slit. Rotation of the plate focuses different radial regions of the plasma on the entrance slit of the monochromator. Thus we are

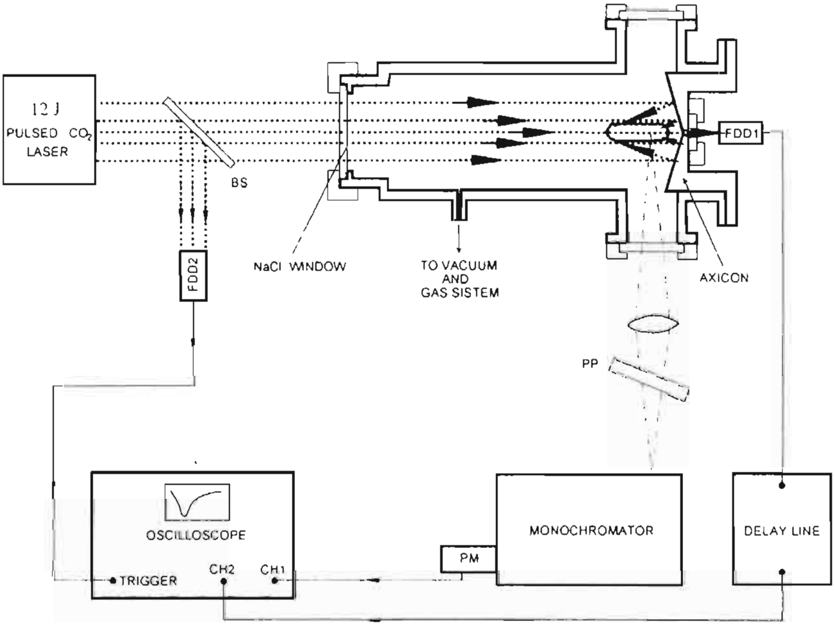

Figure 1

able to observe plasma radially along the diameter and determine precisely the position of plasma cylinder axis.

The time dependence of plasma cylinder radius which is necessary for interferometric determination of plasma density was obtained by high speed photography and by measuring the radial distribution of continuum radiation from plasma.

3. RESULTS AND CONCLUSIONS

The electron density of plasma was determined by spectroscopic measurements both from the Stark broadening parameters of singly ionized and neutral helium lines and interferometrically. For this purpose the time evolution of the following lines was recorded: He II 320.3 nm and He I 388.9 nm and 501.6 nm. The He II 320.3 nm line was used at early stage of plasma evolution starting from 0.25 μs after the breakdown while for period t > 2 μs after breakdown the He I lines and interferometry was used. For interferometric measurements the Mach-Zender interferometer with He-Ne laser was used.

He I lines were strongly self- absorbed for t < 2 μs, so the measured halfwidths are not too reliable. Due to bad signal to noise ratio for the measured He II line the electron densities at early phase of plasma evolution ($N_e \geq 6 \cdot 10^{23} m^{-3}$) are not too reliable. Estimated error in density determination for this period is about 20%. The agreement between the results obtained by interferometry and using He I lines was very good and lies within 7% limits. The final values of N_e were obtained by averaging all experimental data.

The electron temperature in the range of 52 to 65 kK was determined from the ratio of intensities of the He II 468.6 nm and He I 587.6 nm lines. The main source of experimental error in this case was the strong self-absorption of the He I line. Since the intensities of this line were corrected for self-absorption, and the method itself is insensitive to the error of line intensity ratio measurement, we took 10% as a reasonable estimate of the temperature determination error.

We determine FWHM of the line for different densities and mentioned electron temperatures from the recorded He II P_α profiles at different moments after breakdown. The results are given in Fig. 2 together with recent results of Srećković and Djeniže (2000) and calculations of Griem (1961), Kepple (1968) and Greene (1976).

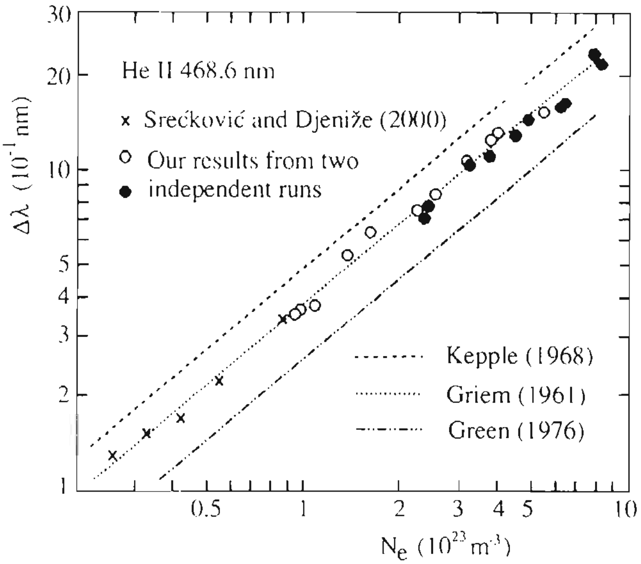

Figure 2

Measured widths agree within a few percent with the calculations of the Griem (1961) and best fit curve obtained by Pittman and Fleurier (1986) at the whole investigated electron density region. This not only confirm the applicability of the given line for the determination of electron density in the broad interval, but also provides us with data in the density range that were scarce in the literature.

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