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MEASURED STARK WIDTH AND SHIFT OF THE P_α HeII SPECTRAL LINE

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SUMMARY: Stark width and shift of the P_α HeII (468.59 nm) spectarl line have been measured in helium plasma. A linear low-pressure arc is used as a plasma source. Measurements have been done at electron density in the range from 0.4 to 3.3 × 10^{22} m^{-3} and at an electron temperature of 40 000 K. Measured Stark width and shift are compared to some theoretical estimations combining electron-impact and ion quadrupole effects. Our experimental data are in agreement with previous measurements.

1. INTRODUCTION

Stark width and shift of the P_α HeII spectral line are very important, because of their use in plasma diagnostics. There are numerous studies of the shift and width of P_α HeII spectral line (Fuhr and Lesage, 1993; and references therein), but their measurements and interpretation have been a matter of controversy (especialy Stark shift measurement).

Shifts to shorter (blue) wavelengths (Neiger and Griem, 1976), longer (red) wavelengths (Pittman *et al*, 1980; Pittman and Fleurier, 1982, 1986; Kobilarov *et al*, 1988; Gawron et al, 1989) or no shift at all (Van Zandt *et al*, 1976) have been reported. More recent experimental results, including our own, have generally reported red shifts for the P_α HeII line, although there are some differences in the shift magnitude.

Also, there is no general theory explaining the shift of P_α HeII line. The shift of this line has often been primarily associated with the so-called plasma-polarization shift (PPS). Berg *et al* (1962, 1966) first invoked PPS in an experiment to explain the observed blue shifts. According to the PPS, an ion emitter will attract an excess negative charge in its surrounding plasma environment. A review of theoretical estimates of the different sources of shift (Fleurier and Gall, 1984) shows that the most probable cause of shift is electron collision effect, including weak and strong collisions.

The aim of this work is to give a further check of value and the sign of the shift (d) and to compare the result with existing theoretical and previous measured values. We also have measured the P_α HeII FWHM (fullwidth at half intensity maximum) (w) and compared it with previous measurements and theories.

In order to estimate Stark parameters of HeII spectral line, we have used a special source of plasma allowing combined glow and pulse discharge following the idea of Djeniže and Labat (1983).

2. EXPERIMENT

The plasma was created in a Pyrex discharge tube represented in Figure 1.

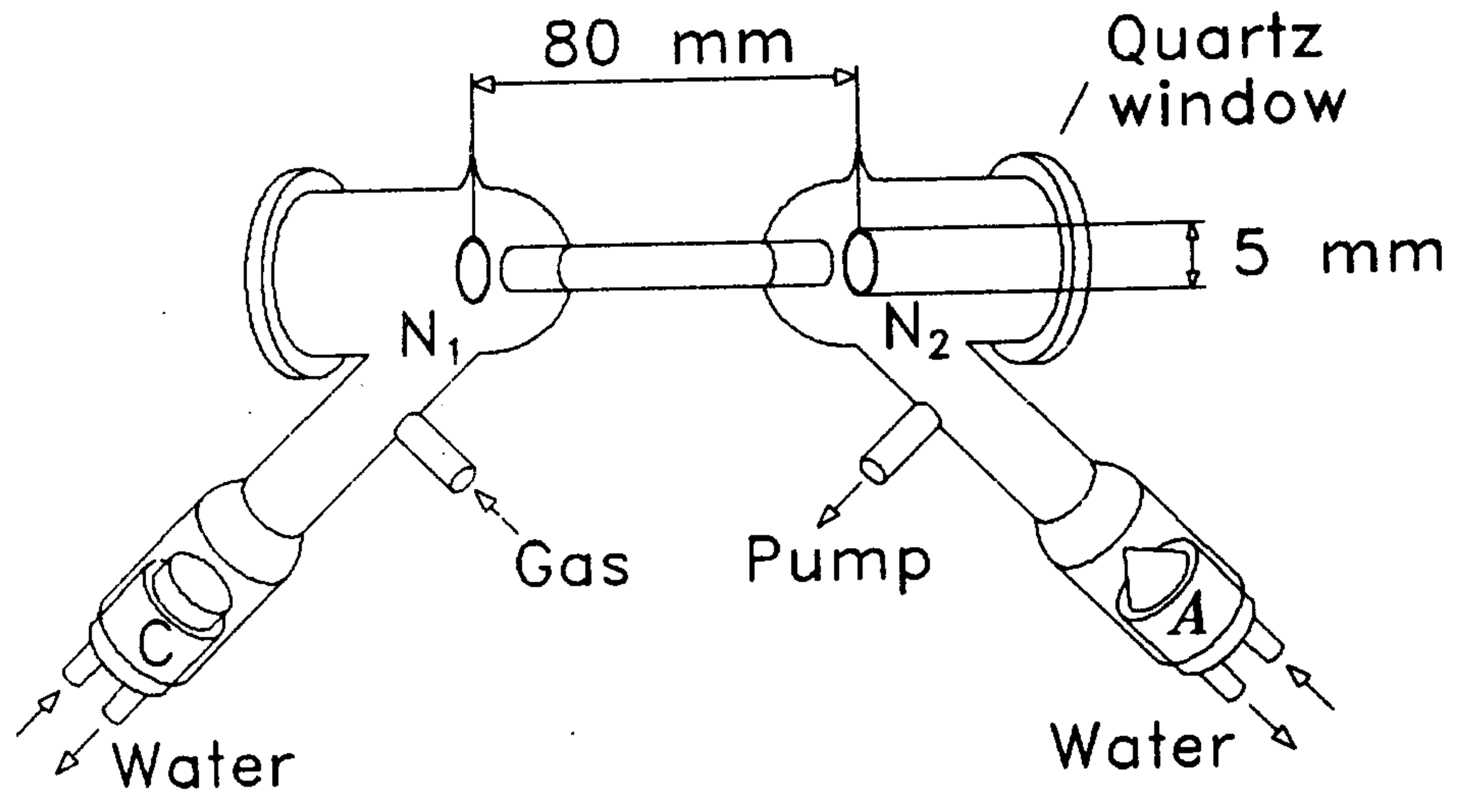

Fig. 1 Pyrex discharge tube with quartz windows, water-cooled cooper glow discharge (C, A) and ring-shape impulse (N_1, N_2) electrodes.

The tube had two quartz windows at both its ends. The effective plasma length was 80 mm, while the inner diameter of linear part of discharge tube was 5 mm. Spectroscopic observations of isolated spectral lines were made along the axis of the discharge tube. By using this source it was possible to get a reproducible and homogenous plasma.

The plasma was generated by a pulse discharge of 80 μF condenser initially charged to 1.2 kV. Auxiliary ring-shape nickel electrodes (N_1 and N_2) were positioned at the optical axis, 80 mm from each other. They were used to drive the pulse discharge.

The electric properties of the pulse discharge were measured by Rogowski coil, and the following values were found: discharge period 80 μs, discharge current maximum 7.1 kA, curcuit self inductance 1.8 μH and decrement 3.2.

The glow discharge was driven between water-cooled ccpper electrodes (C and A) at the current of 7 mA. As a working gas we used the pure helium at the pressure of 260 Pa. The electron density in the positive column of the glow discharge was about $1 \times 10^{17} m^{-3}$. It was obtained from the electric field strength measured between N_1 and N_2 electrodes. For this electron density the Stark broadening effect is negligible.

Parameters of the pulse plasma were determined by standard diagnostic methods. Electron temperature (T) was determined from the ratio of relative intensities of HeII 468.59 nm and HeI 388.89 nm spectral lines assuming existence of the LTE. The maximal value of the electron temperature was 40 000 K with ±15% error. Atomic parameters required were taken from Wiese *et al* (1966). It was found that the electron temperature decayed slowly during the first 40 μs after the beginning of the discharge.

The electron density (N) was measured by a single wavelength laser interferometry (Ashby *et al*, 1965), using the 632.8 nm He-Ne laser line. The measured electron density values were (0.4 – 3.3) $\times 10^{22}$ m^{-3}. The maximal value of the electron density corresponds to 20 μs after the beginning of the discharge. The errors of these measurements are estimated to be within ±10%. Temporal evolutions of the T and N in the decaying plasma are given in Fig. 2.

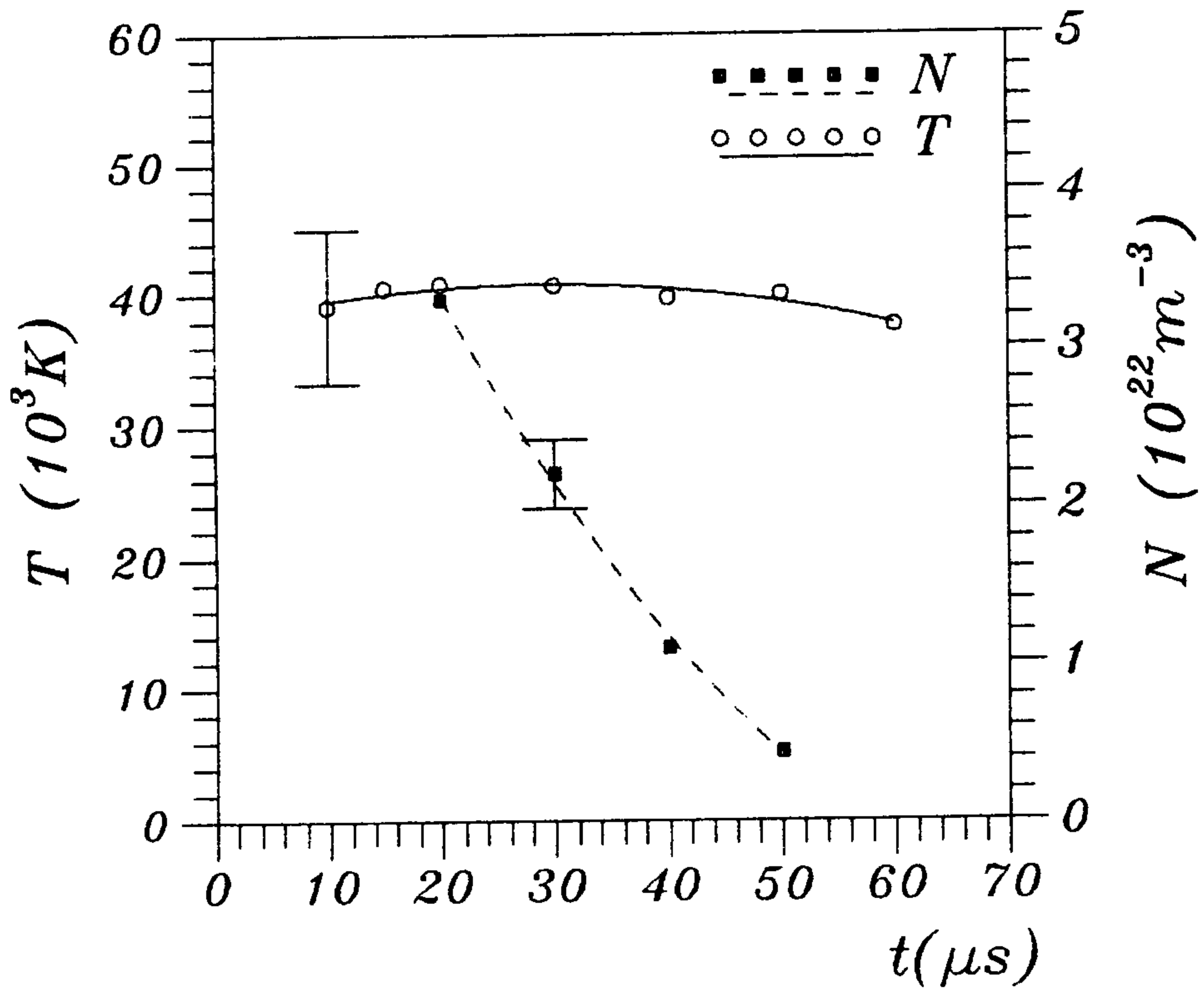

Fig. 2 Temporal evolution of the electron density (N) and temperature (T) in decaying plasma.

For the spectroscopic study, a photomultiplier (*EMI 9789-QB*) and a grating-spectrograph (Zeiss PGS-2, inverse linear dispersion 0.73 nm/mm in the first order) system were used. The photomultiplier signal was digitalized using HAMEG 205-2 oscilloscope interfaced to a computer.

Scanning of the line profile was done by using a shot-to-shot techique, which involved advancing the exit slit-photomultiplier combination in small (0.0073 nm) wavelength steps (Djeniže *et al*, 1991, 1992). The measured profiles were of Voigt type due to the convolution of the Lorentzian Stark profile and the Gaussian profiles caused by Doppler and instrumental broadening. A standard deconvolution procedure was used, as described in Davies and Vaughan (1963). The instrumental FWHM was 0.014 nm in the first order.

3. RESULTS AND DISCUSSION

The profiles of the P_α HeII line were observed at times between 20 and 50 μs after the beginning the discharge. Each profile was independently analysed. They have not shown any self-absorption. This could be verified by comparing the widths at different line intensity heights (3/4,1/2,1/4,1/8) with the theoretical values of Griem (1964).

We have measured the Stark shift (d_m) relative to the unshifted lines emitted by the same plasma. The line profile was observed at later times during plasma decay, at considerably lower electron densities (Purić and Konjević, 1972) and were corrected for the electron temperature decay (Popović *et al*, 1992). The Stark shift value was determined with an absolute error of $\pm$ 0.001 nm at the given electron temperature and density. The results of measured Stark shift value d_m and Stark widths w_m at the given T and N are presented in the Table I.

Table I Measured Stark shift d_m and Stark widths w_m at the given electron temperature T and density N.

T [10^3K]	N [$10^{22}m^{-3}$]	w_m [nm]	d_m [10^{-3}nm]
40	3.3	0.18	3
40	2.7	0.17	
40	2.2	0.17	

The results of our FWHM measurements and comparisons with other experimental and theoretical data are shown in Fig. 3.

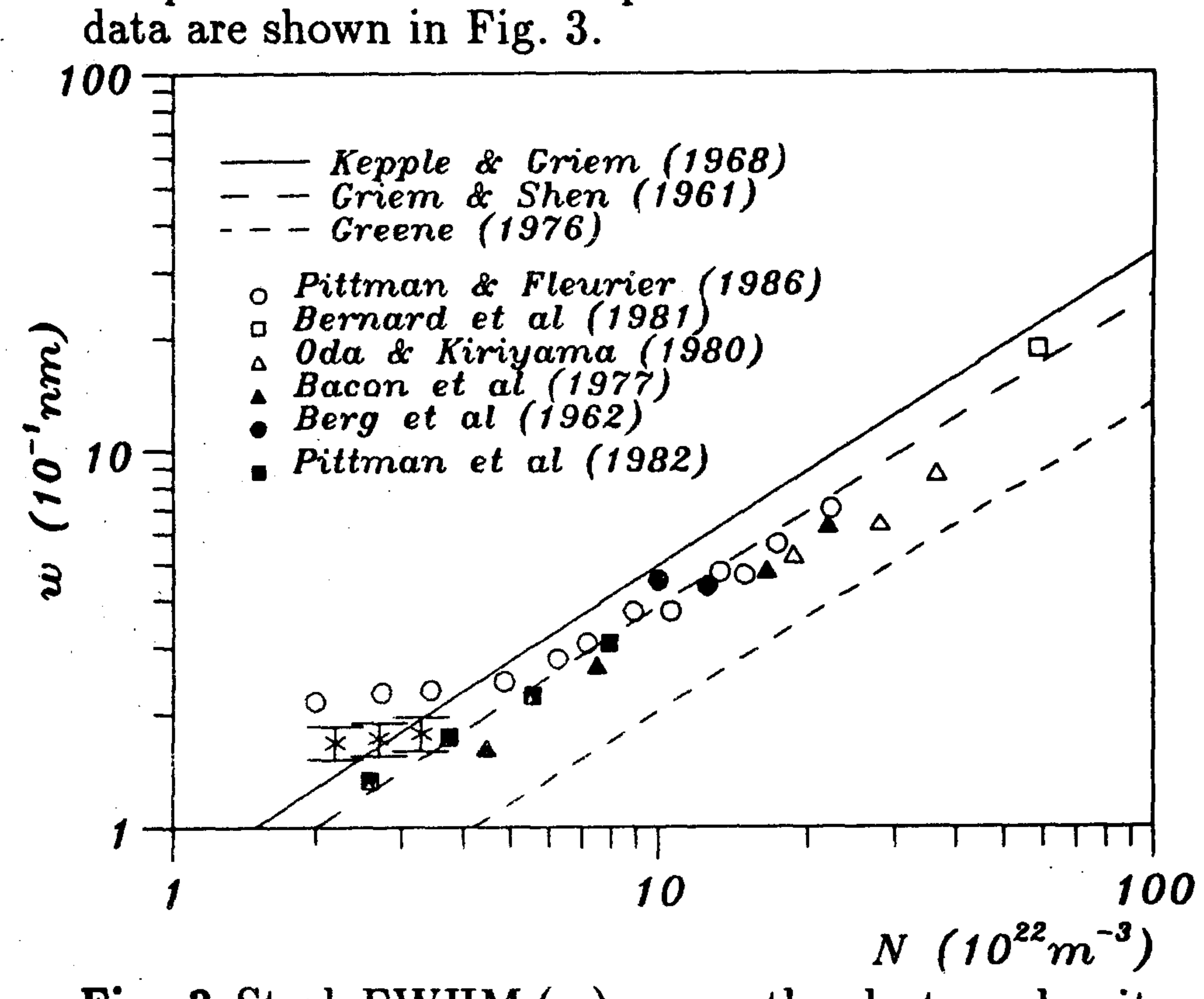

Fig. 3 Stark FWHM (w) versus the electron density (N). $*$ - our present results.

This figure is an extension of a figure given in Pittman and Fleurier (1986). It shows the predictions based on the various theoretical calculations for P_α HeII (n=4 $\rightarrow$ n=3) line. Also illustrated are some experimental results that were obtained during the past two decades by various authors. Our measurements agree well with some other data, and they are between the theoretical calculations by Griem and Shen (1961) and Kepple and Griem (1968). These early calculations neglect both ion dynamics and the so-called upper- loweer state interference term (Gawron *et al*, 1988) whose effects tend to counteract each other in determination of the spectral line width.

Our value of Stark shift and its comparison with other experiments and theoretical data of Griem (1983) are shown in Fig. 4.

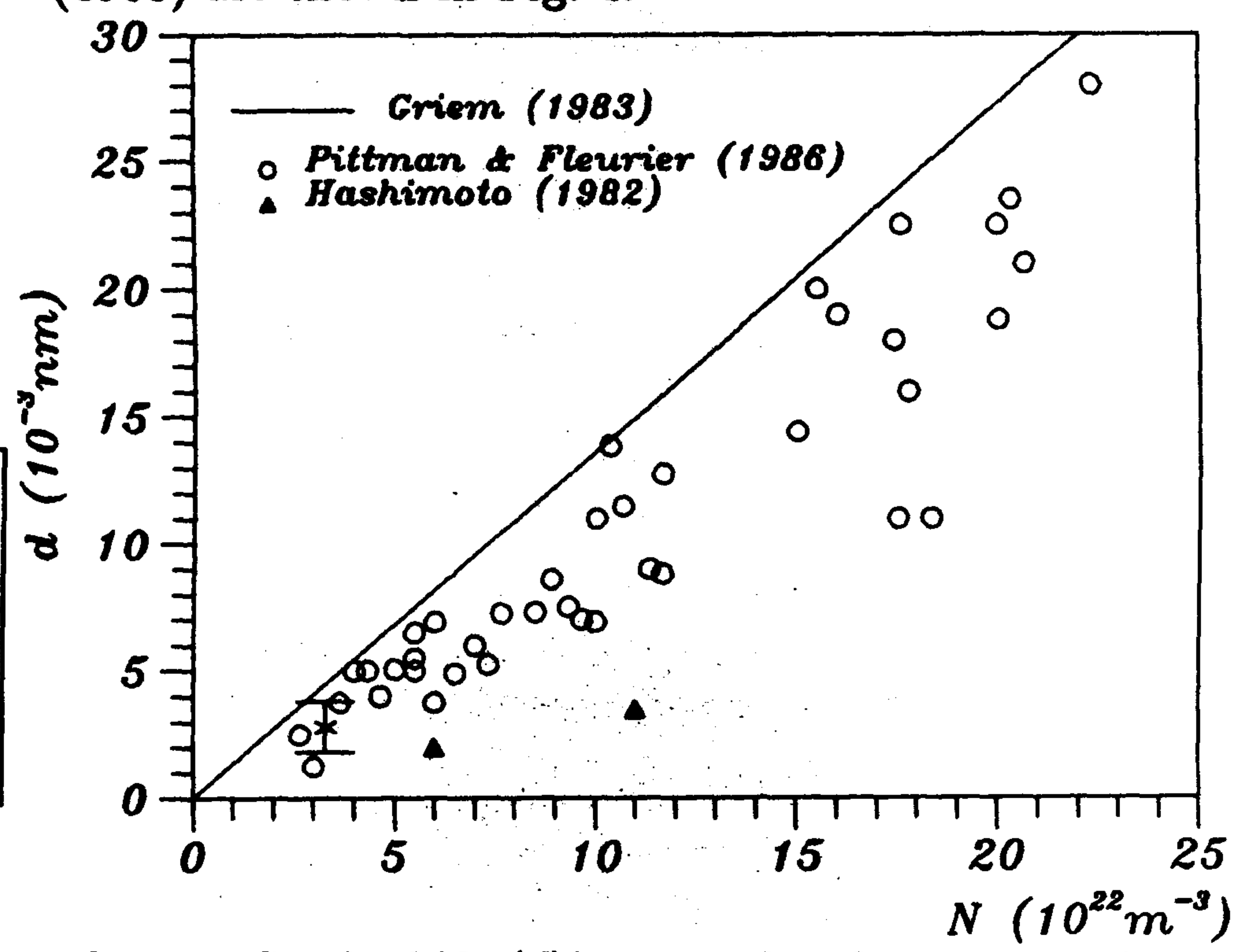

Fig. 4 Stark shift (d) versus the electron density (N). $*$ - our present results.

Our measurement is in good agreement with results of Pittman and Fleurier (1986). The experimental results of Hashimoto (1982) are also presented in this figure but a considerable disagreement is obvious.

4. CONCLUSION

We have measured Stark width and shift of the P_α HeII using the plasma of a linear pulse discharge superimposed to the glow discharge in the helium over density range of 0.4 x 10^{22} - 3.3 x 10^{22} m^{-3} at a temperature 40 000 K. Our measurements of Stark widths agree well with the results of Pittman and Fleurier (1986) and with the theory of Griem and Shen (1961). We have compared, also, our red shift with the measurements of Pittman and Fleurier (1986) and the calculations of Griem (1983). The agreement between our measured d_m value and these data is within the experimental uncertainties. Measured shifts of Hashimoto (1982) are almost four times smaller than ours and results of Pittman and Fleurier (1986).

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МЕРЕНА ШТАРКОВА ШИРИНА И ПОМЕРАЈ P_α СПЕКТРАЛНЕ ЛИНИЈЕ ИЗ СПЕКТРА HeII

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Оригинални научни рад

Штаркову ширину и померај P_α линије (468.59 nm) из спектра HeII мерили смо у плазми хелијума. Као извор плазме коришћен је линеарни импулсни лук на ниском притиску. Мерења су вршена у опсегу електронске концентрације од 0.4 то 3.3×10^{22} m^{-3} и електронске температуре од 40 000 K. Измерене вредности Штаркове ширине и помераја упоређене су са теоријским предвиђањима на основу електрон-сударног и јон-квадруполног ефекта. Наши експериментални подаци се слажу са резултатима првобитних мерења.