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MEASUREMENT OF THE STARK BROADENING PARAMETERS OF SEVERAL SINGLY IONIZED NITROGEN LINES*

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Abstract: A nitrogen plasma was created in an electromagnetically driven T tube. Electron density was determined by the laser interferometry at two different wavelengths while electron temperature from relative intensities of N II lines. Electron density varied from 3.09 to $4.84 \cdot 10^{17}$ cm^{-3}, electron temperature from 16200 to 18300 °K. The profiles of various lines emitted in the plasma were obtained by scanning with a monochromator from shot to shot. Half widths of nitrogen ion lines were measured from the impact broadened profiles and compared with the theory and other experimental results.

1. Introduction

The measurements of broadening parameters of isolated ion lines[1, 2, 3] yielded widths that were 2 — 20 times larger than those predicted by Griem[4] from the generalized impact theory by Griem, Baranger, Kolb and Oertel[5]. The only exceptions were the lines of singly ionized nitrogen where reasonably good agreement existed with this theory[6]. These data were in the mean time reasonably well compared with results from various, more sophisticated theoretical aproaches by Griem[7], Cooper and Oertel[8] and Griem[9]. However, recently Berg, Ervens and Furch[10] published results of their investigation of Stark broadening of N II lines in a newly designed T tube with radio-freqency preionization. Their results were higher from those obtained by Day and Griem[6] for 30 to 370 %. This discrepancy was explained by better plasma homogenity achieved in a new T tube.

The aim of this paper is to provide more data for comparison with previous experiment and theory. The plasma source was an electromagnetically

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driven T tube. For electron density determination the laser interferometry at two different wavelenghts was used in preference to the plasma seeding with helium as employed by two previous authors when electron density was determined from the Stark broadening parameters of neutral helium lines. As details about the apparatus and the experimental procedure can be found elsewhere[11] brief description will be sufficient here.

2. *Experimental arrangement*

Plasma source was an electromagnetically driven T tube (internal diameter 38 mm) with usual back strap configuration. Condensor battery of 7.5 μF was charged to 17 or 25 kV. During the experiment continuous flow of nitrogen (0.8 lit/min.) at a pressure of 1 torr was sustained. All plasma observations were taken 12 mm from the reflector placed 12.5 cm from electrodes.

3. *Interferometric method*

The electron density was determined by the laser interferometric method which recently was employed successfully for the investigation of the reflected shock wave plasma[11]. A small helium-neon laser was used, capable of operating at two wavelengths: 6328 A and 1.15 μ. Expansion tube was placed perpendicularly to the interferometer beam passing through plasma

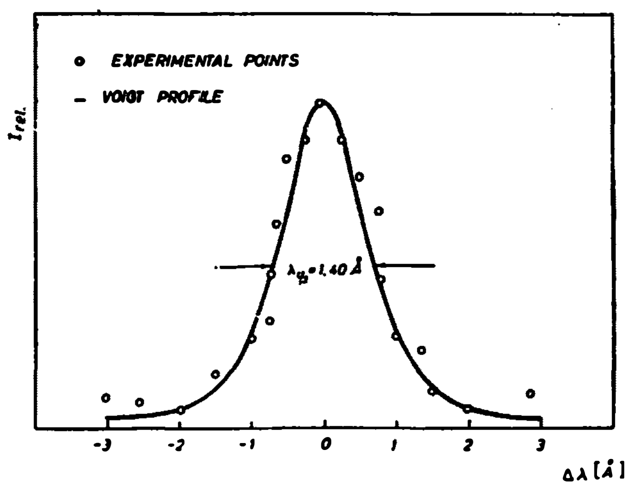

Fig. 1. Experimental data for 3995.0 A line of N II compared with corresponding Voigt profile.

12 mm from the reflector. Interference fringes at 1.15 μ were detected by means of a photomultiplier placed behind the laser. Interferences fringes at 6328 Å were registered in external cavity by inserting a glass plate reflecting a part of interfering beam on photomultiplier[12]. In both cases grating monochromator Zeiss-SPM-2 was used with photomultiplier to separate the plasma stray light from the signal.

4. *Spectroscopic measurements*

The light from the shock tube was observed by the photomultiplier-monochromator system whose output was displayed on an osciloscope and recorded on film for measurement. Linear operation of the photomultiplier was carefully insured during the experiment. The relative spectral response of the photomultiplier was calibrated against a standard ribbon lamp.

Electron temperature was determined from relative intensities of five N II lines, 4630.5 Å, 3995.0 Å, 4447.0 Å, 3838.4 Å and 4552.5 Å. The transition probabilities for these lines were taken from the book by Wiese *et al*[13].

In order to obtain Stark profiles of investigated lines the usual deconvolution procedure for instrumental-Gaussian and dispersion profile was used[14]. Characteristic example of experimental data compared with corresponding Voight profile is given in Fig. 1, which illustrates additionally the

Table 1.

Comparison of electron densities obtained with two different wavelengths at corresponding electron temperatures.

Temperature °K	Interferometric data ($N_e \cdot 10^{-17}$ cm^{-3})			
	6328 Å	1.15 μ	Two wavelength	Average
16200	3.15	3.10	3.09	3.12
18300	4.86	4.83	4.83	4.84

reproducibility of these measurements. For 4552.5 Å line the Stark broadening halfwidth was large and the instrumental width could be neglected since it is less than 1/6 of the total halfwidth of this line[15].

5. Experimental results

Measured electron densities and corresponding electron temperatures are given in Table 1. Good agreement between results obtained at two wavelengths indicates usefulness of the interferometric technique and reproducibility of electron density measurements. Each result represents an average value of at least ten measurements and reproducibility was better than 10 %. The estimated error did not exceed 7 %. Electron temperature was determined with accuracy not better than 20 %. Measured half-half-widths (in Å units and normalized to the electron density of $1 \cdot 10^{17}$ cm^{-3}) of six nitrogen lines are given in Table 2 beside the experimental results by Day *et al*[6] and Berg *et al*[10].

Estimated error of experimental half-halfwidths is ± 20 %, due to the uncertainty in the determination of electron density (± 7 %) and in the measurements of experimental profile (poor reproducibility). In order to compare with the experiment, theoretical values of half-halfwidths computed from Griem's semiempirical formula[9] (all perturbing levels were treated lumped together) are also given in Table 2 (last column). All necessary data for these computations (ionisation and excitation potentials, etc.) were taken from tables of spectral lines by Moore[16], and Striganov *et al*[17]. Theoretical values for the half-halfwidths computed by Griem[7] and Cooper *et al*[8] are also given in the table.

6. Discussion

Within the limits of the errors our experimental results agree with those by Berg *et al*[10] for the two lines 4630.5 Å and 3995.0 Å although our results are systematically lower. However, for 4552.5 Å line the discrepancy amounts to 360 % while good agreement was found with results by Day *et al*[6].

Although the plasma reproducibility during the line scanning was poor in comparison with other gases (e. g. argon[11]), such large discrepancy is hard to explain. In order to assess the advantages of the new design of the T tube and importance of radiofrequency preionisation for the plasma stability, some preliminary measurements have been made in a similar experimental conditions as described by Berg *et al*[10]. However, no appreciable difference in results for 4552.5 Å line was found. It should be noted that reproducibility was improved for about 30 %. Unfortunately our R. F. source was limited in power to 50 W, and so some systematic investigations of the influence of preionization on plasma stability could not be performed.

The average ratio of the measured to the theoretical broadening parameters calculated from Griem's semiempirical formula is 1.30. The values of Stark

Table 2.
Experimental half-halfwidths W (Å) of N II lines at $1 \cdot 10^{17}$ electrons/cm^3, compared with theoretical and other experimental results.

Multiplet	Transition	Line (Å)	Griem[7] W	Cooper et al[8] W	Experim. results: Day and Griem[6] W	Experim. results: Berg et al[10] W	This experiment: Temperature	This experiment: W	Griem[9]
5	$3s^3P_2 — 3p^3P_2$	4630.5	18000 °K *)			22000 °K	16200 °K	0.14	0.14
			0.14	0.12	0.072	0.20			
11	$3s^1P_1 — 3p^3P_2$	4654.6	—	—	—	—	16200 °K	0.14	0.14
12	$3s^1P_1 — 3p^1D_2$	3995.0	—	—	—	22000 °K	16200 °K	0.14	0.11
						0.17	18300 °K	0.15	0.11
14	$3p^1P_1 — 3d^1F_2$	4564.8	—	—	—	—	16200 °K	0.15	0.16
58	$3d^1F_3 — 4f^3G_4$	4552.5	19100 °K			22000 °K	18300 °K	0.25	0.56
			0.41	0.76	0.24	0.90			

*) This results are for 4613.9 Å line which belongs to the same multiplet

broadening parameters for majority of lines do not differ from theoretical for more than 30 %. The exception is 4552.5 Å line where the discrepancy is 120 %.

To clear up the discrepancies between different experimental results, it would be useful to perform similar measurements in nitrogen plasmas produced in other sources (e. g. wall stabilized arc).

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MERENJE PARAMETARA ŠTARKOVOG ŠIRENJA NEKOLIKO LINIJA JEDNOSTRUKO JONIZOVANOG AZOTA

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Sadržaj

Plazma azota je proizvedena u elektromagnetnoj T cevi punjenoj azotom pod pritiskom od 1 tora. Za merenje elektronske gustine korišćen je metod

laserske interferometrije za dve talasne dužine, dok je elektronska temperatura određena iz relativnih intenziteta N II linija. Izmerene vrednosti elektronske gustine nalazile su se u opsegu 3.09 do $4.84 \cdot 10^{17}$ cm^{-3} a temperature u opsegu 16200 do 18300 °K. Pojedine tačke profila snimane su u uzastopnim pražnjenjima, pomoću monohromatora sa fotomultiplikatorom.

Mereni parametri Štarkovog širenja (polu-polu širine linija normalizovanih na elektronsku koncentraciju 10^{17} cm^{-3}) upoređeni su sa teoriskim i eksperimentalnim vrednostima drugih autora. Nađeno je zadovoljavajuće slaganje sa teoriskim vrednostima izračunatim iz Griem-ove semi empiriske formule za širinu jonskih linija u plazmi[9].