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Original scientific paper

ON THE STARK BROADENING PARAMETERS OF THE TWO N II SPECTRAL LINES OF THE 3d-4f TRANSITION

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SUMMARY: Stark parameters (width and shift) of two singly ionized nitrogen spectral lines, that belong to 3d-4f transition have been measured in a linear pulsed, low pressure, arc discharge in the nitrogen-oxygen plasma at a 54000 K electron temperature and at a 2.8 $\times$ 10^{23} m^{-3} electron density. The measured values have been compared to the existing experimental and calculated data.

1. INTRODUCTION

The aim of this paper is to provide some new data on Stark HWHM (half-width at half intensity maximum, w) and stark shift (d) of two singly ionized nitrogen spectral lines belonging to 3d-4f transition at a 54000 K electron temperature (T). Namely, the existing experimental w values (Popović *et al.* 1975; Pittman and Konjević 1986; Purić *et al.* 1987; Djeniže *et al.* 1992) lie under the only theoretical prediction (Griem 1974). On the other hand, only one experiment deals with the Stark shift determination of the spectral lines that belong to 3d-4f transition, to the knowledge of the authors (Fuhr and Lesage 1993 and references therein). Djeniže *et al.* (1992) refere the measured d values of the spectral lines belonging to 3d-4f transition at 31000 K electron temperature. There exists between the measured and calculated (Griem 1974) Stark shift values evident disagreement. In spite of these, new experimental results of the Stark parameters are wellcome. It should be pointed out that the knowledge of the Stark width and shift dependence upon the electron temperature in the plasama is, also, of a great importance for testing their theoretical predictions based on various approaches.

Our measured values of Stark HWHM's and shifts have been compared to the existing experimental values and theoretical prediction based on the semiclassical approximation (Griem 1974).

2. EXPERIMENT

The modified version of the linear low pressure pulsed arc (Djeniže *et al.* 1991; Milosavljević and Djeniže 1997) has been used as a plasma source. A pulsed discharge driven in a quartz discharge tube of 5 mm inner diameter and has an effective plasma length of 6.0 cm. The tube has end-on quartz windows. On the opposite side of the electrodes (Fig. 1 in Djeniže *et al.* 1991) the glass tube was expanded in order to reduce erosion of the glass wall and also sputtering of the electrode material onto the quartz windows. The working gas was nitrogen and oxygen mixture (83% N_2 + 17% O_2) at 70 Pa filling pressure in fowing regime. Spectroscopic observation of isolated spectral lines was made end-on along the axis of the discharge tube.A capacitor of 14 μF was charged up to 4.5 kV and supplied discharge currents up to 7.7 kA. The line profiles were recordered by a shot-by-shot technique using a photomultiplier (EMI 9789

QB) and a grating spectrograf (Zeiss PGS-2, reciprocal linear dispersion 0.73 nm/mm in the first order) system. The instrumental HWHM of 0.004 nm was obtained by using of the narrow spectral lines emitted by the hollow cathode discharge. The recorded profile of these lines has been of the Gaussian type

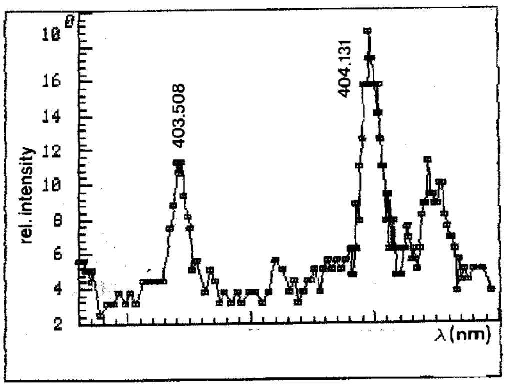

Fig. 1. *Recordered spectrum with the investigated spectral lines.*

within ±8% accuracy in the range of the investigated spectral line wavelengths. The exit slit (10 μm) of the spectrograph with the calibrated photomultiplier was micrometrically traversed along the spectral plane in small wavelength steps (0.0073 nm). The photomultiplier signal was digitized using oscilloscope, interfaced to a computer. A sample output is shown in Fig. 1. Plasma reproducibility was monitored by the N II line radiation, and also, by the discharge current (it was found to be within ±6%). The measured profiles were of the Voigt type due to the convolution of the Lorentzian Stark and Gaussian profiles caused by Doppler and instrumental broadening. For electron density and temperature obtained in our experiment the Lorentzian fraction in the Voigt profile was dominant (over 88%). Van der Waals and resonance (aboute 8×10^{-6} nm) broadening were estimated to be smaller by more than an order of magnitude in comparison to Stark, Doppler (0.008 nm) and instrumental broadening. A standard deconvolution procedure (Davies and Vaughan 1963) was used. The deconvolution procedure was computerized using the least square algorithm. The Stark widths were measured with ±12% error.

The Stark shifts were measured relative to the unshifted spectral lines emitted by the same plasma (Purić and Konjević 1972). The Stark shift of spectral line can be measured experimentally by evaluating the position of the spectral line centre recorded at two different electron density values during the plasma decay. In principle, the method requires recording of the spectral line profile at the high electron density (N_1) that causes an appreciable shift and then later when the electron concentration has dropped to the value (N_2) lower by at least an order of magnitude. The difference of the line centre positions in the two cases is Δd, so that the shift d_1 at the higher electron density N_1 is:

$$d_1 = N_1 \Delta d \; / \; (N_1 - N_2) \; .$$

The shift was corrected for the electron temperature decay (Popović *et al.* 1992). Stark shift data are determined with ±0.0015 nm errors at a given N and T. The plasma parameters were determined using standard diagnostics methods. The electron temperature was determined from the ratios of the relative intensities of the 348.49 nm N IV to 393.85 nm N III and previous N III to 399.50 nm N II spectral lines, assuming the existence of LTE, with an estimated error of ±10%. All the necessary atomic parameters were taken from Wiese *et al.* (1996). The electron density decay was measured using a well known single wavelegth He-Ne laser interferometer for the 632.8 nm transition with an estimated error of ±7%.

3. RESULTS

Our experimental results of the measured Stark HWHM (w_m) and shift (d_m) values at 54000 K electron temperature and 2,8 × 10^{23} m^{-3} electron density are given in Table 1.

Table 1. Experimental Stark HWHM (w_m) and shift (d_m) at a 54000 K electron temperature and a 2.8 × 10^{23} m^{-3} electron density. Negative shift is toward the blue.

Transition	Multiplet	λ (nm)	w_m (nm)	d_m (nm)
3d – 4f	$^3F^0$ – ^3G	403.508	0.057	-0.0028
	(39)	404.131	0.059	-0.0042

4. DISCUSSION

The theoretical Stark HWHM (w) dependence on the electron temperature together with the values of other authors and our experimental results at the electron density of 1 × 10 ^{23} m^{-3} are presented in Fig. 2. Theoretical values are calculated by Griem (1974) up to 40 000 K electron temperature, using the semiclassical approximation. The theoretical Stark shift (d) dependence (Griem 1974) on the electron temperature together with the values of other authors and our experimental results at the electron density 1 × 10^{23} m^{-3} are presented in Fig. 3.

On the basis of our measured Stark parameters, existing experimental and theoretical predictions we can conclude:

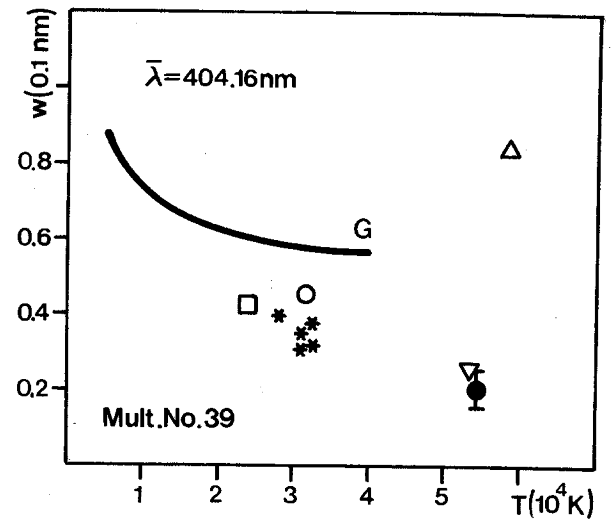

Fig. 2. *Theoretical Stark HWHM (w) dependence on the electron temperature scaled to the electron density of a 1 × 10^{23} m^{-3}. •, our experimental results and those of other authors:* □*, Popović et al. (1975);* Δ*, Källne et al. (1979); *, Pittman and Konjević (1986);* ∘*, Djeniže et al. (1992);* ∇*, Purić et al. (1987). Theory: –, semiclassical electron impact widths (G) after Griem (1974). The error bars include the uncertainties of the width and electron density measurements. $\bar{\lambda}$ is the mean wavelength for the multiplet.*

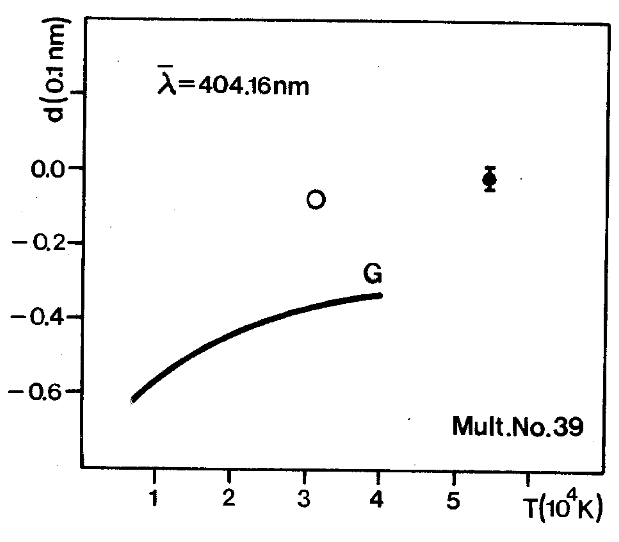

Fig. 3. *Theoretical Stark shift (d) dependence on the electron temperature scaled to the electron density of a 1 × 10^{23} m^{-3}, •, our experimental results and those of other authors:* ∘*, Djeniže et al. (1992). Theory: –, semiclassical electron impact shifts (G) after Griem (1974). The error bars include the uncertainties of the shift and electron density measurements. $\bar{\lambda}$ is the mean wavelength for the multiplet.*

Our experimental Stark HWHM data and those of other authors (Popović *et al.* 1975; Pittman and Konjević 1986; Purić *et al.* 1987; Djeniže *et al.* 1992) lie under theoretical values predicted by semiclassical theory (Griem 1974) except the experimental results from Källne *et al.* (1979). At electron temperature of 58000 K those are higher up to the factor 4 compared with our results. On the other hand our measured w values at 54000 K electron temperature agree well with those of Purić *et al.* (1987) measured at 53000 K electron temperature.

In the case of the Stark shift we can conclude that our measured d_m data, have negative sign, like the calculated (G) values, but the theoretical prediction is several times higher than measured values (Djeniže *et al.* 1992 and our presented results). It should be pointed out that the theoretical prediction of the Stark shift values is very sensitive to the number of the perturbing levels included in the calculation. Namely, the number of the perturbing levels has appreciable influence on the shift, including its sign. Omitting some of them may lead to erroneous results (Djeniže *et al.* 1993). Our new experimental results confirm the disagreement between theoretical predictions (Griem 1974) and existing experimental w and d data.

In view of the evident disagreement between the measured Stark parameters and their calculated values, based on the semiclassical theory, performing new theoretical calculations would be helpfull.

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О ШТАРКОВИМ ПАРАМЕТРИМА ШИРЕЊА ДВЕ СПЕКТРАЛНЕ ЛИНИЈЕ ИЗ СПЕКТРА ЈЕДНОСТРУКО ЈОНИЗОВАНОГ АЗОТА ИЗ ПРЕЛАЗА 3d-4f

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Оригинални научни рад

Штаркови параметри (ширина и померај) две спектралне линије из спектра једноструко јонизованог азота, које припадају прелазу 3d-4f, мерени су у плазми линеарног импулсног лука, при ниском притиску, у мешавини азота и кисеоника при електронској температури од 54000 K и електронској концентрацији од 2.8×10^{23} m^{-3}. Измерене вредности упоређене су са постојећим експерименталним и рачунатим подацима.