

# Experimental Stark Widths and Shifts in the $3p^3D - 3d^3F^o$ O III Transition

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Z. Naturforsch. **59a**, 791 – 794 (2004); received August 19, 2004

Stark widths ( $W$ ) and shifts ( $d$ ) of 3 doubly ionized oxygen (O III) spectral lines (326.085 nm, 326.532 nm and 326.720 nm) in the  $3p^3D-3d^3F^o$  transition have been measured in the optically thin helium-oxygen plasma created in a linear, low-pressure, pulsed arc discharge at a 26 000 K electron temperature and  $1.1 \cdot 10^{23} \text{ m}^{-3}$  electron density. Our Stark shifts are the first measured data at an electron temperature smaller than 30 000 K. No theoretical  $W$  and  $d$  data exist in this O III transition. Our  $W$  and  $d$  values are compared with the existing experimental data. On the basis of the found agreement among the experimental  $W$  and  $d$  values at a 26 000 K electron temperature we have evaluated their dependence on the electron temperature ranged between 10 000 K and 50 000 K.

*Key words:* Plasma Spectroscopy; Line Profiles; Atomic Data.

## 1. Introduction

Doubly ionized oxygen (O III) spectral lines are important in astrophysical plasma diagnostics [1–3]. In plasmas with electron densities ( $N$ ) higher than  $10^{21} \text{ m}^{-3}$ , when Stark broadening begins to play an important role in the line shape and line center position [4–6], knowledge of the Stark FWHM (Full-Width at Half of the Maximal intensity  $W$ ) and shift ( $d$ ) are important in plasma diagnostics. A number of experimental studies has been dedicated to this topic [7–12]. To the knowledge of the authors, no theoretical  $W$  and  $d$  data exist for the  $3p^3D-3d^3F^o$  transition [6].

The aim of this paper is to present measured Stark FWHM ( $W_m$ ) and shift ( $d_m$ ) values of three O III spectral lines (326.085 nm, 326.532 nm and 326.720 nm) in the  $3p^3D-3d^3F^o$  transition at 26 000 K electron temperature and  $1.1 \cdot 10^{23} \text{ m}^{-3}$  electron density. Our  $d_m$  values are the first data obtained at an electron temperature smaller than 30 000 K.

## 2. The Experiment

A linear, low pressure, pulsed arc has been used as optically thin plasma source. A pulsed discharge was created in a pyrex discharge tube of 5 mm inner diameter and 14 cm plasma length. The working gas was a helium-oxygen mixture (1:1.1) at a 266 Pa filling pressure in the flowing regime. The capacitor of 14  $\mu\text{F}$  was

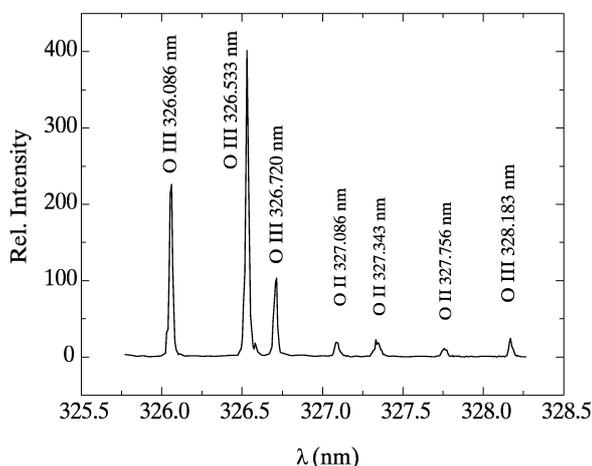


Fig. 1. Part of the recorded O III spectrum with the O II spectral lines used in the Saha-equation.

charged up to 1.5 kV. The spectral line profile recording procedure and the experimental set-up system are described in [13–18]. The averaged photomultiplier signal (five shots in the same spectral range) was digitized, using an oscilloscope, interfaced to a computer. The recorded O III line profiles are shown in Figure 1.

Great care was taken to minimize the influence of self-absorption on the line intensity determinations. Using a technique described in [19], the absence of self-absorption was checked in the case of the investigated O III spectral lines.

Table 1. Measured Stark FWHM ( $W_m$ ) and shifts ( $d_m$ ) given at 26 000 K electron temperature and  $1.1 \cdot 10^{23} \text{ m}^{-3}$  electron density with estimated accuracies. Atomic data are taken from [22]. Negative shift is toward blue.

Multiplet	$\lambda$ (nm)	$d_m$ (pm)	$W_m$ (pm)
$3p^3D-3d^3F^o$			
1-2	326.720	$-3.4 \pm 0.5$	$14.5 \pm 1.4$
2-3	326.085	$-2.9 \pm 0.5$	$15.2 \pm 1.6$
3-4	326.532	$-3.2 \pm 0.5$	$15.1 \pm 1.5$

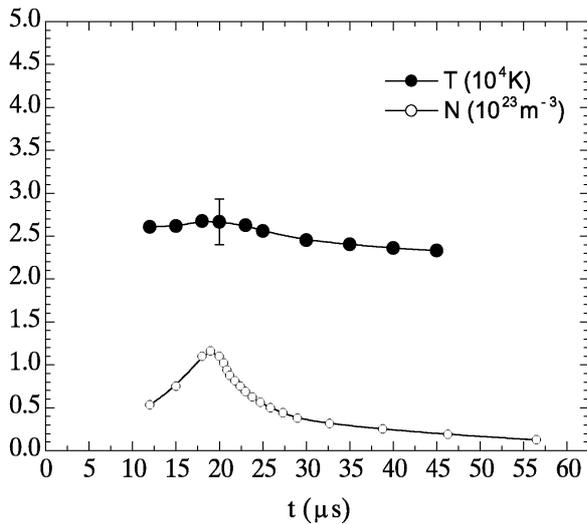


Fig. 2. Temporal evolutions of the electron temperature ( $T$ ) and electron density ( $N$ ).

The electron temperature was determined from the ratio of the relative intensities (Saha-equation) of the O III (326.085 nm, 326.532 nm and 326.720 nm) and O II (327.086 nm and 327.343 nm) spectral lines with an estimated error of  $\pm 8\%$ , assuming the existence of the Local Thermodynamical Equilibrium (LTE), according to the criterion from [20, 21]. The necessary atomic data were taken from [22]. The electron temperature decay is presented in Figure 2.

The electron density was measured using a well-known single laser interferometry technique [23] for the 632.8 nm He-Ne laser wavelength with an estimated error of  $\pm 6\%$ . The electron density decay is also presented in Figure 2.

The measured profiles were of the Voigt type due to the convolutions of the Lorentzian Stark and Gaussian profiles caused by Doppler and instrumental broadening. For the electron density and temperature in our experiment the Lorentzian fraction was dominant. The van der Waals [4] and resonance [4] broadening were

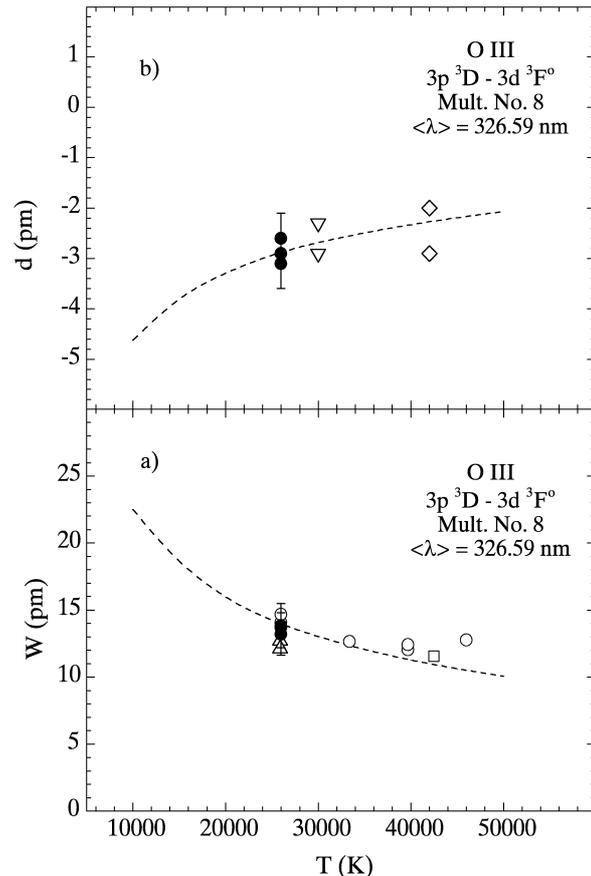


Fig. 3. Measured Stark FWHM a) and shift b) dependence on the electron temperature ( $T$ ) at  $10^{23} \text{ m}^{-3}$  electron density. Filled circles represent our new experimental data with estimated accuracies. Other authors results are given with symbols:  $\circ$ , [9];  $\triangle$ , [7];  $\square$ , [8];  $\diamond$ , [12] and  $\nabla$ , [11]. The dashed line represents our estimated  $W$  and  $d$  values obtained by (2) and (3), respectively.  $\langle \lambda \rangle$  is the mean wavelength in the multiplet.

estimated to be by more than one order of magnitude smaller than the Stark, Doppler and instrumental broadening. The standard deconvolution procedure [24] was applied, using the least squares algorithm. An accurate estimation of the spectrum base line is given in [25]. The Stark widths were measured up to  $\pm 10\%$  error at a given  $N$  and  $T$ .

The Stark shifts were measured relative to the unshifted spectral lines emitted by the same plasma using a method established and applied first in [26]. With this method, the Stark shift of a spectral line is measured by evaluating the position of the spectral line center ( $X_C$ ) recorded at different electron densities during the plasma decay. In principle, the method requires record-

ing the spectral line profile at a higher electron density ( $N_1$ ), resulting in an appreciable shift, and later, when the electron concentration has dropped to a value ( $N_2$ ), lower by at least an order of magnitude. The difference of the line center positions in these two cases is  $\Delta X_C$ , so that the shift  $d_1$  at the higher electron density  $N_1$  is

$$d_1 = N_1 \Delta X_C / (N_2 - N_1). \quad (1)$$

The Stark shift was obtained with  $\pm 0.5$  pm accuracy.

### 3. Results and Discussion

Our measured  $W_m$  and  $d_m$  data are given in Table 1 at a 26 000 K electron temperature and  $1.1 \cdot 10^{23} \text{ m}^{-3}$  electron density. To compare existing Stark FWHM and shift values for different wavelengths in the same transition, measured at different electron temperatures (between 26 000 K and 46 000 K), we have graphically presented in Figs. 3a and 3b available experimental results together with the theoretically founded [4] dependence  $W(T) \sim T^{-1/2}$ .

We have calibrated our plot to follow experimentally obtained data in the vicinity of 26 000 K electron temperature because most transitions are investigated at temperatures close to 26 000 K, showing relatively low scattering of the Stark FWHM data. The specific form of the function is found to be

$$W(\text{pm}) = 2.25 \cdot 10^3 [T(\text{K})]^{-1/2} \cdot N(10^{23} \text{ m}^{-3}). \quad (2)$$

By inspection of Fig. 3a one can conclude that the Stark FWHM measured at 46 000 K in [9] significantly deviates from the proposed dependence. Figure 3b shows available data of the Stark shift together with a plot of the function

$$d(\text{pm}) = -4.62 \cdot 10^2 [T(\text{K})]^{-1/2} \cdot N(10^{23} \text{ m}^{-3}), \quad (3)$$

obtained in a similar way. Equations (2) and (3) correspond to  $10^{23} \text{ m}^{-3}$  electron density.

### 4. Conclusion

We have measured Stark widths and shifts of three lines (326.085 nm, 326.532 nm and 326.720 nm) belonging to the  $3p^3D-3d^3F^0$  transition of the O III spectrum. For the Stark width we have found reasonable agreement with previously published data obtained in different plasma sources at temperatures close to the 26 000 K. We have found that the theoretically founded [4] dependence  $W(T) \sim T^{-1/2}$  closely resembles experimental  $W$  and  $d$  data. This equation enables an accurate determination of the O III  $W$  and  $d$  data for electron temperatures between 10 000 K and 50 000 K at a  $10^{23} \text{ m}^{-3}$  electron density within 15% uncertainties.

This work is part of the project (OI 1228) "Determination of atomic parameters on the basis of spectral line profiles" supported by the Ministry of Science, Technologies and Development of the Republic of Serbia.

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