The C I 247.8561 nm Resonance Line Stark Broadening Parameters

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The Stark width (W) and shift (d) of the neutral carbon (C I) 247.8561 nm resonance spectral line in the $2p^2\ ^1S_0 - 2p3s\ ^1P_1^o$ transition have been measured at 17,600 K electron temperature and $1.08 \cdot 10^{23}\ m^{-3}$ electron density in an oxygen-carbon plasma created in an optically thin, linear, low-pressure, pulsed arc discharge. They represent the first experimental results obtained at an electron temperature higher than 14,000 K. We have found a symmetrical line profile, generated dominantly by electrons as perturbers. Our W and d values have been compared to the existing experimental and theoretical data. Good agreement was found between the results calculated by a semiclassical approximation and our data, particulary in the case of the Stark shift.

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

1. Introduction

The neutral carbon (C I) 247.8561 nm resonance spectral line in the $2p^2\ ^1S_0 - 2p3s\ ^1P_1^o$ transition is of importance in astrophysical plasma diagnostics [1 – 3]. As impurities, carbon atoms are also present in laboratory plasmas giving the possibility to be used for plasma diagnostics. Atomic data such as Stark widths (W) and shifts (d) play an important role in the diagnostics and modeling of various cosmic and laboratory plasmas. Basic plasma parameters, such as the electron temperature (T) and density (N), can be obtained on the basis of the known W and d values. Only two papers are dedicated to C I resonance line Stark width [4, 5] measurements, and only one work deals with its Stark shift [5]. The calculated W and d values are presented in [6].

The aim of this paper is to present measured Stark FWHM (full-width at half of the maximal intensity W) and shift (d) values of the C I 247.8561 nm resonance spectral line in an optically thin laboratory oxygen-carbon plasma created in a linear, low-pressure, pulsed arc discharge at 17,600 K electron temperature and $1.08 \cdot 10^{23}\ m^{-3}$ electron density. To the knowledge of the authors the W and d values are the first experimental data at electron temperature higher than 14,000 K ([7, 8] and references therein). Measured Stark parameters have been compared with the existing experimental and theoretical data calculated on the basis of the semiclassical approximation [6].

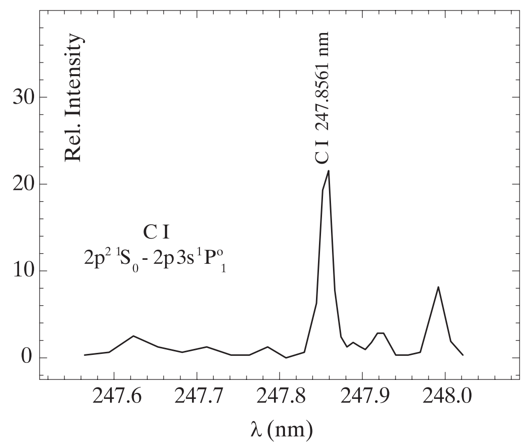

Fig. 1. The recorded C I line profile at 30 μs after the beginning of the discharge.

2. Experimental

A linear, low-pressure, pulsed arc has been used as optically thin plasma source ([9 – 12] and references therein). A pulsed discharge was created in a Pyrex discharge tube of 5 mm inner diameter and plasma length of 14 cm. The working gas was CO_2 at 67 Pa filling pressure in the flowing regime. The capacitor of 14 μF was charged up to 2.2 kV. The discharge conditions have been chosen to minimize the self-absorption. The plasma reproducibility was monitored by the O II and O III line radiation, and also by the discharge current. The spectral line profile recording procedure and the

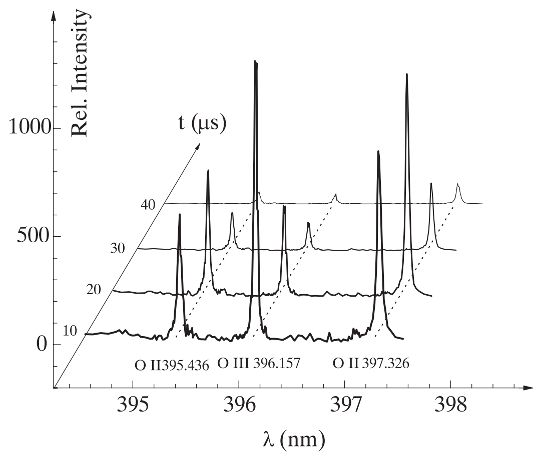

Fig. 2. Temporal evolutions of the O II and O III spectral line intensities used for the electron temperature (T) determination during the plasma decay.

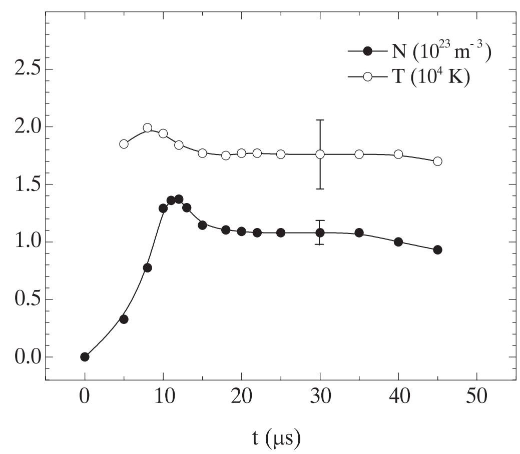

Fig. 3. Electron density (N) and electron temperature (T) decays in the oxygen-carbon plasma. Error bars represent 10% and 16% uncertainties, respectively.

experimental system are described in [12 – 14]. The line profile was recorded using a step-by-step technique [13]. The averaged photomultiplier signal (six shots of the same wavelength) was digitized using an oscilloscope, interfaced to a computer. The recorded C I line profile is shown in Figure 1.

The electron temperature was determined from the ratio of the relative intensities (Saha-equation) of the O III (396.157 nm) and O II (395.436 nm and 397.326 nm) spectral lines with an estimated error of ±16%, assuming the existence of the local thermodynamical equilibrium (LTE), according to the criterion from [15]. The necessary atomic data were taken from [7]. Temporal evolutions of the mentioned O II and O III spectral line profiles are presented in Figure 2.

Table 1. Measured Stark FWHM (W_m) and shift (d_m) of the 247.8561 nm C I line at a given T and N with their estimated accuracies. Positive shift is toward red.

N (10^{23} m^{-3})	T (10^4 K)	W_m (pm)	d_m (pm)
1.08 ± 0.11	1.76 ± 0.28	7.40 ± 0.9	4.70 ± 0.8

The electron density decay was obtained using convenient Stark widths of the 395.436 nm, 397.326 nm, 407.215 nm, 407.586 nm, 418.544 nm and 418.979 nm O II spectral lines [6, 13] within ±10% accuracy. The electron density and electron temperature decays are presented in Figure 3.

3. Line Width and Shift Measurements

The C I line profile represents the convolutions of the Lorentzian Stark (electron + ion) and Gaussian profiles caused by Doppler and instrumental broadening. For the electron density, electron temperature and density of the emitters in our experiment the van der Waals [6] and resonance [6] broadenings were estimated to be smaller by more than one order of magnitude in comparison to the Stark, Doppler and instrumental broadening. We expect that the ion contribution to the total Stark width is small (within 3%, see the ion broadening parameters for the C I line in [6]) and can be neglected, giving a symmetrical C I line profile. This approximation results in slightly lower accuracies of the measured (W_m) value (up to ±12%). For symmetrical (Voigt) line profiles the standard deconvolution procedure [16] was applied, using the least squares algorithm. Accurate estimation of the spectrum base line is based on the procedure reported in [17]. The Stark shift (d) was measured relative to the unshifted spectral line emitted by the same plasma ([18] and references therein) within ±0.8 pm accuracy.

4. Results and Discussion

Our measured W_m and d_m data are presented in Table 1 at a given electron temperature and electron density.

In order to compare measured and calculated Stark FWHM and shift values, the theoretical Stark FWHM and shift dependence on the electron temperature together with the values of other authors and our experimental results, at an electron density of $1 \cdot 10^{23}$ m^{-3}, are graphically presented in Figure 4.

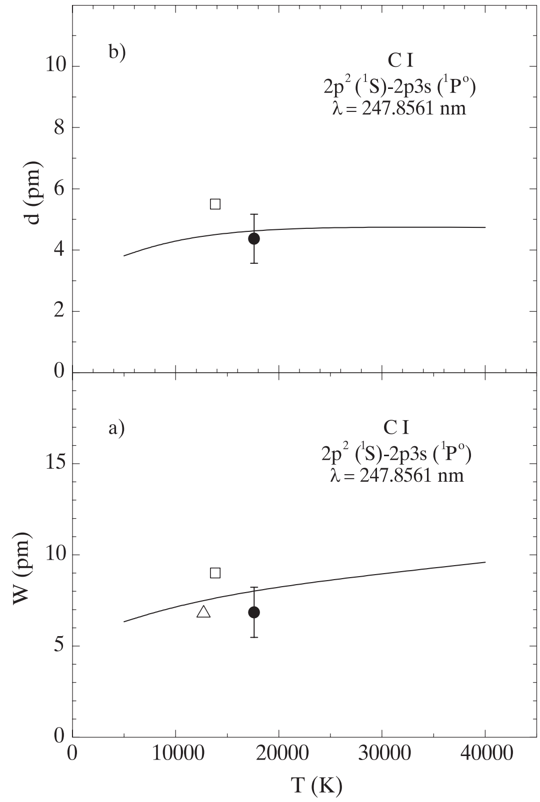

Fig. 4. a) Measured Stark FWHM and b) shift dependences on the electron temperature (T) at 10^{23} m^{-3} electron density. Filled circles represent our new experimental data with estimated accuracies. Other authors results are given with symbols: △, [4] and □, [5]. The solid line represents Griem's theoretical data from [6] using electrons as perturbers, only.

Our W_m value represents a total (electron + ion) Stark width and lies by about 18% below Griem's [6] theoretical value calculated on the basis of the semiclassical approximation for electrons as perturbers only. Taking into account the accuracy of the W_m value and the uncertainties of the calculations the mentioned discrepancy can be considered as tolerable. As similar behavior shows the W value from experiment [4], while the experimental value from [5] is by about 12% higher than the ones from [6] (see Fig. 4a). It should be pointed out that the calculated ion contribution to the total line width (and shift) is small. It is up to 3% of the estimated electron contribution [6] at electron densities up to 10^{23} m^{-3}.

Our d_m value agrees well (within 7%) with theoretical ones [6]. The first measured d value in [5] is 5.5 pm and lies by about 22% above Griem's data (see Fig. 4b).

Finally, it should be mentioned that the W and d values from [19, 20] are much higher than other data, so they are not included in our discussion.

5. Conclusion

Our measured Stark width and shift values and the other experimental data [4, 5] show tolerable agreement with theoretical Griem's [6] values calculated for electrons as perturbers, only. This means that the C I 247.8561 nm resonance line shape and shift are generated dominantly by electrons in plasmas at electron temperatures up to 18,000 K and electron densities up to $1.1 \cdot 10^{23}$ m^{-3}.

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