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Stark broadening parameters of the 381.96 nm He I line

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Abstract. Stark width (W) and shift (d) of the neutral helium (He I) 381.96 nm spectral line in the high lying $2p$–$6d$ transition has been measured in the optically thin linear, low-pressure, pulsed arc discharge operated in the helium at 50 000 K electron temperature and 6.1×10^{22} m^{-3} electron density. These values are the first experimentally obtained W and d related to this line. Unfortunately, comparison with theoretical results is not possible due to the fact that only one existing theoretical calculations has been done at a 10^{19} m^{-3} electron density only. We have found negative line shift (toward the blue) that agree well with existing theoretical predictions.

PACS. 52.70.Kz Optical (ultraviolet, visible, infrared) measurements – 32.70.Cs Oscillator strengths, lifetimes, transition moments – 32.70.-n Intensities and shapes of atomic spectral lines

1 Introduction

The neutral helium (He I) 381.96 nm spectral line represent a sum of seven, mutually very close spectral lines (see [1]) with the dominant intensity of the 381.96028 nm line in the high lying $2p\ ^3P^o_2 - 6d\ ^3D_3$ transition. It has been registered in many spectra of astrophysical light sources [2–7] and can be used for diagnostics purposes of cosmic plasmas.

Unfortunately, there are no experimental investigations dedicated to the shape and shift of this line, see [8] (and references therein). Only one study [9] deals with its Stark FWHM (full-width at a half intensity maximum, W) and shift (d) based on the semiclassical perturbation formalism at 10^{19} m^{-3} electron density (N) only.

The aim of this work is to present the first measured W and d values of the 381.96028 nm He I spectral line in laboratory helium plasma created in the optically thin linear, low-pressure, pulsed arc discharge at 50 000 K electron temperature (T) and 6.1×10^{22} m^{-3} electron density.

2 Experiment

A linear, low-pressure, arc has been used as a plasma source [10–13]. A pulsed discharge was driven in a Pyrex discharge tube of 5 mm inner diameter and plasma length of 14 cm with magnesium electrodes. The tube has an end-on quartz windows. The working gas was helium in flowing regime at a 532 Pa pressure. A capacitor of 14 μF was charged up to 55 J bank energy. The discharge conditions have been chosen in order to find the maximum of the population of the high lying $6d$ parent energy level of the 381.96 nm transition. Spectroscopic observation of isolated spectral lines was made end — on along the axis of the discharge tube. The line profiles were recorded using a step-by-step technique described in our previous publications [10–16]. The averaged photomultiplier signal was digitized using an oscilloscope interfaced to a computer. The recorded He I spectral line profile is shown in Figure 1 at two different plasma conditions during the plasma decay.

The plasma parameters were determined using standard diagnostics methods [17]. The electron temperature (T) was obtained using the relative line intensity ratio method between the He II P_α 468.6 nm and the He I 587.6 nm lines with ±8% accuracy. The electron density (N) decay was measured using a well-known single wavelength He–Ne laser interferometer technique [18] for the 632.8 nm transition with an estimated error of ±7%. Temporal evolution of the N and T values is presented in Figure 2.

3 Line width and shift measurements

Due to the fact that the 381.96 nm He I line originates from high lying parent energy level with 24.21 eV excitation energy, near to the ionization energy (24.59 eV) of the helium atoms, one can expect that corresponding Stark FWHM will be considerable, especially on the electron densities (N) higher than 10^{22} m^{-3} [19]. Accordingly, shape of the line can be approximated, with sufficient accuracy, by the symmetrical Lorentz profile [19]. Solution of the problem connected to the base line estimation is

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Table 1. Measured Stark FWHM (W_m) and shift (d_m) at a given T and N with their estimated accuracies. The quantities J_f and J_i are the inner quantum numbers of the final (f) and initial (i) state of the transition. Atomic data: the energy of the initial level (E_i) and the wavelength (λ) are taken from NIST [1]. Negative shift is toward the blue.

Transition	λ (nm)	E_i (eV)	N (10^{22} m^{-3})	T (10^4 K)	W_m (nm)	d_m (nm)
$2p\ ^3P^o - 6d\ ^3D$						
$J_f - J_i$						
2–3	381.96028	24.21	6.1	5.0	1.28 ± 0.15	-0.031 ± 0.005

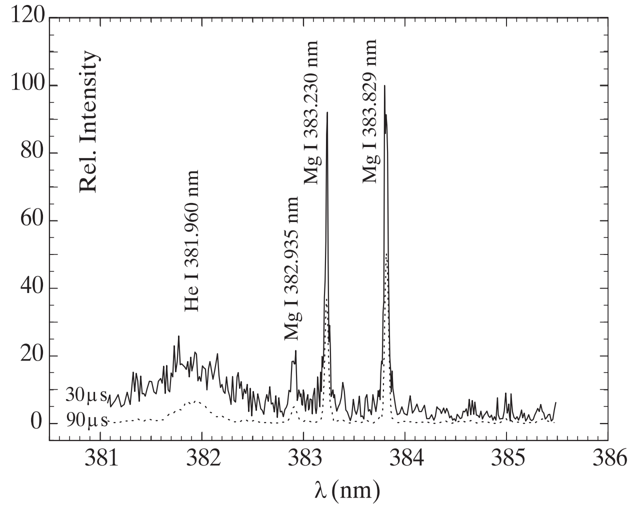

Fig. 1. The recorded profile of the 381.96 nm He I line at two different plasma conditions in the 30th μs and 90th μs (dotted profile) after the beginning of the discharge. The Mg I lines originate from the magnesium atoms evaporated from the discharge electrodes.

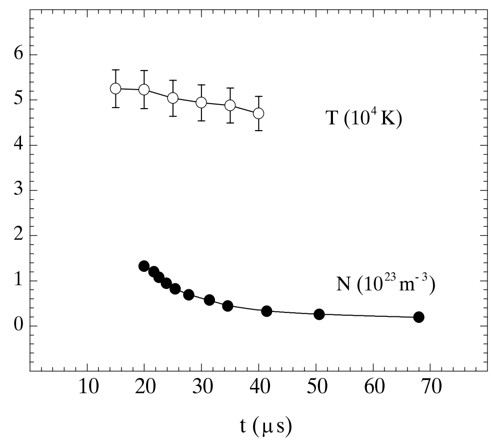

Fig. 2. Temporal evolution of the electron temperature (T) and electron density (N) during the plasma decay. Error bars represent experimental accuracies.

presented in [20]. The Stark width was obtained within ±12% accuracy.

The Stark shifts were measured relative to the unshifted spectral lines emitted by the same plasma using a method established and applied first in [21]. According to this method the Stark shift of a spectral line can be measured experimentally by evaluating the position of the spectral line center (X_C) recorded at different electron density values during the plasma decay. In principle, the method requires recording of the spectral line profile at a higher electron density (N_1) resulting in an appreciable shift and then, later, when the electron concentration has dropped to a value (N_2) lower by at least an order of magnitude (see Figs. 1 and 2). The difference of the line center position in these two cases is ΔX_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 ±16% accuracy.

4 Results and discussion

Experimentally obtained Stark width and shift of the 381.96028 nm line are given in Table 1.

Our (W_m) and (d_m) are the first measured data. As we mentioned before there is just one study dedicated to the calculation of the Stark width and shift of the 381.96 nm He I line. According to this calculation, based on the semiclassical perturbation formalism and done for 10^{19} m^{-3} electron density, shift of the mentioned line is negative and agree with our measured shifts sign. Unfortunately, further comparison with our results has no sense because our data are obtained at about 6×10^3 times higher electron density. At this density the theoretical model [9] needs additional approximations, especially for transitions that originate from high lying parent energy levels near to the He I ionization energy. The 381.96 nm He I originates from high lying (24.21 eV) parent energy level. New calculations in this field will be welcome.

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