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Stark widths and shifts of Ar II spectral lines in visible part of spectrum

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ABSTRACT

Stark widths and shifts of 13 Ar II spectral lines in the visible part of spectrum were measured. Spectral lines were emitted from pulsed wall stabilized Ar arc plasma under atmospheric pressure. Profiles were recorded at plasma electron densities of $1.3 \times 10^{23}\ m^{-3}$ and $1.6 \times 10^{23}\ m^{-3}$ and plasma electron temperatures of 13,400 K and 14,200 K respectively. Obtained results are compared with other experimental results as well as with theoretical values. The analysis of the experimental and theoretical data is given as well.

1. Introduction

Diagnostics of different laboratory, industrial and astrophysical plasmas is often based on Stark effect that causes broadening and shifting of the spectral lines emitted from this medium. The width and shift of the spectral lines depend dominantly on plasma electron density. In many laboratory and industrial plasmas, spectral lines of different atoms and ions are used for diagnostic purposes. This is because various gases are often used as a working gas in plasma sources.

In the case of astrophysical plasmas, this is due to the presence of the gases in the atmospheres of the stars and other astrophysical media. Considering astrophysical plasmas and the relevance of the argon atomic data, one should have in mind that argon can be found in various astrophysical media. For example argon is found in CVn binary σ^2 Coronae Borealis [1], "Chandra's" X-ray spectra of young supernovas 1998S and 2003bo [2], Be star Hen 2-90 [3] and in planetary nebulae and H II regions in the two dwarf irregular galaxies Sextans A and B [4]. Also, in its compilation of solar abundance works, Asplund et al. [5] recommended a solar argon abundance (Ar/O ratio) $A/(Ar)_{\odot}=6.18$. Stark broadening mechanism of different ion's spectral lines is the dominant in the stars of O, B and A types [6–8]. The spectral lines of singly ionized argon has been analyzed in [9] in B type stars and in Orion nebula [9,10].

Probably the most investigated lines are the atomic lines of hydrogen and helium as well as ionic helium spectral lines. Many of the papers were devoted to these lines during last decades and good agreement between experiments and theories has been found (see [11] and reference therein). Among other gases, especially noble gases, argon is often used gas for many applications and astrophysics. Spectral lines of neutral, Ar I, and ionized argon are widely investigated during the last decades [12–18]. The problem in these cases is the high discrepancy between various experimentally obtained Stark parameters for both, Ar I and Ar II spectral lines, that is indicated in [19,20].

Development of new, CCD based, devices for spectral line recordings enables higher quality of recorded spectra and better defined experimental spectral line profiles.

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This, in combination with appropriate methods for spectral line deconvolution, may result in more reliable data of Stark parameters.

For ionic spectral lines for which the electron impact broadening is the dominant plasma-broadening mechanism Stark profiles can be described by the Lorentz distribution. In that case the experimental profile is the Voigt profile [21] which is the convolution of the Stark profile (Lorentzian) and Doppler+instrumental profile (Gaussian). So, in the deconvolution procedure symmetrical Lorentz +Gauss profiles are used in this work.

Here we report the results of experimental determination of Stark halfwidths (FWHM) and shifts of 13 Ar II spectral lines. Experimental results are compared with the theoretical ones, calculated by Griem [22], when available, and by using semiempirical formula [23] for halfwidths and [24] for shifts. For these comparisons the experimental data of other authors [25–43] have also been taken into account.

As already mentioned above there are considerable discrepancy between existing Stark halfwidth experimental results. The aim of this paper is to repeat some Stark parameters measurements for some ionic spectral lines in visible part of the spectrum, analyze the present status and try to offer some reliable data which can be used for diagnostic purposes. To do this we paid special attention to the data acquisition system, proper experimental data treatment, proper diagnostic methods, check of selfabsorption and the use of stable and well defined plasma source.

2. Experiment

An atmospheric pressure wall stabilized arc is used as a plasma source. The arc is described elsewhere [19,20]. Here, we only give a short description. The diameter of the channel is 6 mm and its length is 60 mm. The arc operated in argon with a small addition of hydrogen which is used for diagnostics purposes. The argon is introduced into the arc through the hollow electrodes at both ends of the arc channel. The gas mixture of Ar+H_2(4%) is introduced into the central part of the channel. The gases are exhausted through the holes placed close to the electrodes.

In DC regime the arc operates with supply current of 30 A. In that case plasma electron density of around few times 10^{22} m^{-3} and temperatures of around 10,000 K can be reached. Under such conditions only neutral argon lines appear. Increasing the arc current, conditions for appearance of ionized argon spectral lines can be reached. To achieve this, additional high current pulses were added to the DC current using the civil network. In the DC regime the arc is supplied from current stabilized electrical source with the stability of 0.3%. An additional circuit is used to introduce high current pulses into the arc. The control electronic circuit controls the thyristor, as the high current switch, that passes high current pulses from the civil network with the frequency of 1 Hz (the frequency can be arbitrary chosen). An additional resistor, in the pulsed circuit, limits the maximum current of 180 and 240 A which lasts about 4 ms (see Fig. 1). These pulses are added

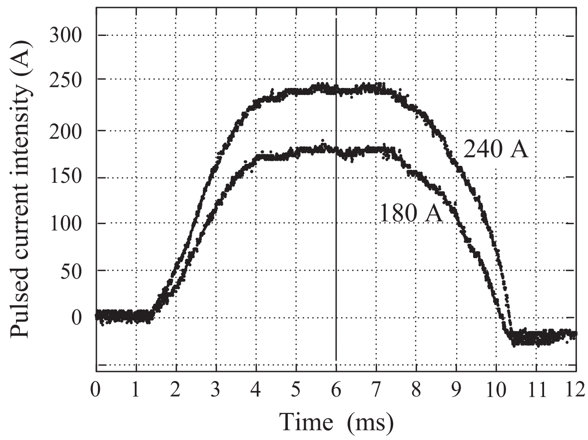

Fig. 1. The example of pulsed currents.

to the DC current of 30 A. The reproducibility of high current pulses is inside 2%.

Current pulses are monitored and measured by a calibrated Rogowski coil. The signals from the Rogowski coil are also used to trigger the ICCD camera. The complete experiment was controlled by a personal computer. The detailed description of the arc working in pulsed regime can be found in [20].

3. Plasma diagnostics

For the purpose of plasma electron density determination small amount of hydrogen was introduced in the middle part of the arc column. This enabled plasma electron density determination from the Stark halfwidth of hydrogen Balmer H_β spectral line in conjunction with the theory [22]. The amount of hydrogen in the gas mixture was set to avoid selfabsorption of the H_β line but have enough radiation intensity. Since spectral recordings of Ar II spectral lines were made for the maximums of high pulses, the electron densities were determined for the same conditions. For lower pulses, the plasma electron density was found to be 1.3×10^{23} m^{-3}, while for higher 1.6×10^{23} m^{-3}. The estimated errors of measured electron density do not exceed 9%.

Plasma electron temperatures were 13,400 K for lower current pulse and 14,200 K for higher current pulse. They were determined from the Boltzmann plot [44] for 9 Ar II spectral lines which is shown in Fig. 2. Some of the lines 480.60 nm, 484.78 nm and 487.98 nm are superimposed on the H_β line profile. This did not make a problem since the halfwidth of H_β profile is more than 100 times larger than halfwidths of the Ar II lines. So, the intensity of the H_β line was treated as continuous radiation and subtracted from the total line intensity. The errors of the determined Ar II line intensities were estimated to be between 14% and 22% and depend mostly of line intensity-to-noise ratio. The errors are presented in Fig. 2 for some of the lines for the lower temperature, as illustration. The errors for higher temperature are a few percents lower. The errors for electron temperature were derived from the slope uncertainty and estimated to be within ± 20%. The position of the points in