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STARK SHIFT IN THE Si IV SPECTRUM

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Abstract. Stark shifts measurements and semiclassical calculations of six Si IV spectral lines belonging to four transitions have been presented for elctron temperature 10^4 K and 10^{23} m^{-3} electron density.

1. INTRODUCTION

Atomic data such as Stark widths (W) and shifts (d) play an important role in the diagnostics and modelling of various cosmic and laboratory plasmas (Griem 1974; Lesage& Fuhr 1999; NIST 2002). The basic plasma parameters such as electron temperature (T) and density (N) may be obtained on the basis of the known d and W values. However, various optical depths of the emitting plasma may result in self-absorption influencing the line width value (screening the Stark contribution). Thus, Stark shifts independent of self-absorption are more reliable and consequently more interesting for diagnostic purposes. Silicon ions are among the most abundant emitters or absorbers in many kinds of the cosmic plasmas. As impurities they are present also in many, high current, laboratory plasma sources. The knowledge of the triply (Si IV) ionized silicon spectral lines Stark shifts is necessary in various astrophysical calculations. According to available bibliographies (Lesage & Fuhr 1999) no experimental Stark shift data exist for Si IV and only one work (Dimitrijević et al 1991) is devoted to the Si IV Stark shift calculation.

In this work we wish to present the first Stark shifts measurements of six Si IV spectral lines belonging to four transitions. Our measured shift values have been compared to the existing data taken from recent available data sources.

2. EXPERIMENT

The linear pulsed arc (Djeniže & Bukvić 2001; Djeniže et al 2002a,b; Srećković et al 2001a) has been used as a plasma source. A pulsed discharge was driven in a Pyrex discharge tube of 5 mm inner diameter and effective plasma length of 7.7 cm.

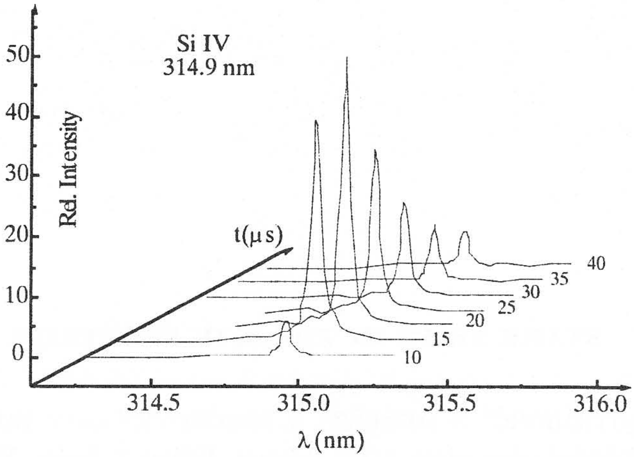

Fig. 1: Temporal evolution of the 314.9 nm Si IV spectral line profiles in oxygen plasma.

Spectroscopic observations of isolated spectral lines were made along the axis of the discharge tube. Atoms of silicon were obtained as impurities by sputtering from a Pyrex discharge tube. As a driving gas oxygen and SF_6 have been used at filling pressures of 130 Pa and 70 Pa, respectively. Highly ionized oxygen, sulfur and fluorine ions facilitate erosion of the glass walls of linear part of discharge tube. Furthermore, O_2 and SF_6, as working gases, left the observed lines of Si IV isolated. Discharge of the condenser of 8 μF capacity charged to 4 kV was selected for maximum efficiency in releasing silicon atoms. The reproducibility of the investigated silicon spectral line radiation intensities was 90%, which can be taken as acceptable considering the method by which the impurity atoms were introduced.

The line profiles were recorded using a step-by-step technique described in Refs. [5-7]. The averaged photomultiplier signal (five shots at the same spectral range) was digitized using an oscilloscope, interfaced to a computer. A sample output, is shown in Fig. 1.

Plasma reproducibility was monitored by the O III and S III lines radiation and by the discharge current (it was found to be within $\pm 5\%$). The discharge characteristics were determined by analyzing the Rogowski coil signal. The values found were: discharge current = 6.7 kA, discharge period = 28 μs, thermal resistance = 0.29 Ω, and decrement = 2.4.

The plasma parameters were determined using standard diagnostic methods (Griem 1974; Rompe& Steenbeck 1967). Thus, in the case of the oxygen plasma the electron temperature was determined from the Boltzmann plot of the relative intensities of nine O III spectral lines, with an estimated error of $\pm 13\%$, assuming the existence of local thermodynamic equilibrium (LTE). All necessary atomic data were taken from NIST (2002). In the case of the SF_6 plasma, electron temperature was determined from the ratio of the relative intensities (Saha equation) of the 334.6 nm S III to the 481.6 nm S II spectral lines supposing the existence of LTE with an estimated error of $\pm 11\%$.

Electron density, in the case of the oxygen plasma, was measured using the well-known single laser interferometry technique for the 632.8 nm He-Ne laser wavelength with an estimated error of ±6%. In the case of the SF_6 plasma the electron density decay was observed by monitoring the Stark width values of the convenient 375.9 nm O III spectral line within an estimated error of ±8%. Namely, oxygen ions produced as impurities in SF_6 discharge, due to their small concentration give convenient Stark width values due to the absence of the self-absorption. Corresponding N values, predicted by semiclassical theory (Griem 1974), were taken from Srećković et al. (2001b).

The Stark shifts were measured relative to the unshifted spectral lines emitted by the same plasma (Djeniže et al 2002a,b and references therein). Stark shift data are determined with ±0.8 pm error at a given N and T. Our measured (d_{exp}) Stark shifts are presented in Table. I. and in Djeniže et al (2002b).

3. METHOD OF CALCULATION

The semiclassical perturbation formalism (SCPF), as well as the corresponding computer code have been updated and optimized several times. The calculation procedure, with the discussion of updatings and validity criteria, has been briefly reviewed (Dimitrijević et al 1991). The calculated S IV d values are presented in Dimitrijević et al. (1991) and in Table 1. at our plasma parameters.

4. RESULTS AND CONCLUSION

The results of the measured Stark shift (d_{exp}) values are shown in Table.1. Our calculated Stark shift values (d_{Th}) are presented also in Table.1.

Table 1. Our measured (d_{exp} in pm) and calculated (d_{Th} in pm) electron Stark shift values at a given electron temperature (T in 10^4 K) and at 10^{23} m^{-3} electron density. Atomic data are taken from NIST (2002). Positive shifts is toward the red.

Transition	λ (nm)	E_u	T	d_{exp}	d_{Th}
Si IV					
4s $^2S_{1/2}$– 4p $^2P^o_{3/2}$	408.886	27.08	3.3	-1.2 ± 0.8	−0.86*
4p $^2P^o_{1/2}$– 4d $^2D_{3/2}$	314.956	30.99	5.2	2.0 ± 0.8	1.15*
4p $^2P^o_{3/2}$– 4d $^2D_{5/2}$	316.569	30.99	3.1	1.7 ± 0.8	1.08*
4d $^2D_{5/2}$– 5p $^2P^o_{3/2}$	376.245	34.29	3.2	1.5 ± 0.8	−0.18*
4d $^2D_{3/2}$– 5p $^2P^o_{1/2}$	377.315	34.28	3.2	0.3 ± 0.8	−0.18*
5p $^2P^0_{3/2}$– 5d $^2D_{5/2}$	670.121	36.14	5.2	7.5 ± 0.8	22.3*

Our measured Stark shifts and calculated ones presented in Dimitrijević et al (1991) are very small and agree very well mutually within the experimental accuracy and uncertainties of the calculations. The only exception is the d value of the higher lying $5p^2P^o - 5d^2D$ (670.121 nm) transition where the d_{Th} overvalues measured ones about 3 times.

Generally, we have found satisfying agreement between measured and theoretical Stark shift values calculated on the basis of the semiclassical perturbation formalism (SCPF).

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