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Self-absorption effects in the equivalent width of the spectral lines in a neon plasma at atmospheric pressure

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Abstract. The ratio of the intensities is related to the *equivalent width*, W, of the spectral lines, which shape is approximated to a Voigt function resulting from the convolution of a Lorentzian (Stark and Van der Waals effects) and Gaussian (Doppler effect and optical broadening) profiles. Thus, we have studied the influence of the self-absorption over W in different plasma column lengths.

Key words. Microwave discharges-Atmospheric pressure-Atomic emission spectroscopy-Equivalent width-Self absorption effect

1. Self-absorption effect

The self-absorption effect of the atomic spectral lines emitted by the plasma can be used to measure the population density of the metastable and resonant atoms in the discharge. The total transmitted intensity at the end of the medium, I, can be expressed as (Santiago et al. 2004):

$$I/I_0 = W/S\,l \tag{1}$$

where I_0 is the total transmitted intensity in the absence of absorbing atoms and l is the length of the medium in the observation direction. In (1), W is the equivalent width of the line given by:

$$W = \int [1 - \exp(-k(\nu)\cdot l)]\, d\nu \tag{2}$$

and S is the strength of the line defined as

$$S = \int k(\nu) d\nu = \pi e^2 n f/mc \tag{3}$$

f being the oscillator strength and n is the absorbing atoms concentration At atmospheric pressure, the spectral lines profiles can be approximated to a Voigt profile. In this case, the absorption coefficient has the expression:

$$k(\nu) = k_0 \frac{a}{\pi} \int \frac{\exp(-y^2)}{a^2 + (\omega - y)^2} dy \tag{4}$$

where $\omega = 2(\nu - \nu_0)\sqrt{\ln(2)}/\Delta\nu_D$, $a = \Delta\nu_L \sqrt{\ln(2)}/\Delta\nu_D$ (*damping parameter*), and $k_0 = 2S\sqrt{\ln(2)/\pi}/\Delta\nu_D$, $\Delta\nu_D$ and $\Delta\nu_L$ being the Doppler and Lorentzian widths at half-height, respectively. The Doppler width is given by:

$$\Delta\nu_D = 2\sqrt{2R\ln(2)}\frac{\nu_0}{c}\sqrt{\frac{T_{gas}}{M}} \tag{5}$$

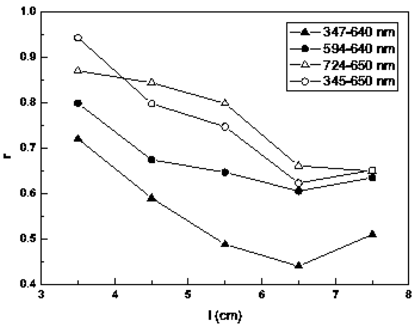

Fig. 1. Experimental values of r for different column plasma lengths

Table 1. Parameters of the pair lines used to measure the metastable and resonant atom population

λ(nm)	Transition	f	a
347.26	4p-3s($^3P_2$)	0.0043	0.75
594.48	3p-3s($^3P_2$)	0.0599	0.68
640.23	3p-3s($^3P_2$)	0.373	0.70
724.52	3p-3s($^3P_1$)	0.0736	0.88
345.42	4p-3s($^3P_1$)	0.0022	0.65
650.65	3p-3s($^3P_1$)	0.318	1.0

where T_{gas} is the gas temperature in the discharge. In the self-absorption method, the ratio of two partially self-absorbed line intensities, r, is used. Both lines end at the same level for which one wishes to determine the population: line (1), with the higher oscillator strength, will be more strongly absorbed than line (2). Table 1 shows the parameters of the lines used in this work. The r value is the ratio between the total intensities emitted by this line in the absence of absorption , I_{01} and I_{02}, and the total self-absorbed intensities, I_1 and I_2. This ratio will be a function of the equivalent width of the lines as follows:

$$r = \frac{I_1}{I_2} / \frac{I_{01}}{I_{02}} = \frac{S_2}{S_1}\frac{W_1}{W_2} = r\left(k_{01} l, \frac{k_{01}}{k_{02}}, a_1, a_2\right) \quad (6)$$

The ratio r is connected with the absorbing atom density through the coefficients of the more self-absorbed line (k_{01}).

2. Results and discussion

The experimental setup is extensively described by Santiago et al. (2004). The intensity of the lines was collected from the plasma by an optical fiber in two directions, longitudinally (I) and transversally (I_0), considering that in the transversal direction there is no absorption due to the very small ($\sim$ 2.4 mm) plasma diameter. The determination of a was as follows: $\Delta\nu_D$ was calculated with (5) considering T_{gas} equal to the OH ro-vibrational band temperature ($T_{gas} \sim 1200K$) and $\Delta\nu_L$ was obtained by deconvolution of the considered spectral lines. It was found that a was practically constant along the plasma column for all the lines (see Table 1).

In Fig.1 are shown the experimental values of r at different plasma lengths. As can be seen, the r parameter decreases with l as a consequence of the self-absorption. According to the expression (2) an increase of the self-absorption produces a decrease of the W value. Assuming that the line (2) presents a negligible self-absorption the r value is proportional to W_1. So, the behavior of this ratio r with the self-absorption effect implies to obtain information about the influence of this effect in the W values of the considered lines. Thus, from Fig. 1 we can conclude that W is affected by the line self-absorption in same direction as the r values.

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References

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