

## On the electron densities calculation from computer-simulated Balmer-alpha line profiles

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**Abstract.** Balmer-alpha line profile has been computer-simulated including ion dynamics effects for non-equilibrium conditions. The results obtained allow us to know the Stark broadening spectral line profile and so the value of the electron density in a plasma.

*Key words:* Plasma diagnosis; Plasma spectroscopy; Computer simulation.

### 1. Introduction

In general, the profile of the spectral lines observed in cold plasmas at low density and pressures over 100 Torr, can be approximated to a Voigt function. This profile is the result of the convolution of a gaussian function with a lorentzian function [1], characterized by their broadenings. Starting from the intensities and broadenings of the spectral lines it is possible to obtain the values of the fundamental parameters of the plasma: the electron density from the Stark FWHM, the populations of the excited states from the area of the Voigt profile and the temperature of the gas from the Doppler FWHM.

In the present work, we have compared the experimental profiles of the first Hydrogen Balmer serie lines,  $H_{\alpha}$ , with the computer-simulated profile obtained from the theoretical Stark profiles given by *Gigosos-Cardenoso model (GC model)* [2-3]. This model was based in the *Model Microfield Method (MMM model)*. For the computer-simulation of the  $H_{\alpha}$  line it is necessary to know the contributions of the different effects on the spectral profile such as the Van der Waals, Doppler, and Stark broadening ones. Also, the additional broadening due to the optical device used in the register of the lines (instrumental broadening) has to be included in the simulation process.

The use of the theoretical profiles provided by *GC model* allows us to the inclusion of ion dynamics effect over the profiles. It permits to take into account the difference between

$T_e$  and  $T_{\text{gas}}$  existing in the plasma by means of the reduced mass ( $\mu$ ) of the pair emitter-ion. The plasma emitting the atomic spectral lines was an argon surface-wave-sustained discharge (WSD) created at atmospheric pressure with a *surfaguide* device [4], with  $T_e = 6500$  K,  $T_{\text{gas}} = 1400$  K and the  $\mu$  approximately equal to 4 [2].

## 2. Methods

The Voigt profile comes given by the following mathematical expression:

$$I(\lambda) = I_G(\lambda) \otimes I_L(\lambda) = \int_{-\infty}^{\infty} I_G(\lambda - y) I_L(y) dy \quad (2.1)$$

$I_G$  and  $I_L$  being normalized and centred around  $\lambda = \lambda_C$  whose expressions are:

$$I_L = \frac{A_L 2 \ln 2}{\pi} \frac{w_L}{w_L^2 \ln 2 + (4 \ln 2)(\lambda - \lambda_c)^2} \quad (2.2)$$

$$I_G = \frac{2\sqrt{\ln 2}}{w_G \sqrt{\pi}} e^{-4 \ln 2 (\lambda - \lambda_c)^2 / w_G^2} \quad (2.3)$$

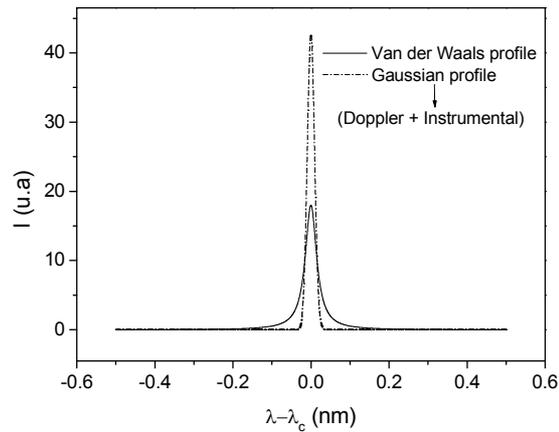
The convolution has been carried out by a commercial process of convolution (Microcal Origin, Microsoft®), which is based on the Levenberg-Marquardt non-linear fitting algorithm for minimum squares.

The broadening values of the different components of the spectral profiles are shown in Table I. The Gaussian component is trained by two Gaussian contributions such as the instrumental and the Doppler profiles, and the Lorentzian component by the Stark and Van der Waals profiles. The fine structure has not been considered because it begins to have influence on the profiles for electron density values less than  $1 \times 10^{14} \text{ cm}^{-3}$  [5].

PROFILE	TYPE	FWHM (nm)
LORENTZIAN	Van der Waals	0.035
	Stark	0.024-0.038
GAUSSIAN	Doppler	0.017
	Instrumental	0.013

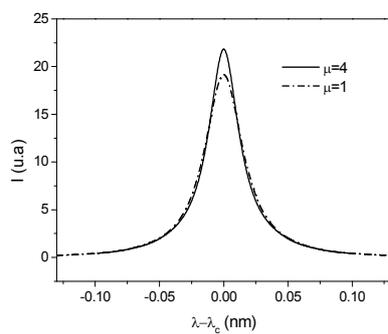
**Table I.** Profiles for the convolution

The Van der Waals, Doppler and Instrumental profiles have been simulated and normalized to the unity. These profiles are presented in (Figure 1)

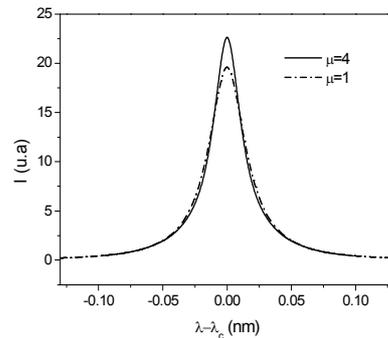


**Figure 1.** Van der Waals and Gaussian profiles

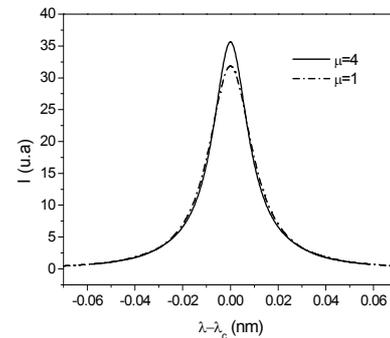
Gigosos *et al.* [2-3] have proposed a few theoretical profiles for different values of three parameters: electron density ( $n_e$ ), electron temperature ( $T_e$ ) and reduced mass ( $\mu$ ). An example of these profiles is shown in Figures 2.



**Figure 2(a).** Stark profile for  $n_e = 4.67 \times 10^{14} \text{ cm}^{-3}$ ;  $T_e = 6952 \text{ K}$  and two reduced mass.



**Figure 2(b).** Stark profile for  $n_e = 4.67 \times 10^{14} \text{ cm}^{-3}$ ;  $T_e = 5108 \text{ K}$  and two reduced mass.



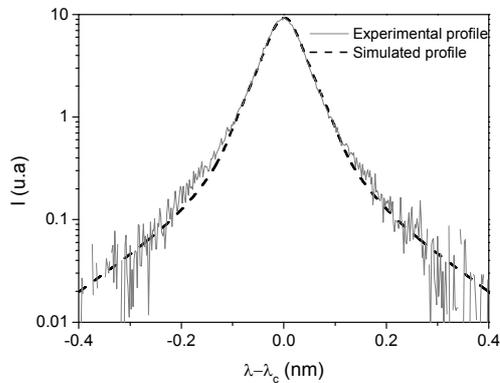
**Figure 2(c).** Stark profile for  $n_e = 2.14 \times 10^{14} \text{ cm}^{-3}$ ;  $T_e = 5380 \text{ K}$  and two reduced mass.

Under our experimental conditions, the experimental comparison between the experimental profile of the  $H_\alpha$  line with the theoretical one corresponded to a simulated profile for  $\mu$  equal to 4, electron temperature  $\approx 6500 \text{ K}$  and electron density  $\approx (4-5) \times 10^{14} \text{ cm}^{-3}$ . The approximation between both profiles simulated and experimental was of a 95% (Figure 3).

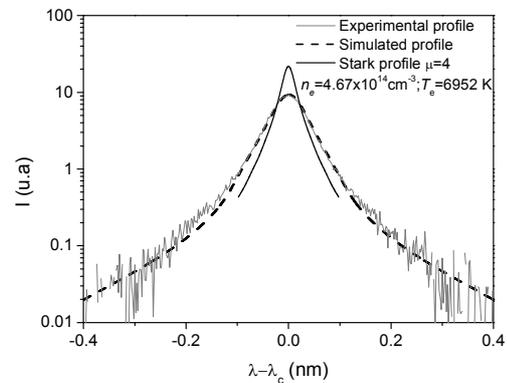
In Figure 4, it has been represented the Stark profile from *Gigosos-Cardenoso model*. This shows that it is necessary take into account the van der Waals contribution to the

lorentzian broadening in order to the tails of the simulated profile adjust well to the experimental.

Similar studies have been carried out for the  $H_{\beta}$  line profile by other authors [6-7].



**Figure 3.** Representation of the simulated profile for  $n_e = 4.67 \times 10^{14} \text{ cm}^{-3}$ ;  $T_e = 6952$  and  $\mu = 4$ , and the experimental profile.



**Figure 4.** Comparison of the experimental profile with the simulated convoluted profile and the theoretical Stark profile

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