Publ. Astron. Obs. Belgrade No. 89 (2010), 197-200 *Contributed Paper*

CORRECTION OF THE H_β SPECTRAL LINE PROFILE TO THE INFLUENCE OF THE NEIGHBOUR HYDROGEN LINES FOR HIGH ELECTRON DENSITIES

STEVICA DJUROVIĆ and IGOR SAVIĆ
Faculty of Sciences, Department of Physics, Trg Dositeja Obradovića 4,
21000 Novi Sad, Serbia
E-mail: djurovic@uns.ac.rs

Abstract. The influence of the neighbour hydrogen lines H_α and H_γ on the H_β spectral line profile has been studied in the electron density range of $(2 - 7) \cdot 10^{23}$ m^{-3}. For the analysis of the mentioned influence, theoretical profiles were used and the results were applied for the correction of experimental H_β profiles.

1. INTRODUCTION

The knowledge of theoretical and experimental profiles of hydrogen Balmer H_β line is very important for plasma diagnostics purposes. However, it should be noted that the accuracy of the density diagnostics from the line halfwidth is in fact limited by the existence of the characteristic peaks of H_β profile and due to the continuum level determination. The problems in this method and in the methods using fiiting of H_β profile are described in Goode and Deavor (1984), Chan and A. Montaser (1989), Ishii et a. (1990), Thonmsen and Helbig (1991). Comments of these and other fitting methods are given in Ivković and Konjević (1999).

New theoretical models based on the effects of microfield nonuniformity and electron impact shifts (Djurović et al. 2005) and the standard theory and computer simulations with separately included quadrupolar and quadratic Stark effects (Djurović et al. 2009), finally made possible fitting of the whole asymmetric experimental H_β profile. This is especially important for the electron densities higher than 10^{23} m^{-3}. Possibilities of fitting the whole H_β profile, for electron densities lower than 10^{23} m^{-3} using symmetrical theoretical profiles (Vidal et al. 1973, Griem 1974, Gigosos and Cardeñoso 1996, Stehlé and Hutcheon 1999) are described in Žikić et al. (2002). Even with this, one more problem still exists. The problem is the influence of the neighbour hydrogen lines, especially of the H_γ on the H_β spectral line profile. In both techniques, using halfwidth measurements and fitting of the whole profile, especially for higher electron densities where hydrogen lines are very broad, this effect can increase the error of the electron density determination.

The aim of this work is to analyze the influence of the overlapping of the neighbour hydrogen lines on the H_β spectral line.

2. EXPERIMENTAL SETUP AND PLASMA DIAGNOSTICS

The plasma was produced from an electromagnetically driven T-tube, having a diameter of 27 mm. The T-tube was energized using a 4 μF capacitor bank, charged up to 20 kV. The filling gas was hydrogen at a pressure of 300 Pa. More details on this experiment can be found in Djurović et al. (2005, 2009).

Electron densities of the T-tube plasma, ranging from $2.28 \cdot 10^{22}$ m^{-3} to $7.30 \cdot 10^{23}$ m^{-3}, were determined from Stark widths of the H_β line profiles (Griem 1974). The estimated uncertainties of the electron densities did not exceed ± 9%. Electron temperatures, ranging from 19400 K to 34000 K, were determined from the line-to-line continuum ratios for the H_β line (Griem 1964) with the uncertainties between ± 8% and ± 15%, for the lower and higher values respectively.

3. ANALYSIS OF THE H_α AND H_γ INFLUENCE TO H_β LINE PROFILE

In this analysis, three first lines, H_α, H_β and H_γ, in the hydrogen Balmer series are considered. For this purpose theoretical H profiles (Griem 1974) were generated for our experimental conditions, electron densities (2.28, 2.73, 3.30, 4.09, 5.69 and 7.30) $\cdot 10^{22}$ m^{-3} and electron temperatures (19400, 20200, 21200, 24200, 28000 and 34000) K. The H_β profile (Griem 1974), which correspond to higher experimental electron density, is shown in Fig. 1 together with H_α and H_γ intensities.

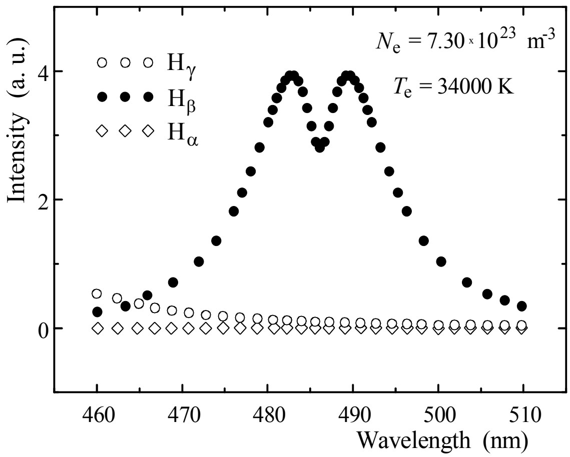

Figure 1: Theoretical H_β line profile (Griem 1974) with corresponding H_α and H_γ theoretical intensities for electron density of $7.30 \cdot 10^{23}$ m^{-3}.

These influences are calculated for the different positions along the H_β profile, namely, in the centre λ_0, at the line maxima $\Delta\lambda_{max}$, at the distance $\Delta\lambda_{1/2}/2$ and $\Delta\lambda_{1/2}$ from the line centre in both directions. The $\Delta\lambda_{1/2}$ denotes the halfwidth of the H_β line profile. H_α intensities are very small in comparison with both the $I(H_\beta)$ and $I(H_\gamma)$ intensities and the influence of H_α on the H_β profile can be neglected.

However, the influence of the H_γ on the H_β profile must be taken into account. The calculated corrections for different electron densities are given in Table 1.

Table 1. Percentages of the necessary correction of the H_β profile intensity at the different positions.

N_e	T_e	Corrections (%)						
(10^{23} m^{-3})	(K)	$-\Delta\lambda_{1/2}$	$-\Delta\lambda_{1/2}/2$	$-\Delta\lambda_{maxB}$	λ_0	$\Delta\lambda_{maxR}$	$\Delta\lambda_{1/2}/2$	$\Delta\lambda_{1/2}$
2.28	19400	3.140	0.780	0.327	0.459	0.287	0.522	1.431
2.73	20200	4.746	1.076	0.454	0.625	0.391	0.685	1.994
3.30	21200	6.571	1.520	0.634	0.845	0.550	0.919	2.487
4.09	24200	10.202	2.281	0.926	1.198	0.768	1.257	3.297
5.69	28000	21.386	4.370	1.859	2.289	1.399	2.089	5.282
7.30	34000	34.131	8.295	2.858	3.430	2.159	3.190	7.178

4. CORRECTION OF THE EXPERIMENTAL PROFILES

Before the comparison of the pure experimental and corrected experimental profiles, the continuum was eliminated. For this purpose, the linear dependence of the continuum of the wavelength was assumed. The experimental H_β line profile correction is illustrated in Fig. 2 for an electron density of $7.30 \cdot 10^{22}$ m^{-3}.

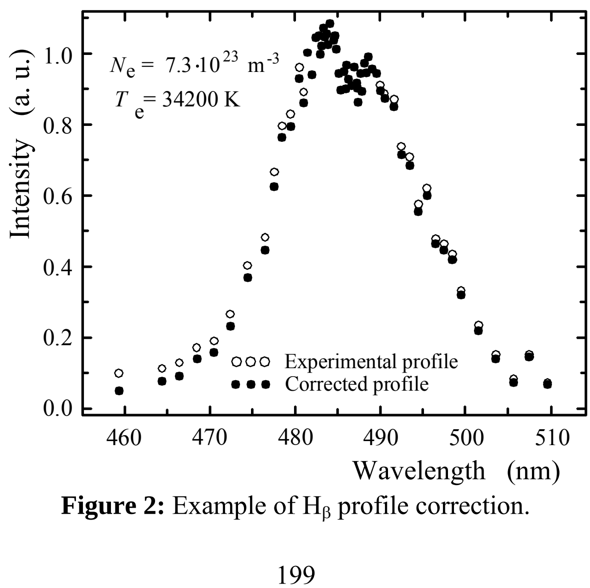

Figure 2: Example of H_β profile correction.

The H_β profile correction influences, of course, the halfwidth profile determination, and thus, the electron density determination. The percentage of the halfwidths and electron density reductions are given in Table 2.

Table 2. Percentage of halfwidth and electron density correction after the H_β profile correction.

N_e (10^{23} m^{-3})	Correction (%)	
	$\Delta(\Delta\lambda_{1/2})$	$\Delta(N_e)$
2.28	1.9	3.0
2.73	2.2	3.4
3.30	2.5	4.0
4.09	3.0	4.7
5.69	4.0	6.1
7.30	5.0	7.5

It is obvious that for electron densities above $6 \cdot 10^{23}$ m^{-3} the error caused by the influence of the neighbour lines on the H_β profile is the same as the error of the electron density determination, which was estimated to be 6% (Wiese et al. 1972).

Acknowledgements

This work is supported by the Ministry of science and Development of the Republic of Serbia, Project 141024.

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