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A SIMPLE CORRECTION OF LOW N BALMER LINE INTENSITIES FOR BOUNDARY LAYER INFLUENCE IN SMALL T–TUBE PLASMAS

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1. INTRODUCTION

It has been generally accepted (Kolb, 1957; Pavlov and Prasad, 1968) that plasmas produced in small electromagnetic T–shaped shock tubes are quite homogeneous radially and also axially behind the reflected shock front. Thereafter these plasmas appear as very attractive for spectroscopic observations of their radiation, since no, say Abel inversion is required. Apart from small-scale turbulence, the only inhomogeneities encountered occur in the boundary layers between the inner plasma and the cold glass tube walls. The thickness of these boundary layers reaches approx. 1 mm within a few microseconds after the reflected shock front has passed the point of observation (Pavlov and Prasad, 1968; Pavlov and Djurović, 1982). Because these boundary layers are thin compared to typical tube diameters of 25 mm, it has been assumed that they do not introduce noticeable changes in spectral intensities (Meins and Weiss, 1976; Hay and Griem, 1975). Influence of simplified boundary layer model on line profiles (Pavlov and Terzić, 1987) showed that this need not be true. Emitted spectral intensities (per unit wavelength) in the cited paper (Pavlov and Terzić, 1987) were calculated by numerical integration of the equation for radiative transfer (Griem, 1964).

2. LINE INTENSITIES EMITTED BY T–TUBE PLASMAS

Total line intensities J_b influenced by boundary layers, for H_α, H_β and H_γ were calculated by numerical integration of spectral intensities (per unit wavelenght) of the lines. So were calculated total line intensities J_h when T–tube is filled from wall-to-wall with homogeneous plasmas. It turned out that the ratios J_b/J_h are linear functions of boundary layer thickness δ as illustrated in Fig. 1. for H_β line. It means that the ratio J_b/J_h can be presented as

$$\frac{J_b}{J_h} = 1 + A \cdot \delta \quad . \tag{1}$$

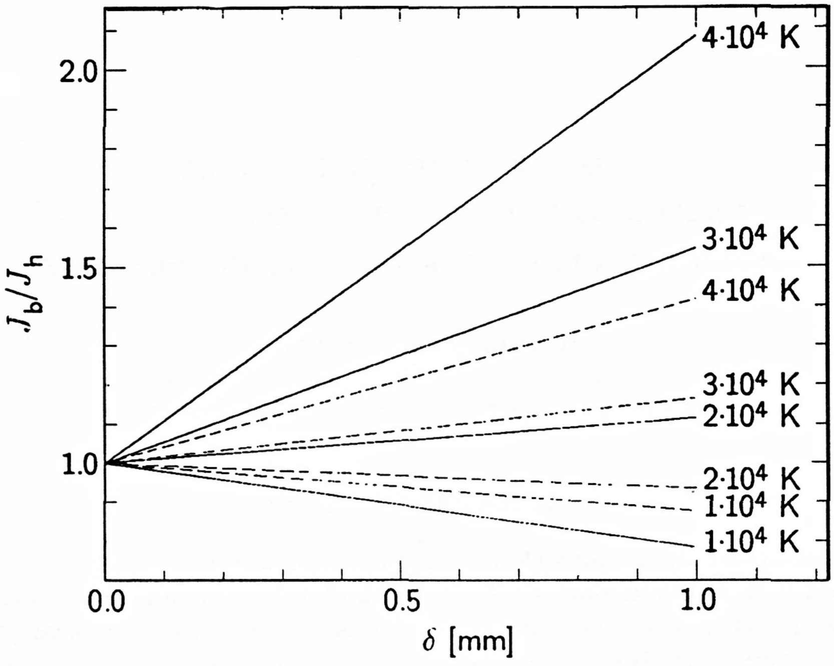

Fig. 1. Ratio of total line intensities influenced by boundary layers J_b / homogeneous plasma J_h, as function of the boundary layer thickness for electron concentration of $N_\mathrm{e} = 1 \cdot 10^{22}$ m^{-3} (solid lines) and $N_\mathrm{e} = 5 \cdot 10^{23}$ m^{-3} (dashed lines).

Correction factor $A \cdot \delta$ can be calculated using Tables 1, 2 and 3 for relevant values of A, as well as independently determined (or at least estimated) thickness δ of the boundary layer (Pavlov and Prasad, 1957; Pavlov and Djurović, 1982). The intensity J_h, without influence of boundary layers can then be calculated from the above-adduced equation after J_b is measured say by shot-to-shot scanning technique.

Table 1.
Coefficient A of Eq. 1. (in mm^{-1}) for H$_\alpha$ line

N_e [m^{-3}]	T [K]			
	$1 \cdot 10^4$	$2 \cdot 10^4$	$3 \cdot 10^4$	$4 \cdot 10^4$
$1 \cdot 10^{22}$	-0.183	0.159	0.697	1.413
$2 \cdot 10^{22}$	-0.162	0.117	0.581	1.203
$5 \cdot 10^{22}$	-0.141	0.048	0.435	0.934
$1 \cdot 10^{23}$	-0.135	0.002	0.326	0.754
$2 \cdot 10^{23}$		0.044	0.203	0.560
$5 \cdot 10^{23}$		0.082	0.047	0.313
$1 \cdot 10^{24}$		0.099	-0.052	0.093

Table 2.
Coefficient A of Eq. 1. (in mm^{-1}) for H_β line

N_e [m^{-3}]	T [K]			
	$1\cdot10^4$	$2\cdot10^4$	$3\cdot10^4$	$4\cdot10^4$
$1\cdot10^{22}$	-0.217	0.130	0.545	1.080
$2\cdot10^{22}$	-0.215	0.095	0.466	0.936
$5\cdot10^{22}$	-0.207	0.042	0.372	0.767
$1\cdot10^{23}$	-0.192	0.007	0.297	0.657
$2\cdot10^{23}$	-0.164	-0.025	0.243	0.547
$5\cdot10^{23}$	-0.124	-0.067	0.137	0.415
$1\cdot10^{24}$	-0.102	-0.087	0.103	0.309

Table 3.
Coefficient A of Eq. 1. (in mm^{-1}) for H_γ line

N_e [m^{-3}]	T [K]			
	$1\cdot10^4$	$2\cdot10^4$	$3\cdot10^4$	$4\cdot10^4$
$1\cdot10^{22}$	-0.221	0.099	0.480	0.950
$2\cdot10^{22}$	-0.221	0.075	0.449	0.827
$5\cdot10^{22}$	-0.218	0.037	0.424	0.695
$1\cdot10^{23}$	-0.215	0.001	0.302	0.585

3. DISCUSSION

For the purpose of say inner plasma electron temperature T determination from line to continuum intensity ratio (Griem, 1964), it is necessary to use J_h as well as J_hc (continuum intensity for homogeneous plasma). Influence of the boundary layers on continuum intensity is descused elsewhere (Pavlov and Radujkov, 1985; Radujkov and Pavlov, 1986).

Inspecting the Tables 1, 2 and 3 for H_α, H_β and H_γ one can see that for small values of electron temperature and densities of inner part of plasma, the ratio $J_\mathrm{b}/J_\mathrm{h}$ can considerably differ from unity having in mind that δ is typically a fraction of a millimetre.

The ratio $J_\mathrm{b}/J_\mathrm{h}$, that is the value of correction factor $1+A\cdot\delta$, for a given δ is the largest at the high temperature and low density part od the Table 1, 2, and 3. Luckily, the T–tube plasmas decay starts typically at the high density and temperature corner of the Tables 1, 2 and 3 terminating at the opposite corner, that is at low density and temperature of the plasma. One can see that along the Tables diagonals the values of A are very small. That means, the correcting factor $1+A\cdot\delta$ is close to 1 particularly at the beginning of the plasma decay where the boundary layer thickness δ is also small, typically 0.1 mm during the first 2 μs (Pavlov and Radujkov, 1985; Radujkov and Pavlov, 1986).

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