



HAL
open science

MODELING OF THE NET EMISSION COEFFICIENT IN HIGH INTENSITY DISCHARGE (HID) LAMPS

Mohamad Hamady, Antoine Sahab, Yann Cressault, Georges Zissis

► **To cite this version:**

Mohamad Hamady, Antoine Sahab, Yann Cressault, Georges Zissis. MODELING OF THE NET EMISSION COEFFICIENT IN HIGH INTENSITY DISCHARGE (HID) LAMPS. IEEE International Conference on Plasma Science (ICOPS), Dec 2020, Singapore, Singapore. pp.PID6322237. hal-03269413

HAL Id: hal-03269413

<https://hal.science/hal-03269413>

Submitted on 6 Jul 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Laplace

Lumière & Matière

UMR 5213

Net Emission Coefficients in HID Lamps



Hamady, A.SAHAB, Y. Cressault, G. Zisis
antoine.sahab@laplace.univ-tlse.fr








1

Laplace

Introduction

UMR 5213

Problem Positioning

- HID Lamps
- Cylindrical Symmetry
- Resolution Of Radiative Transfer Equation
- Assume LTE
- Atomic constants calculated by BORN
- Atomic constants calculated by Stromberg
-

Objectives:

Evaluation:

- Spectral Intensity
- Spectral Flux
- Photometric characteristics
- Photometric curves.
- Comparison BORN & Stromberg



Radiations of plasma discharge lamps come from different mechanisms that take place inside the lamp. The knowledge of atomic data responsible for these radiations is essential to describe the radiations that take place inside them. A ray tracing method based on the resolution of radiative transfer equation is adopted. The discharge is divided into small cells responsible for launching rays in all directions. The calculations consider that the discharge has a cylindrical symmetry and assume the plasma is at local thermodynamic equilibrium (LTE). Hence, the only knowledge of temperature profile and pressure is sufficient to calculate the plasma composition and to account the mechanisms of broadening of spectral lines in the treatment of radiative transfer. In this work, the atomic data is the only resource to calculate both coefficients. We will show the results for a pure mercury HID lamp. For each spectral line, the local absorption and emission coefficients are strongly dependent on the broadening constants. Calculations reported in the literature use different values for these constants, leading to marked differences in output of the models








2

Laplace **Importance of atomic constants** UMR 5213

Atomic constants calculated by BORN

line (nm)	E _b (eV)	E _h (eV)	G _b	G _h	A _{ki} (10 ⁸ s ⁻¹)	C ₃ (10 ⁻¹⁵ m ³ s ⁻¹)	C ₄ (10 ⁻²² m ⁴ s ⁻¹)	C ₆ (10 ⁻⁴² m ⁶ s ⁻¹)
404.7	4.66	7.73	1	3	0.20	2.97	3	2.5
435.8	4.88	7.73	3	3	0.55	3.86	3	2.5
546.1	5.46	7.73	5	3	0.48	0	6	2
577.0	6.7	8.85	3	5	0.23	6.24	0.046	2.76

Atomic constants calculated by STROMBERG

line (nm)	E _b (eV)	E _h (eV)	g _b	g _h	A _{ki} (10 ⁸ s ⁻¹)	C _n (10 ⁻³⁶ m ⁴)	C _s (10 ⁻³³ m ⁴)	C _{qs} (10 ⁻⁶² m ⁷)
404.7	4.66	7.73	1	3	0.17	1	0	1
435.8	4.88	7.73	3	3	0.37	1.3	0	1.3
546.1	5.46	7.73	5	3	0.52	0.6	0	0.3
577.0	6.7	8.85	3	5	0.58	19	17	4

Lumière & Matière

3

Laplace **Plasma at local thermodynamic equilibrium L.T.E** UMR 5213

□ Temperature profile $T(r) = T_c - (T_c - T_p) \left(\frac{r}{R}\right)^\beta$

⇒ Number of atoms at « j » level by unit volume (Boltzmann law)

$$n_j = g_j \frac{N_T}{U(T)} \exp\left(-\frac{E_j}{kT}\right)$$

⇒ Number of electrons, n_e, or ions, n_i (n_e = n_i) by unit volume (Saha's law)

$$n_e^2 = 2N_T \frac{U_{ion}(T)}{U_{atome}(T)} \frac{(2\pi m_e kT)^{3/2}}{h^3} \exp\left(-\frac{E_i}{kT}\right)$$

□ Pressure P

⇒ Total number of atoms by unit volume $N_T = \frac{P}{kT}$

⇒ Partition function $U(T) = \sum_j g_j \exp\left(-\frac{E_j}{kT}\right)$

Lumière & Matière

4

UMR 5213

Doppler & Stark Broadening

> Doppler broadening (negligible)
 > Pressure broadening

✓ Neutral broadening

$$\Delta_n = 0.36\delta_n \quad \delta_n = C_n N_T$$

$$C_n = \frac{\lambda_0^2}{4\pi c} 8.08 C_6^{2/5} v_n^{3/5} \quad v_n = 4\sqrt{\frac{k_b T}{\pi M}}$$

✓ Stark broadening by electron and ions,

$$\Delta_s = 0.86\delta_s \quad \delta_s = C_s n_e$$

$$C_s = \frac{\lambda_0^2}{4\pi c} 11.37 C_4^{2/3} v_e^{1/3} \quad v_e = \sqrt{\frac{8k_b T}{\pi m_e}}$$

$P(\lambda)$: normalized line profile

> Spectral line profile = convolution of different profiles

$$\delta = \delta_n + \delta_s \quad \Delta = \delta_s + \delta_n$$

UMR 5213

5

UMR 5213

Local Emission and Mesh

Local emission and absorption coefficients:

For a spectral line : Upper level E_u → Lower level E_l $\frac{hc}{\lambda_0} = E_u - E_l$

$$\varepsilon_\lambda(\lambda) = \frac{hc}{4\pi\lambda_0} n_u A_{ul} P(\lambda)$$

Source Function : $S_\lambda(\lambda) = \varepsilon_\lambda(\lambda) / k(\lambda)$

At E.T.L.: $S = \frac{2hc^2}{\lambda_0^5} \exp\left(-\frac{hc}{\lambda_0 KT}\right)$

Schematic atomic structure

Mesh

Cylinder

Base

Height

UMR 5213

6

Laplace **Radiation Transfer Equation**

UMR 5213

Integral Form of radiation transport equation

$$I_{\lambda}(x) = I_{\lambda}(x_0) \exp\left(-\int_{x_0}^x \kappa(\lambda, x') dx'\right) + \int_{x_0}^x \varepsilon_{\lambda}(\lambda, x') \exp\left(-\int_{x'}^x \kappa(\lambda, x'') dx''\right) dx'$$

Discretized form:

$$I_{\lambda}(x_{i+1}) = I_{\lambda}(x_i) \exp(-\kappa(\lambda, i)\Delta x_i) + \frac{\varepsilon_{\lambda}(\lambda, i)}{\kappa(\lambda, i)} (1 - \exp(-\kappa(\lambda, i)\Delta x_i))$$

Homogeneous Medium :

$$I_{\lambda}(x) = I_{\lambda}(x_0) \exp(-\kappa(\lambda)(x - x_0)) + \frac{\varepsilon_{\lambda}(\lambda)}{\kappa(\lambda)} (1 - \exp(-\kappa(\lambda)(x - x_0)))$$

Lumière & Matière UMR 5213

7

Laplace **Influence of atomic constants on output flux**

UMR 5213

Model output:

line (nm)	404.7	435.8	546.1	577.0
Flux (W) calculated by Born's Constants	45.5	70.37	59.6	31
Flux (W) calculated by Stromberg's Constants	27.49	49.3	41.6	70.8

Intensity (W/m²) vs radius (cm) for the line 577 nm

Influence of atomic constants on total intensity for the line 577 nm

Lumière & Matière UMR 5213

8

Laplace
More Results

UMR 5213

Photometric curves

The photometric curves are calculated from the side-on Intensity for different directions in the horizontal and vertical plan.

Color temperature

For this discharge, we find 86 lm/W as luminous efficacy. In addition, the proximal color temperature is about 6630K

9

Laplace
More Results

UMR 5213

Thank you

10