One Dimensional DC Mercury-Argon Fluorescent Lamp model

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Introduction

Mercury-Argon discharge: high efficiency UV radiation
∴used widely as commercial fluorescent lamp

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We need plasma properties to improve lamps

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Data is not enough both in experimental and theoretical way

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We develop a 1 dimensional model and calculate radial distribution of Hg excited atoms to investigate plasma properties in DC Hg–Ar fluorescent lamp

Model

•DC model

•We consider excitation and ionization for Ar. These process are not considered in past models.

•Collisional-radiative model
•Assumption

1. Lamp is cylindrical is enclosure.
2. The positive column is axially uniform.
3. The positive column is radially symmetric
4. Electron energy distribution function is Mxwellian.
5. The number of considered excited levels are 6 for Hg and 2 for Ar.

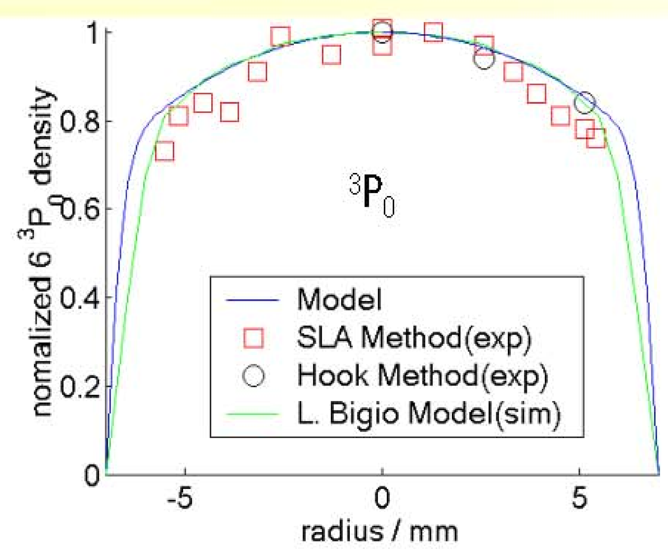
•Basic equation — Boundary condition[1]

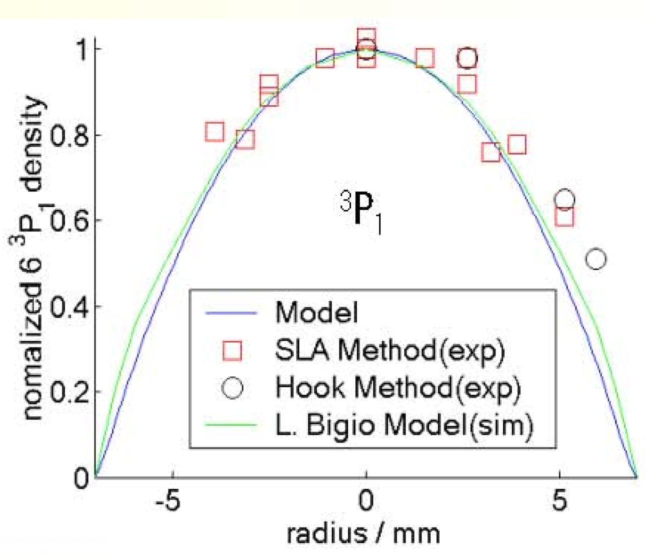
Continuous equation	center	wall
Electron density N_e : $\frac{\partial N_e}{\partial t} = D_a \nabla^2 N_e + S_e$	$\left.\frac{\partial N_e}{\partial r}\right\|_{r=0} = 0$	$\left.N_e\right\|_{r=R} = 0$
Ion density N_+ : $\frac{\partial N_+}{\partial t} = D_a \nabla^2 N_+ + S_+$	$\left.\frac{\partial N_+}{\partial r}\right\|_{r=0} = 0$	$\left.N_+\right\|_{r=R} = 0$
Excited atom density N_j : $\frac{\partial N_j}{\partial t} = D_e \nabla^2 N_j + S_j$	$\left.\frac{\partial N_j}{\partial r}\right\|_{r=0} = 0$	$\left.N_j\right\|_{r=R} = 0$
Energy conservation equation		
Gas temperature T_g : $\frac{3}{2}k\frac{\partial (N_{Ar} T_g)}{\partial t} = \kappa_{Ar}\nabla^2 T_g + S_{Tg}$	$\left.\frac{\partial T_g}{\partial r}\right\|_{r=0} = 0$	$\left.T_g\right\|_{r=R} = T_w$
Electron energy $\bar{\varepsilon}$: $\frac{\partial(\bar{\varepsilon})}{\partial t} = \nabla\left(-\frac{5}{3}\mu_e E_r \bar{\varepsilon} - \frac{5}{3} D_e \nabla \bar{\varepsilon}\right) + S_{\bar{\varepsilon}}$	$\left.\frac{\partial \bar{\varepsilon}_e}{\partial r}\right\|_{r=0} = 0$	$\left.\bar{\varepsilon}\right\|_{r=R} = 0$

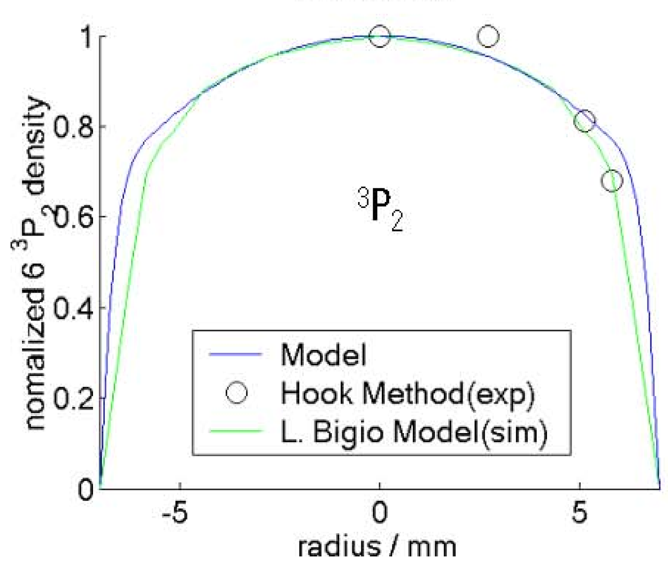
k : Boltzmann constant D_a : ambipolar diffusion coefficient D_e : electron diffusion coefficient μ_e : electron mobility κ_{Ar} : Ar thermal conductivity E_r : ambipolar electric field S_x : generation-loss term of x

$\bar{\varepsilon} = \frac{3}{2} k N_e T_e$

Comparison of simulation results and references[2] 1





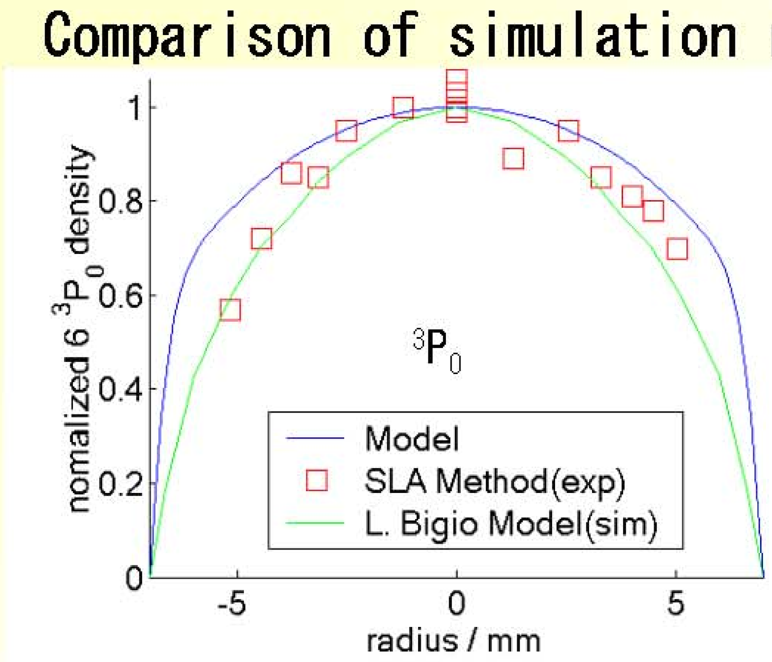


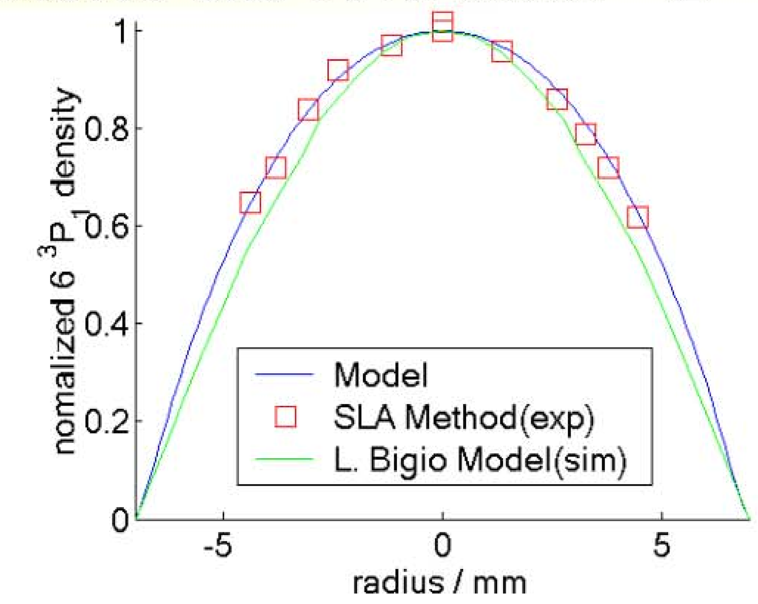
Lamp diameter:14 mm
Ar pressure:3 Torr
Lamp current:0.27 A
Wall temperature:313 K

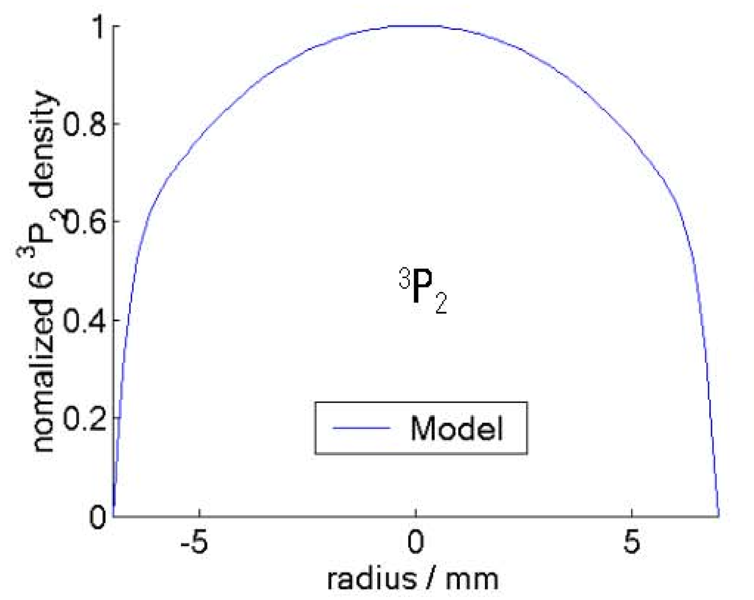
•Good agreement with experimental data.
•Accuracy of this model is equal to L. Bigio's model.

Fig. 1 : Comparison of ^3P_j density from experiment and model (T_w=313 K)

Comparison of simulation results and references[2] 2





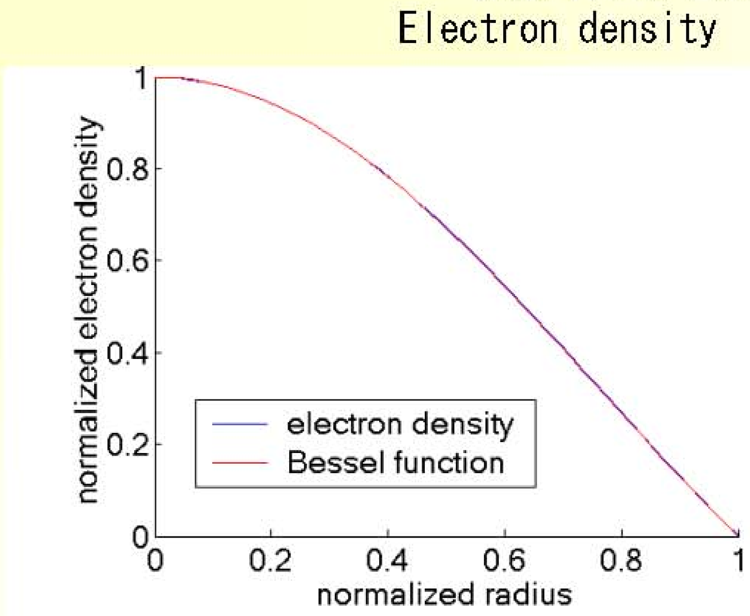


Lamp diameter:14 mm
Ar pressure:3 Torr
Lamp current:0.27 A
Wall temperature:323 K

•Accuracy $^3P_1$ of this model is better than L. Bigio's model.
•By adding collisional process on Ar, applicable range of wall temperature is increases.

Fig.2 : Comparison of ^3P_j density from experiment and model (T_w=323 K)

Distribution of electron density and excitation atom density



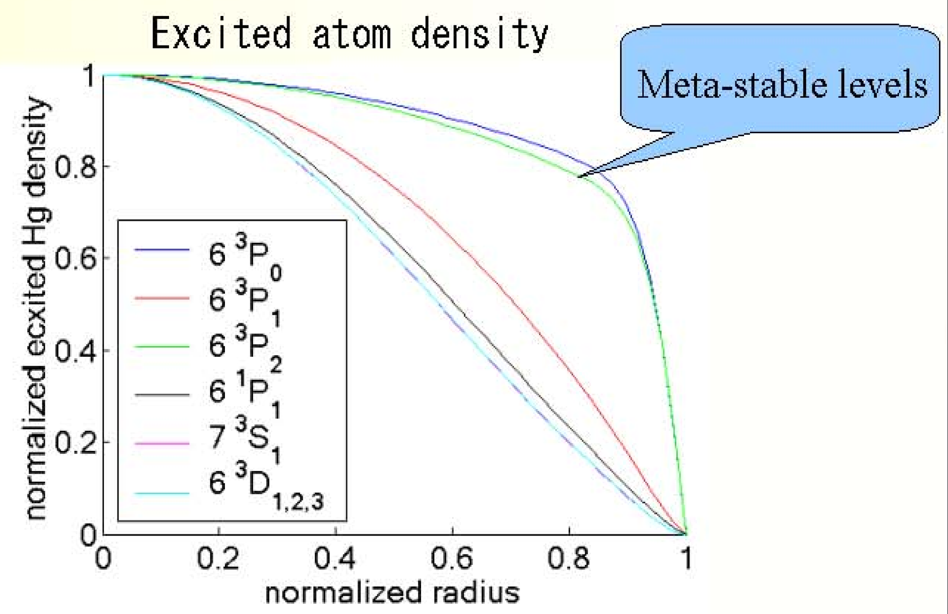


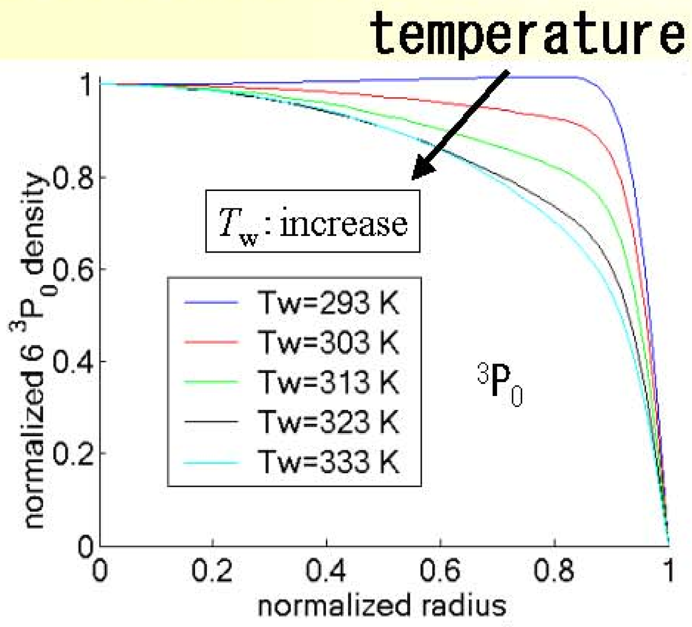
Fig.3 : Electron density and mercury excited densities

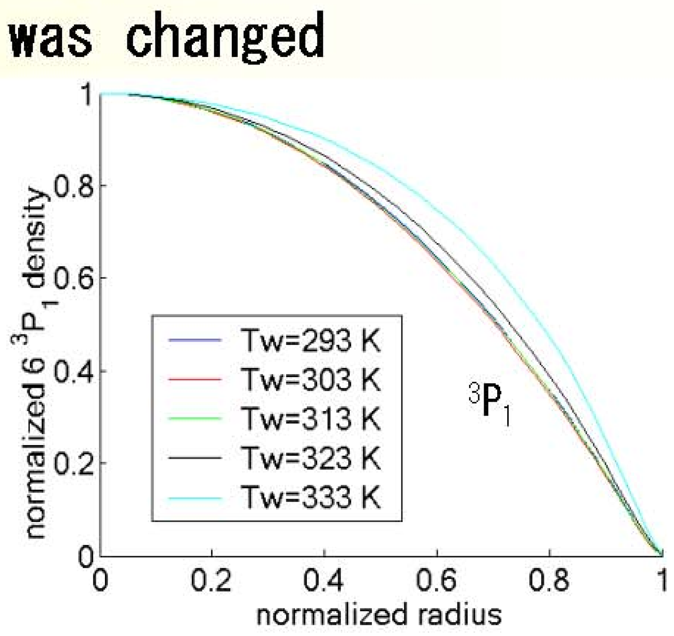
Lamp diameter:14 mm
Ar pressure:3 Torr
Lamp current:0.27 A
Wall temperature:313 K

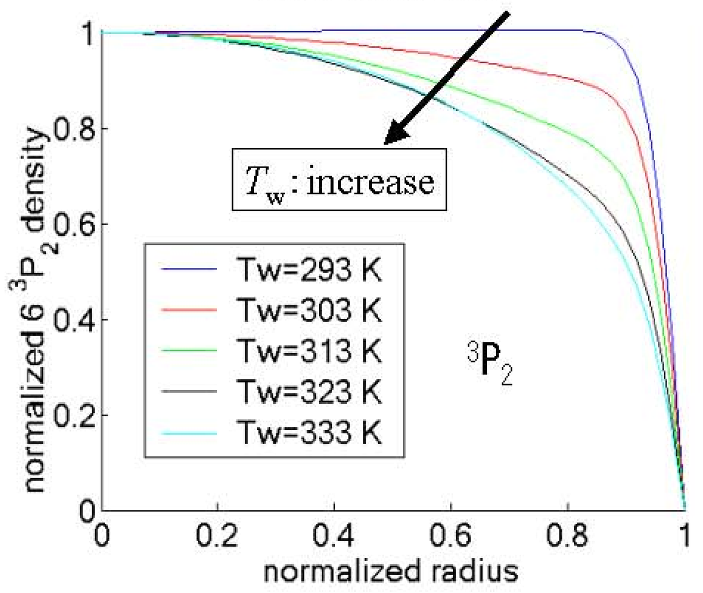
Electron density distribution: Distribution matches zeroth order Bessel function very much
Excited atom density distribution: Only meta-stable levels are broad to the wall.

Meta-stable atoms diffuse to the wall because radiation are forbidden from meta-stable.

Meta-stable and resonance atom densities when wall temperature was changed







Lamp diameter:14 mm
Ar pressure:3 Torr
Lamp current:0.27 A
Wall temperature:293 K - 333 K(each 10 K)

Fig.4 : Meta-stable and resonance atom density when wall temperature was changed

Meta-stable level: When T_w is increase, distributions become narrow
Resonance level: Density does not change very much until T_w is 323K

Conclusion

We developed the model which has good agreement with experiment and show difference of excited atom distributions and of meta-stable and resonance level atom distribution dependence on wall temperature.

references

[1] G. G. Lister: Computer Physics Communications, **Vol. 75**, p. 160 (1992)
[2] L. Bigio *et.al*: Journal of Applied Physics, **Vol. 65**, p. 375 (1989)