Topic #2

Radiation trapping in non-equilibrium plasmas: matrix methods and its application to arcs and glow discharges

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Summary of recent experimental and theoretical studies by authors, related to radiation trapping in non-equilibrium plasmas is presented. A free-burning Ar arc and a constricted positive column of the Ar glow discharge were considered as plasma sources. Role of radiation trapping in formation of spatial distributions of excited species is demonstrated. Excited species densities and its radial distributions are determined by means of emission and absorption spectroscopy. Experimental data is compared with results of simulations. A new universal matrix method of radiation transport description in plasmas of arbitrary geometry, line shape and absorption coefficient is presented. The method is tested against existing matrix methods which are based on source symmetry.

1. Introduction

Processes related to radiative transfer with reabsorption play a significant role in non-equilibrium plasmas. Multiple approximate approaches were developed over the last decade, among them so called matrix method (reviewed in [1]) for plasma sources of certain symmetry. The latter allows for accurate treatment of the radiation trapping process within consistent collisional-radiative models [2].

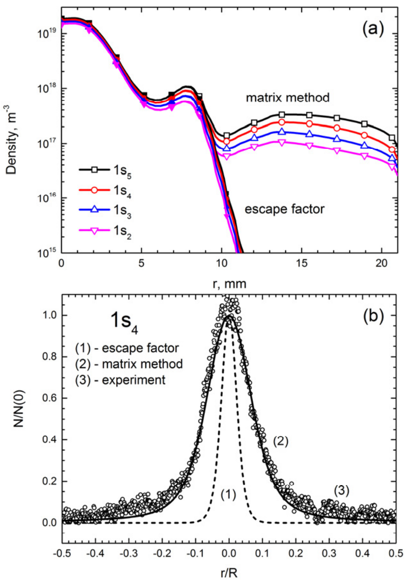

Figure 1: Density profiles of excited Ar atoms, obtained by means of matrix method and using escape factors: (a) free-burning arc; (b) constricted glow discharge.

2. Radiation transport and density profiles

Radiation transport equation for resonance atoms is solved in coupling with balance equations for other species. As Fig. 1 clarifies, correct description of radiation transport causes notable broadening of radial profiles of excited argon atoms, leading to an excellent agreement with experiment (Fig 1(b)).

3. Matrix method for arbitrary geometry

For an arbitrary 3D object the source geometry is discretized on a Cartesian voxel grid. Matrix coefficients, which describe a coupling between unit volumes, are computed using fast ray traversal algorithm [3]. Numerical scheme is efficiently parallelized for running on a graphical processing unit. As an example, solutions of the Holstein-Biberman equation for case of finite cylinder with point excitation source in the center using previously developed matrix approach and a new one are illustrated by Fig.2. Results are in a good agreement.

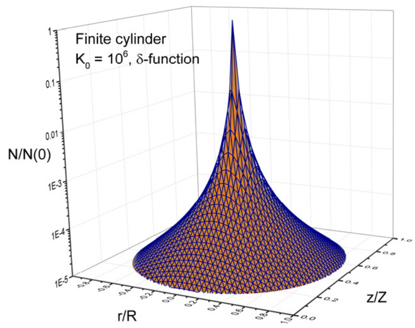

Figure 2: Solution of the equation with point excitation source in the finite cylinder. Orange – old matrix method, blue – ray tracing method.

4. References

[1] Yu. B. Golubovskii et al., Plasma Sources Sci. Technol. **22** (2013) 023001.

[2] Yu. B. Golubovskii et al., J. Phys. D. Appl. Phys. **49** (2016) 475202.

[3] J. Amanatides, A. Woo, *Eurographics* **87** (1987) 3–10