Investigation of the excited state population density of Xe plasma by active and passive spectroscopy

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At preset paper the excited state concentrations distribution of a Hall Thruster (HT) at 300 W operating conditions was investigated by Laser Induced Fluorescence (LIF) and compare with results of passive diagnostics. The main challenge is that researching object is non-equilibrium low-temperature xenon plasma: $T_e \approx$2-100 eV, $n_i \approx n_e \approx 10^{11}$ cm^{-3} ,$n_0 \approx 10^{12}$ cm^{-3}, $r_D \approx 10^{-5...-6}$cm, that can't be describe in the network of classical plasma models. The necessity of the multilevel kinetic model is shown. Excited state population density of neutral atoms is at good agreement with passive method, however for ions due to its space anisotropy can't be measurement near thruster face using integral method. Stepwise ionization and excitation is observed for one charged Xe ions but not significant for neutral atoms.

1. Introduction & theory

Electrically powered spacecraft propulsions have a wide application in use with space vehicles. However, modern space-programs aims require thrusters those main characteristics such as: thrust, specific impulse and life time must be far beyond of currently available ones [1]. Thus researching of physical process of HT is still important. The excited state populations density (ESPD) is indicator of the presence defined process (ionization, excitation, transfer etc.) in the plasma and its parameters [2].

2. Experimental setup

Experiments are performed in the vacuum test facility – TMVC11 [3]. The work pressure is approximately 8×10^{-5} mbar. Pumping produces by Nd: YAG pulsed laser with wave length wide 192 – 2600 nm and with the output pulse energy from 1 to 400 mJ. Impulse duration is 5…9 ns. Measurements of the ESPD were made for points (volume of about 16 mm^3) all over the plane perpendicular to thruster axis in five positions on this axis (10 mm, 50 mm, 100 mm) and for 4 location of objective.

2. Results & conclusions

In this paper, we describe the results of a ESPD of Hall thruster in 3D by LIF compare with passive diagnostic method. We explored 10 transitions by LIF and more than 60 by passive diagnostics. The value of the measurements error is shown on the fig. 1. The results of ESPD for ions and neutrals are demonstrated on fig 2. Neutral atoms ESPD is comparatively homogeneous for different thruster region and state with good agreement with passive method. It can be described using one model (Collision–Radiative model). Ions ESPD not uniform at cathode area and near the thruster face and strongly depends on transitions that lead to divergence results of two method. In other words ones needs multilevel kinetic model for linking to excited state populations density and ion concentrations

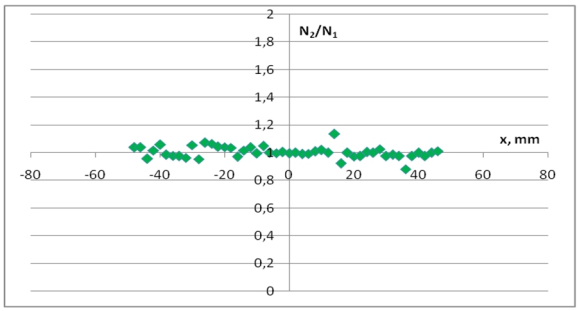

Fig.1. Measurements errors.

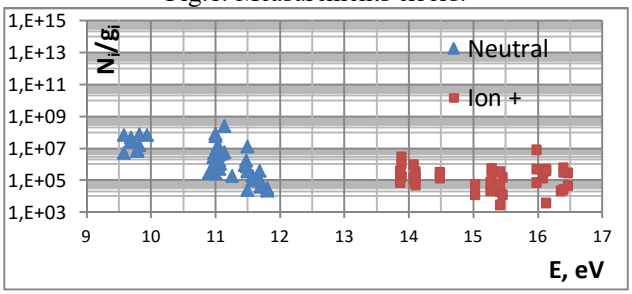

Fig 2. ESPD for ions and neutral atoms.

Classic model can be used for far plume region or for specific electron levels. Also was notice that ion ESPD is strongly not Boltzman.

3. References

[1] Griem H. Plasma Spectroscopy. — M.: Atomizdat, 1969. — 452 pages.

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[3] Krivoruchko D.D., Skrilev A.V. Skorokhod E.P. , Excited state population density and spontaneous emission probabilities XeI plasma of Hall Thruster , MAI proceeding, № 92, 2017.