*31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-1.186 (2004)*

Plasma electron densities from singlet and triplet spectral series of the noble gas ions

D. Shuvaev[1], L. Bureyeva[2], V. Lisitsa[1], D. Petrov[1], F. Rosmej[3], R. Stamm[4]

1. Nuclear Fusion Institute, RRC "Kurchatov Institute", Moscow, Russia

2. Institute of Spectroscopy of the RAS, Troitsk, Russia

3. GSI, Darmstadt, Germany

4. Universite de Provence, Marseille, France

The problem of a redistribution of incoming power in edge plasma is under strong interest last years. The problem can be partly solved by using inert gas pumping to irradiate a part of the incoming power. So there are noble gas ions and neutral atoms in the edge plasma and they can be used for plasma parameter's diagnostics. It is possible to evaluate plasma characteristics interesting for diagnostic.

The spectral lines of neutral helium He I, Ne III and Ar III are of a special interest due to the existence of two series of spectral lines belonging to radiative transitions between a singlet and triplet energy levels [1].

There are several different population mechanisms for singlet and triplet atomic energetic states: three body recombination and collision excitation from ground and methastable triplet state. The population sources have different dependence on electron density N_e. The difference makes it possible direct measurements of electron densities in plasmas by an analysis of singlet and triplet spectral series of the inert gas ions.

Spectral lines due radiation transitions from Rydberg state of Ar III with a principal quantum number n to triplet state ($3s^2$ $3p^3$ (2P°)3d ^{3}D) with n=2 and to singlet states ($3s^2$ $3p^3$ (2P°)3d ^{1}D) are separated substantially because of large difference between energies of the states 3p3d ^{3}D and 3p3d ^{1}D. This difference is 0.85 eV (NIST) [2].

The main population source for highly excited triplet levels is three body recombination depended on N_e^2 (N_e is the electron density) whereas singlet levels are mainly populated by collision excitation from methastable level 3s3p ^{1}S which is in proportion to first power of N_e (fig. 1). So a comparison between triplet and singlet manifolds makes it possible direct measurements of electron densities in plasmas.

The spectral line intensity of radiative transition depends on population of initial state. These populations are defined by rate of collision excitation from methastable state which depends on methastable state population. Thus it is needed to know atomic state populations of Ne III and Ar III in order to obtain spectral line intensities of them.

The exact formal populations calculation can be carried out with the help of a return matrix of system of the equations for populations (in a case of noncollisional plasma - Seaton cascade matrix), in which elements all elementary processes influencing on kinetic are taken into account. However in practice such account is rather bulky, as every time should be solved new system of the equations and, in view of the greater number of levels, the quantity of the equations in system grows, as n^2.

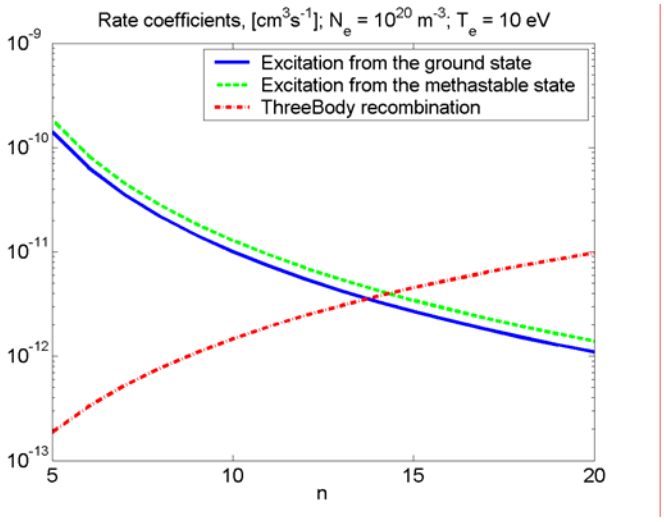
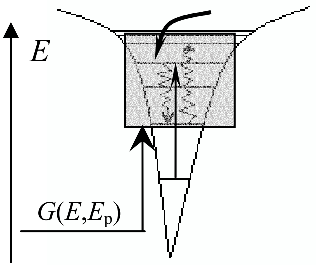


Fig. 1
The dependence of electron collisional excitation from the ground and methastable states and threebody recombination of Ar III on principal quantum number n for the electron temperature 10 eV.

Taking into account all said above in frameworks of quasi static model the method of calculation of atomic excited level populations in plasma synthesizing account of the bottom power levels with the help of a return matrix of system of equations for populations with analytical highly excited states populations calculation on the basis of the Beigman theory [2] was created.

The match of the solution by return matrix of the system of the equations for populations (for the bottom area of a spectrum) and solution of the integro-differrential equation, which nucleus is the Green function [2] (for the top area of a spectrum), is the basis of the method.



The model considers the highly excited energy spectrum as a continuum distribution over energies $E=-Z^2/2n^2$. The atomic state populations are described by a universal Green function $G(E,E_p)$ being the probability of radiative-collisional transitions between two points in the energy space [2], see the scheme.

Rate coefficients of collisional transitions were taken from [3,4]. The Born-Coulomb approximation is used there. Such approximation has made a good showing for calculating of rate coefficients of collisional transitions in ions. Radiative transition probabilities were taken from NIST data base [3].

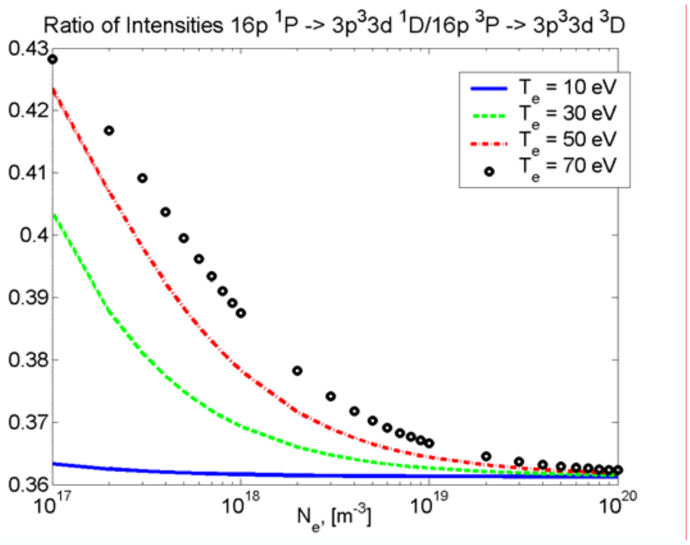


Fig. 2
Dependence of ratio of singlet-singlet transition intensity to triplet-triplet transition intensity of Ar III on electron density N_e for different values of electron temperature, principal quantum number n = 16

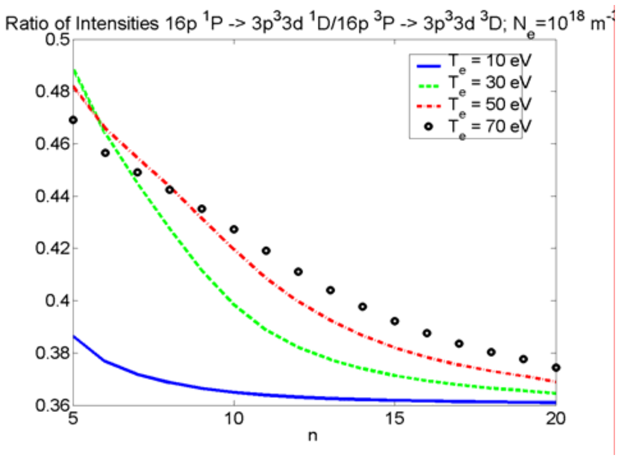


Fig. 3
Dependence of ratio of singlet-singlet transition intensity to triplet-triplet transition intensity of Ar III on principal quantum number *n* for different values of electron temperature, electron density $N_e = 10^{18}$ m^{-3}

Spectral line intensities for various plasma parameters were calculated by following model described above. An analysis of the data shows that ratio of singlet and triplet transition intensities depends on electron density, see Fig. 2,3. Intensity ratio both when electron density is increased and when principal quantum number is increased tends to ratio of statistical weights.

It is seen from figure 2 that the dependence of the ratio of intensities on electron density is not so strong but nevertheless the method allows us to evaluate electron density in wide range $N_e \sim 10^{18} - 10^{20}$ m^{-3} which is typical for large experimental device divertors. The wide domain of electron densities makes it possible to consider the method suggested as a universal one.

This work was supported by the Russian Federal program on support of leading scientific school researches, Grant No. 2024.2003.2 and INTAS grant 03-54-6348.

References

1. L. Bureyeva, V. Lisitsa, D. Petrov, F. Rosmej, D. Shuvaev, R. Stamm. Proceeding of 30th EPS Conference on Contr. Fusion and Plasma Phys. ECA, 2003, Vol. 27A, P-2.67.
2. Beigman I.L., Proc. Of the Lebedev Physical Institute, 179 , p. 160 (1987).
3. http://physics.nist.gov/cgi-bin/AtData/levels_form
4. I.I. Sobelman, L.A. Vaishtein, E.A. Yukov, Excitation of atoms and broadening of spectral lines. Springer, New York, 1980.