§10. Atomic Processes in Non-Maxwellian Plasmas

Fujimoto, T., Furukubo, T. (Dept. Engng. Phys. Mech., Kyoto Univ.)
Kagawa, T. (Dept. Phys., Nara Women's Univ.)
Yoneda, H. (Laser Engng. Center, Univ. Electro-Comm.)
Kawach, T. (RIKEN)
Nagashima, K. (JAERI)
Kato, T.

Until recently, the velocity distribution of electrons in a plasma has been sometimes automatically assumed to be Maxwellian and we assumed an electron temperature for it. However, with a progress in techniques of producing and heating plasmas, and of observing them, we frequently encounter non-thermal plasmas. Electrons and ions may have a velocity distribution that deviates from Maxwellian more or less, and we cannot assume a temperature. In this case, many of the conventional concepts in plasma spectroscopy break down; Examples are the Boltzmann distribution, the Saha-Boltzmann distribution, and the principle of detailed balance for the excitation and deexcitation rate coefficients. Furthermore, we should be aware of the fact that, in many cases, a non-Maxwellian distribution is also spatially anisotropic. In this latter case, the excited atoms and ions (simply called atoms henceforth) become anisotropic, or aligned, and the radiation emitted by these atoms is polarized. This situation poses another difficult problem to spectroscopy, because, in general, the observed intensity of line radiation by our detection system is not necessarily proportional to the population of the atoms in the upper level of the transition; It also depends on our experimental geometry and the polarization characteristics of our detection system.

The objective of the present coordinated research program is to investigate various facets of non-thermal or non-Maxwellian plasmas in plasma spectroscopy and relevant atomic processes in these plasmas.

Fujimoto introduced a general method of spectroscopy for spatially anisotropic plasmas, Plasma Polarization Spectroscopy (PPS). For axially symmetric plasma, each of the excited level of atoms is allocated two quantities, the population and the alignment. A spatially anisotropic velocity distribution of perturbers is expressed in terms of the Legendre polynomials. By combining these ingredients, we formulate the population-alignment collisional-radiative model. For the ionizing plasma component, this formulation has been completed. For the recombining plasma component, however, a similar formulation is undeveloped so far. Radiative recombination of electrons with anisotropic velocity distribution is rather straightforward. The anisotropic three body recombination has to be incorporated in the formalism, but its method has still to be developed. To this end, the ionization process was discussed in detail.

Furukubo reported a PPS experiment on a tokamak plasma. A heliumlike carbon impurity line and a berylliumlike oxygen line were found polarized. An example of the velocity distribution functions of electrons as deduced from the experimental polarization degree was shown.

Kagawa discussed the excitation cross section of ions necessary in the population-alignment collisional-radiative model. He pointed out the difficulty in producing a reliable cross section between the magnetic sublevels.

Dubau discussed various examples of x-ray spectroscopy from the viewpoint of polarization.

The velocity distributions of several plasmas were reviewed. Examples were the inductively coupled plasma by Hori, laser-produced plasmas by Nagashima with emphasis on a short pulse laer. It was noted that, for the non-Maxwellian distribution, spatial isotropy has been somehow assumed. Yoneda reported the polarization observation of a laser produced plasma; the resonance series lines of heliumlike fluorine and its recombination continuum were found polarized. The recombination continuum and the higher members of the series indicate that this plasma is a typical recombining plasma.