§4. Plasma Polarization Spectroscopy: Application to Plasma Diagnostics

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The basic formulation of Plasma Polarization Spectroscopy (PPS) has been developed. We assume axial symmetry and no fields present. We adopt the semi-classical approximation.

The ensemble of atoms in state p is described by the density matrix $\rho(p)$. We expand $\rho(p)$ in terms of the standard irreducible tensorial components. Besides the population $\rho^0{}_0(p)$, we have the alignment $\rho^2{}_0(p)$. We consider the temporal development of $\rho(p)$ induced by collisions and radiative transitions. The first step is to define a superoperator on a vector in the Liouville space for electron collisions in the direction of the quantization axis. The matrix element of the superoperator is integrated over the impact parameter to yield the integral cross section. The cross section for transition of population → population, population → alignment, alignment → population and the 0-th moment of alignment → alignment is expressed in terms of the magnetic sublevel → magnetic sublevel cross sections, but the alignment → alignment cross section for higher orders cannot be expressed by them.

We now consider the velocity distribution of electrons which is axially symmetric. We expand the angular distribution function in terms of the Legendre polynomials. The transition rate coefficients between the populations and alignments are given from the combinations of the cross sections derived above and the components of the velocity distribution. For example, the rate coefficient for creation of alignment from population is given from the population → alignment cross section integrated over the second moment of the velocity distribution function multiplied by the third power of the relative velocity.

The radiative transition probability is defined for population → population and for alignment → alignment. For the former transition the probability is nothing but the conventional transition probability. The latter is given from the former multiplied by a 6-j symbol.

The rate coefficients and the transition probability are defined for elastic transitions as well as for inelastic transitions.

We construct a set of the rate equations for population and another for alignment. Following the spirit of the collisional-radiative model, we ignore the time derivative for excited levels. We thus obtain two sets of simultaneous equations, one for population and another for alignment.

In many cases, it is expected that the magnitude of alignment is in the order of a percent of population. Thus it is justified to ignore the effect of alignment in solving the set of equations for population. The solution is obtained as a function of electron density and temperature with the ground-state population and the ion density as parameters. The solution is substituted in the the equations for alignment, and this solution is expressed likewise with the ground-state popualation and the ion density as parameters.