§3. Plasma Polarization Spectroscopy for Diagnostics of Fusion Plasma by Neutral Beam Injection

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Atomic spectroscopy has been mainly concerned with the wavelength of a spectral line and its identification with a pair of energy levels, thus contributing to establishing the energy level structure and electronic structure of various atoms and ions (called simply *atoms* hereafter). *Plasma spectroscopy* is concerned with the intensity of spectral lines emitted from a particular plasma, and thus with the population distribution over excited levels and its relationship with the state of the plasma concerned. *Plasma polarization spectroscopy* is the next generation of spectroscopy in which we are concerned with polarization of a spectral line, and thus with the anisotropic characteristics of the plasma.

Polarization phenomena relevant to plasma polarization spectroscopy may be categorized into three classes;

[Class 1]: Excitation is isotropic, but a static electric or magnetic field is present, and a spectral line is split by the Stark effect or the Zeeman effect into several components, each of which is linearly or circularly polarized.

[Class 2]: Excitation itself is anisotropic and polarized atoms are created in excited states, usually alignment. Emitted radiation by these atoms has anisotropic intensity distribution and is polarized. Electric or magnetic fields may be present, but they do not play any essential role in the atomic polarization.

[Class 3]: Excitation is anisotropic and polarization is initially created in the excited atoms, and an electric field and/or a magnetic field are present, affecting the characteristics of the polarized atoms.

Class 1 polarization is well understood and has been already utilized for studying magnetic field present in tokamak plasmas. A neutral beam is injected into a plasma and, depending on the energy of the beam, the Zeeman effect by the magnetic field or the Stark effect due to the motional electric field splits a spectral line. From the observed splitting , the magnitude and direction of the field are determined.

Class 2 polarization has not been attended to until recently. However, there are several situations of plasma in which polarization of this class may be observed. 1. Plasmas in which the velocity distribution of electrons is anisotropic, *e.g.*, a shifted Maxwellian, a presence of high-energy non-thermal electrons, and depletion of an electron group by a streaming motion. 2. Excitation of ions by a neutral atomic beam, *i.e.*, charge exchange recombination. 3. Anisotropic radiation trapping effect which is due to the geometrical anisotropy (self alignment) or to the anisotropic streaming motion of the plasma.

Class 3 polarization is most important for the NBI diagnostics of the plasma, but is almost completely undeveloped so far. This demands our understanding of the alignment production and its subsequent temporal development under the electric and/or magnetic field. The latter involves very complicated treatment of atomic states. Efforts in this directionshould be made for the purpose of proper understanding and new developments of the NBI diagnostics.