Diagnostics of the Fusion Plasmas Using Fast Hydrogen Atomic Beam Emission Spectroscopy

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Parameters in magnetically confined fusion-relevant toroidal plasmas usually have radial profiles so that the optical emission passive spectroscopy only yields those in the brightest position. Therefore, high-speed (several tens to several hundreds keV) neutral beam injection (NBI) is used as an active probe beam to obtain the spatial distribution of them. Beam emission spectroscopy (BES) and its variation such as motional stark effect (MSE) spectroscopy are regarded as powerful tools in the devices with NBI system for plasma heating.

Emission from the beam atom is governed by the collisional processes to populate the exited state. Therefore, intensity and its fluctuation of the Doppler-shifted beam emission correspond to the density and its fluctuations, respectively. This is the principle of BES. In addition, since the beam emission is polarized due to MSE, polarization-sensitive detection yields the direction of the magnetic field vector, B, which can induce the Lorenz field, E = vxB, with beam velocity, v. This electric field results in the Stark splitting of the beam emission. One can deduce plasma current profile from the pitch angle of the magnetic field.

BES by making use of an NBI heating system has been developed in mid-'80s and remarkable results about the behavior of the long-wavelength density fluctuations in tokamak have been obtained. In contrast in helical systems, partly due to the complexity of the magnetic configurations, there had been no BES measurements system until recently when we developed it on compact helical system (CHS) in National Institute for Fusion Science (NIFS) [1, 2]. CHS is a middle-size low aspect-ratio helical device (R = 1 m, a = 0.2 m). In the discharge with steep density gradient in the edge region, called edge transport barrier (ETB) discharges, a type of low-frequency (~4 kHz) coherent MHD fluctuations with second harmonics frequency was observed. This is similar to what we call edge harmonic oscillation (EHO) in tokamak [3].

The magnetic field and the beam energy in CHS are about 1 T and 40 keV, respectively while those in the large helical device (LHD) (R = 4 m, a = 0.6 m), are 3 T and 170 keV, respectively. In this case, splitting of the line spectra due to MSE should be taken into consideration in the design of the dispersion (grating or interference filter) system. Our development of the BES system on LHD is currently underway.

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References:
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