Investigation of Highly Charged Xe Ions Measured in Xe Puffing Experiment at Large Helical Device Through Detailed Atomic Structure and Electron-Ion Collision Calculations

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The study of spectral lines emitted from individual extrinsic impurities in high-temperature tokamak devices plays an essential role in diagnosing the fusion plasma in their edge and core regions through various diagnostic methods [1]. In large-scale fusion plasma devices such as ITER and CFETR, etc. higher atomic Z elements (e.g. Kr and Xe) are considered to be suitable to serve as the impurity seeding element for the X-ray Crystal Spectrometer (XCS) diagnostics [2]. The contribution of each charge state of the highly charged Xe ions has not yet been clarified in detail in high-temperature fusion plasma, and their detailed atomic data and collision cross-section data are required for plasma modling purposes.

In view of this, Extreme Ultraviolet (EUV) spectral diagnostics of highly charged Xe ions were programmed for the 24th campaign of the Large Helical Device (LHD). In the present work, early Collisional-Radiative (CR) model calculations were carried out for the Xe^{25+} charge state. An impurity seeding experiment was conducted using the Xe gas puff. In the experiment, LHD plasma was ignited using the electron cyclotron heating system, while Negative-ion-based Neutral Beam Injection (N-NBI) #1-3 was utilized to sustain the plasma from 3.3-7.3s. Xe gas was injected at 4.0s, and emission spectra of highly charged Xe charge states were measured in the EUV wavelength regions. The detailed spectral analysis of measured Xe-ions was performed to validate the theoretical collisional data and CR model calculations. The CR model calculation included various population transfer kinetic processes among the fine structure levels of the considered Xe-ion. Detailed atomic structure and collision calculations were performed for the excitation energies, oscillator strengths, wave functions, and their cross-sections for various fine structure transitions from the ground state and excited states to the other fine structure levels using the Flexible Atomic Code (FAC) [3]. Further, these calculated data incorporated into the CR model to solve the kinetic rate balance equations. Theoretical synthetic spectrum was generated through the population of the considered fine structure levels of the Xe-ion. The comparison of theoretical spectra with the LHD-measured spectra validated the atomic structure and collision data calculations prominent for spectroscopic diagnostics of future fusion plasma experiments in different tokamak devices.

References

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