Progress of EUV impurity lines spectral diagnostics of highly charged Xe ions measured in Large Helical Device

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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]. Many impurity seeding experiments have been conducted using Nitrogen (N_2), and inert gases such as Neon (Ne), Argon (Ar), and Krypton (Kr), to study the radiation enhancement and reduction of the particle heat load in the divertor region for the divertor detachment in the fusion devices [2-6]. However, 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 [7-8]. 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 [9]. Therefore, the proper analysis of such high Z spectra through a suitable plasma model is relevant for international large tokamak devices, viz. ITER, DEMO reactors, etc. [7-8].

In view of this, Extreme Ultraviolet (EUV) spectral diagnostics of highly charged Xe ions have been programmed for the 24th campaign of the Large Helical Device (LHD) at the National Institute for Fusion Science (NIFS) Japan using a suitable Collisional Radiative (CR) plasma model calculation. In the present work, early CR model calculations have been carried out for the Xe^{18+}-Xe^{19+} charge states for the preparation of the LHD experiment and detailed CR model. An impurity seeding experiment was conducted using the Xe gas puff. In the experiment, LHD plasma was ignited using the Electron Cyclotron Heating (ECH) system, while Negative-ion-based Neutral Beam Injection (N-NBI) #1-3 were 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 long (8-26nm) and EUV short (2-9nm) wavelength regions. The detailed spectral analysis of measured Xe-ions will be performed to validate the theoretical collisional data and CR model calculations by comparing the LHD-measured spectra with theoretical synthetic spectra.

The CR model calculation includes various population transfer kinetic processes among the fine structure levels of the considered Xe-ions, such as electron impact excitation and ionization, radiative decay, and their reverse processes. Detailed atomic structure and collision calculations have been 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) [10]. In addition, relativistic multi-configuration Dirac-Hartree-Fock (RMCDHF) calculations will be carried out for the Xe^{18+}-Xe^{19+} charge states using the General Purpose Relativistic Atomic Structure Packages (GRASP2018) to confirm the reliability of the FAC calculations [11]. Further, these calculated data will be incorporated into the CR model to solve the kinetic rate balance equations. Theoretical synthetic spectra will be generated through the population of the considered fine structure levels of the Xe-ions. The comparison of theoretical spectra with the LHD-measured spectra will validate the atomic structure and collision data calculations prominent for spectroscopic diagnostics of future fusion plasma experiments in different tokamak devices. Detailed experimental and theoretical results will be discussed at the conference.

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