2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Electron Impact Excitation of Xe^{+} Ions and Plasma Modeling

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There has been recent interest in carrying out the diagnostics of the inert gas plasma through their ionic lines observed in the emitted spectra. The characterization of plasma i.e. for its diagnostics a collisional-radiative (CR) plasma model is required. The modeling requires large amount of accurate atomic data for the proper inclusion of all relevant processes occurring in the plasma. The dominant processes involved in the plasma are electron impact excitation (EIE). For this purpose, the study of EIE of inert gas ions are needed [1]. The development of suitable CR model is then done by incorporating the calculated fine-structure excitation cross sections for the plasma.

The study of neutral and ionic state of Xenon has important fundamental interest and applications [2]. As xenon is an ideal and preferred propellant for Hall thrusters and ion thrusters due to its relatively low ionization potential. The studies on xenon and its ion have been found to lead several important applications, such as electric propulsion systems, gas discharge lasers and light sources. There are number of reports on the theoretical and experimental electron impact excitation cross sections of neutral xenon atoms and these data have been utilized to characterize various xenon imbedded plasma. However, there are no experimental or theoretical calculations available for the EIE of xenon ions. In fact, it is important to mention here that there are very limited efforts made even for the study of EIE of inert gas ions. Chiu *et al*. [3] recorded the luminescence spectra in a single collision beam experiment where they observed twelve emission lines in the visible spectra coming from Xe and Xe^{+}. In order to explain Xe^{+} ionic lines observed in the spectra coming out from its plasma a collisional–radiative model is needed. Consequently, electron impact excitation cross sections for various atomic states of the Xe^{+} ions are required.

In the present work, the electron impact excitation of Xe^{+} ion has been studied using fully relativistic distorted wave theory from its ground $5p^5$ (J=3/2) state to the different fine structure excited states of $5p^46s$, $5p^46p$, $5p^47s$, $5p^47p$, $5p^45d$ and $5p^46d$ configurations. The relativistic distorted wave (RDW) method is quite successful for the calculation of cross section of inert gas atoms which show in general strong spin-orbit effects. However, for relatively heavier Xe and its ions with atomic number Z=54, the spin-orbit coupling is very dominant. This can be seen through the large fine-structure splitting of the different states of the xenon. In our RDW method, the transition matrix is evaluated using, the initial and final bound states of Xe^{+} wave functions and the projectile electron scattered wave functions obtained from the solutions of relativistic Dirac equations. The bound states of Xe^{+} are represented through multi-configuration Dirac-Fock wave functions and have been calculated by the GRASP2K [4] program while for continuum projectile electron wave functions we solve the Dirac equations numerically. The detailed RDW cross sections are calculated for the electron excitation of Xe^{+} from the ground 5p5 state to various fine structure levels of $5p^46s$, $5p^46p$, $5p^47s$, $5p^47p$, $5p^45d$ and $5p^46d$ excited states in the wide range of incident electron energies up to 500 eV and their corresponding excitation rate coefficients are obtained which are used for the diagnostics of xenon embedded plasma. For the plasma modelling purposes, the analytic fittings to our all calculated fine structure excitation cross sections are also provided. Further, using our calculated magnetic sub-level excitation cross sections for the $5p^46s$, $5p^47s$, $5p^45d$ and $5p^46d$ states, the linear polarizations of the photon emissions from these excited states to the ground state are also reported. All the details of calculations along with the results will be presented in the workshop.

References:

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