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Theoretical study of W^{27+} spectra in EBIT plasma

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Synopsis Corona modeling of spectral lines for the W^{27+} ion is performed. Energy levels and radiative transition probabilities are calculated using GRASP2K and FAC codes. Electron-impact excitation rates are studied in the distorted wave approximation and are taken proportional to the electric dipole line strengths.

Emission of the tungsten ions that penetrate central regions of the fusion plasma leads to undesirable energy losses and has to be controlled for the successful performance of thermonuclear reactors. Transitions from many ions contribute to the line-of-sight measurements in the fusion plasma. The electron beam ion trap (EBIT) devices provide a unique opportunity to study emission mainly from the desirable ionization stage determined by the energy of the electron beam. Such plasma features low density of electrons that leads to the dominant population of the ground and long-lived levels.

The aim of the current work is to investigate the strongest lines of the W^{27+} ion in $2-30$ nm wavelength range using corona model. The excitations from all levels of the ground configuration with subsequent radiative cascades are investigated in this work. The total number of configurations included in the present study amounts to 52, they produce 20861 levels. Energy levels and electric dipole, quadrupole and octupole as well as magnetic dipole and quadrupole transitions are calculated using multiconfiguration Dirac-Hartree-Fock [1] and Dirac-Fock-Slater [2] methods. The electron-impact excitation rates from the levels of the ground configuration are calculated at the electron beam energy of 870 eV and the electron beam density of 10^{12} cm^{-3}. The Gaussian distribution function with a full width at half-maximum of 30 eV is used for the electron energy.

The investigations of the W^{29+} – W^{37+} ions in the EBIT plasma demonstrated that relative line intensities calculated by studying excitations from the corresponding ground levels are in quite good agreement with the data from the collisional-radiative modeling [3]. There the electron-impact excitation rates were considered as being proportional to the electric dipole transition probabilities because the plane-wave Born matrix element transforms to the matrix elements of the electric multipole transition operators with additional factors. Two approaches are used for modeling spectral lines of the W^{27+} ion in this work. In the first one, electron-impact excitation rates are obtained in the distorted wave (DW) approximation. In the second approach, the electric dipole line strengths are used instead of the electron-impact excitation rates because for the collision cross sections within the plane-wave Born approximation the leading term of the first order is proportional to the electric dipole (spin-allowed) transition probabilities divided by the third power of transition energy, i.e., is proportional to the transition line strength.

The intensive emission of the tungsten ions at 5 nm is determined by the $4d^94f^2 + 5d \to 4f$ transitions. Study of configuration interaction strengths reveals that the $4d^{-2}4f^2$ type correlation has the largest impact on these configurations. All corresponding configurations are included in corona modeling of spectral lines.

Large contribution to the spectrum is observed for the transitions from the $4d^94f5p$ and $4d^94f5f$ configurations to the ground one at the shorter wavelength side. The strongest lines in the $10-30$ nm wavelength range are formed by the $5d \to 5p$, $5g \to 5f$, and $4d^94f5p \to 4d^94f5s$ transitions.

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