Analysis of Fe XXI spectral lines measured in LHD plasmas

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Fe ions are one of major impurities in various plasmas and we have been constructing a set of collisional-radiative models for Fe ions in order to use spectral line intensities for plasma diagnostics of laboratory and astrophysical plasmas [1,2,3]. Here we are interested in Fe XXI lines and analyzed extreme ultraviolet (EUV) spectra measured for plasmas in the Large Helical Device (LHD) at National Institute for Fusion Science. Iron pellets were injected to the LHD plasmas and strong Fe emission lines were measured in plasmas of shot numbers 64912 and 64921. We analyzed Fe XXI lines, λ 12.12nm and λ 12.88nm in the EUV spectra.

These lines are transitions between the fine structure levels of the ground state $2s^22p^2$ and excited state $2s2p^3$: $2s^2\ 2p^2\ {}^3P_2$ – $2s2p^3\ {}^3P_2$ (λ 12.12nm) and $2s^2\ 2p^2\ {}^3P_0$ – $2s2p^3\ {}^3D_1$ (λ 12.88nm). The population density of the upper level $2s2p^3\ {}^3P_2$ is affected by the excitation from the $2s^22p^2\ {}^3P_2$ to $2s2p^3\ {}^3P_2$ levels. This causes the electron density dependence of population density of the $2s2p^3\ {}^3P_2$ level and thus the line intensity ratio of this pair can be used for electron density diagnostics. At the same time proton impact excitation processes between the fine structure levels of the ground state $2s^22p^2$ are also important for Fe^{20+} ion [4]. This process also affects the line intensity ratio.

A collisional-radiative model for Fe^{20+} ion includes all fine structure levels up to principal quantum number n=5 and radiative decay, electron-impact excitation/de-excitation, electron-impact ionization, and proton-impact excitation/de-excitation processes are considered for this analysis. Atomic data are calculated by HULLAC code [5]. Transition probabilities of some dipole transitions between n=2 and 3 levels are replaced with data taken from the NIST database [6]. For a comparison, the electron-impact excitation effective collision strengths between n=2 and 3 transitions calculated with an R-matrix method are also used [7]. Recommended data of proton impact excitation rate coefficients [4] are used in the model.

An electron density dependence of the line intensity is seen in the range 10^9 – 10^{15} cm^{-3}. There is not big difference between the line intensity ratios calculated using HULLAC data and R-matrix data at electron temperature around 1keV. The inclusion of proton impact excitation increases the intensity ratio with about 30% at most, when we assume the proton density and temperature are equal to the electron density and temperature. The measured intensity ratios and the model calculations agree well.

[1] N. Yamamoto *et al*., Astrophys. J. **689** (2008) 646.
[2] T. Watanabe *et al*., Astrophys. J. **692** (2009) 1294.
[3] S. A. Sakaue *et al*., submitted to Astrophys. J. (2009).
[4] I. Skobelev *et al*., NIFS-DATA-99 (2007).
[5] A. Bar-Shalon *et al.*, J. Quant. Spect. Rad. Transf. **71** (2001) 179.
[6] Yu. Ralchenko *et al.*, http://physics.nist.gov/asd3 (2008).
[7] N. Badnell *et al.*, J. Phys. B **34** (2001) 5071.