§ 4. Radiation Loss of C and Ne Ions from the LHD and Atomic Data Needed for Plasma Diagnostics

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Time dependent VUV spectra are measured in LHD. The spectra are taken every 100ms with 33ms exposure time. CIII、OVI, H Lyα、NeVII, NeVI、NeV lines are observed.

We have analysed VUV spectra for a NBI heated (#28967) experiment with neon gas puffing which showed radiation collapse and identified the radiation loss impurity ions compared with the radial distribution of bolometer.

CIII line intensity ratios can distinguish ionizing or recombining plasma phases since the intensity ratio of I(117.5nm, $2s2p\ ^3P - 2p^2\ ^3P$)/I(97.7nm, $2s^2\ ^1S - 2s2p\ ^1P$) is smaller than one in ionizing plasma and greater than one in recombining plasma. In this shot we found the plasma is always in ionizing phase and temperature changed as follows; Te ~ 40 eV (t = 0.2 - 0.8sec), Te ~ 40 eV -> 20 eV (t = 0.8 –1.1sec) Te ~ 3 eV(Max radiation, t =1.3sec), Te drops to 2 eV (t = 1.4 - 1.7sec).

We identify 2s - 2p fine structure transition lines from neon L-shell ions as a second order diffraction. Ne VII ($2s2p\ ^3P_J$ - $2p^2\ ^3P_{J'}$, 6 lines), Ne VI ($2s^22p\ ^2P_J$ - $2s2p^2\ ^2P_{J'}$, 3 lines) Ne V ($2s^22p^2\ ^3P_J$ - $2s2p^3\ ^3D_{J'}$, 6 lines), Ne IV($2s^22p^3\ ^4S_J$ - $2s^22p^4\ ^4P_{J'}$, 3 lines). We calculate the intensities of Ne VII, VI lines by our collisional radiative model. Ion density ratios are derived comparing spectra and calculations. We find ion densities of Ne^{6+} about equal to Ne^{5+}

The absolute neon ion density is derived from charge exchange spectroscopy (CXS) at t = 1.0 sec. The neutral hydrogen heating beam has 140 keV energy. The 5249A line (n = 11 – 10) of Ne X is produced by charge transfer. Emission rate coefficient to produce NeX 5249A line by charge exchange is calculated by ADAS code as $<\sigma_{CX}v>$ = 1.0 x 10^{-8} cm^3 s^{-1}. State - selective charge transfer cross sections to high nl states are important to calculate emission rate coefficients. $N(Ne^{10+})$=2.5 x 10^{11} cm^{-3} at center is derived.

We derived absolute time dependent radiation loss from impurities from the absolute value of neon ion density and VUV spectra. Based on the density of Ne^{10+} , other neon ion densities are calculated by MIST code; $N(Ne^{9+})$ = 6.3 x10^{10} cm^{-3}, $N(Ne^{8+})$ = 1.3 x10^{11} cm^{-3}, $N(Ne^{7+})$ = 3.1 x10^{10} cm^{-3}, $N(Ne^{6+})$ = 3.1 x10^{10} cm^{-3}, $N(Ne^{5+})$ = 2.5 x10^{10} cm^{-3} . Radiation loss rate coefficient of neon ions by ADAS code are $R(Ne^{9+}) = 10^{-26}$ W cm^3 at 1 keV, $R(Ne^{8+}) = 10^{-26}$ W cm^3 at 1 keV, $R(Ne^{7+})$ = 5 x10^{-26} W cm^3 at 100 eV, $R(Ne^{6+}) = 10^{-25}$ W cm^3 at 100 eV, $R(Ne^{5+}) = 10^{-25}$ W cm^3 at 100 eV. Assuming $n_e = 10^{13}cm^{-3}$ the radiation loss from neon K-shell ions is 17 KWm^{-3} at 1 keV and neon L-shell ions gives 72 KWm^{-3} at 100 eV.

From the observed intensity of NeVII $2s2p\ ^3P - 2p^2\ ^3P$, the absolute intensities of other ions are estimated. With $N(Ne^{6+})$ = 3 x10^{10} cm^{-3}, n_e = $10^{13}cm^{-3}$ and effective excitation rate coefficients, C_{eff}(561A) = 2 x 10^{-9} and C_{eff}(564A) = 7 x 10^{-10}, absolute intensity I(561A) = 6 x 10^{14} photons cm^{-3} s^{-1} and absolute intensity I(564A) = 2 x 10^{14} photons cm^{-3} s^{-1} are obtained.

From CIII 977.0A $2s^2\ ^1S$ – $2sp^2\ ^1P$ observed intensity, absolute intensity I(CIII 977A) = 4.6 x 10^{14} photons cm^{-3} s^{-1} is derived using the intensity of neon emission lines. With C_{eff}(977A) = 6 x 10^{-8} cm^3 s^{-1} and n_e = $10^{13}cm^{-3}$, density of C^{2+} ions $N(C^{2+})$ = 7.6x10^8 cm^{-3} is obtained. From our collisional radiative model, assuming the ion density from MIST code, the radiation loss from C^{2+} is $L(C^{2+})$ = 0.8KW m^{-3} and radiation loss of carbon L shell ions is 2.3KW m^{-3}. Based on the radiation loss at t = 1 sec, time dependent radiation loss for C^{2+} is derived from time variation of VUV line intensity. From OVI 1031A $2s\ ^2S$ – $2p\ ^2P$ observed intensity at t =1.0s, absolute intensity I(OVI 1031A) = 6.6 x 10^{14} photons cm^{-3} s^{-1} is derived. With C_{eff}(1031A) = 1.3 x 10^{-8} cm^3 s^{-1} and n_e = $10^{13}cm^{-3}$ density of O^{5+} ions $N(O^{5+})$ = 7.7x10^9 cm^{-3} is obtained. Radiation loss 8 KWm^{-3} from O^{5+} is derived. Radiation loss from L-shell is estimated to be 16 KWm^{-3}.

We analyzed impurity spectral emission quantitatively 1) Electron temperature is derived from the intensity ratio of CIII line intensities. 2) Radiation loss sources are identified using spectroscopy and bolometer in the case of radiation collapse caused by neon gas puffing. 3) Time dependent radiation loss of impurity ions are derived from line intensities of impurities. 3) Due to radiation loss by neon L-shell ions, temperature falls from periphery until radiation collapse. 4) After radiation collapse, low charged carbon ions are the dominant source of radiation.

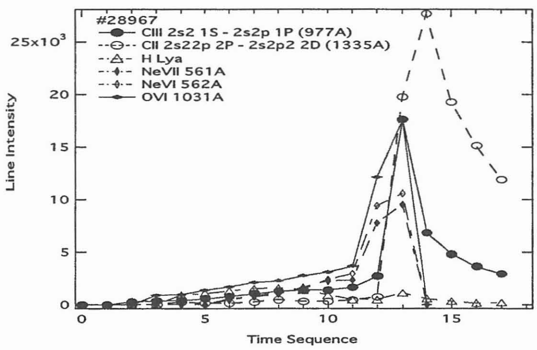

Fig.1 Time dependent observed VUV line intensities.

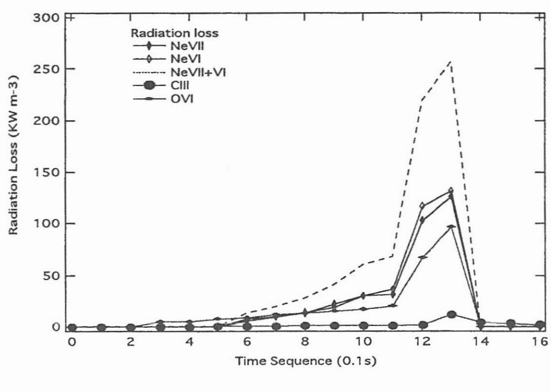

Fig2 Time dependent radiation loss of various ions