§17. Vacuum-ultraviolet Spectroscopy in Detached Plasmas with Neon Gas Seeding in LHD

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Impurity gas seeding is one of the promising scenarios to mitigate divertor heat loads through the enhanced radiation power in edge plasmas. In this context, impurity gas seeding experiments have been extensively performed in LHD to achieve the divertor detachment in the last few years[1]. In addition to nitrogen, neon, and argon gasses, a krypton gas seeding experiment has recently been launched in LHD to explore the possibility of more radiation enhancement from high Z impurity ions. The vacuum ultraviolet (VUV) spectroscopy would be helpful to determine which charge states emit dominantly, where they emit the radiation, and how much they contribute to the total radiated power. In this study, we have carried out VUV spectroscopy in the Ne seeding experiments in LHD to observe temporal evolutions of line intensities of Ne IV–VIII simultaneously.

VUV spectra are observed by a 2 m Schwob-Fraenkel grazing incidence spectrometer[2]. The spectrometer can record spectra in two different spectral bands at the same time. In this study, Ne VI–VIII (n=2-3) lines in 8–12.5 nm and Ne III–VII (n=2-2) lines in 45–60 nm can be monitored simultaneously using a grating with 133.6 g/mm groove density. The integration time of the detector was set at 50 ms, which is enough to follow the temporal evolutions. The line of sight of the spectrometer was fixed at the position passing through the plasma center in this experiment. Spectral lines used for the analyses in this study are listed in Table I.

Figure 1 shows waveforms of various parameters in a typical Ne seeded discharge, together with temporal evolutions of the intensities of Ne IV–VIII lines listed in Table I. After the Ne gas was puffed during 3.7–3.8 s with a flow rate of about 5 Pa m^3/s, the total radiated power (P_{rad}) increased three times or more, then slightly and slowly decreased until the end of the discharge without serious degradation of the stored energy (W_p). The ion saturation current of a divertor probe (I_{is}) clearly dropped after the Ne gas puff as shown in Fig. 1 (c). As is clearly seen in Fig. 1 (d) and (e), temporal evolutions of the line intensities are completely different between higher charged states (Ne VI-VIII; ***a**-**e***) and lower charged states (Ne IV–V; ***f**-**i***). Also, the temporal behaviors of the lower charged states are quite different from that of the increment of P_{rad}. These observations imply that the contributions of Ne IV–V to the total radiated power is less than those of Ne VI–VIII.

Table I: Spectral lines from Ne ions used for the analyses in this study.

	Ion	Transition	Wavelength
a	Ne VIII	$1s^22s\ ^2S$ - $1s^23p\ ^2P^\circ$	8.81 nm
b	Ne VIII	$1s^22p\ ^2P^\circ$ - $1s^23d\ ^2D$	9.83 nm
c	Ne VIII	$1s^22p\ ^2P^\circ$ - $1s^23s\ ^2S$	10.3 nm
d	Ne VII	$2s2p\ ^3P^\circ$ - $2s3d\ ^3D$	10.6 nm
e	Ne VI	$2s^22p\ ^2P^\circ$ - $2s^23d\ ^2D$	12.3 nm
f	Ne IV	$2s^22p^3\ ^2D^\circ$ - $2s2p^4\ ^2D$	47.0 nm
g	Ne V	$2s^22p^2\ ^3P$ - $2s2p^3\ ^3P^\circ$	48.3 nm
h	Ne IV	$2s^22p^3\ ^4S^\circ$ - $2s2p^4\ ^4P$	54.4 nm
i	Ne V	$2s^22p^2\ ^3P$ - $2s2p^3\ ^3D^\circ$	57.2 nm

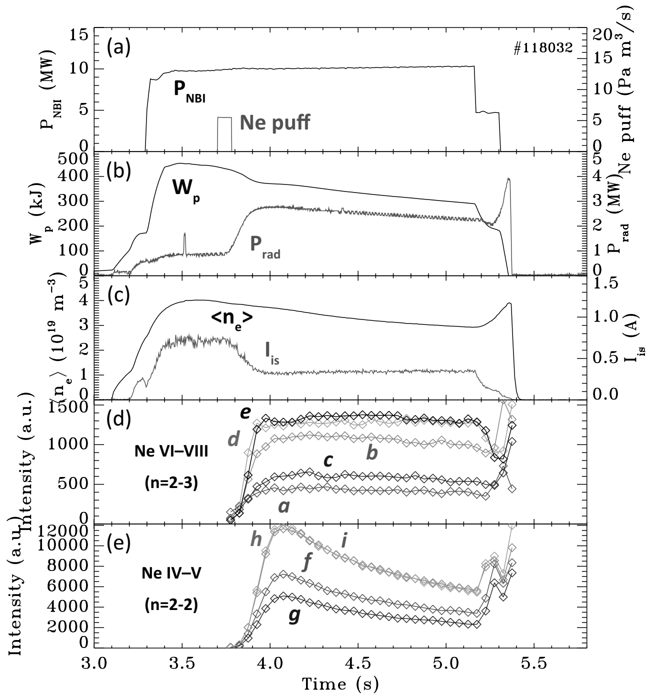

Fig. 1: Waveforms of parameters in a typical Ne seeded discharge together with line intensities of Ne IV–VIII listed in table 1 as ***a**–**i***. Temporal evolutions of (a) total neutral beam heating power (P_{NBI}) and flow rate of Ne gas puff, (b) plasma stored energy (W_p) and total radiated power (P_{rad}), (c) line-averaged electron density ($< n_e >$) and ion saturation current (I_{is}) measured by one of the divertor probes, intensities of spectral lines from (d) Ne VI–VIII, and (e) Ne IV–V.

1) Masuzaki, S. et al.: J. Nucl. Mater. **438** (2013) S133.

2) Schwob, J. L., Wouters, A. W. and Suckewer, S.: Rev. Sci. Instrum. **58** (1987) 1601.