§49. Forbidden M1 Transitions Emitted from Argon Discharges in LHD

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Forbidden lines arising from magnetic dipole (M1) transitions of highly charged ions are useful in spectroscopic studies and plasma diagnostic applications. The M1 transitions of highly charged ions have been studied in many laboratory and space plasmas [1]. The M1 transitions in $2s^2 2p^x$(x=1 to 5) ground and 2s2p excited configurations of highly charged argon have been also identified using electron beam ion trap (EBIT) in visible spectral region [2-3]. However, the study of those transitions in VUV spectral region has not been done so far [4].

Observation of the M1 transitions is generally difficult in high-temperature plasmas, because the M1 transitions are much weaker than allowed transitions. In LHD, pure argon discharges have been created for ion heating experiments. Argon discharges were produced by neutral beam heating with injection power up to 12 MW. The density was initiated by argon gas puff at the beginning of the discharge and maintained during 2-3s with electron densities up to 2×10^{19} m^{-3}. The central electron temperature was very high (4 keV) in the argon discharges. Almost pure argon discharges were performed remaining a small amount of hydrogen. In such discharges visible and VUV emissions from argon ions drastically increased and the M1 transitions were observed for the first time in LHD. The M1 transitions of argon are emitted from the edge plasma, because the ionization potentials in such argon ions are smaller than the central electron temperature. On the other hand, x-ray lines from H- and He-like argon ion have been observed for ion temperature measurement in the central column of LHD plasmas [5].

VUV spectra have been measured using a space-resolved VUV system, consisting of a 3 m normal incidence spectrometer with a 1200 grooves/mm grating, CCD detector and a pair of two focusing mirrors [6]. Visible spectra have been also measured using two 50 cm Czerny-Turner type spectrometers equipped with CCD detectors. Low-resolution 100 and 150 grooves/mm gratings were selected for monitoring a wider spectral band.

Forbidden M1 transitions of Ar ions were successfully detected in such argon discharges. Typical examples of the VUV and visible spectrum are shown in Fig.1 and Fig.2, respectively. Five lines were identified as an M1 transition of ArXII($2s^2 2p^3$: 649.03Å), ArXIV($2s^2 2p$: 4412Å), ArX($2s^2 2p^5$: 5533Å), ArXV(2s2p: 5944Å) and ArXI ($2s^2 2p^4$: 6917Å), by analyzing the Doppler broadening and time behaviors. The visible emissions of the Ar M1 transitions were bright. As a result, the relatively strong M1 emissions enabled us to study the physical mechanism of the M1 transitions. Intensities of the M1 transitions are being calculated using a simple model and some of them are compared with the experimental results.

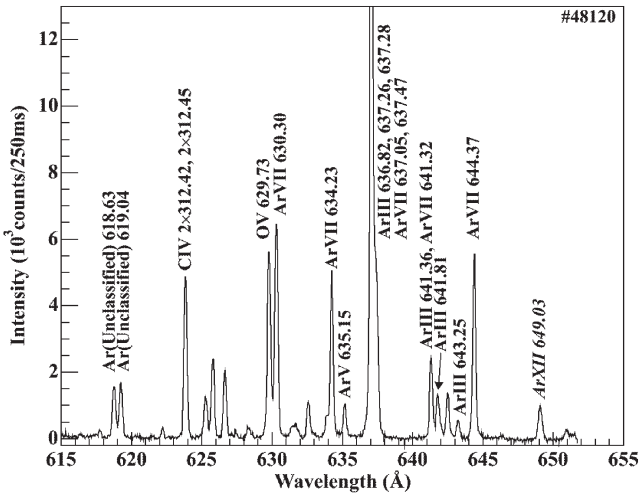

Fig. 1. VUV spectrum obtained from argon plasmas using 3 m normal incidence spectrometer. Italic fonts indicate Ar M1 line.

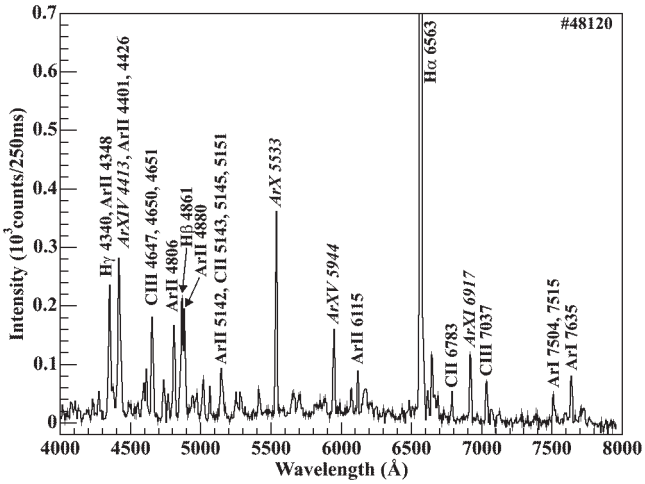

Fig. 2. Visible spectrum obtained from argon plasmas using 50 cm Czerny-Turner type spectrometer. Italic fonts indicate Ar M1 lines.

Reference
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