§68. Fraction of Neutral Beam with Different Energies Measured by the Beam Emission Diagnostic

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Supply of fast ions is a key issue to produce high temperature plasmas for fusion development. Neutral beam injection (NBI) is one of the effective technique to heat fusion particles. We have installed the low-energy NBI system in order to improve the ion temperature in the LHD as shown in Fig. 1. The design of this system requires the 3MW of a hydrogen neutral beam power with two ion sources at the beam energy of 40keV. We have used a positive-ion source because high ion current density is necessary. It is well known that a hydrogen ion source produces H^+, H_2^+ and H_3^+ ions [1]. So the different energy particles such as the full energy of E, the half energy of E/2 and the one thirds energy of E/3 are produced in the neutralizer cell. Increasing of the full energy component of the neutral beam is necessary in order to improve a gross heating power. So the information of relative flux of the fractional-energy is important for improving the beam injection power. The optical system consists of quartz lenses and quartz optical fibers. The optical sight line is arranged along the beam injection axis with the angle of 14.3 degree on the LHD 5-O port. So the beam emission separates from a plasma emission spectrum by the Doppler effect. The intensified charge couple device (ICCD) detector is coupled on the focal plane of the spectrometer.

Figure 2 shows the measured spectrum from the hydrogen discharge with the magnetic field strength of 1.5 T. The spectrum of the Balmar-α from the neutral hydrogen atoms around the low temperature region is observed at 656.3nm. Beam emission spectra are shifted to the red shift side due to the Doppler effect. We have clearly observed the three beam emission components with the energy of 38keV, 19keV and 12.7keV. The Doppler shift values are the consistent of the expected shifts. We have also observed a few impurity spectra near the Hα emission lines, but it dose not have an influence on the beam emission because it is sharp.

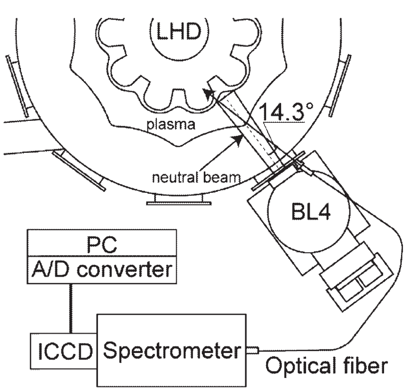

Fig. 1. Schematic diagram of the NBI and the measurement optics.

We estimate the strength of the beam emissions of the different beam energy by integrating of apart of the beam emission spectrum. Figure 3(a) shows the time evolution of $I_{BE}E_{beam}/\sigma_{emi}$ that corresponds to the beam power. Here we use the cross-sections of σ_{emi}=8.39x10^{16}cm^2 for E=12.7keV, σ_{emi}=7.88x10^{16}cm^2 for E=19keV and σ_{emi}=8.23x10^{16}cm^2 for E=38keV. The beam power of full energy beam at t=2.3s is improved from that power at t=0.5s by 3 times. The beam power of full energy beam is 2.7 times larger than that of the half energy beam at t=2.3s. Fraction of the injection beam power of the full energy has been improved to 63% at t=2.3s from 50% at t=0.5s as shown in Fig. 3(b). Intensities of the beam emission of E/2 and E/3 slightly increase, but these fractions decrease against of the total beam power. These results are the net fractions of the injected neutral beam after the neutralization. It is expected that the proton ratio inside of the arc chamber is larger than the fraction of the full energy beam component because of the neutralization efficiency decreases when the beam energy increases. Then the acceleration drain current increases to 126A at t=2.3s from the 92A at t=0.5s with the constant hydrogen feeding due to the increasing of the arc discharge current in the ion source. So injection beam power depends on the fraction of the full-energy beam influenced by an arc discharge condition.

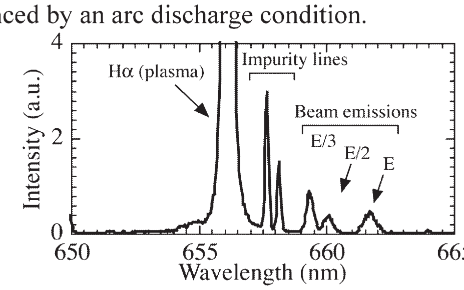

Fig. 2. Hydrogen Balmar-α spectrum of both plasma emission and the beam emission. Beam emission consists of three different energy spectra. Impurity spectra located near the hydrogen spectrum dose not have an influence on the beam emission measurement.

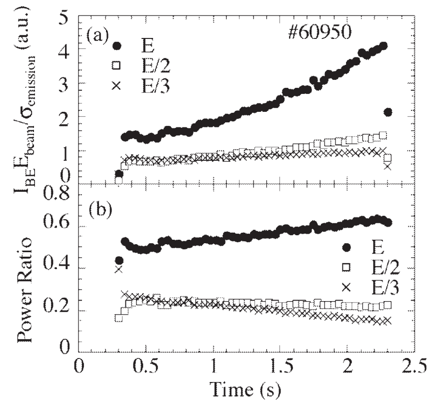

Fig. 3. Time evolutions of $I_{BE}E_{beam}/\sigma^{eff}$ (a) and the ratio of the beam power for each energy beams (b). Beam power of the full energy component large increases. Fraction of the full-energy beam power has been improved at the last of the discharge.

Reference

1) Y. Oka et al., JJAP, **22**, (1983) 688.