(4) High Energy Beam Technology

High energy beams are used in various fields of magnetic field confining nuclear fusion research. Neutral hydrogen/deuterium beam is commonly used for plasma heating, current drive, and diagnostics such as charge exchange recombination spectroscopy (CXS) and beam emission spectroscopy (BES). Heavy Ion Beam Probe (HIBP) is another diagnostic tool using high energy beam. These tools are also used in LHD, and the successive development on the beam formation system or improvement of the diagnostic system is undertaken through the collaborations. Among them, the activities on the development of NBI system are reported here. Those of diagnostics (BES and HIBP) are reported in other category of this annual report.

In LHD, neutral beam injection (NBI) is a main plasma heating source as in other helical devices and tokamaks. NBI is also utilized as plasma production, which is a unique feature of LHD assisted by the fact that the confining magnetic field exists in steady state. The neutral beam is also used for measurement of ion temperature and velocity profiles via CXS, and the induced current can be used to change magnetic field configuration for MHD studies under the week magnetic field strength.

The very specific feature of LHD NBI systems is that three among four beam lines are negative-ion based injection systems. Production of negative ion beam is an advanced technology to make high energy neutral beam (>1MeV) that can be applicable for ITER and future reactors. In LHD, the maximum injection energy of hydrogen beam is 180 keV, which is even too high to construct an injection system based on conventional positive-ion technology because the neutralization efficiency is so small. The negative ion technology is still in the course of development. Therefore, the R&D activity continues in NIFS as well as other institutes such as JAEA, Max-Planck Institute, and Consorzio RFX for JT-60SA and ITER NBI.

The fourth NBI was introduced in 2006 which is a low energy (40keV), positive-ion based hydrogen beam injector for CXRS. The specific feature of this beam line is that the injection angle is normal to the LHD plasma. The choice of beam angle was done judging from the successful results of ICRF, and it is also the case for the normally injected beams.

Here is a report on the status of LHD NBI system, and three report for R&D of ion sources.

The report-1 "Injection Summary of Neutral Beam Injection System in the 12th Campaign" by Takeiri et al. is a summary of the injected beam power of three negative-ion based NBI's (N-NBI) and a positive-ion based NBI in LHD through the 12th experimental campaign in FY 2008. As for N-NBI, the maximum total input power was 16MW, which is the same value as that in the 11th campaign, but high-power injection of more than 14MW is constantly achieved throughout the campaign. As for P-NBI, it was operated reliably at the power of more than 6MW with the energy of 40keV, which has become one of the most important diagnosing tool for the Ti-profile measurement by the CXS method.

The report-2 "Full scale positive helium ion source for alpha particle measurement" by Kobuchi et al. is on the development of high convergence helium ion source for alpha particle diagnostics. The profile of the beam was measured by IR camera seeing a 2-D temperature profile on a carbon plate target. The focusing of the beam was evaluated by the dependence of 1/e-folding-half-width of the beam on the distance from the ion source. The minimum width was obtained at 720 mm downstream from the electrode, which is almost the same as designed value.

The report-3 "Plasma potential simulation for improvement of beam extraction efficiency from a negative ion source" by Matsumoto et al. is to discuss the electrostatic potential effect on the extraction efficiency of negative ions in the arc plasma. A two-dimensional Particle -In-Cell code has been newly developed. It reconstructs the potential profile in the vicinity of the extraction grid, but the absolute value does not match. The improvement of the code is under way.

The report-4 "Characterization of High-Density Helicon Plasma Source with Large Diameter and Short Axial Length for Negative Ion NBI" by Shinohara et al. is on the study of dense plasma production by helicon wave in the cylindrical chamber with the diameter of 40cm changing the axial length. It was confirmed that the high density Ar plasma (~ 10^{13} cm^{-3}) with ~ 2 kW rf power (7MHz) was successfully obtained with the axial length as low as 10 cm, which is favorable for NBI application.

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List of Reports

1. "Injection Summary of Neutral Beam Injection System in the 12th Campaign," Takeiri Y. (NIFS)
2. "Full scale positive helium ion source for alpha particle measurement," Kobuchi T. (Tohoku Univ.)
3. "Plasma potential simulation for improvement of beam extraction efficiency from a negative ion source," Matsumoto Y. (Tokushima Bunri Univ.)
4. "Characterization of High-Density Helicon Plasma Source with Large Diameter and Short Axial Length for Negative Ion NBI," Shinohara S. (Kyushu Univ.)