(4) High Energy Beam Technology

In the nuclear fusion research, high-energy particle beams are widely utilized for plasma heating, plasma diagnostics, and plasma control. Plasma heating and control by injecting high-energy neutral hydrogen/ deuterium beams into the magnetically confined plasma is most prospective to realize the burning fusion plasmas. Therefore, development of the high-energy neutral beam technology is quite important to fusion relevant devices, such as ITER and DEMO, as well as the LHD experiments. Although this kind of high energy beams are also employed for the plasma diagnostics such as charge exchange spectroscopy (CXS) and beam emission spectroscopy (BES), the present beam technology satisfies the requirements for these diagnostics. Heavy-ion beam probe (HIBP), which diagnoses the plasma potential and fluctuation, requires high-energy metal ion beams accelerated to an energy of several MeV with a tandem accelerator, and improvement of a negative metal ion source is carried out in LHD. The HIBP-related technology is reported in other category of this annual report. For the ITER alpha particle diagnostics, intense and high-energy helium negative ions are required, and the beam system for the alpha particle diagnostics is being developed.

The LHD is equipped with neutral beam injection (NBI) system as a main heating system. The LHD-NBI system consists of three negative-ion-based NB injectors and one positive-ion-based NB injector. The negative-NBI, which was operational in FY1998, is characterized by high-energy tangential injection of 180keV, and achieved the specified total injection power of 15MW in FY2007 in the course of development in parallel to the injector operation in the LHD experiments. For further improvement of the performance, investigation of the negative-ion-related physics including the beam physics is carried out. These technology developments of the negative-NBI also contribute to the design and construction of the ITER-NBI system of 1MeV-17MW.

The positive-NBI in LHD, which started its operation in FY2006 as the fourth injector, is characterized by low-energy perpendicular injection of 40keV, and mainly used for the ion heating and the ion temperature measurement with the CXS. The ion temperature is now recorded as 5.6keV by effective ion heating with the positive-NBI. Considering the successful results of ion heating experiments, the additional positive NB injector is now under construction as the fifth injector.

The R&D activities of the negative-ion-related technology are carried out in the NIFS collaboration program for the next-step negative-NBI system as well as the LHD-NBI system. Also, development of the helium beam system and the multiply charged ion production for the future beam-based diagnostics are implemented in the NIFS collaboration program. Here, these activities for the high-energy beam technology are reported.

The report-1 is a summary of the injection performance of the LHD-NBI system throughout the 13th LHD experimental campaign in FY2009. The injection powers of 15MW and 6MW in the negative- and the positive-NB injectors, respectively, were available for the LHD experiments. Especially, the BL1 injector of negative-NBI showed a high availability of high power injection of 6-7 MW, described in the report-2.

The report-3 is on the negative ion density measurement with the cavity ringdown method. The absolute negative ion density was successfully measured, and the correlation with the extracted negative ion current is discussed. The plasma potential effect to the negative ion extraction is discussed in the report-4. The second filament is inserted in the extraction area to control the plasma potential there, and the preliminary results are shown.

The report-5 discusses the multiple beam emittance extracted from strongly focused concave grid system in a positive helium ion source. The helium source was developed for the alpha particle diagnostics, and is a primary beam source for production of the negative helium ions by the double charge exchange. The emittance diagram shows no phase mixing in merging 301 beamlets into a beam.

The report-6 is on production of dense helicon plasmas with a large diameter of 40-74 cm and a short axial length of 5.5 cm for development of an efficient large rf-driven ion source needed in a future NBI system. The report-7 shows development of a compact microwave ion source for multiply charged beams, which is projected to active beam probe systems for the plasma diagnostics.

(Takeiri, Y.)

List of Reports

1. "Injection Performance of Neutral Beam Injection System in the 13th Campaign", Takeiri, Y. (NIFS)
2. "High power and stable injection", Tsumori, K. (NIFS)
3. "Absolute negative ion density measured with Cavity Ringdown Method in Negative-Hydrogen-Ion-Source Plasma", Nakano, H. (NIFS)
4. "Improvement of H^- extraction by adjustment of plasma potential in a H^- source", Matsumoto, Y. (Tokushima Bunri Univ.)
5. "Physics study of strongly-focusing beam emittance by the 3A He^+ ion source", Sasao, M. (Tohoku Univ.)
6. "Development of High-Density Helicon Plasma Source with Large Diameter and Short Axial Length for Negative Ion NBI", Shinohara, S. (Kyushu Univ.)
7. "Extraction of multiply charged ions from a microwave ion source for a beam-probe-system", Wada, M. (Doshisha Univ.)