§6. Researches of Extremely Super-high Speed Neutral Particle Flow Injection by Using CT Injection Technology

Fukumoto, N., Nagata, M., Kikuchi, Y., Liu, D. (Univ. Hyogo),
Takahashi, T. (Gunma Univ.),
Masamune, S., Himura, H., Sanpei, A. (Kyoto Inst. Tech.),
Takahashi, T., Asai, T. (Nihon Univ.),
Hirano, Y. (AIST),
Inomoto, M. (Univ. Tokyo),
Irie, M. (Waseda Univ.),
Miyazawa, J., Yamada, H., Narushima, Y.

A compact toroid (CT) injector of an advance fueller for LHD, SPICA (SPeromak Injector using Conical Accelerator), has been developed. Recently, we have improved the SPICA injector to enhance the performance of CT acceleration and ejection, and attempted production of extremely super-high speed neutral particle flow by using the injector as a new approach to effective fuelling. We aim finally to establish advanced technologies for refueling in large fusion devices. As a realistic target, we have focused on investigation of production of super-high speed neutral particle flow by using the improved SPICA injector. In the experimental scenario, an accelerated CT penetrates into a long drift tube as a neutralizer cell, which is filled with H_2 up to the order of 10^{-2} to 10^{-1} Torr, then super-high speed neutral particle flow is produced through charge-exchange (CX) between CT plasma and neutral gas in the neutralizer cell. The neutral particle flow has a high speed of 300 km/s (equivalent to about 1 keV) and a high density of 10^{21} m^{-3}. Such a neutral particle flow is expected to achieve deeper fuel penetration and higher fueling efficiency than the conventional fuelling methods.

In the preliminary experiments, the performance of CT acceleration has been improved effectively by optimization of the conical accelerator length and CT plasma has been successfully ejected from the M-type SPICA injector (the accelerator length of 1.978 m), resulting in CT transport in long distance. The experimental setup using the M-type injector is shown in Fig. 1. PIN diodes are mounted at 4 P-ports for the observation of CT transit to calculate CT speed. The He-Ne laser interferometer measures the line-averaged electron density of CT plasmas by being moved to each position along the drift tube. The magnetic probe arrays also provide magnetic field profile measurements of the CT. We have observed that the CTs can pass through a 1.8 m drift tube with a density on the order of 10^{21} m^{-3}. In response to the results, we have replaced piezoelectric valves with fast solenoid valves to prevent the adverse effect of surplus gas diffusing from the injector to the neutralizer, and mounted the piezoelectric ones on the vacuum chamber to fill the neutralizer cell with H_2 gas. Then, using the solenoid valves, CT has been successfully generated and accelerated. We have intended to optimize the SPICA for production of fast neutral particle flow.

The neutralization efficiency of CT plasma has been also calculated using the model of the axial NBI in Field Reversed Configuration (FRC), and which is equivalent to the model of CT injection into neutral gas. As a result, although the efficiency due to CX is as low as 40% even for the neutralizer length of 2 m and the pressure of 10^{-1} Torr, the whole efficiency appears to increase owing to enhancement of recombination process in the CT plasma. Furthermore, within the range of SPICA's parameter, the efficiency is found not to depend on the CT speed by comparison between 50 km/s and 300 km/s.

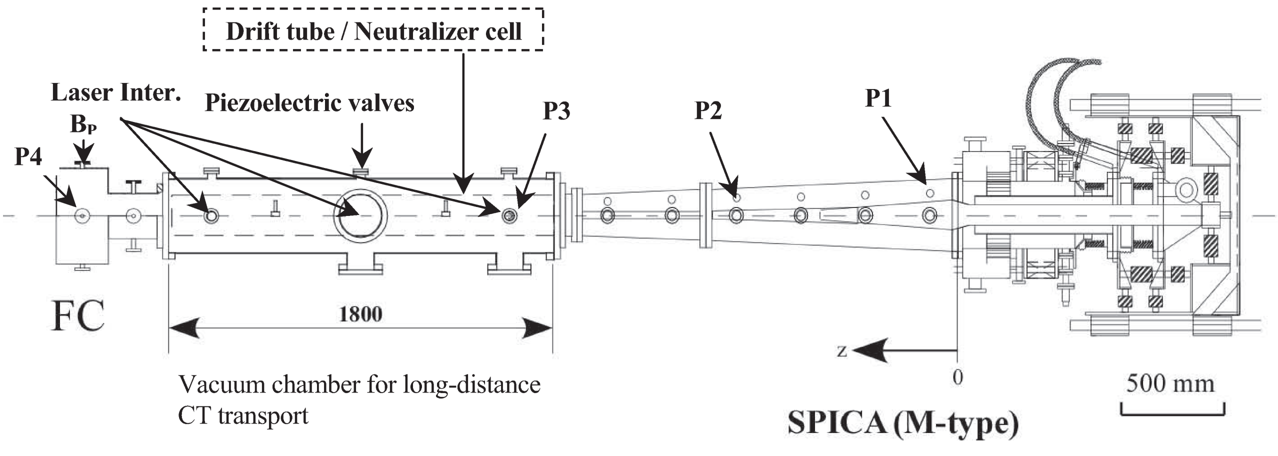

Fig. 1 Experimental setup for CT transport and production of super-high speed neutral particle flow.