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

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Compact Toroid (CT) injection is an advanced fueling method for fusion reactor. Recently, as a new approach to effective fuelling, production and injection of extremely super-high speed neutral particle flow by using a CT injector has been proposed. In a series of research, we have improved and trialed the CT injector of SPICA (SPeromak Injector using Conical Accelerator) to realize injection of CT and super-high speed neutral particle flow on LHD. The main purpose is to establish advanced technologies for refueling in large fusion devices. The realistic target is to efficiently product low energy and high particle flux with a high speed of 300 km/s (equivalent to about 1 keV) and a high density of 10^{21} m^{-3} through charge-exchange (CX) between CT plasma and neutral gas in the neutralizer cell. It is expected that the particle flow injection has deeper penetration ability and higher fuelling efficiency than a super-sonic gas puffing.

In this fiscal year, we attempted to experimentally demonstrate production of super-high speed neutral particle flow by using the improved SPICA injector as shown in Fig.1[1]. In the experimental scenario, SPICA accelerates a CT plasmoid and injects it into a long drift tube as a neutralizer cell (a length of 1.8 m, a volume of 0.055 m^3) filled with H_2, then super-high speed neutral particle flow is produced through CX between CT plasma and neutral gas. In addition, numerical calculations were made to understand the neutralization process and investigate the conditions for high neutralization efficiency at the Gunma University. It was found that the neutralizer cell was required to be at a pressure of 10^{-1} Torr. We thus tested characteristics of piezoelectric valves on the vacuum chamber and fast solenoid ones at CT formation region on SPICA. And then we optimized the trigger timing and the width of a pulse driving a piezoelectric valve in consideration of neutral gas diffusion, leading to the pressure of more than 7×10^{-2} Torr in the neutralizer cell. In the experiment using hydrogen as working gas, however, decrease in both electron density and visible light emission was observed at the measurement point after the neutralizer. As a result, evidence of neutralization was not obtained. The experimental reproducibility got worse with increasing shot number. It would be due to hydrogen adsorption on the inner wall surface of the neutralizer cell and injector. We therefore conducted an experiment using helium. The result was remarkably different from the hydrogen case. PIN diode signals have the same waveform shape from the CT acceleration to the neutralization region. The reproducibility was high owing to less effect of gas adsorption on the wall surface. Evidence of neutralization was, however, not obtained.

We have also conducted basic experiments for production of super-high speed neutral particle flow using a CT injector with a single-stage accelerator at University of Hyogo. The result showed that electron density decreased, obversely, intensity of H_β spectrum increased at the front part of a CT plasmoid penetrating in the neutralizer. This suggests the possibility of production of neutral particle flow corresponding to a calculation result in Fig.2. We will compare this result with that on SPICA to improve the experiment. In a follow-on work, we also intend to make quantitative measurement of neutralization efficiency.

1) D. Liu *et al.*, 14th International Congress on Plasma Physics, Fukuoka, Japan, Sep. 8-12, 2008, BET·P1-203.

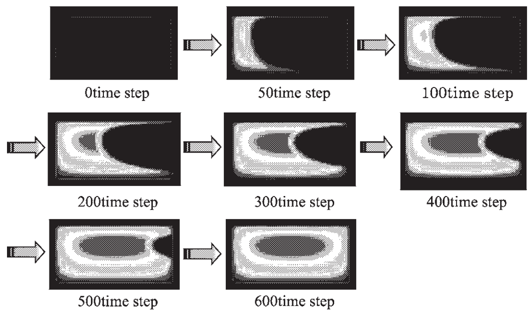

Fig. 2. Time evolution of neutralization of CT plasmoid through charge-exchange process by numerical calculation.

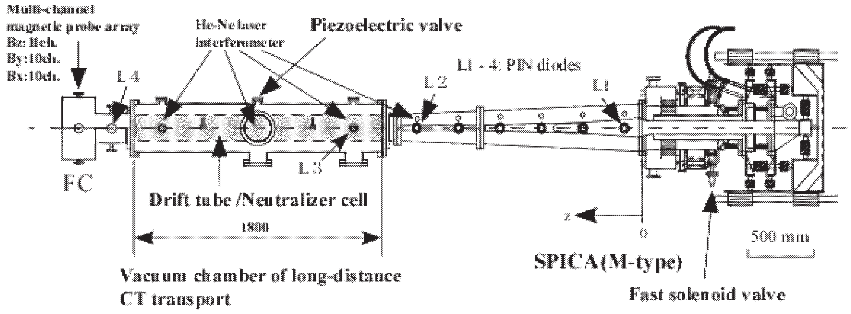

Fig. 1. Experimental setup for CT transport and production of super-high speed neutral particle flow.