§7. Optimization Study of Super-high Speed Neutral Particle Flow Injector for LHD by Using CT Injection Technology

Fukumoto, N., Nagata, M., Kikuchi, Y. (Univ. Hyogo),
Takahashi, T. (Gunma Univ.),
Masamune, S. (Kyoto Inst. Tech.),
Asai, T. (Nihon Univ.),
Miyazawa, J., Goto, M., Yamada, H.

We have developed the Compact toroid (CT) fueler of SPICA (SPheromak Injector using Conical Accelerator) for LHD at NIFS. The performance of CT acceleration and ejection was investigated on the single-stage SPICA with connecting only the acceleration bank unit to both electrodes as shown in fig.1. A CT was accelerated to 76 km/s, and its density was up to 1×10^{22} m^{-3} at the muzzle of the injector. The kinetic energy density of the hydrogen CT was calculated at 34 kJ/m^3, which was an energy density to penetrate into a LHD plasma at a low magnetic field of 0.3 T. Although the energy density is rather low, the density is remarkably high. If the CT plasmoid is completely neutralized, the particle inventory of the neutral particle flow (NPF) is estimated to be 5×10^{20} from the full-width at the base. The value corresponds to a density increment of 2×10^{19} m^{-3} in an LHD plasma at the volume of 30 m^3. Here, considering that the fueling efficiency of 40% in CT injection on JFT-2M, the particle inventory is 2×10^{20}. In the penetration process, the NPF has a kinetic energy of 100 eV and would have a thermal energy of less than 1 eV. Thus the radial diffusion is two orders smaller than the NPF penetration. The speed of NPF is two orders larger than that of supersonic gas jet with a laval nozzle. The NPF injector by using CT injection technique can be useful as a new fueling device.

By using the simple SPICA injector, a CT plasma was injected into the neutralizer cell filled with hydrogen gas at the bank charging voltage of 15 kV. [1)] Figure 2 shows the typical evolution of PIN diode signals and the CT density. Although the electron density at the end region of the neutralizer cell decreased much less than that at the muzzle, the electron density of about 5×10^{20} m^{-3} remained. Both plasma and NPF reached the flux conserver (FC), therefore neutralization of the CT plasmoid was not completed. The spectrum was also measured in the end region of the neutralizer cell. The several Balmar series lines appeared discretely. Result of the rough analysis indicated the visible spectrum would be due to emission from the recombining plasma with an electron temperature of about 0.5 eV.

In addition, a Monte-Carlo simulation has been made to understand the neutralization process and investigate the conditions for high neutralization efficiency at the Gunma University.[2)] As a result, the transit time at a speed of 50 km/s requires 20 μs at a pressure of 5×10^{-4} Torr to complete neutralization of CT plasma. The neutralization efficiency decreases by less than only 10 % even if the speed varies from 50 km/s to 200 km/s. Here, in the experiment, the neutralizer length is 1.8 m. The transit time is 18 μs at a CT speed of 100 km/s. Therefore, a CT plasma ejected from the SPICA can be fully neutralized. However, the complete neutralization was not experimentally obtained. Moreover, a result of spectroscopic measurement indicated that the other reaction process in the neutralization should be considered.

In the follow-on work, we intend to make quantitative measurement of neutralization efficiency, and also compare the experimental result with the calculation included the other reaction process in the neutralization.

1) N. Fukumoto et al., 23rd IAEA FEC, Daejon, Korea, Oct. 10-16, FTP/P1-05 (2010).
2) Fujii, S. et al.: IEEE Trans. Plasma Sci. **38** (2010) 1473.

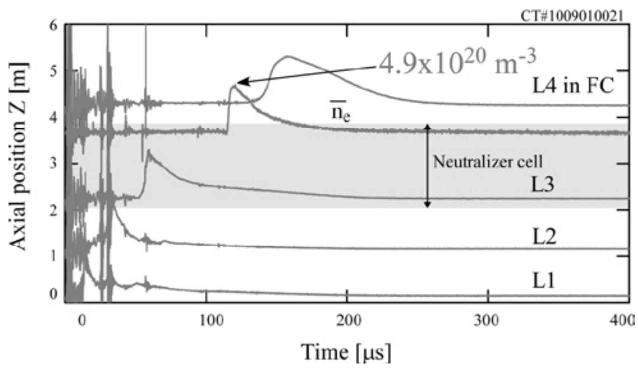

Fig. 2 CT trace on the acceleration region and neutralizer cell filled with hydrogen gas. The vertical offsets are proportional to the axial location of each measurement.

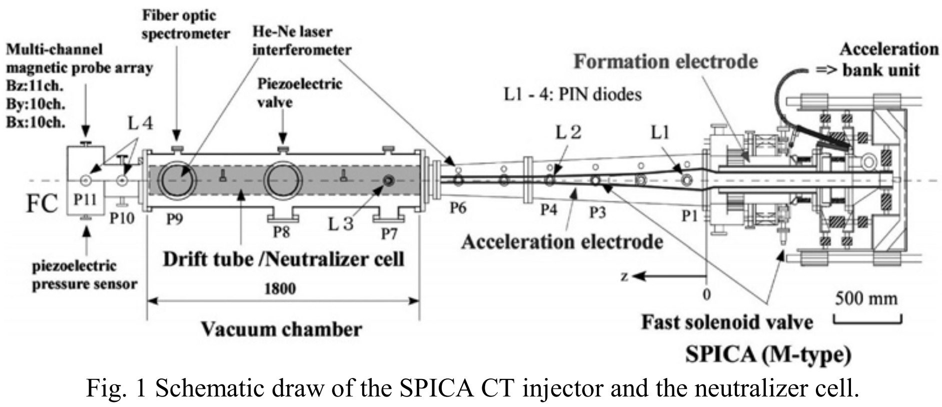

Fig. 1 Schematic draw of the SPICA CT injector and the neutralizer cell.