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Change in parameters of a CT passing through a neutralization cell, and its relation to production of a neutral particle flow
中性粒子化セル中におけるCTパラメータの変化と中性粒子フロー生成との関係

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Recently, in order to apply Compact toroid (CT) injection technique to more effective fueling, production and injection of super-high speed neutral particle flow have been studied. The neutral particle flow injection has a performance advantage over supersonic gas jet and can play a specific role beyond neutral beam injection. We have then proposed a fueling system of CT-based neutral particle flow by using a CT injector. The system may allow us to make various plasma controls.

1. Introduction

We have developed the Compact toroid (CT) injector of SPICA (SPheromak Injector using Conical Accelerator) for furling LHD at NIFS [1]. The CT formation and acceleration performance was investigated on the single-stage SPICA with connecting only the acceleration bank unit to both electrodes as shown in fig.1. SPICA achieved a CT speed of 76 km/s and a density of 1×10^{22} m^{-3} at the muzzle [2]. The kinetic energy density of the hydrogen CT was calculated at 34 kJ/m3, which was an energy density to penetrate into a LHD plasma at a low magnetic field of 0.3 T. The energy density is rather low. However, the density is remarkably high. If the CT plasmoid is completely neutralized, the particle inventory of the neutral particle flow (NPF) is estimated at be 5×10^{20} from the full-width at the base. The inventory corresponds to a density increment of 2×10^{19} m^{-3} in an LHD plasma at the volume of 30 m3. Here, for the same fueling efficiency of 40% as CT injection on JFT-2M, the particle inventory is calculated at 2×10^{20}. In the penetration process, while a kinetic energy of the NPF is 100 eV, a thermal energy would be 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

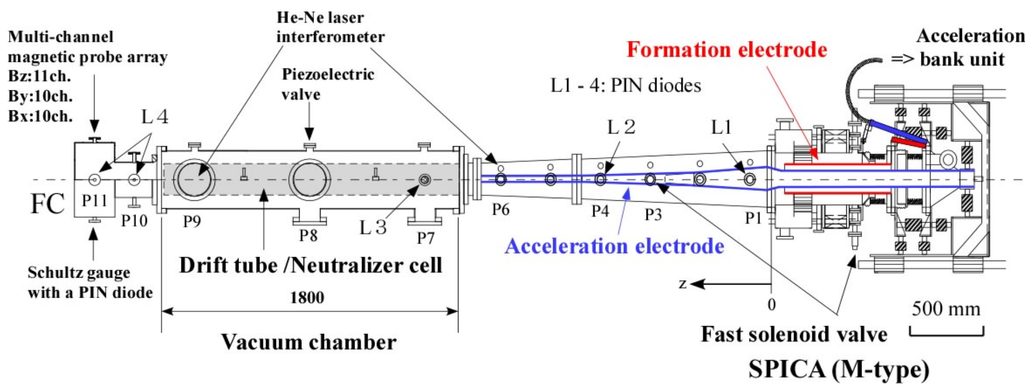

Fig.1. Schematic draw of the SPICA CT injector and the neutralizer cell.

nozzle. The NPF injector by using CT injection technique can be useful as a new fueling device.

2. Experimental Setup

SPICA injector has a single-stage coaxial electrode with connecting only the acceleration bank unit to both inner electrodes (for formation and acceleration) as shown in fig. 1. By using the simple SPICA injector, we started the research on production of super-high speed NPF. The experimental scenario is considered as follows; the single-stage SPICA accelerates a CT plasmoid and injects it into the neutralizer cell filled with hydrogen gas, then super-high speed NPF is produced owing to CX reaction between the CT plasma and the neutral gas on the back ground.

A piezoelectric valve was mounted at the upper port of P8 to puff hydrogen gas into t the neutralizer cell (a length of 1.8 m, a volume of 5.5×10^{-2} m^3). The characteristics were tested, and the trigger timing and the pulse width for driving a piezoelectric valve were optimized in consideration of neutral gas diffusion. The pressure in the neutralizer cell is up to 10^{-2} Torr. We also arranged measurement systems to investigate the performance of the simple SPICA and the production of NPF. PIN diodes (L1-4) were mounted at P1, P4, P7 and P10/P11 for the observation of a CT moving, and a He-Ne laser interferometer was at P6 for CT plasma density at the injector muzzle. Then the interferometer was moved to be set at the side port of P9 for that in the end region of the neutralizer. Recently, a Schultz-Phelps type ion gauge with a PIN diode was also installed at P11 to detect a fast increase in pressure in the flux conserver (FC). The PIN diode monitored emission from a filament of the gauge.

In the operation of SPICA, the charging voltage of the acceleration bank was set at 25 kV for the performance test of the single-stage SPICA and 15 kV for the production test of NPF.

3. Experimental Results

By using the simple SPICA injector, a CT plasma was injected into the neutralizer cell filled with hydrogen gas. Figure 2 shows the typical evolution of PIN diode signals and the CT density. The vertical offsets are proportional to the axial location of each measurement. 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 FC. The complete neutralization was not experimentally obtained yet. The other result also showed that CT plasma was decelerated in the cell filled with hydrogen gas. The partially NPF would separated from the plasma, and then reach the FC earlier than that.

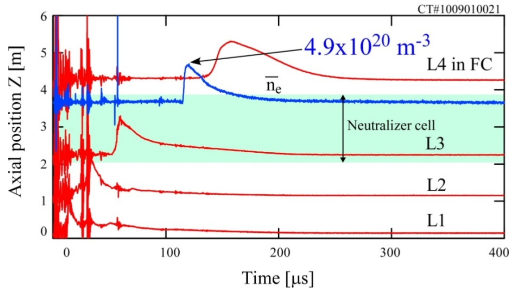

Fig. 2. Typical evolution of PIN diode signals and the CT density along CT's path.

4. Summary

We have conducted the experiment to produce NPF by using the single-stage SPICA. From estimating NPF parameters based on the obtained CT parameter, the performance advantage of NPF injection over supersonic gas jet and neutral beam injection was indicated. However, in the experiment, the complete neutralization was not achieved yet. Thus, in order to understand the neutralization process and investigate the conditions for high neutralization efficiency, we have made measurement of the partially NPF by using Schultz-Phelps type ion gauge with a PIN diode. In addition, Gunma Univ. group has made a Monte-Carlo simulation on the neutralization of CT plasma [3].

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