§7. Design and Assembling of Compact Toroid Injector for LHD

Miyazawa, J., Yasui, K., Kato, S., Yamada, H., Motojima, O., Fukumoto, N., Nagata, M., Uyama, T. (Himeji Inst. of Tech.)

A compact toroid (CT) injector named SPICA mk.I (SPheromak Injector using Conical Accelerator) has been successfully assembled. CT injection is thought to be one of the ultimate fueling method on fusion plasmas as it is capable of center fueling, profile control, and rotation induction. This method utilizes a dense plasmoid formed as a spheromak. Using electro-magnetic scheme, CT is accelerated to several hundreds of km/s of velocity before the injection. A CT should have sufficient kinetic energy $E_{CT} = m_{CT}v_{CT}^2/2$ that is comparable to the magnetic potential energy $V_{CT}B^2/(2\mu_0)$ of the main plasma. Parameters of SPICA mk.I, listed in Table. I, are determined to be sufficient to carry out the CT injection on LHD plasmas confined in the 3T magnetic field.

SPICA is equipped with some characteristic parts that cannot be seen on the other CT injectors, such as;

i) the conical co-axial electrode for CT acceleration,
ii) the expansion chamber for strong differential pumping,
iii) first piezo-valves for gas-puffing,

which are depicted in Fig.2. The conical accelerator is adopted to realize the adiabatic compression. CT compression is a general technique although the other CT injectors use this to increase the CT density, not the electron temperature. A CT injected to a large fusion device such as LHD should have sufficiently long life-time because the time-of-flight in such a case is also long. The CT life-time is largely depends on the electron temperature as it determines the plasma resistivity and magnetic diffusion time. To achieve the long life-time, the electron heating is effective. The most simplest heating method that requires any other devices is the adiabatic heating. Slow compression is necessary to realize the adiabatic condition and therefore, the conical electrode, which compress the CT as slow as the acceleration time, is employed on SPICA mk. I. The expansion chamber is necessary to pump out the neutral gasses that are not ionized in the CT injector. The inflow of neutral gasses into the main plasma is annoying because this makes it difficult to see the fueling effect only by CT. Although this chamber is equipped with a turbo molecular pump of pumping rate 1,000 ℓ/s, inside of this chamber will be Ti coated to realize more large pumping rate of over 20,000 ℓ/s. Use of first piezo-valves, which are the same model as ones already installed and operated on LHD, are also different from the other CT injectors, which adopt the solenoid-valves in general. Stable flow rate and the less mechanical shock are the merits of the piezo-valves compared with the solenoid-valves.

The power supply for CT formation will be installed in this year, and the formation experiment will be carried out after the installation. Before that, the wall conditioning using baking technique and the He glow discharge will carefully and completely be done.

Table I. Design parameters for SPICA mk.I.

CT volume, V_{CT} (m^3)	1×10^{-3} to 5×10^{-3}
CT electron density, n_e (m^{-3})	1×10^{21} to 2×10^{22}
CT mass, m_{CT} (μ g)	2 to 170
Particle inventory, N_{CT}	1×10^{18} to 1×10^{20}
CT magnetic field, B_{CT} (T)	1.0 to 3.0
CT initial velocity, v_0 (km/s)	200 to 500
CT kinetic energy E_{CT} (kJ)	>15
CT electron temperature T_e (eV)	10 to 100
Working gas	H, He, Ne etc.

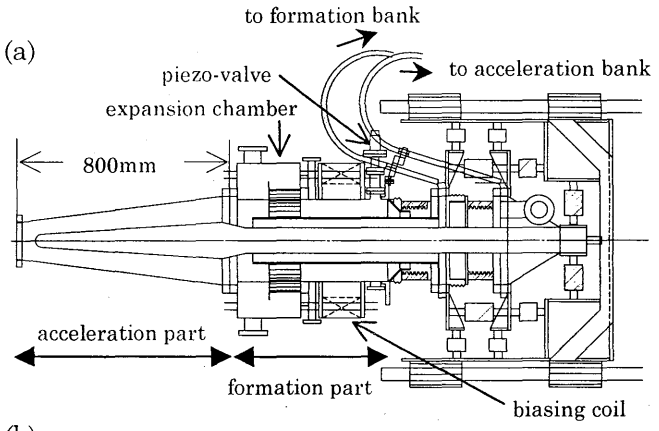

Fig. 2. (a) The schematic of SPICA mk. I, and (b) the photograph from the same view point.