§51. An Advanced Fuelling by Compact Toroid Injection on the QUEST Device

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Compact Toroid (CT) injection experiment has been planned on the new ST device of QUEST (Q-shu University Experiment with Steady-State Spherical Tokamak) to study on advanced fuelling into Spherical Tokamak (ST). In this fiscal year, however, plasma start-up experiments were mainly conducted, and a CT injector has not been installed on QUEST yet. We thus analyzed data from the relevant CT experiments on the Compact Plasma wall interaction experimental Device (CPD) [1-3], and carried out the data calibration experiment.

On CPD the experiments were conducted using a fast camera (HPV-1, 1 μs x 100 frames) and an infrared (IR) camera (TVS-700, 8-14 mm) to investigate CT penetration. The experimental measurement systems are shown in Fig.1. The IR camera is mounted on the window port at the angle-A and B, and the fast camera is at A. These are set on the midplane. 304 stainless steel (SS) plates with thicknesses of 1.4 mm and 0.2 mm are installed at respective positions of R= 230 mm and 450 mm in front of the CT injection port in CPD. The IR camera captures the face of the plate attacked by CTs at R= 230 mm from the angle-A, and the back shot at R= 450 mm from the angle-B. The calorimetric measurement allows us to estimate CT kinetic energy deposited as heat in the plates. However, since 304 SS has a low emissivity and resultant increment in temperature was relatively low, we calibrated the data from the IR camera by comparison to thermistor measurement[1]. As the other setup, trip wires are stretched at R = 280 and 390 mm, and a target plate is put at R= 190 mm. The fast camera captures emission of light due to CT plasma moving across the wires to impact the plate. Analysis of the movies enables us to estimate CT length and speed. In addition parameters before CT ejection out of the injector are monitored at P3 and P4 with magnetic probes and a He-Ne laser interferometer. The parameters can be controlled by varying the voltage for accelerator bank $V_{acc.}$ and that for the bias poloidal coil bank V_{bias}. That for the formation bank $V_{form.}$ is set at 12 kV.

From the IR camera data, CT kinetic energy $E_{CT,cal}$ deposited in the target plate was calculated as shown in Fig.2. Here, CT speed v_{CT} and length L_{CT} were estimated at 67 km/s < v_{CT} < 200 km/s and 0.15 m < L_{CT} < 0.50 m, through analysis of the fast camera movies in the tripwire experiment. For the length and a CT diameter of 0.10 m obtained in the previous experiment, CT kinetic energy density D_{CT} was derived to be 64±23 kJ/m^3 < D_{CT} < 213±77 kJ/m^3 (CT#12284) and 108±18 kJ/m^3 < D_{CT} < 358±58 kJ/m^3 (CT#12287). These agree with D_{CT} = 51 kJ/m^3 (CT#12284) and 157 kJ/m^3 (CT#12287) estimated from CT parameters at the muzzle of the CT injector. Therefore both CT speed and density seem not to decay remarkably after ejection from the CT injector.

In the present work, we successfully estimated kinetic energy of CT traveling in vacuum with the IR and fast cameras. It was found that a CT plasmoid could penetrate in vacuum with its initial kinetic energy. The result provides us useful information to install the CT injector on QUEST and to set up the parameters for successful CT penetration into core plasmas. The CT injector has a sufficient performance to be utilized as a fueller for ST plasmas in QUEST operated at B_T= 0.25 T for a steady-state mode and B_T= 0.5 T for a pulse mode.

1) H. Honma *et al.*, 14th International Congress on Plasma Physics, Fukuoka, Japan, Sep. 8-12, 2008, BET·P1-207.
2) N. Fukumoto *et al.*, 22nd IAEA Fusion Energy Conference, Geneva, Switzerland, Oct. 13-18, 2008, EX/P5-7.
3) R. Bhattacharyay *et al.*, Nucl. Fusion **48**, 105001(2008).

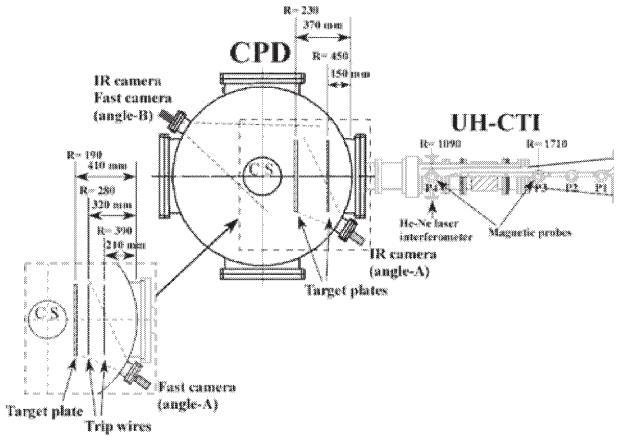

Fig. 1. Measurement systems on CPD and a part of CT injector.

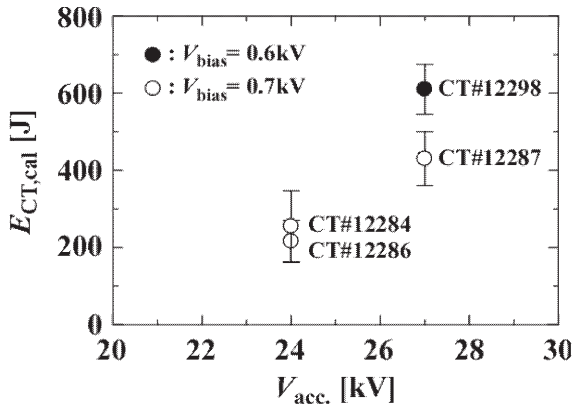

Fig. 2. CT kinetic energy estimated by the calorimetric measurement with an IR camera.