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Plasma response to a compact torus injection in QUEST
QUESTにおけるコンパクトトーラス入射によるプラズマ応答

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Compact toroid (CT) injection is an advanced fueling method for fusion reactors The CT injection experiment has been carried out on the QUEST devise to produce a high dense spherical tokamak (ST) plasma. The UH-CTI injector installed on QUEST has a performance to penetrate a CT plasma into a tokamak plasma at a toroidal field of 1T. By using the injector, CT injection has been successfully conducted in an ohmic heating ST plasma. A density increment due to CT injection has been observed without plasma disruption.

1. Introduction

Compact toroid (CT) injection has been proposed as an advanced fueling method for fusion reactors [1]. In Japan, CT injection experiments had been successfully demonstrated in OH and NBI-heating plasmas on JFT-2M at JAERI (presently JAEA) until FY2003 [2-6]. The CT injector of UH-CTI (the former HIT-CTI) and the related system were moved to the Advanced Fusion Research Center in Kyusyu University in 2005. CT injection was conducted on the CPD devise to study dynamics of CT plasmoid in a vacuum magnetic field. After that, CT injection experiment on QUEST was planned to study on advanced fueling into ST plasmas. The initial test injection was carried out in 2012. The QUEST devise can be operated at B_T= 0.25 T for a steady-state mode and B_T= 0.5 T for a pulse mode. Here, in simple theory, the central penetration of a CT into a ST plasma requires that the kinetic energy density of a CT ($D_{CT,E}$) should exceed the magnetic energy density of the toroidal field W_B= $B_T^2/2\mu_0$ at an ST plasma center. The UH-CTI can inject a CT plasma with $D_{CT,E}$ at B_T= 1 T. The energy density is four times as high as the required $D_{CT,E}$ on QUEST. Thus an injected CT plasmoid can readily penetrate into an ST plasma, resulting in deposition of the fuel particles at the high-field side beyond the magnetic axis. This allows us to optimize particle deposition point corresponding to CT penetration depth by varying CT parameters in order to efficiently increase a ST plasma density. Presently we have performed CT injection experiment to produce a high dense ST plasma on QUEST.

2. Experiment setup

The CT injector is installed on QUEST as shown Fig.1. The injector is set up perpendicularly on the magnetic axis on the midplane, and can inject a CT plasmoid with a high density of the order of 10^{21} m^{-3} at about 200 km/s. The density is measured with a He-Ne interferometer at the muzzle of the injector. The velocity is obtained by the time-of-flight method with magnetic probes on the CT acceleration electrode. On Quest, plasma responses to CT injection are observed typically with a microwave interferometer and spectroscopies. In addition, a trigger system is set up to synchronize the actions of a thomson scattering system developed by the University of Tokyo measurement team and the CT injector. This allows us to investigate changes due to CT injection in electron temperature and density profiles. We have performed the CT injection experiment mainly in OH ST plasmas with RF power (8.2GHz) injection to optimize CT parameters and QUEST conditions for effective and efficient fueling.

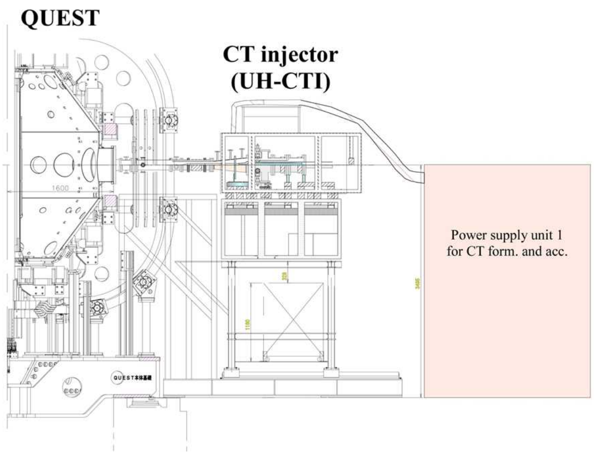

Fig. 1. A schematic drawing of UH-CTI installed on QUEST

3. Experimental results

Plasma responses to a CT injection has been observed in OH ST plasmas with RF power injection. The CT injector is typically operated at V_b= 0.8 kV, V_f= 17 kV, V_a= 25 kV, which are charging voltages of banks for the bias poloidal coil, CT formation and acceleration respectively. In a non-inductive start-up ST plasma (the inboard null configuration) in the previous experiment the plasma current suddenly dropped to be less than 20% after CT injection, whereas in an OH ST plasma the current remains at more than 90%. The difference between the current responses might be due to robustness of ST plasmas to CT injection. In the non-disruptive CT injection, the line-average electron density increases by a factor of 9. Radial density profile change measured by the thomson scattering is shown in Fig.2. The profile becomes more peaked after CT injection. The peak density increases by almost three times. This indicates that a CT plasmoid penetrates into the plasma center, and the particles are deposited in the ST plasma core. The obtained plasma density is, however, less than a predicted one of the order of 10^{19} m^{-3}. In the experiment, an extra drift tube (520 mm in length) is attached between the CT injector and QUEST. The presence of the tube might affect the CT plasma parameters.

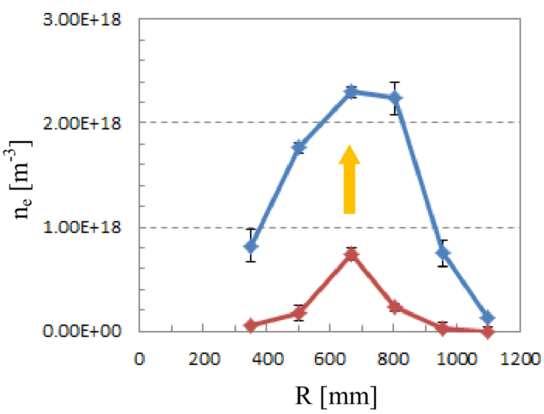

Fig. 2. Electron density profiles. The red line (lower) is the initial profile, and the blue line (upper) is the one after CT injection.

4. Conclusions

CT injection has been successfully conducted in OH ST plasmas on QUEST. As a result, the non-disruptive central fueling has been obtained. We intend to optimize the CT injector settings and parameters for effective fueling in QUEST.

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