1st Asia-Pacific Conference on Plasma Physics, 18-23, 09.2017, Chengdu, China

Present status of current-drive system in QUEST spherical tokamak

T. Onchi[1], H. Idei[1], K. Nakamura[1], M. Hasegawa[1], K. Yamasaki[1], O. Watanabe, K. Mishra[2], K. Kuroda[1], A. Kuzmin[1], H. Ohwada[1], A. Ejiri[3], H. Togashi[3], N. Matsumoto[3] and K. Hanada[1]
[1] RIAM, Kyushu University, Japan, [2] IPR, India, [3] GSFS, University of Tokyo, Japan

In the medium size spherical tokamak QUEST, plasma current can be ramped up solely by electron cyclotron heating (ECH). Steady-state tokamak operation (SSTO) for approximately 2 hours was performed with CW 8.2 GHz Klystrons [1]. In short pulse operations using 28 GHz Gyrotron (270 kW), second harmonic EC wave was injected via multi-wall reflection and plasma current reached $I_p = 66$ kA [2]. Ohmic heating (OH) achieved $I_p >$ 100 kA with high current power supply although electron density is as low as $n_e < 10^{18}$ m^{-3}. For more efficient and effective heating and current-drive, new systems of ECH and OH are under development in QUEST. Co-axial Helicity Injection (CHI) has been also installed recently to start-up plasma current initially.

Present 28 GHz second harmonic ECH system is equipped with two quasi-optical mirrors. EC wave after the wave guide are reflected at the 1st convex mirror. Expanded beam is focused by the 2nd concave mirror in to the resonance position. Size of the focused beam can be about 5 cm diameter. The power density becomes 75 MW/m^2 with 150 kW injection power. A pair of polarizers ($\lambda/4$ and $\lambda/8$) has been also installed so that X-mode can be formed and be injected [3]. In EC current drive experiments with such local second harmonic X-mode injection, plasma current reaches $I_p > 70$ kA with increasing vertical magnetic field in about 1 s discharge, as presented in Fig. 1(a), where electron density in the central region is $n_e > 10^{18}$ m^{-3} [4]. Inboard-limited configuration is formed in such plasma as shown in Fig.1(b). To achieve SSTO following 28 GHz ECH, a new CW-ECH system is under development. Frequency of the Klystron is 8.56 GHz and the maximum injection power can be 250 kW.

Upgrade of OH system is also in progress. A capacitor bank of $C = 55$ mF has been refurbished and reinstalled in the system recently. Tokamak configuration with $I_p > 70$ kA can be obtained more stably owing to the OH system assisted by 28 GHz ECH. As a next step, a unit, consisting of the capacitor bank and two high current power supplies, is designed to drive bipolar primary-current.

Plasma current can be driven by a variety of scenarios with ECH, OH and CHI. A fully non-inductive current drive scenario is applying ECH after CHI. Using 8.56 GHz CW-ECH, SSTO is achievable as long as plasma current is ramped up enough. OH after non-inductive current start-up is also promising. Experiment of electron Bernstein wave would be possible on condition that electron density exceeds the cut-off density and O-X-B mode conversion occurs with 8.56 GHz O-mode injection from low field side. As presented in Fig. 2, higher plasma current than I_p of 100 kA is expected for both short-pulse operation and SSTO in the future scenarios.

References

[1] K. Hanada *et al.*, Proceedings of 26th IAEA Fusion Energy Conference (2016) EX/P4-49
[2] H. Idei *et al.*, Proceedings of 26th IAEA Fusion Energy Conference (2016) EX/P4-50
[3] T.I. Tsujimura et al., Fusion Eng. Des., 114 (2017) 97–101
[4] Y. Takase *et al.*, Proceedings of 26th IAEA Fusion Energy Conference (2016) OV/5-5

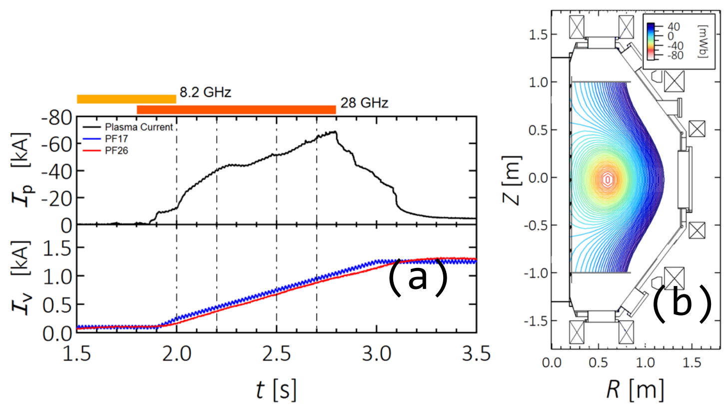

Figure 1 (a) Waveforms of plasma current, I_p, and vertical-field coil currents, I_v. Injected power is 140 kW. (b) Cross-section of magnetic surface at $t = 2.7$ s obtained from an equilibrium reconstruction.

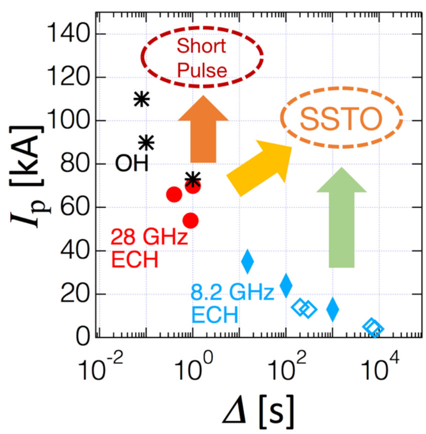

Figure 2 Plasma current versus discharge duration. The plotted data are obtained in the QUEST experiments. Higher current is required for both short-pulse operation and SSTO in the future scenarios