§48. Development of a Long-Pulse NBI System by Repetitive Discharge of Washer Gun

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The long-pulse, low-voltage and high-current neutral beam injector (NBI) was developed using a repetitive discharge of the washer gun for sustainment of ultra-high beta ST experiment [1,2]. The idea of this low-cost and maintenance-free NBI system was obtained by combining the washer-gun plasma source techniques with the electrode design technique and its pulse length can be easily extended by repetitive discharge of the washer gun.
In the fiscal year 2012, we extended the NBI duration time from 0.1ms to 2ms using oscillating discharge of washer gun current.

Figure 1(a) shows the experimental setup of three NBIs installed on the TS-4 device. The maximum NBI power ~ 0.6MW (40A, 15kV) is significantly higher than our initial design value 0.3MW[1] but its power was reduced to 0.4 MW in the 1msec operation as reported in the fiscal year 2011 and further down to 0.3MW in the 2msec operation in 2012. In the present capacitance of the power supply, the duration time of 1.5-2msec is upper limit for the gun current. However, this 2msec pulse NBI maintains the thermal pressure and current density of high-beta ST plasma formed by merging/reconnection.

Figure 2 shows the radial profile of thermal pressure, toroidal current density and loop voltage of spherical tokamak (ST) plasma with and without the NBI. This data were measured directly by the 2D array of magnetic probe. A new finding is that this NBI mainly increases the thermal pressure and current density mainly around 15cm outside of the magnetic axis[1].

As shown in Fig. 3, the fast ion orbit calculation was made using the measured 2D magnetic field profile. It clearly shows that the fast ion orbit is located 10-20cm outside of the magnetic axis but number of fast ions is much lower than the bulk ions. The pulse NBI was bound to improve the stability of high-beta ST significantly, maintaining the thermal and magnetic pressure mainly around 15cm outside of the magnetic axis. This NBI effect was found to increase as the plasma beta of ST plasma was increased by the merging/ reconnection heating. The more detailed mechanism for NBI sustainment of high-beta ST is need more experimental and theoretical investigation.

1) T. Ii, Y. Ono et al., "Development of a low-energy and high-current pulsed neutral beam injector with a washer-gun plasma source for high-beta plasma experiment", RSI 83, 083504, (2012).
2) T. Ii, Y. Ono et al., "Stability and Confinement Improvement of Oblate Field-Reversed Configuration by Neutral Beam Injection", Fusion Energy 2012, ICC/P3-01.

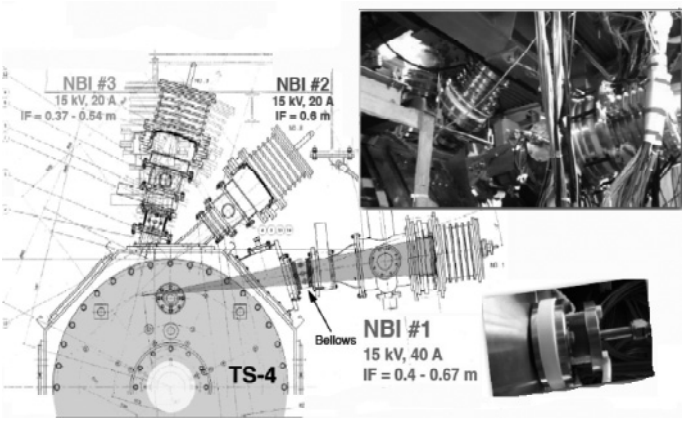

Figure 1: Setup of three new NBI systems for TS-4 CT/ST merging device,

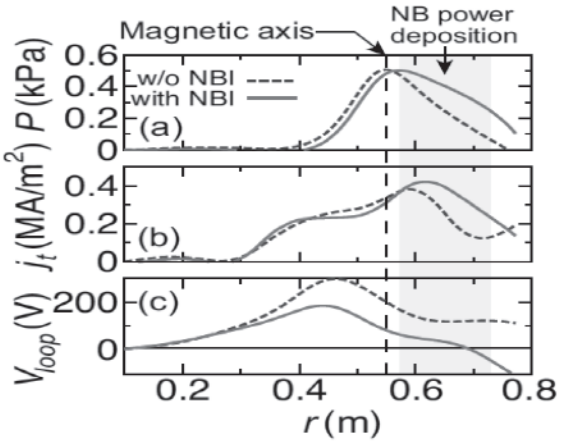

Figure 2: Radial profiles of radial electron density profile of spherical tokamak (ST) with and without the developed NBI.

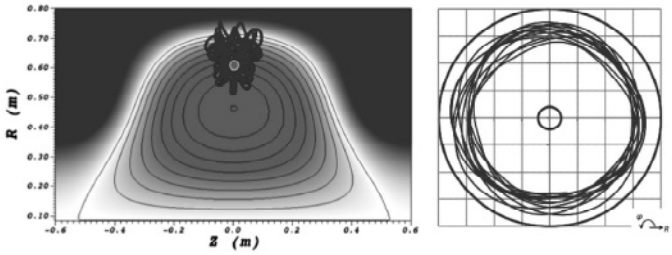

Figure 3: Fast ion orbit calculated from the measured 2D magnetic field profile of high-beta ST with the developed NBI with washer gun.