§28. SuperSonic Gas Puffing Using an Ultra-Long Laval Nozzle

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Since the 17th campaign, an ultra-long Laval nozzle of 2.4 m long has been installed on the 3.5L port of LHD for SuperSonic Gas Puff (SSGP) experiment (Fig. 1). Compared with the longest Laval nozzle of 0.4 m long in the former SSGP system [1], the length of the Laval nozzle has been elongated for 6 times. The main purpose of this ultra-long Laval nozzle is to set the nozzle exit close to the plasma surface and decrease the projection area of supersonic gas flow. Then, local cooling of the peripheral plasma by SSGP will become possible. It will be also beneficial for the Helium Beam Probe (HeBP) experiment [2]. The expansion ratio defined by the ratio of the cross section at the nozzle exit (ϕ = 100 mm) to that at the throat (ϕ = 0.2 mm) is as large as 2×10^5. Theoretically, the Mach number is calculated to be > 30 at the nozzle exit for the case of hydrogen gas. It should be noted, however, that the gas temperature will decrease to ~1/20 at ~10 cm from the throat, *i.e.*, if the hydrogen gas temperature is ~300 K at the throat, then it will become condensed inside the Laval nozzle and presumably form a cluster beam.

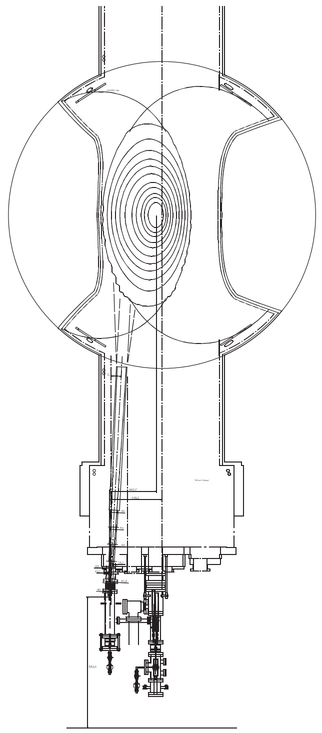

Fig. 1. Schematic view of the ultra-long Laval nozzle of 2.4 m long installed on the 3.5L port of LHD. The nozzle exit is set near the torus. Projections of the supersonic gas flow with the expansion angle of 0 and 5 degrees are also depicted from the nozzle exit to the plasma surface.

In the plasma experiment using the ultra-long Laval nozzle, the toroidal and/or poloidal asymmetry was observed in the ion saturation current, I_{sat}, measured on the divertor tiles at various toroidal/poloidal positions. In the case shown in Fig. 2(a), which was observed in the inward-shifted configuration of R_{ax} = 3.65 m (R_{ax} is the major radius of the magnetic axis in vacuum), I_{sat} measured at the 2I and 8I port rapidly increased after SSGP from the 3.5L port (t = 4.00 – 4.04 s), while those measured at the 6I and 7I ports showed gradual increase. In the outward-shifted configurations of R_{ax} = 3.75 m (Fig. 2(b)) and R_{ax} = 3.90 m (Fig. 2(c)), on the contrary, the rapid increase of I_{sat} was observed at the 6I and 7I ports. Furthermore, I_{sat} continued to increase longer and kept for a while in the outward-shifted configurations. The duration time of the I_{sat} flattop became longer as R_{ax} increased from 3.65 to 3.90 m.

The asymmetry in I_{sat} might be explained by the magnetic field line structure in the peripheral region. However, no working hypothesis for the long I_{sat} flattop observed in the outward-shifted configurations has emerged yet at this moment. Further study on this is desired.

1) A. Murakami, The Graduate University for Advanced Studies, Doctor Thesis (2011).
2) T. Morisaki, et al., Ann. Rep. NIFS (2013) 31.

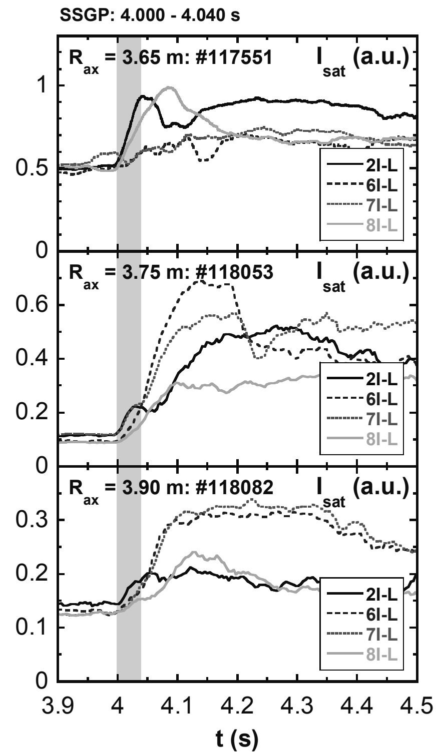

Fig. 2. Waveforms of the ion saturation current, I_{sat}, measured at the left-hand-side divertors (viewing the inboard side from the plasma) in the 2I, 6I, 7I, and 8I ports. Supersonic gas puffing was applied at t = 4.00 – 4.04 s (hatched region) to the plasmas confined in different magnetic configurations of R_{ax} = 3.65 m, 3.75 m, and 3.90 m, from top to bottom, respectively.