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Recombining Plasma Production and Spatial Distribution of Neutrals in DT-ALPHA Device

DT-ALPHA装置における再結合プラズマ生成のための中性粒子分布制御

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Aiming for compatibility of a constant neutral pressure in a plasma production region and a wide range of the pressure in a recombining test region, orifices and a differential pumping port are installed in a radio frequency plasma source, DT-ALPHA. When the pressure at the test region changes from 2.6×10^{-3} Torr to 0.16 Torr, the pressure at the production region is kept within one order of a suitable operation range. The electron temperature at the test region decreases to a few eV as the pressure at the test region increases.

1. Introduction

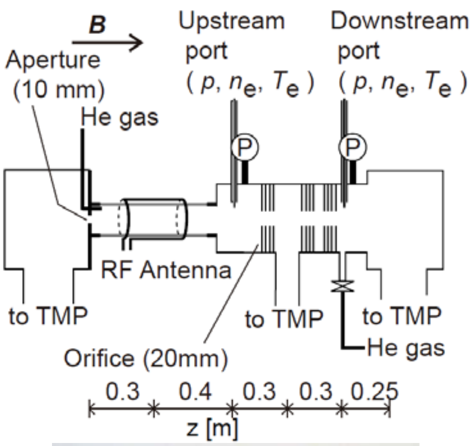
Since the divertor configuration is essential to magnetic confinement fusion reactors, it is necessary to reduce heat and particle fluxes on the divertor plates using the detached plasma operation[1]. In order to study compatibility of the volumetric recombining processes with energetic ions caused by the edge localized modes (ELMs), a divertor simulating experiment has been started using a radio frequency (RF) plasma source and an ion beam[2].

While the RF plasma source has advantages in coexistence with energetic ion beams, it was difficult to sustain suitable working pressure in a plasma production region for a wide range of neutral pressure in a recombining test region. In this article, development of pressure control using orifices is described. Spatial distribution of the neutral pressure is experimentally evaluated and controlled to match with the recombining plasma experiments.

2. Experimental Setup

The experiments were performed in a linear plasma device, originally designed as a ``Diagnostic Tool Assisted by Linear Plasma device for Helium Atom beam (DT-ALPHA)"[3]. A schematic of the experimental setup is shown in Fig. 1. The vacuum chamber consists of a quartz pipe (0.4 m in length, 36 mm in diameter) coupling an antenna to a plasma at z = 0.3 m and a main chamber (1.1 m in length, 63 mm in diameter) made of stainless steel, where z is the distance from an aperture at the entrance of the quartz pipe. Ionization gauges and single/double Langmuir probes are installed at the upstream port (z = 0.7 m) and the downstream port (z = 1.3 m) to measure neutral pressure and electron temperature, respectively. Helium gas is used as a working gas for plasma production and is injected from a tube adjacent to the aperture, while secondary gas for the recombining process study is injected from the downstream port. A converging axial magnetic field up to 0.2 T at the downstream port is applied. A 13.56 MHz RF power supply is used for plasma production. The RF power is about 2 kW.

(a)



(b)

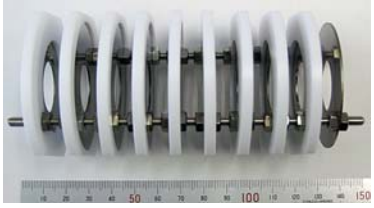


Fig.1. (a) Schematic of the experimental setup and (b) photograph of a set of orifices installed in the DT-ALPHA device.

3. Neutral Pressure Control

In order to suppress pressure variation in the plasma production region due to the secondary gas injection, three set of 10 orifices (z = 0.8-1.2 m) and a differential pumping port (z = 1.0 m) were designed and installed in the DT-ALPHA device. Each set of the orifices, inner diameter of which is 20 mm, reduces a conductance of a 0.15 m length-section of the chamber from 0.4 m^3/s to 0.01 m^3/s in the molecular flow condition.

For plasma production experiments, a pressure variation was investigated. The working gas was injected at a constant flow rate, while the secondary gas injection rate was varied. Relation of the pressure measured at the upstream port and that at the downstream port is shown in Fig. 2. Variation of the upstream pressure, which is an index of the pressure in the plasma production region, is successfully suppressed within one order, while the downstream pressure changes in a more than two-order range.

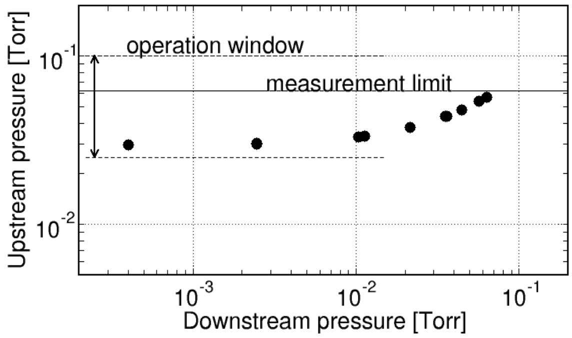


Fig. 2. Upstream pressure as a function of downstream pressure. Filled circle represents experimental results. Dashed lines indicate the operation window suitable for plasma production.

4. Plasma Production with High Pressure Test Region

Plasma parameters were measured for a constant gas injection from the upstream end-plate. Radial profiles of the electron temperature at the upstream port and the downstream port are almost uniform as shown in Fig. 3.

While the pressure at the downstream port changes from 2.6×10^{-3} Torr to 0.16 Torr, the upstream pressure little changes as shown in Fig. 2. The electron temperature at the upstream port is about 5 eV and is almost unchanged against the downstream pressure as shown in Fig. 3(a). On the other hand, the electron temperature at the downstream port [Fig. 3(b)] decreases to a few eV as the pressure increases. The result indicates that the higher collision frequency between the electron and neutrals makes the lower electron temperature.

In plasmas such a few eV of electron temperature, it is expected that the reaction rates of the electron collision excitation and ionization become small comparable with that of the volumetric recombining processes. Spectroscopic studies as well as evaluation of the particle flux along the magnetic field remains our future work.

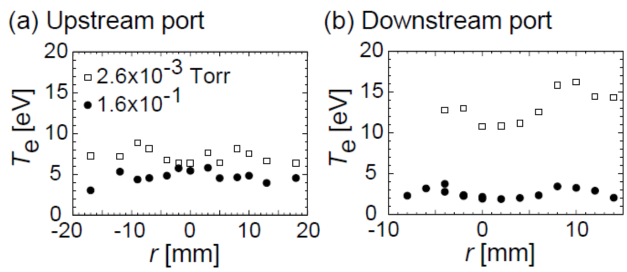


Fig. 3. Spatial distribution of electron temperature for different neutral pressures. Open square represents p = 2.6×10^{-3} Torr at the downstream port; filled circle, 0.16 Torr.

5. Summary

Three set of 10 orifices and a differential pumping system are installed in the DT-ALPHA device. Those enable us to keep the pressure at the plasma production region in a suitable range, when the pressure at the recombining plasma test region changes from 2.6×10^{-3} Torr to 0.16 Torr. The electron temperature at the test region decreases to a few eV as the pressure increasing, while that at the plasma production little changes as the pressure at that region.

Acknowledgments

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References

[1] P. C. Stangeby: *The Plasma Boundary of Magnetic Fusion Devices* (IoP publishing, Bristol, 2000), Chap. 16, p. 483.

[2] A. Okamoto, T. Isono, T. Kobuchi, S. Kitajima, and M. Sasao: J. Plasma Fusion Res. SERIES **8** (2009) 39.

[3] A. Okamoto, T. Isono, T. Nishiuchi, H. Takahashi, S. Kitajima, and M. Sasao: J. Plasma Fusion Res. SERIES **9** (2010) 428.