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Helium Volumetric Recombining Plasma with Pulsed High Energy Ion Flux in the Radio-frequency Plasma Source DT-ALPHA

高周波プラズマ源DT-ALPHAにおける
高エネルギーイオン流束存在下のヘリウム体積再結合プラズマ

Hiroyuki Takahashi, Atsushi Okamoto Takuya Takahashi, Takatsugu Miura, Kenta Aiba and Sumio Kitajima
高橋宏幸, 岡本敦，高橋拓也，三浦隆嗣，相場健太，北島純男

Department of Quantum Science and Energy Engineering, Tohoku University
6-6-01-2, Aza-Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan
東北大学大学院工学研究科量子エネルギー工学専攻 〒980-8579 仙台市青葉区荒巻字青葉6-6-01-2

A divetror simulating experiment was developed. A steady-state helium recombining plasma was produced in a radio-frequency plasma device. Helium energetic ion beam was extracted using a compact miticusp ion source. Penetration of the beam component through the plasma device was confirmed. Target plasma characterization and plasma diagnostics with/without ion flux injection cases were performed with optical emission spectroscopy and Langmuir probe methods. These results offered experiments aiming for divertor plasma study, where energetic helium ion beam is injected into helium recombining plasma.

1. Introduction

Plasma detachment has received considerable attention in the edge plasma study associated with heat and particle load dispersion flowing onto divertor plates. Volumetric recombination in plasma was investigated and characterized using divertor simulating devices because it is expected to have essential role for heat/particle load reduction [1,2]. A scenario for forming helium detached plasma was investigated based on energy balance between electrons, ions and neutral particles [3]. In the next generation fusion devices as ITER, plasma heat flux reduction and high-confinement mode (H-mode) operation are required to achieve simultaneously. Therefore, comprehensive understanding of the divertor plasma dynamics that coexists with transiently inflowing energetic plasma particles and divertor-simulating experiments with large plasma flux, are important subjects in recent divertor plasma study [4-6]. Though it has demonstrated that energetic electrons injected into helium detached plasma enhance ionization processes, the influence that energetic ions bring into divertor plasma remains ambiguous.

We have been developing a divertor simulating experiment with a radio-frequency (RF) plasma source and a compact ion beam source. To investigate the divertor plasma behavior with energetic ions, (1) steady-state helium detached/recombining plasma as a target plasma and (2) energetic helium ion component, are required. In our previous works, helium volumetric recombining plasma production and energetic ion extraction with large beam current were achieved [7,8]. So, in this report, the first results of the helium energetic ion beam injection into helium recombining plasma will be presented and discussed.

2. Experimental setup

Experiments were performed using an RF plasma source DT-ALPHA [9] and a compact multicusp ion source [10]. A schematic of experimental setup is as illustrated in Fig. 1. 13.56 MHz oscillating field supplied through an RF antenna is used for helium ionizing plasma production. A plasma is terminated at the upstream and downstream end-plates. A Faraday cup of 8 mm inner diameter, used for beam measurement, is equipped near the each end-plate. Downstream Faraday cup has three grids and potential of each grid is controlled independently. Gas-puffing system is introduced at the test region (z = 1.58 m) to enhance volumetric recombination. Measurements were performed using optical emission spectroscopy and Langmuir probe both the test region and plasma production region with/without beam injection case.

Energetic helium ion beam was produced using multicusp ion source and extraction components. Plasma is produced by the direct current arc discharge. The beam extraction component consists of acceleration, deceleration, and grounded electrodes. An einzel lens electrode and deflectors are equipped between the ion source and the DT-ALPHA device to optimize beam transport.

During this experiment, the arc current and beam extraction voltage were kept about at 5 A and 12 kV, respectively.

3. Experimental results and discussion

Before superimposing an energetic ion beam onto a helium recombining plasma, energetic beam transport along the DT-ALPHA device was investigated without plasma production. However, axial distribution of neutral pressure and magnetic field were similar as recombining plasma production case. Figure 2 represents a time evolution of (a) upstream Faraday cup current and (b) upstream end-plate current. These were obtained simultaneously. The ion beam was extracted from $t = 0$. At upstream Faraday cup equipped DT-ALPHA device, ion beam of approximately 200 μA was measured. On the other hand, upstream end-plate current was much smaller than that. This indicates that extracted ion beam components well penetrated through the upstream end-plate.

Radial distribution of the target plasma was investigated with spectroscopic method. Figure 3(a) shows the Boltzmann plot using 2^3P-n^3D series (n = 6 ~ 12) measured at z = 1.43 m. n is the principal quantum number. Figure 3(a) indicates that excited atoms over n = 10 are in the local thermal equilibrium with bulk electrons and gives electron temperature T_e ~ 0.05 eV. Figure 3(b) is the radial distribution of emission intensity from 2^3P-10^3D transition. This figure indicates that volumetric recombination is more enhanced at central region of cylindrical plasma than at peripheral region. In the presentation, the effect of energetic ion beam on recombining plasma will be reported and discussed.

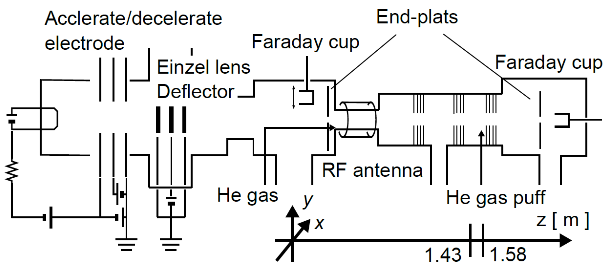

Fig. 1. A schematic of the DT-ALPHA device with multicusp ion source.

4. Summary

Divertor simulating experiment was developed using a compact multicusp ion source and a radio-frequency plasma device DT-ALPHA. Energetic helium ion beam was extracted and injected into DT-ALPHA device. Ion beam current obtained using upstream Faraday cup was approximately 200 μA. In addition, a target plasma was investigated with spectroscopic method for beam injecting experiments. Radial distribution of the Rydberg helium atoms have center-peaked profile. This indicates volumetric recombination is more enhanced at the central region in a plasma. Helium recombining plasma diagnostics were also performed with/without beam injection cases.

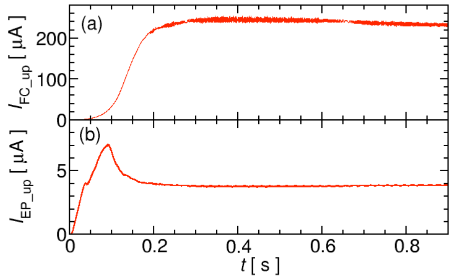

Fig. 2. The time evolution of (a) upstream Faraday cup current, (b) upstream end-plate current.

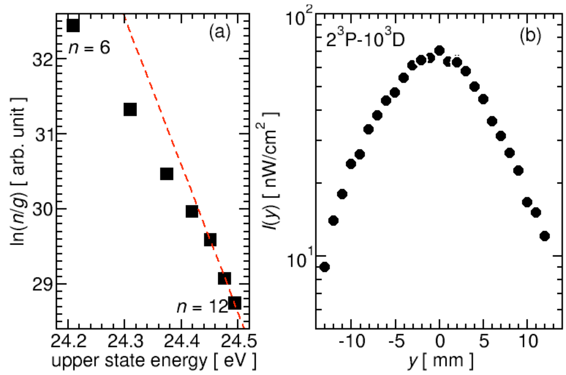

Fig. 3. (a) Boltzmann plot using 2^3P-n^3D transitions and (b) the radial distribution of the emission intensity from 2^3P-10^3D obtained at z = 1.43 m.

Acknowledgments

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