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Effect of additional plasma heating on the heat flux in GAMMA 10/PDX impurity gas injection experiments

GAMMA 10/PDX 不純物ガス入射実験における
プラズマへの追加熱が熱流に与える影響

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This paper presents detailed results of the heat flux measurement with calorimeters in the divertor simulation experimental module (D-module). In this experiment, we injected impurity gases (H_2, Xe) to D-module and produced detached plasma. The detached plasma was observed to make transition to attached phase during applying ECH. We compare the heat flux distribution in D-module between attached and detached states. As the results, the heat flux distribution in detached plasma decreases toward V-shaped target corner. In attached state with ECH, the heat flux increases much more than that in detached state and the heat flux distribution shows a strong peak at middle of the V-shaped target plate.

1. INTRODUCTION

The divertor in future fusion devices is exposed to high heat load of tens MW level in a steady state. It is also exposed to further heat pulse by ELM. Therefore it is necessary to generate and sustain the detached plasma for reducing heat load. In tandem mirror device GAMMA 10/PDX in University of Tsukuba, divertor simulation experiments were conducted for analyzing physical mechanism of detached plasma by use of the high heat flux flowing out of the end-mirror [1-3]. A divertor simulation experimental module (D-module), in which a V-shaped target is mounted, was installed in the west end-cell of GAMMA 10/PDX. In the GAMMA 10/PDX central-cell, plasma with high ion temperature (~10 keV) can be generated with ion cyclotron range of frequency (ICRF) wave [4,5]. High temperature plasma with electron temperature of 100 eV; heat flux of > 10 MW/m^2 was obtained by using electron cyclotron heating (ECH). Therefore we can access in the plasma parameter region that is similar to the SOL region. In this study, we measured the heat flux distribution with/without ECH in the case that H_2 and Xe gases are injected for making the detachment plasma.

2. Experimental setup

GAMMA 10/PDX is a tandem mirror device. Figure 1 shows the schematic view of GAMMA 10/PDX. GAMMA 10/PDX consists of a central-cell with a simple mirror configuration, minimum-B anchor-cells for MHD stability and a plug/barrier-cell for potential confinement. A central-cell is a main plasma confinement region. Hydrogen plasma is initially produced by magneto plasma dynamics (MPD) arc-jet type plasma injections which is installed in both ends of GAMMA 10/PDX [6]. Then the plasma is heated by ICRF and ECH.

In D-module, a V-shaped target plate, made of tungsten, is installed. There are three gas injection ports in D-module. Two are on the target plate; the other is near plasma inlet aperture. In this study, the angle of the target plate is set at 45 degree. H_2 gas is injected from the port of near the inlet aperture and Xe gas is injected from lower target port. On the upper target plate, 13 Langmuir probes are installed to measure electron temperature and density. 13 calorimeters are on the lower target plate to measure the heat flux onto the target plate surface [7]. Calorimeters consist of stainless steel substrates (φ10mm, 0.2mm in thickness) which are connected to thermocouples. The heat flux is evaluated from temperature difference (ΔT) between before and after plasma discharge. Figure 2 is side view of V-shaped target plate and shows the location of calorimeters.

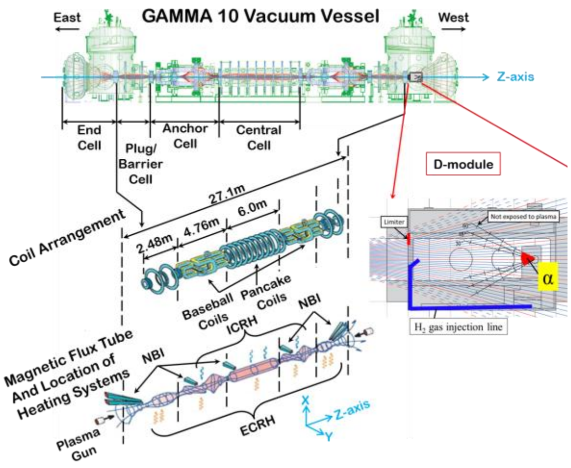

Fig.1. Schematic view of GAMMA 10/PDX and D-module.

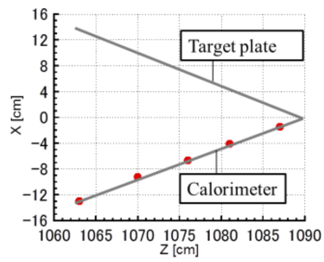

Fig.2. Side view of V-shaped target and the location of calorimeters

3. Results and discussion

In the present experiment, we inject H_2 gas 0.3 s before plasma discharge and Xe gas 0.4 s before that. The duration of gas injection is 0.5 s. The plenum pressure of both gases is 1000 mbar.

Results of the heat flux distribution in both cases are shown in Figure 3 and Figure 4. Figure 3 shows the distribution of the heat flux in the attached state without gases and ECH and the detached state with gases and without ECH. In the detached state, the heat flux decreases toward the corner of V-shaped target. It is because that the heat flux is significantly reduced in penetrating the interaction area between impurity gas and plasma. [7]

Figure 4 shows the distribution of heat flux in the detached state and the attached state with ECH. In the attached state with ECH, the heat flux increases much more than that in the detached state and that in attached state without gases and ECH. This is due to electron heat flux increase by applying ECH. The heat flux at Z=1070 (middle of target plate) is higher than other points. It is suggested that the change of heat flux distribution is due to heating distribution of ECH and plasma-impurity gas interaction in D-module.

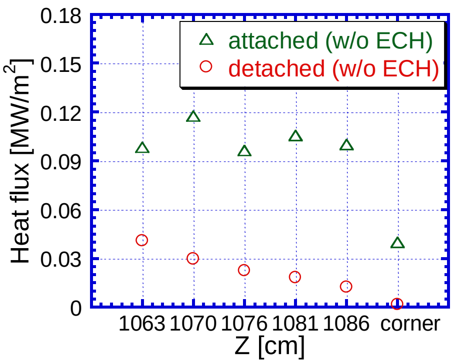

Fig.3. The heat flux distribution in detached state and attached state without gases and ECH.

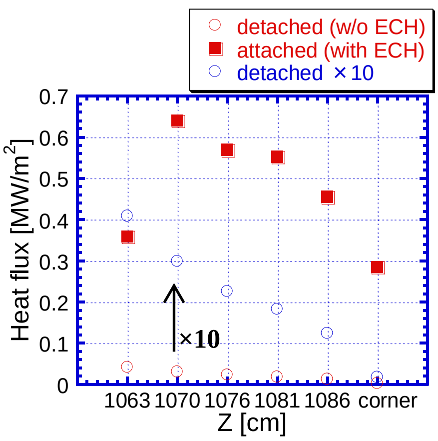

Fig.4. The heat flux distribution in detached state and attached state with ECH

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