24P042-P

Analysis of plasma behavior near the target plate in divertor simulation experiment

ダイバータ模擬実験におけるターゲット板近傍のプラズマ挙動解析

Hisato Takeda[1], Yousuke Nakashima[1], Katsuhiro Hosoi[1], Kazuya Ichimura[1], Tetsuro Furuta[2], Kazuhiko Higashiyama[2], Mitunori Toma[2], Akiyoshi Hatayama[2], Takashi Ishii[1], Hedeaki Ueda[1], Shigehito Takahashi[1], Satoshi Kigure[1], Satoru Hotaka[1], Makoto Icnimura[1], Masashi Yoshikawa[1], Jyunko Kohagura[1], Mizuki Sakamoto[1] and Tuyoshi Imai[1]

武田寿人[1]，中嶋洋輔[1]，細井克宏[1]，市村和也[1]， 古田哲朗[2]， 藤間光徳[2]， 畑山明聖[2]， 石井貴[1]， 上田英明[1]， 高橋樹仁[1]， 木暮 諭[1]， 保高 暁[1]， 市村 真[1]， 吉川正志[1]， 小波蔵純子[1]， 坂本瑞樹[1]， 今井 剛[1]

[1]*Plasma Research Center, University of Tsukuba,*
3-1-1, Tennoudai, Tsukuba 305-8577, Japan
プラズマ研究センター 〒305-8577 つくば市天王台3-1-1

[2]Science and Technology, Keio University,
3-14-1, Hiyoshi, Minatokitaku, Yokohama 223-8522, Japan
慶応義塾大学大学院理工学研究科 〒223-8577 横浜市港北区日吉3-14-1

Recently, divertor simulation study was planed using GAMMA 10 tandem mirror device. For organizing this research, end-loss plasma which is to be irradiated on to target materials has been investigated. As the result, end-loss plasma in GAMMA 10 has high ion-temperature that is much higher than electron temperature and is easily controlled. These characteristics do not exist other divertor simulation devices. In the case of only ion cyclotron resonance heating, heat-flux has strong dependence on diamagnetism which is time integrated in central-cell. While, particle-flux is proportional to electron line-density in central-cell. Development of numerical code describing background plasma has been started.

1. Introduction

In the International Thermonuclear Experiment Reactor and Demo reactor for future nuclear fusion power generation, heat-load of plasma particles led to divetor plate approaches tens of MW/m^2 on steady-state operation. In addition it reaches several GW/m^2 when ELM occurs. Therefore, it is important to develop materials which withstand the level of high heat-load from the divertor plasma. For solving this problem, it is needed to find out the physical mechanism to keep detaching divertor plate from the plasma influx steady. The divetor simulation experiments are widely performed by using linear devices because magnetic fields in liner devices are similar to magnetic field in actual fusion devices.

In GAMMA 10 tandem mirror, divertor simulation experiments were planed and started [1-3]. In the present experiments, characteristics of end-loss plasma in GAMMA 10 were measured.

2. Experimental device

GAMMA 10 consists of central-cell, two anchor-cells two plug/barrier-cells and two end-cells. Plasma heating systems which are ion cyclotron resonance heating (ICRF), neutral beam injection (NBI) and electron cyclotron heating (ECH) are installed for plasma production/heating and confinement. By applying ICRF in the central-cell and anchor-cells, end-loss can be generated with much higher ion temperature than electron temperature. In this plasma state, contribution of ion dominates the heat-flux density. In the case of superimposing ECH in plug/barrier-cell on ICRF-produced plasmas, on the other hand, the effects of electron become significant.

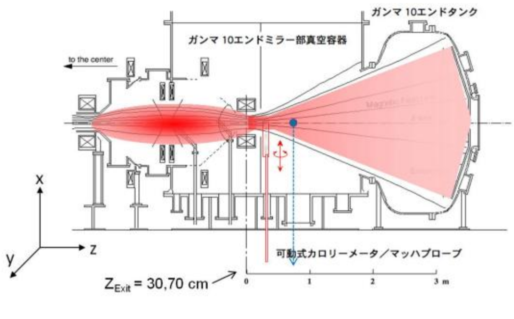

Fig.1. Schematic view of the west end-cell in GAMMA 10

In this divetor simulation experiments, directional probes and calorimeters are inserted near the exit of the end-mirror coil in the west End-Cell (z = 30, 70 cm). By using these diagnostic tolls, axial and radial profiles of particle-flux and heat-flux of end-loss plasma are measured.

3. Experimental results

In GAMMA 10, main plasma is produced at the central-cell and then leeks toward both end-cells through coulomb collision. Therefore, it is important that investigate the relationship between main plasma parameter of the central-cell and heat and particle flux at the end-cell. In the case of heat-flux, the result is shown in Fig.2. Heat flux depends on the time integral diamagnetism in central cell. On the other hand, results of particle flux are shown in Fig.3. Particle-flux is proportional to electron line-density in the central cell.

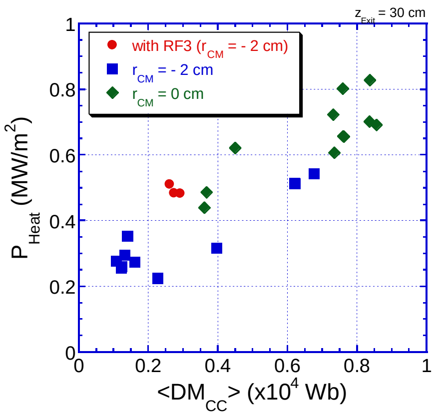

Fig.2. Heat-flux dependence on diamagnetism in the central cell

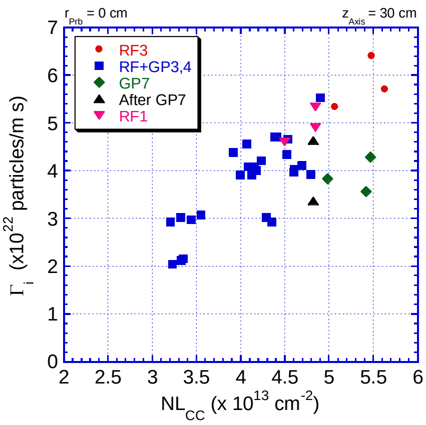

Fig.3. Particle-flux dependence on electron line density in the central cell

4. Numerical Code

Numerical simulation study is also important to understanding the behavior of background plasma in actual divertor environment. In an collaboration between Tsukuba and Keio universities, the numerical code is remodeled in simplification of B2 code [4]. A new code is modified to apply the GAMMA 10 end-mirror region. This numerical code is two-dimensional fluid code and utilizes finite volume method. Equations in this code are continuity equation, momentum balance equation, diffusion equation, electron energy balance equation and ion energy equation as follows,

$$\frac{\partial n}{\partial t} + \nabla \cdot \left(n\vec{u} \right) = S_n \quad (1)$$

$$\frac{\partial}{\partial t}(mnu) + \nabla \cdot \left(nmu_{//}\vec{u} \right) - \vec{\eta} \cdot \nabla u_{//} = -\nabla p + S_{mu} \quad (2)$$

$$v = -D_n \frac{\partial}{\partial y}(\ln n) \quad (3)$$

$$\frac{\partial}{\partial t}\left(\frac{3}{2} n_e T_e \right) + \nabla \cdot \left[\left(\frac{5}{2} n\vec{u} T_e - \kappa^e \nabla T_e \right) \right] = \overrightarrow{u_e} \cdot \nabla p_e - k\left(T_e - T_i \right) + S_E^e \quad (4)$$

$$\frac{\partial}{\partial t}\left(\frac{3}{2} n_i T_i + \frac{1}{2} nmu_{//}^2 \right) + \nabla \cdot \left[\left(\frac{5}{2} n\vec{u} T_i + \frac{1}{2} mn\vec{u} u_{//}^2 \right) - \nabla \left(\kappa^i T_i + \frac{1}{2} \eta u_{//}^2 \right) \right] = -\vec{u}_e \cdot \nabla p_e + k\left(T_e - T_i \right) + S_E^i \quad (5)$$

The mesh structure of the magnetic field of GAMMA 10 end-cell is shown in Fig. 4.

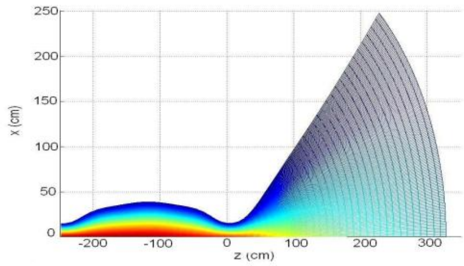

Fig.4. Example of the mesh structure of the magnetic fields in GAMMA 10 end-cell.

5. Summary

Heat and particle flux of end-loss plasma are influenced strongly by the central-cell plasma parameter. Especially, it is founds that the increase with the central-cell diamagnetism and that the particle-flux is proportional to the central-cell electron line density. Numerical simulation which evaluates the background plasma parameter has been started.

References

[1] Y. Nakashima, et al. Fusion Eng. Design 85 issue 6, Nov. (2010) 956-962.

[2] Y. Nakashima, et al. Fusion Sci. Technol. 59 No.1T (2011) 61-66.

[3] Y. Nakashima, et al. 23rd IAEA Fusion Energy Conference (October 11-16, 2010, Daejeon, Korea) IAEA-CN-180 FTP/P1-33.

[4] B.J. Braams, NET Rep. 68 EURFU/X Ⅱ 80/87/68, CEC, Brussels (1987).