§1. Studies of the Plasma Transport Control Physics and the Divertor-simulating Boundary Plasma in making use of Open End Magnetic Field and Effects of Potential and Radial Structure of Electric Fields

Imai, T., GAMMA 10 Group (Univ. Tsukuba)

The control of both core and edge plasma transport is a key to achieve both good confinement and practical wall heat load on the fusion reactor. Since the electric field structure/profile affects the plasma flow, studies of effects of radial electric field structure on the core and edge transport are crucial issues for fusion plasma researches. The GAMMA 10 is the world largest tandem mirror, and the plasma confinement is achieved by a magnetic mirror configuration as well as positive and negative potentials at the plug/barrier region by electron cyclotron heating (ECH). Mirror devices having open magnetic-field lines provide advantages for the control of radial and axial potential structures through the modification of axial particle-loss balance by end-plate biasing and/or by ECH. Moreover, it also resembles the Scrap Off Layer (SOL) plasma configuration of torus systems, Therefore, mirror-based systems enable both core and edge plasma experimental studies with these noticeable characteristics. In addition to these main subjects of the GAMMA 10, the development of high power gyrotron for the ECH, main tool for these experiment, is the big theme, too. The main plasma confined in the central cell of GAMMA 10 is produced and heated by ion cyclotron range of frequency (ICRF) waves. The typical electron density, electron and ion temperatures are about 2×10^{18} m^{-3}, 0.1 keV and 5 keV, respectively.

In the first medium term plan, the intensive studies of correlations between the radial electric field, drift type fluctuations and radial transport.[1)] The parameter dependences of those had been investigated. It is clearly seen that the potential profile changes from concave shape without Plug (P)-ECH to the convex one with P-ECH, namely, and successive suppression of the fluctuations and hence the radial transport were observed.[2)] But it is not clear which is essential for these phenomena, radial electric field, its shear or the other field structure. To see these in details, multi-channel detector of the Gold Neutral Beam Probe (GNBP) has been developed, which determines the radial electric field accurately with simultaneous measurements of two radial point potentials. The preliminary results of the multi-channel detector measurements are shown in Fig. 1. It is clearly seen the radial electric field profile increases with the application of the P-ECH and it changes from negative to positive in the region of r < 6 cm and its profile largely changes. using this powerful tool, detailed studies of the radial plasma transport will be done soon.

The Thomson scattering system using YAG Laser has been improved. Since it is difficult to get good S/N ratio because of the low density, new thick fiber and noise reduction system have been installed. They were very successful and we can measure the T_e less than 100eV.

For the divertor plasma simulating experiments, the west end section of the GAMMA 10 has been modified to install divertor test plate, calorimetric and directional probes, and observing port. The port enables the imaging diagnostics with fast camera and spectroscopic measurements. The preliminary observations of divertor test plates of C, SUS and W showed the clear difference of the recycling of these materials. The heat flux density dependence on the P-ECH power at the mirror throat is shown in Fig. 2. The heat flux density of 9 MW/m^2 has been obtained and it is seen that more than 10 MW/m^2 is possible with our available ECH power of 400 kW.[3, 4)]

The gyrotron for heating and the potential control tool progressed largely. In the over-1 MW development program, we do collaborate strongly with NIFS. In the 77GHz tube for LHD, the 3rd tube has achieved 1.8 MW power for 1 sec, which is the world record of long pulse gyrotron output. The CW operation of 0.3 MW has been also achieved[5)]. In the development of 1MW-28 GHz gyrotron for GAMMA 10, the 1 MW has been demonstrated in short pulse and long pulse operation of 0.4 MW x 1sec has been obtained.[5)]

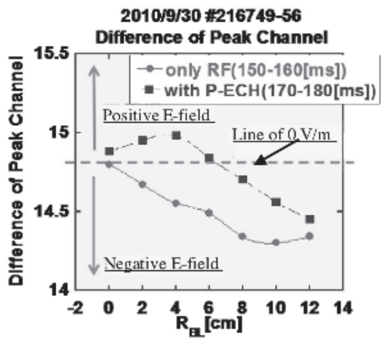

FIG. 1 The preliminary results of the radial profile of the radial electric field with and without P-ECRH

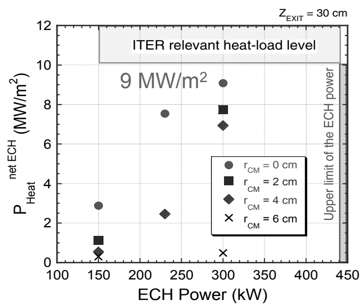

FIG. 2 The dependence of heat flux density near the mirror throat on the ECRH power.

1) M. Yoshikawa, et. al ., Trans. of Fusion Sci. and Tech. **55**, 2T, 19 (2009).
2) M. Yoshikawa, et al., Fusion Sci.&Tech. 57 (2010) 312.
3) T. Imai, et al.,. Trans. of Fusion Sci. and Tech. **59**, 1T, (2011) 1-8.
4) Y. Nakashima, et al.,. IAEA-CN-165/FTP/P1-33 (2010).
5) T. Imai, et al.,. IAEA-CN-165/FTP/P6-12 (2010).