21PA-010

Relaxation of Space Potential and Generation of Toroidal Flow by Applied Vertical Magnetic Field in Toroidal ECR Plasmas
垂直磁場印加によるトロイダルECRプラズマの空間電位の緩和とトロイダル流の発生

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In toroidal ECR plasmas the charge separation current is caused by the vertical drift of the electrons and the ions due to toroidal field gradient and curvature. The current circulates via return circuits of the vacuum vessel or helical field lines (when a vertical field applied). When no vertical field applied, a large potential hill forms to regulate electron and ion flows. When a vertical field applied, a toroidal plasma current which is the return current along helical field lines flows and the potential hill which regulate the flows relaxes significantly. As the vertical field increases, the profiles of electron density and temperature and space potential changes with poloidal field due to the increasing toroidal plasma current.

The electron cyclotron resonance (ECR) heating is a useful method to assist the start-up of toroidal plasma current in tokamak plasmas. In the Low Aspect ratio Torus Experiment (LATE) device a non-inductive toroidal plasma current had been generated and a closed magnetic surface had formed when a week vertical field was applied in addition to the toroidal field. Here, we have investigated detail formation processes of the plasmas.

In the ECR plasmas the electrons and ions drift vertically in the opposite direction due to the field gradient and curvature, generating a charge separation current.

When no vertical field is applied, the current almost flows in the only vertical direction. The electron pressure would form uniformly in the vertical direction and a vertically uniform charge separation current flows and circulates via vacuum vessel. In the LATE device experiment we had found that the simple toroidal plasma is maintained by forming a potential hill shifted to the ion drift side. The electron and ion flows are regulated by E ×B drift along equipotential contours of the hill and vertically uniform electron pressure forms. In the ion drift side the slow ion flow is accelerated by steep potential down slope toward the wall and balanced to the electron flow toward the opposite wall [see 21PA-014].

When a vertical field is applied the plasmas are more complicated. Portion of the charge separation current returns through helical field lines which connect top and bottom parts of the plasma and a toroidal plasma current flows. As the current increases, a closed magnetic surface forms by the self field.

In this study we has investigated the changes of plasma profiles and the charge separation current as the troidal plasma current increases in order to understand the forming process of the closed magnetic surface .

Figures 1-3 show the results when hydrogen plasmas are produced by 2.45GHz microwaves at P_{inj}=1.5kW with the vertical field Bv = 0～5G and at P_{inj}=2.0kW with Bv=10G. Figure 1 shows CCD plasma images and profiles of the electron pressure (pe) and space potential (Vs). Figure 2 shows radial profiles of the currents flowing to the top (red line) and bottom (blue line) boundaries measured by radially aligned electrode arrays.

When Bv is 0G, the CCD image shows a vertical emission belt. The profile of electron pressure is similar to the image and shows a vertically uniform ridge along near the ECR layer (R=13.7cm). The top and bottom arrays are detected positive and negative current, respectively. Both radial profiles are similar and have a peak near the ECR layer, corresponding to electron pressure. The profile of space potential shows a large size of upper sifted hill which regulates electron and ion flows to maintain the discharge as mentioned above.

When Bv is only 1G, a quite relaxation of the potential hill is observed, in which ～30A of toroidal plasma current flows. The electron pressure profile increases slightly and still shows the vertical uniform ridge. The array current profiles change corresponding to change of pe profile. While the electron pressure and array current profiles change a bit, the flows of electron and ion would change significantly by the vertical paths of helical field lines.

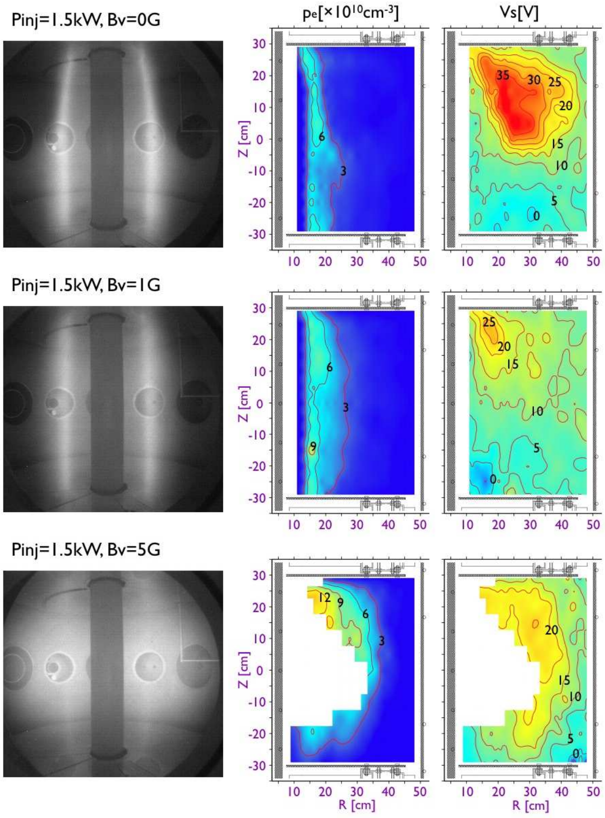

Fig.1. Plasma images and profiles

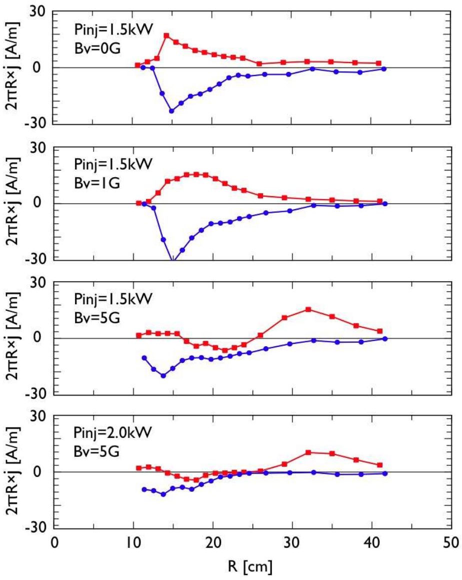

Fig.2. Radial profiles of top and bottom array currents

When Bv is 5G, ～240A of toroidal plasma current flows. The white parts of profiles are unknown because the plasmas are disturbed significantly or terminate when the probe is inserted at the parts. The CCD image and electron pressure profile become spherical. The top array current profile has a positive peak at R～32cm and a negative peak at R～22cm. The bottom array current profile shifts to higher field side. Both profiles are different each other and do not correspond to electron pressure.

When the microwave power P_{inj} is 2.0kW and Bv is 10G, ～900A of toroidal plasma current flows and a closed magnetic surface forms as shown in Fig. 3. Broad areas of high electron temperature (Te~15 eV) and high space potential (Vs~35 V) distributed along poloidal field lines and surround the last closed flux surface. Profiles of electron density and pressure are roughly coincident with the toroidal current profile.

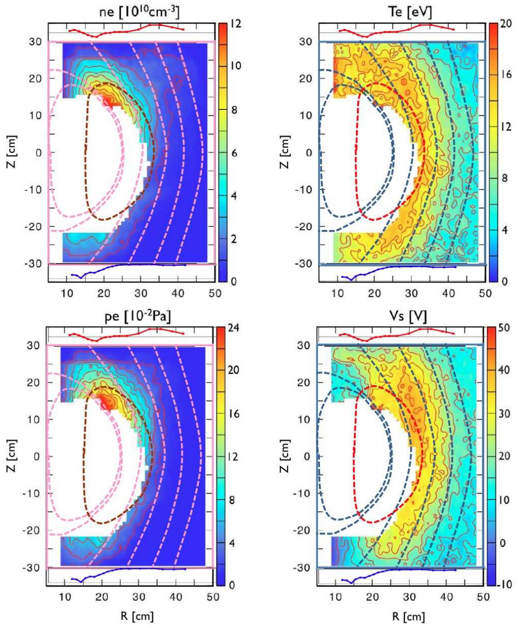

Fig.3. Profiles of ne, Te, pe and Vs at P_{inj}= 2.0kW with Bv=10G. Red and brown dot lines show main toroidal plasma current profile and other dot lines show poloidal field lines. Top and bottom array current profiles shown in Fig. 2 are shown above and below profiles.