§48. Experiments of Current Start-up by RF on QUEST

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1. Introduction

Spherical tokamak (ST) is a candidate for cost-effective fusion reactor and the improvement of the plasma performance of ST has been tried in many institutes. It is important to obtain the academic basics to support high beta and steady state operation approaches. The QUEST (Q-shu University Experiment with Steady State Spherical Tokamak) project focuses on the steady state operation of the spherical tokamak (ST) which has the capability to attain high β rather than conventional tokamaks. A final target of the project is the steady state operation of ST with relatively high β under controlled plasma wall interaction (PWI).

Closed magnetic flux surface formation (CSF) is an indispensable process to produce tokamak configuration. The combination of electron cyclotron heating (ECH) and ohmic heating (OH) and the only ECH are applied for plasma current start-up. ITER and future fusion power plants will have poloidal field (PF) coils made of superconductors, therefore the operation range of PF coils will be tightly restricted. The formation of a field null using external PF coils enforces the tough operation for PF coils and there is a possibility that PF coils are sometimes beyond the operation range. Plasma current start-up with no field null should be developed.

2. Plasma start-up experiments by the combination of RF and OH

The time evolutions of 2-dimentional (2D) visible radiation images were measured by a high speed camera as shown in Fig. 1. The radiation on the surface of the center stack was observed due to the plasma production by the injection of RF. As shown in the top left of Fig. 1 After the application of OH (~0.48s), the radiation at top side was glowing more. This was caused by the ware pinch of electrons due to toroidal electric field. For a while, the radiation at the mid-plane developed rapidly and at last a bright point appeared. After the termination of RF (~0.4925s), the radiations at top and bottom side were significantly reduced, however the radiation at the mid-plane remains in high level. The bright point was the source of CSF as shown in Fig.1. Magnetic measurements and these radiation images show that the plasma current on open magnetic flux surface was driven by the microwave at the fundamental and the second ECR layer and a field null was induced on the surface of the center stuck. When P_{RF} was not enough, no filed null was induced and as the results plasma current start-up could not be obtained. When the current on center stack (I_{CS}) was higher, the driven current required to induce a field null was higher. Therefore I_P did not ramp-up, when the I_{CS} was high. Thus, the self-induced field null played the essential role in CSF.

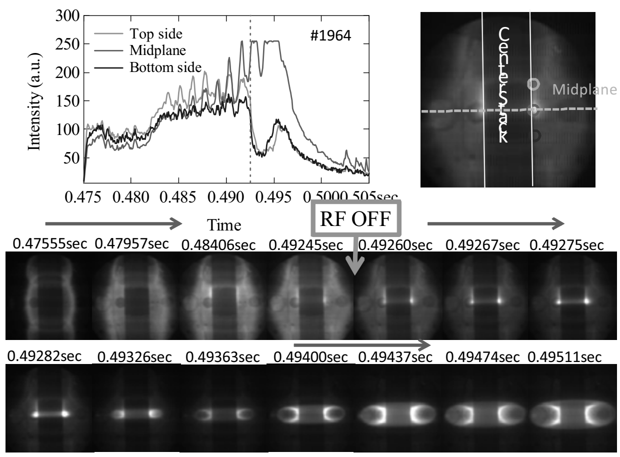

Fig. 1 Top left: time evolutions of radiation at the points colored in the top right figure. Top right: structures in each image are illustrated. Bottom figures: time evolution of 2D images of visible radiation measured by high speed camera.

3. Plasma start-up experiments by the only RF

Plasma current start-up and maintenance for more than 0.7 sec by the only RF was successfully obtained with no filed null on QUEST. The CSF can be clearly shown by the reconstructed flux surface as shown in Fig. 2.

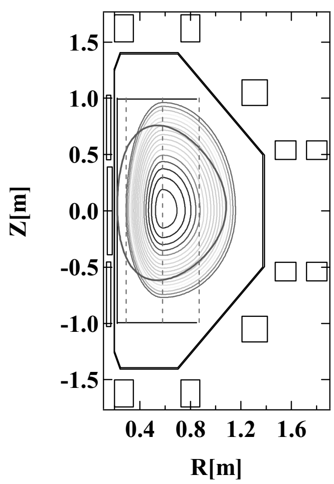

Fig. 2 Reconstructed magnetic surface of a 10kA, 0.7s, 30kW discharge and various constructions including the vacuum vessel and the PF coils is shown. A fat blue line shows the most outer flux surface and rainbow-colored lines shows the contour of plasma current density. The aspect ratio of 1.6 was obtained.