P07

Calorimetric Direct Loss Measurement of Energetic Electrons with Movable limiter on QUEST

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Abstract

Total heat load on MLs located in LFS is corresponding to 10% (5kW) of the inject RF power (50kW), and it mainly provides direct bombardment of RF induced energetic electrons. Rough estimated stored energy of the plasma is 200 J and confinement time of energetic electrons is approximately 40ms (t_F~20). This suggests the current drive efficiency is subject to direct losses of energetic electrons. IR camera views show the heat load on the downside ML was mainly deposited on electron drift side and this indicates heat load is dominantly coming from electrons, and especially passing electrons. Half maximum full width of the heat load is 1.5 cm and this indicates particle energy of loss electron is in the range of 93 keV – 150 keV. This typical energy of loss electrons is possible to derive the number of loss electrons and its value is 1.92×10^{16} ～ 6.66×10^{16} [s^{-1}].

1. Introduction

Non-inductive current drive (NICD) is a crucial technique to make a steady state operation of tokamak type fusion devices, and start-up of tokamak plasmas with NICD is a quite important research assignment in spherical tokamaks (STs). Radio frequency current drive (RFCD) is a promising way, however the current drive efficiency is not sufficient to make a full-blown ST plasmas, which can be almost fully maintained with a boot-strap current. The improvement of current drive efficiency plays an essential role in success and failure of ST type fusion power plants. It is well-known that direct losses of RF induced energetic electrons provides a significant effect on the current drive efficiency on RFCD [1,2]. In fact, many of hot spots on plasma facing components (PFCs) located in low field side (LFS), potentially induced with direct bombardment of energetic electrons, are observed [3,4] To investigate quantitatively direct losses of energetic electrons provides an essential step on realizing improved efficiency of the non-inductive RFCD drive. Experiments was done on QUEST, where electron cyclotron heating (ECH) and current drive (ECCD) are usually utilized to start-up. Direct loss of the energetic electrons is evaluated though a heat load measurement of a pair of water-cooled movable limiters (MLs) which have a vertical distance of 0.3m on a poloidal cross section (mid-plane and 0.3m downward) locating on the vessel wall in LFS.

2. Experiment Srt Up

Fig.1 shows the MML (Movable Middle Limiter) and MDL (Movable Downward Limiter). Left and right figure shows that MML is located in the equatorial plane, MDL is located in the 0.255 m downward from the equatorial plane. Red horizontal and dotted line shows the equatorial plane. Left and right below is a photograph of the MLs were taken from inside the vacuum vessel.

(Q-shu Univ. Experimental Steady-State Spherical Tokamak) QUEST is a medium-sized ST at Kyushu University. Experiments was done on QUEST, where electron cyclotron heating (ECH) and current drive (ECCD) are usually utilized to start-up. Direct loss of the energetic electrons is evaluated though a heat load measurement of a pair of water-cooled movable limiters (MLs) which have a vertical distance of 0.255m on a poloidal cross section (MML and MDL) locating on the vessel wall in LFS. The plasma-facing part of MLs tip is made of tungsten, there is cooling water pipe diameter 8mm with the copper block located in the back side of the tungsten limiter. In this experiment, I measured heat load of MLs when the MML is fixed in R=1.279 m and MDL is migrated 30mm (R= 1.209 ~ 1.239 m) between side of plasma and side of vacuum vessel.

3. Result and Discussion

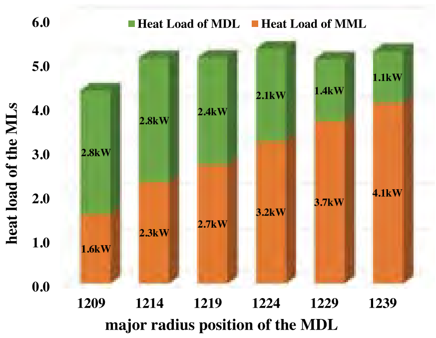

Fig.2 The vertical axis shows the total heat load of the MLs, the horizontal axis indicates the major radius position of the MDL. Green Bar shows the heat load of MLD. Orange Bar shows the heat load of the MML.

As you can see in the Fig.2, heat load on the MLs is total 5 KW and approximately constant. This result shows that heat selectively flows into MLs projected at the plasma side. It is shown that heat load is not caused by a light, radio-frequency and neutron particles being dispersed equally and widely, but by plasma which is strongly dependent on the magnetic field line structure. Additionally, it is Lowly possible that heat load on the MLs is due to the bulk plasma. This is because the position of MLs is far from the outermost magnetic surface.

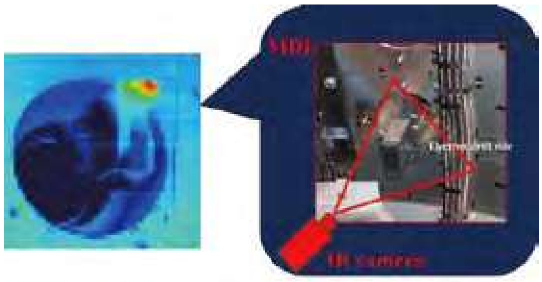

Fig.3 Right figure shows the picture of MDL taken from inside the vacuum vessel. Left figure is a video during the discharge of DML by IR camera. Temperature rising has been observed only at a location that is surrounded by a circle in the right figure.

IR camera views show the heat load was mainly deposited on electron drift side and this indicates heat load is dominantly coming from electrons.

It is Lowly possible that heat load on the MLs is due to the bulk plasma because the position of MLs is far from outermost magnetic surface.

It is adequately considered that the greatly accelerated energetic electrons at the resonant layer hits the MLs directly.

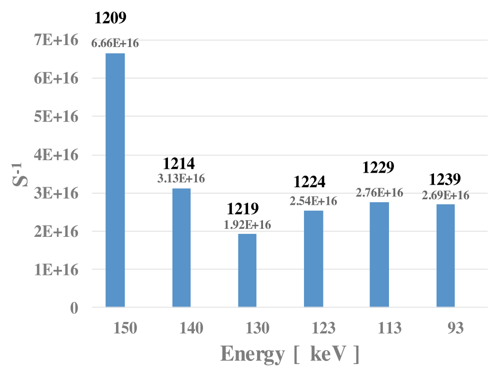

Fig4. Particle energy of loss electron is in the range of 93 keV – 150 keV. This typical energy of loss electrons is possible to derive the number of loss electrons and its value is 1.9× 1016 ～ 6.66×1016 [s-1].

Reference

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