IAEA FEC 2014

Contribution ID: **791** Type: **Poster**

ICRF Actuator Development at Alcator C-Mod

Thursday, 16 October 2014 08:30 (4 hours)

Future fusion reactors will present more severe constraints on ion cyclotron range of frequency (ICRF) heating and current drive actuators than ITER. Reliably coupling power to the plasma despite load variations is critical. In addition, ICRF interaction with the edge plasma, particularly impurity contamination and enhanced localized heat loads, is challenging. We report on progress developing an ICRF actuator with favorable scaling towards reactors.
Using a field aligned (FA) antenna, we have found that the FA antenna loading is similar to TA antennas but the FA antenna reflection coefficient has significantly reduced variation, thus it is inherently load tolerant. We speculate the variation in reflection coefficient is a result of slow wave coupling of neighboring straps and field alignment significantly reduces this coupling.
The underlying physics of RF plasma edge interaction is thought to be linked to RF electric fields parallel to the magnetic field, E||. One source of RF E|| is from the antenna itself and can minimize integrated E|| through geometry. Experiments comparing a field aligned (FA) and a toriodally aligned (TA) antenna have demonstrated that FA antenna has significantly reduced impurity contamination compared to TA antennas. The impurity sources measured at the antenna are nearly eliminated for the FA antenna. This is an important milestone since this is the first demonstration that an ICRF antenna can be made with reactor compatible materials. Furthermore, the heat flux to the FA antenna is reduced to a level similar to that observed for identical discharges heated by the TA antenna and the FA antenna is not powered. The estimated energy deposited is 0.4% of the total injected energy and marks the first time an ICRF antenna has achieved the target level for the ITER design, 0.625% of 20 MW.
One path to increase antenna power density is to use materials with high strength and high melting temperature. Furthermore copper will be restricted to thin coatings in a reactor due to material swelling and poor strength at high temperature. We have found that the higher strength materials have higher breakdown voltage compared to copper. Highly polished molybdenum and tungsten breakdown field is 40% higher than copper. The latest results and analysis will be presented.

Paper Number

FIP/2-3

Country or International Organisation

USA

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Session Classification: Poster 5