The Problem of RF Launchers in a DEMO Environment and Requirements to Address them

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Techniques for plasma heating, current profile control, rotation control, MHD stability control will be required for a DEMO reactor based on the Advanced Tokamak concept. Other concepts will have similar needs. Techniques utilizing radio frequency waves have been used on present devices and proposed for application on DEMO. The radio frequency energy is coupled from external sources into the plasma utilizing complicated launching structures in close proximity to the plasma. Experience with present application of these techniques indicates a number of challenges that need to be overcome before successful utilization on DEMO. While some of these uncertainties lie in the interaction between the rf waves and the core plasma, a large class of the difficulties lies in the interaction of the rf waves and launchers with the scrape-off plasma. Challenges include:

1. RF launchers require a significant amount of space penetrating the breeding blanket. Can launchers be constructed that have sufficiently high power density levels?
2. Present RF launchers have delicate components close to the plasma (ECH – mirrors, LH - narrow waveguide walls, ICRF – Faraday screens) that may not be able to withstand the plasma heat fluxes of a DEMO. Even in present devices damage and melting is observed.
3. The DEMO environment will require operation of launchers at temperature \( \sim 700^\circ C \), which has not been attempted in any experiment to date.
4. The DEMO radiation environment will require materials not presently used in launchers.
5. Present LH and ICRF launching techniques dissipate significant (varying depending on a number of not understood variables) amounts of power in the SOL plasma. Power that ends up in concentrated spots on either the launchers themselves (ASDEX, TORE SUPRA ICRF) or plasma wall components. (see figures 1 and 2) (JET LH, Alcator C-Mod ICRF NSTX HHFW)
6. Present launcher use passive or water-cooling. This will not be practicable on DEMO
7. Production of impurity influxes incompatible with reactor requirements (Bornization is not a steady state solution)
8. Modification of the plasma pedestal incompatible with reactor requirements

Some of these issues (particularly 2 and 5 will be addressed in a significant way in the ITER program. However, the ITER environment is not nearly as challenging as DEMO and the ITER rf launchers are conservative in not being designed to address the other issues. Success in the ITER mission is the driving requirement, not extrapolation to DEMO. For ICRF the port space expected to be required to couple design levels of power is larger than can be accommodated on DEMO, antennas do not use DEMO required materials, and power loading to divertor and antenna
surfaces will be significantly lower. Lower Hybrid is not in the presently included and may not be incorporated in ITER. ECH launchers have mirrors located close to the plasma. All these launchers rely on water-cooling which will not be practical on DEMO.

In order to properly prepare for DEMO additional facilities will be required. One such facility is the proposed IFMIF device that can be used to qualify materials to be considered for use in rf launching structures. Small samples of candidate materials can be tested and be shown to satisfy the radiation requirements. These materials could then be incorporated in a complete antenna to be tested on a confinement device. Such a high-power, hot-walls, long-pulse confinement device is required to allow a range of reactor relevant launchers to be tested in the presence of DEMO relevant plasma conditions (except for radiation effects) such as rf power densities, SOL power flows, and reactor relevant plasma performance. Test stands can be used to solve issues of voltage breakdown with new materials and innovative designs to minimize parasitic rf field generation but past experience has shown that only by using launchers in the plasma environment are the real problems uncovered.

**Figure 1** Hot spot in divertor region associated with HHFW ICRF on NSTX. Intensity of spot is sensitive to antenna phasing

**Figure 2** Scrape off layer field lines that pass in front of the C-Mod ICRF launcher and terminate on the outer divertor shelf. Erosion of the deposited Boron layer is seen on the shelf associated with rf operation