Extension of Alcator C-Mod's ICRF Experimental Capability.

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Abstract. A new 4-strap single-ended ICRF antenna has been added to the Alcator C-Mod tokamak. PPPL designed, fabricated, and tested the antenna up to 45 kV on an rf test stand. It is capable of symmetric phasing for ICRF heating studies, and asymmetric phasing with an improved directed wave spectrum for current drive. Two new 2 MW transmitters, tunable from 40-80 MHz, allow operation in plasma at 43, 60, and 78 MHz to match a variety of toroidal fields and plasma conditions. This addition increases the total available ICRF power to 4 MW at 80 MHz plus 4 MW at 40-80 MHz. Plasma heating and current drive experiments at the extended power levels and new frequencies are planned, and initial system performance will be discussed.

OVERVIEW

The Alcator C-Mod tokamak's experimental capability (1) is being enhanced through the addition of a new 4-strap ICRF antenna coupled to two 2 MW transmitters, tunable from 40 – 80 MHz. The existing ICRF system (2) is composed of two 2-strap antennas, optimized for plasma heating, and coupled to one 2 MW 80 MHz fixed-frequency transmitter each. The new antenna (3), shown mounted inside C-Mod in Figure 1, has its current straps connected to the two new transmitters in interleaved pairs. Each current strap pair and its connecting transmission line forms a resonant loop with the strap currents out of phase, allowing greater flexibility in the launched wave spectrum by simple transmitter-transmitter phasing. A decoupler link has been added to compensate the mutual strap inductance for phased operation. The antenna may be phased for heating, Figure 2, but the directed wave spectrum for current drive application is considerably improved over the older version, as is shown in Figure 3.

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FIGURE 1. Photograph of the new PPPL 4-strap ICRF antenna inside the C-Mod tokamak.

FIGURE 2. Launched wave spectrum of the new antenna for two different symmetric transmitter phasing settings.

FIGURE 3. Directed launched wave spectrum of the new antenna for three different asymmetric transmitter phasing settings.

OPERATING REGIMES

Three operating frequencies have been selected within the tunable range of the new transmitters: 43, 60 and 78 MHz. The corresponding ion resonances within C-Mod are shown in Figure 4 as a function of toroidal magnetic field and major radius.

FIGURE 4. Position of the ion cyclotron resonances in C-Mod as a function of toroidal magnetic field and major radius. Plotted for frequencies of 43, 60 and 78 MHz.

Using the full complement of antennas and transmitters, a variety of plasma heating and current drive scenarios now becomes possible.

Both similar and split frequency heating experiments may be performed:

- 78 MHz + 80 MHz D(H) on-axis minority heating at 5.4 Tesla,
- 78 MHz + 80 MHz D(³He) on-axis minority heating at 7.9 Tesla,
- 60 MHz + 80 MHz D(³He,H) on-axis minority heating at 5.2 – 6 Tesla,
- 60 MHz + 80 MHz D(H) off-axis minority heating at 4.4 Tesla.

Current drive experiments may be performed at:

- 60 MHz + 80 MHz D(³He,H) on/off-axis MCCD at 6.2/5.4 Tesla,

60 MHz + 80 MHz D(H) on-axis FWCD at $1.5 \Omega_D$ at 5.4 Tesla.

Mode converted IBW flow shear experiments may be performed at:
60 MHz + 80 MHz D(^3He ,H) off-axis MCCD at 5.4 Tesla.

PHYSICS INVESTIGATIONS

The increased rf power will allow the C-Mod parameter space to be extended. The H-mode threshold at 8 Tesla may now be exceeded, while the H-mode threshold at 5.4 Tesla may be exceeded by a multiple of 2-3. The enhanced D_α (EDA) H-mode may be investigated at lower values of the safety factor, q . High power loading of the divertor plates may be assessed. Higher values of β_N up to 2 at 5.4 Tesla may be achieved. The pellet enhanced performance (PEP) mode may be extended to higher levels.

In addition, basic ICRF physics issues may now be addressed or their investigation extended. The contribution of ICRF to observed toroidal rotation, without external momentum input, may be extended to higher power levels. The control of radial electric fields through toroidal rotation may then be attempted. D(^3He) minority and mode conversion heating may be studied. A directed wave launch allows the exploration of mode conversion current drive.

Generation of a mode converted ion Bernstein wave allows the investigation of RF poloidal flow drive. The properties of internal transport barriers may now be investigated under conditions expected in a tokamak reactor: no central fueling, no external torques, and $T_i \approx T_e$. Flow shear suppression of turbulence through off-axis mode conversion will be explored, and the formation of an internal transport barrier will be attempted.

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