1. Purpose of Experiments

Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones or ITER R&D commitments.

The goal of this mini-proposal is to explore direct electron heating using H-D and H-^3^He mode conversion. Electron heating is accomplished by the mode converted IBW damping directly on electrons, as opposed to indirect electron (and ion) heating via minority ions. In addition to being more suitable for RF power modulation experiments, this mode offers the possibility of off-axis heating and current drive.

2. Background

Discuss Physics basis of the proposed research, Prior results at Alcator or elsewhere, and any related work being carried out separately.

So far, only D(H) minority heating has been used in C-Mod. While it is the most straightforward ICRF heating scenario, analysis of power deposition is complicated by the fact that RF power is first absorbed by the minority ions, then transferred to electrons and ions by collisions. In mode conversion heating, the fast wave mode converts to the IBW (ion Bernstein wave), which directly damps on electrons. In order to maximize mode conversion heating, it is necessary to minimize ion cyclotron absorption by the minority and majority ions. H-^3^He mode conversion has been proposed as a promising mode conversion scenario for C-Mod at \(B_T = 6.2\) T (see attached figure\(^1\)). H-^3^He mode conversion has also been suggested for JET, and has recently been (successfully) attempted at Tore Supra.

3. Approach

Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

In order to optimize mode conversion heating, it is necessary to minimize ion absorption and maximize mode conversion. This is accomplished by shifting the ion resonances off-axis and adjusting the density and the minority ion concentration ratio. It is necessary to run at \(B_T = 6.0 - 6.2\) T (up to 6.4 T, if possible) and at a fairly high \(^3^He\) concentration \((n_e/n_i = 10 - 15\%)\). H-D mode conversion will also be investigated during the D to H changeover preceding the H-^3^He experiment.
4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 6.0–6.4 T
Plasma Current: 0.8–1 MA typical.
Working gas species: H, $^3$He (variable concentration)
Density: $n_e = 1–2.5 \times 10^{20} \text{ m}^{-3}$

Equilibrium configuration (if possible, refer to database equilibria): Lower single-null or inner-wall limited, 1.5 cm outer gap

Pulse length, typical current & density waveforms, etc. Refer to database or sketch desired waveforms: current flat-top to at least 1 sec.

4.2 Auxiliary Systems

RF Power, pulse length, phasing: 2 MW to full power, with power modulation
Pellet Injection (species): none
Impurity blow-off injection: none
Special gas puffing: $^3$He (need to calibrate the pulse gas valve)

Other:

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

All available diagnostics. Spectroscopic determination of $^3$He concentration (McPherson and OMA), if possible. OMA looking into the main plasma with appropriate filters. ECE polychromator with appropriate grating.

4.4 Neutron Budget

Estimate the neutron dose rate at the site boundary. Give basis for estimate. (Once some experience has been gained a standard formula will be provided for estimating dose rates.)

Less than $10^{13}$ per shot.

5. Experimental Plan

5.1 Run sequence plan

Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period (10 hours maximum), etc.

2 consecutive runs.
5.2 Shot sequence plan

For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

ECDC should be done with hydrogen rather than deuterium before each run. Hydrogen will be used for prefill and gas puff. Discharge development (with breakdown during the TF ramp) is probably required during the first run. The main parameter scans are the toroidal field, $^3\text{He}$ (or H) concentration, and density. The RF power will be fixed at 2 MW (or maximum power that can be run reliably) with approximately 20% power modulation.

First set up a discharge with $n_{el} = 1 \times 10^{20} \text{m}^{-2}$ at $B_T = 6.2 \text{T}$. Based on a previous change-over experiment, it is estimated to take about 10 shots for the deuterium concentration to be reduced to a low enough level ($\leq 5\%$). H-D mode conversion heating will be monitored during the change-over. After D to H change-over is complete, the $^3\text{He}$ concentration will be varied shot-to-shot from $n_{3\text{He}}/n_{e} = 0.05$ to 0.3. The mode conversion layer is swept across the plasma (and the mode conversion efficiency is varied) during the concentration scan. The location of the power deposition zone is determined from grating polychromator and soft X-ray response to RF power modulation. The $^3\text{He}$ concentration will be estimated from the (calibrated) pulse gas valve programming, density rise from the puff, from spectroscopic measurements (if possible), and the RGA trace. The $^3\text{He}$ concentration scan will be repeated at 6.0 T (and 6.4 T, if possible) at the same density ($n_{el} = 1 \times 10^{20} \text{m}^{-2}$), then at 6.2 T at two other densities, $n_{el} = 0.6 \times 10^{20} \text{m}^{-2}$ and $n_{el} = 1.5 \times 10^{20} \text{m}^{-2}$.

6. Anticipated Results

Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.

Demonstration of mode conversion electron heating in C-Mod. This mode can be used for transport studies using RF power modulation. It also provides the basis for advanced tokamak operating regimes, as well as off-axis heating and current drive.

7. References

Include references both to external and internal literature or communications which bear on this proposal. See Section 2.

$^1$R. Majeski, private communication (J. Hosea, APS 1994).