1. Purpose of Experiments

The purpose of these experiments is to optimize double transport barrier plasmas with regard to control of the density, duration of the barrier, heating of the core and the barrier location, and to clarify the mechanism(s) responsible for the barrier formation. This is in support of Milestone 76.0, Investigation of ITB Control with Multiple Frequency ICRF. In particular, the following questions will be addressed: Can the density peaking be stopped at any density? Can this steady state period be extended in time? Does too much on-axis power kill the barrier? Does the order of application of the 2 frequencies matter? Can the barrier foot location be moved? What is the role of rotation in the barrier formation? Is there a power threshold? Is there a $B_T$ threshold? Can the double barrier be formed at lower $B_T$ with 70 MHz on the high field side? Is there a fast poloidal rotation precursor to the toroidal rotation drop? Are there relevant fluctuations near the ITB foot location? Is the 60 Hz up-down motion interesting, and can it be controlled/eliminated? How is impurity transport affected by the barrier?

2. Background

A previous run, 1001220, raised a lot of provocative questions, while demonstrating (after struggling half the run) that the double barrier forms more easily (at 4.5 T with 2 MW at 80 MHz) with a high target density, that the barrier exists for both particles and energy and that the density peaking can in fact be arrested by application of additional core heating (at 70 MHz). The longest sustained steady state ITB (200 ms) was achieved with only 600 kW of core heating; at higher powers the barrier terminated earlier. Under most operating conditions, the foot of the barrier is in the same location, $r/a \sim 0.5$. 
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.

With regard to the barrier foot location, it’s possible that it depends on the q profile. One of the only ways the q profile can be changed on C-Mod is by varying the plasma current, since the primary prescription for achieving the double barrier is to operate at 4.5 T, with the fixed 80 MHz ICRF waves. Scanning the plasma current from 600 kA to 1.2 MA should provide enough of a variation in the q profile to reveal any possible dependence of the barrier location. However, there is limited experience in producing these plasmas for currents outside the range of 0.8-1.0 MA, and it may be that some variation in the target plasma density will be necessary, so some discharge development may be required.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- Toroidal Field: 4.5 T (3.9 T)
- Plasma Current: 0.6 to 1.2 MA
- Working gas species: D$_2$ with (5% H)
- Density: $n_{e0} = 2 \times 10^{20}/m^3$ (target)
- Equilibrium configuration (if possible, refer to database equilibria): 1001220016
- Pulse length, typical current & density waveforms, etc. Refer to database or sketch desired waveforms: 1001220016

4.2 Auxiliary Systems

- RF Power, pulse length, phasing: D+E 2MW, maximum pulse length (800 ms?), J variable power, variable pulse length at 70 MHz
- Pellet Injection (species): CaF$_2$
- Impurity blow-off injection: CaF$_2$
- Diagnostic Neutral Beam: if available
- Special gas puffing: argon
- Other:

4.3 Diagnostics

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

HIREX, HIREX Jr, neutrons, core and edge Thomson, ECE, visible bremsstrahlung, TCI, bolos, x-ray arrays, heterodyne ECE, GPC channels all on the high field side
5. Experimental Plan

Both sections must be filled in.

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.

6 runs (1 extended)

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 contin-
gency plans, if appropriate.

All runs require reliable ICRF performance and low H content with freshly boronized
walls. Some selected shots will have impurity injection by LBO.

1st run (extended), to see if the density rise can be arrested for a range of densities:
Establish good EDA H-mode from J port only at 70 MHz- 2 shots. Establish double
barrier with 2 MW of 80 MHz off-axis only- 3 shots. Add 600 kW at 70 MHz with timing
of 1001220016, to verify that the density can be arrested- 3 shots. Vary delay of J relative
to D+E, from 200 ms to 600 ms in 100 ms intervals, 2 shots each- 20 shots.

2nd run, to optimize maximum power from J port to heat the double barrier plasma:
Use optimum plasma from previous run, with D+E at 2 MW, probably with J port delayed
by 300-400 ms. Raise J port power in 200 kW steps from 0 to 2 MW- 11 shots. Try
ramping J port power continuously during the shot, up to 2 MW, at different rates- 5
shots. Depending on results, repeat the second step with D+E power at 1 MW and at
maximum power (3 MW?)- 6 shots.

3rd run, to attempt to move the barrier foot location: (the previous 2 runs were at
800 kA plasma current.) Using the optimum double barrier plasma from the 2 previous
runs, repeat at various plasma currents, from 600 kA to 1.2 MA in 100 kA intervals, 3
shots each- 21 shots.

4th run, to investigate \( B_T \) dependence for barrier formation: (this was also requested
in 277a) Operate with 2 MW from J port only at 70 MHz, and vary \( B_T \) in .2 T steps from
5.5 to 3.5 T, 2 shots each- 22 shots.

5th run, to measure core ion temperature and toroidal rotation velocity profiles using
HIREX. Depending on the results of the above run days, select the four most interesting
plasmas, and perform detailed scans, 6 shot each- 24 shots.

6th run, to investigate possible influence of the order of the 2 frequencies, and to
examine the ITB formation dynamics near the threshold. Initiate EDA H-mode plasma
at 4.5 T using 2 MW from J antennas at 70 MHz, then add 2 MW from D and E with
varying delay times, similar to Run 1 above- 10 shots. Establish double barrier plasma
with slow TF ramp from 4.7 to 4.5 T, to determine exact value of the field required. In
successive shots reramp the TF back up slowly to examine any hysteresis in the barrier
formation. This may require attempts at different reramp rates- 10 shots

All of the above runs require the J antennas at 70 MHz, with the exception of Run 3.
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.

Optimization of double barrier plasmas for AT operation is a 2001 milestone. This
will be an attractive target for LHCD experiments. Will probably lead to a PRL and/or
other publications, and APS invited talk(s).

7. References

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

see MPs 275 and 277, Rice et al., NF 41, 277 (2001), Fiore, APS invited talk, 2000