1. Purpose of Experiments

The purpose of this experiment is to measure SOL turbulence with the newly upgraded GPI diagnostic and compare the results with theoretical models for SOL turbulence. We will also compare the SOL turbulence with the SOL width as measured with $\text{D}_\alpha$ and Langmuir probes. These results should contribute to the Joint Research Milestone of 2010 to measure and understand the heat flux SOL width, since the SOL turbulence is very likely an important factor in determining this width.

2. Background

Empirical scalings of the SOL width of tokamaks have been attempted at least since 1982 [1], but such scalings have not clarified the underlying physics and are not very useful for predictions of future machines. The problem is that the SOL is very likely determined by the SOL turbulence, and the SOL turbulence is not yet understood from first principles. The present experiment aims to clarify the relationship between the SOL turbulence and the SOL width in C-Mod.

Previous measurements of SOL turbulence in Alcator C-Mod have shown a strong variation with poloidal angle [2], therefore it is likely this variation will influence the SOL width. The poloidal variation of the SOL turbulence will be measured in this experiment as a function of the plasma shape, SOL collisionality and normalized gyroradius, and the results will be compared with theoretical models for this variation. The radial transport due to the SOL turbulence will be estimated from the radial propagation speed and correlation length, and the results will be compared with the SOL widths as measured by the $\text{D}_\alpha$ emission (by GPI) and with Langmuir probes.
This year we have improved GPI diagnostic capabilities to measure all three locations simultaneously and at a higher speed than in previous years. Specifically, we now have 2 Phantom 7.3 cameras with a ‘turbo’ mode capable of 250,000 frames/sec (compared with 150,000 frames/sec previously), and an inner-wall GPI system with 45 radial and poloidal views of which 23 can viewed at any one time, compared with 6 radial views previously. Thus the quality of the GPI data this year should be significantly improved.

This new data can be compared with the developing 3-D linear and nonlinear simulations of SOL turbulence [3], e.g. BAL (Lodestar), BOUT (Umansky/Xu), XGC-1(Chang), or GEM-Z (Scott). The results will also be valuable for comparisons with 2-D codes such as SOLT (Lodestar), which assume a simplified model for the relationship between the midplane turbulence and other poloidal regions.

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.

This MP can be done with Ohmic plasmas, in two sequential parts.

The first part would be a short a ‘diagnostic check-out’ phase to test the GPI diagnostic signals and backgrounds. This can initially be done in ‘piggyback’ if and when we can get a NINJA D₂ puff for both the X-region and midplane GPI systems. Based on previous experiences, the signal/background ratio for the midplane GPI will always be high (>10), but it is not yet clear whether the signal/background ratio for the X-region GPI for LSN discharges will be high enough to be usable. If the signal/background ratio in D₂ for the X-region GPI for LSN discharges is high (>10 or so), then we can proceed directly to the main XP (below). If the signal/background ratio in D₂ for the X-region GPI for standard LSN discharges is low (<5), then we would like to test two other options for getting high-quality GPI data from the X-region system:

a) DN or USN discharges with D₂ puffing (these had high signal/background previously)
b) LSN discharges He puffing in NINJA with a HeI GPI filter (not tried previously)

After this diagnostic check-out phase we should know which configuration (LSN, USN, or DN) and which GPI gas (D₂ or He) will be used for the main experiment below. In the main XP the approach is to vary the SOL parameters such as collisionality and normalized gyroradius within the normal operation range of C-Mod to obtain data on the scaling of the SOL poloidal structure turbulence with these parameters. This is similar to the approach already taken for previous comparisons of SOL turbulence with the GEMR code [4]. The main variations for this MP are:

1) density scan of 0.8 MA, 5.4 T to vary SOL collisionality (varying gas fueling)
2) B scan at same q(a) as #1, to vary normalized gyroradius
3) comparison of inner wall limited to DN (to vary inner/outer midplane connection)
4) observation of turbulence/SOL during an Ohmic H-mode transition.

July 29, 2009
4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 2.7-6.75 T
Plasma Current: 0.4-1.0 <A
Working Gas Species: D2
Density: from no gas puff to maximum gas puff
Boronization Requested: TBD
Equilibrium configuration (if possible, refer to database equilibria): TBD

4.2 Auxiliary Systems

ICRF Power, pulse length, phasing: NONE
LHCD Power, pulse length, phasing: NONE
Pellet Injection (species): NONE
Impurity blow-off injection: NONE
Diagnostic Neutral Beam: NONE
Special gas puffing: NINJA GPI, either D2 or He
Cryopump: NONE
Non-axisymmetric Coils (Connections, Current): NONE
Other:

4.3 Diagnostics

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

GPI diagnostics (outer midplane, X-region) necessary. Inner-wall GPI not necessary for first part, but necessary for main XP (unless He gas is used in outer GPI).

Scanning Langmuir probes and divertor probes not necessary for first part, but necessary for main XP.

Edge Thomson scattering desirable but not necessary.

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.

two separate run periods optimal:
- one short period (~ 2-3 hrs) for testing signal/background ratio in X-region GPI
- ½ to 1 day for the main XP in the shot sequence plan below

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.

1) baseline and collisionality scan @ B=5.4 T, I=0.8 MA, vary fueling (4-8 shots)
2) B scan @ B=2.7 T, I=0.4 MA and B=6.75 T, I=1.0 MA (4-8 shots)
3) inner wall limited vs. DN @ B=5.4 T, I=0.8 MA (4 shots)
4) Ohmic H-modes (4 shots)

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, an ITER request, or an external database.

The SOL turbulence vs. poloidal angle will be compared with respect to:

a) the poloidal variation of frequency spectrum, intermittency, fluctuation level, etc.
b) simple flux-tube model of turbulence shape vs. poloidal angle
c) analytical and linear models of the 3-D structure of SOL turbulence, e.g. BAL
d) 3-D simulations of SOL turbulence, e.g. BOUT, XGC-1, GEM-Z

This should lead to at least one good publication and to a significant contribution to the joint research milestone of 2010 (“SOL width”).

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