TG6 Multiphase Interfaces
Parallel Session Summary

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1 Introduction

The overall research objectives of the NSTX program have been described in reports generated following previous Research Forums (the FY 1998 and FY 1999 reports, in particular). Since those objectives have not changed and since the research timeline envisioned even two years ago is still intact, interested readers should consult those documents for that information.

This topical group parallel session focused on research to be carried out in FY 2002 through 2005. Those presentations are summarized here, and prioritized recommendations are provided.

2 Experimental Presentations

S. Zweben: ***Why Does Wall Conditioning Affect Plasma Confinement?***
Tokamak operators have uncovered a variety of situations in which wall conditions affect plasma confinement, both positively and negatively. However, to date there have been no systematic studies. This proposal listed some of the relevant observations and theories. The experiments suggested for NSTX can begin with a simple comparison of gas puffing and the desorption coming from poorly conditioned walls; this experiment is being considered for the FY 2001 run period.

However, achieving real understanding will require the additional diagnostics expected to come on line during the period under consideration in this document.

R. Maqueda: ***Infrared Imaging of Plasma Facing Surfaces, Heat Load Reduction Development***

At full heating power and pulse length, NSTX is expected to require active methods of heat load reduction to prevent damage to divertor tiles. Techniques used successfully elsewhere, including divertor detachment, radiative divertor, radiative mantle, and strike point sweeping, will be developed as part of this proposal. The diagnostic required to evaluate the efficacy of these techniques is a high sensitivity, high frame rate, digital infrared camera (3-5 μm). In addition to measuring heat loads on the divertor target plates and other critical surfaces, this diagnostic would permit localization of hot spots, impurity sources, and lost fast particles. A steerable mirror would permit the view to be adjusted between shots so that a variety of surfaces can be monitored with a single camera.

R. Maqueda: ***Fast Visible Imaging of Edge Plasmas for Wall Conditioning Studies***

A fast framing (more than 1 kHz) visible, digital camera could be used to quantify plasma-material interactions. By focusing on small (~ 15 cm) regions near the surface of various plasma-facing components, high spatial resolution data can be obtained for confinement-related experiments and for benchmarking plasma-material interaction codes. Interference filters would provide data on deuterium recycling and on generation of carbon, boron, or lithium impurities. A tangential sightline would allow 2-D profiles to be inferred by inversion.

D. Majeski: ***CDX-U Liquid Lithium Results and Plans for Future Research***

This presentation briefly summarized CDX-U results with the liquid lithium rail limiter. The main result is that CDX-U experience with macroscopic amounts of lithium is benign; there were no problems with cleanup or window coatings. Macroscopic droplets of lithium falling into the core plasma not only did not disrupt the discharge, no discernable impact on the plasma current trace was observed. Because of substantial plasma contact with the center stack, the impact of the lithium limiter on the core plasma was difficult to discern. However, a clear increase in the deuterium pumpout rate and a reduction in the core oxygen content with clean, liquid lithium were seen. The next step for the CDX-U experiment is a toroidally symmetric stainless steel tray that will serve as a lithium belt limiter on the bottom of the device.

M. Ulrickson: ***Liquid Surface Module for Particle Control***
If the CDX-U experiments show lithium living up to its promise, NSTX would be an ideal platform for a more ambitious project. This proposal described a flowing lithium module that would sit at the midplane of NSTX. The flow rate would be high enough to pump the entire plasma particle content in 1 second; smaller pumping rates obtained with slower flow. The UEDGE code predicts that the reduced recycling (a recycling coefficient of 0.5) would lower the edge density and increase the edge temperature by 100 to 300 eV. Experiments with this module would also address MHD issues and the heat removal properties of flowing lithium.

J. Boedo: ***Edge Transport and Poloidal Asymmetries in NSTX***
UEDGE modeling indicates that strong poloidal asymmetries are expected in NSTX scrape-off layer temperature and density. Likewise, BOUT modeling shows poloidal variations in plasma fluctuations. Recent work by Schaeffer has highlighted the importance of ExB flows in the X-point region. Verifying the existence of these phenomena in the experiment will require measurements beyond those provided by the midplane scanning and fixed target Langmuir probes. A second scanning probe in divertor - X-point region is proposed to provide a third data point. Its location in the lower divertor would make it available for support of CHI studies. The study of radiating or detached divertor regimes would need such a probe to quantify convective energy flows and to measure drifts.

3 Modeling Presentations

J.-P. Matte: ***Modeling of Non-Local Parallel Electron Heat Transport in Divertor Plasmas - From 1-D to 2-D***
Fluid models of parallel thermal transport in the SOL are expected to be marginally valid or invalid in the spherical torus geometry. The companion proposal for FY 2001 will attempt to benchmark some non-local kinetic expressions for use in the fluid codes to remedy this situation. This presentation outlined a procedure for extending those models from 1-D (along a flux surface) to 2-D (adding radial variation).

M. Rensink: ***NSTX Edge-Plasma Simulation with the UEDGE Code***
This presentation described the status and recent results from the UEDGE code.

Results from a symmetric double null geometry with cross field drifts (so results are asymmetric) were shown. Included were the variations in heat fluxes, densities, and midplane radial electric field in scans of input power and transport coefficients. More comprehensive benchmarking of the code is needed. However, diagnostics beyond those presently on NSTX will be required to do so; this topic will be addressed directly in the next section.

X. Xu: ***Dynamical Evolution of Boundary Plasma***
Results from the BOUT turbulence simulation code were shown, focusing on the dynamical evolution of the boundary plasma. The fluctuating density in the far SOL was seen to be large while the fluctuating temperature was small. Another important conclusion is that the timescales for boundary turbulence and plasma transport are comparable. The implication is that one should not imagine doing turbulence calculations on a static (equilibrium) background. The BOUT (and the DBM code from U. Md.) code will be used to simulate the turbulence measured in the gas puff turbulence visualization experiments.

4 Research and Diagnostics Prioritization

The multiphase interface area does serve in part a ”service” role in characterizing and providing the machine conditions required for core plasma experiments. The section below, on establishing ”Global Power and Particle Balance”, makes a ”service” contribution insofar as verifying consistency of code results is a benefit to all groups using those results. On the other hand, dedicated boundary physics experiments may be carried out in pursuit of this objective. Furthermore, the lower aspect ratio of NSTX brings with it a variety of physics effects that would not be seen in conventional aspect ratio tokamaks; the multiphase interface group should be prepared to investigate them. Some of the possibilities are listed in the section below ”Edge Modeling and Transport-Related Experiments”. At the same time, though, our objectives should go beyond just repeating work done on existing devices. New and exciting science experiments and measurement techniques facilitated by the characteristics of the NSTX device and its team should be identified and given high priority during this period of the machine’s operation. The liquid lithium module described by Ulrickson falls in this category.

During the discussion two topics were highlighted as missing but probably of interest. First, existing experimental results and modeling indicate that helium can be pumped at an adequate rate in a reactor scale tokamak of conventional aspect ratio. The same may not be true for spherical torus aspect ratios. Targeted experiments designed to address this question would be desirable.

Second, virtually all of the materials-related diagnostics on the machine and proposed in this and earlier Forums deal with particles flowing into the plasma from the surface. To truly understand the plasma-material interactions, data are needed on the fluxes of particles striking the surfaces as well as a characterization of the composition of the surface. Developing such diagnostics to an extent that permits an expansion of particle balance analyses to include the materials is a long-term task. Nonetheless, NSTX could benefit from serving as a test bed for prototypes of diagnostics of this type.

0. Heat Flux Scaling
The ET5 (Boundary Physics) report from this Forum places the highest priority on establishing the scaling of divertor heat fluxes with input power and pulse length so as to meet the corresponding FY 2003 milestone. These efforts should also assess the adequacy of the plasma facing components for long pulse operation. This topic was not directly discussed during the TG6 parallel session. But, given that the objectives will not likely be completely met during the FY 2001 run period, they are cited again here as being of the highest priority.

1. Global Power and Particle Balance
The primary objective in the Multiphase Interface area should be to establish the tools and techniques required to demonstrate global power and particle balance on any given shot. The result will be an assurance that diagnostic and code data are at least globally consistent, and that they can be traded between codes.

Verifying particle balance in the divertor requires quantifying the level of recycling with combined upstream and downstream plasma density measurements. The upstream density can be obtained with the ORNL reflectometer. The fixed Langmuir probes in the divertor target can provide the downstream measurements. Presently, two of these are instrumented. Power supplies for two more will soon be available. Instrumentation of some or all of the other 20 remaining fixed probes is desirable over the longer term.

Once the particle inventories in the torus can be measured, the experiments described by Zweben could be begun. Fully achieving the intended objectives of that proposal, though, would require additional efforts during subsequent run periods with additional diagnostic coverage along the lines described below.

The existing 15 bolometer chords will be able to measure the core contribution to the total radiated power. Three additional chords, one viewing the entire divertor and one for each of the divertor targets, will suffice for a global determination of the divertor radiation.

2. Edge Modeling and Transport-Related Experiments

Doing science-oriented experiments and generating sufficient data to benchmark codes will require additional data. The UCSD midplane reciprocating probe will provide upstream density and temperature profiles essential for running scrape-off layer codes such as UEDGE and for doing kinetic modeling calculations. Corroborating data from an additional three scrape-off layer chords of Thomson scattering would be desirable. The UCSD probe will also yield flows, electric fields, and fluctuation levels that will be useful for transport related experiments.

3. Spherical Torus-Specific Science

Spherical-torus-specific science studies must also be undertaken during this period for NSTX to meet its mission objectives. The divertor X-point probe described in Boedo's presentation would permit the study of scrape-off layer asymmetries in plasma parameters and fluctuations. Turbulence and transport as well as CHI related experiments would benefit from data obtained with this diagnostic.

Detailed modeling of the recycling behavior in NSTX will involve resolving, spatially and temporally, particle sources at the material surfaces. Such data can be used to benchmark existing codes. With enough data, more detailed materials codes could also be tested. The fast visible camera described by Maqueda is one example of a diagnostic capable of providing such information.

Power spreading techniques (radiative divertor or mantle, detached divertor, strike point spreading) will likely be necessary to handle 5-second pulse lengths in NSTX at full heating power. Near term heat flux scaling studies should be able to quantify the need for these techniques. A fast IR camera of the sort described in Maqueda's presentation would facilitate this work, as well as provide data for other experiments on fast particle losses and impurity generation and transport. A divertor X-point probe like that proposed by Boedo would be needed to measure convective energy flows.

The long-term solution to the power-handling problem may lie in the use of flowing liquid metal surfaces. The potentially beneficial impacts associated with the use of the lithium as the working material make the proposal presented by Ulrickson very attractive.