For more information on diagnostic needs and opportunities, including recommendations from the NSTX Turbulence Diagnostics Workshop (January 2001), click on ......

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NSTX Measurement Needs Requiring New Diagnostic Techniques

NSTX is a relatively new facility, and is only part way to having a full complement of diagnostics permitting detailed research on a broad range of topics. Research in many areas would clearly benefit from the addition of many diagnostics based on well-established techniques. The table below lists NSTX measurement needs which may require the development of new techniques. The listing is organized according to NSTX Experimental Task Groups. For general diagnostic and interface information, contact **R. Kaita** or **D. Johnson.**

Macroscopic Stability	**Contacts: S. Sabbagh, J. Menard**
Electron temperature profile measurements with high time resolution	Due to the low toroidal field $B_{\varphi} \leq 0.6T$ and moderate plasma densities, conventional electron cyclotron emission is not available for measurements of electron temperature. Multipulse Thomson scattering measurements are limited to 3 snapshot profiles ~ every 10 ms. Obtaining T_e profiles with high time resolution (100 kHz) would permit detailed MHD studies as well as enhanced transport studies. An example of the latter would be RF deposition studies.
High resolution edge current density and edge plasma pressure profiles	Stability at high beta is critically dependent on gradients of the edge current (j(R))and plasma pressure (n(R), T(R)). Motional Stark effect diagnostics based on both collisionally-induced fluorescence and laser-induced fluorescence are being developed with targeted spatial resolution of ~ 3 cm and time resolution of ~ 10ms. With full implementation, snapshot Thomson measurements at the edge electron temperature and density will ultimately have a resolution of ~ 1cm. Charge exchange recombination spectroscopy (CHERS) is being developed to measure ion temperature with an outer edge resolution of ~0.5 cm and time resolution of 10ms. Measurement of edge current and pressure profiles in the outer 10 cm with spatial resolution ≤ 0.5 cm and time resolution adequate to study the evolution of edge instabilities (≤ 0.1 ms) would be very desirable.
Radial location and mode amplitude of magnetic fluctuations	Edge Mirnov coils have detected magnetic perturbations with frequencies from a few kHz to a few MHz. The low frequency modes have been tentatively identified as ideal low –n, kink/ballooning modes and neoclassical tearing modes, and the high frequency modes as compressional Alfven waves. Internal measurements of the radial location and mode amplitude of these perturbations would permit mode identification and assessment of impact on stability and transport. Fpr the high frequency modes, measurement bandwidth of a few MHz is needed.

Fast tangential imaging of MHD structures	Conventional 1-D x-ray pinhole arrays cannot resolve structures that evolve on time scales much different from the plasma rotation period and structures with short poloidal wavelength. Fast 2-D tangential x-ray images with high sensitivity and a field of view encompassing most of the core plasma offer the promise of resolving high-m instabilities and decoupling the measurements from rotation. Frame times of ~ 10 μs are needed. Such a system could investigate stationary plasma asymmetries, disruptions, sawteeth, plasma response to pellet injection, as well as MHD instabilities. 2-D imaging at slow speeds could also provide constraints on magnetic equilibrium reconstructions.
Transport and Turbulence	**Contacts: S. Kaye, B. LeBlanc**
Survey measurements of core density fluctuation amplitudes	Even if measurements do not resolve the fluctuation spectrum, survey capability with good time and some spatial resolution could provide valuable information such as correlations with transitions to improved transport, and confirmation of large in/out asymmetries for the low aspect ratio ST configuration. Microwave collective scattering is a good candidate for such measurements.
Core measurements of poloidal wavenumber of density fluctuations for long wavelength modes	Poloidal resolution of the wavelength of low k modes provides a measurement of distinguishing characteristics of turbulence such as ITG modes that can serve to clarify turbulence dynamics models. Imaging reflectometry is a promising, ongoing development for these measurements.
High-k fluctuation measurements	Enhanced confinement regimes show ion transport reduced to near neoclassical values but electron transport remains anomalous and dominant in some cases. To understand the role of electron-temperature-gradient driven turbulence in this transport, measurements of fluctuations (in any of n, T, B, φ, etc) at k > 1 - 2 cm^{-1} are needed.
2-D imaging of turbulence fields (n_e,T_e,T_I, B, ϕ, etc) in plasma core and edge	Numerical simulations of microturbulence now provide detailed visualizations of predicted turbulence. Obtaining local, high dynamic range, wide field images of core or edge turbulence with high time resolution (100kHz) would help elucidate parameters such as eddy size and correlation lengths and constrain models. Views of a heating beam with E_{beam}~ 80 keV and J_{beam} ~ .03 A/cm^2 are feasible.
Ion temperature fluctuation measurements	To sort out the type of microturbulence that dominates core transport, spatially resolved measurements of ion temperature fluctuations may be critical. On NSTX measurements are needed where T_I varies from 0.2 to 2.0 keV and n_e varies from 0.2-8.0x10^{19} cm^{-3}. Views of a heating beam with E_{beam}~ 80 keV and J_{beam} ~ .03 A/cm^2 are feasible.
Zonal flow and radial electric field measurements	Zonal flows are predicted theoretically to play a major role in turbulence and transport, and many of these effects are enhanced at low aspect ratio. There are currently plans to measure the toroidal and poloidal rotation of C^{5+} ions with charge exchange

	recombination spectroscopy using the heating beam. This system should have a spatial resolution of ~0.5 cm for the outer 20 cm and ~3.0 cm for the core, with a time resolution of ~ 10 ms. Measurements with higher spatial and time resolution would be desirable. Spatially resolved measurements of the evolution of the radial electric field would also provide critical information in the understanding of core and edge transport barriers, particularly in high performance discharges, where pressure gradients and plasma rotation speeds are high. Two motional stark effect systems are currently planned for NSTX, with spatial resolution of ~ 3 cm and time resolution of ~ 10ms, which, in principle, would be capable of separating B_θ and E_r. Measurements with higher time and space resolution would be desirable.
HHFW, EBW Heating and Current Drive	**Contacts: JR. Wilson, D. Swain**
Ion temperature profiles in the absence of heating beam	On NSTX, high resolution measurements of T_I(R,t) are normally done with charge exchange recombination spectroscopy, which relies on doping from the heating beam. Even short pulses with the high power beam represent a significant perturbation for studies of ion heating during rf experiments. Thus measurements, particularly in the core, of T_I(R,t) in the absence of neutral beam injection would be very useful for RF experiments.
RF waves	Core and edge measurements of RF wave propagation during high harmonic fast wave experiments (30 MHz, k ~ a few cm^{-1}, $k_{÷÷}$~ 4 – 14 m^{-1}) would provide useful comparisons to code predictions of wave–plasma interaction.
Coaxial Helicity Injection	**Contacts: R. Raman, D. Gates**
Probe measurements of CHI edge plasma	A fast reciprocating probe drive is being installed in June, 2001. This drive can, in principle, accommodate a variety of probe heads. Initially, it will be equipped with a 5 pin head to measure rms fluctuation amplitudes of n_e, T_e, and φ_{fl}. A probe head with radially and toroidally displaced triple tips and B_{dot} coils oriented to measure B_T and B_r can investigate dynamo electric fields generated during CHI. A tip with arrays of B_{dot} coils can study the evolution of the CHI driven current sheet.
Fast visible imaging of specific regions during CHI	Two views are currently available for use by two fast visible cameras. A midplane radial view is available but lacks the ability to view tangent to the plasma edge. A narrow view of the plasma outside upper edge is also available that views a gas puffing manifold roughly parallel to edge field lines. For CHI studies, additional views would be helpful: - narrow view of injector gap region from midplane

	- narrow view of absorber gap region from midplane - tangential view of injector gap region from gap between outer divertor and lower passive plate.
Fast high resolution doppler measurements of Ti and flow.	Edge Ti and flow measurements during the formation and evolution of CHI plasmas would provide information on the transition of these plasmas to the preferred operating mode. Instrument should have a resolution of ~0.25 nm with a time response of better than 100 µs. Impurity lines of interest would be OV, CV,OII and CIII. Ion temperatures in the range of 10 to 500 eV and velocities in the range of 0 to ≥ 200 km/s should be accessible.
Wall current measurement	For EFIT, it would be helpful to know the current in or out of the wall as a function of poloidal location, in order to specify the SOL and private flux current distribution as input, rather than treating it as unknown. There are two concepts: Measure the voltage at several locations on the vessel wall to obtain initial estimates of the CHI injector current exit points on the vessel wall as discharges transition from the wide foot print case to the narrow footprint case. Measurements at about 10 poloidal and 4 toroidal locations needed. Install an array of halo current probes on the wall (10 poloidal locations x 4 toroidal locations) to measure current entrance and exit points along the wall (like Alcator C-mod did to measure disruption halo currents).
Langmuir probe array on divertor plates	A poloidally distributed array of Langmuir probes along the divertor target and wall surfaces, could be used for measuring currents that flow the short way around (private flux) versus the long way around in the SOL. This could be particularly helpful for experiments in which CHI is added to an existing LSN OH discharge and assist in current penetration studies.
Magnetic field fluctuations with interferometry/polarimetry	FIR or microwave interferometry/polarimetry could be a good way to unfold density and magnetic field fluctuations, if the time response is fast enough.
Boundary Physics	**Contacts: R. Maingi, C. Skinner**
Electron temperature and density measurements in the SOL and divertor x-point region	T_e and n_e profiles in the SOL and the divertor x-point provide fundamental information needed for modeling of processes in these regions. Parameter ranges are T_e ~ 1 - 100 eV, and n_e ~ 0.1-10x10^{19} cm^{-3}. Spatial resolution of ~0.5 cm is needed. The NSTX MPTS system has some capability at the midplane for such measurements, and a fast reciprocating Langmuir probe is also planned near the midplane. A compact, affordable multipulse divertor Thomson scattering system would be a powerful technique. A fast reciprocating divertor Langmuir probe would also provide valuable measurements of these and other important parameters near the x-point.

Radiated power in the divertor and edge regions	Robust, cost effective, absolutely calibrated, broad band, divertor bolometer systems with a sufficient number of intersecting sightlines to allow 2-D tomographic characterization of divertor and edge region radiation profiles are needed. In addition, fast radiative process measurements (H-Mode Dynamics, transport barrier formation, impurity injection, disruptions) are desired with high temporal (~10 microsecond) and high spatial (0.1 cm) resolution.
Edge and divertor region outflows and turbulence	Measurements of atomic and molecular neutral and impurity particle outflows and the fluctuations in these quantities are desired, with high temporal (~10 microsecond) and high spatial (0.1 cm) resolution. These measurements will be used to create a database of edge and divertor plasma parameters which can be used for comparison with models of plasma transport, leading to a greater understanding of Spherical Torus edge conditions.
Divertor and edge neutral pressures	Poloidal and radial, fast (~ <5 millisecond), broad range (10^{-6} to 10^{-2} torr), cost effective, neutral pressure measurements are needed from the divertor region to the midplane, and from the near edge to the vessel wall to characterize and simulate plasma parameter dependencies on edge neutral pressure.
Real time measurements of wall and divertor efflux and SOL flows	Methods are needed to provide time resolved measurements on a per discharge basis at selected poloidal positions of the Z, mass, and energy (or velocity) of all boundary efflux and the consequent deposition and erosion. This data is needed with time resolution of better than 5 milliseconds and should be analyzable within about 5-10 minutes after the discharge and before the following discharge.
Wall Measurements	Controlled measurements of wall composition and local erosion and deposition on a shot by shot basis are needed. These could utilize collector probes, microbalances, or laser desorption. The data would be coupled to edge codes to improve the understanding of the link between wall conditions and plasma performance.