Summary of Diagnostic Discussions

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One of the underlying reasons for the NSTX Physics Forum was to derive community input in the consideration of NSTX diagnostics. As the physics Working Groups discussed the elements of the NSTX research program, it was necessary to consider the tools needed for these studies. All of the working groups had a number of presentations on diagnostic issues, which are appropriately recorded in the separate Working Group Summaries.

There were two diagnostic presentations at the plenary sessions, one given by R. Kaita on the Baseline Diagnostic Set at the Introductory Session, and another by D. Johnson on a Summary of Needed Measurements at the Summary Session. This is a written summary of the Forum discussion on diagnostics, including the need for further effort in the area of profile diagnostics. This report further tabulates the list of measurement needs, taking advantage of the Expert Group's evaluation of the ITER diagnostics, and identifies diagnostic topics where presentations were made at the forum.

NSTX provides an attractive environment for diagnostic installations. Diagnostic access is excellent with wide angle views readily available. In the initial years of NSTX research, eight midplane ports can be allocated to diagnostic use. The toroidal field is low and major disruptions is likely rare so that eddy current forces will be readily accommodated by the diagnostics systems.

However, relative to the state of the art in tokamak diagnostics, large differences in the spherical torus plasma and field parameters will require renewed diagnostics development and innovation. For example, with the low TF and high densities anticipated, ECE diagnostics will not be possible for measuring $T_e(r,t)$ in the plasma core. Motional Stark Effect measurements of the poloidal field and hence J(r,t) may become inadequate, because the reduced $\mathbf{v} \times \mathbf{B}_T$ Stark splitting and polarization fraction are expected to require increased accuracy for the polarimeter measurement. Strong paramagnetic to diamagnetic variations in the toroidal field expected in spherical torus plasmas during auxiliary heating will complicate the interpretation of poloidal flux measurements. The large variations in field pitch strongly alters the viewing geometry for BES measurements, and the antenna launch geometry for reflectometer measurements. Identification of the MHD poloidal mode numbers for this geometry will require an increased number of magnetic pickup coils near the inboard, center stack tiles. The reduced temperatures for NSTX at high densities will increase the edge background light, challenge the accuracy of CHERS measurements, and call for sensitive x-ray imaging detectors to achieve adequate response to high frequency MHD. The new plasma regimes anticipated for NSTX therefore call for a fresh and innovative look at a large number of diagnostic techniques.

The first two challenges cited above, measuring $T_e(r,t)$ and the poloidal field [(and J(r,t)] profiles, were discussed extensively at the forum. The results of discussion should be useful in improving the plan for the baseline diagnostics on NSTX in these two areas. The baseline plan includes the utilization of an existing single-pulse TVTS system and an existing MSE system, because of budget limitations.

In this regard, several Working Groups strongly recommended a multipulse, multichannel, Nd:YAG-based Thomson scattering system, particularly in view of the lack of effective

ECE measurements of $T_e(r,t)$. Reuse of an existing ruby laser system would still require considerable effort to install new collection optics, and would be inherently limited to single pulse capability. This limitation was viewed as a severe handicap. The needed Nd:YAG technology is straightforward, relatively costly, but modular in construction, permitting phased installation to fit resource constraints.

The suggestion to use the electron Bernstein waves to measure $T_e(r,t)$ was also generally favored by the Working Groups. If further study confirms this potential, this technique could be tried on an existing device such as the CDX-U, prior to installation on NSTX.

The signal to noise ratio for the existing MSE system will be seriously degraded due to the reduced polarization fraction. Changes in the physics mechanisms and the techniques of measurements are needed to achieve the required precision in pitch angle. The potentially large radial electric fields and the large variability in toroidal field will further complicate the interpretation of the signals. Possible enhancements of the MSE technique such as by laser fluorescence was suggested. Alternative techniques were also discussed, including Faraday rotation, and a heavy ion beam probe. A task group to review, analyze and compare the merits of these options for measuring the poloidal field and current profile was suggested by several of the Working Groups.

A related critical core profile parameter is $n_e(r,t)$. Both Thomson scattering measurements of $T_e(r,t)$ and Faraday rotation measurements of the poloidal field involve techniques capable of measuring $n_e(r,t)$ as well. Clearly, the core profile measurement alternatives need further evaluation.

The discussion of these core profile measurements at the Forum was extensive due to their importance in confinement, heating and stability studies, as well as the large improvements they would bring to the baseline diagnostics systems in NSTX. While this area received significant discussion at the forum, many valuable comments were presented also on other measurements.

A summary of the diagnostics discussed at the forum is presented in the tables below, adapted from the list of measurements being considered for the ITER engineering design. Measurements are grouped into three tables covering the following areas:

i) essential for machine protection and plasma control
ii) necessary for plasma control in specific studies (i.e.. profile control)
iii) necessary for specific physics studies.

Candidate techniques for each measurement of the NSTX plasma are listed, including the NSTX baseline and "day one" diagnostics. Also listed are key considerations of the measurement, and the Forum participants who presented ideas on the techniques of measurement.

Advances in innovative diagnostics will enable effective investigation of the very exciting fusion and plasma sciences of the spherical torus plasma. With first plasma scheduled for April 1999, there is time for developing important new tools of measurement. NSTX has excellent access and a user-friendly environment for diagnostics. This summary of

diagnostics discussion and the tabulation of ideas and contributions provide initial information for use by researchers interested participating in advancing the diagnostics capabilities of the NSTX scientific research. We look forward to discussing the exciting opportunities of collaboration in this important area of NSTX scientific research.

GROUP 1	**ESSENTIAL FOR MACHINE PROTECTION AND PLASMA CONTROL**		
measurement	**candidate technique**	**comment**	**presenter**
Shape/Position	Magnetics		
	Multiple Soft X-Ray Arrays	use small in-vessel cameras as in CMOD	
	CCD Cameras		
	Slow Tang. X-Ray Camera		
Locked Modes	Locked Mode Coils		H. Takahashi
Plasma Current	Ip Rogowski Coils		
'Halo' Currents	Halo Rogowski Coils	may relate to locked modes	H. Takahashi
Energy Content	Diamagnetic Loop	first "slow" version, using TF coil	
Impurity Influx	UV Survey Spect. (SPRED)		
	Visible Spectroscopy (VIPS)		
	SXR CV,CVI cameras	measure impurity transport at edge	M.Finkenthal
			M.Finkenthal
Runaways	Hard X-Rays		
Tile Temp. (body)	Thermocouples		
Surface Temp.	IR TV		H. Kugel
Line-ave. Density	1 Chord Interferometer		
ne, Te (plate)	Langmuir Probes		H. Kugel
Total Rad. Power	Bolometer Array	need separate core and divertor arrays	
	XUV Photodiode Array		
Neutron Flux	Fission Chambers		D. Jassby
Gas Comp. (div)	RGA		
Zeff line average	Vis. Continuum Array		
H/L Mode Indicator	H-Alpha Monitor		
Fast Ion Loss	Fast Ion Loss Probes	numerous possible loss mechanisms need poloidal array of SBD probes	D. Darrow
	RF Probes		D. Darrow
	Neutral Particle Analyzer		
	"baseline"		
	"day one"		

GROUP 2 **NECESSARY FOR PLASMA CONTROL IN SPECIFIC STUDIES (ie. PROFILE CONTROL)**

measurement	candidate technique	comment	presenter
Te Profile (core)	Multipulse Th. Scatt. (core)		
	EBW Emission	needs further study and trial (CDX-U)	P. Efthimion
	X-Ray PHA	centrally weighted value only	
	Multiple Soft X-Ray Arrays	Use small in-vessel cameras with filters	k. Hill
ne Profile (core)	Multipulse Th. Scatt. (core)		
	Tangential Multichord Interf.	2nd harm. interf. needs lab demonstration	F. Jobes
	Tangential Faraday Rot.	measures TF (and diamag.) as well as ne	T. Peebles
	Poloidal Faraday Rotation	lower spatial res., also measures pol. field	H. Park
Ti(r), Rotation	CHERS	spatial resolution 3-5 cm with heating beam	R. Bell
Imp. Profile	X-Ray Crystal Spect.	needs bit of Ar., for non-NBI studies	M. Bitter
MHD Activity	Mirnov Coils	need good tor. coverage, some hf channels	Fredrickson
	Multiple Soft X-Ray Arrays	use small in-vessel cameras as in CMOD	K. Hill
	HIPB		
	SXR CV,CVI Cameras	monitor edge MHD	M.Finkenthal
	EBW Emission	needs further study and trial (CDX-U)	P. Efthimion
J(r) Profile	Motional Stark Effect	low field means small polarization ratio	B. Stratton
	LIF + MSE	laser enhances signal S/N. power adequate?	F. Levinton
	Poloidal Faraday Rotation	low spatial resolution, good time response	H. Park
	Pellet Plume	perturbative technique	
	Charge Exchange q diag. (NPA)	central value only with heating beam, DNB?	
	TIP Probe	perturbative technique	
ELMs	H-Alpha Monitor		
Sawteeth	Multiple Soft X-Ray Arrays	use small in-vessel cameras as in CMOD	K. Hill
ne Profile (edge)	Tangential Multichord Interf.	2nd harm. interf. needs lab demonstration	F. Jobes
	Multipulse Th. Scatt. (edge)		
	Atomic Beam Emission Spect.		
Edge Recycling	H-Alpha Spect.		
	Filtered Plasma TV		
Zeff Profile	Vis. Cont. Array		
	Multiple Soft X-Ray Arrays	avoids reflection problems if have Te and ne	K. Hill
Prad Profile	Bolometer Array		
Neut. Dens. (duct)	Fast Pressure Gauges		H. Kugel
Neut. Dens. (x-pt)	Laser Induced Fluorescence		H. Kugel
Deposition Mon.	Quartz crystal monitors		H. Kugel
	"baseline"		
	"day one"		

GROUP 3 **NECESSARY FOR SPECIFIC PHYSICS STUDIES**

measurement	candidate technique	comment	presenter
Fishbones	Mirnov Coils	need good tor. coverage, some hf channels	Fredrickson
TAE modes	O-mode Reflectometry		E. Mazzucato
	BES	spatial resolution OK for MHD	S. Paul
Divertor ne, Te	Th. Scatt. (div)		H. Kugel
	Flush Mount Probes		H. Kugel
Edge Te	Th. Scatt. (edge)		
	Atomic Beam Emission Spect.		
	Reciprocating Probe		
Div. Plas. Flow	Spectroscopy		H. Kugel
Plasma Potential	HIPB		
Core Te Fluct.	EBW Emission	needs further study and trial (CDX-U)	P. Efthimion
Core ne Fluct.	O-mode Reflectometry	needs further study	E. Mazzucato
	BES	pol. res. poor with broad beam, large pitch	S. Paul
	FIR Scattering		
	Phase Contrast Imaging	interpretation with large pitch ??	
	HIBP		
Edge ne Fluct.	Fixed or Reciprocating Probes		H. Kugel
	Atomic Beam Emission Spect.		
	Fast Imaging Camera	image H-alpha or impurity light	S. Zweben
	LIF Imaging	2-D imaging of LIF	C. Skinner
Radial E Field	Poloidal CHERS	measure poloidal rotation, vertical view	R. Bell
	MSE	??	
	FIR Scattering		
	HIPB		

"baseline"

"day one"