

Diagnostics Working Group (WG6) Summary Report National Spherical Torus Experiment FY98 Research Forum

Princeton Plasma Physics Laboratory
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Diagnostic Working Group

Co-chairmen

David Johnson	Princeton Plasma Physics Laboratory
Robin Snider	General Atomics

Attending Members

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Ron Bell	Princeton Plasma Physics Laboratory
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Ed Cecil	Colorado School of Mines
Tom Crowley	Rensselaer Polytechnic Institute
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Ben LeBlanc	Princeton Plasma Physics Laboratory
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Ricky Maqueda	Los Alamos National Laboratory
Ernesto Mazzucato	Princeton Plasma Physics Laboratory
Sid Medley	Princeton Plasma Physics Laboratory
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Alan Ramsey	Princeton Plasma Physics Laboratory
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Introduction

As was the case at the first Research Forum, this second Forum benefited from ample discussion of diagnostic challenges and measurement needs. Each of the Physics Working Groups was charged to give special attention to this area, and to integrate into its research plan a consideration of the availability of the required measurement tools.

In a change from the organization of the first Forum, the second Forum featured a dedicated “Diagnostics Working Group” (WG6), charged with balancing the needs of the overall program and reviewing the plan for the phased implementation of the diagnostic set. A list of those who attended the WG6 discussions appears above.

There were diagnostic presentations by Bob Kaita on the Baseline Diagnostic Set and by David Johnson on the Upgrade Diagnostic Plans at the Joint Plenary Session the first day of the Forum. These presentations summarized the considerable evolution of diagnostic planning for NSTX that has taken place in the last year, due to discussion at the first Forum and subsequent Program Advisory Committee recommendations.

The morning of the second day, the Physics Working Groups (WG1-WG5) met in parallel sessions. These WG’s were asked to consider measurement needs in the morning session and to prepare a summary of measurement needs for another joint session in the early afternoon of the second day. Each WG6 member chose which morning session to attend, to participate in the individual WG discussion of measurement needs. Then after the joint early afternoon session, WG6 met for the first time as a group.

Co-chairman Robin Snider led the group in a discussion of a series of questions aimed at providing feedback to the project on the strategy for implementation of diagnostics. This discussion also considered the measurement needs highlighted in the previous session by the other WG’s. Following this general discussion, specific diagnostic presentations were made on various topics.

On the morning of the third day, Co-chairman David Johnson then summarized the WG6 discussion and listed a number of action items.

This Report will highlight changes in the diagnostics planning since the FY97 Forum, including several diagnostic issues that were prominent in the various discussions at the FY98 Forum. It should be noted that each of the other working groups will have its own comments on measurement needs and even on specific diagnostic priorities in its summary report. While this report will anticipate some of these issues and provide some response, a full integration of these comments will take time.

Summary of Plenary Session Presentations on Diagnostics

Bob Kaita presented plans for the baseline set of diagnostics shown in red in Figure 1, which has changed significantly since the last Forum. A year ago, a single pulse ruby Thomson scattering system and a conventional motional stark effect diagnostic were both in the baseline set. Due largely to discussions at the FY97 Forum last February and concurrence from the NSTX PAC, and OFES, these diagnostics were removed from the baseline set and given special consideration. There were strong recommendations and subsequent support to design and install a multipulse Nd:YAG laser Thomson system. It

was also decided to install an existing X-ray PHA to provide early central T_e measurements and heavy impurity data. The decision to stress multipulse Thomson scattering was largely due to the fact that the very low toroidal field on NSTX (0.3T at R_0) prevents the use of conventional electron cyclotron emission techniques for measuring $T_e(r,t)$. The toroidal field is also too low for conventional MSE techniques to perform polarimetry of the motional stark components of the beam-excited D-alpha emission, the technique developed in recent years to derive $J(r,t)$ in tokamaks. For this reason MSE was also removed from the baseline set and $J(r,t)$ diagnostic development was given special consideration as discussed below. Another addition to the baseline set since the last Forum was a neutral particle analyzer, added to give capability for core T_i measurements before charge exchange recombination spectroscopy (CHERS) measurements are available, and to provide fast ion measurements in neutral beam and RF heated plasmas. It is planned to use an existing PPPL analyzer system.

Bob described the availability of port space for the diagnostics and showed the current allocation plan, pointing out that midplane port space for diagnostics is adequate for the baseline set and some upgrades, but that careful planning and future reallocation will be needed to accommodate future upgrades.

Bob then listed the baseline diagnostic techniques and planned capabilities, with particular emphasis on the magnetic diagnostics. He presented the layouts of the flux loops, the segmented loops and the locked mode coils, used for plasma control and equilibrium, as well as the Mirnov coils used for MHD stability measurements.

Bob summarized the philosophy of the baseline diagnostics as those essential for machine operation and for characterization of fundamental discharge parameters. They must be straightforward techniques requiring little or no R&D. Furthermore, to minimize costs, existing equipment is to be reused whenever possible.

David Johnson presented proposals for supplementing the baseline set with other needed diagnostics. A proposed implementation plan for this so-called 'upgrade set' is also shown on Fig. 1. As mentioned above, the highest priority diagnostic upgrades are currently the multipulse Thomson scattering system, which is a PPPL project, and a $J(R)$ diagnostic, which is proposed to be a collaborative task.

The design goals for the multipulse Thomson scattering system were described by Dave, along with a schedule aimed at providing partial availability for the FY99 initial NSTX run. A design concept with a backscattering geometry was shown along with proposed placement of the laser and detector hardware.

At the FY97 Research Forum, it was recommended that a dedicated Study Group should meet to discuss ideas for development of an effective $J(R)$ diagnostic. Dave summarized this meeting, held at PPPL in July, which involved about 25 community experts. A number of techniques were considered, and encouragement for continued investigation was given in the areas of Faraday rotation FIR polarimetry, flux surface mapping with soft x-ray imaging, enhanced MSE techniques, heavy ion beam probe, and Fizeau interferometry. The technique with the most promise for yielding results comparable to existing MSE results on tokamaks was MSE polarimetry, enhanced with modifications to reduce line broadening effects, to reduce the passband of the spectral filters, and to increase the photon flux. The Study Group Summary gave a strong endorsement to support these areas of development.

Dave pointed out that similar Study Group meetings are planned in the areas of ‘Fluctuation Diagnostics’ and ‘Divertor Diagnostics.’

The first day’s Plenary Session ended with WG Leaders briefly discussing plans for the parallel sessions scheduled for the second day. Dave Johnson offered the following questions to serve as guidance for the WG6 discussion:

- Are there critical gaps in the diagnostic set planned for day one operation?
- In the current plan, diagnostics from many areas are phased in following the baseline set, but core profile diagnostics would receive most of the resources. Is this appropriate? Other comments on longer term additions?
- In addressing measurement needs requiring significant new technical development, which needs have the highest priority? Is a Diagnostic Study Group meeting needed to solicit expert help?
- Are there diagnostic “infrastructure” issues that we should be addressing?

WG6 Discussion of Diagnostic Implementation Strategy

The afternoon of the second day, after WG6 members had participated in WG1-5 morning sessions and listened to WG1-5 Leaders summarize measurement needs, Robin Snider led a discussion guided loosely by the questions listed above. Nearly all of the WG6 members listed above attended this session.

- Are there critical gaps in the diagnostic set planned for day one operation? Are there any diagnostics that should be removed?

WG6 agreed with several other group’s recommendations that if a reciprocating probe can be installed at low cost, it should be moved to a start-up diagnostic for edge characterization, particularly during RF experiments. There was a discussion of the need for central T_i measurements before the heating beam is available, brought up by WG5. The WG6 conclusion was that the project should study cost/benefit tradeoffs of 1) x-ray crystal spectrometer installation, 2) VIPS modification and 3) NPA capability to provide for such measurements for the initial run. There was considerable discussion of the baseline plans for two x-ray arrays. With care in design, the two x-ray arrays can be configurable to address different needs as research evolves. For example, for low T_e to high T_e plasma evolution during CHI research, the two arrays can be configured as an USXR array and a SXR array for broad energy coverage for both phases of the discharge. For some information on $T_e(r,t)$ for RF deposition studies and other research requiring fast T_e information both arrays can be configured as SXR arrays at different toroidal locations, providing toroidal mode number information as well.

Although it was not discussed in the WG6 parallel session, another issue which came up in the plenary session the third day was concern about fringe counting reliability of the baseline 170 Ghz microwave interferometer. Listed in the implementation plan shown in Fig. 1 is a tangential interferometer/polarimeter, which would likely be an FIR system with several midplane chords. It was suggested that the project consider

accelerating the implementation of multichord tangential interferometry with a single chord operational for the initial run.

- In the current plan, diagnostics from many areas are phased in following the baseline set, but core profile diagnostics would receive most of the resources. Is this appropriate? Other comments on longer-term additions?

WG6 felt that the right balance exists in the current plan in the phasing of diagnostics after the baseline set, with proper emphasis on core profile diagnostics. Multipulse Thomson scattering should be highest priority, with a J(R) diagnostic a not too distant second.

Triggered by a strong recommendation from WG4 that core fluctuation measurements are a high priority for NSTX and that FIR scattering the best technique, there was considerable discussion of the appropriate priority for implementing such a diagnostic. The consensus of WG6 was that fluctuation diagnostics, including FIR scattering, are at a lower priority than core profile diagnostics, and are not essential “near day one”. However, it was recognized that more attention should be given early to this area. (See next question)

To aid in the planning for diagnostics, there is a need for definition of requirements for measurements. It was suggested that a table of measurement needs be created, similar to that used in ITER diagnostic planning, with column headings such as plasma parameter, plasma region, spatial resolution, temporal resolution, and measurement precision. As an example, there were several discussions of enhanced capability in the plasma edge region for profile diagnostics. There is a need to define expectations for edge pedestals to properly specify edge spatial resolution needs in profile diagnostics. (such as MPTS, CHERS,...)

- In addressing measurement needs requiring significant new technical development, which needs have the highest priority? Is a Diagnostic Study Group meeting needed to solicit expert help?

Several WG6 members, who had participated in the July, 1997 J(R) Diagnostic Study Group Meeting, felt that the meeting was a success in defining the challenges and identifying candidate techniques, but that the project (along with OFES) needs to follow-up more aggressively on the resulting recommendations, and more actively nurture hopeful approaches.

Members felt that “Fluctuation Diagnostics” is an appropriate choice for a second Study Group meeting. Many felt that the meeting, tentatively scheduled for the summer of 1998, should be held sooner. FIR scattering, laser-enhanced BES, reflectometry and heavy ion beam probe techniques should be among those considered.

- Are there diagnostic “infrastructure” issues that we should be addressing?

NSTX collaborators as well as PPPL physicists interested in installing diagnostics would benefit from a concise description of the instrumentation and control interface.

Following a design review in March, the project is asked to provide this information, would be very useful in writing grant proposals

There was a discussion of urging that the project do it's best in anticipating future diagnostic needs in the assignment of port allocations. There was also a request to make port information available on web.

Finally, there was a discussion about being pro-active to encourage diagnostic ideas. The project needs to be vigilant enough to spot a good diagnostic idea even though that idea may not have a dedicated, vocal champion. It must also be flexible enough to nurture these ideas.

List of Action Items Identified by WG6

- Define edge pedestal expectations, to properly design edge profile diagnostics.
- Establish a list of measurement needs, listing plasma parameter, plasma region, the required spatial and temporal resolution, and the required measurement precision.
- Consider elevation of reciprocating probe to day one diagnostic.
- Reconsider various diagnostic options for pre-beam measurement of T_i .
- Generate and make available a concise description of instrumentation and control interface.
- Make port allocation information available on the web.
- Follow up on J(R) Diagnostic Study Group recommendations and schedule Fluctuation Diagnostic Study Group Meeting soon.

Individual Diagnostic Presentations in All Working Group Parallel Sessions

Presenter	Institute	Topic	WG
E. Cecil	CSM	Fast Ion Loss Probes	2
S. Medley	PPPL	Fast Ion Physics & Neutral Particle Analysis	2
A. Ramsey	PPPL	Passive Spectroscopy	4
J. Boedo	UCSD	Fast Scanning Probe Arrays	?
F. Levinton	FP&T	MSE Enhancements	1,3
H. Park	PPPL	Tangential Interferometer/ Polarimeter	6
T. Crowley	RPI	Heavy Ion Beam Probe	6
R. Bell	PPPL	CHERS and Poloidal Rotation	4
B. LeBlanc	PPPL	Multipulse Thomson Scattering	6
R. Maqueda	LANL	Fast Camera and IR Camera	1
M. Bitter	PPPL	X-Ray Crystal Spectroscopy	6
C. Skinner	PPPL	LIF Edge Fluctuations	6
D. Stutman	JHU	MLM Soft X-ray Array	6

Proposed Availability of NSTX Diagnostics



NSTX

	FY99	FY00	FY01	FY02
NSTX Experimental Program	first plasma CHI & ind. startup with HHFW	NBI Full scale conf. & β -lim studies nonind. ECH startup operational		
Basic Diagnostics	magnetics SPRED VIPS 1 chord μ wave interf. X-ray PHA NPA	flux surface mapping camera fission chambers fast neutron detectors scintillator	fast ion probes	
Core Profile Diagnostics	TS 10 ch, 30hz VB array core bolometry	CHERS → TS 30 ch, 60hz tang. Interferometer/polarimeter poloidal CHERS J(R) diagnostic		
MHD Diagnostics	SXR array Mirnov coils		tang. SXR imaging	
Fluctuation Diagnostics			FIR scattering Laser enhanced BES O-mode reflectometry heavy ion beam probe fast edge imaging	
Edge Diagnostics	H α monitor plasma TV fast plasma TV MLM USXR arrays reciprocating probe		edge interferometer Phase 2 edge and divertor diagnostics	atomic beam emission
Divertor Diagnostics	IRTV fixed Langmuir probes div. bolometer	divertor SPRED div. bolometer arrays		divertor TS
	FY99	FY00	FY01	FY02

Baseline Set (PPPL)
PPPL Upgrades
Proposed Collaborative Activities
Preliminary Consideration Only

Figure 1