**11.2 – NSTX-U National Collaboration Research Capabilities and Plans**

The capabilities and plans of the NSTX-U national collaboration research are organized by the list of collaborating institutions, principal investigators, and research topics are provided below:

**University of Colorado (T. Munsat)**

Velocity Field Analysis of Edge Turbulence Images from NSTX

**Columbia University (S.A. Sabbagh)**

Study of MHD Stability and Active Mode Control in NSTX

**CompX (R. Harvey)**

Collaboration with NSTX in Calculations of RF and NBI Heating and Current Drive Sources

**Florida International University (W. Boeglin)**

A Fast Fusion Proton Diagnostic for NSTX

**General Atomics (R. La Haye)**

National Spherical Torus Experiment Research Participation

**Johns Hopkins University (D. Stutman)**

Soft X-Ray Measurements of Transport and MHD Activity in the Core and Edge NSTX Plasma

**Lawrence Livermore National Laboratory (B. Hooper)**

Coaxial Helicity Injection (CHI) Modeling on NSTX

**Lawrence Livermore National Laboratory (V. Soukhanovskii)**

NSTX Program Support

**Lodestar, Inc (J. Myra)**

Edge and Scrape-Off-Layer Physics for NSTX

**Massachussetts Institute of Technology (P. Bonoli)**

Numerical Modelling of HHFW Heating in the NSTX Device Using the TORIC Code

**Nova Photonics (F. Levinton)**

The Motional Stark Effect Diagnostic for NSTX

**Oak Ridge National Laboratory (D. Hillis)**

Boundary Physics, Heating & Current Drive Program

**Purdue University (A. Hassanein**)

Impact of Disruptions and ELMs on Liquid Li Surfaces in NSTX and … for ITER

**Purdue University (J.P. Allain)**

Upgrade of MAPP, Deciphering the PMI Surface Chemistry of Lithium-based PFCs

**Sandia National Laboratory (R. Nygren)**

Fusion Research on the NSTX Experiment

**University of California - Davis (N.C. Luhmann, Jr.)**

FIR Density Monitoring, Feedback Control and fluctuation diagnostic for NSTX

**University of California - Irvine (W. Heidbrink)**

Fast-Ion D-Alpha Diagnostic for NSTX, Beam Ion Studies in NSTX

**University of California - Los Angeles (T. Peebles)**

Cross-Cutting Research Studies on NSTX-U

**University of Illinois (D. Ruzic)**

LLD and SOL Interactions on NSTX

**University of Tennessee (B.D. Wirth / R. Maingi)**

Diagnostic and Modeling in Support of Boundary Physics Research on NSTX Upgrade

**University of Washington (T. Jarboe)**

Coaxial Helicity Injection (CHI) on NSTX

**University of Washington (R. Raman)**

Disruption Mitigation Studies in NSTX in Support of ITER and Future STs Using MGI

**University of Wisconsin (G. McKee)**

Investigations of Long-Wavelength Turbulence and Instabilitie in the Spherical Torus

**University of Wisconsin (R.J. Fonck)**

Test of Point-Source Helicity Injection for Non-Solenoidal Startup in NSTX

**X Science LLC (R. Maqueda)**

Absolutely Calibrate Tangential Imaging Divertor

**C-1. University of Colorado at Boulder**

Research Topic: **Assessment of Edge Turbulence and Convective Transport through Velocity Field Analysis**

Principal Investigator: Tobin Munsat

Participating Graduate Students: Yancey Sechrest

Funded under DOE Grant: DE-FG02-08ER54995

**Introduction**

This collaboration involves both analysis of data from the NSTX Gas Puff Imaging (GPI) diagnostic and hardware modifications to this diagnostic instrument. The goal of the data-analysis portion of the project is to bring the unique GPI data to bear on the diverse topics of scrape-off layer turbulence and transport, identification of zonal flows and geodesic acoustic modes (GAMs) in the NSTX edge, the relationship between edge poloidal flow and turbulence, relationships between flows and transport bifurcations (including L-H transitions), ELM physics and ELM-related transport including Lithium effects, and divertor and x-point fluctuation studies. Analysis of this type and advanced understanding of the quantities uniquely accessible to GPI are critical to the evaluation the plasma-boundary interface in fusion plasmas, and can have significant impact on next-step devices.

The hardware portion of the project involves a continual evolution of the GPI instrument (as space and budget allow) to address several of the scientific goals of NSTX-U through a suite of edge turbulence studies. Potential modifications include the implementation of multiple cameras and multiple simultaneous views (increased from 1 view currently). The hardware plans are kept as simple as possible, taking advantage of re-entrant windows and external coherent fiber bundles (i.e. avoiding in-vacuum optical hardware), while making use of fast cameras that are already in-hand. The enhanced capability will enable extended measurements of 3-D turbulent structures along common B-field lines, as well as detailed information on the interplay between 3-D resonant magnetic perturbations (RMPs) and turbulence dynamics.

**Current research contributions to NSTX Upgrade**

Recent studies include the development of the HOP-V velocimetry code, written by the Principal Investigator specifically for use with the NSTX GPI data [1], as well as a series of edge-turbulence studies which have characterized the behavior of coherent structures in the NSTX edge [2-5]. We have collaborated closely with Dr. Stewart Zweben on this work.

**Summary of proposed research plan for 2014-18**

 To address several of the scientific goals of the forthcoming NSTX upgrade, we propose to continue our experiments with the curent Gas-Puff Imaging (GPI) diagnostic for a suite of edge turbulence studies, as well as implement a series of upgrades, as access and budget allow. Critical topics addressed by this diagnostic (in its current and modified form) include scrape-off layer turbulence and transport, identification of zonal flows and geodesic acoustic modes (GAMs) in the NSTX edge, study of the underlying relationship between edge poloidal flow and turbulence, relationships between flows and transport bifurcations (including L-H transitions), ELM physics and ELM-related transport including Lithium effects, and divertor and x-point fluctuation studies. Many of the topics studied for general understanding of edge turbulence and flow will have additional importance when studied in the context of resonant magnetic perturbations (RMPs) in the upgraded NSTX.

 While there is not currently budget for an extensive modification of the diagnostic or the NSTX interface, there are several diagnostic enhancements that are possible using existing hardware. Specifically, the current single GPI view can be extended to include a second view from Bay B with only a minor modification of the existing GPI re-entrant port and will enable simultaneous sightlines in opposite directions along the same flux tube. In addition to the second Bay B view, we may have an opportunity to make use of a top-view (Bay E) onto a divertor-region gas manifold, all of which exists or is already under development.

 Furthermore, we may be able to implement two additional Phantom v710 cameras, which were purchased by PPPL and are currently in use at C-Mod, if they become available (the additional cameras are perhaps the most costly component of an enhanced GPI system).

 These relatively minor modifications will enable extended measurements of 3-D turbulent structures (along common B-field lines), as well as detailed information on the interplay between 3-D resonant magnetic perturbations (RMPs) and turbulence dynamics.

The elements of our plan displayed in a timeline are:

**Timeline**

**FY2014:**

* Continue analysis of single-view GPI data, emphasizing "blob" transport and interplay with edge turbulence, transport bifurcations, and ELM studies.

**FY2015:**

* Continue analysis of single-view GPI data, emphasizing "blob" transport and interplay with edge turbulence, transport bifurcations, and ELM studies.

**FY2016:**

* Implement second Phantom v710 camera at Bay B for dual-view studies.
* Analysis of extended 3-D structures in NSTX edge.

**FY2017:**

* Implement top-view camera of divertor gas-manifold.
* Analysis of divertor behavior and linkage between divertor and edge structures.

**FY2018:**

* Continue analysis of combined GPI dataset for boundary turbulence studies.

**Contributions to the NSTX-U 2014-18 Five Year Plan:**

Dr. Ahmed Diallo is the present leader of the Boundary Physics topical science group and is responsible for overseeing the Boundary Physics chapter of the NSTX-U Five Year Plan. The plan above was defined in a process carried out over CY2011-12 in coordination with the NSTX-U Research Team. The research defined above contributes heavily to the plan.

**References**

[1] T. Munsat and S.J. Zweben, “Derivation of time-dependent two-dimensional velocity field maps for plasma turbulence studies,” *Review of Scientific Instruments* **77**(10) 103501:1-13 (2006).

[2] Y. Sechrest, T. Munsat, D.J. Battaglia, and S.J. Zweben, “Two-Dimensional Characterizaton of ELM Precursors in NSTX,” Nucl. Fusion **52** 123009 (2012).

[3] D.A. Russell, J.R. Myra, D.A. D’Ippolito, T.L. Munsat, Y. Sechrest, R.J. Maqueda, D.P. Stotler, S.J. Zweben, and the NSTX Team, “Comparison of scrape-off layer turbulence simulations with experiments using a synthetic gas puff imaging diagnostic,” *Physics of Plasmas* **18** 022306 (2011).

[4] Y. Sechrest, T. Munsat, S.J. Zweben, R.J. Maqueda, D. Russell, D.A. D’Ippolito, and J.R. Myra, “Flow and Shear Behavior in the Edge and Scrape-off Layer in NSTX L-Mode Plasmas,” *Physics of Plasmas* **18** 012502 (2011).

[5] S.J. Zweben, R.J. Maqueda, R. Hager, K. Hallatschek, S. Kaye, T. Munsat, F.M. Poli, L. Roquemore, Y. Sechrest, and D.P. Stotler, “Quiet Periods in Edge Turbulence Preceding the L-H Transition in NSTX,” *Physics of Plasmas* **17** 102502 (2010).