Planning for GPI on NSTX-U

S.J. Zweben

draft v.2

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**1) Existing GPI hardware on NSTX-U**

a) all existing ex-vessel GPI hardware is presently in B209, including:

 - Phantom 710 camera used for GPI (P28651, owned by B. Stratton)

 - Dell computer used to run GPI from control room (M46057, owned by me)

 - new zoom GPI optics and new coherent fiber bundle on 2’x3’ optical bench

 - old GPI optics and old (browned) coherent fiber bundle in a box

 - large new GPI Dalpha (656 nm) filter screwed onto Phantom camera lens

 - GPI target/calibration plate which attaches to GPI manifold inside vessel

b) this is what needs to be done to get existing GPI hardware working on NSTX-U:

 - GPI gas line needs to be reconnected (was taken off for first Upgrade ca. 2013)

 - determine if lead shielding for camera/bundle is needed for higher neutron rate

 - determine if magnetic shielding is needed for camera due to higher fields

 - identify better mounting location for GPI camera outside Bay B midplane

 - design and install new camera stand and its physical/electrical support

 - test LabView camera control software on PC and upgrade if necessary

 - review choice of camera and front-end lenses to define imaging field of view

 - clean holes in GPI gas manifold and check gas fittings inside vessel

 - test camera operation with computer (may need new camera trigger cable)

 - test new gas puff control system without vacuum, to whatever extent possible

 - install re-entrant optics on Bay B midplane port and remote camera controls

 - do in-vessel calibration with target plate (preferably w/ final camera location)

 - absolutely calibrate GPI gas puffer in Torr-liters with D2 and He (into vacuum)

 - test camera triggering and data transfer/storage from GPI PC to main computers

c) relevant files for existing NSTX hardware in folder on my computer “GPI hardware”

 - GPI equipment

 - GPI drawings

 - GPI calibration

 - GPI photos

 - GPI zoom optics

d) all relevant papers and talks/posters are at:

 http://w3.pppl.gov/~szweben/Papers/szpaperslist.html

 http://w3.pppl.gov/~szweben/Talks/talks.html

**2) Potential GPI hardware upgrades (can be done before or after start of NSTX-U)**

a) add 2nd Phantom 710 for “side view” of GPI gas cloud from the across the machine

 - use the Phantom 710 presently on loan to GA for 1 year (P28620 owned by me)

 - measure average parallel length of gas cloud to determine GPI spatial resolution

 - synchronize frames with main GPI camera to view individual filaments in 3d

 - develop diagnostic to measure edge magnetic field line angle inside cloud

 - further validate DEGAS 2 and XGC1 neutral physics using 3d cloud images

b) add remote control of ex-vessel re-entrant GPI optics inside Bay B midplane port

 - 2010 GPI results had loss of resolution in shots at largest B field misalignments

 - 2016 optics has a manual adjustment of zoom and pan, not very useful for a run

 - search for sub-cm structure needs shot-to-shot zoom/pan to align view with B

 - suitable remote control can be designed by Gus Smalley (but needs some time)

 - ideally this system should be spatially calibrated during a vessel opening

c) improved GPI gas injector (present 30 hole gas manifold has been used since 2002)

 - present gas injector is un-collimated, with ~10-15 cm GPI cloud length along B

 - TEXTOR developed simple collimated GPI injector (Shesterikov RSI ’13)

 - new design should be tested and calibrated using off-line vacuum chamber

 - can replace present manifold with collimated design, or add it nearb

 - could also investigate controlled dust injector, e.g. for seeding blobs

d) add C-Mod GPI avalanche photodiode (APD) arrays to augment present GPI camera

 - proposed for NSTX-U within MIT-PPPL collaboration by Jim Terry in 2013

 - these detectors are more sensitive and faster than 710 camera, in 9x10 array

 - can potentially extend GPI to ~1 MHz and/or farther inward radially

 - work needed to install new optics and electronics in basement is identified

 - this upgrade can be done without any in-vessel activity, with post-calibration

e) add “thermal helium beam” (THB) to existing GPI view (i.e. for helium line ratios)

 - proposed collaboration for NSTX-U by RFX (Padova) group in 2015

 - can measure edge electron density and temperature fluctuations (and profiles)

 - not sure if Padova hardware is still available, but other hardware options exist

 - requires significant interface work, e.g. fiber penetrations and new rack

 - good theory/modeling work for NSTX-U done by Muñoz Burgos (PoP 2016)

f) new GPI view(s) to measure 3d turbulence structure (proposed by Munsat in 2012)

 - easiest way is backward view along B from existing port to edge of RF limiter

 - new GPI gas sources can be installed using narrow capillary tubes

 - also relatively easy is new radial view of center column gas puffer

 - divertor plate GPI would be useful to correlate with divertor Langmuir probes

g) new GPI camera for much higher speed/sensitivity (can be purchased for ~$100k)

 - LLNL recently bought a Phantom v1211 with 5x higher sensitivity than v710.

**3) Existing GPI data storage and data analysis**

 a) Zweben GPI analysis codes for NSTX: /p/gpi/szweben (≥ 2010) or /u/szweben

 b) Zweben GPI analysis codes for C-Mod on PSFC computers in /home/zweben

 c) *all GPI codes start with restoration of data from stored Phantom .cine files*

 d) NSTX GPI database of 2010 with sample videos and shot list <http://w3.pppl.gov/~szweben/NSTX2013/NSTX2013.html>

 e) C-Mod database of 2019-2012 with sample videos and shot list

 http://w3.pppl.gov/~szweben/CMod2017/CMod2017.html

 f) Bill Davis’ blob tracking codes can be found in http://nstx.pppl.gov/nstx/Software/Applications/BlobTracking.html

**4) Possible improvements in data analysis using existing NSTX GPI database**

 a) blob creation and dynamics (how do blobs form, drain, split, merge, or shear ?)

 b) continued search for hidden trigger mechanism of L-H transition

 c) cross-comparisons of GPI with probe, reflectometer, high-k, and BES data

 d) look for effects in GPI of RMP fields, divertor shape, RF power, MHD, etc.

 e) search for neutral ‘shadowing’ effects in GPI data

 f) analyze 2016 “passive” data taken with GPI view but without gas puffing

 g) validation of edge turbulence simulations (XGC1, SOLT, BOUT, GBS)

**5) Possible future experimental directions on NSTX-U**

 a) try to directly connect of GPI data with divertor plate heat/particle SOL widths

 b) search for small-scale (e.g. ETG) turbulence with GPI zoom and q(a) scan

 c) active tests for effect of snowflake/divertor shape on GPI

 d) active tests effect 3-d RMP fields on GPI

 e) active tests of neutrals/impurity injection on GPI

 f) active tests effect of HHFW RF on GPI

**6) Some people who are already or might be interested in NSTX-U GPI**

 - Ahmed Diallo

 - Daren Stotler

 - Michael Churchill

 - Tim Stoltfus-Dueck

 - Santanu Banerjee (India)

 - Filippo Scotti (LLNL)

 - Jim Myra (Lodestar)

 - Jim Terry & Co. (MIT)

 - Yancy Sechrest (Nova)

 - Ricky Maqueda (X Science)

 - Matteo Agostini (Padova)

**7) Possible external collaborations on GPI:**

 - MAST, DIII-D, EAST, W7-X, TCV, AUG, HL-2A, India

 - for other devices see GPI review: RSI 88, 041101 (2017)

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