U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

ORNL RF Program Diagnostic plans for FY16-18

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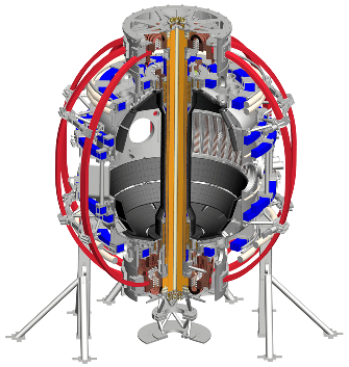
Oak Ridge National Laboratory

NSTX-U Collaborator Diagnostics Meeting
NSTX-U Control Room Annex
05/27/2016

OAK RIDGE National Laboratory

PPPL



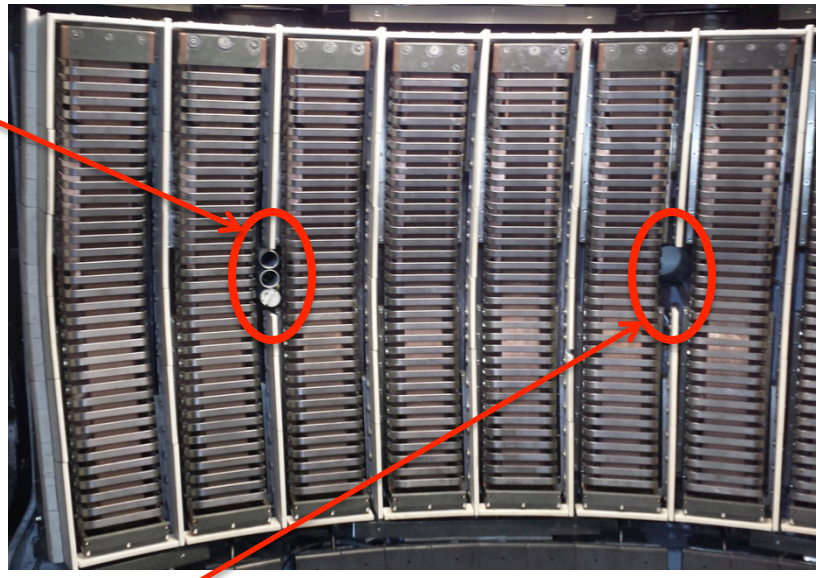
ORNL RF Research: Team and Goals

- ORNL maintains two independent but coordinated research teams on NSTX-U (coordinates w/UT-K)
  - Boundary Physics Program (M. Reinke– 5/17)
  - Heating and Current Drive (J. Caughman – today)
- ORNL RF Program has ongoing research in:
  - Understanding and improving HHFW power deposition, heating, and current drive efficiency, including increasing reliability
  - Understanding and improving power propagation through the edge plasma to the core
  - Providing heating power to transition from non-inductive startup plasmas to neutral beam injection target plasmas
- ORNL RF staff
  - Staff (Caughman, Lau, Bigelow, Diem, Green) supports operations, diagnostics, and simulation of HHFW and EBW programs
  - Available on-site during RF plasma operations or run days needing diagnostic support, available remotely for other run days

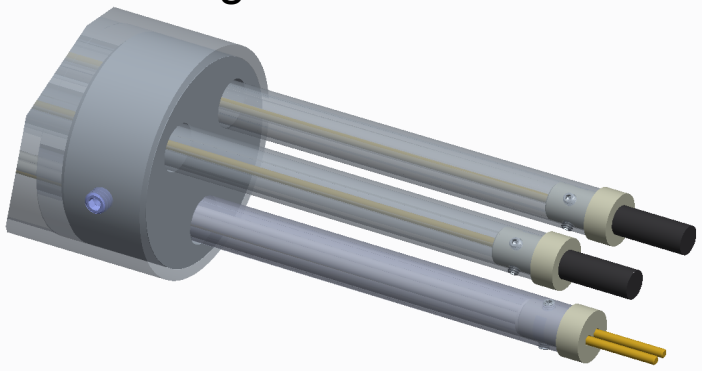
Present FY 16 Diagnostics & Status

- SOL X-mode reflectometer upgraded to handle higher NSTX-U magnetic fields
  - New technique using X-mode L, R cutoffs, and O-mode cutoffs to resolve density profile will allow for both NSTX B fields and higher NSTX-U B fields
  - SOL reflectometer electronics are installed for density measurements and working through calibration tests with oscilloscope
  - new 4 channel, 65 MSPS DTACQ digitizer is still being debugged
- An updated RF Langmuir probe will be used to measure near-field plasma interactions
  - Mechanical design review held in April
  - Expect installation on Bay D port within next few weeks

HHFW Antenna



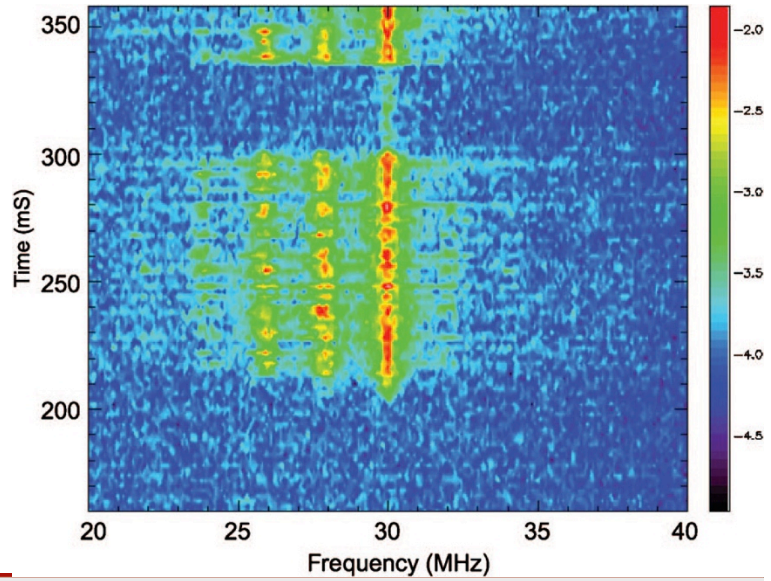
New Langmuir Probe Head



FY 16-18 reflectometer plans

- FY16
  - commission density profile and fluctuations measurements
- FY 17
  - between shot density profile analysis
  - commission ~30 MHz HHFW density fluctuation and PDI measurement
- FY 18
  - use reflectometer measurements as inputs into RF simulations
  - investigate simultaneous 30 MHz RF wave and density profile measurement

J.B. Wilgen, RSI **77** (2006) 10E933



FY 16-18 Langmuir probe plans

- FY16
  - Make initial near-field electron temperature and density measurements in front of antenna
- FY 17
  - Increase understanding of near-field plasma interactions in front of the antenna, particularly electron temperature changes, and link to sheath rectification observations in the divertor
- FY 18
  - Support Bay-D flange modifications to maintain near-field diagnostic capability if MIT Scanning Mirror Langmuir Probe is installed
  - Continue to use near-field measurements as inputs into RF simulations to explain SOL power losses

FY 17+ Develop He Line-Ratio Technique for Antenna Near-Field Characterization

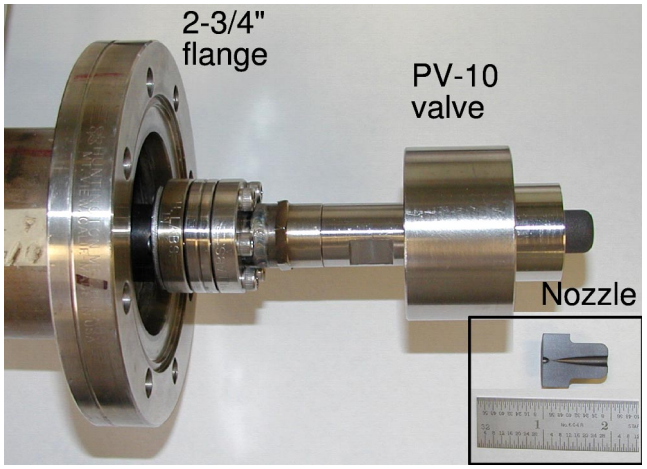
- Understanding RF power losses in the edge requires knowledge of the change in electron density and temperature profiles at the antenna
  - Density in front of the antenna affects wave propagation (e.g., fast wave cutoff)
  - Changes in the electron temperature may be related to sheath rectification (heat deposition both near and far from the antenna)
- Filterscope imaging the line emission from a beam of helium injected near the antenna can provide up to 10 μs resolution of changes in density and temperature near the antenna
  - Technique has been demonstrated on TEXTOR*
  - A 3-5 cm long radius away from the antenna can be measured
- Supports other boundary physics issues (fluctuations, turbulence, etc.)

*E.A. Unterberg, et al., RSI **83**, 10D722 (2012)

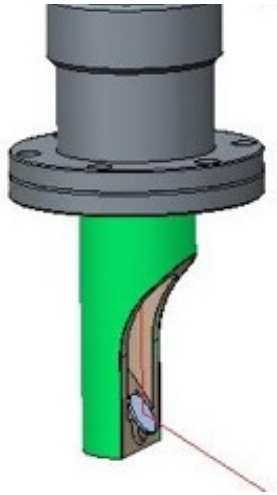
FY 17+ Develop He Line-Ratio Technique for Antenna Near-Field Characterization: implementation requirements

- Need a gas jet that crosses magnetic field lines passing in front of the antenna
  - Possibly use a piezoelectric valve with a Laval nozzle for supersonic gas injection
  - Can potentially be placed within the HHFW antenna array
  - Big issue: do not want to raise neutral gas pressure in the antenna box
  - Could also be placed *near* the antenna in a position to intersect field lines that pass in front of the antenna (spirals that connect to divertor)
- We need a port where we could put optics to image the resulting helium beam
  - Possibly a periscope-type optics system with a lens that focuses on a fiber array

V.A. Soukhanovskii, et al., RSI **75**, 4320 (2004)



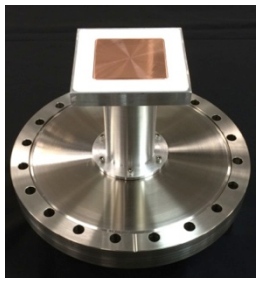
Possible periscope design



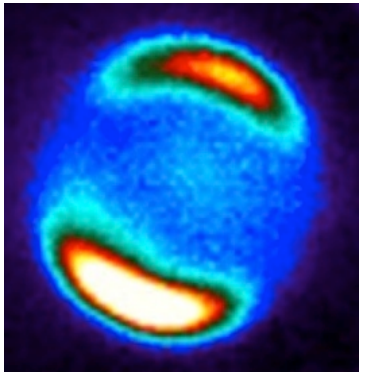
FY 17+ Develop He Line-Ratio Technique for Antenna Near-Field Characterization: development plan

- The Proto-MPEX device at ORNL can be used to develop the technique
  - RF electrostatic coupling experiments using a simple electrode structure to simulate RF voltages on antenna surfaces are planned
  - The puffer could be installed near the powered electrode and locally imaged
  - Calibration can be confirmed with Langmuir probes
  - Can also be used to diagnose helicon-generated localized areas of high Te (generates hot spots on surfaces tied to the helicon antenna)
  - Initial puffer imaging is already being developed using He-line filtered cameras (thanks to Ted Biewer)
  - Part of a student thesis project (could help with installation and initial operation on NSTX-U)
- Open to collaborations with other groups/ researchers (e.g., O. Schmitz (U. Wisconsin), etc.): not restricted to RF-only applications

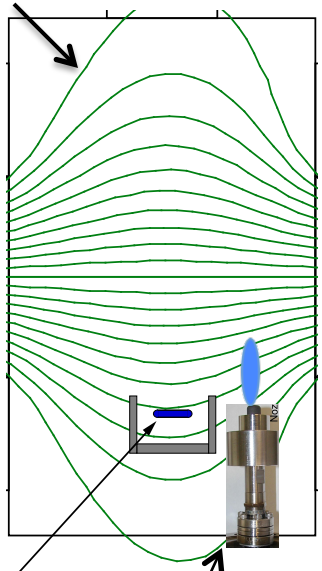
RF electrode



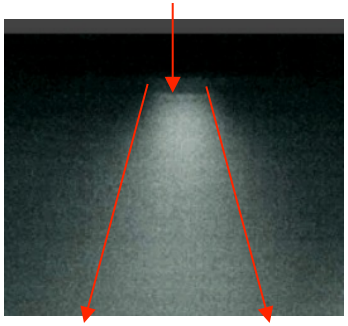
Areas of enhanced target power deposition



B-field lines in central chamber of Proto_MPEX

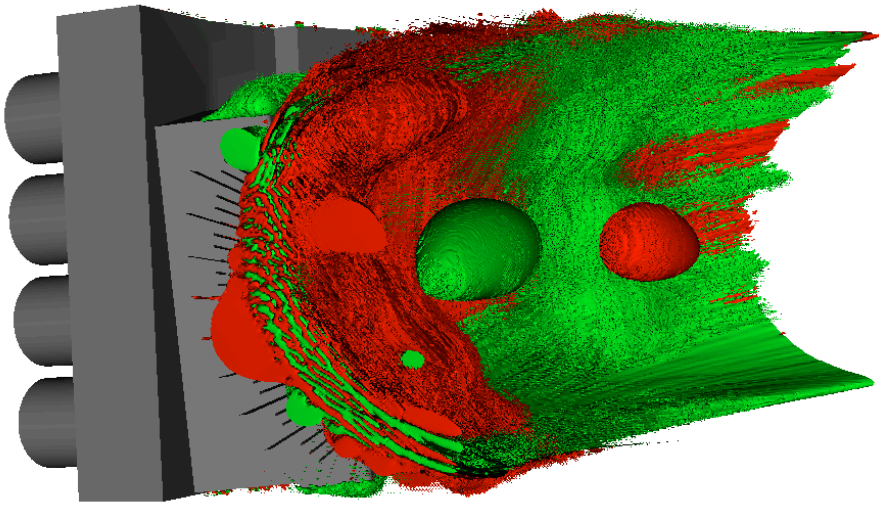


He emission from a puffer nozzle

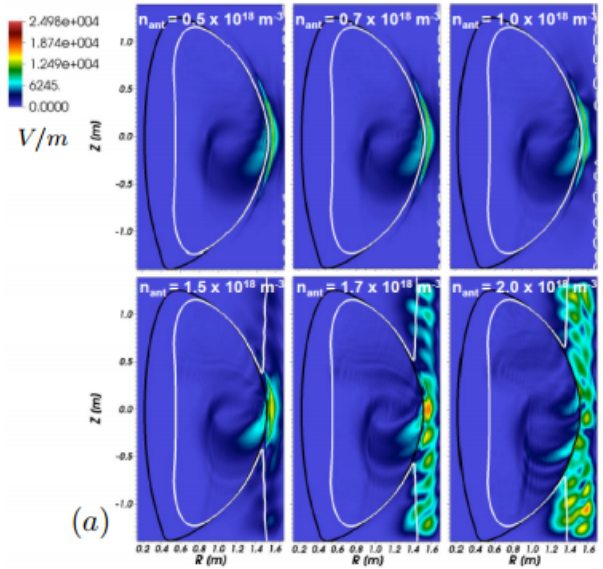


Measurements and modelling efforts will be essential to understand RF issues

- RF SCIDAC community (Bertelli, Green are co-PI's) is spending significant efforts to understand RF-SOL interactions
  - SOL density profiles is key input to simulations
  - RF electric fields are key output from simulations



Jenkins (Tech-X), Smithe (Tech-X)



Bertelli (PPPL), Lau (ORNL), Green (ORNL)

Summary/Discussion

- The ORNL RF Program supports ongoing research in understanding and improving HHFW power deposition and power propagation through the edge plasma to the core, as well as providing heating power to transition from non-inductive startup plasmas to neutral beam injection target plasmas
- FY16 diagnostic goals: commission the new reflectometer and RF Langmuir probes
- FY17+ diagnostic goals:
  - Develop between shot reflectometer density profile analysis and fast density fluctuation measurements
  - Increase understanding of RF near-field interactions and sheath rectification through probe analysis (supports modeling efforts)
  - Implement helium line ratio technique to better understand RF near-field interactions, wave propagation, and link to divertor power deposition, as well as provide an additional diagnostic for boundary physics issues during startup and steady-state operations