NSTX-U

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Spectroscopic and IR diagnostics for upper divertor and central column of NSTX-U: overview of the UTK collaboration

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ORNL, 16 January 2013

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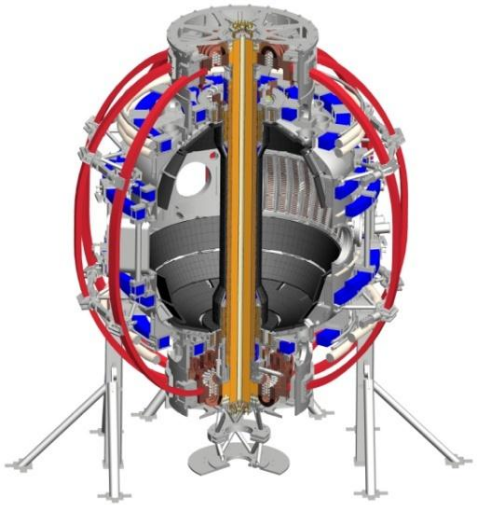

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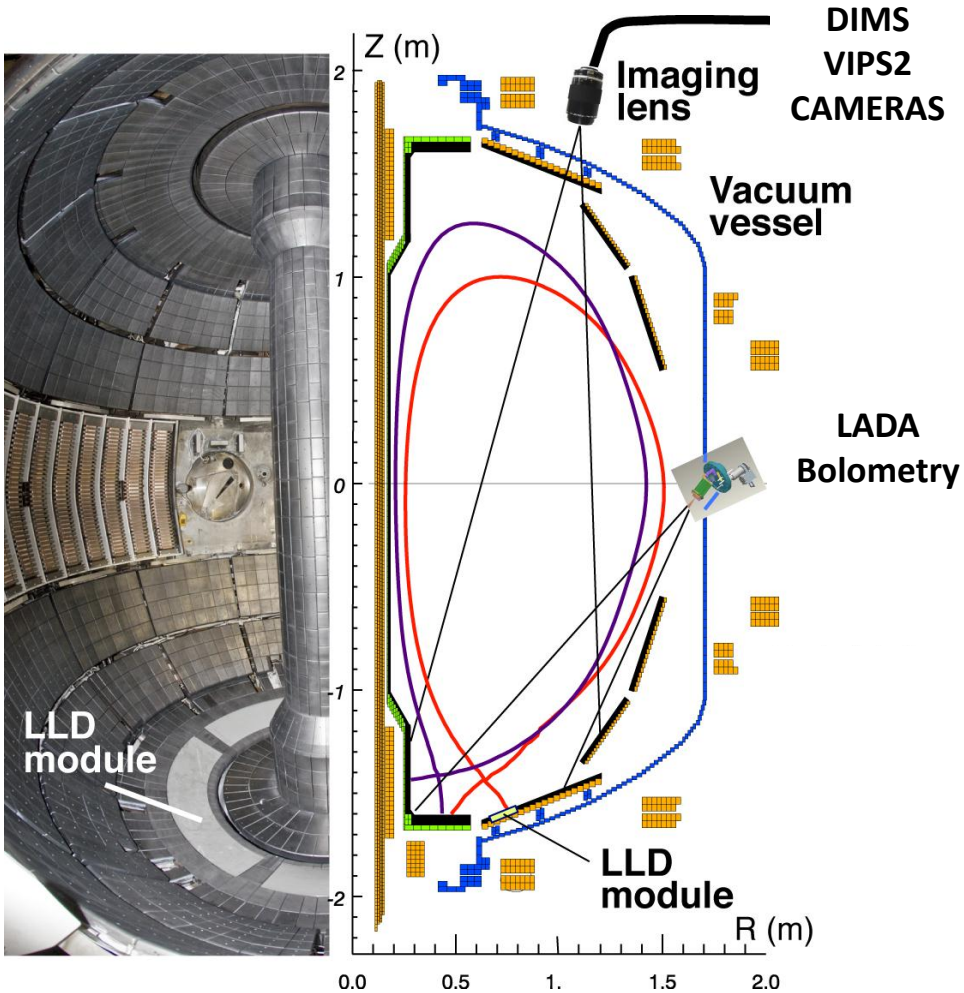
Motivation: understanding Li coating effectiveness

- Li proved to be focal point in NSTX experiments
  - Improved energy confinement, profile peaking ,ELM stabilization
- Open question
  - Improvement increases linearly with pre-discharge evaporation
  - But… Nominal coating thickness >> ion implantation
  - What governs the effectiveness of Li deposition?
- Possible mechanism at play:
  - Role of regions low Li coverage
  - Erosion and re-deposition
  - Deposition of carbon-rich films during discharge
  - Lithium-Carbon chemistry
- Spatial distribution of Li coating is a key element

Lower divertor was well diagnosed on NSTX



- Multi channel spectrometers (DIMS/VIPS2, LLNL/PPPL)
  - UV-VIS-NIR range, high resolution
  - 48 chords (30 simultaneously)
- Single channel spectrometers (ORNL)
  - 4X, VIS-UV, low resolution
- Diodes array (LADA/filter-scopes)
  - Lyα, Dα, C III, Li I
- Visible cameras (1D/2D)
  - Li I, Li II, C II, C III
- IR cameras (ORNL)
  - Fast dual band (L/MWIR, 1.6 kHz)
  - Wide angle (180° divertor coverage)

Poor coverage of the central stack and upper divertor

UTK-PPPL collaboration

- Scope of the collaboration:
  *Evaluation of the dependence of the **effectiveness** of Lithium evaporation on the **spatial asymmetries** in the coatings, on NSTX-Upgrade*

- Experimental part:
  - Spatially resolved spectroscopic measurements of the upper divertor and central stack regions
  - IR imaging of the same regions
- Modeling part (supported by measurements)
  - Boundary/SOL transport (SOLPS-B2, EIRENE)
  - Evolution of material morphology/composition (TRIM, LAMMPS)
- Timescale: 2012-2015 (NSTX-U startup Sept 2014)

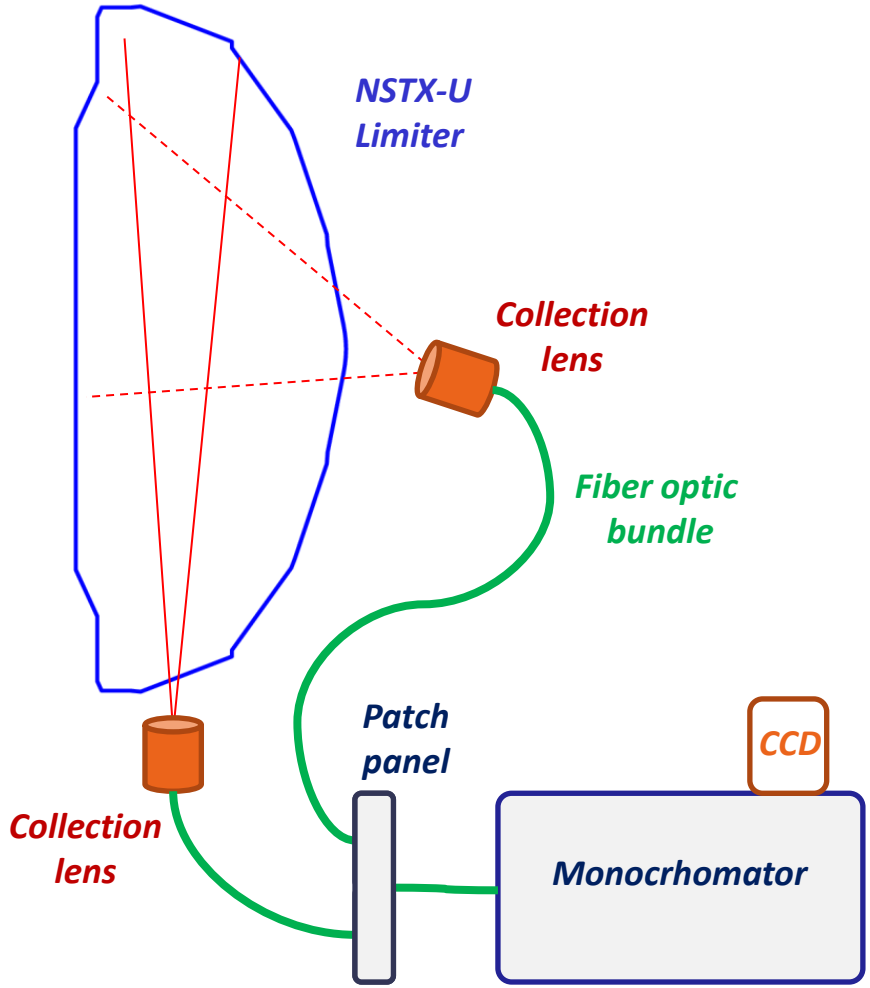
The project fits the NSTX-U program

- NSTX-Upgrade operation scenario
  - Additional off-axis NBI sources (6→12 MW)
  - Increased B_{tor} and achievable I_p (0.5 → 1T, 1 → 2MA)
  - Longer discharge duration (1 → 2 s)

- Challenging power handling and conditioning
  - Larger exhausted power to PFC
  - Smaller area of deposition (strike-point footprint) as I_p increases
  - Time evolution of coating efficiency over discharge time

- Graphite PFC on upper and lower divertor
  - Double Null as standard operation configuration (snowflake)
  - Li evaporation as baseline procedure for wall conditioning
  - New Li evaporator for coating of the upper divertor foreseen

PFC spectroscopy of upper divertor and central stack



- 2 light collection lenses
  - 105mm, F/4.5, transmission UV-VIS-NIR
- 2 bundles of optic fibers (15x)
  - 400 um core, high OH (UV transmission)
- Patch panel to relay with spectrometer
- High resolution spectrometer
  - f=0.67 m, F/4.7,
  - 3600, 2400, 1800 G/mm for UV, VIS, and near-infrared
- CCD detector (multichannel acquisition)
  - 512x512, 8.2x8.2mm, back illuminated

Initially, the spectrometer system is shared with DIMS diagnostic (PPPL/LLNL)

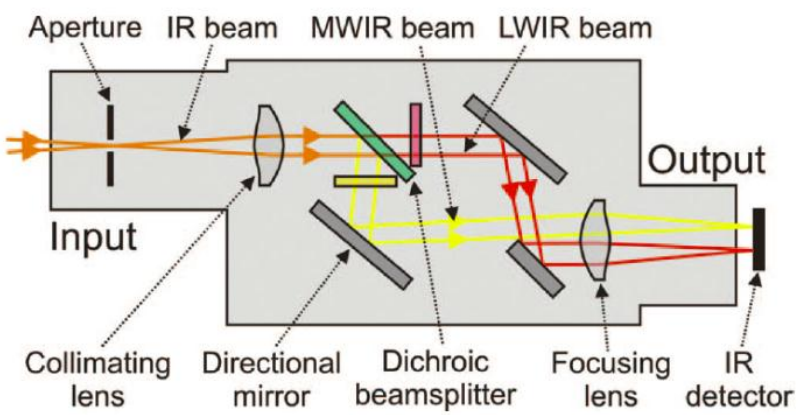
High resolution spectroscopy provides key information

- Spatially resolved, photometrically calibrated measurement of emission from PFC
  - Low charge states of from Li, C (350-800 nm)
  - Molecular bands (LiD, CD, Li_2, etc.)
  - Deuterium (Balmer, Paschen series)
- Assess ability of affecting erosion of graphite
  - Monitor ration of spectrally close C an Li lines
    e.g. CI / Li I : 493/497nm, 601/610nm 805/812nm
- Document the evolution of PFC

- Influxes of impurities (from S/XB, but local T_e, n_e are required)
- Ion temperature (Doppler broadening)
- Estimate of n_e from Stark broadening

IR camera for the upper divertor

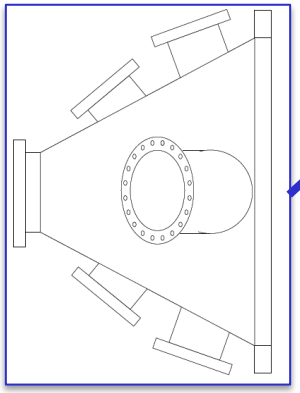
- Plasma heat flux to the PFC serves input and data constraints to modeling of surface physics (morphology, sputtering)
- Emissivity of Li coated PFC can vary significantly with temperature and morphology (under ion and impurity flux)
- Dual band approach: PFC temperature from ratio of signal in 2 wavelength ranges (e.g. 7-10µm LWIR, 4-6 µm MWIR):
  - Greatly reduced effect of variation of PFC emissivity and optic transmission
  - Successfully implemented and exploited on NSTX [McLean RSI 2012]



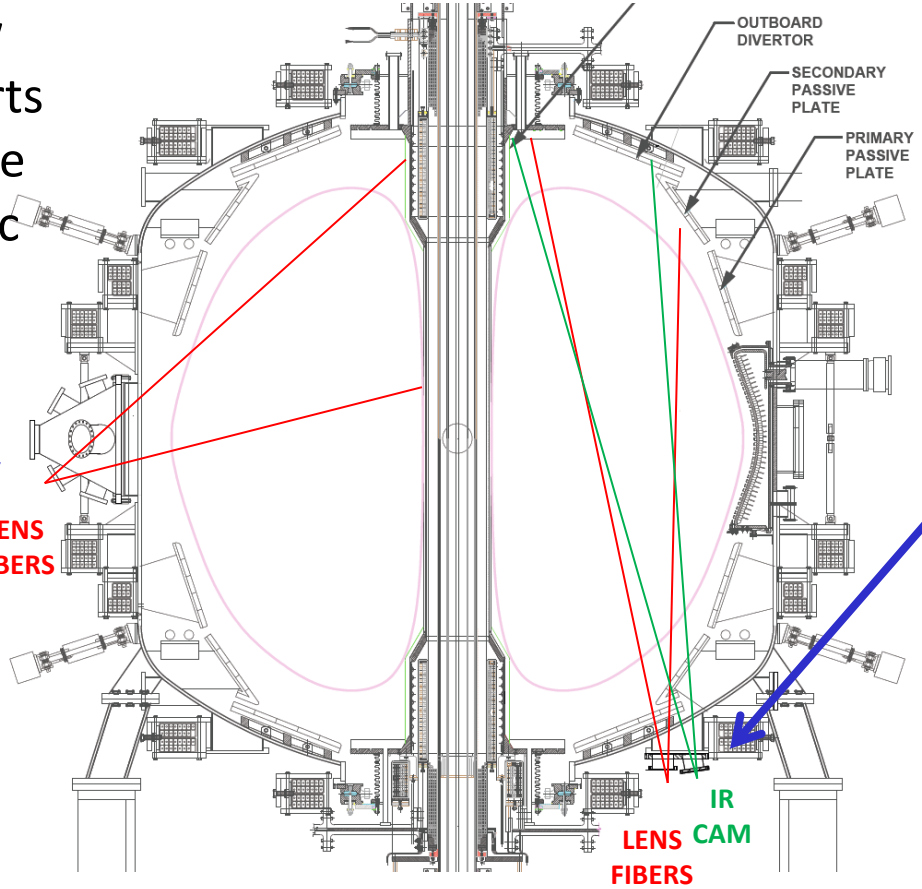
- Infrared camera FLIR
  - 60Hz, 640x480 pixel
- Dual band adapter
  - Dichroic beam splitter
  - MWIR and LWIR filters
- IR lens, 35mm, FOV 18°x14°

Diagnostic port allocation

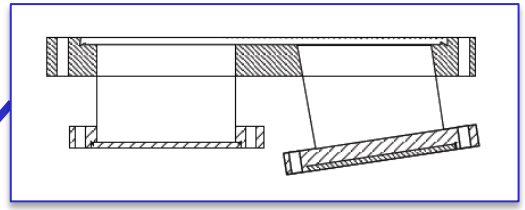
Central stack view
Two dedicated ports on Bay I/J midplane on multi-diagnostic bay port-cover



Design of multi diagnostic bay-port covers in progress



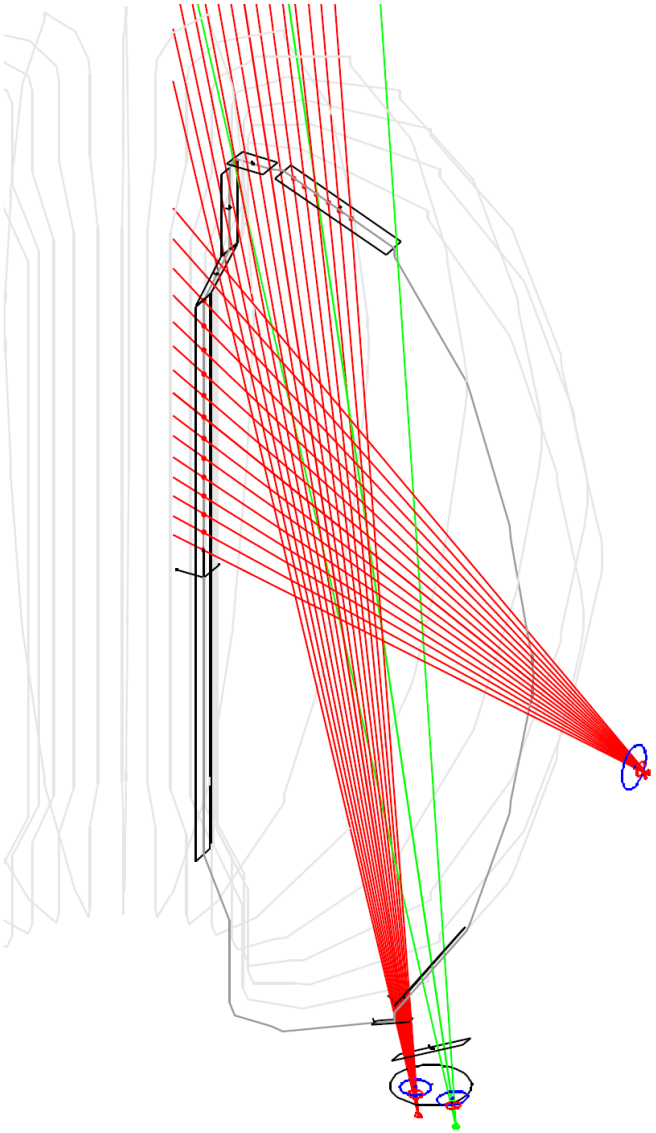
Upper divertor view
Two dedicated ports on Bay G bottom

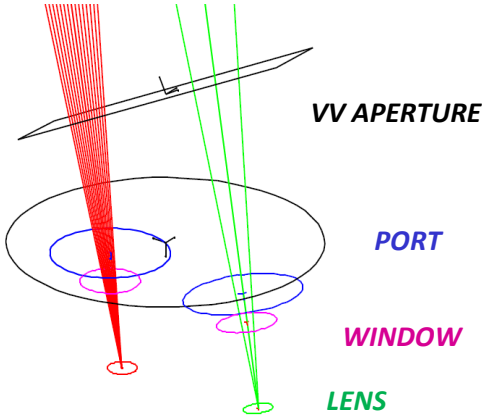


Port cover allows for reentrant windows

- 2x sapphire windows (2’’) for spectroscopy
- 2x ZnSe windows (2’’) for IR cameras

Example of observation configuration





The geometry optimized accounting for vignetting form port and vessel structures

- Upper divertor spectroscopy
  - 15 LOS, FOV 30deg
  - Radial resolution 4 cm, spot size 1.3 cm
- Central stack spectroscopy
  - 15 LOS, FOV 30deg
  - Vertical resolution 8 cm, spot size 0.6 cm
- Upper divertor infrared camera
  - Radial coverage R=0.6-1.2 m

Conclusions

- UTK is going to support the NSTX-U boundary and PWI program with key experimental data and modeling

- Project in line with ORNL boundary program on NSTX-U
  - Work on site (PPPL) in tight collaboration with ORNL staff
  - Synergistic effort for an effective and integrated diagnostic park

- NSTX-U (early) startup on Sept. 2014
  - Diagnostic calibration and installation start from summer 2013
  - Final design of diagnostic ports and allocation is being decided
  - Final configuration to be established by end of Jan 2013