Radiative Divertor Diagnostics

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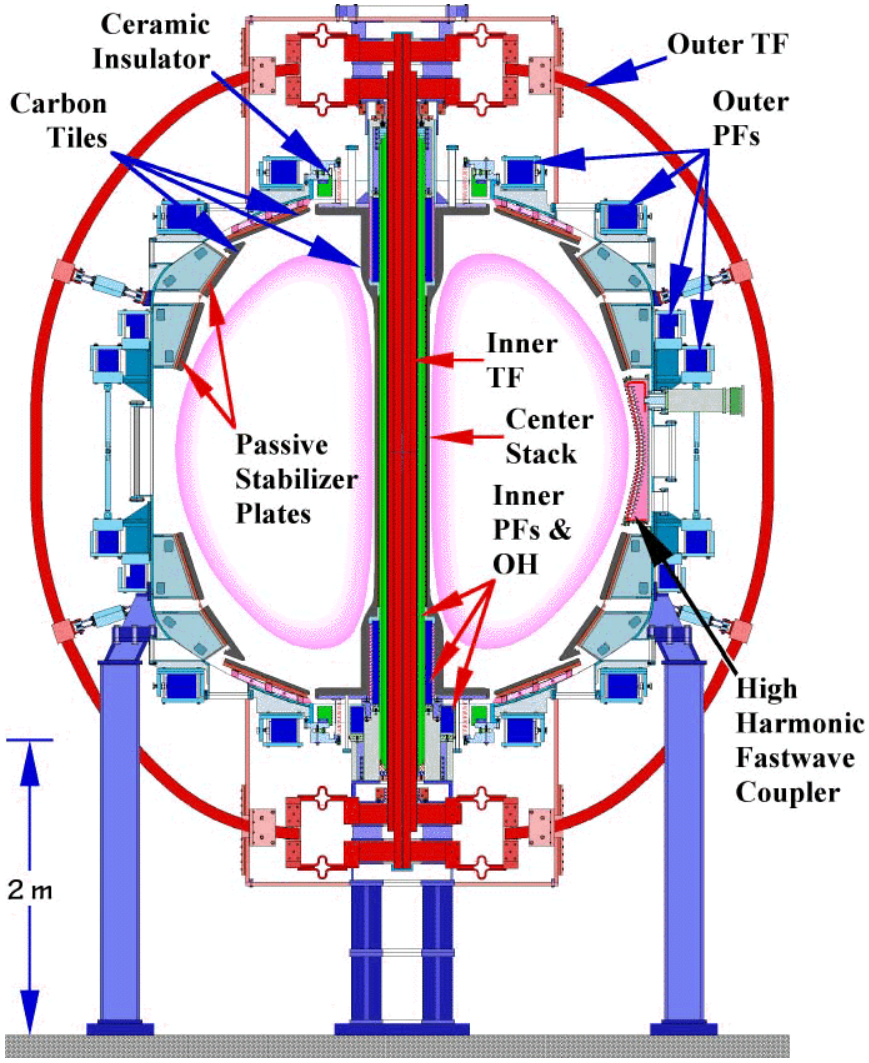
Divertor and plasma boundary research in NSTX

- The major goals of the Divertor and Boundary Physics studies are the control of impurities, efficient heat removal and understanding a role of the edge plasma that plays in the global energy confinement of the plasma.
- Implementation of diagnostics and plasma modeling are needed to understand both detached and attached divertors and their effect on the core and SOL plasmas.
- Diagnostics already installed for divertor power balance:
  - A divertor bolometer array to measure radiation along chords that pass through the divertor for emission profiles
  - Infrared cameras to measure the surface temperature from which the heat flux is derived.
  - Spatially resolved D_α camera



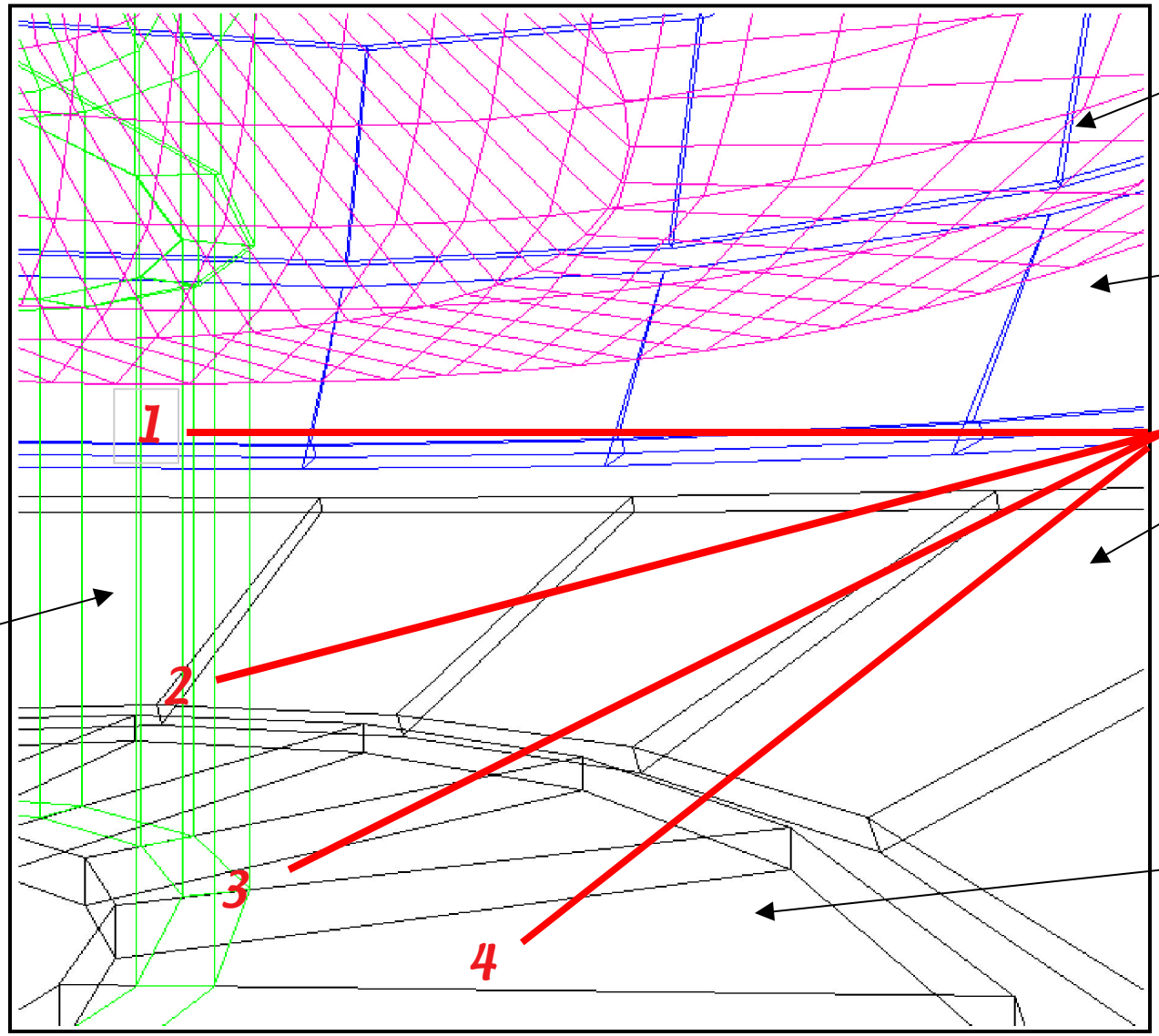
Divertor access

- *Open divertor configuration*
- *Allows viewing from midplane and between plate structures*

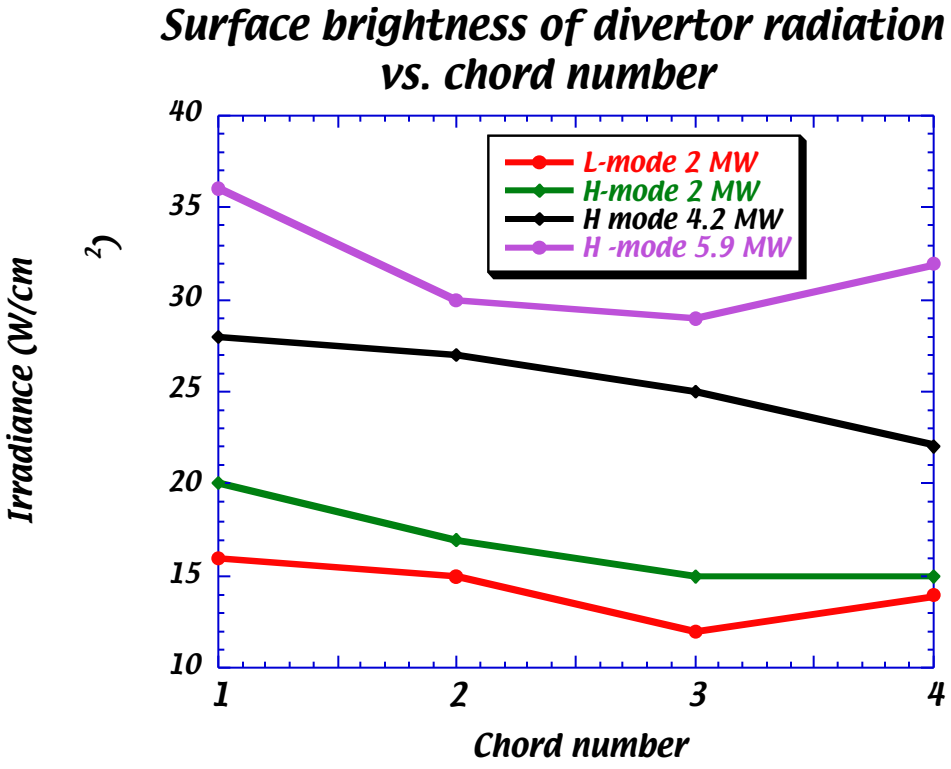
4 channel divertor bolometer array installed on NSTX

- Prototype for 12-16 channel system; similar to that used on JT-60 and ASDEX.
- 4 μm gold foil on 20 μm mica substrate, able to tolerate 160°C
- Cooling time constant is .15 sec, both a direct heat sensor and an integrator
- Array is water cooled to prevent overheating during bakeout; normal operation is at room temperature
- Highly sensitive -- 1 $\mu W/cm^2$ noise limit, measured 1,000 $\mu W/cm^2$, but noise pickup is quite high -- need to rework grounding

Divertor bolometer view:



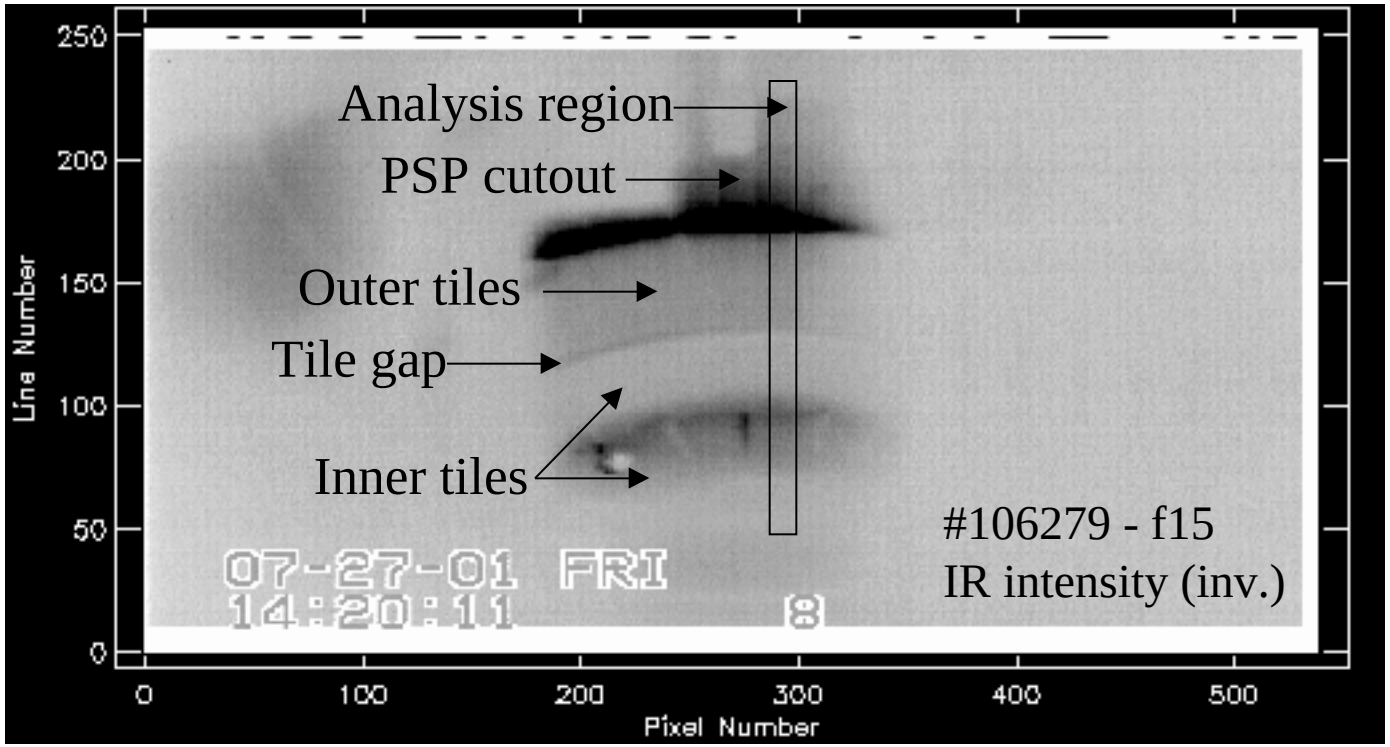
Divertor radiated power increases with NBI power in H-mode

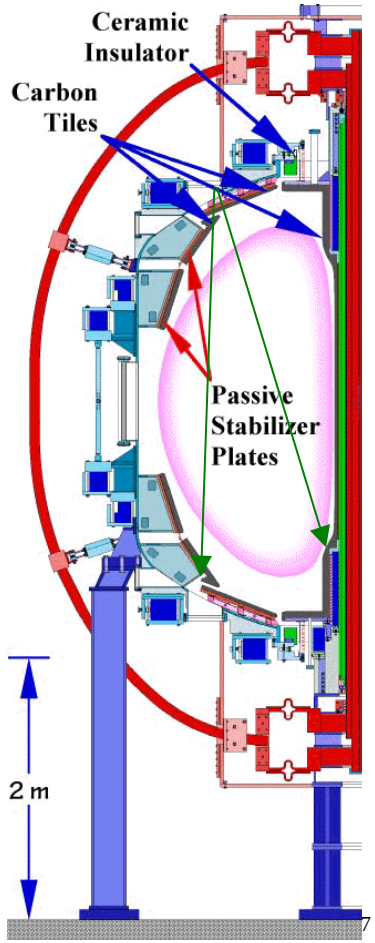


At same power level, divertor radiation is about 25% less in L-mode
Radiation profile rather diffuse
Rough estimate of divertor radiated power up to about 1 MW

IR camera view allows radial profile measurements

IR camera: 7-13 μm range, 30 Hz, 25ms thermal e-folding time, spatial resolution ~ 1 cm with present optics





Additional diagnostics being contemplated

Data needed for studying the mechanism of the SOL plasma by comparing with SOL codes (DEGAS, UEDGE):

-Multichord, multi-pulse divertor Thomson scattering system to measured n_e and T_e in the divertor (and SOL).

-Langmuir Probes Needed to determine local density, temperature, particle flux (saturation current), edge current, and floating potential

-A spatially resolving divertor spectrometer (VIS/near UV) to determine radial absolutely calibrated distributions from various atomic and low ionization states of impurities in the vicinity of plasma-facing components. Derive quantities that affect fueling, recycling, particle retention and exhaust, erosion & deposition, recombination, etc.

-Filterscopes could serve as an impurity flux monitor from different positions of the target plates.

LANGMUIR PROBES FOR THE NSTX DIVERTOR

-*Needed to determine local density, temperature, particle flux (saturation current), edge current, and floating potential*

-Comparison of a cold and detached divertor plasmas

-Need to utilize divertor code to obtain characteristics of SOL/divertor plasma data → transport studies of neutrals and carbon/oxygen impurities

- 20-30 Langmuir probes in the NSTX divertor stike plates along the inner and outer strike plates, both lower (and upper?) divertor

-Spatial separation: 30-40 mm; time resolution: 1-10 msec fast sampling; 100 msec standard

-Type: CFC, single probe, 6-8 mm diameter, 1 mm protrusion

-References:

- *D. Buchenauer, W. L. Hsu, J. P. Smith, D. N. Hill, Review of Scientific Instruments 61, 2873 (1990)*
- *N. Asakura et al., Journal of Nuclear Materials, 266-269 (1999) pp.182-188.*
- *C S Pitcher and P C Stangeby, Plasma Phys. Control. Fusion, 39 (1997) 779-930.*

Thomson Scattering for the NSTX Divertor

Use as input to boundary physics codes such as UEDGE and DEGAS.

Utilize familiar 30 Hz Nd:YAG (1 J, 15 ns, 1064 nm) lasers to measure the electron temperature and density profile

Design for high spatial resolution (0.5 cm), narrow temperature range (5 ev - 100 eV).

The scattered photons to be dispersed by five channel interference filter polychromators to cover the divertor temperature (with alternative optics for the SOL?)

Light to be detected by cooled, temperature controlled Si-APD.

References:

1 T.N. Carlstrom et al., Rev. Sci. Instrum. 63 4901 (1992).
2 T.N. Carlstrom et al., Rev. Sci. Instrum. 66 493 (1994).

VISIBLE SPECTROSCOPY FOR THE NSTX DIVERTOR

Fiber optic bundles viewing inboard and outboard strike plates each equipped with channels to observe low ionizations states of carbon and oxygen

Narrow-band (FWHM ~ 1.5- 1 nm) interference filters in each view; temporal resolution: 0.1 msec

Divertor survey spectrometers -- spectral overview along two lines of sight
Simple, flexible, low-cost spectrometer with a compact design and no moving parts

Employ Ocean Optics PC-spectrometer UV/VIS factory calibrated card, priced at $2,449
Crossed Czerny-Turner and A/D converter on preconfigured optical bench small enough fits into an ISA-bus in a PC. The result is a flexible, low-cost spectrometer with a compact design and no moving parts.
Spectral range is 200-850 nm.
2048-element Sony ILX511 linear CCD-array detector
Standard configuration: 600 lines/mm grating groove density and 25 mm entrance slit
Yields optical resolution to ~1.5 nm (FWHM).
Coupled through single-strand optical fiber via a SMA 905 connector
Minimum integration time: 3 milliseconds (with 1 MHz A/D converter)
Sensitivity: 86 photons/count