Princeton Plasma Physics Laboratory

Creating Innovations to make Fusion Power a Practical Reality

NATIONAL SPHERICAL TORUS EXPERIMENT

The need for an expanded set of divertor diagnostics in NSTX over the next few years

S.F. Paul

NSTX 5 year plan boundary physics meeting

February 12, 2006

NHTX mission requires extensive divertor diagnostics

- Divertor heat flux problem is not just a "peripheral" edge issue
- Serious physics degradation for advanced reactors including inadequate confinement, strong thermal instability, inadequate helium exhaust
- Likely to need very high radiation fraction and is a principal rationale behind NHTX
- NSTX boundary physics team needs to demonstrate strong diagnostic program to maintain a significant presence in this area

PPPL has had a history of cycling its fusion devices every 15 years

- Reasonable for physics program, but diagnostics systems are constantly being built from scratch
- In contrast other major devices, like DIII-D have built up diagnostic capabilities over a very long time
- Result in sophisticated diagnostic systems with excellent coverage
- NSTX boundary physics team needs to build a similar capability -- start immediately with at least an 8-channel tangential divertor bolometer array
- Should develop at minimum a divertor Thomson scattering and a dense array of routinely operating divertor Langmuir probles

Measuring toroidal flows in the inboard edge

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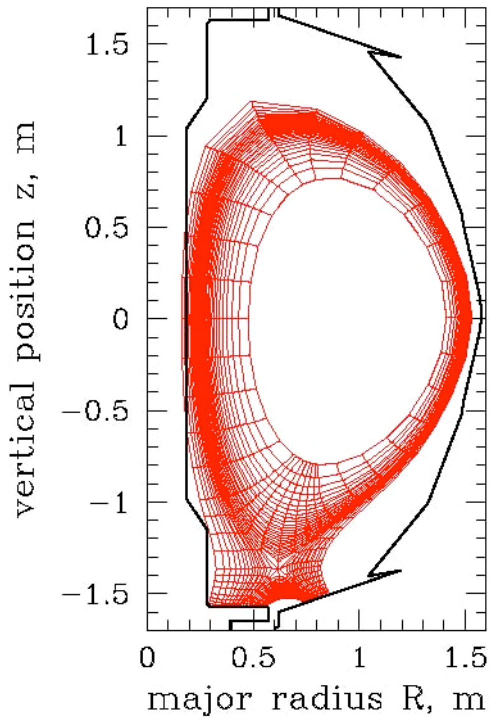
Examining parallel flows at the edge of the plasma

- Fast intermittent convective cross-field transport has been observed in the outer SOL of NSTX and other tokamaks. If this transport has a ballooning like asymmetry, it can result in near-sonic, asymmetric parallel plasma flows in the SOL.

- Parallel plasma flows can strongly affect edge plasma parameters via particles and energy flux to the inner divertor
- The flows have been simulated by A.Yu. Pigarov using UEDGE and are caused by asymmetries in magnetic configuration and cross-field transport.

Asymmetries in LSN magnetic configuration of NSTX

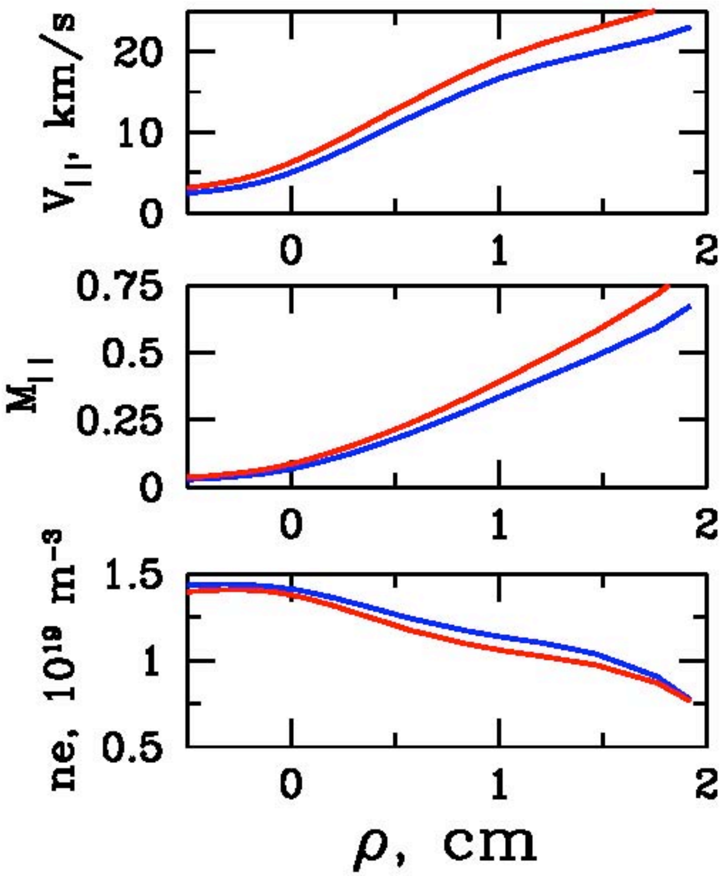


Shot #109033

In the Lower Single Null magnetic configuration, the surface area connected to the inboard SOL is much (~10X) smaller than the area connected to the outboard SOL.

Total magnetic field strength at the inner SOL mid-plane is 8-10X higher than at the outer SOL mid-plane.

The plasma flow up to M≈0.8 is predicted by UEDGE at the inner mid-plane of NSTX



Here magnetic flux surfaces are mapped to the outboard mid-plane. The inner SOL is ~2.5X broader.

At the inner mid-plane, plasma in over entire width of SOL moves down toward the inner divertor plate.

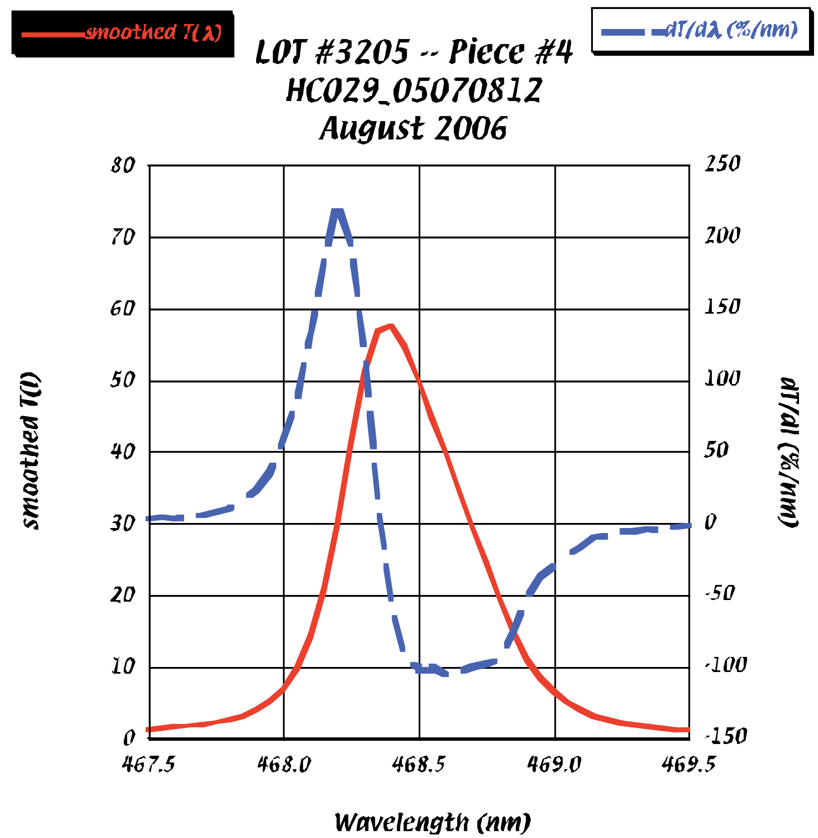
Parallel plasma velocity $V_{||}$ is 10-25 km/s.

Both $V_{||}$ and $M_{||} = V_{||} / [(T_e+T_i)/m_i]^{1/2}$ are increasing toward the chamber wall. In the far SOL, $M_{||}$ increases mostly because of increase in $V_{||}$|.

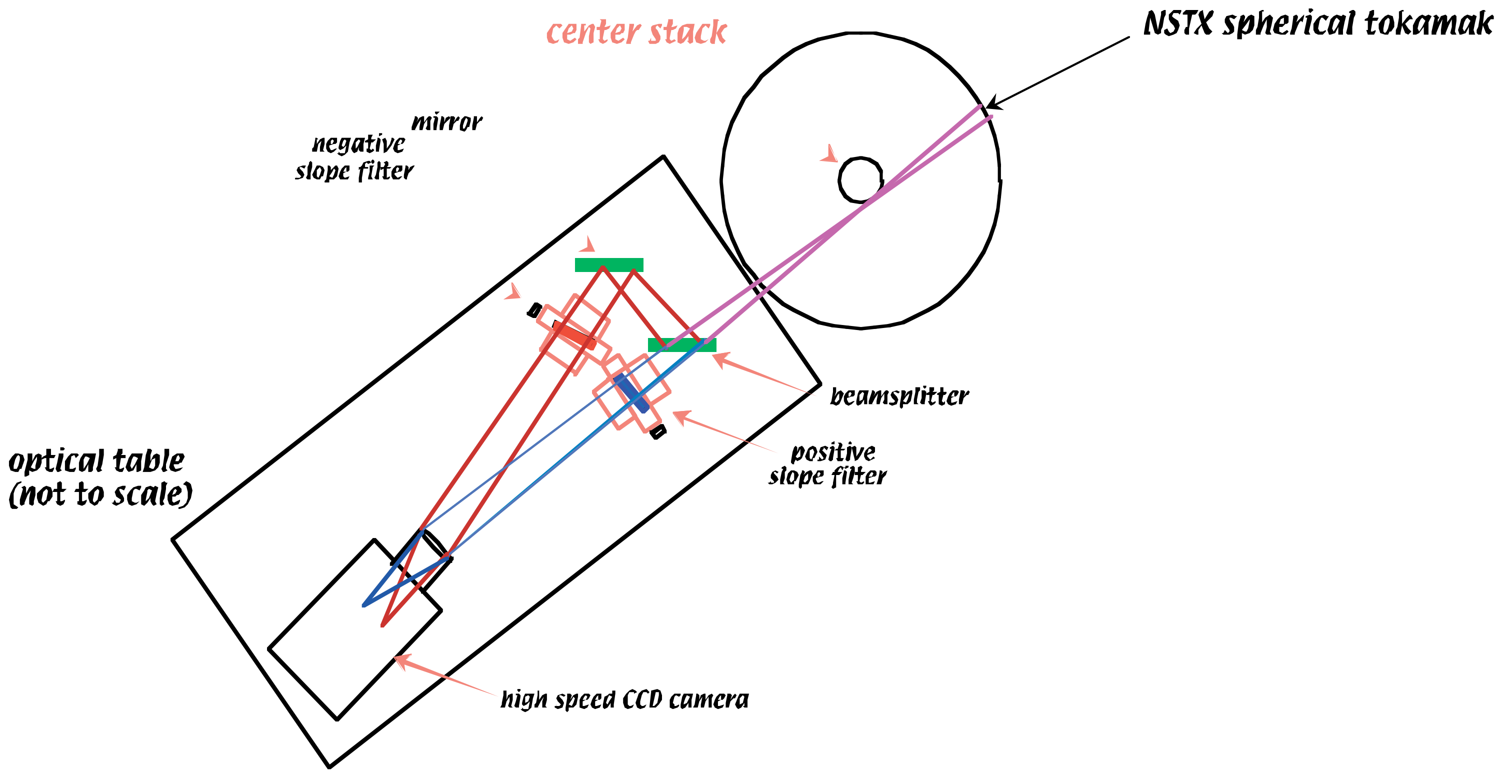
$V_{||}$ attained at inner mid-plane doesn't depend on boundary conditions at the divertor plates.

Crossed interference filters
($3K each from Barr Associates)

- *3-cavity filters; .6 nm bandwidth*
- *Linear over 0.4 nm*
- *$T_{peak} \geq 60\%$*
- *Tune center by tilting*
- *Temperature controlled to < 0.1° C*
- *Rejects O II at 469.9 nm*



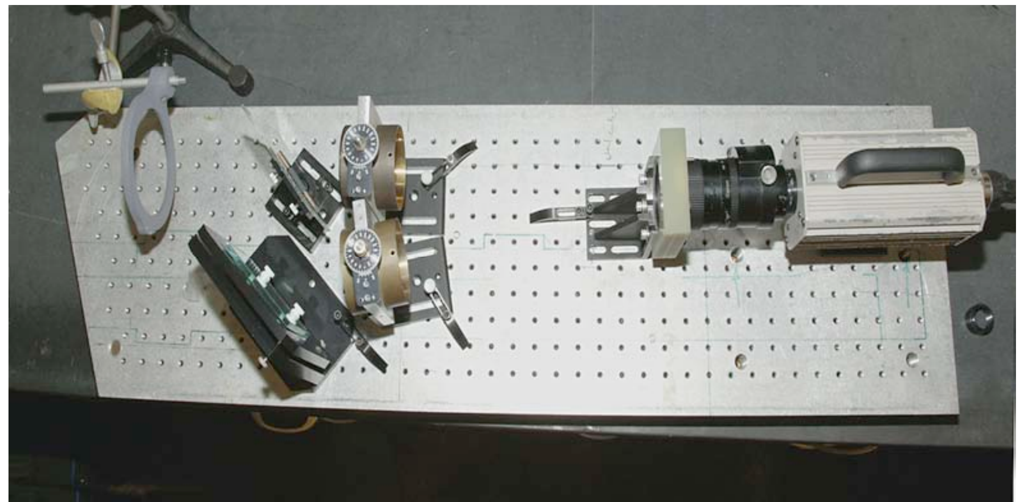
Experimental Setup on NSTX

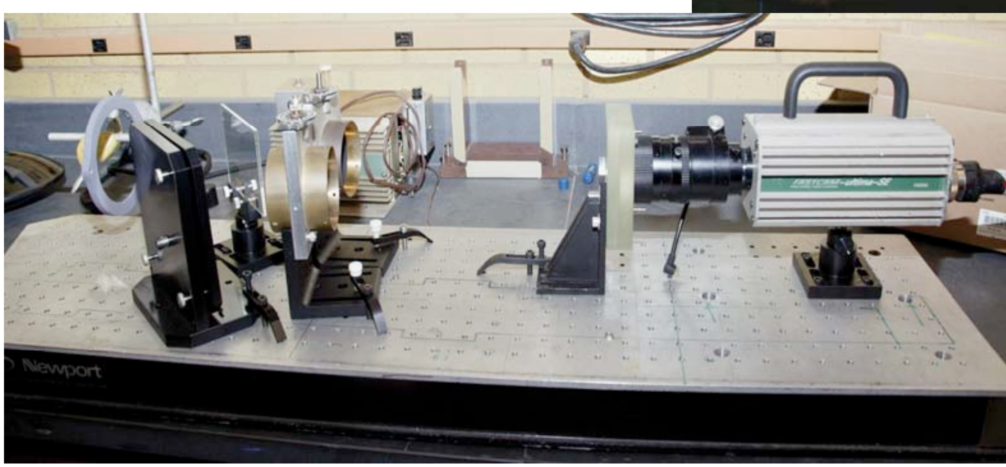


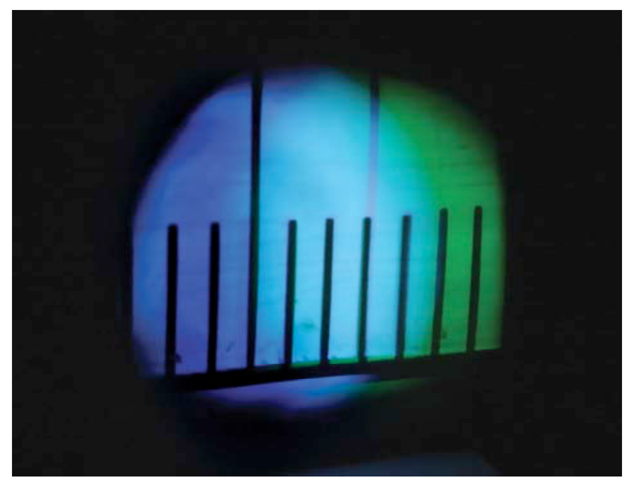
- Apparatus is designed so both detectors view the identical volume of plasma
- Filters are tilt-adjusted to isolate the region of flattest slope of transmission band
- Effect of changing plasma intensity is removed
- Filters are temperature stabilized with a controller that maintains T within 0.1°C

Bench set-up with camera from Hiroshima Univ.

- A high frame-rate Photron Ltd. U1tima SE CMOS digital camera views He II line emission at 468.6 nm at the edge of the center stack.
- A preliminary optical system was bench-tested and the lens used can image a 20 x 20 cm region of the plasma with 3 mm spatial resolution.







Try-out last run with camera

- From data taken when viewing through a He II interference filter, the light level in helium discharges in NSTX is adequate to make observations at 1,150 frames per second.
- Preliminary data taken to observe light levels in an NSTX discharge (2 MW NBI) with helium gas puffing
- Camera lent through courtesy of R. Maqueda of Nova Photonics.