NSTX

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Turbulence and Transport TSG Group Meeting

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B252 Sep. 8th, 2011

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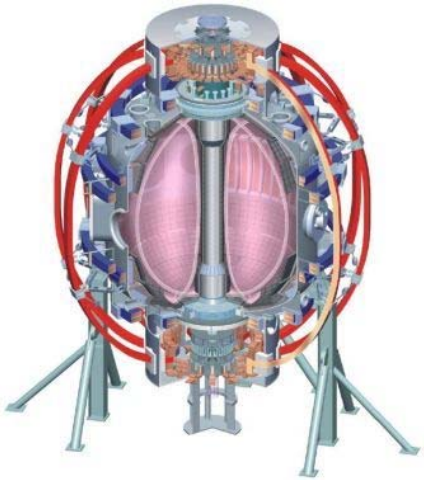

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Meeting Goals

- FY14-18 5-year plan goals for T&T TSG (this meeting)
  - With your input, we will modify/append/question the goals
- "Best" diagnostic needed to support achieving each agreed upon goal (this meeting or to be scheduled next group meeting) and guidance for Jon:
  - Ability of a diagnostic to support goals of multiple TSGs
  - Development and implementation cost and schedule
  - (related to above) - impact on vessel, port requirements
  - … others you think are important

Introduction

- The major goal of NSTX-U is to explore ST as a viable concept for FNSF/Pilot

- In order to project the performance of FNSF/Pilot, we need to understand the underlying mechanisms for
  - Particle/impurity transport
  - Momentum transport
  - Thermal transport
  - L-H transition

- Note that with the accelerated upgrade plan, NSTX will be back to operation in FY14

Draft Goals (from Jon)

- FY 14:
  - Implement new high-k system
  - Measure low-k turbulence response to reduced ν^* at higher Ip and Bt in Upgrade
- FY 15:
  - Measure high-k turbulence at reduced ν^* at higher Ip and Bt to determine modes responsible for e-transport, utilize global confinement trends to project size and power requirements for FNSF/Pilot
- FY 16:
  - Compare low-k and high-k turbulence to measured diffusivity trends to determine dominant instabilities for e-transport and i-transport
- FY17:
  - Utilize turbulence understanding and ST confinement trends to finalize FNSF/Pilot size, power requirements
- FY18: ?

Some Thoughts and Needs of YOUR Input

- Add FY12 JRT tasks: multiple-channel transport and comparison with simulations
- Add elements of comparisons with numerical codes
  - The effort of validating numerical codes can contribute to conventional tokamaks
- Add specific goals for each physics topic:
  - Particle/impurity transport
  - Momentum transport
  - Thermal transport
  - L-H transition
- Inputs from experts in each topic are essential

Prioritization Aiming at Identifying Critical Diagnostics

- Should we prioritize physics topics first (1st, 2nd priority etc.)?
  - Particle/impurity transport
  - Momentum transport
  - Thermal transport
  - L-H transition
- Then prioritize proposed goals within each topic
- Diagnostics supporting a particular goal will receive the same priority of the goal
  - More goals supported then the higher priority, but does not move 2nd priority to 1st priority

Proposed Diagnostics

- BES with expansion and increased resolution
- Ion temperature and velocity fluctuation measurement with BES optics
- Doppler backscattering (DBS)
- Radial polarimetry
- Cross polarization scattering for B fluctuations
- Phase Contrast Imaging (PCI) for NSTX-U
- 3-D Gas puff imaging diagnostic (presentation)
- 2D wavenumber spectra measurement via high-k scattering (presentation)
- FIReTIP (presentation)
- Upgraded reflectometer array (presentation)
- ME-SXR (presentation)

Backup slides

BES: Expansion and Increased Resolution

D. Smith, R. Fonck, G. McKee, I. Uzun-Kaymak, *University of Wisconsin*

- BES provides low-k ñ fluctuation measurements (0.1<r/a<1) for:
  - Turbulence and transport investigations
  - Energetic particle-driven mode/GAE studies
  - Pedestal structure and instabilities
- Increase number of channels from 32 to 64 (32 new detection channels)
  - Simultaneously sample wide region of plasma
  - Extended poloidal capability (L_c~10 cm)
- Implement wide-field 2D (~8x8) capability (new fiber bundles/mount)
  - Turbulence imaging; direct shear flow measurement; nonlinear analysis
  - 2D correlation, wavenumber spectra, velocimetry
- Increase spatial resolution (smaller viewing spots)
  - Currently ΔX~2.5 cm; decrease to ΔX~1.5-2 cm (access higher-k)
  - Pedestal studies can especially benefit
- Measure toroidal mode # of pedestal instab. (PB/KBM), zonal flows, xAEs
  - Exploit new neutral beam injection system
  - Add toroidally-displaced viewing channels; also, measure background signal

Ion Temperature and Velocity Fluctuation Measurement

D. Smith, R. Fonck, G. McKee, I. Uzun-Kaymak, *University of Wisconsin*

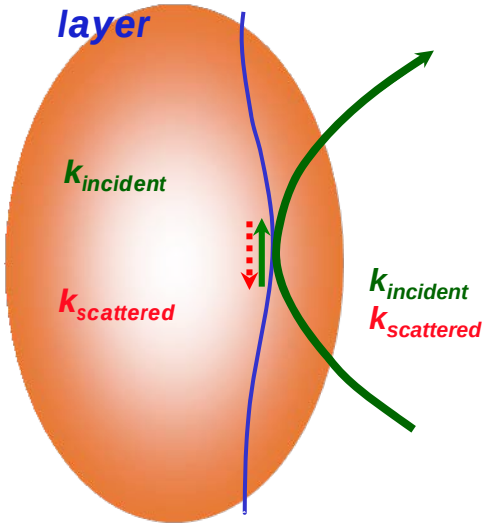
- T_i fluctuation measurements can provide crucial data for:
  - Basic turbulence characterization
  - Turbulence mode identification
  - Testing & validation of nonlinear simulations
  - Turbulent transport (correlated with ñ & ˜v)
  - Fast T_i/rotation changes at L-H transition, pedestal and ITB development
- Very fast, high throughput CHERS-style diagnostic
  - Observe CVI (n=8-7) at 528-530 nm
  - Utilize high-throughput BES optics
  - Exploit new high-efficiency transmission grating spectrometers
    - ~80% grating efficiency
    - Large-area Prism-coupled gratings provide sufficient dispersion
  - Cooled-APD detectors
    - Custom-designed low-noise preamplifier circuits
- Currently developing and testing prototype UF-CHERS at DIII-D

Doppler backscattering (DBS): Determine E_r, GAMs, zonal flows via Doppler shift of scattered data: Scattered power gives fluctuation levels

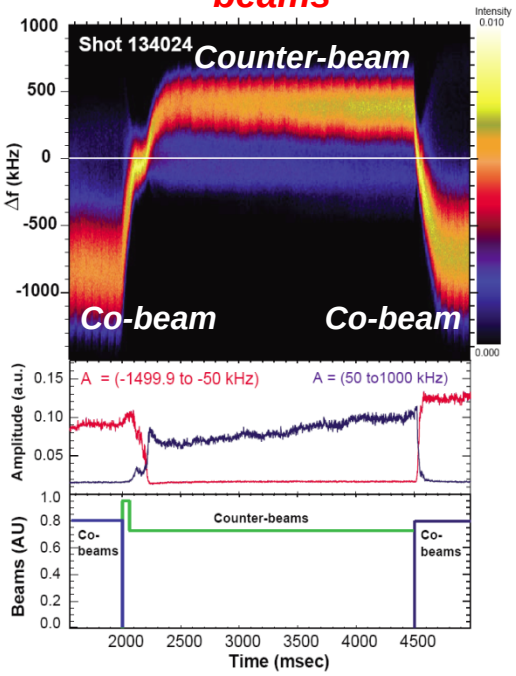
- DBS locally measures scattering from intermediate scale turbulence
  - Doppler shift provides information on turbulent flow (~E_r), GAMs, etc.
  - Scattered power provides info on turbulent fluctuation levels at intermediate-scale wavenumbers

DBS on NSTX requires a flexible antenna arrangement to probe in plane perpendicular to magnetic field.

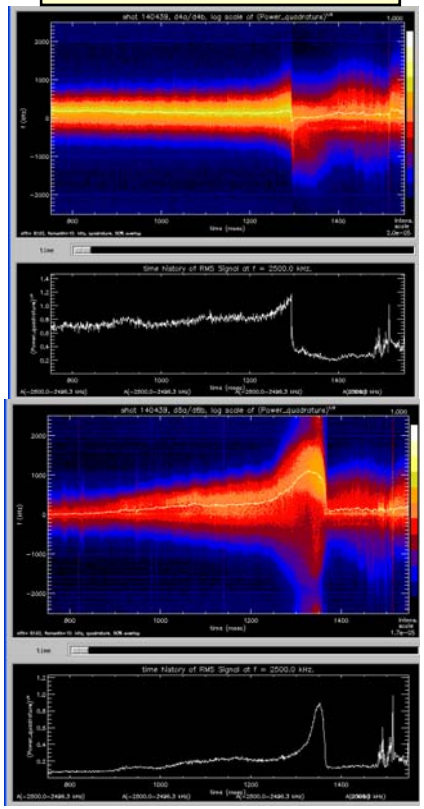
X-mode cutoff layer



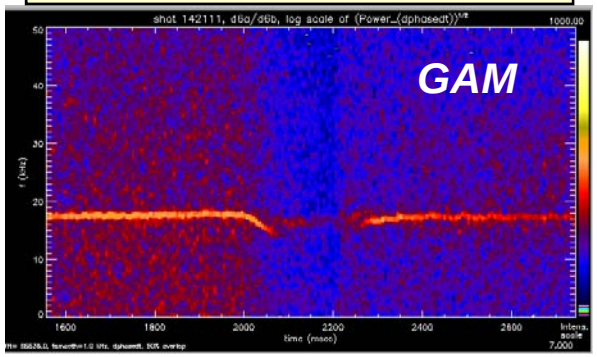
Quadrature data for co- and counter beams



Quadrature data for L-H transition



Phase analysis of DBS data reveals the GAM

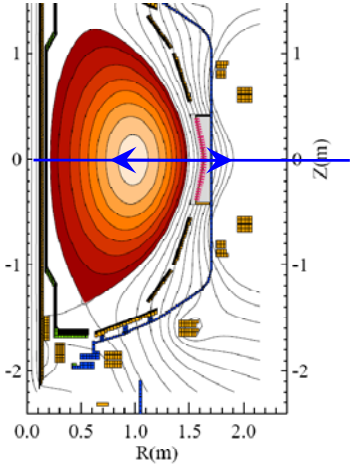


Radial polarimetry: Direct measurement of magnetic field fluctuations: constraint on central q; can operate as radial view "simple" interferometer

Radial view is insensitive to density fluctuations as long as measurement close to mid-plane - where the equilibrium B_{ll} is small

Use simulated magnetic and density fluctuations associated with micro-tearing modes (Walter Guttenfelder) as input to calculate expected polarimetry signal

Results indicate that internal direct measurement of magnetic fluctuations is possible in NSTX



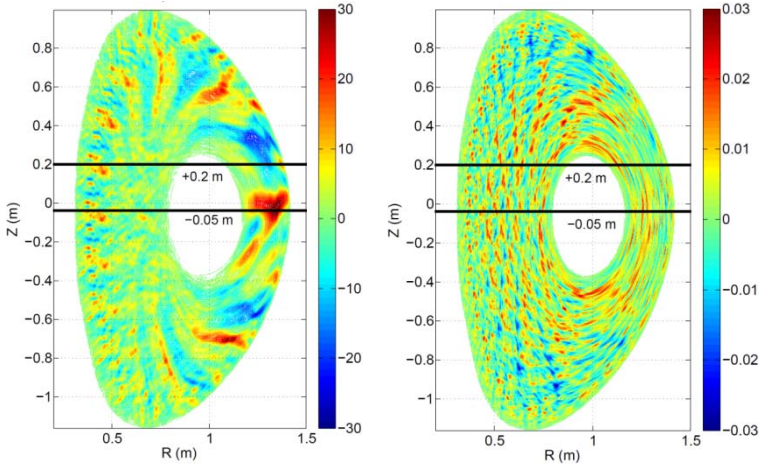
- *Radial-view, retroreflects from center-stack tile*
- *Prototype single channel system to be installed in early August*

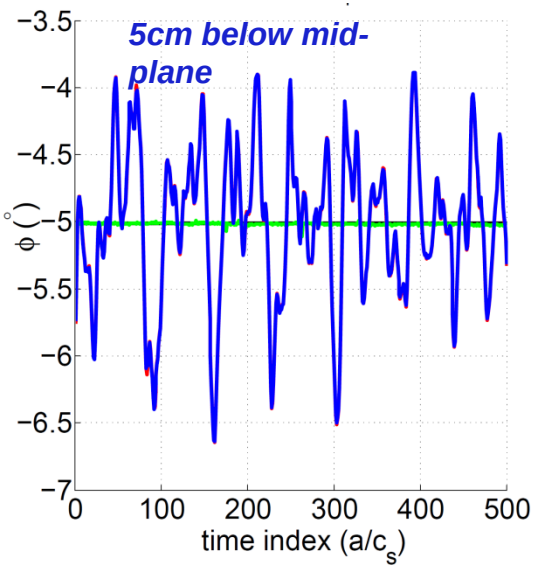
$$\Psi = 2.62\times10^{-13}\,\lambda^2 \int B_{\parallel}(z)n(z)dz$$

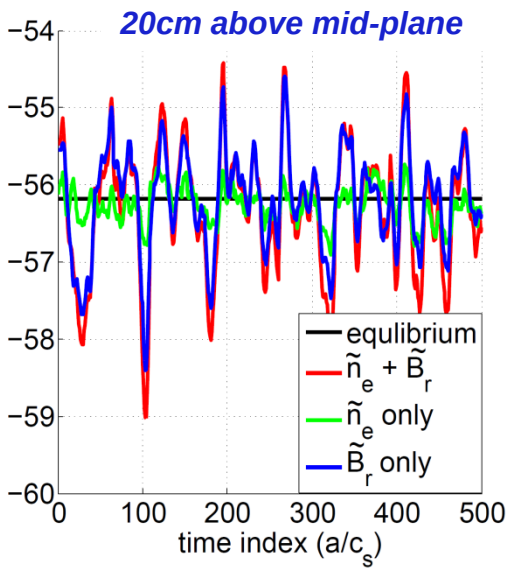
$$\Psi = \Psi_0 + \tilde{\Psi}$$

$$\tilde{\Psi} = 2.62\times10^{-13}\,\lambda^2 \int \left[\tilde{B}_{\parallel}(z)n_0(z) + B_{\parallel,0}(z)\tilde{n}(z)\right]dz$$

$\tilde{B}$ $\tilde{n}$







Cross polarization scattering for B fluctuations

D. Smith – UW-Madison

- Magnetic fluctuations ($B_\perp$) scatter EM waves and change the wave polarization
  - $B_\perp$ fluctuations induce O->X or X->O mode conversion
  - Density fluctuations preserve polarization
  - Cut-off layers can reduce/eliminate contamination from density fluctuation scattering
  - Vahala, Vahala, and Bretz, PoFB 4, 619 (1992)
    Zou et al, PRL 75, 1090 (1995)
    Mase et al, RSI 68, 454 (1997)

Phase Contrast Imaging (PCI) for NSTX-U

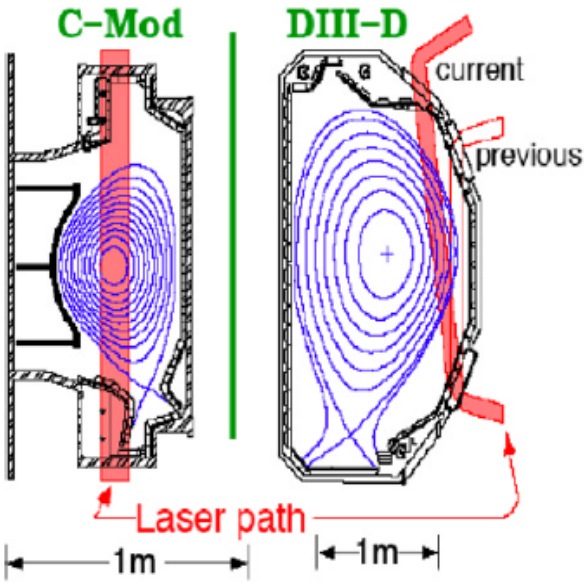
- Idea: Phase Contrast Imaging (PCI) to measure density fluctuations over a broad wavenumber range that could *fill the gap between, and overlap with,* BES ($k_\perp$<1.5 cm^{-1}) and high-k scattering ($k_\perp \geq 10$ cm^{-1})

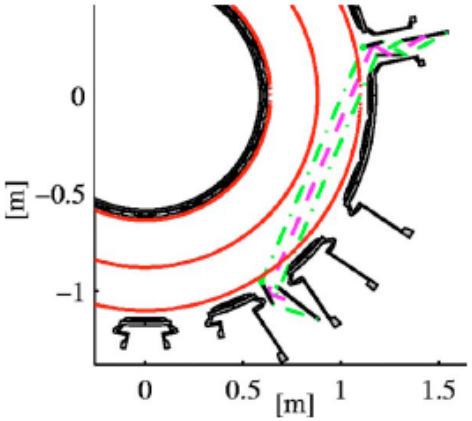
- Physics motivation: May expect to see changes in this presently unmeasured range of k-space as mode dominance varies between low-k (ITG/TEM/microtearing) and high-k (ETG) instabilities

- Resolution: $k_\perp$~0.5-30 cm^{-1}, >1 MHz

- Requires CO2 laser, ZnSe phase plate, 1D (or 2D) array of LN_2 cooled HgCdTe photoconductors
- Vertical (DIII-D, C-Mod, LHD) or tangential (CDX-U, TCV) views plausible, ~10-20 cm beam width
- Localization possible due to strong local **B** shear and $k_\perp >> k_{||}$
- Synthetic diagnostics developed for comparison with GK codes (Rost et al.; Ernst et al.) – could try out on NSTX sims for feasibility study

- Supports 5 year plan to "*measure low-k and high-k turbulence, compare with transport trends, validate with gyrokinetics, inform confinement projections to FNSF/Pilot*"
- Well suited for university collaboration [e.g. MIT; K. Tanaka (NIFS) *et al.* is ready and willing to support design study]





r online) Top view of the TCV tokamak showin