Results from the NSTX MSE-CIF diagnostic

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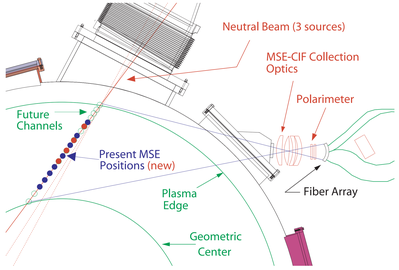
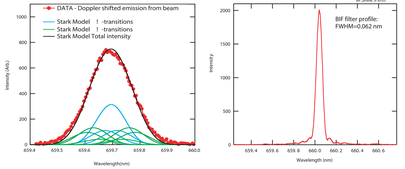
A 12 channel (16 planned for 2007) Collisionally-Induced Fluorescence Motional Stark Effect diagnostic, covering the plasma minor radius on the outboard side, is routinely operated for the primary purpose of providing internal magnetic pitch angle measurements for equilibrium reconstruction. Magnetic reconstructions using MSE data for reversed shear discharge have been made possible through LRDFIT (Menard), making studies of RS discharge transport possible. Fast MSE data is sensitive to localized density and field angle perturbations and its use to complement soft Xray and magnetics data for the study of MHD is explored.

While the NSTX MSE-CIF requires the use of novel high-throughput, narrow bandpass (0.07 nm) Lyot filters to operate at low magnetic field (0.3-0.55T), a traditional PEM based polarimeter is still used to make the angular measurement. The polarimeter is calibrated by reconciling MSE measured angles with magnetic reconstructions during beam injection into gas-fill-torus with vacuum fields. It has recently been suggested that fast ions resulting from ionization of the beam neutrals with the fill gas may contaminate the measured angle by emitting additional Balmer-alpha after re-neutralizing via charge-exchange. Initial results from 3D-2V simulations of this widely used MSE calibration technique are presented.

Diagnostic Upgrades and Status

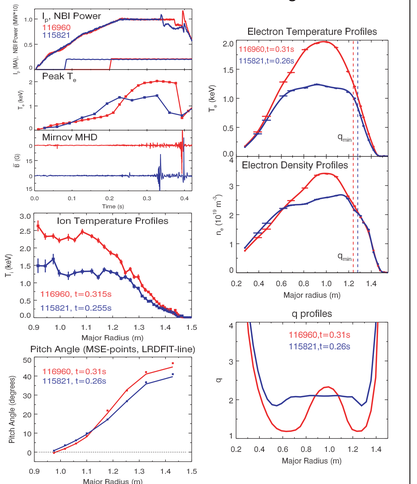


- 4 new channels installed and calibrated for a total of 12 during 2006 run
- 4 additional channels planned for 2007
- Plasma well diagnosed by MSE from magnetic axis to near the edge
- In-between shot analysis of MSE data automated
- New digital lockins implemented featuring:
  - High accuracy PEM (photoelastic modulator) reference frequency
  - FFT windows containing integral PEM (photoelastic modulator) cycles
  - Overlapping Hanning windows minimizes apodization & conserves power
  - Low prime factors FFT sample windows speeds analysis (all chans <2 min)
  - Standard deviation of polarimeter reduced by a factor of 2 to ~0.08°
- Gas-filled torus calibration agrees with first principals geometric calculations and polarimeter modeling
  - Calibration error ~0.12°



Low field on NSTX requires high throughput, high spectral resolution filter to resolve Stark multiplets. Polarization fractions would be ~1-2% with interference filters vs. ~40% with birefringent Lyot filters

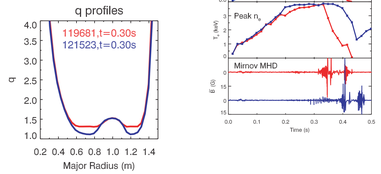
Transport improvements in Reversed Shear Discharges



- Improved transport observed in L-mode reversed shear discharges
- 58% increase in core T_e from low shear to reversed shear q-profiles
- Comparison is between MHD quiescent discharges
  - No significant MHD measured on Mirnovs, soft Xray, or MSE
  - Reversed shear profiles more robust to MHD activity
- Effect can be shown between different discharges and within a single evolving discharge
- Interpretation of high-k fluctuation data progressing (see D. Smith QP1.12)
- Transport simulation calculations ongoing, ITG/TEM turbulence E×B stablized. Examining microtearing and ETG modes.
- See Invited Talk by Levinton for more results (ZI1.3)

Lithium Evaporation Effect on Reversed Shear Discharges

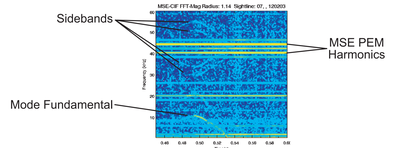
- Improved RS high performance duration, longest RS pulse
- Little effect on q-profiles, T_e
- Core density is not decreased, but held constant
- β limiting MHD at mid radii may be delayed by better density control



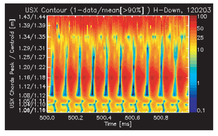
Fast MSE can be used as MHD diagnostic

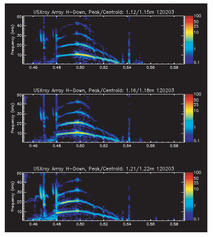
- Fast MSE data is sensitive to density and pitch angle fluctuations[1,2]
- Amplitudes of $\tilde{\gamma}$ and $\tilde{n}_e$ can be determined using fundamental and sidebands
- Planned improvements to MSE filter transmission will increase sensitivity
- Recent work reveals relative phases of sideband to fundamental necessary

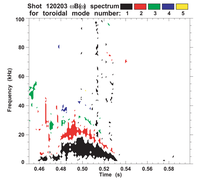
[1]F.M.Levinton, A. Fredriksen, RSI **75**, 4162
[2]R.J. Jayakumar, M.A. Makowski, S.L. Allen et. al. RSI **75**, 2995

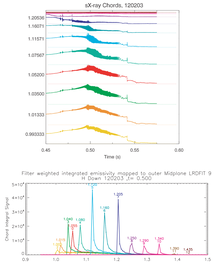


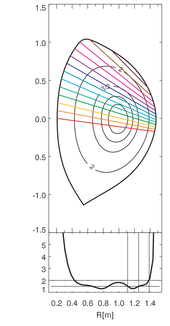
- Combined with toroidal Mirnovs and soft Xray data, mode numbers and fluctuating quantities and amplitudes can be quantified
- Poloidal sXray chords are line integrated and sensitive to n_e^2, Z_{eff}, and $f(T_e)$











- Soft Xray line integrated data is mapped to midplane using MSE constrained reconstruction
- Xray emissivity calculated using measured n_e,T_e, and Z_{eff} profiles
- Line integration of filtered signal shows good localization, can deduce m

MSE Gas-filled Torus Calibration Simulation

Procedure is widely used on polarimeter based MSE systems (NSTX, DIII-D, JET, C-Mod, Tore Supra, TFTR) with varying degrees of success

Method provides primary absolute calibration of NSTX system with results consistent with geometric, polarimeter modeling, and plasma measurements

C-Mod shows large discrepencies (>20°) between calibration and plasma measurements

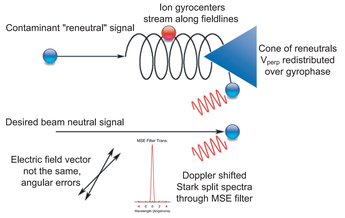
Secondary neutrals ("reneutrals") emission from attenuated beam neutrals has been seen in C-Mod beam-into-gas spectra and can explain calibration trends and angles quantitatively (see Ko, QP1.58)

For perpendicular beam injection, as is the case on C-Mod, the ion density can be estimated trivially because the gyrocenter velocity is negligible

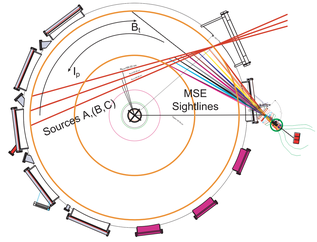
The equilibrium ion to beam neutral density ratio is simply the ratio of ionization to charge exchange cross sections

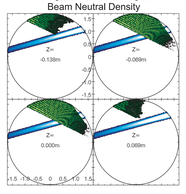
For tangential beam injection, the situation is complicated

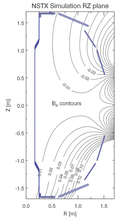
A simulation for arbitrary and real machine geometries is under way



NSTX Geometry Setup



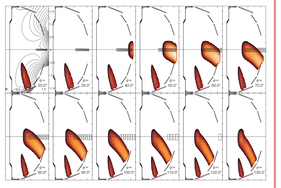




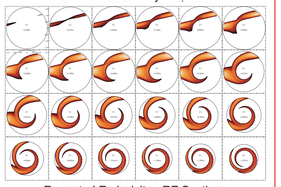
Preliminary Simulation Results for NSTX

Low Pitch Angle

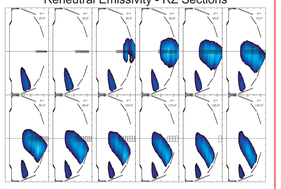
Reneutral Birth Density - RZ Sections



Reneutral Birth Density - Rϕ Sections



Reneutral Emissivity - RZ Sections



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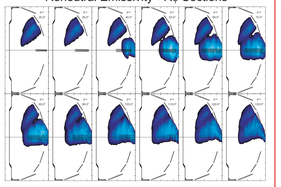
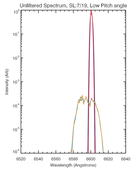


Spectrum with reneutrals
Low pitch angle



High Pitch Angle

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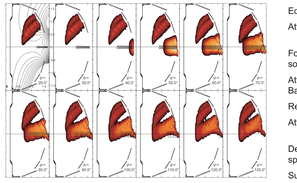
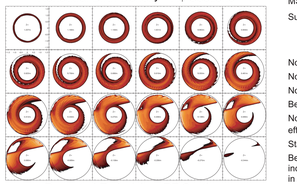
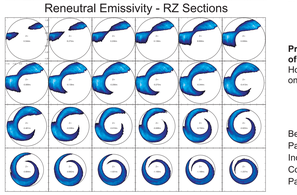


Reneutral Birth Density - Rϕ Sections



Reneutral Emissivity - RZ Sections



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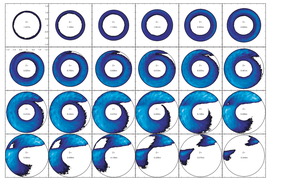

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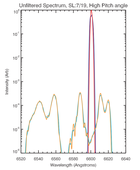

Simulation Outline

- Equilibrium solution of all quantities
- Attenuate beam along pathlength→ ion birth rates
- Follow ion gyrocenters along fieldline with drifts, solve for ion continuity along fieldline
- Attenuate ions along ion pathlength using Balmer-α production CX
- Redistribute v_{perp} over gyrophase
- Attenuate excited reneutrals along pathlength
  - Finite decay lifetime = 3.3cm decay length
- Determine Stokes vector, Doppler shift, Stark splitting for all emissive elements in SL volume
- Sum all multiplet lines for unfiltered spectra
- Pass each emissive elements' spectrum through MSE filter for Stokes vector intensity
- Sum all Stokes vectors for MSE observed angle

Simulation Assumptions

- No recycling
- No slowing down
- No beam beam reactions
- Beam divergence not included
- No tertiary effects (will be necessary if secondary effect large, but if secondary effect is large...)
- Statistical upper state distributions
- Beam excitation population not modeled (will include Foley's CRISP collisional-radiative model in the future)

Preliminary results show insignificant effect of reneutral contamination for NSTX. However, resultant spectra shows dependencies on field topology and gas pressure.

Future Work

- Benchmark code against limiting cases
- Particle conservation audit
- Include additional machine geometries
- Convergence tests
- Parameter scans