Generation of Synthetic Data for 2D BES Turbulence Diagnostic on MAST

Gryokinetic in Laboratory and Astrophysical Plasmas

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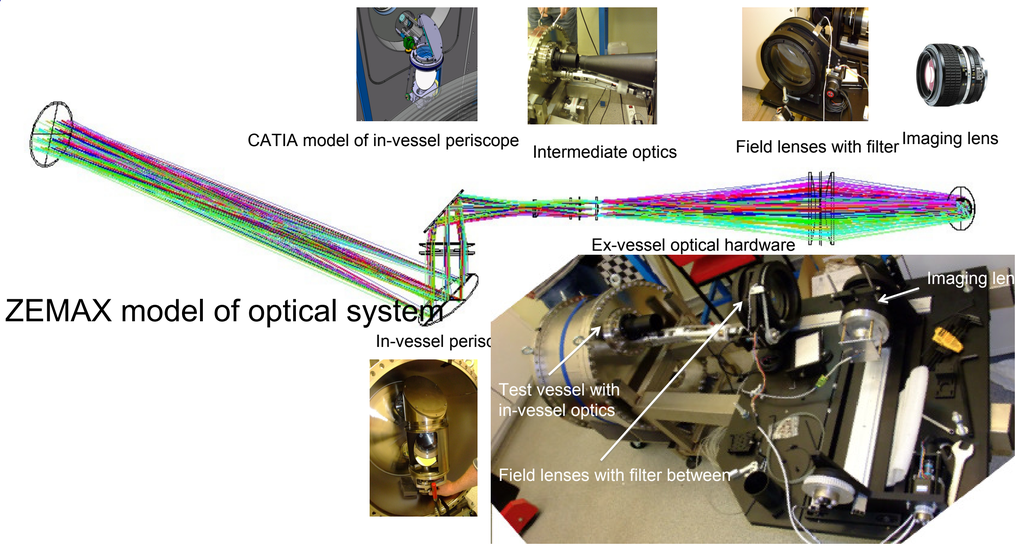
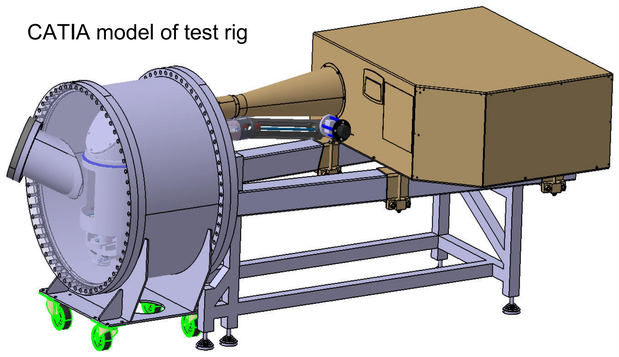
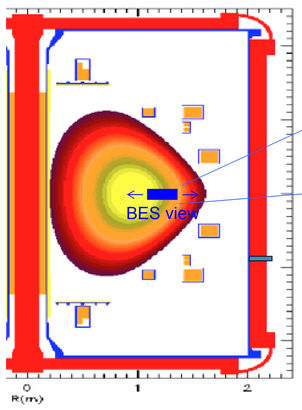
1. MAST 2D BES SYSTEM

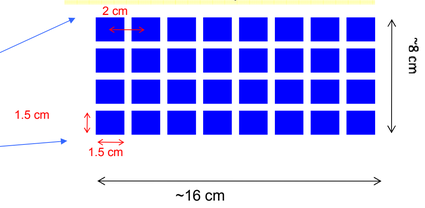


CATIA model of test rig





Detector: 8 radial x 4 poloidal channels



Radially: movable
Polidally fixed (Z = -3, -1, 1, 3 cm)

Detector: Avalanche Photo Diode
Nyquist Frequency: 1MHz

This system is installed on MAST in 2010.

2. HOW DOES BES WORK?

BES detects photons released from excited neutrals.

Inject neutral beams into hot plasma (usually to heat plasmas)

↓

Neutrals collide with electrons, ions and impurities

↓

Excited neutrals are populated

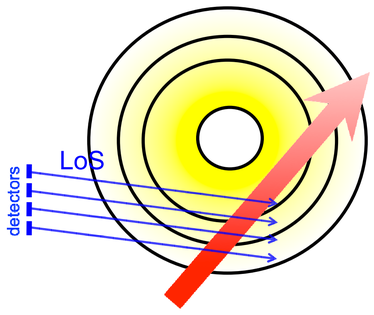
↓

Radiative decay (Emission of fluorescence)

↓

Detect and count emitted photons (typically D_α)

Tokamak top view



The number of detected photons carry information:

$$\frac{\delta I}{I} = \beta \frac{\delta n}{n}$$

I: the number of detected photons
n: the plasma density
β: some constant (= 1/3) determined by atomic physics

3. FACTORS INCLUDED IN SYNTHETIC BES DATA

➢ Emission (interaction of beam with plasmas)

-Beam flux attenuation as the beam penetrates plasma (collisions between beam and plasmas)
-Beam cross-section profile (divergence of beam)
-Beam excitation rate
-Atomic transition time (finite half-life of the D_α)

➢ Collection

-B-field topology along LoS
-Optical light cone size along LoS
-Optical magnification factors along LoS
-LoS integration of the Doppler shifted D_α emission
-Etendue (conserved quantity for a given optical configuration)

4. GENERATING SYNTHETIC BES DATA

➢ Beam Profile

- Beam attenuation along beam path

$$\Gamma_j(l_j) = \Gamma_j(l_{j-1})\left(1 - R_j \frac{\Delta l}{v_{bj}}\right) \quad \text{where } R_j = n_e \langle \sigma v \rangle_{bs,j} \text{ is the beam stopping rate}$$

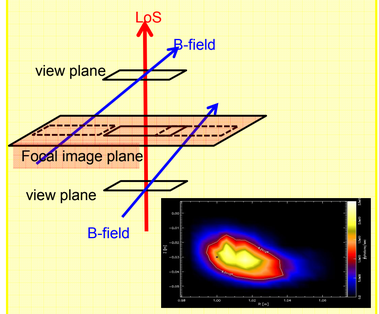
- Beam cross-section profile

$$n_{bj}(l_i, y, z) = \frac{\Gamma_j(l_i)}{\pi v_{bj} W_{yi} W_{zi}} \exp\left[-\left\{\left(\frac{y}{W_{yi}}\right)^2 + \left(\frac{z}{W_{zi}}\right)^2\right\}\right] \quad \text{where } W_{yi,zi} = W_{y0,z0} + 2 l_i \tan\left(div_{y,z}\right)$$

- Beam excitation rate: Emissivity

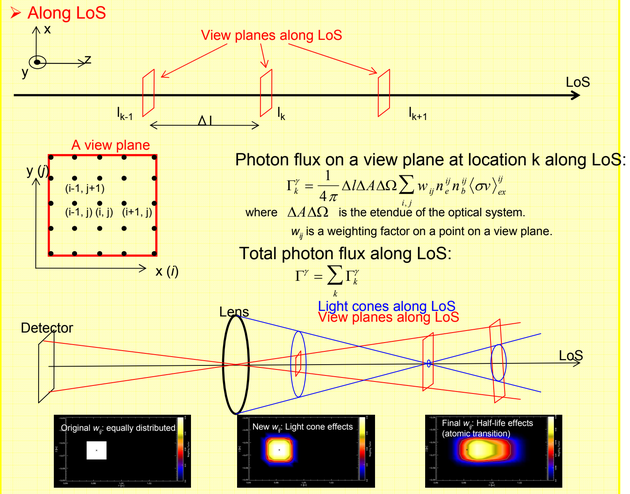
$$\varepsilon_j(y, z, l_i) = n_{bj}(l_i, y, z) n_e \langle \sigma v \rangle_{ex,j}$$

➢ B-field Effects

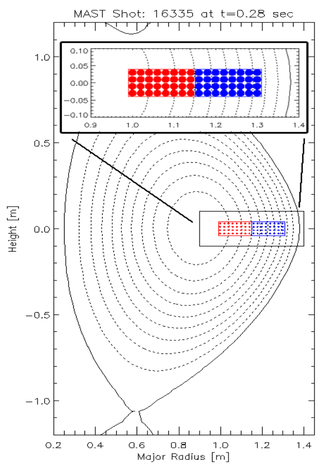


Results of B-filed effects on one channel

➢ Along LoS

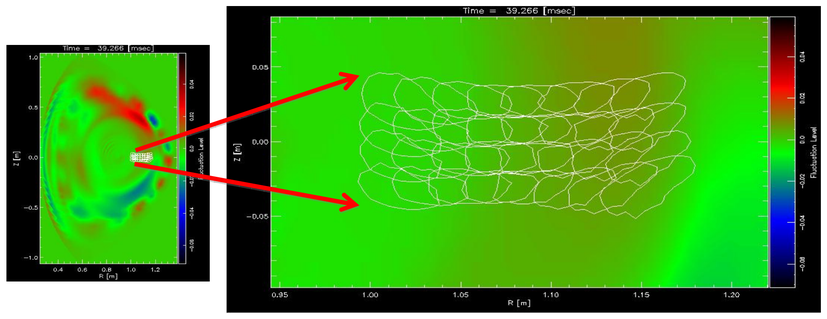


5. SYNTHETIC BES DATA DOMAIN AND CUTIE DATA



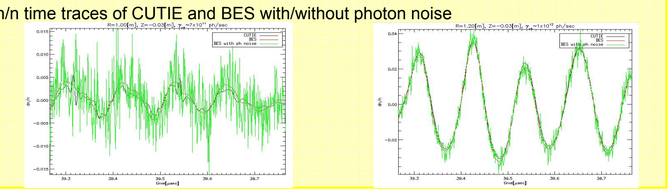
1. R_{Major} = 0.99 – 1.15 m (ψ_N = 0.05 – 0.3)
2. R_{Major} = 1.15 – 1.31 m (ψ_N = 0.3 – 0.8)

Z = -0.03, -0.01, 0.01, 0.03 m



CUTIE Simulation: 1 MHz for 500 μsec duration

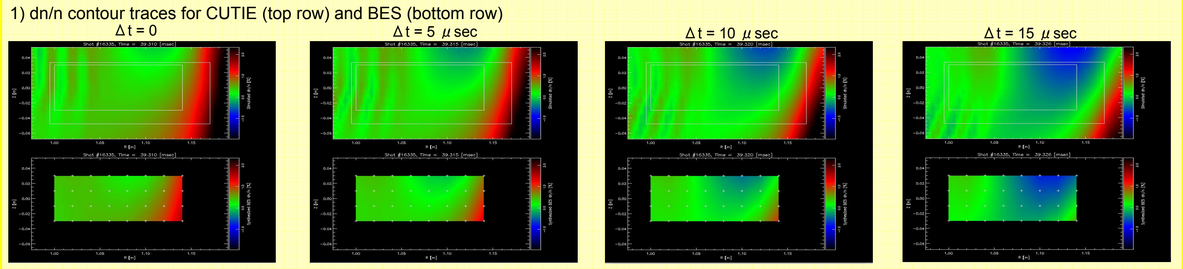
dn/n time traces of CUTIE and BES with/without photon noise



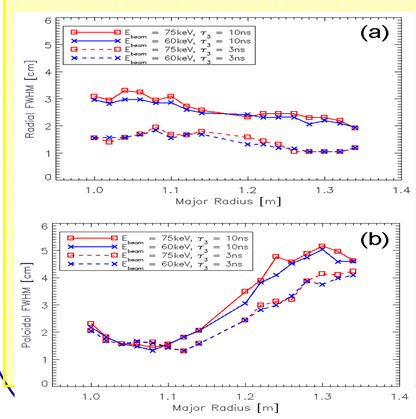
6. RESULTS AND DISCUSSIONS

Synthetic BES data are generated based on CUTIE data.

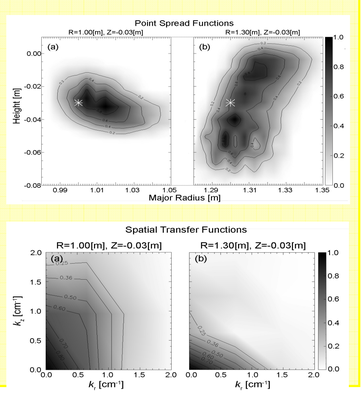
1) dn/n contour traces for CUTIE (top row) and BES (bottom row)



2) Radial/Poloidal FWHM Profiles as functions of beam energy and n=3→2 half-life.



3) PSF and STF at two different radii



4) RMS dn/n and poloidal group velocity profiles