

UCLA Microwave and Millimeter-Wave Diagnostic Capabilities for FY07

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NSTX Physics Meeting

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List of Diagnostics for FY07



List of Diagnostics

- Low-k Fluctuation:
 - **FMCW profile reflectometers** (13-20, 20-32, 33-50 GHz)**
 - **Quadrature reflectometers** (30, 35*, 42, 44.5*, 50, 65* GHz)
 - **1 mm interferometry/forward scattering****
 - **Correlation reflectometers** (26-40 GHz)**
 - > Radial correlation
 - > Poloidal correlation
- High-k Fluctuation:
 - **Back-scattering** (65 GHz)*

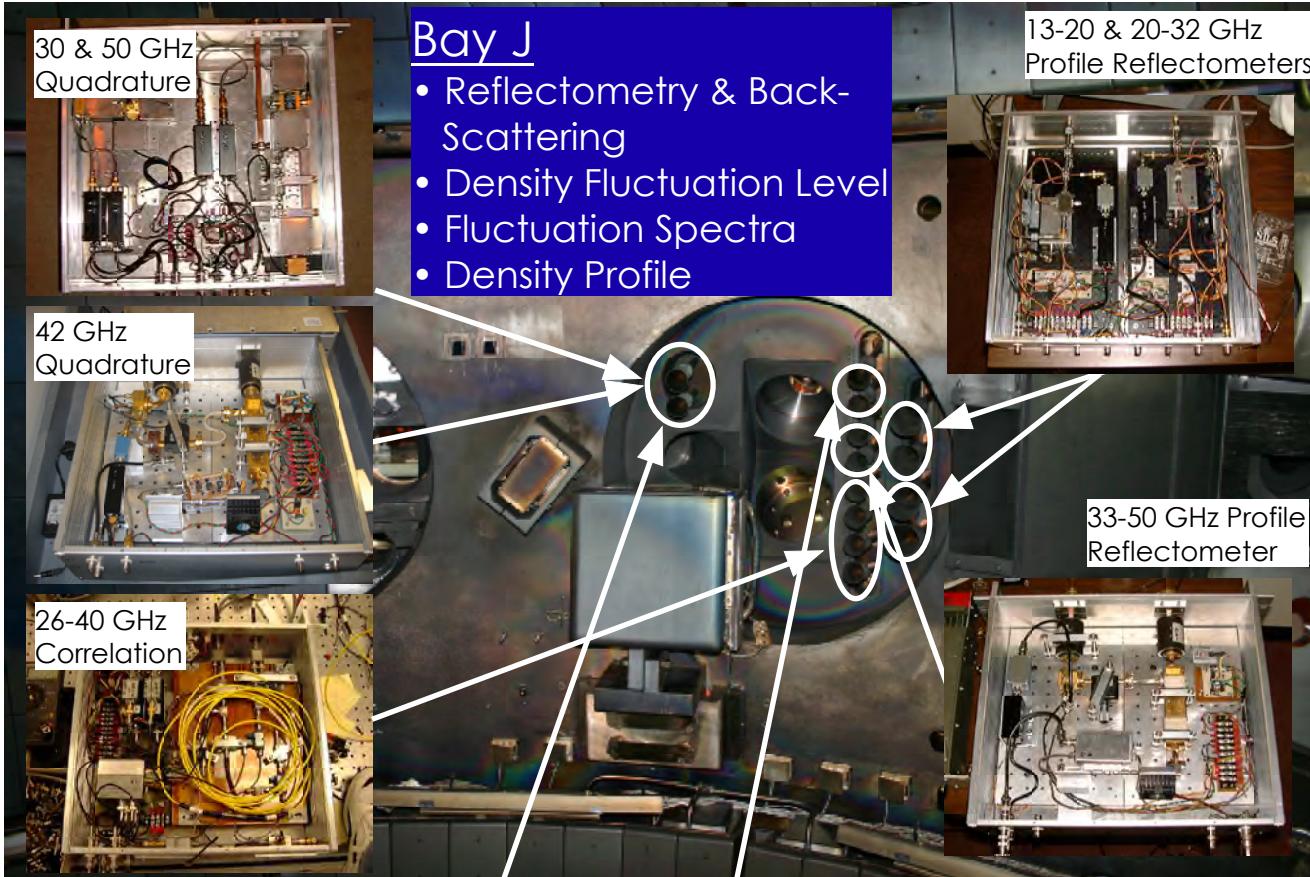
*Under construction.

**Modification or repair.

Important to Note

- All systems are under various state of construction.
- Certain diagnostics will be available at certain times during FY07 run.
- Some diagnostics cannot be operated simultaneously.
- Some have higher priority than others (e.g. support Joule milestone).

Location of Diagnostics on NSTX



30 & 50 GHz
Quadrature

Bay J

- Reflectometry & Back-Scattering
- Density Fluctuation Level
- Fluctuation Spectra
- Density Profile

13-20 & 20-32 GHz
Profile Reflectometers

42 GHz
Quadrature

26-40 GHz
Correlation

33-50 GHz Profile
Reflectometer

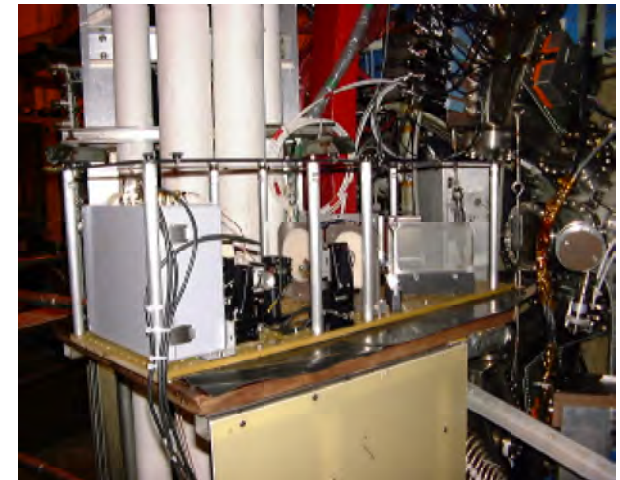
35 & 44.5 GHz
Quadrature

65 GHz Reflectometry
& Back-Scattering

New Systems

Bay G

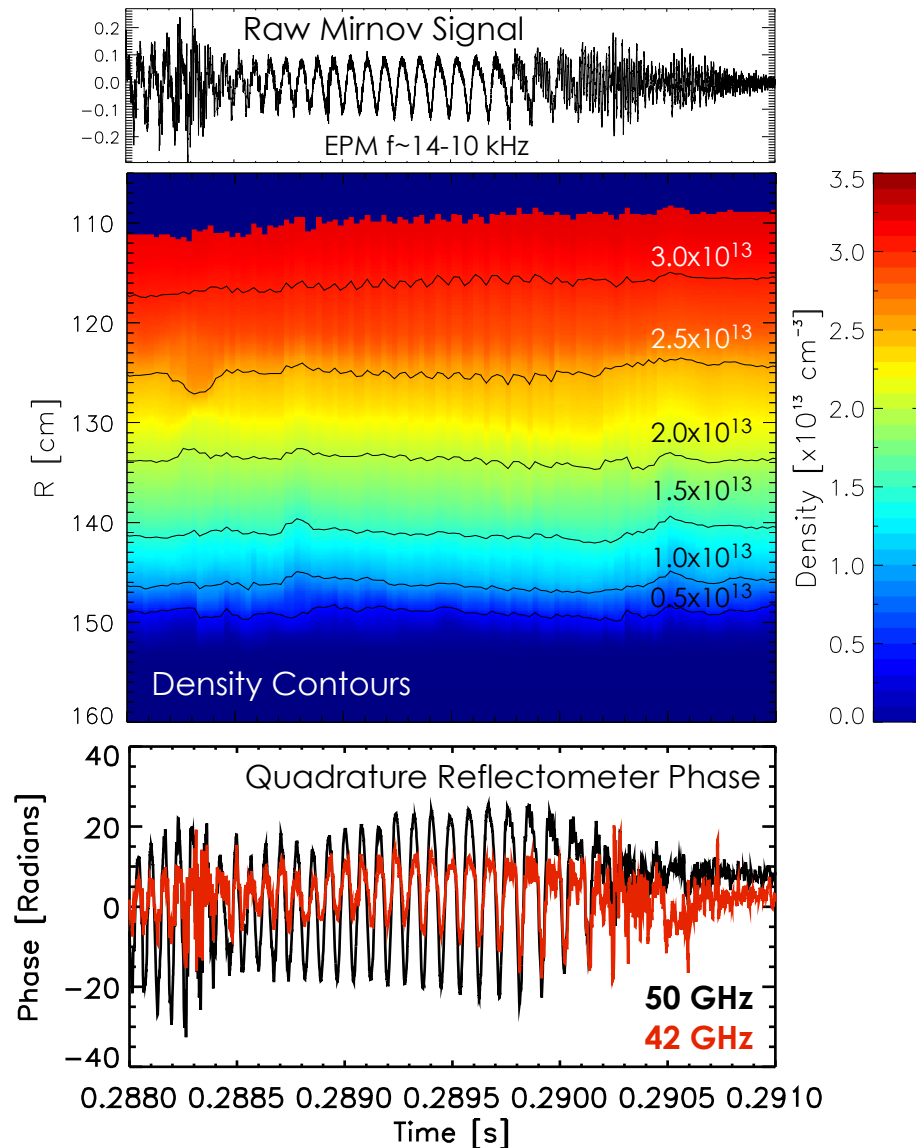
- Interferometry-
Radial Line Density
- Forward Scattering
- $\lambda=1$ mm Source



Status FMCW Reflectometry



25 $\mu\text{s}/\text{sweep}$



FMCW System

- 13-53 GHz coverage (2.1×10^{12} to 3.5×10^{13} cm^{-3}).
- Maximum repetition rate of **20 $\mu\text{s}/\text{sweep}$** (3840 total profiles per shot). For FY07, goal of **10 $\mu\text{s}/\text{sweep}$** .
- **Radial structure of modes with $f < 50$ kHz from $\delta n/n$. FY07 Joule Milestone.**
- Highly desirable or required for analysis of all other reflectometry data.

Status

- Large portion of work for 10 $\mu\text{s}/\text{sweep}$ completed last year. However ...
- Problem with wide bandwidth IF amplifiers.
- New oscillator for 33-50 GHz system needs to be test and calibrated.
- Relocation of 13-20 and 20-32 GHz equipment in diagnostic rack requires additional cable lengths (long lead times).

Incompatibilities

- Causes problems for EBW emission diagnostic.
- 10 ms/sweep requires high-speed digitizers (100 MSa/s) which are also required for HHFW measurements.

Status of Fixed Frequency Reflectometers



Existing System

- Density fluctuation levels and spectra at 1.1 , 2.2 , and $3.1 \times 10^{13} \text{ cm}^{-3}$ (30, 42 and 50 GHz).
- **Radial structure fast particle-driven modes from $\delta n/n$. FY07 Joule Milestone.**

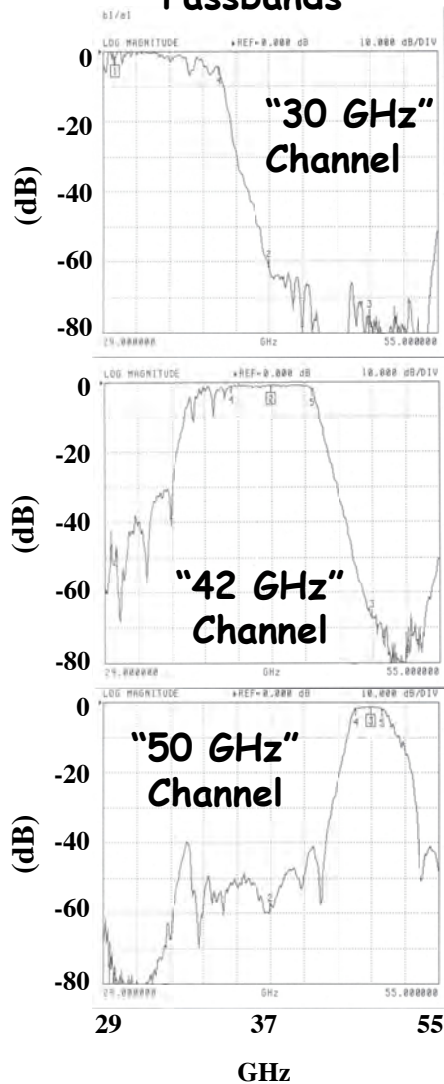
Modifications for FY07

- Multiplexer to combine frequencies for use with single pair of launch/receive horns.
- Additional channels at 35, 44.5, and 65 GHz (1.5 , 2.4 , and $5.2 \times 10^{13} \text{ cm}^{-3}$).

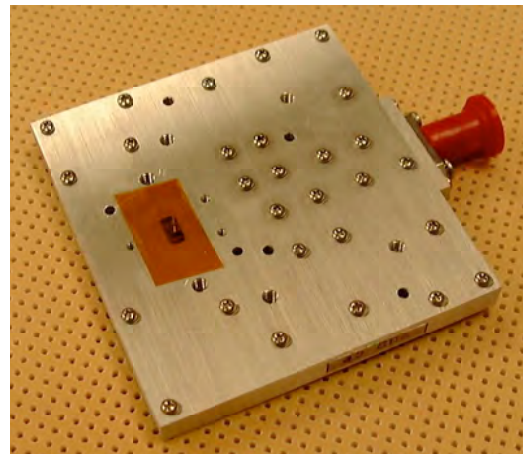
Status

- Hardware for new channels need to be fabricated.
- New data acquisition for additional channels.

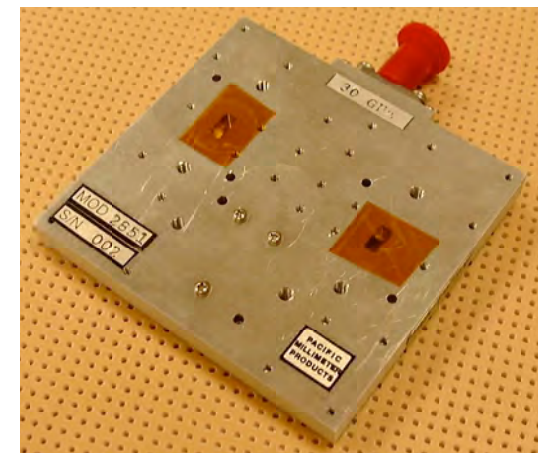
Multiplexer Channel Passbands



Fullband Input/Output (side 1)



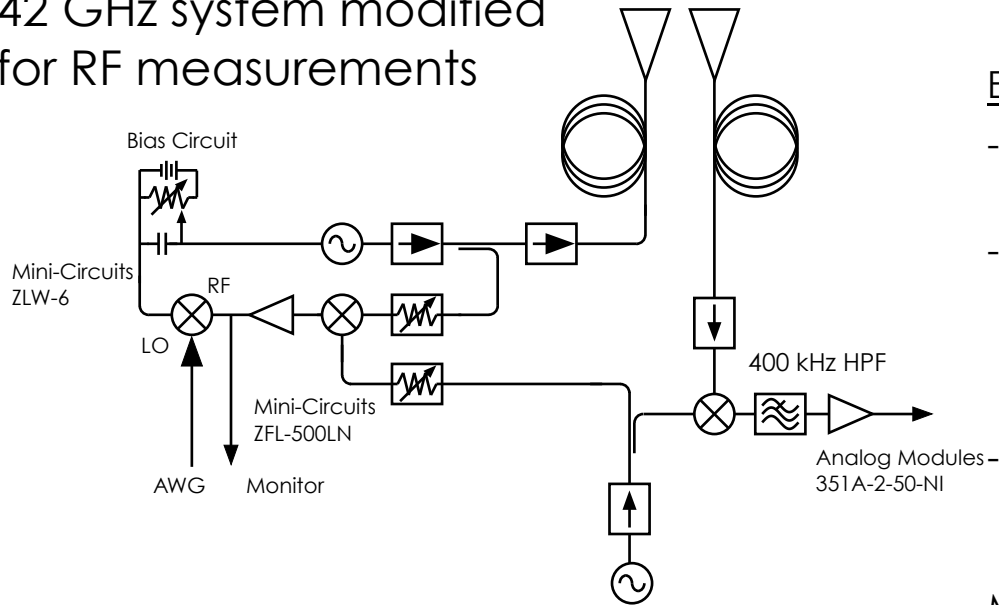
Passband Inputs/Outputs (side 2)



RF Measurements



42 GHz system modified for RF measurements



Existing System

- Measures density fluctuations associated with 30 MHz HHFW.
- For FY06, converted 42 GHz fixed-frequency homodyne quadrature channel to heterodyne reflectometer with $\Delta f = 27\text{-}32$ MHz. ($f_{\text{probe}} < f_{\text{lo}}$). PoP measurements for core plasma.

Digitizer sampling rate of 8 MSa/s. LPF at 5 MHz, IF amplifier cutoff (6.5 MHz), digitizer cutoff 9 MHz.

Modifications for FY07

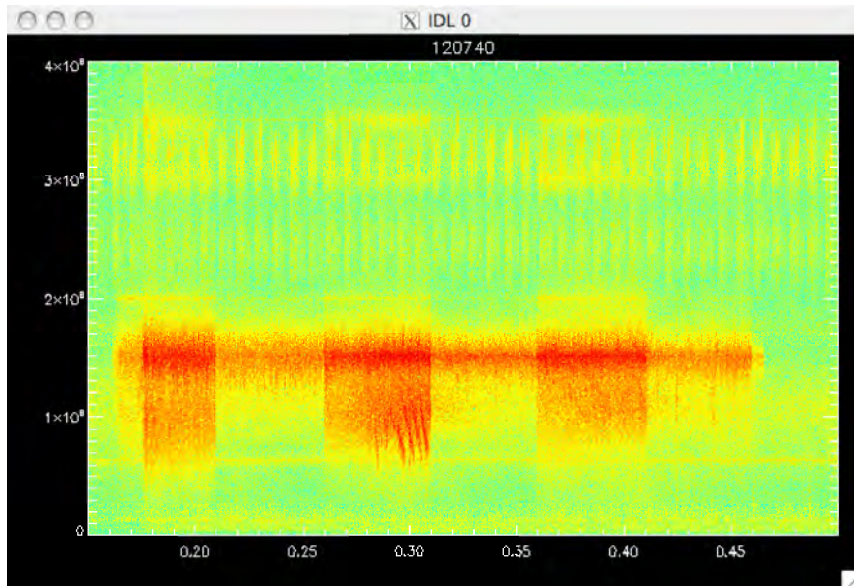
- IF source relocated inside shield box for better noise suppression.
- Use 100 MSa/s digitizers to monitor RF pickup.

Status

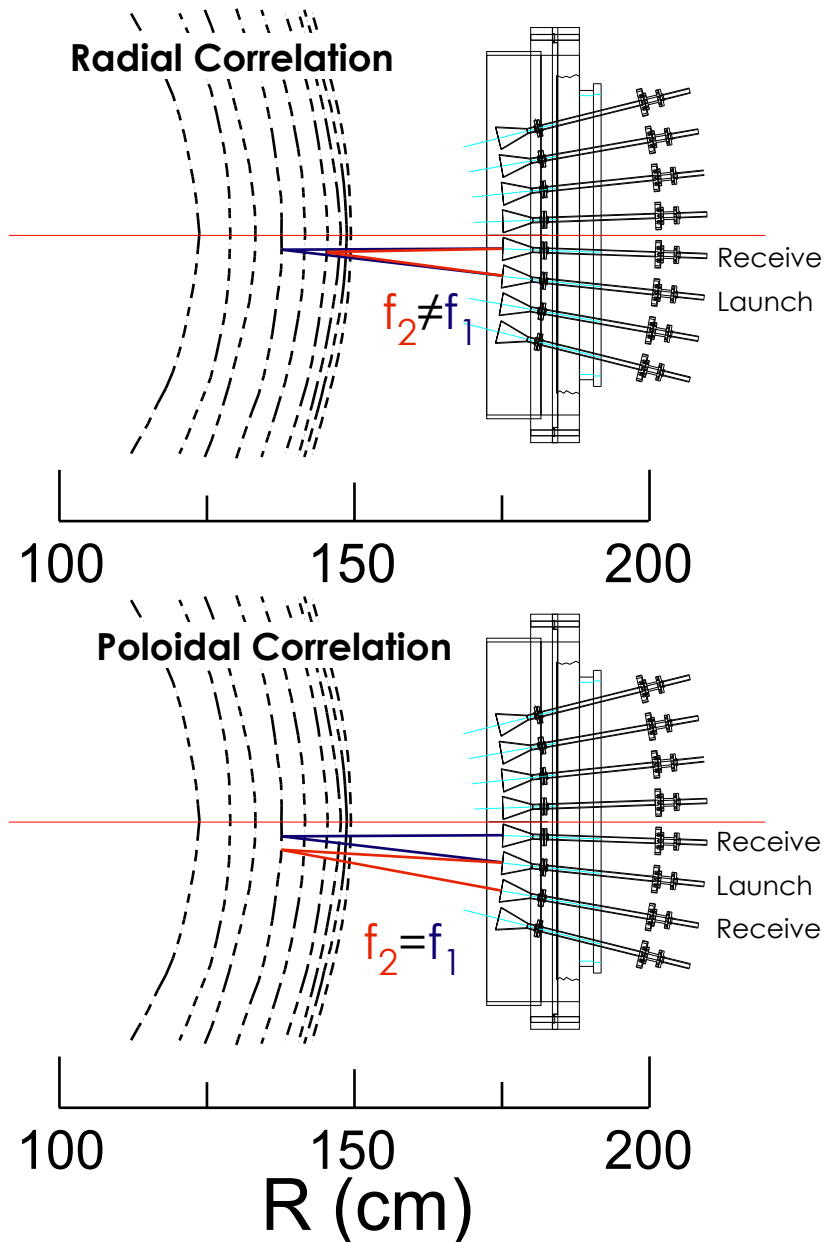
- Ready for reinstallation.

Incompatibilities

- Shares high speed digitizers with FMCW system.
- Cannot simultaneously monitor low frequency fluctuations and RF.



System Description: Correlation Reflectometers



Existing System

- Reflectometer uses direct-conversion quadrature detection. Complex amplitude provides **simultaneous measurements of fluctuation level, spectra, correlations.**
- This is important for using existing models and simulation codes for numerical estimates of turbulence quantities.
- Can trade off spatial resolution for time resolution.
- Radial and poloidal correlations possible.

Modifications for FY07

- Addition of single-sideband modulator (SSBM) for heterodyne detection to increase S/N.

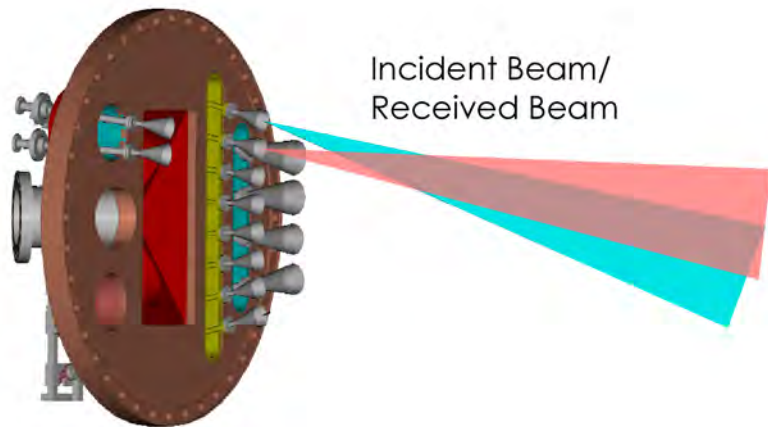
Status

- Operated for few shots in FY06. Needs lots of commissioning time.
- Delivery of SSBM may cause delay.

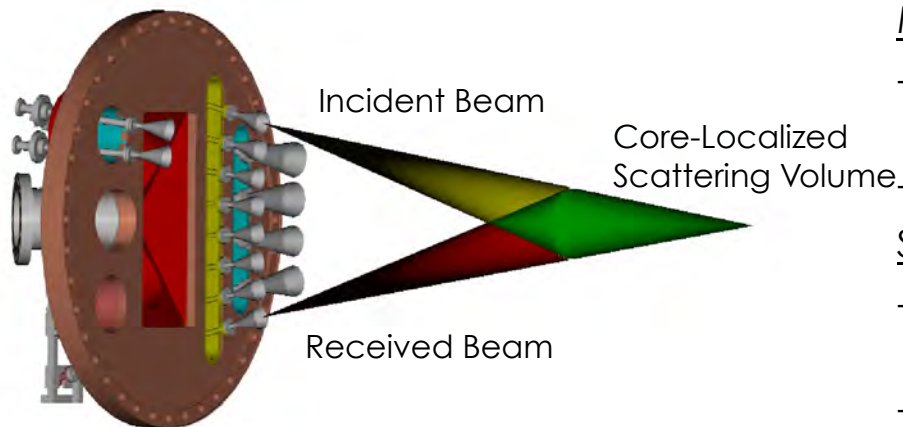
Incompatibilities

- **Radial and poloidal measurements cannot be made simultaneously. Switch-over is time-consuming.**
- Causes problems for EBW emission diagnostic.

New Back-Scattering/Reflectometry Diagnostic



FY07



FY08

Details of New Back-Scattering Diagnostic

- 65 GHz source.
- Fixed launch and receive antennas.
- $k \sim 27 \text{ cm}^{-1}$.
- 180° back-scattering geometry offers high discrimination against contamination from low-k.
- Basic operating scenario requires $B_T = 5.5 \text{ kG}$ and $n_{e0} \sim 2.5 \times 10^{13} \text{ cm}^{-3}$ for 65 GHz. X-mode launch beam dump at $2f_{ce}$ layer.
- Can also operate as a fixed frequency reflectometer channel at higher densities.
- Similar system exists on DIII-D at 94 GHz.

Modifications for FY07

- Addition of single-sideband modulator (SSBM) for heterodyne detection to increase S/N.
- FY08 modifications to allow core localization.

Status

- Vacuum interface installed (see left). Microwave hardware to arrive late in FY07 run.
- Dedicated XMP time required for diagnostic shake-down.

Incompatibilities

- Either reflectometry or back-scattering.

Projected Availability



Week

1	2	3	4	5	6	7	8	9	10	11	12
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30, 42, 50 GHz Fixed-Frequency Reflectometers

35, 44.5 GHz

65 GHz

Profile Reflectometers

1 mm Interferometer

42 GHz Heterodyne Reflectometer for RF

Correlation Reflectometers

1 mm Forward Scattering

Back-Scattering

- 1 mm forward scattering to be commissioned piggyback.
- Correlation reflectometers and back-scattering will require XMP.

Some Systems Cannot Be Operated Simultaneously



x : Uses same hardware.

	30, 35, 44.5, 50 GHz	42 GHz	65 GHz	Profile Reflectometer	1 mm Interferometer	1 mm Scattering	RF Measurements	Radial Correlation	Poloidal Correlation	Back-Scattering
30, 35, 44.5, 50 GHz										
42 GHz										
65 GHz										
Profile Reflectometer										
1 mm Interferometer										
1 mm Scattering						X				
RF Measurements		X		X						
Radial Correlation										
Poloidal Correlation								X		
Back-Scattering			X							

Requested XMP for Back-Scattering



- **Starting Scenario for Back-Scattering:**
 - $B_T=5.5$ kG, $n_{e0}\sim 2.5\times 10^{13}$ cm⁻³, kept in L-mode with low NB power.
 - Density will be ramped to allow standard and Doppler reflectometry later in the same discharge.
 - Deuterium working gas is suitable.
- **Proposed Scans:**
 - NB power scan: vary T_i , momentum, amount of MHD.
 - Density scan to clearly switch from backscattering to reflection regimes.
 - Vertical position scan: vary k-matching or mismatching condition over plasma.
- **Diagnostic Requirements:**
 - MSE and EFIT for equilibrium reconstruction.
 - 30-point MPTS, toroidal CHERS (and poloidal if available) and profile reflectometers.
 - Fixed frequency reflectometers, 1 mm interferometer, FIR interferometers, tangential scattering, etc. for fluctuation measurements.
- **Requested XMP Time: 1 day.**

Requested XMP for Correlation Reflectometry



- **Relevance:**
 - 1) First measurement of $\delta n/n$ and k between edge and core, E_r , GAMs.
 - 2) Benchmark for all future low- k measurements (comparison to other advanced diagnostics as well as gyrokinetic codes).
 - 3) Provides necessary estimates for analysis of all previous reflectometry turbulence measurements.
- **Additional Diagnostics required:**
 - CHERS, MSE, MPTS, mirnov coils, etc.
- **Post-processing:** FWR2D, GYRO.
- **Target:**
 - Simple as possible plasma, quiescent, L-mode for good core access, monotonic shear.
 - Target He discharges with low NB power: e.g. shot 121212 has long (~100 ms) quiescent period.
- **Requested time: 2 days.**

Correlation reflectometers set for radial measurements.

 - 1) 1/3 day fixed at base shot at 4.5 kG.
 - 2) 2/3 day for B_t and I_p scans (either fixed and constant q).

Switch to poloidal correlation.

 - 3) Same as 1).
 - 4) Same as 2).