Dual-mode Reflectometry Measurements of Magnetic Field Strength and Turbulent Correlation Length in NSTX

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Motivation

- In emerging high beta confinement devices such as *NSTX* (PPPL), Pegasus (Wisconsin) and the *Electric Tokamak* (UCLA,), an accurate knowledge of the magnetic field structure and turbulent correlation length internal to the plasma is of great importance for understanding stability and transport.

- The relatively low magnetic fields in these devices are modified significantly from vacuum levels due to large diamagnetic and paramagnetic effects.

- ***In "dual-mode" correlation reflectometry O and X-mode radiation is launched into the plasma from the same antenna and signals arising from naturally occurring microturbulence are cross-correlated.***

  - *Frequency at maximum correlation determines magnetic field strength*

  - *Width of cross-correlation determines turbulent correlation length.*

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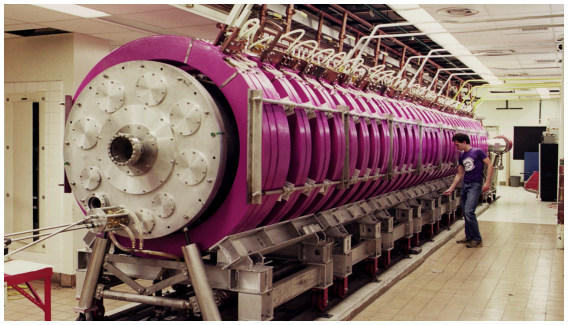
Magnetic Field Diagnostic Development Program

1. Perform a proof of principle experiment on the LArge Plasma Device (LAPD) at UCLA. The LAPD is a linear device with simple magnetic geometry and well-known magnetic field and density profile.



2. Develop $|B|$ measurement on the Electric Tokamak (*ET*) at UCLA where B can be locally measured using a Hall probe, and where magnetic shear is moderate. Establish accuracy of measurements in a tokamak environment.

3. Fully demonstrate on a mainline, high β device - NSTX

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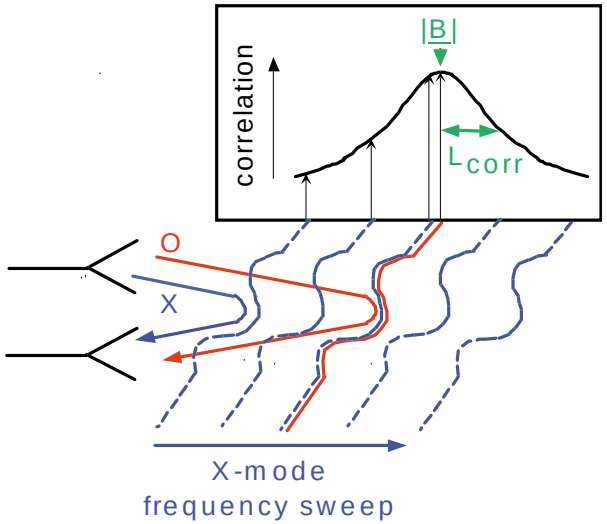
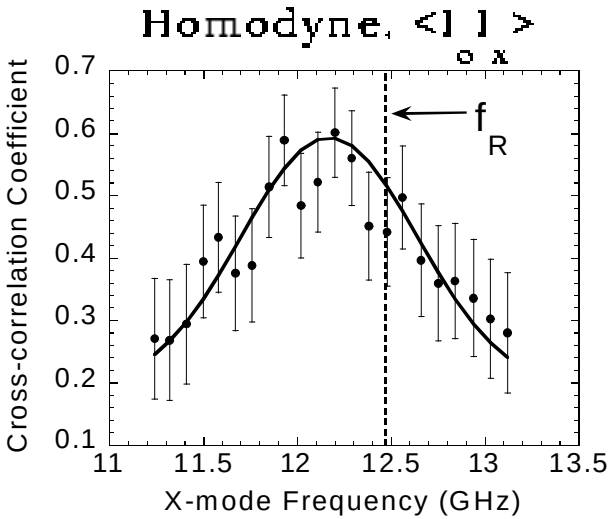
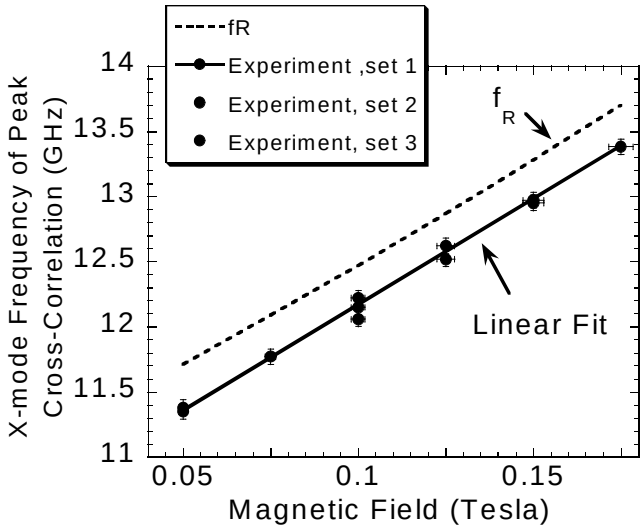
Dual mode correlation reflectometry –
Determination of local magnetic field strength & turbulent correlation length



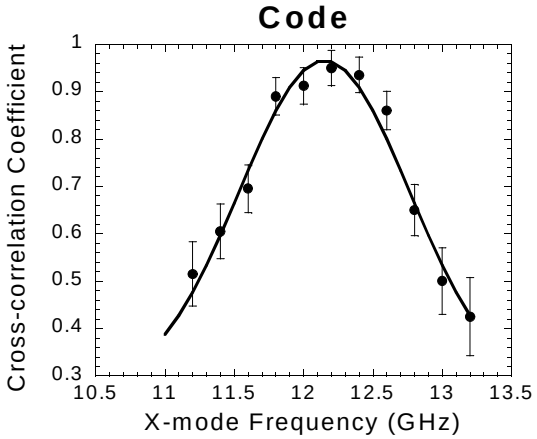
- Launch O and X-mode radiation - different frequencies, same antenna.
- After reflection from their separate cutoff layers, fluctuating signals from naturally occurring turbulence are collected and cross-correlated.
- *Peak* of correlation can provide ***field strength*** & *width* of correlation provides ***turbulent correlation length***

LAPD Results

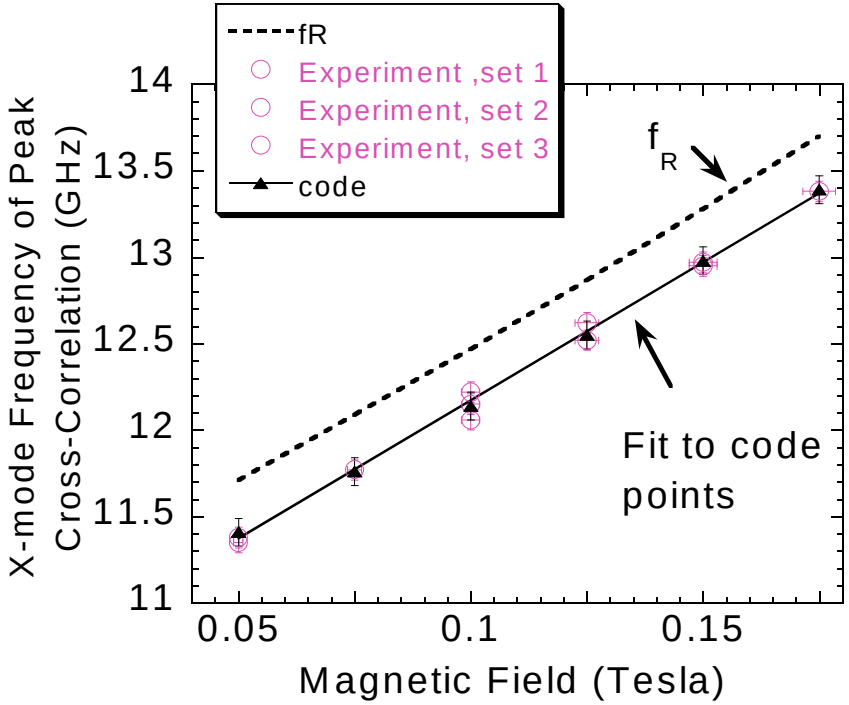




Experiment-Model Comparison:
X-mode Frequency of Peak Cross-Correlation



- $f_{o\text{-mode}}$ = 11.0 GHz
- Δk = 1.8 cm^{-1} (measured)
- Measured density profile

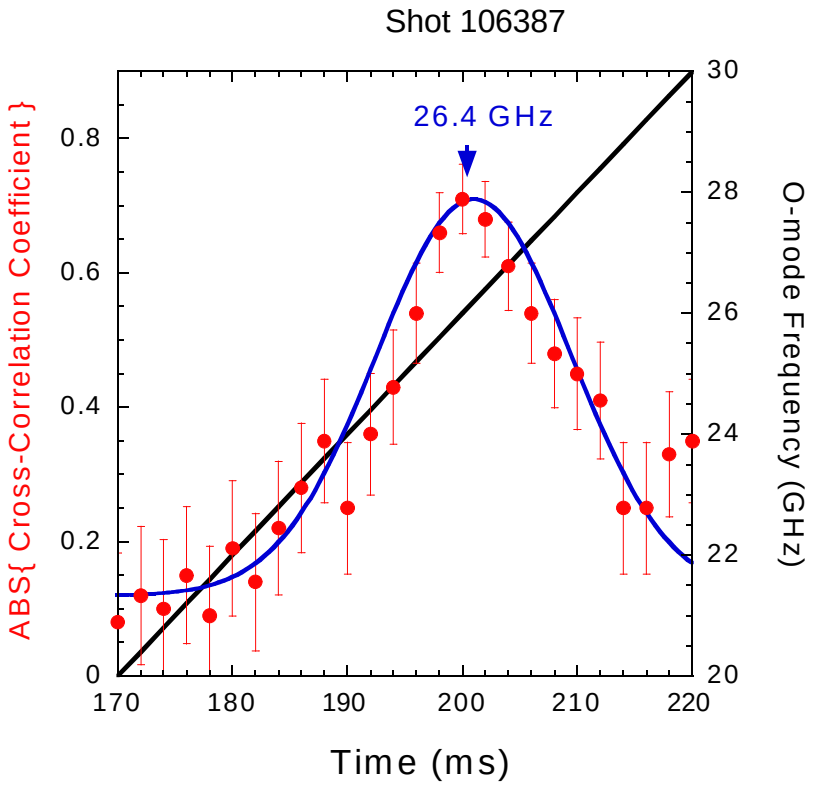


⇒ The code has accurately reproduced the X-mode frequency of peak cross-correlation, $f_{x,pk}$, given measurements of L_n and the turbulent k-spectral width, Δk.

Preliminary O-X Correlation Reflectometry Experiments on NSTX are Encouraging

- A 20-30 GHz correlation reflectometer was modified to operate in a dual mode (O-X) configuration.
- $f_{x\text{-mode}}$ = 30.0 GHz
- $f_{o\text{-mode}}$ swept over 20-30 GHz

- EFIT[1] gives $|\underline{B}| \approx 2.4$ kG at this radius, R=1.47 m
- ***Interpretation of the data using a 1-D model indicates B = 2.5 ± 0.15 kG.***
- ***Assuming reflection occurs at cutoff gives B=2.42kG.***



[1] S. Sabbagh, to be published in *Nuclear Fusion*

Preliminary correlation length measurements NSTX

- **Preliminary turbulent radial correlation length measurements have been made**
  - **measurements to-date have been in the 20-30GHz band (n = 0.5 - 1 $\times$ 10^{19} m^{-3}) using both O-X and O-O correlation.**
  - **correlation lengths are currently measured over tens of milliseconds - this will be improved during future operation**
  - **1/e Δr varies from ~0.7cm (edge) to 2.8cm (core). These values are roughly equal to the ion gyro radius.**

- **It should be noted that UCLA also has capability to determine turbulent correlation lengths in DIII-D, NSTX and ET. Cross-comparison should lead to improved knowledge of the relevant step-size for transport in these devices.**

- **In addition, comparison with simulation predictions is underway (Leboeuf, Dorland) This should improve overall understanding of transport mechanisms as well as bench-marking of codes.**

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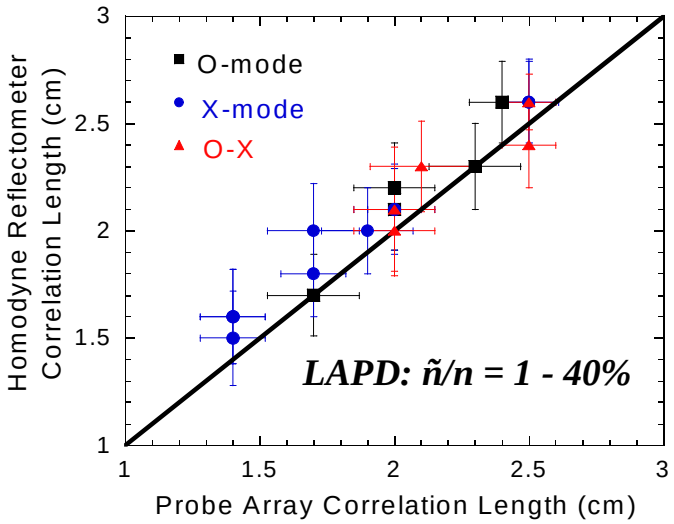
Preliminary correlation length measurements NSTX - continued

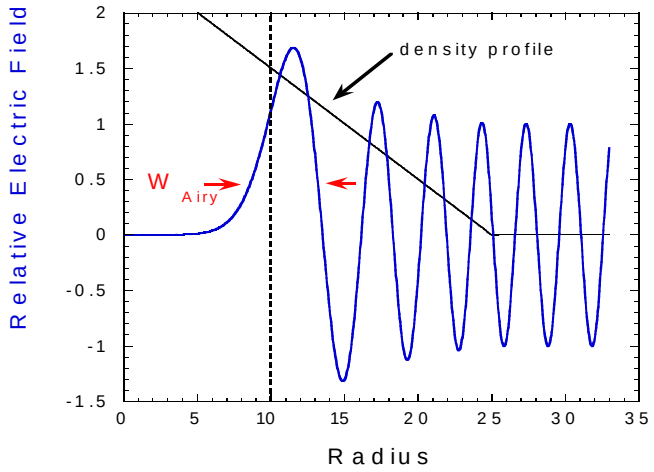
	LAPD	NSTX
f (GHz)	8 - 18	20 - 30
Δr (1/e, cm)	1.5 - 2.5	0.7 - 2.8
$\Delta r/W_{Airy}$	> 0.8	0.7 - 2.8

• Scaled (to W_{Airy}) correlation lengths measured in NSTX are similar to the range measured previously in LAPD.

Reflectometer-probe comparison in LAPD



$W_{Airy} \approx 0.48 L_n^{1/3} \lambda_0^{2/3}$



Summary

- **Dual-mode correlation reflectometry measurements have been performed on NSTX over the frequency range 20 to 30 GHz.**
- **Preliminary analysis indicates correlation lengths of ~1cm near the plasma edge rising towards the core.**
- **Preliminary magnetic field measurements in the edge plasma are within 5% of values predicted by EFIT.**
- **These results are extremely encouraging and development of O-X correlation reflectometry for both magnetic field strength and correlation lengths will continue both on ET and NSTX.**
- **This approach is complementary to MSE. The technique requires no neutral beam and is insensitive to internal electric fields.**

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