Low- and Intermediate-k Fluctuation Diagnostics

S. Kubota

NSTX 5 Year Planning Mini-Workshop
February 27, 2007

Ideas for Low- & Intermediate-k Measurements

NSTX

List of Diagnostics and Measured Quantities

- **Doppler Reflectometry**
  - Fluctuations with **intermediate-k** selectivity (**2-10 cm^{-1}**, Δk~1 cm^{-1}).
  - Time- and space-resolved (~100 μs, ~1 cm) **velocity** and **δn/n**.
    - > **E_r** (ExB shear and connection to turbulence)
    - > **v_{phase}** (when v_{ExB}~0, turbulence ID)
    - > **δv_{ExB}** (Zonal Flows, GAMs)
- Fast Radial-View **Interferometry/Polarimetry** Array
  - Chord-averaged **δn/n** and with time response >3MHz.
    - > Coherent modes and turbulence.
  - $\delta\Psi$ proportional to chord-averaged **δB_r** (when beam is through axis).
    - > Comparison with calculations for Alfven eigenmodes.
  - **J_0** and **δJ_0** from dΨ/dz. Constraint to EFIT. Complements MSE.
- HHFW Measurements **Heterodyne Correlation Reflectometry**
  - Space- and time-resolved measurements of fluctuations up to **f~50 MHz**.
    - > Quantify HHFW fluctuations in the core plasma at Bay J and interaction processes (mode conversion, turbulence scattering).
  - **δn/n** by comparison of specular reflection and RF sidebands.
  - **k_r** measurements from radial correlation.

Principles of Doppler Reflectometry

wavevector selection:
(Bragg condition)

$$K_\perp = 2k_0 \sin\left(\theta_{\rm tilt}\right)$$

wavevector resolution:
(Gaussian beam: w=e^{-1} width of amplitude)

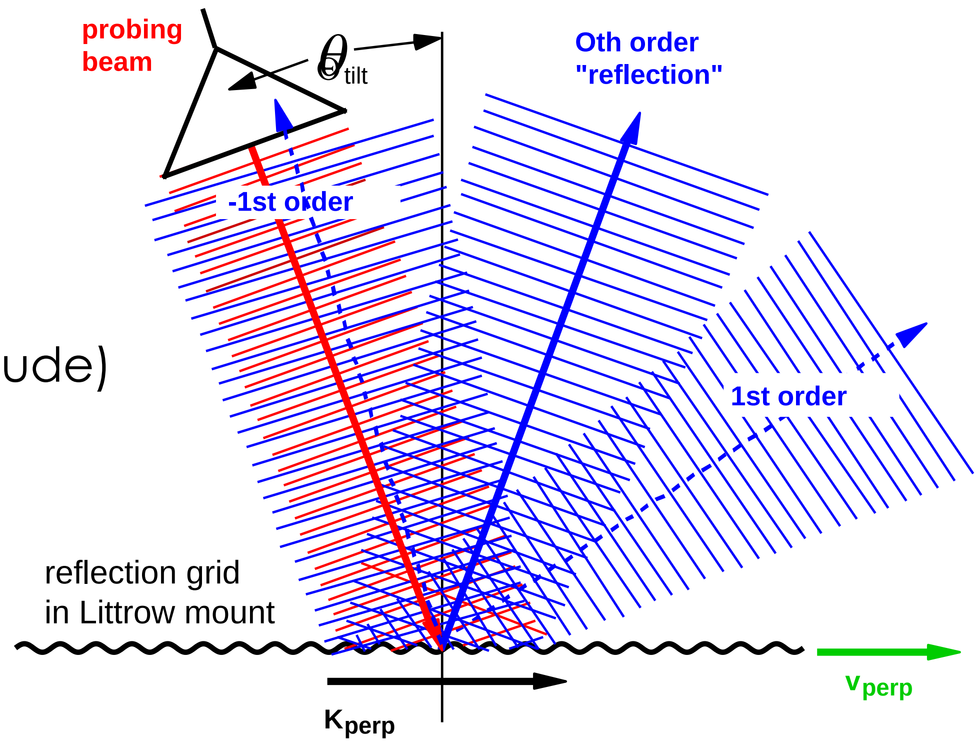
$$\delta K_\perp = 2\sqrt{2}/w$$

frequency shift (-1 order):

$$\Delta\omega = \overrightarrow{K} \cdot \overrightarrow{v} \simeq K_\perp v_\perp$$

fluctuation velocity:

$$v_\perp = v_{E\times B} + v_{\rm ph}$$



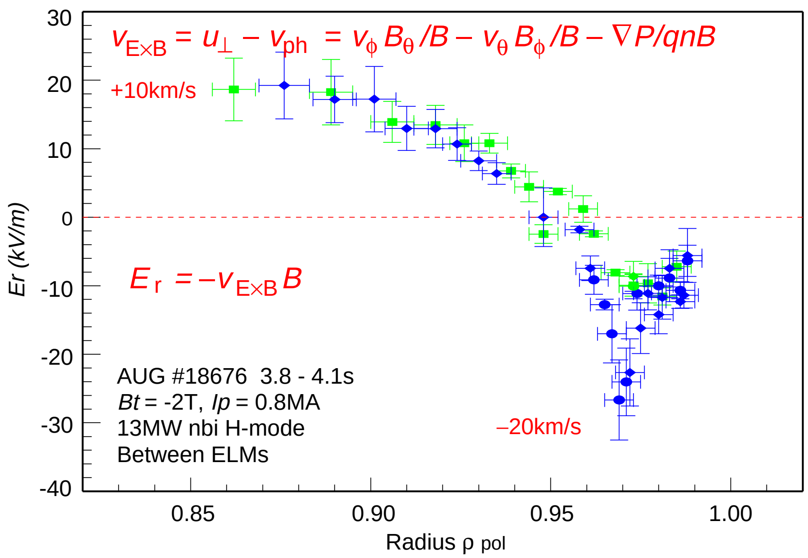
M. Hirsch, et al., PPCF (2001)

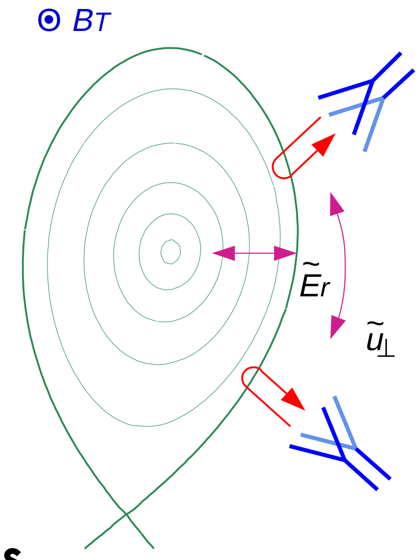
Measured quantities.

1) Tilt angle $\theta_{\rm tilt}$ selects k .
2) For small δn/n, received power vs $\theta_{\rm tilt}$ gives k spectrum.
3) Can measure mean flow and perturbations. If $v_{ExB} \gg v_{ph}$, then $\Delta\omega$ gives v_{ExB} or E_r. If v_{ExB}~0, $\Delta\omega$ gives v_{ph}.

Doppler Reflectometry Used Extensively on ASDEX

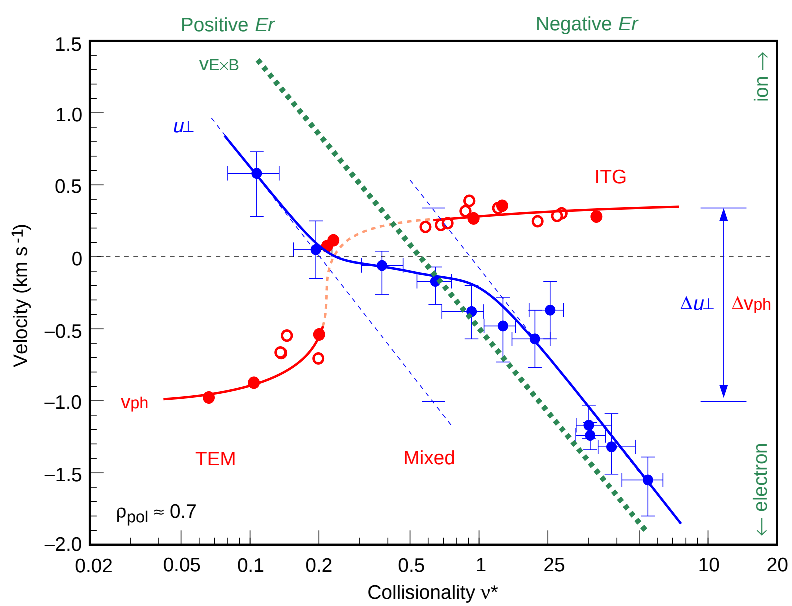
v_{ExB}>>v_{ph} H-Mode E_r Radial Profile

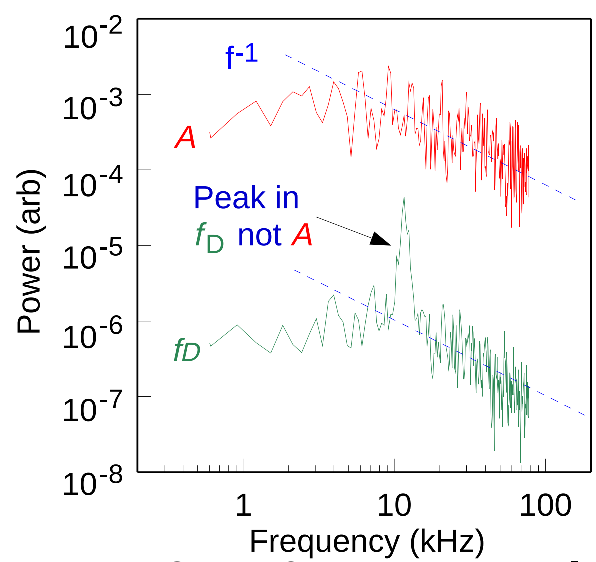




$\tilde{v}_{ExB}$ GAMs

v_{ExB}~0 TEM-ITG Transition

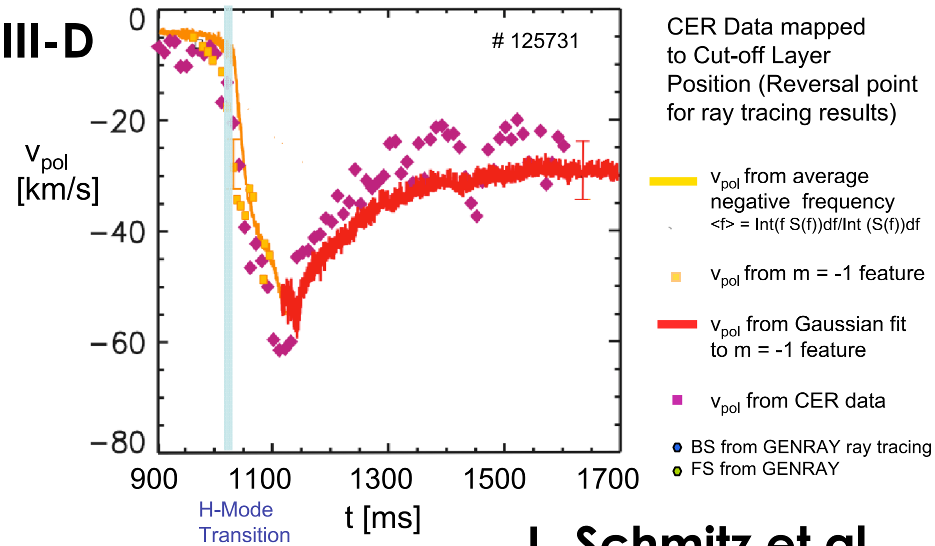




From G.D. Conway et al., IAEA06

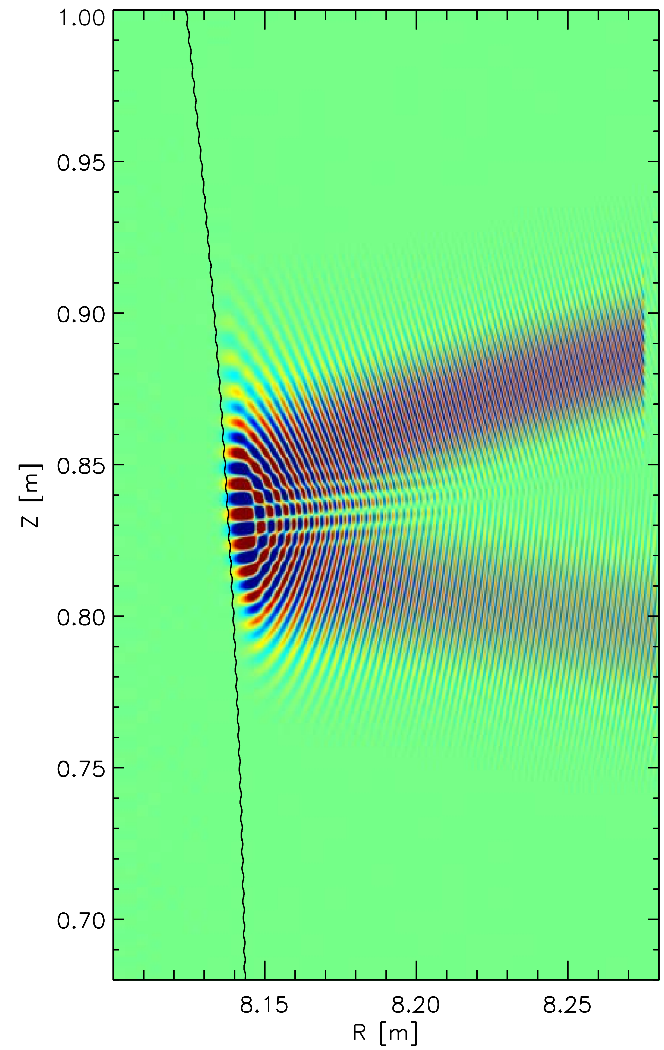
Work is Already Under Way at DIII-D/PPPL

DIII-D

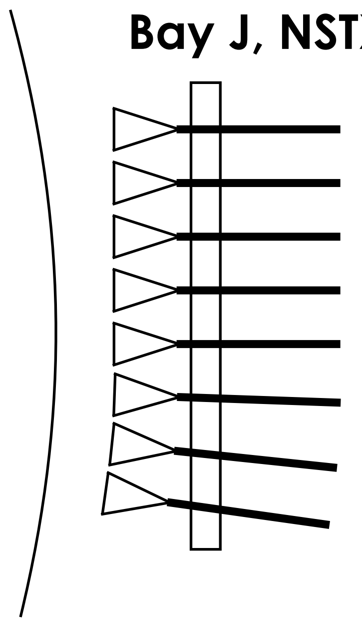


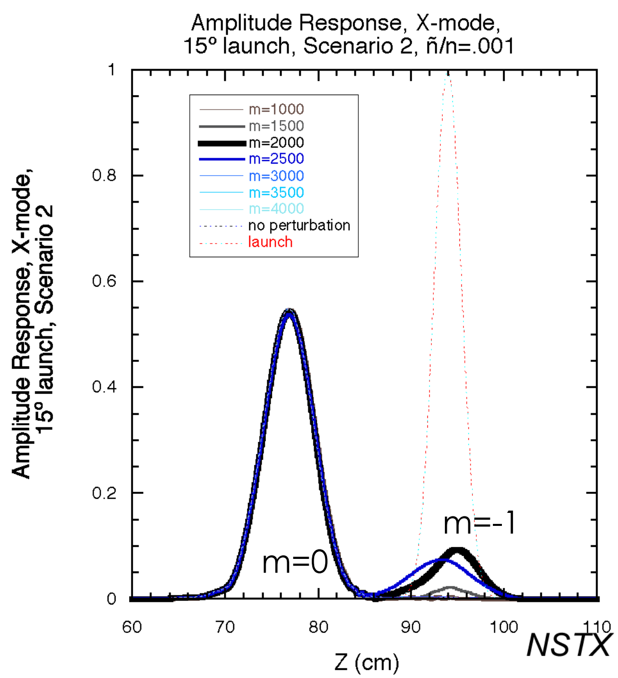
L. Schmitz et al.

Full-Wave Code on PPPL Cluster



Possible Design Bay J, NSTX





Fast Radial-View Polarimetry Principles

NSTX

Faraday Rotation Angle

$$\Psi = 2.62 \times 10^{-13} \lambda^2 \int n(z) B(\vec{z}) \cdot \vec{dl} = c_F \int B_{\|} n(z) dz$$

Fluctuating Component

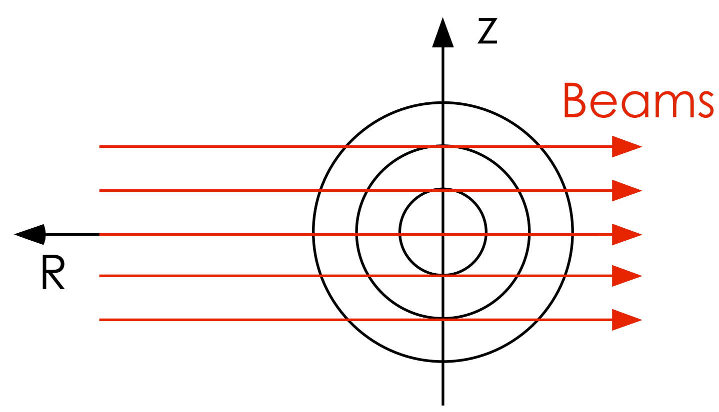
$$\tilde{\Psi} = c_F \int \left[\tilde{B}_{\|}(z) n_0(z) dz + B_{\|0} \tilde{n}(z) \right] dz$$

Equilibrium Component

$$\Psi_0 = c_F \int B_{\|0}(z) n_0(z) dz$$

On-Axis Current

$$J_z(0) = \left(\frac{d\Psi}{dx} \right) \frac{2}{c_F \mu_0} \frac{1}{\int n_e f(r, \alpha) dz}$$

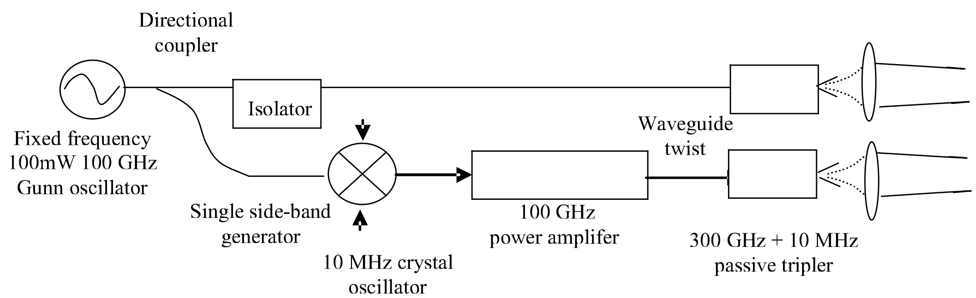


Chord-Averaged B_r On-Axis

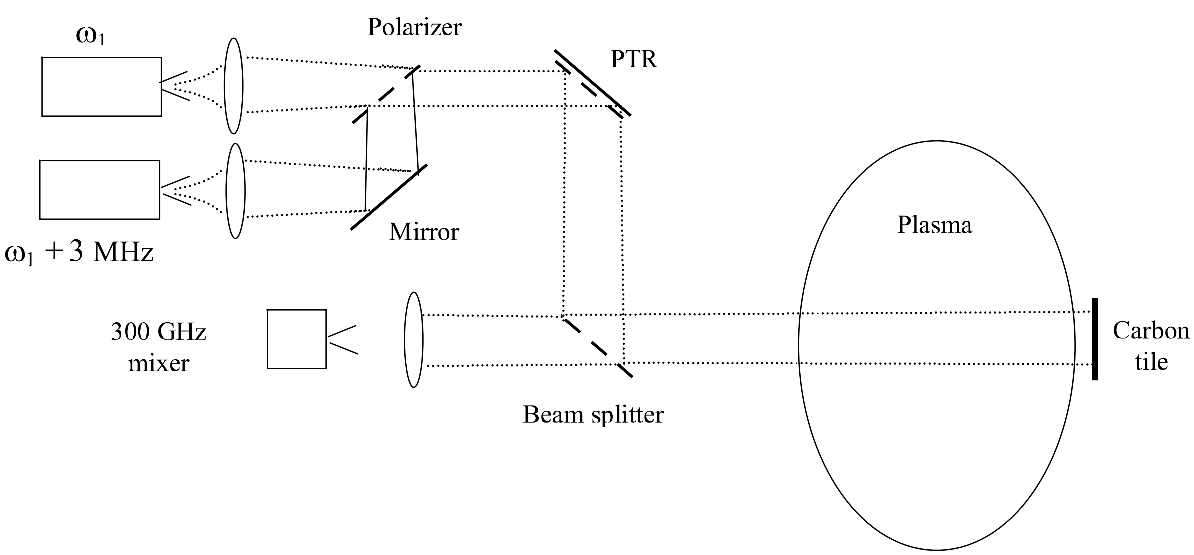
$$\tilde{\Psi}(z = 0) \propto \int \tilde{B}_r(z) n_0(z) dz$$

Possible Implementation on NSTX

Arrangement for Generating Two Orthogonally Polarized, Frequency Offset Beams

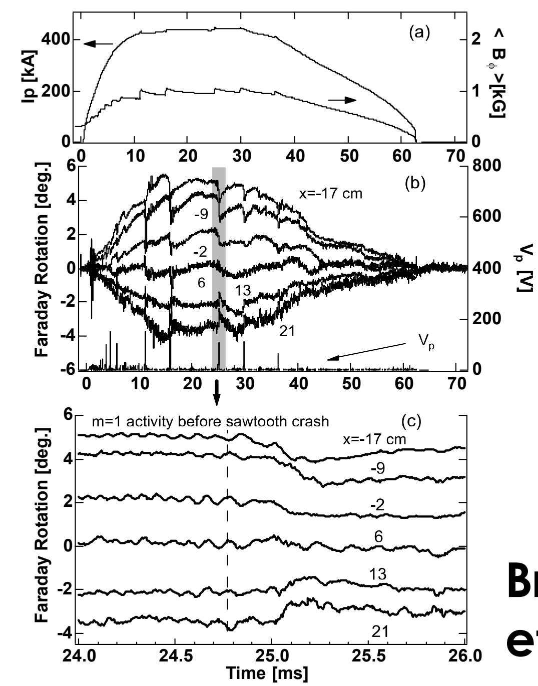


Optical Arrangement for Polarimetry on NSTX



- Upgrade to existing 288 GHz radial interferometer.
- Initially, 3 chords straddling magnetic axis. Vertical dimension: 3 inches.
- Fast (3 MHz) chord-averaged $\delta n/n$ and $\delta B_r/B$, J_0, δJ_0.
- Resolution: ~0.01%
- Similar systems already exist on MST, DIII-D, HSX, Pegasus.

MST



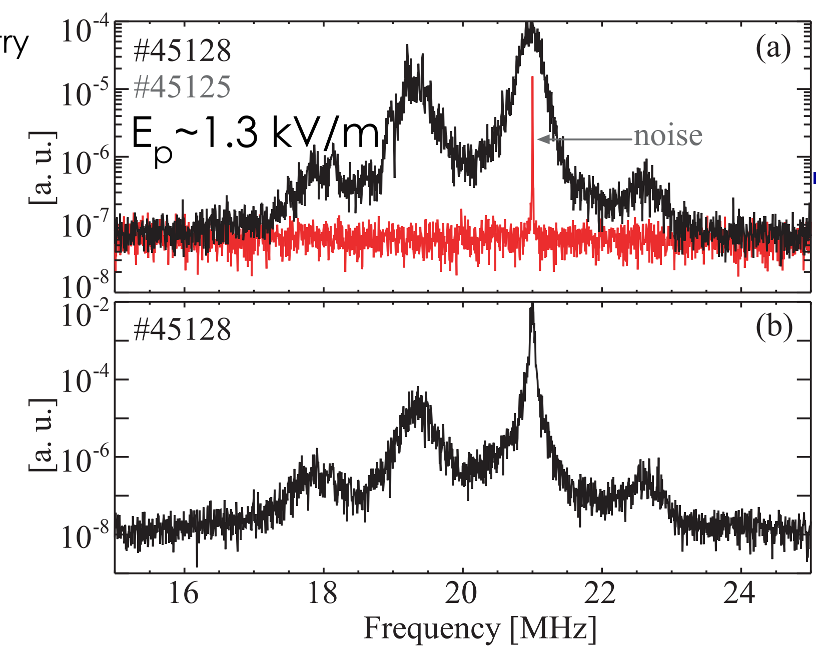
Brower, et al.

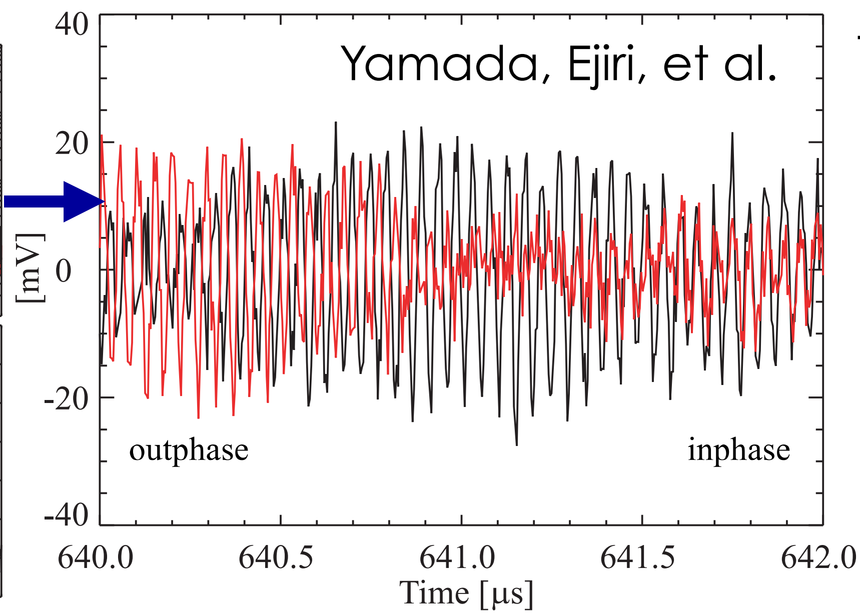
HHFW Measurements Using Correlation Reflectometry

- Reflectometry for HHFW measurements.
  - $\delta n/n$ based on technique used by J.H. Lee et al. on DIII-D. Radial profile of $\delta n/n$ (local measurement).
  - Radial correlation reflectometry for k_r measurements.
- Simultaneously measure fluctuations from DC to 50 MHz. Observe processes such as mode conversion, turbulence scattering. Simultanous measure-ment of local turbulence.
- Heterodyne technique for correlation reflectometer necessary. Use of SSBM is begin investigated. Successfully used on TORE-Supra.
- Single-channel fixed-frequency system already exists! Will be tested this year. (Feasibility of technique can be assesed this year).

Reflectometry

RF Probe





TST-2