Faraday-Effect Polarimetry-Interferometry Diagnostic for Internal Measurement of Magnetic Fluctuation in NSTX-U

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University of California Los Angeles

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NSTX-U/Magnetic Fusion Science Meeting

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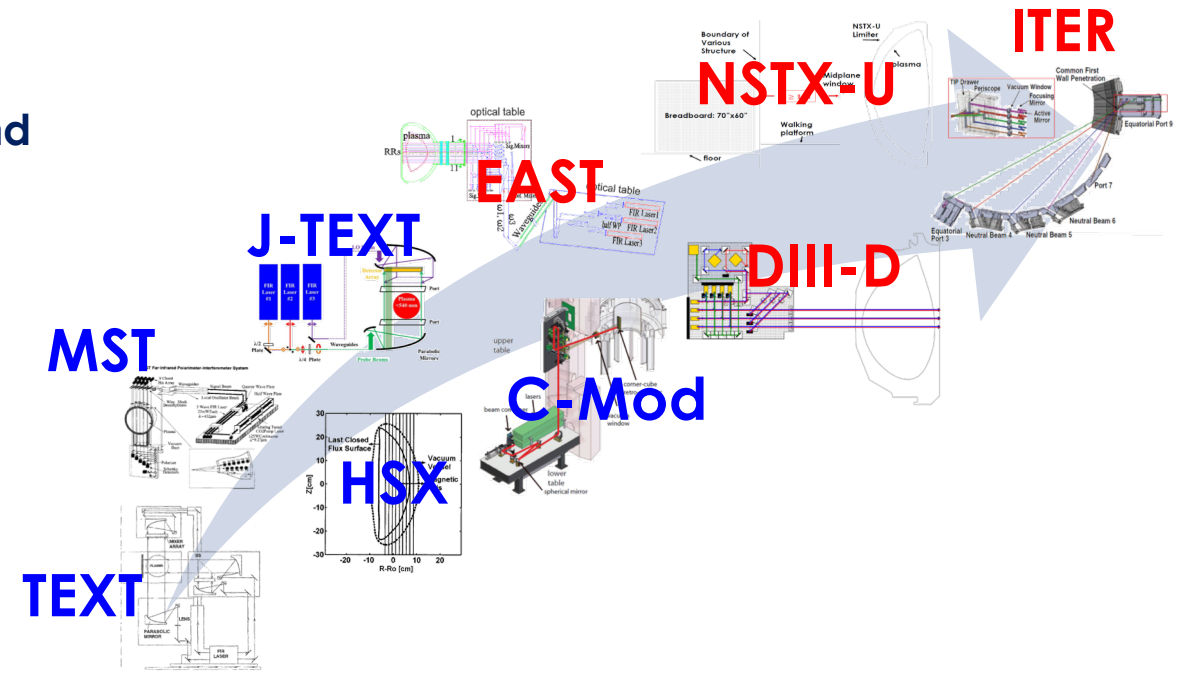

UCLA Polarimetry-Interferometry projects (active)

New UCLA grant supports experimental effort focused on measurement of magnetic fluctuations and 3D effects

- **Develop internal measurement of non-axisymmetric magnetic perturbations associated with**
  - MHD instabilities
  - magnetic turbulence
  - fast ion driven instabilities
  - RMP
- **Method: Faraday-effect Polarimeter-Interferometer (FEPI) diagnostic**
- **Research Goals Support NSTX-U Objective 1:**
  - Extend confinement and stability physics basis at low-A and high beta to lower collisionality relevant to burning plasma regimes
  - measure magnetic turbulence, ...connect to transport, code validation
- **Research Goals Support NSTX-U Objective 2:**
  - measure magnetic fluctuations (MHD and turbulence) in noninductive scenarios

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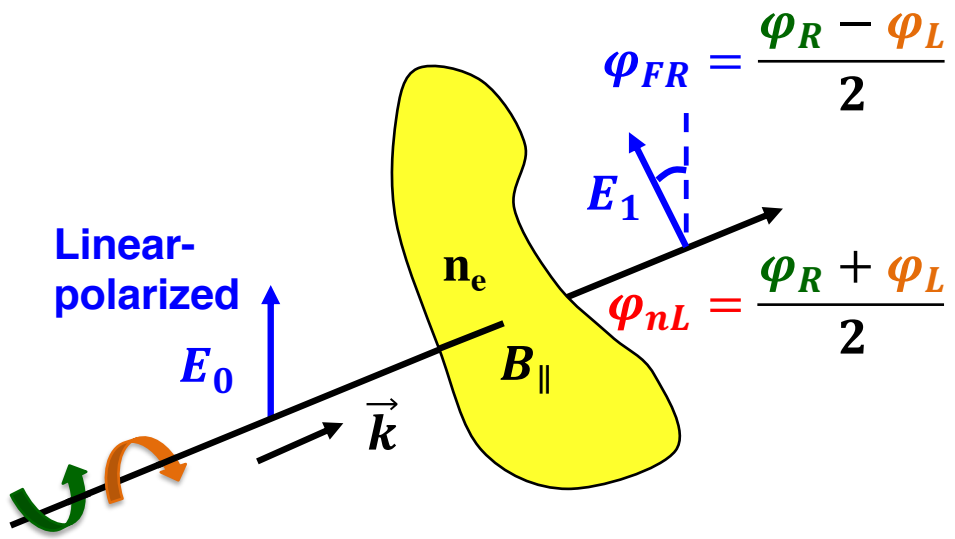
High-Resolution Polarimetry-Interferometry Measures Faraday Rotation and Line-integrated Electron Density

- Launch right (R) and left (L)-handed circularly-polarized electromagnetic waves ($\omega \gg \omega_{ce}, \omega_p$) into magnetized plasma
- Faraday-effect
  - $\frac{\varphi_R - \varphi_L}{2} = \varphi_{FR} = c_p \int n_e B_{\parallel} dl$
- Line-integrated electron density
  - $\frac{\varphi_R + \varphi_L}{2} = \varphi_{nL} = c_i \int n_e dl$
- High phase (~0.1 Gauss) and temporal resolution (~0.1μs) allows both equilibrium and low-k ($k_{\perp,max} \sim 1/cm$) fluctuation measurements



Simultaneous Polarimetry-Interferometry Measurement along the same chord

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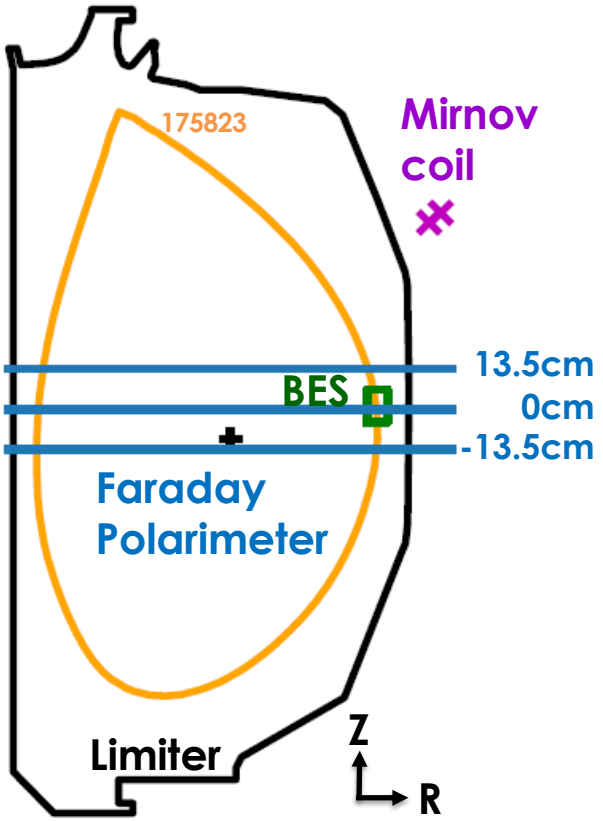
DIII-D Faraday-effect Radial-Interferometer-Polarimeter (RIP) is Optimized to Internally Measure Magnetic Fluctuations

- 3 chords: Z=0 & ±13.5 cm near / at magnetic axis
  - B_R along chords close to zero
  - Faraday fluctuation dominated by magnetic fluctuation: $\delta\varphi_{FR} \propto \int n_e \delta B_R dR + \int B_R \delta n_e dR$
- Low-k ($k_\theta \leq 1/cm$), $10\ MHz$, $\sim 0.1\ Gauss/\sqrt{kHz}$
- Measures density fluctuation $\int \delta n_e dR$ simultaneously
- Line-averaged radial magnetic fluctuation by Faraday polarimeter
  - $\delta\overline{B}_R \equiv \frac{\int n_e \delta B_R dR}{\int n_e dR}$
  - absolutely calibrated measure of radial component which determines transport



Poloidal cross-section of DIII-D

DIII-D Faraday-effect Radial-Interferometer-Polarimeter (RIP) is Optimized to Measure Internal Magnetic Fluctuation

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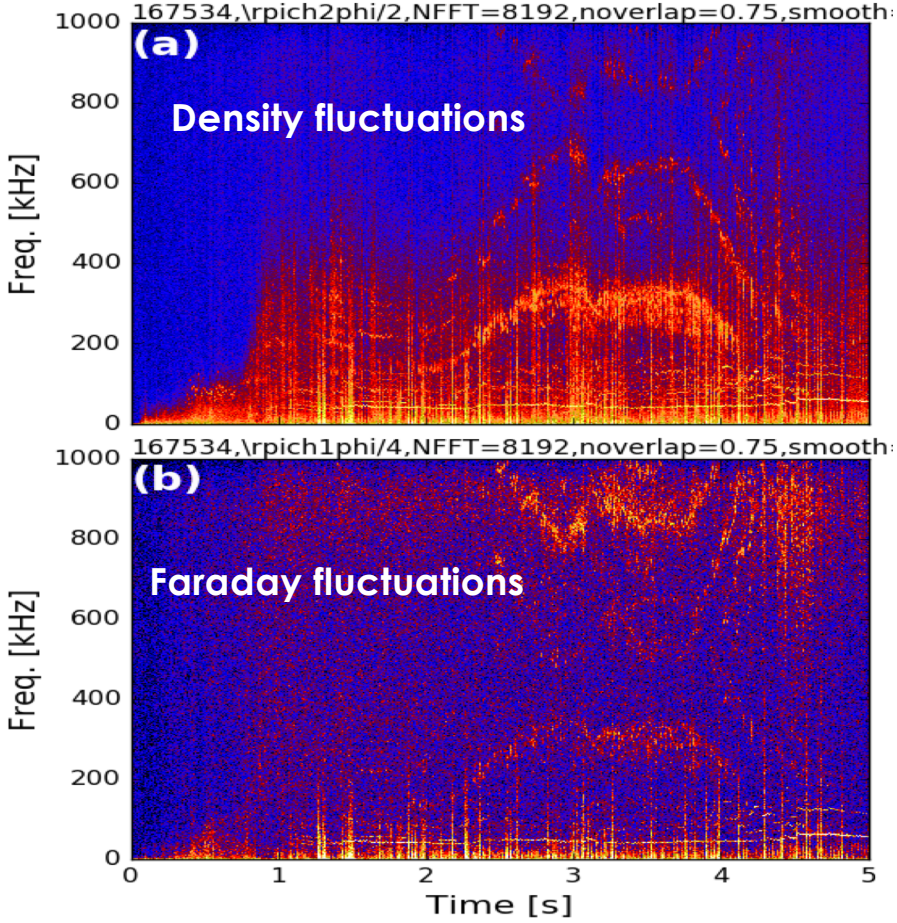
  - Faraday fluctuation dominated by magnetic fluctuation: $\delta\varphi_{FR} \propto \int n_e \delta B_R dR + \int B_R \delta n_e dR$
- Low-k ($k_\theta \leq 1/cm$), $1\ MHz$, $\sim 0.1\ Gauss/\sqrt{kHz}$
- Measures density fluctuation $\int \delta n_e dR$ simultaneously
- Measurements reveal MHD and fast ion instabilities at frequencies up to 1 MHz.
- Significant differences bewteen density and Faraday fluctuation data



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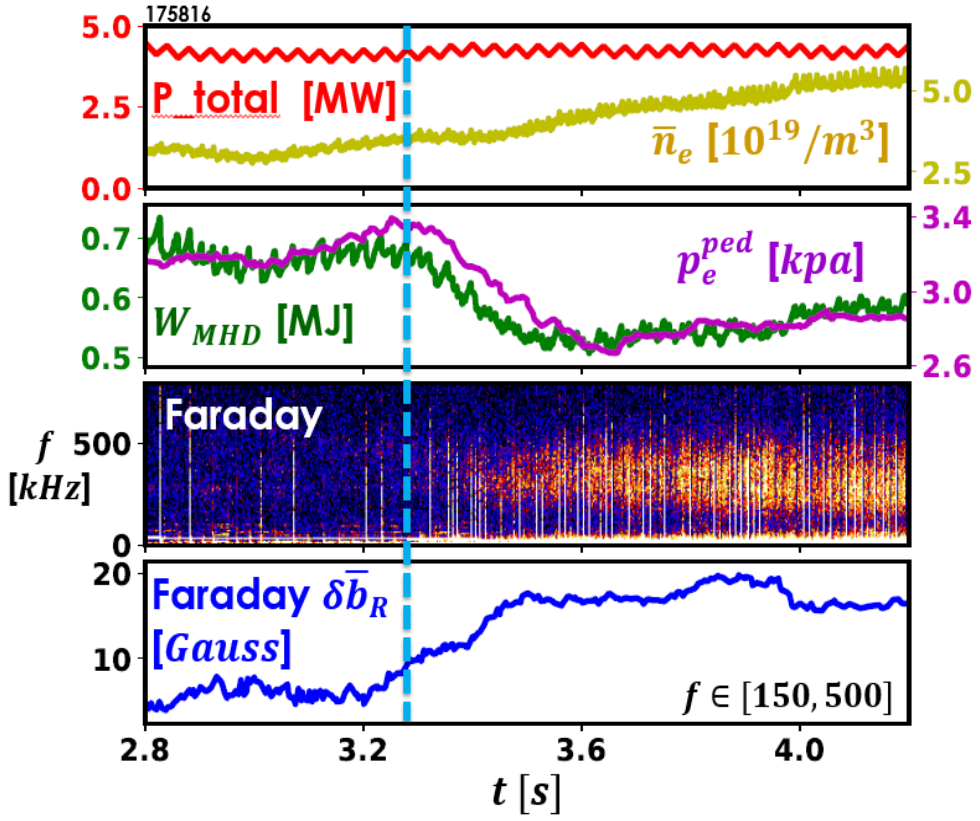
- Low-k ($k_\theta \leq 1/cm$), $1\ MHz$, $\sim 0.1\ Gauss/\sqrt{kHz}$
- Measures density fluctuation $\int \delta n_e dR$ simultaneously
- Measurements reveal broadband magnetic turbulence
- Growth of magnetic turbulence correlates with decrease in stored energy and confinement



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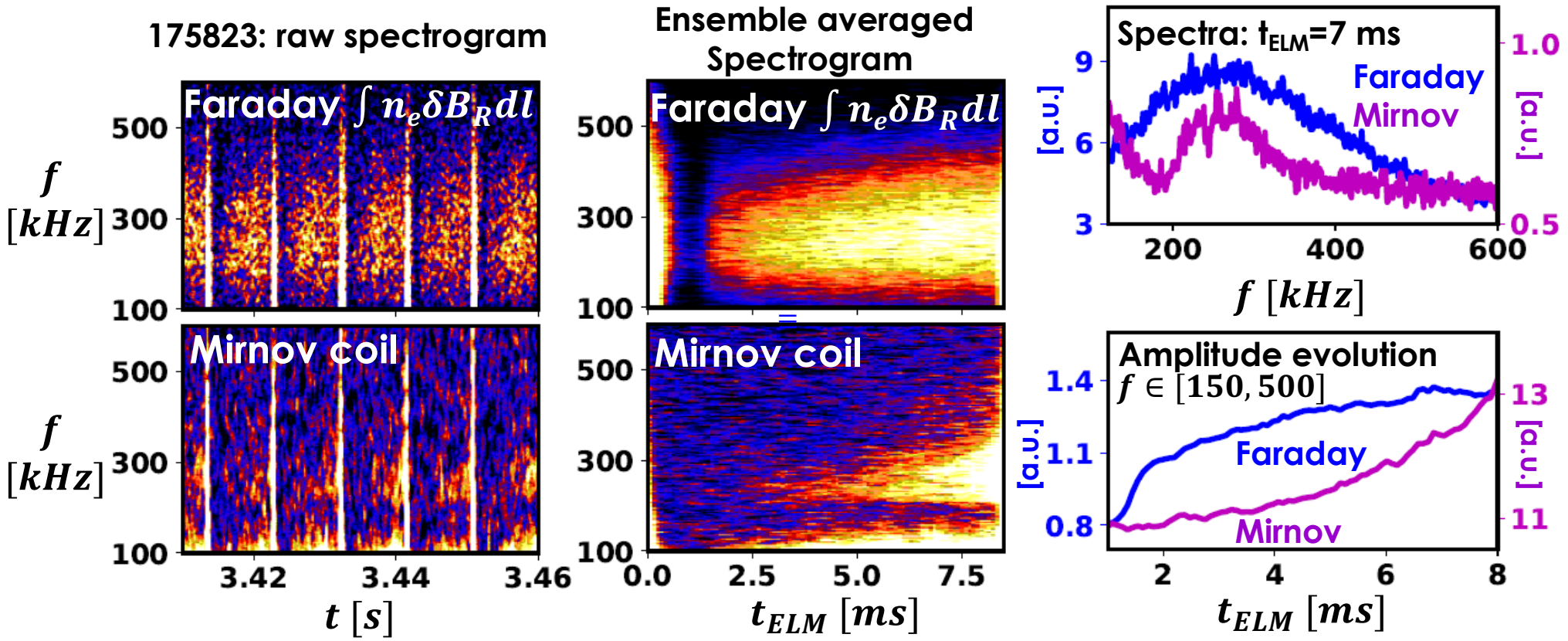
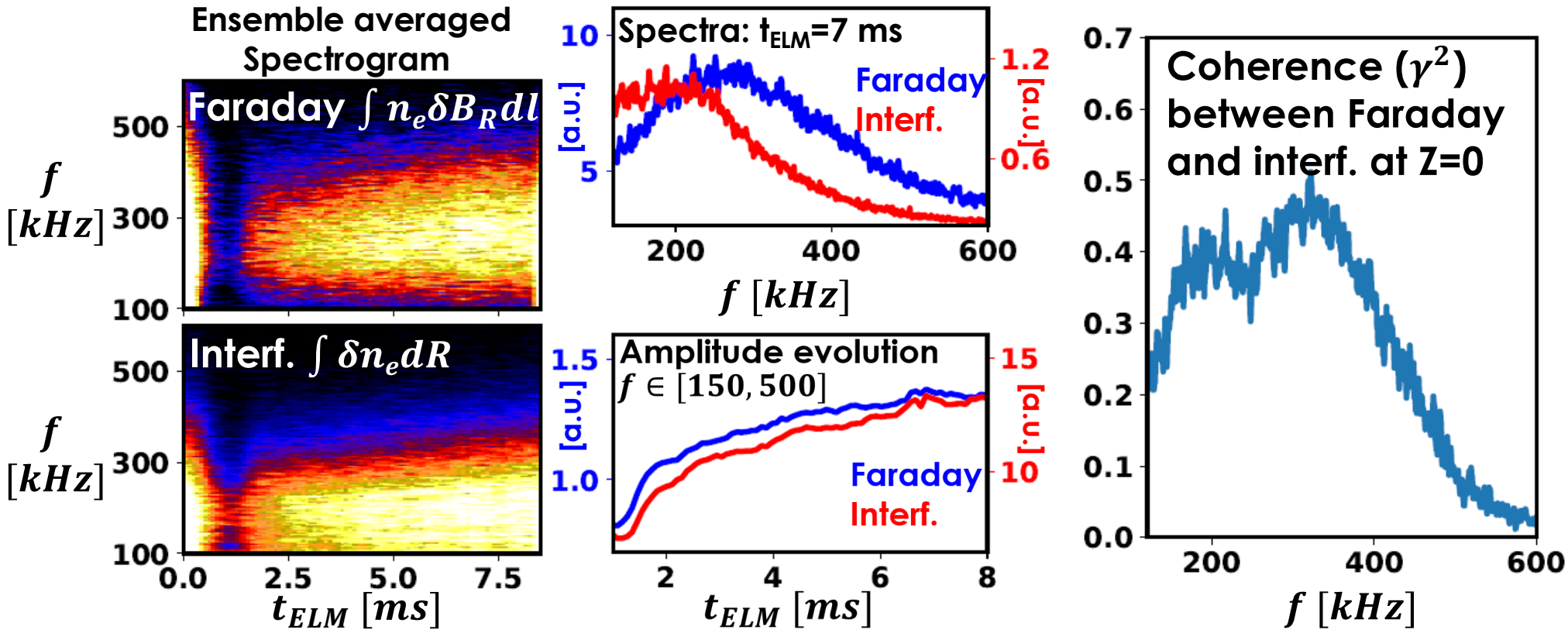
Internal Measurement Provides New Magnetic Fluctuation Information: DIII-D ELMing H-mode plasma



$\delta \overline{B}_R \equiv \frac{\int n_e \delta B_R dR}{\int n_e dR}$ ~ 1(15) Gauss at 250 kHz (150-500 kHz), lower bound

Density and Magnetic Fluctuations Have Finite Coherence



finite coherence Indicates the magnetic and density fluctuations have same $(\omega, \vec{k})$ and originate from the same instability

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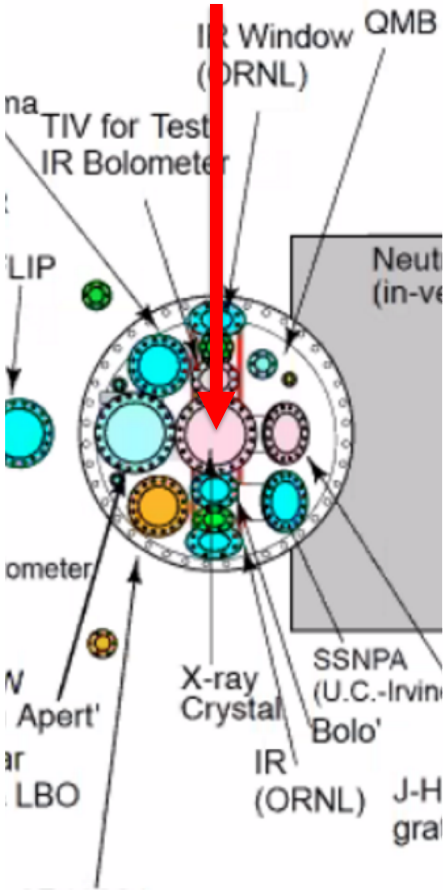
Initial thoughts for NSTX-U Faraday-effect Polarimeter-Interferometer (FEPI)

- **Location: Bay I, mid-plane 8" window**
- **Baseline configuration: Single horizontal chord at mid-plane**
  - Measure line-integrated magnetic field and electron density
  - Measure line-integrated, absolute magnetic & density fluctuations and their correlation
- **Other options under consideration**
  - Two toroidally separated chords at mid-plane
    - Measure toroidal mode number n up to ~50
  - Two poloidally separated chords (similar to DIII-D)
    - extra equilibrium constraint
    - Estimate poloidal mode number
  - Three chords with toroidal and poloidal separations
    - More equilibrium constraint
    - Measure toroidal and poloidal mode number

Comments & suggestions are welcome

For FEPI, 8 in. dia.



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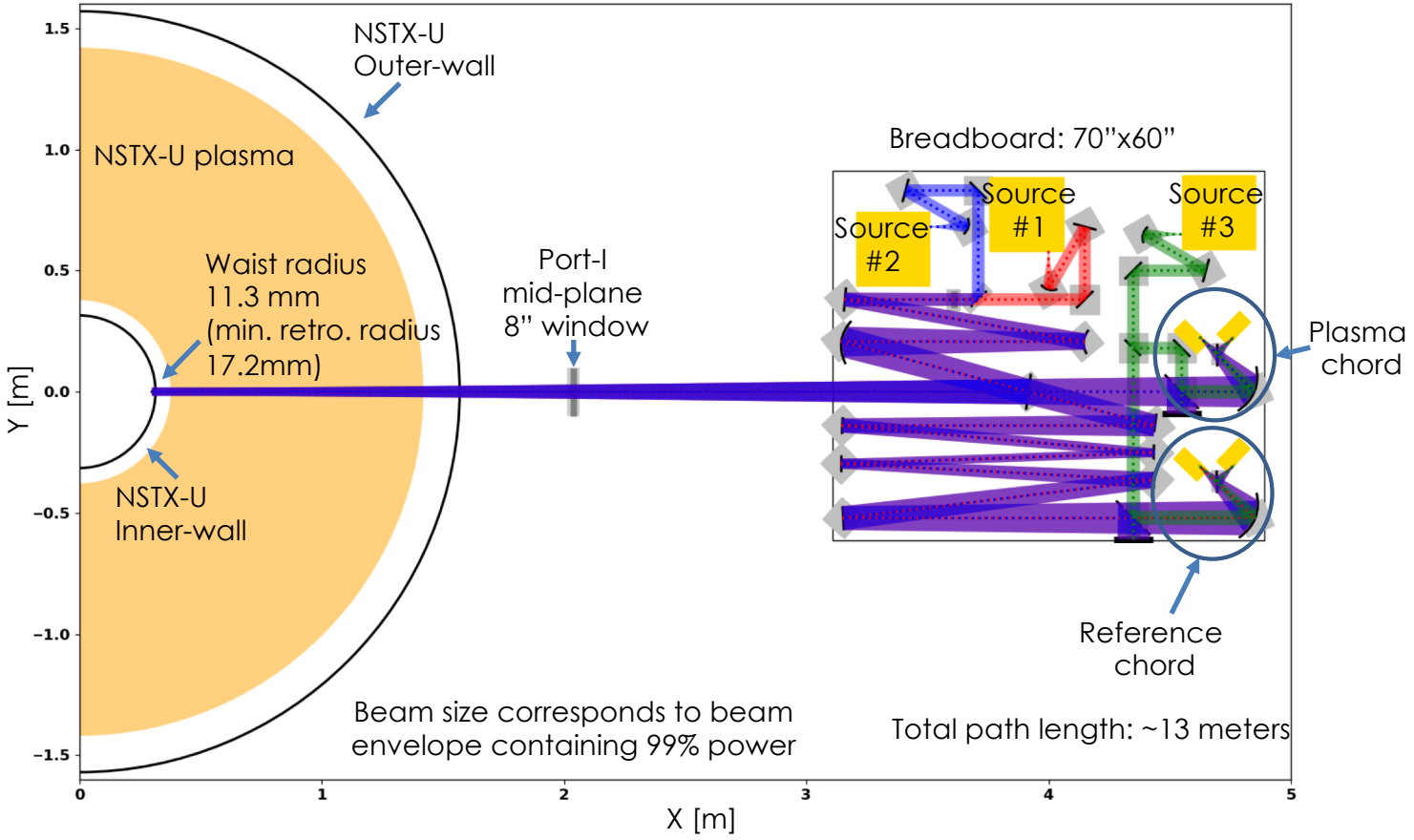
NSTX-U optical layout - initial design (top view)



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Faraday-Effect Polarimetry-Interferometry Diagnostic for Internal Magnetic Field and Magnetic Fluctuation Measurements in NSTX-U

Primary Deliverable: internal measurement of magnetic perturbations from equilibrium to 10 MHz

- Magnetic fluctuations associated with MHD, EPM and broadband turbulence (e.g. KBM, MTM)
- Equilibrium changes during fast transients and RMPs
- **Plan to have postdoc/researcher onsite at PPPL, …search ongoing**

Plan

- YEAR 1: Finalize diagnostic design optimized for NSTX-U plasmas
- YEAR 2: Complete hardware purchase and fabrication
- YEAR 3: Complete bench test and machine interface
- YEAR 4: Complete installation and obtain first result in NSTX-U
- YEAR 5: Complete optimization in NSTX-U and ready to support physics research program

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