Far Infrared Tangential Interferometry and Polarimetry (FIReTIP) System on the National Spherical Torus Experiment

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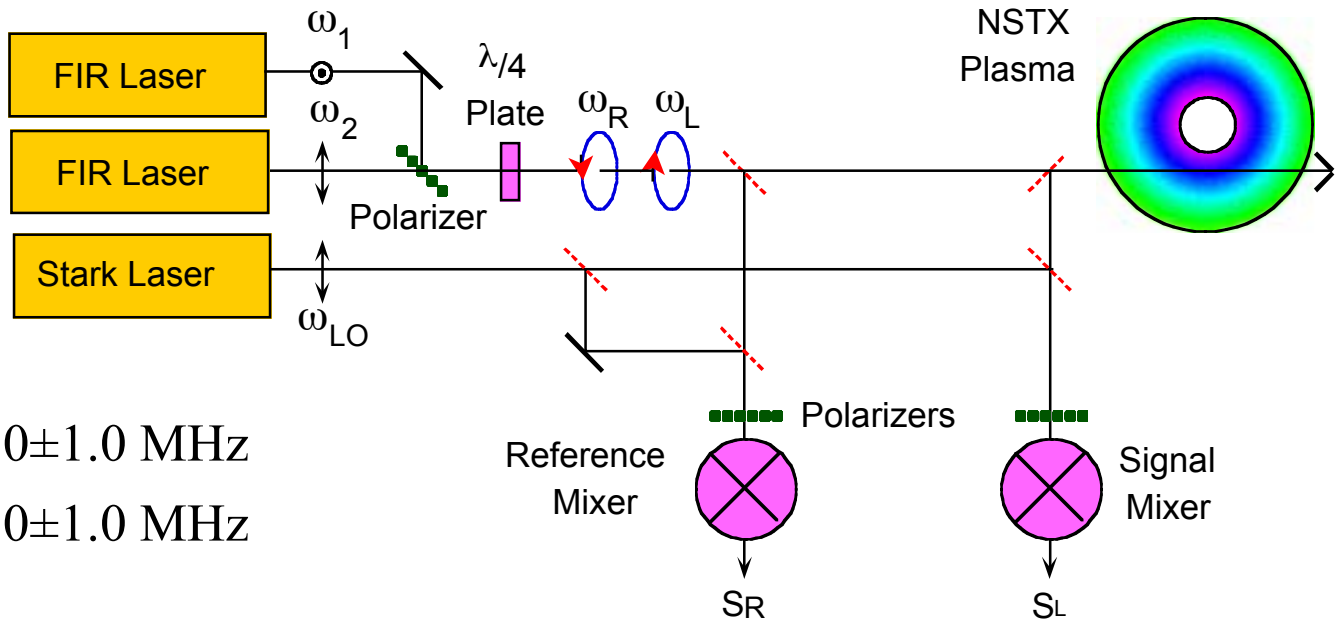
Principle of FIReTIP system on NSTX

$$\phi(x) = 2.8 \times 10^{-15} \lambda \int_o^x n(x')\,dx'$$

$$\Psi(x) = 2.6 \times 10^{-13} \lambda^2 \int_o^x n(x') B_T(x')\,dx'$$



Rommers & Howard

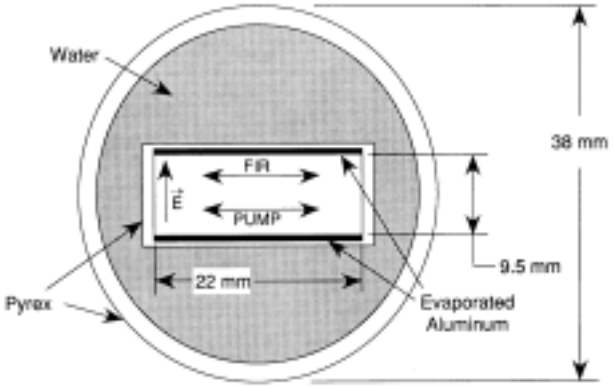
$$\mathbf{W}_{LO} - \mathbf{W}_1 = 4.0 \pm 1.0 \text{ MHz}$$

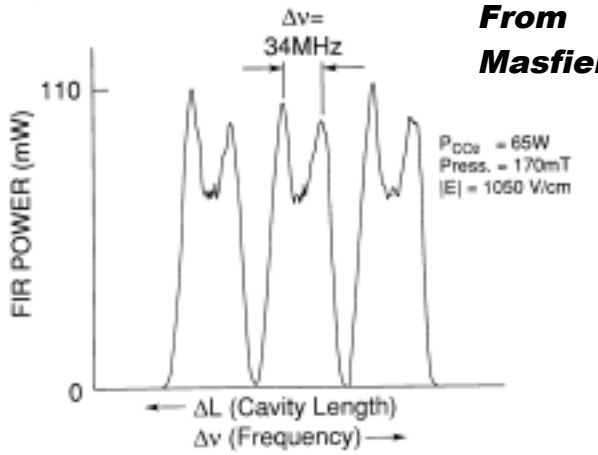
$$\mathbf{W}_{LO} - \mathbf{W}_2 = 6.0 \pm 1.0 \text{ MHz}$$

$$\frac{d\phi(t)}{dt} << \omega_{if}$$

Stark laser system

- Input/output characterisitcs
  - CO_2 P36: 50 W
  - Pressure : 50 mT
  - Output power: ~20 mW
  - Wavelength : 119 micron
- Cavity characteristics
  - Applied voltage: ~400 V
  - Cavity length: ~ 2 m
  - Gap distance: 1 cm
  - Offset frequency : ~5 MHz
- Used as a local oscillator

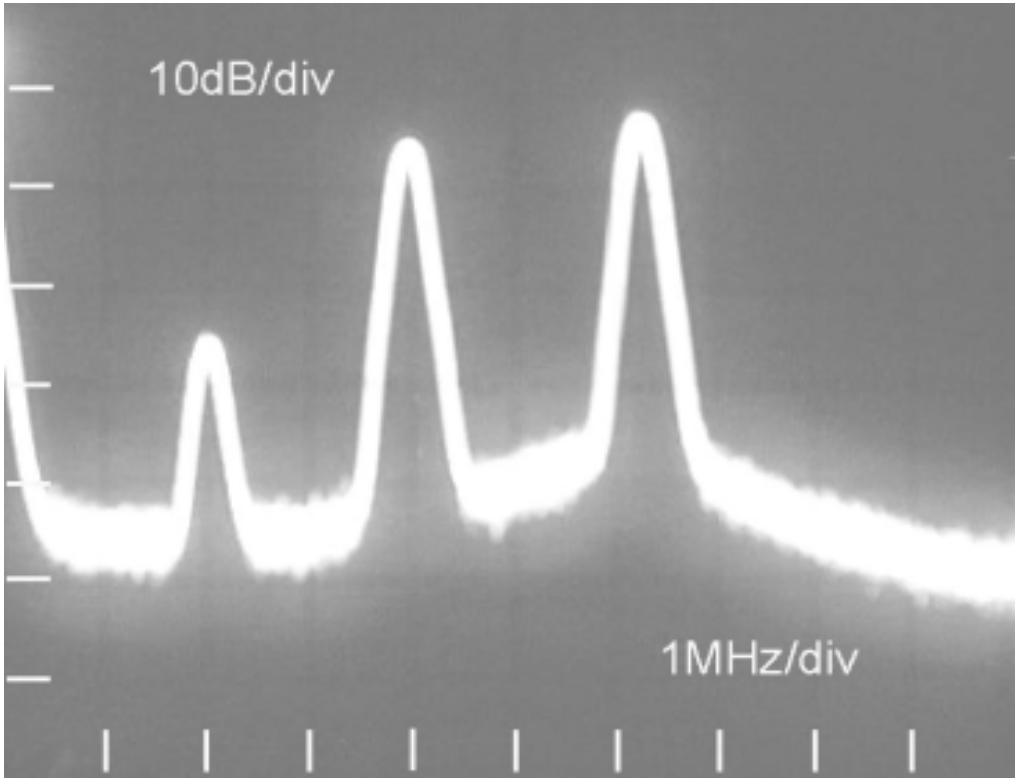




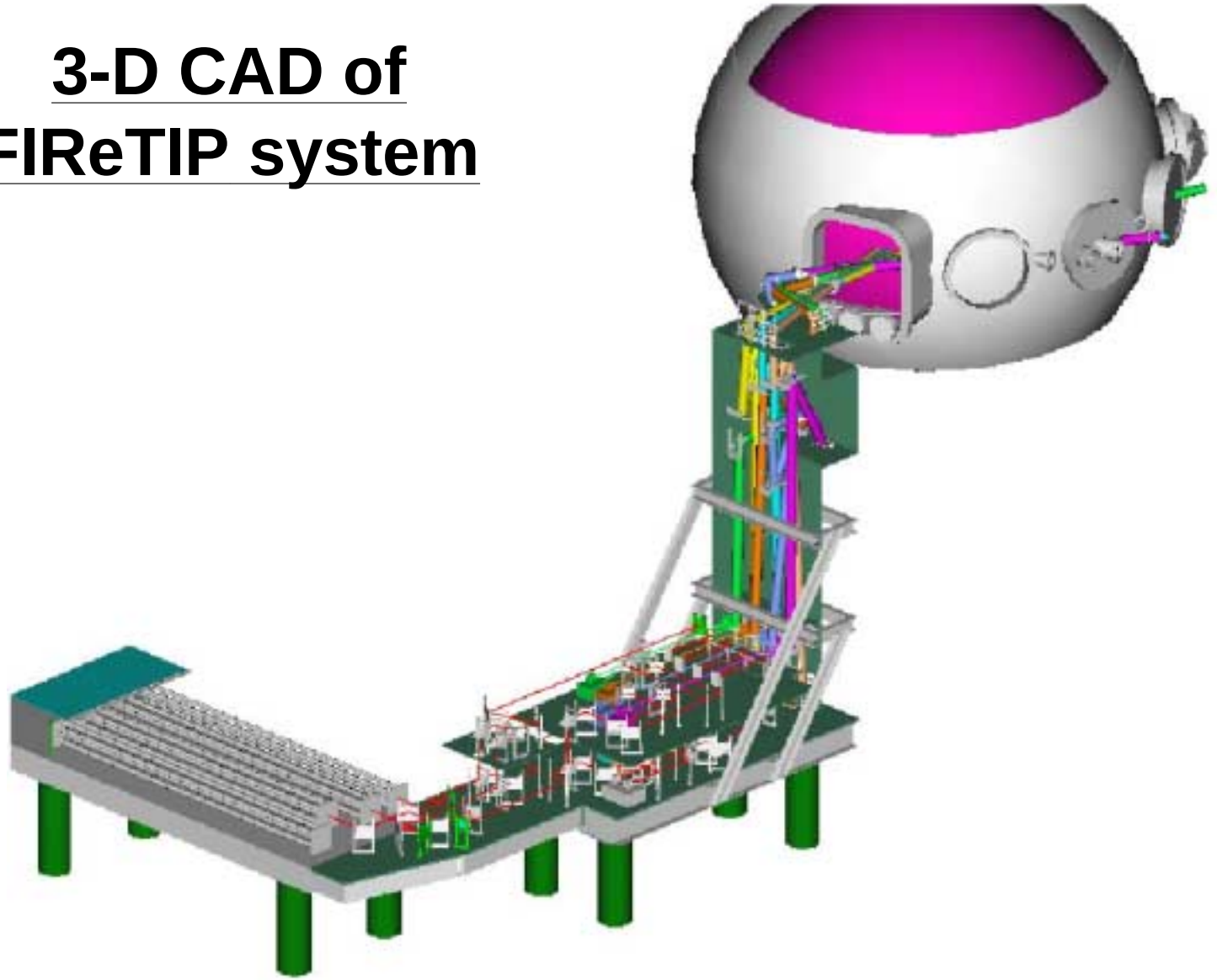
From Masfield et al.

IF signal of the Stark laser system

- Beat spectrum of three FIR lasers from IF signal in the reference mixer (right hand side is 6 ± 1MHz, middle one is 4 ± 1MHz and left hand side is ~2MHz that is the beating frequency between the FIR1 and FIR2)

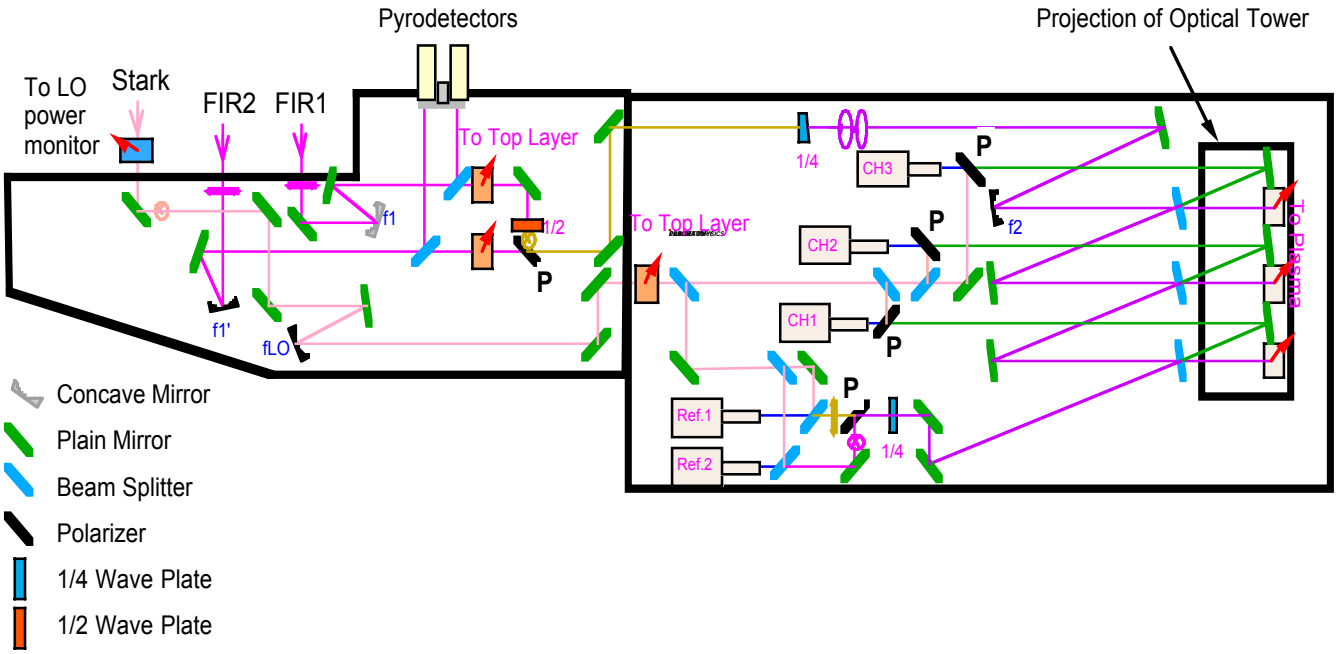


3-D CAD of FIReTIP system



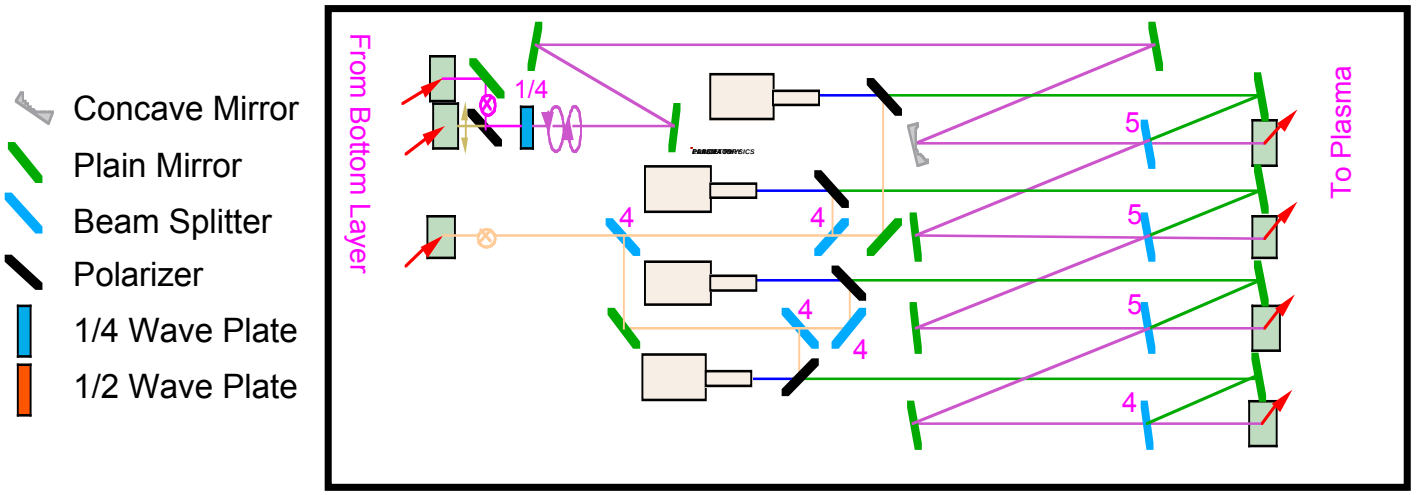
Optical Layout of the FIReTIP System (1)

- Layout of the bottom layer of three channels and reference mixers.

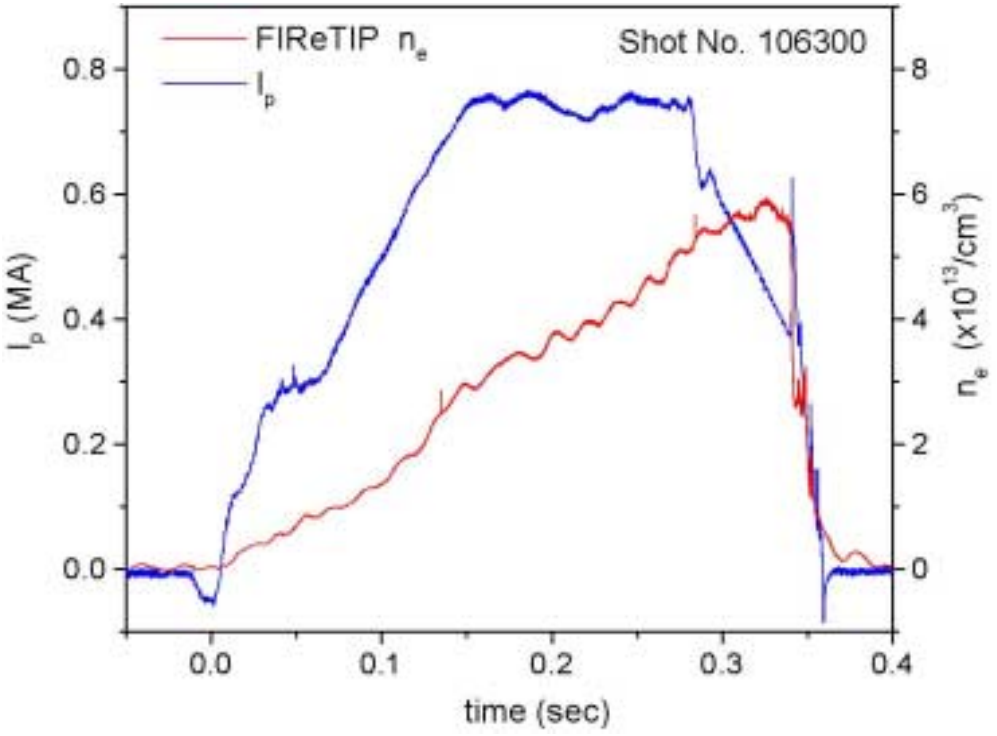


Optical Layout of the FIReTIP System (2)

- Schematic for the four channel system (Phase 2). These channels will be added on top of the first three channels.



Density Measurement Improvement by Vibration Free Stand

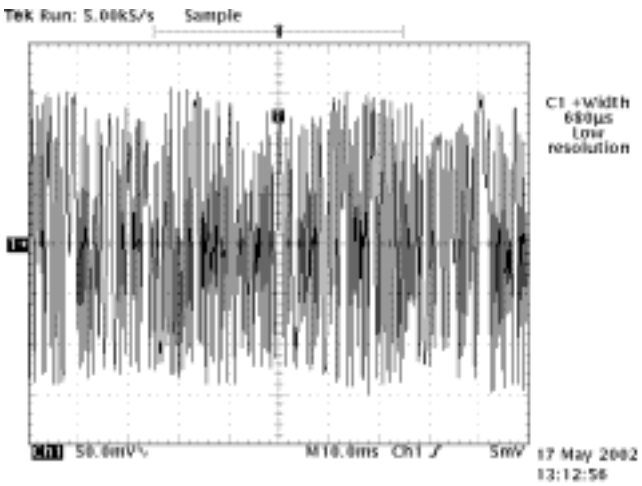


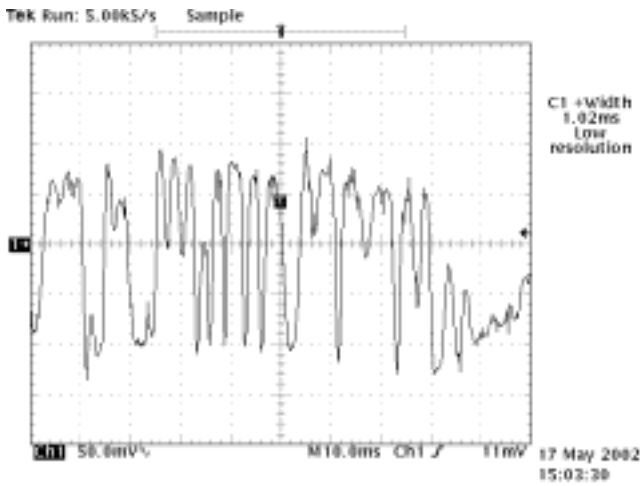
Typical FIReTIP density time traces before the installation of a vibration free stand (2001)

- **Sources of vibrations**
  - **Magnetic field**
    - *** Magnetic Isolation**
  - **Vibrations induced by**
    - **OH force**
    - *** though floor : optical table floating by air cushion**
    - *** retro-reflector : install vibration free stands**
- **Characteristics of vibrations**
  - **~ 50 microns at ~ 30 Hz**

Vibration Free Stand Test

- Vibration reduced to factor of 10 at 30 Hz

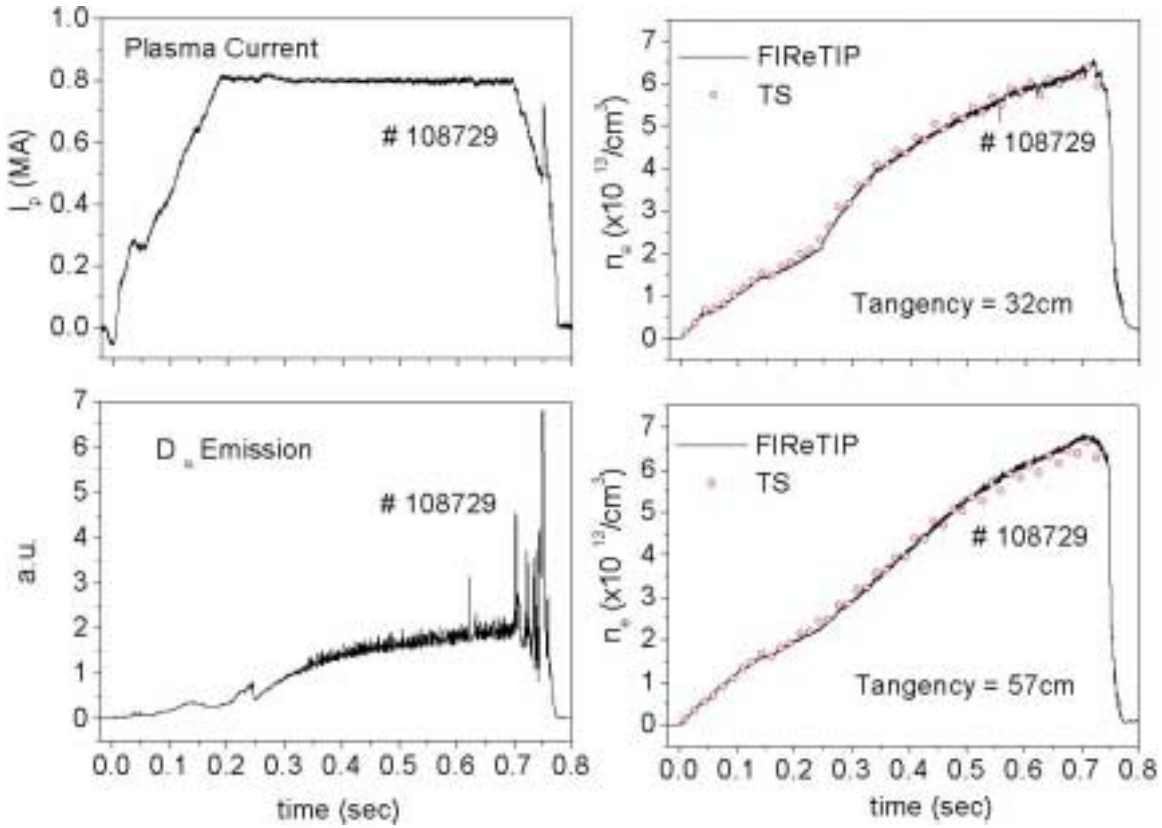




- Vibration free stand
- Without Vibration free stand
- With Vibration free stand

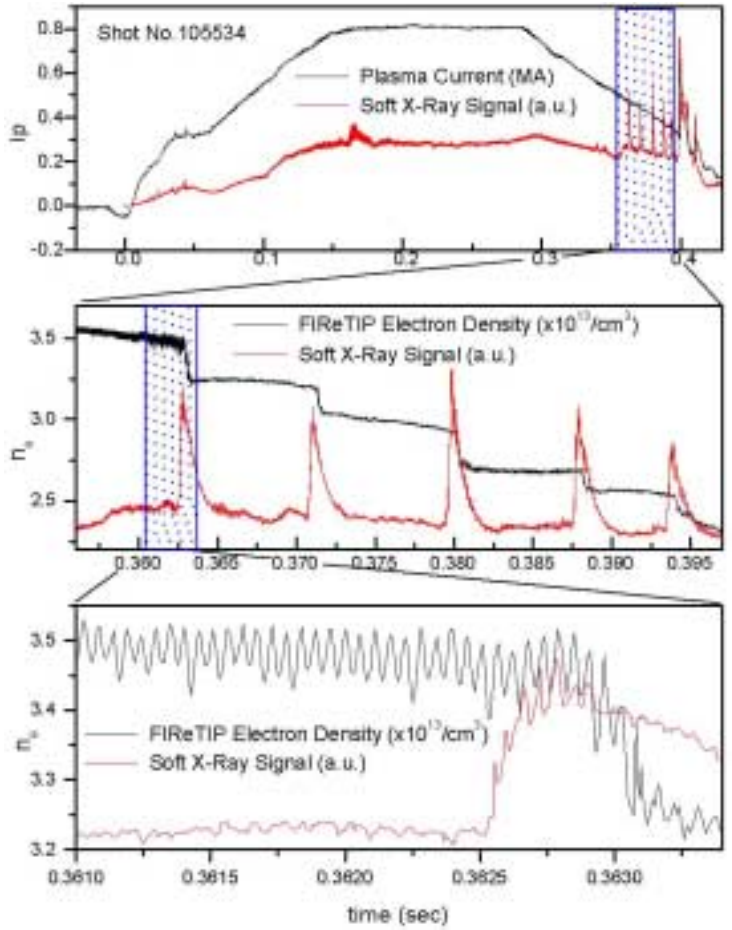
- One full cycle of sine wave corresponds 0.6micron, number of cycles in a wave packet is proportional to the amplitude of the vibration

Density Measurement with Vibration Free Stands

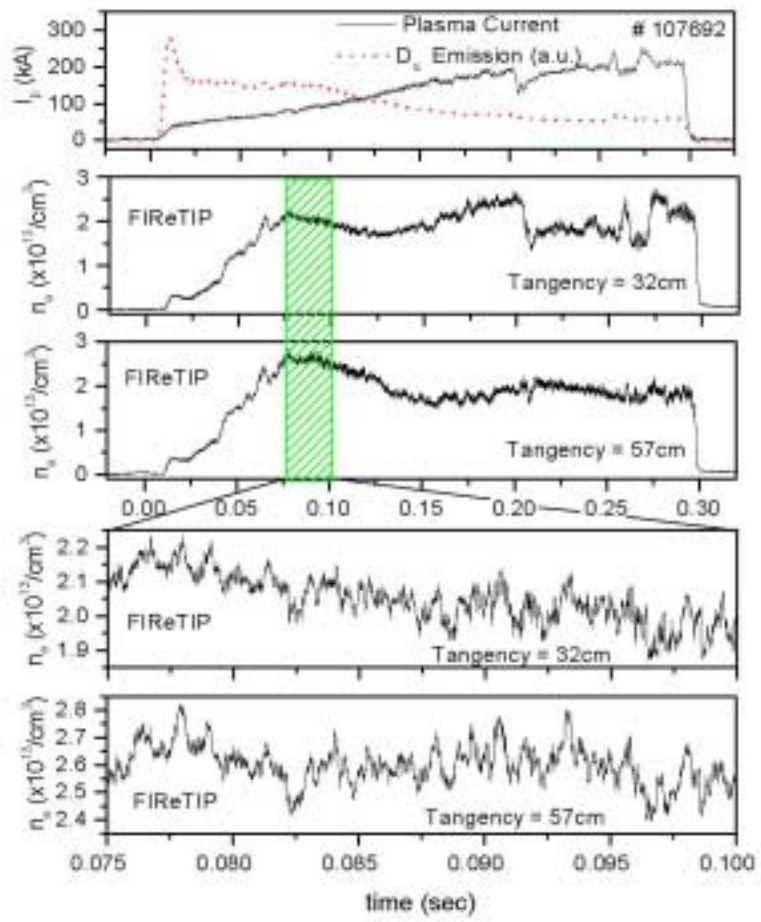


Density traces (channel #1 and #2), free of mechanical vibration, is demonstrated with the line-integrated Thomson scattering data along the same beam paths (2002)

Examples of MHD and CHI plasma measurements



Measurement of sawteeth and Mirnov oscillations by FIReTIP

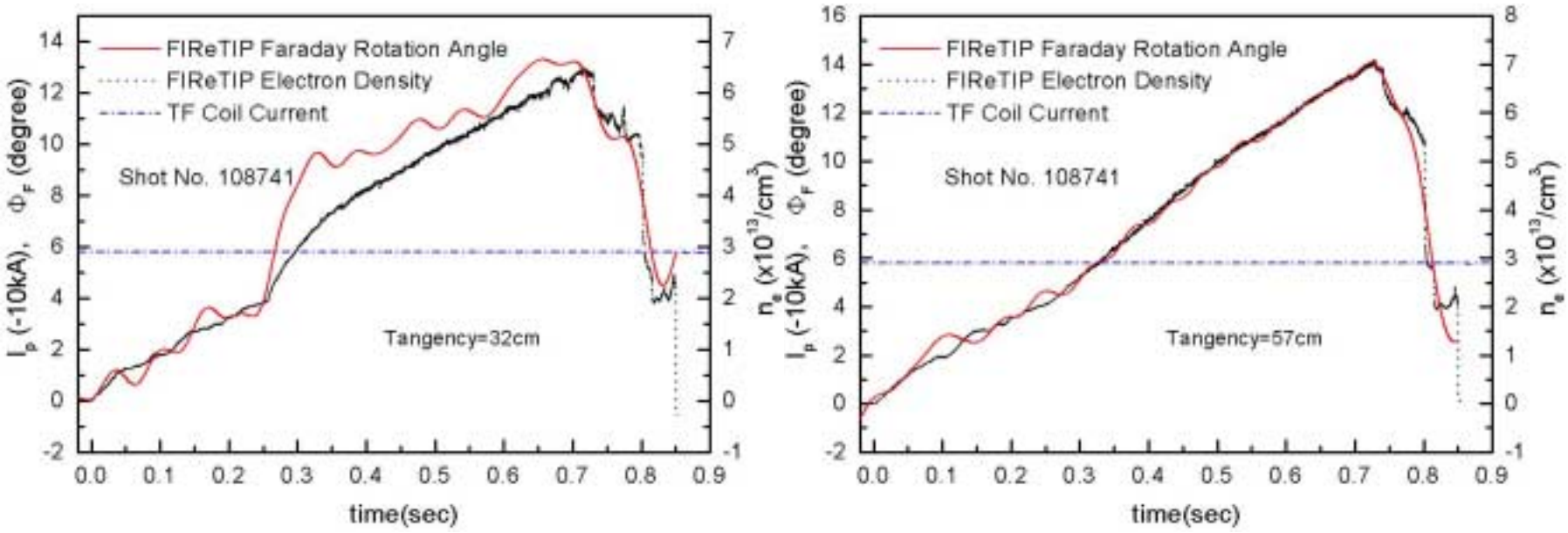


Density evolution during the Coaxial Helicity Injection (CHI)

Para/diamagnetism Study in Conjunction with EFIT

Interferometry : $\phi(x) = 2.8 \times 10^{-15} \lambda \int_o^x n(x')dx'$

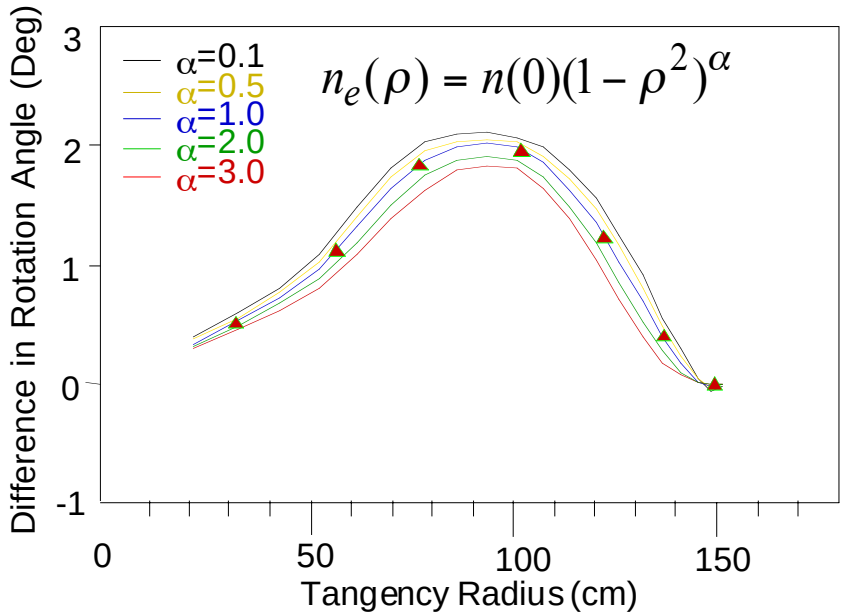
Polarimetry : $\Psi(x) = 2.6 \times 10^{-13} \lambda^2 \int_o^x n(x') B_T(x')dx'$



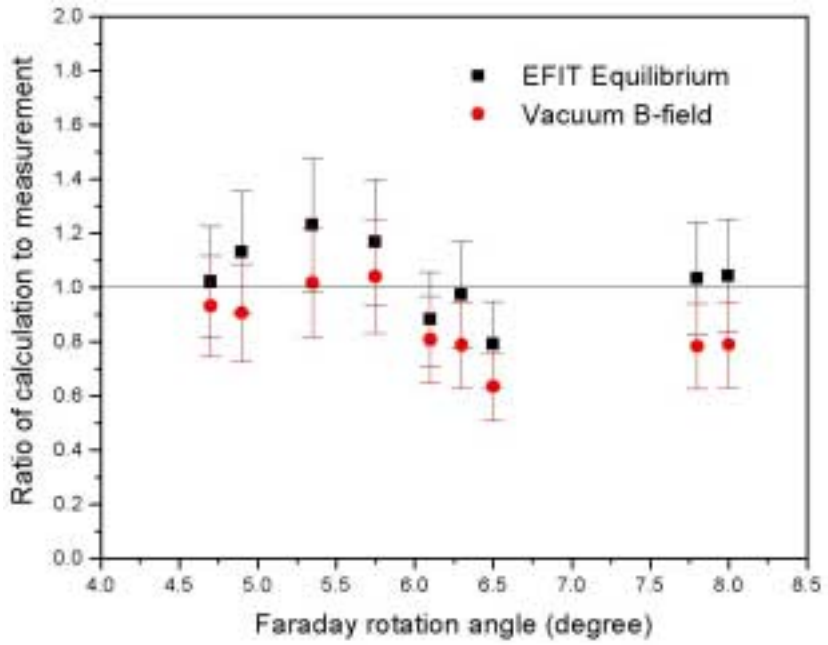
Faraday rotation data were smoothed by filtering out high frequency components above 33Hz

Para/diamagnetism Study in Conjunction with EFIT

Continue

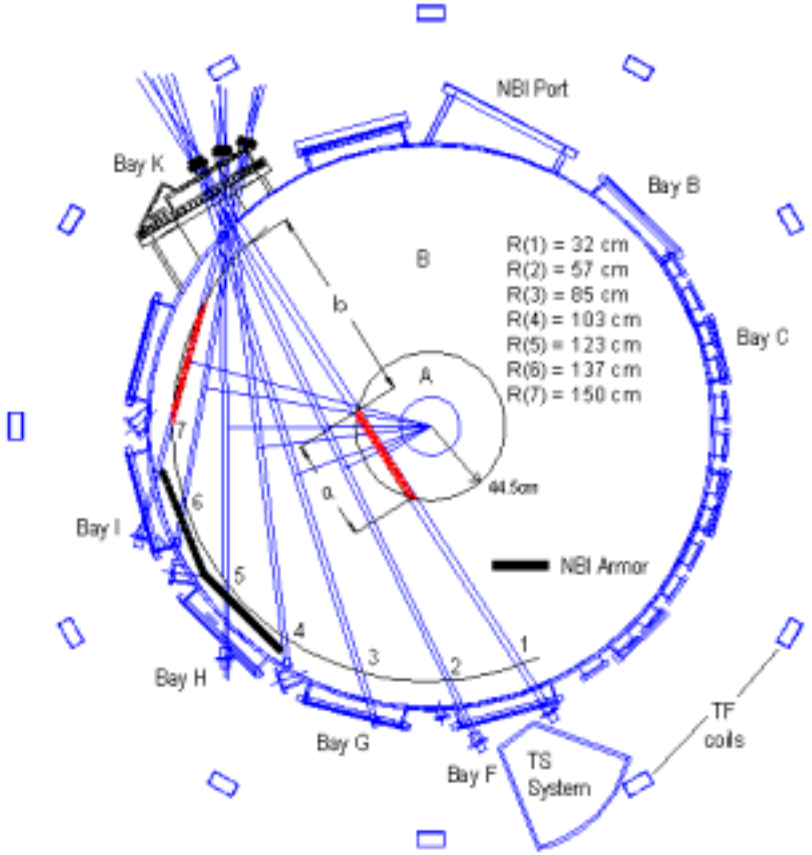


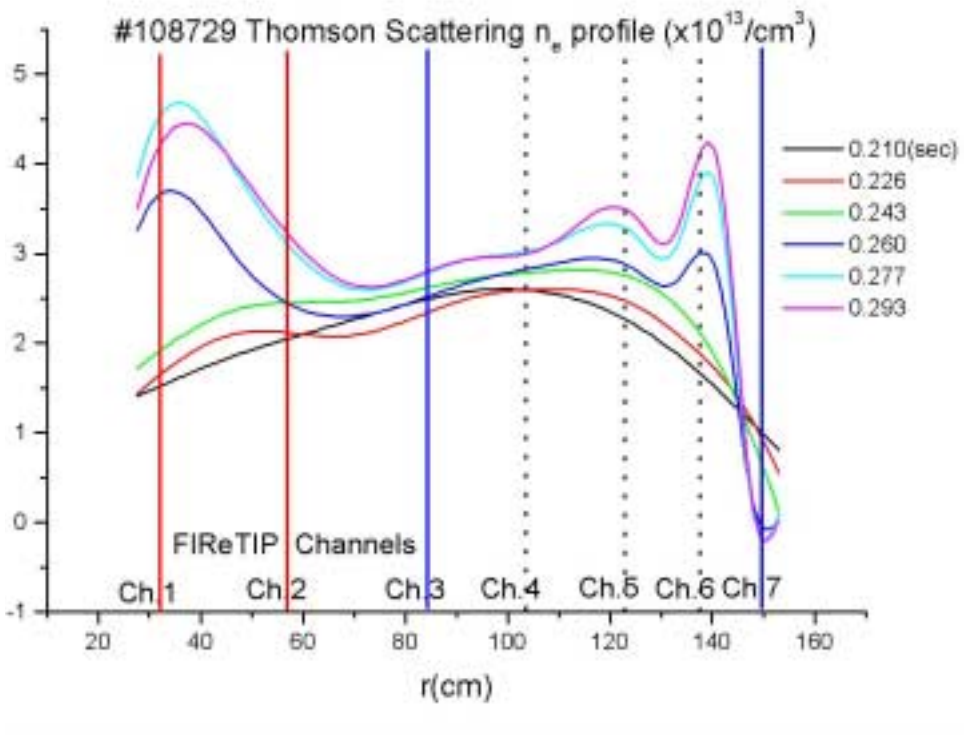
Difference in Faraday rotation angle between vacuum field and presence of diamagnetic effects (~0.5 kG)



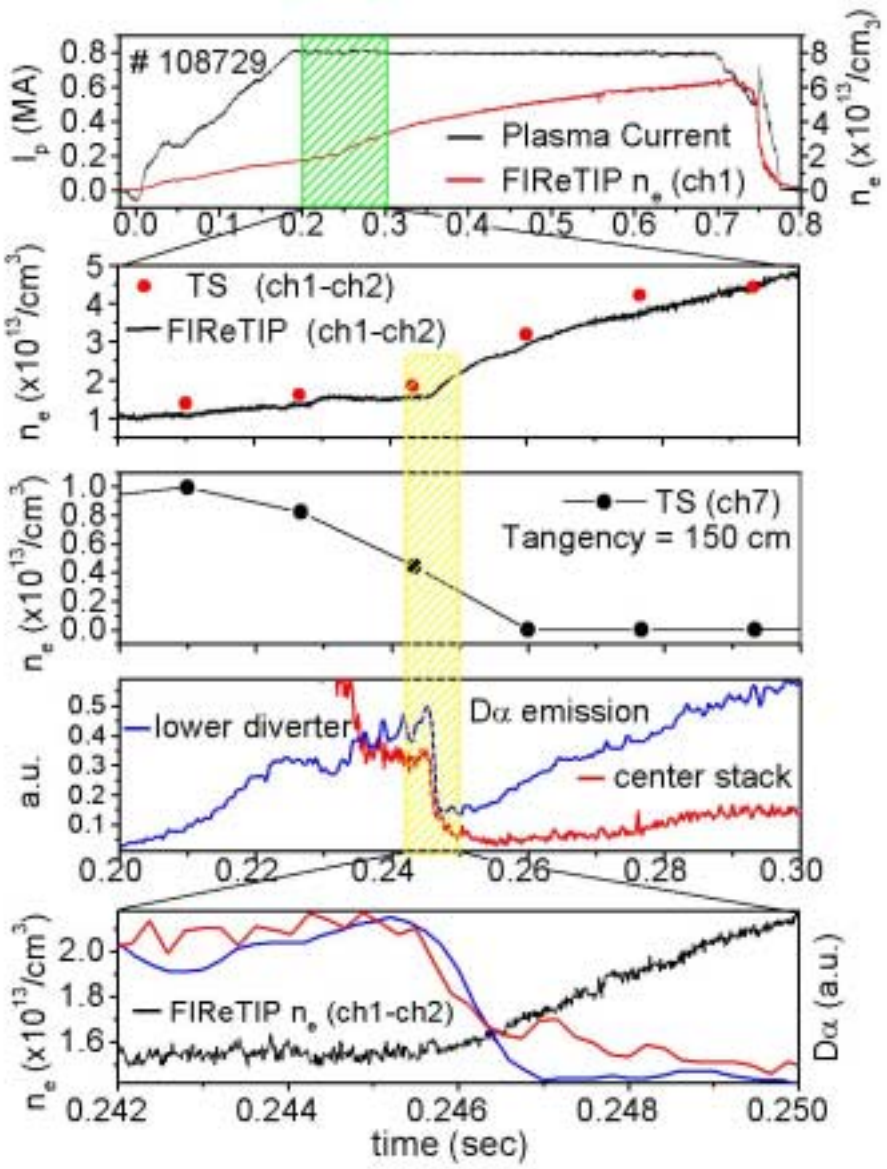
Comparison between Faraday rotation data and calculated rotation angles using both vacuum magnetic field and magnetic field calculated by EFIT equilibrium code (2001)

Edge Density Transition (L-H Mode)





Time evolution of density shows the "ear structure" of the spherical torus

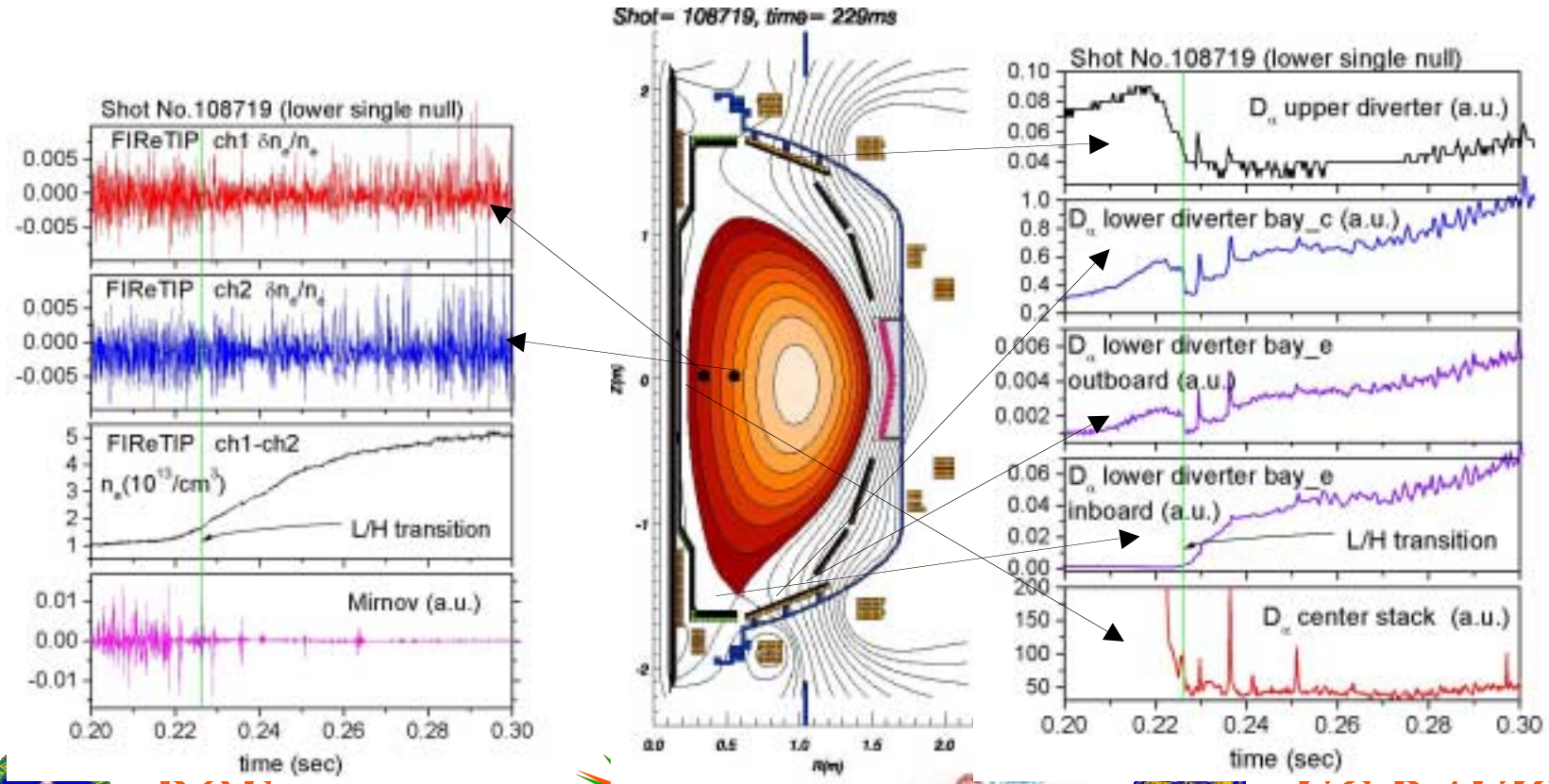


Correlation of Density Rise with D_a Emission

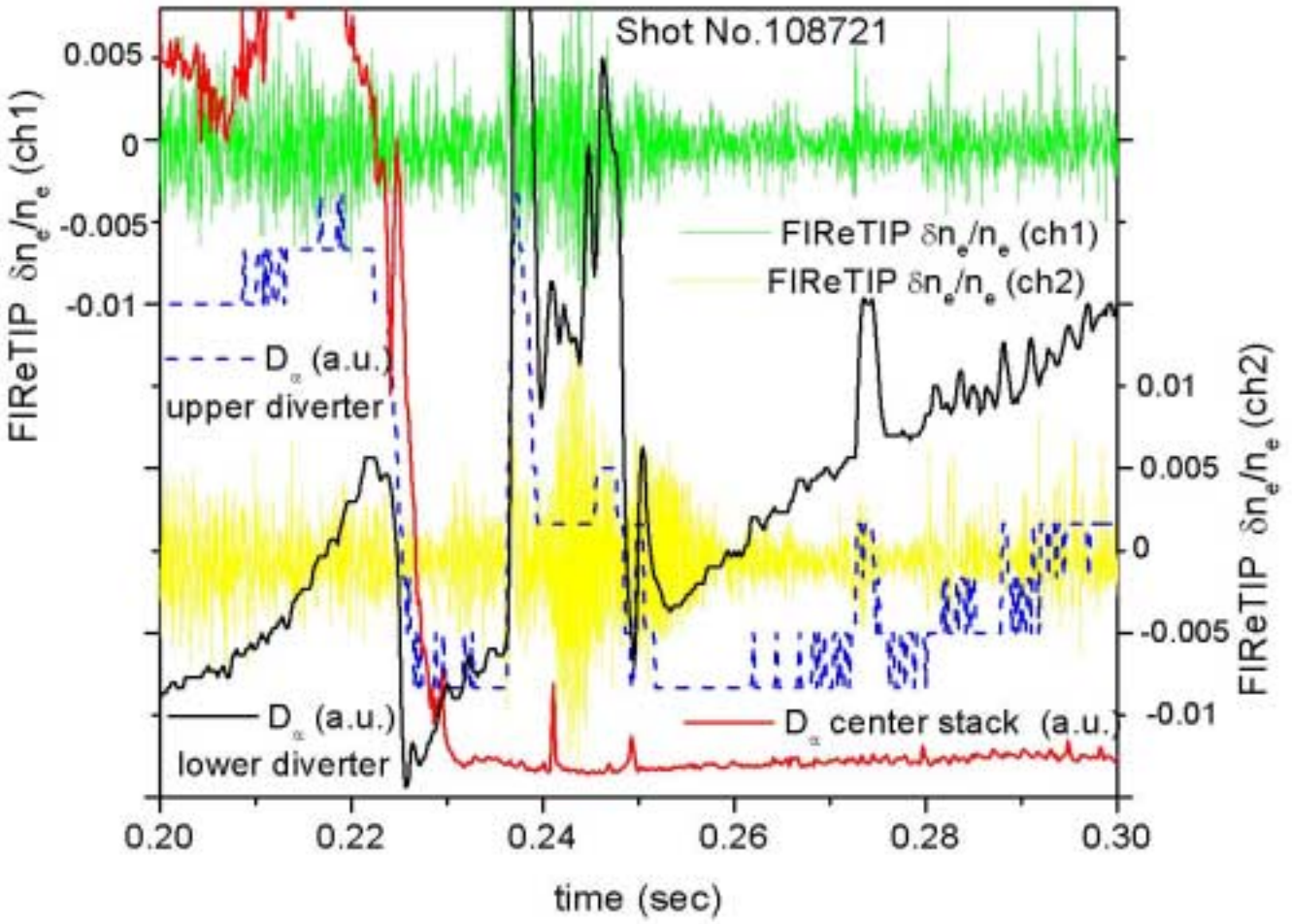
- Subtraction ch2 from ch1 indicated sudden rise of L-H mode transition
- FIReTIP edge channels(ch6,ch7) will provide high time resolution data
- FIReTIP (ch1-ch2) density rise is close to D_a/diverter and D_a/center stack

Formation of edge density in H-mode

- Combination of a strong fueling (inner divertor side)
- local confinement improvement via fluctuation suppression



L/H transition (single null)

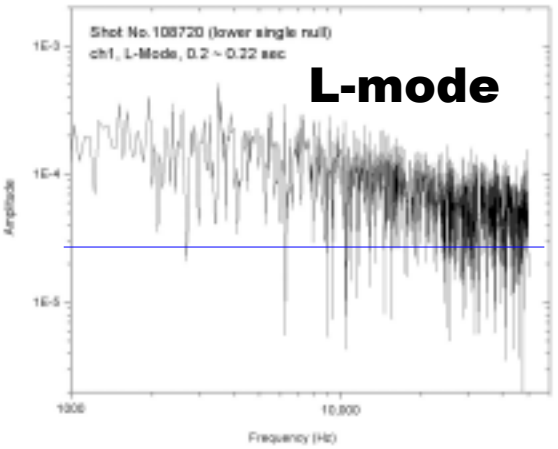


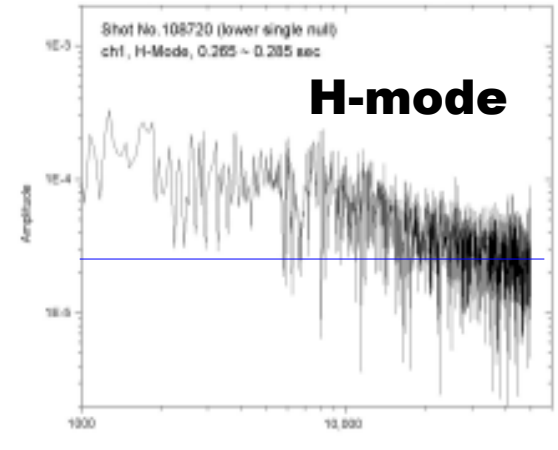
- Density fluctuation suppression is clear (before and after transition)
- ELM at the diverter is well correlated with the fluctuation increase

Frequency spectra changes (L/H)

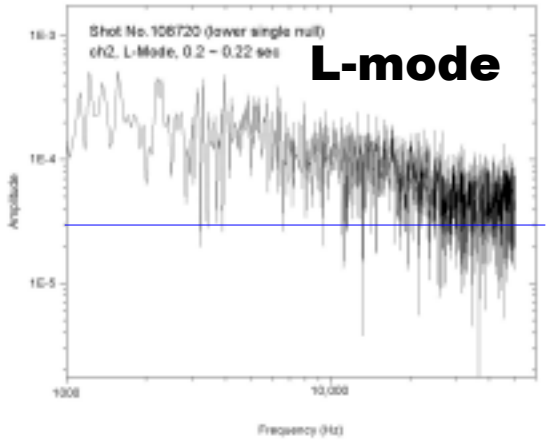
- During H mode phase, non-MHD parts are reduced
  - 10 ~ 40 kHz bands are reduced
  - Fishbones and TAE are around 50 ~100 kHz (evident in ch#2)

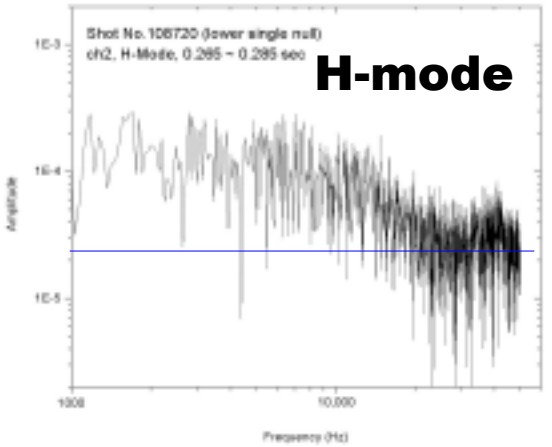
Channel #1





Channel #2





Summary

- Instrumental Improvement

FY 2002	CO2 Laser Power : ~50 W	Number of Channels : 2 Channels	Fluctuation Measurement Limit : 100 kHz	Polarimetry Measurement : Small Signal (ch1, ch2)
FY 2003	~90 W	4 Channels	~ MHz	Large Signal (ch3)

- Physics Study Improvement

FY 2002	▪ System began to show clear density fluctuation on 2 channels ▪ L\H Transition ▪ Comparison of Polarimetry with EFIT
FY 2003	▪ MHD & Stability study (dia/paramagnetism effect) ▪Transport Physics ▪ - 4 Channel Fluctuation Study ▪ - In & Out Asymmetry in Density and Fluctuation ▪ Density Control by Real Time Feedback can be installed