NSTX

Supported by U.S. DEPARTMENT OF ENERGY | Office of Science

Initial Results of Millimeter-wave Polarimeter/Interferometer Prototype Test

Jie Zhang

W. A. Peebles, N. A. Crocker, T. L. Rhodes, E. J. Doyle, T. A. Carter, L. Zeng, S. Kubota,

UCLA

W. Guttenfelder (PPPL),

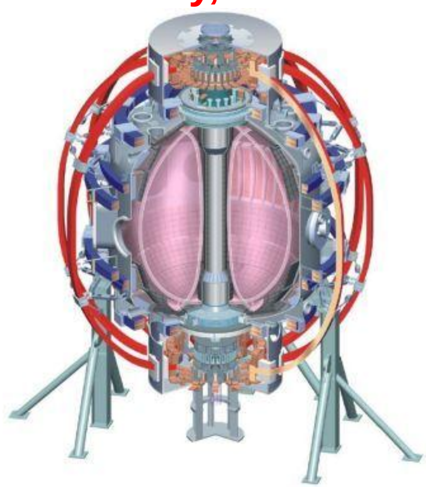
the NSTX Research Team

and the DIII-D Fusion Group

53rd Annual Meeting of the APS Division of Plasma Physics

November 14-18, 2011

Salt Lake City, UT



Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
ORNL
PPPL
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin

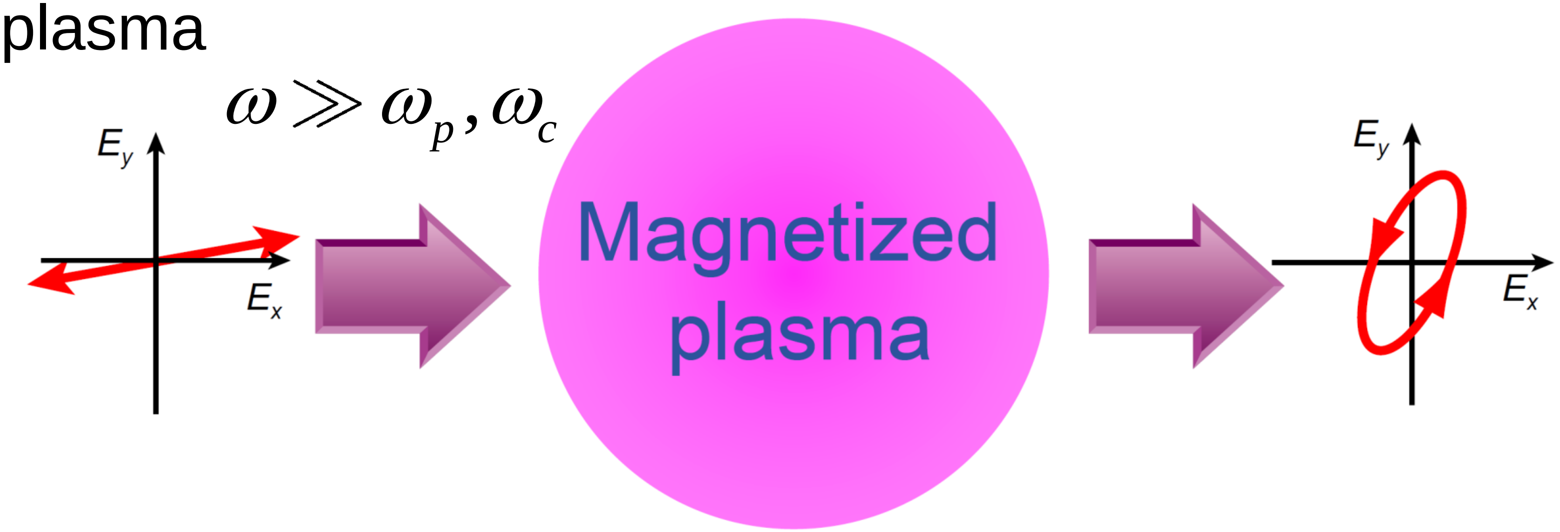
Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
NFRI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

Overview

- Polarimetry is a sensitive diagnostic for internal ***B***, especially its fluctuations (δ***B***)
- Simulations indicate detectable polarimetry response to MicroTearing modes on NSTX
  - Signal dominated by δB, not δn
- A *288 GHz* polarimeter/interferometer system has been designed, fabricated, and tested in laboratory by UCLA
  - Quasi-optical isolation critical to achieve sub-degree phase sensitivity
- Prototype tests are being conducted on DIII-D during NSTX-Upgrade downtime
- Polarimetry data looks promising; data interpretation is underway
- Interferometry measurements also demonstrate possible use for density control in NSTX-U especially during initial plasma operating phase

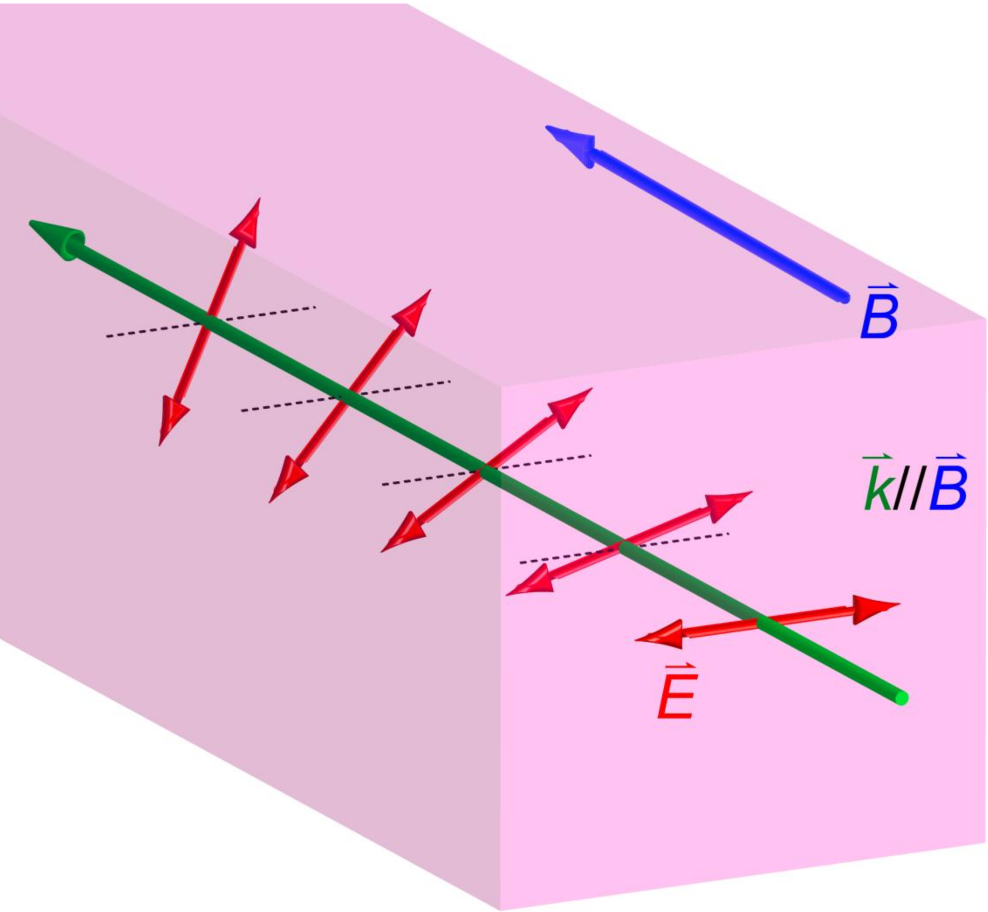
Polarimetry is a sensitive diagnostic for internal *B* measurements

- Polarimetry measures the polarization change of a high-frequency EM-wave after it goes through a magnetized plasma



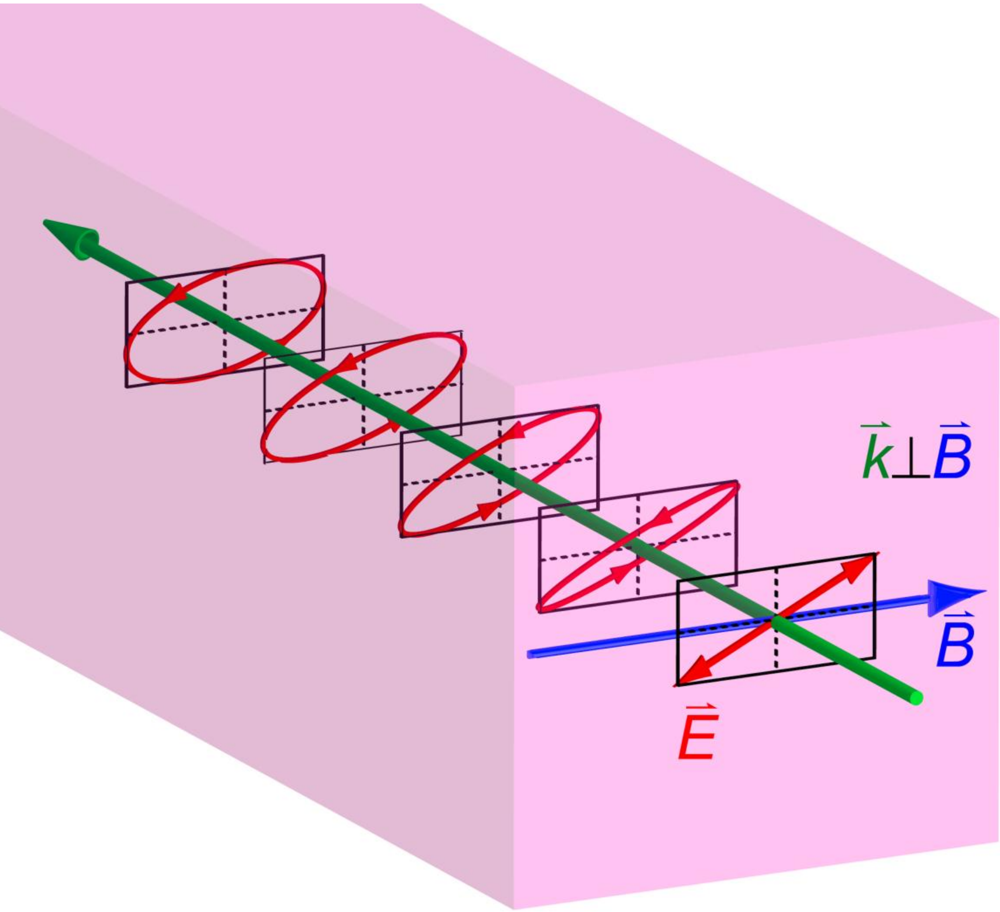
- Faraday Rotation and Cotton-Mouton effects are two principal effects in polarimetry
  - $B_{||} \neq 0 \Rightarrow$ Faraday Rotation
  - $B_{\perp} \neq 0 \Rightarrow$ Cotton-Mouton effect

Faraday Rotation causes a rotation of linearly polarized wave when *k*||*B*



- A linearly polarized wave is a combination of left- and right-handed circularly polarized waves
- Left- and right-handed circularly polarized waves propagate with different phase velocities for ***k*||*B***
- The resultant phase difference causes a rotation of the linearly polarized wave

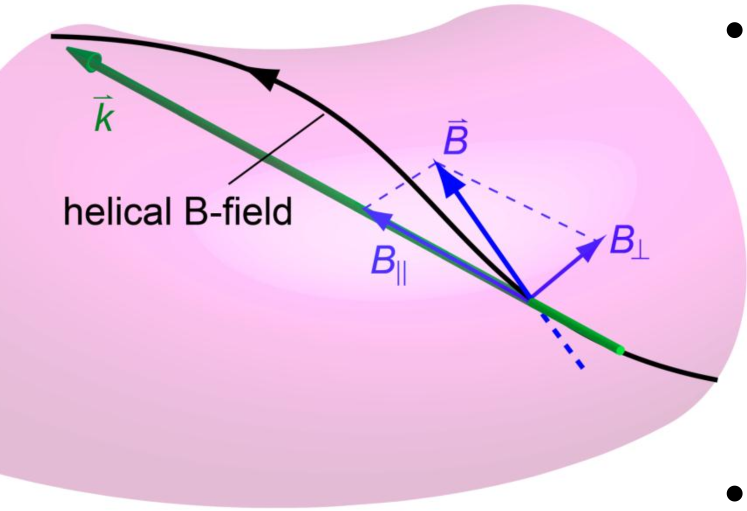
Cotton-Mouton effect can cause a linearly polarized wave become elliptized when ***k⊥B***

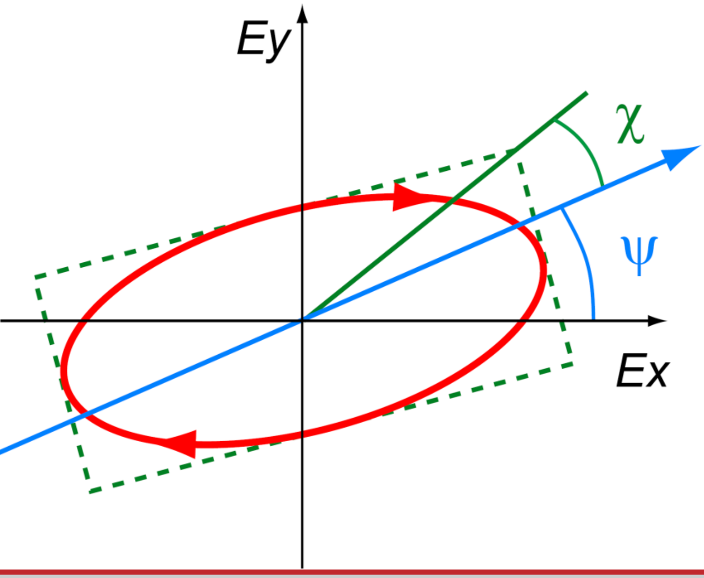


- When ***k⊥B***, O(Ordinary)- and X(eXtraordinary)-modes (linearly polarized) propagate with different phase velocities

- Their phase difference can cause a linearly polarized wave to become elliptized

A 1-D polarimetry simulation code has been developed





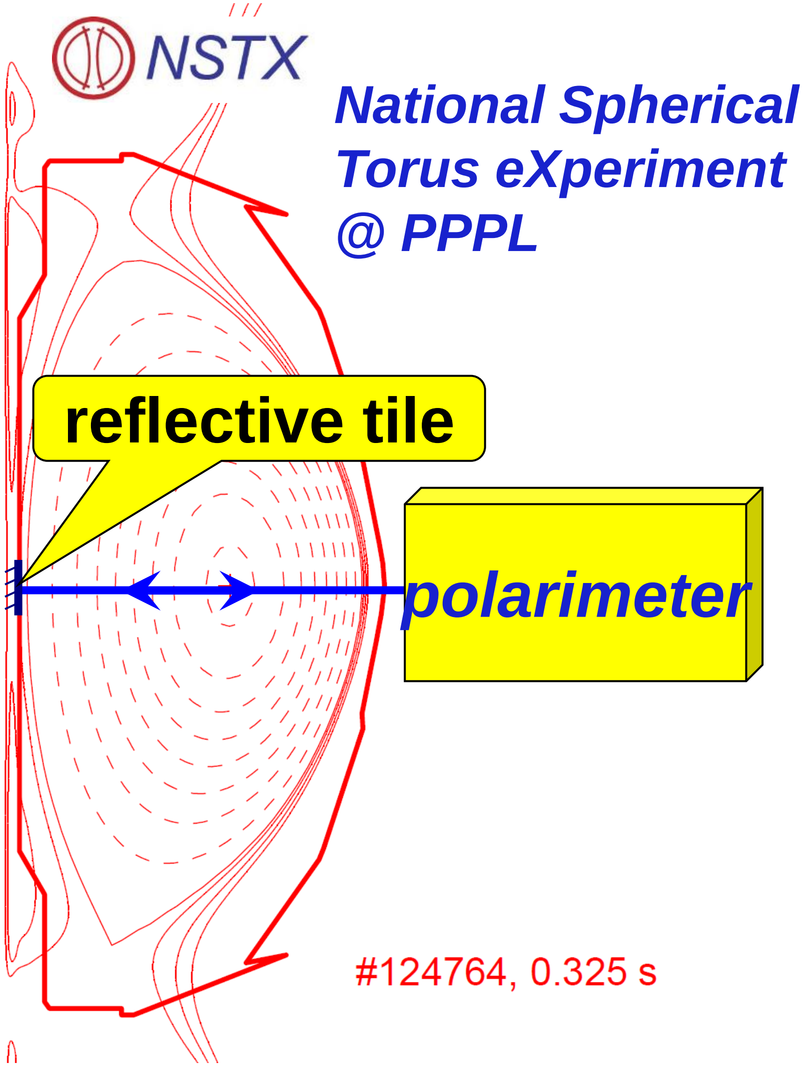
- Both Faraday Rotation and Cotton-Mouton effects occur in ST & tokamak due to the helical B-field structure
  - Oblique B has both $B_{||}$ and $B_{\perp}$ components
  - Complication requires numerical simulations
- A 1-D polarimetry code has been developed to simulate the response of this diagnostic

$$d\psi|_{FR} = -\frac{\omega_{pe}^2 \omega_{ce}}{2c\omega^2}\frac{B_{||}}{B}dz \propto \lambda^2, B_{||}, n_e$$

$$d\delta|_{CM} = \frac{\omega_{pe}^2 \omega_{ce}^2}{2c\omega^3}\left(\frac{B_\perp}{B}\right)^2 dz \propto \lambda^3, B_\perp^2, n_e$$

$$d\chi = \frac{1}{2}\sin 2\psi\, d\delta|_{CM}$$

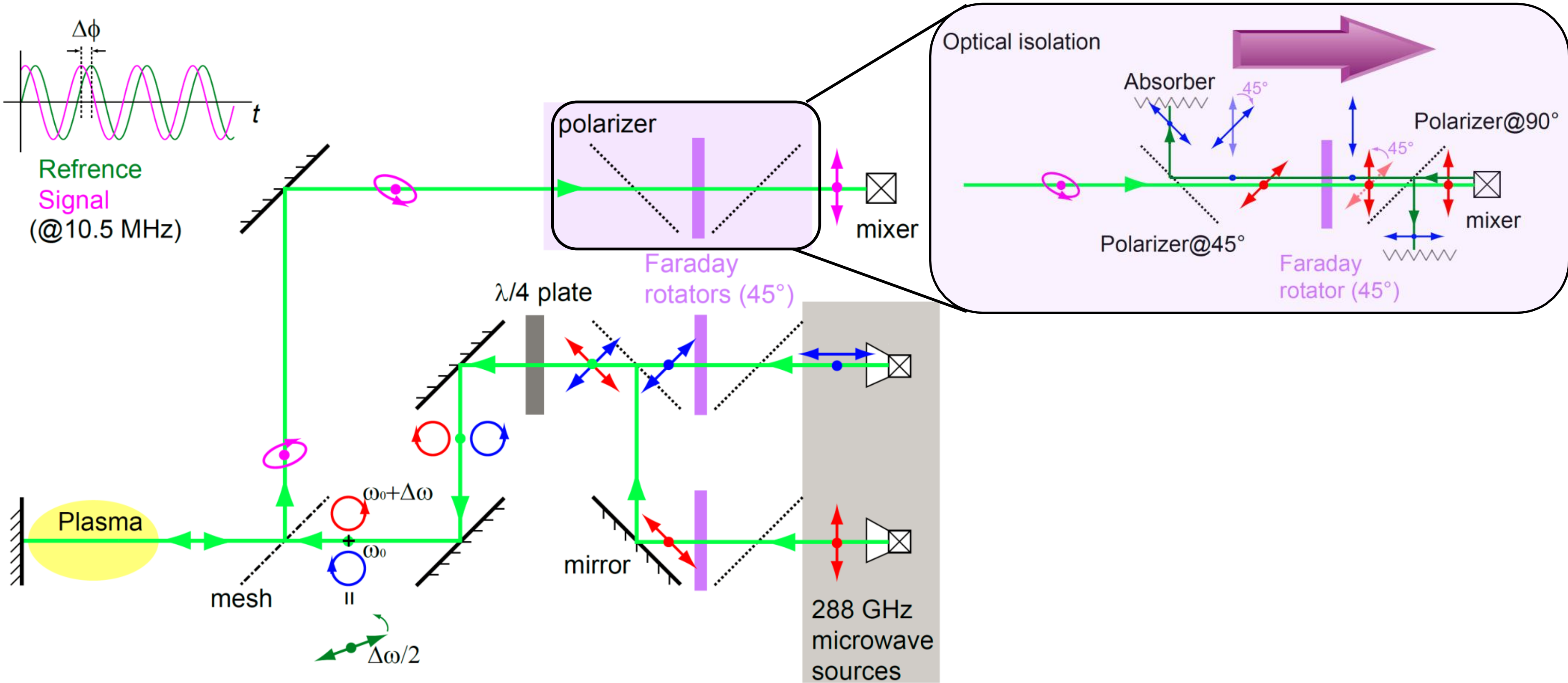
A 288 GHz polarimeter has been designed and fabricated by UCLA for NSTX using a radial retroreflection geometry



- Radial propagation near mid-plane & retroreflection from inside wall

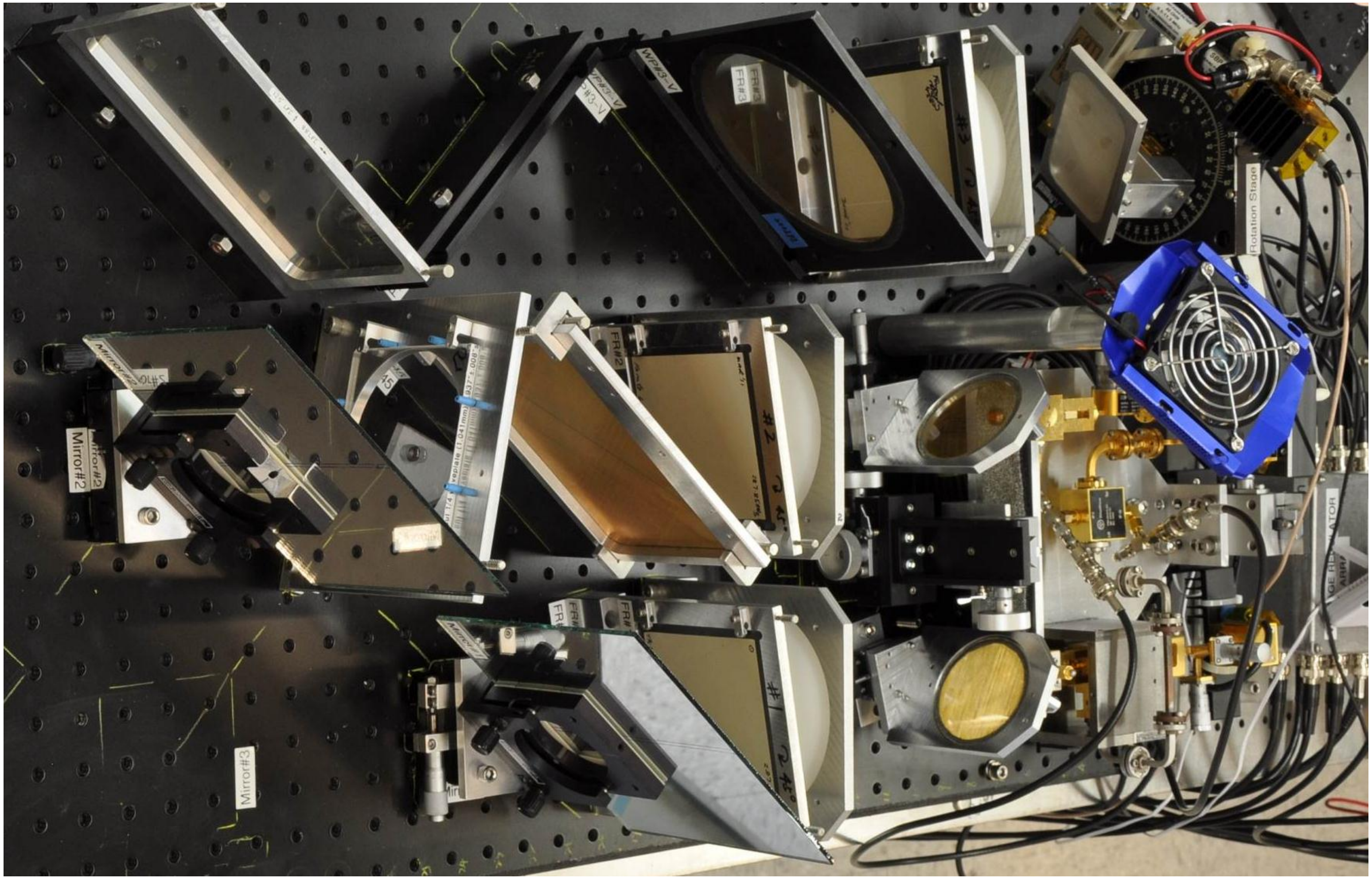
- Sensitivity to internal $\delta\mathbf{B}$ associated with MicroTearing Modes has been evaluated by simulating the polarimetry response

Quasi-optical isolations critical to achieve sub-degree polarimetry phase resolution

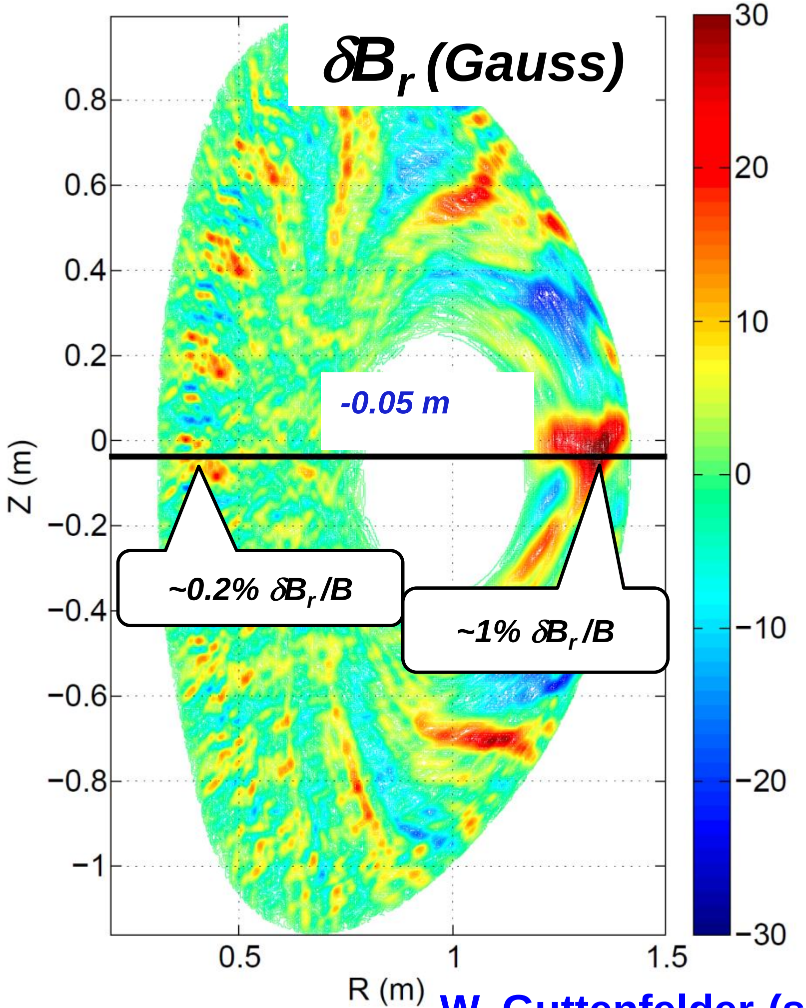


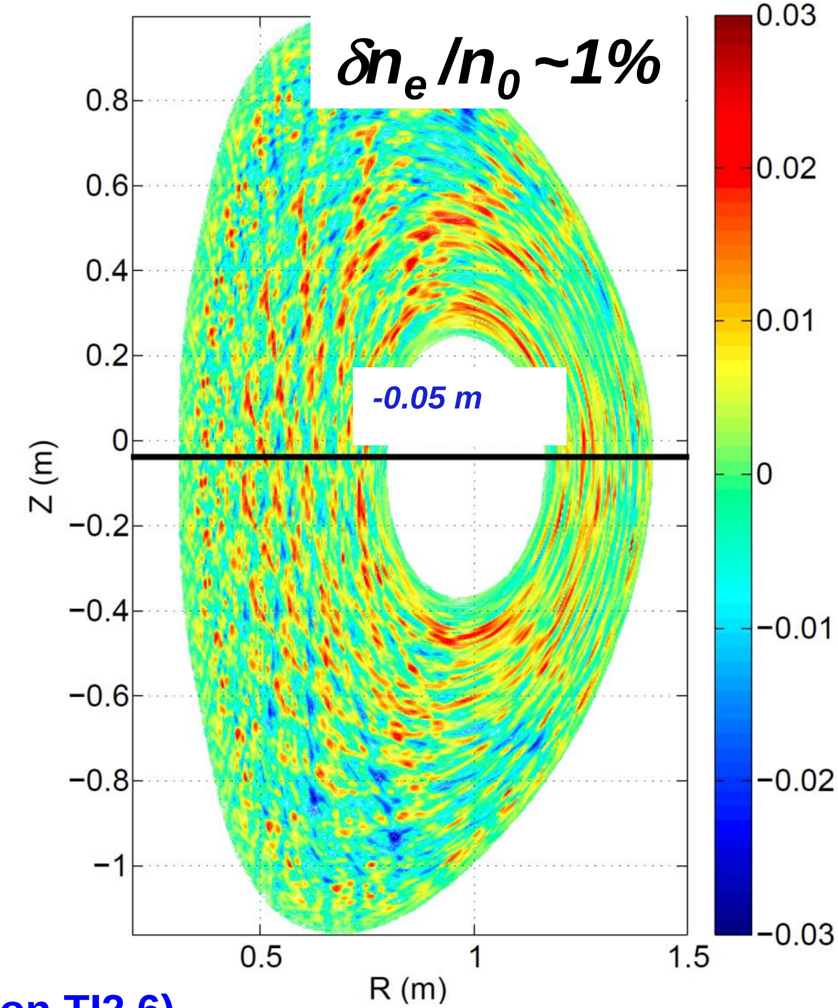
- Multiple reflections hinder sensitive phase measurements
  - Quasi-optical isolations with usage of Faraday rotators greatly suppresses this problem

Polarimeter on bench



Can Microtearing modes be measured via polarimetry



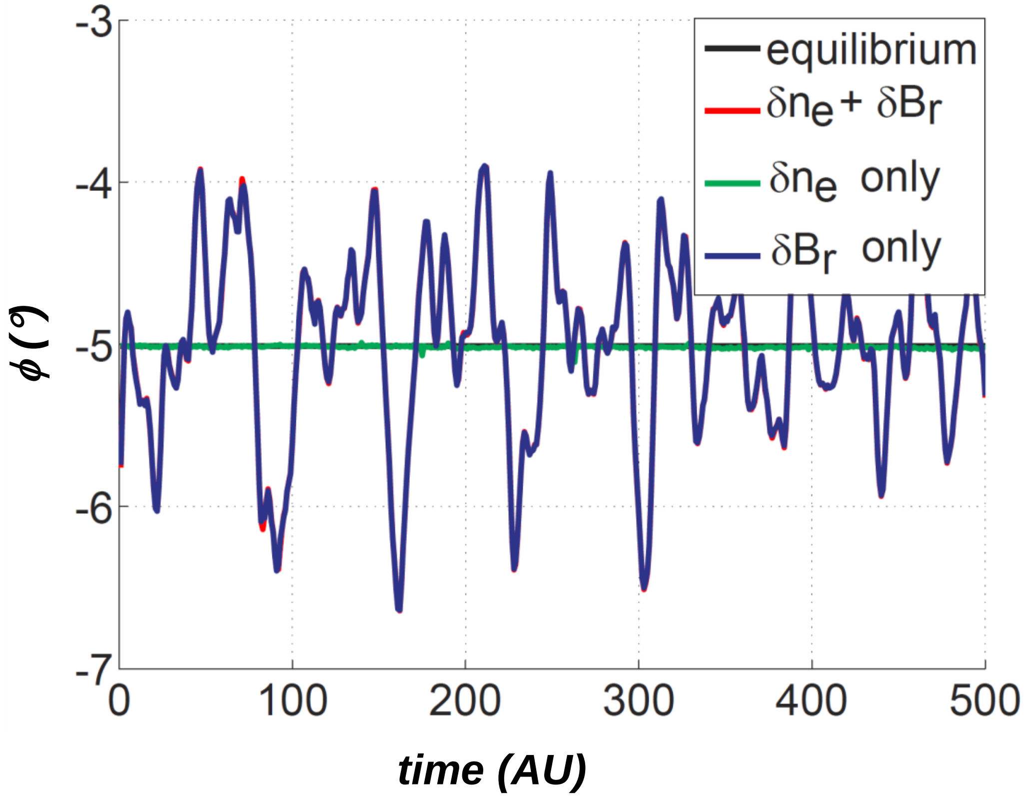


W. Guttenfelder (session TI2.6)

"GYRO* simulation of microtearing turbulence in NSTX"

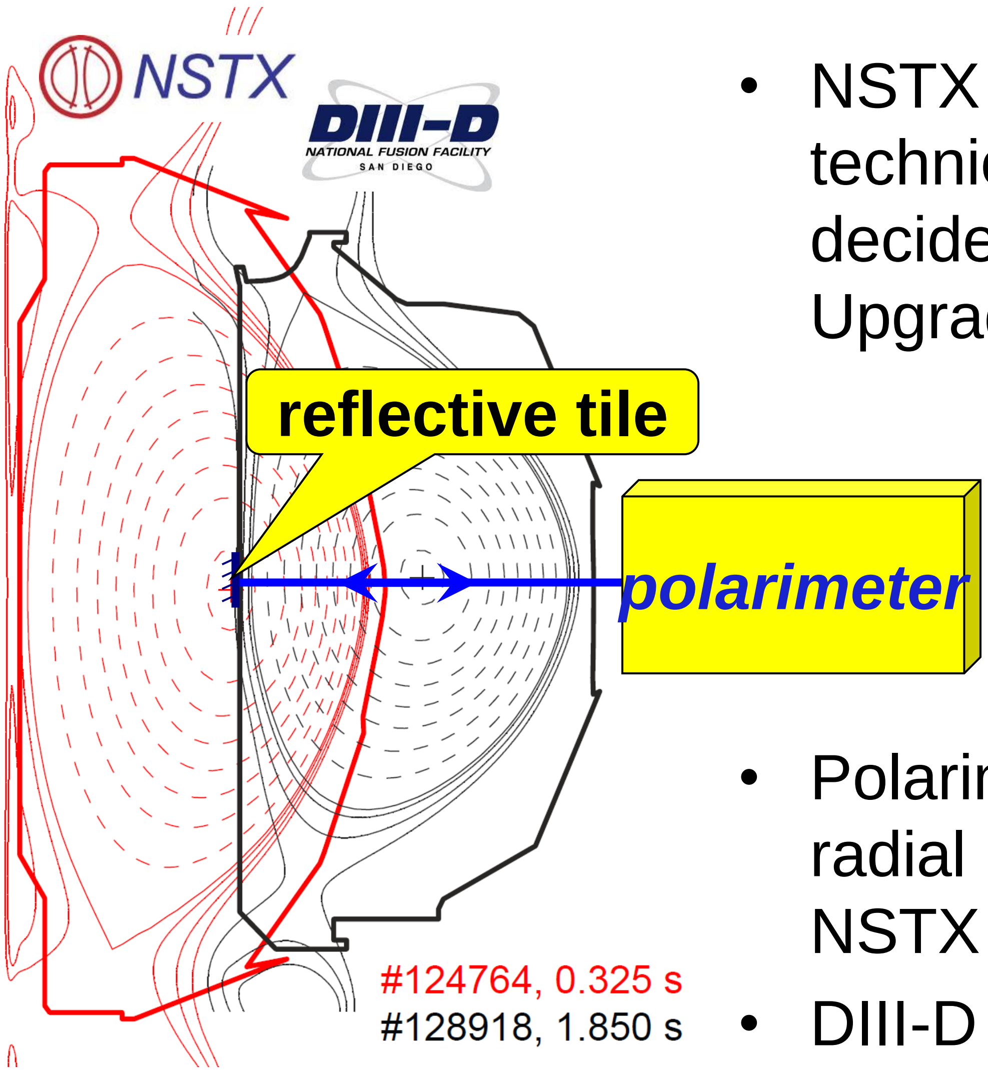
****J. Candy & R.E. Waltz, Phys. Rev. Lett. (2003)***

Simulation results indicate MicroTearing modes in NSTX are detectable; signal dominated by δB



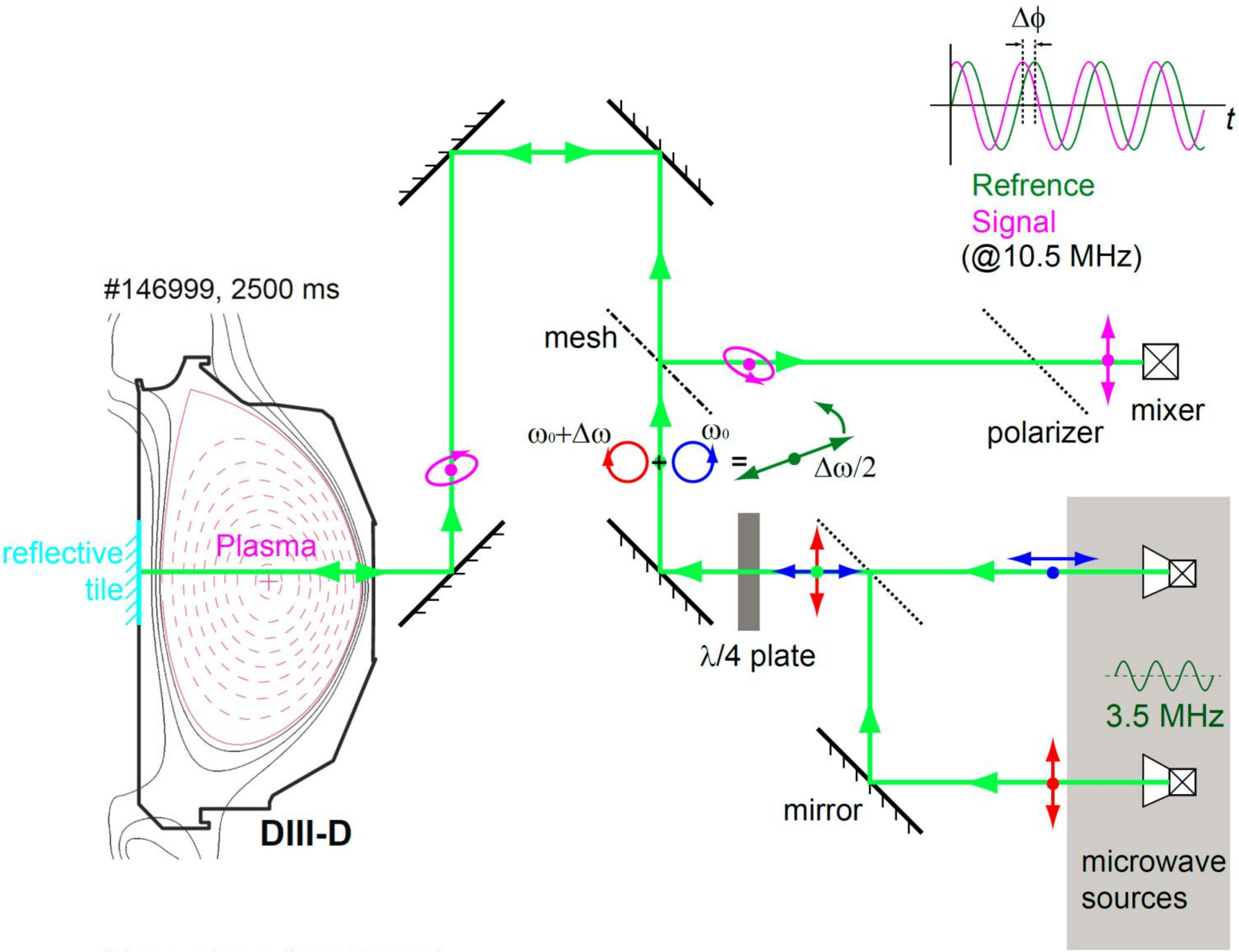
- $\Delta\phi \sim 1\text{-}2°$, detectable
- Comparable $\delta B_r/B$ and $\delta n_e/n_0$, but polarimetry phase fluctuations are dominated by δB_r, not δn_e

Prototype tests are being conducted on DIII-D during NSTX-Upgrade downtime



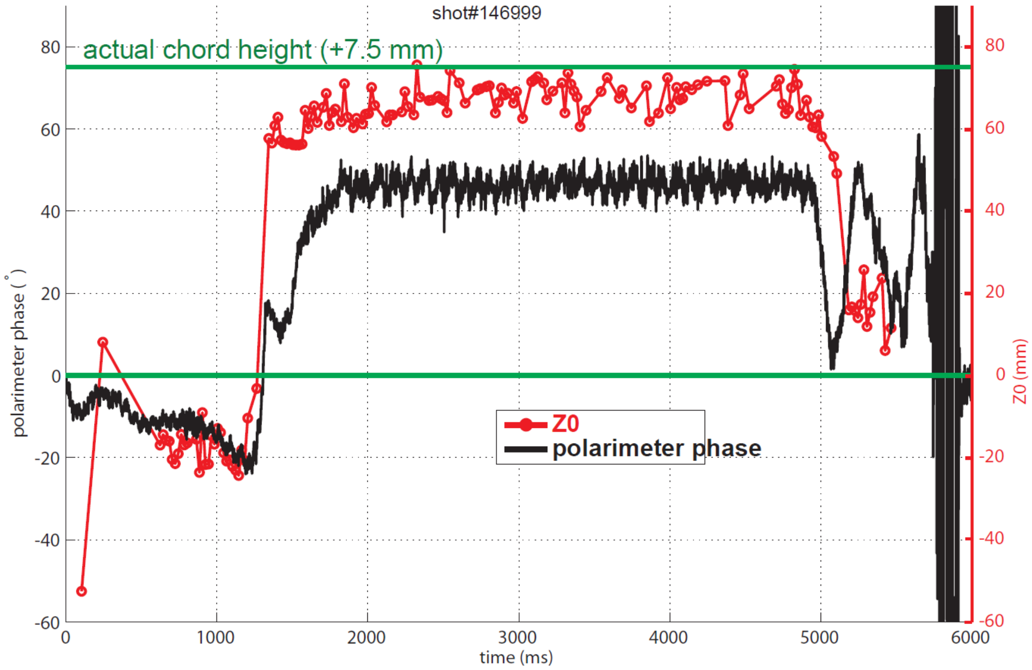
- NSTX experienced an unexpected technical failure and PPPL/DoE decided to accelerate the NSTX Upgrade project (2.5 years)
- Polarimetry on DIII-D has the same radial retroreflection geometry as NSTX
- DIII-D good test bed in preparation for NSTX-U

The *288 GHz* polarimeter/interferometer has been implemented on DIII-D



*Note: schematic not to scale

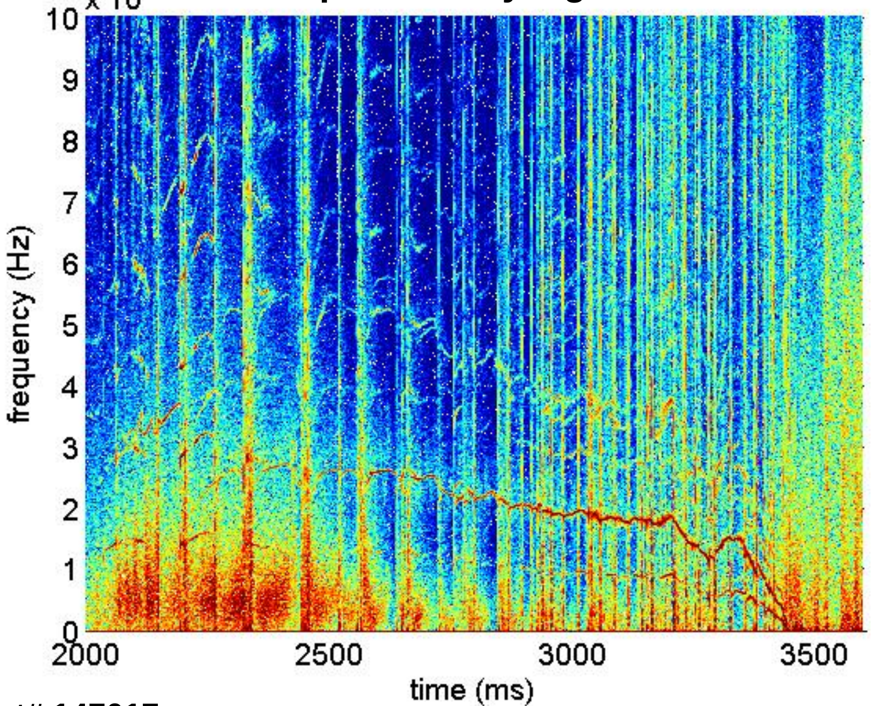
Initial polarimetry equilibrium data looks promising



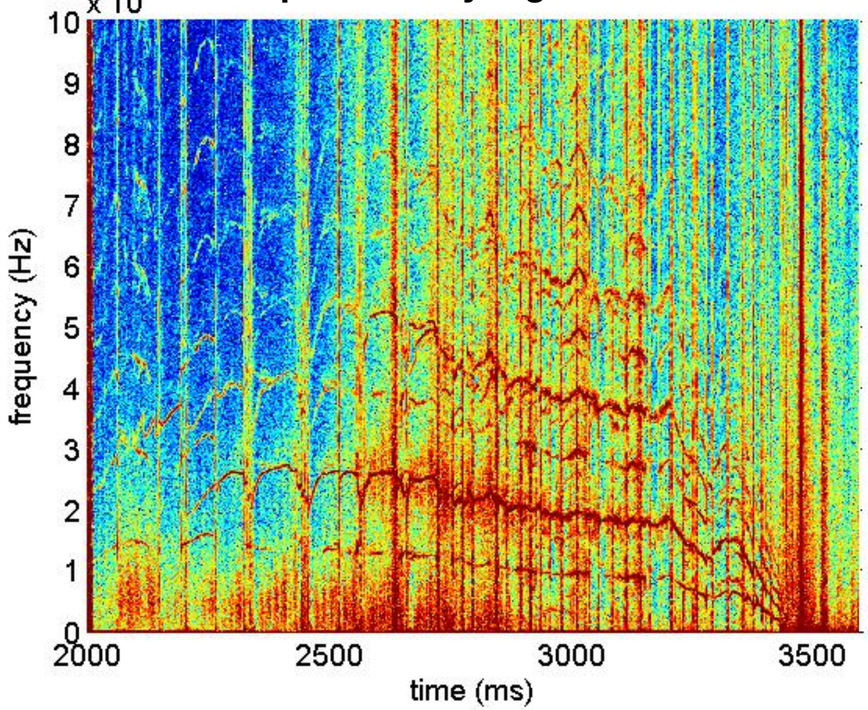
- Polarimeter phase qualitatively tracks plasma center height during a shot changing from LSN (Lower Single Null) to USN (Upper Single Null)
  - Non-zero phase as the beam goes through plasma center possibly caused by interaction between Faraday rotation and Cotton-Mouton effects
- Data interpretation is underway

Polarimetry fluctuation data clearly shows mode dynamics

Amplitude spectrum of polarimetry signal



Phase spectrum of polarimetry signal

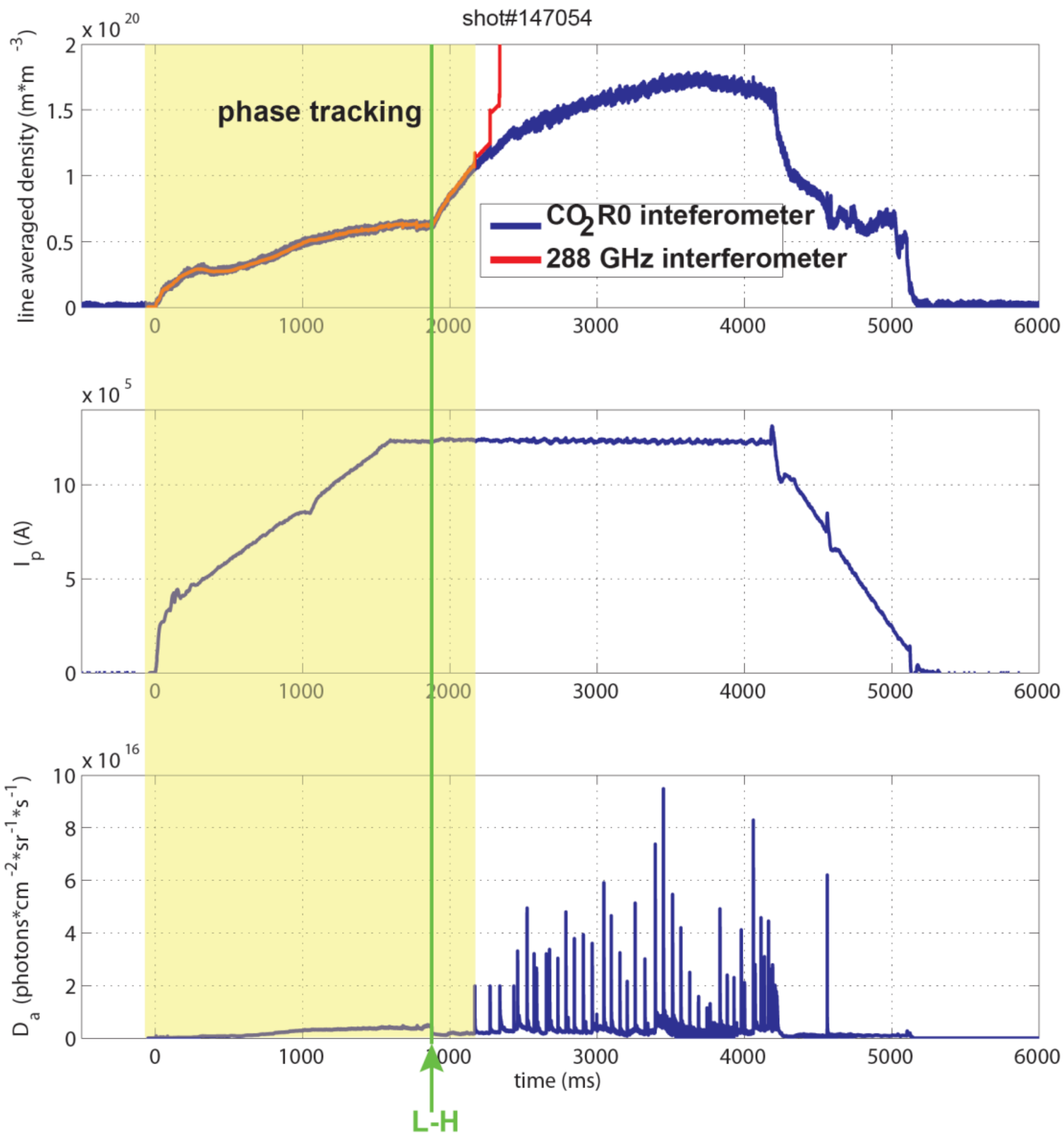


Shot# 147017

- Further analysis incorporating theoretical simulations and other diagnostics can help to determine $\delta \boldsymbol{B}$ amplitude

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

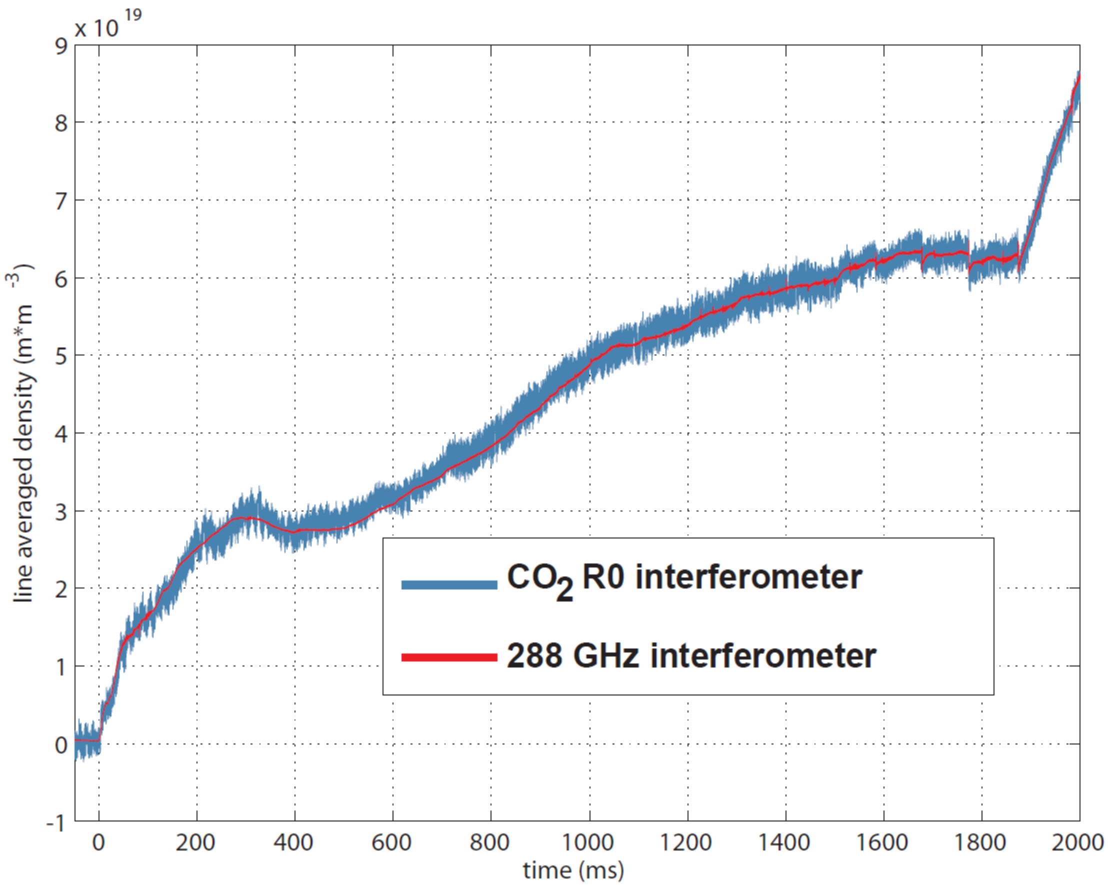
288 GHz interferometer can track plasma density up to H-mode



- Phase failed to track at high plasma density region
  - Fringe jumps caused by refraction

DIII-D NATIONAL FUSION FACILITY SAN DIEGO

Interferometry measurements demonstrate possible use for density control during initial plasma operating phase



- Good phase sensitivity at low density due to usage of relatively long wavelength ($\lambda \approx 1$ mm)

DIII-D
NATIONAL FUSION FACILITY
SAN DIEGO

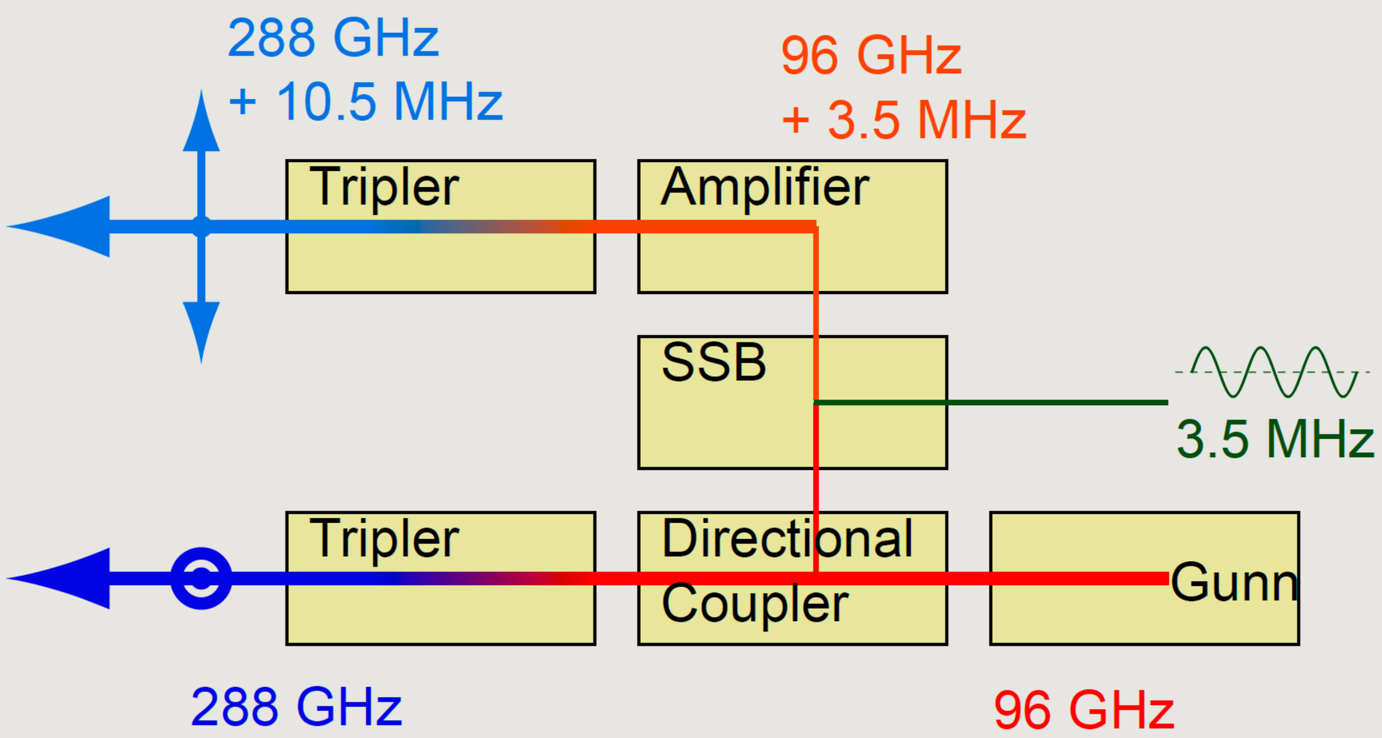
Summary

- Polarimetry is a sensitive diagnostic for internal ***B***, especially its fluctuations (δ***B***)
- Simulations indicate detectable polarimetry response to MicroTearing modes on NSTX
  - Signal dominated by δB, not δn
- A *288 GHz* polarimeter/interferometer system has been designed, fabricated, and tested in laboratory by UCLA
  - Quasi-optical isolation critical to achieve sub-degree phase sensitivity
- Prototype tests are being conducted on DIII-D during NSTX-Upgrade downtime
- Polarimetry data looks promising; data interpretation is underway
- Interferometry measurements also demonstrate possible use for density control in NSTX-U especially during initial plasma operating phase

Electronic copy requests

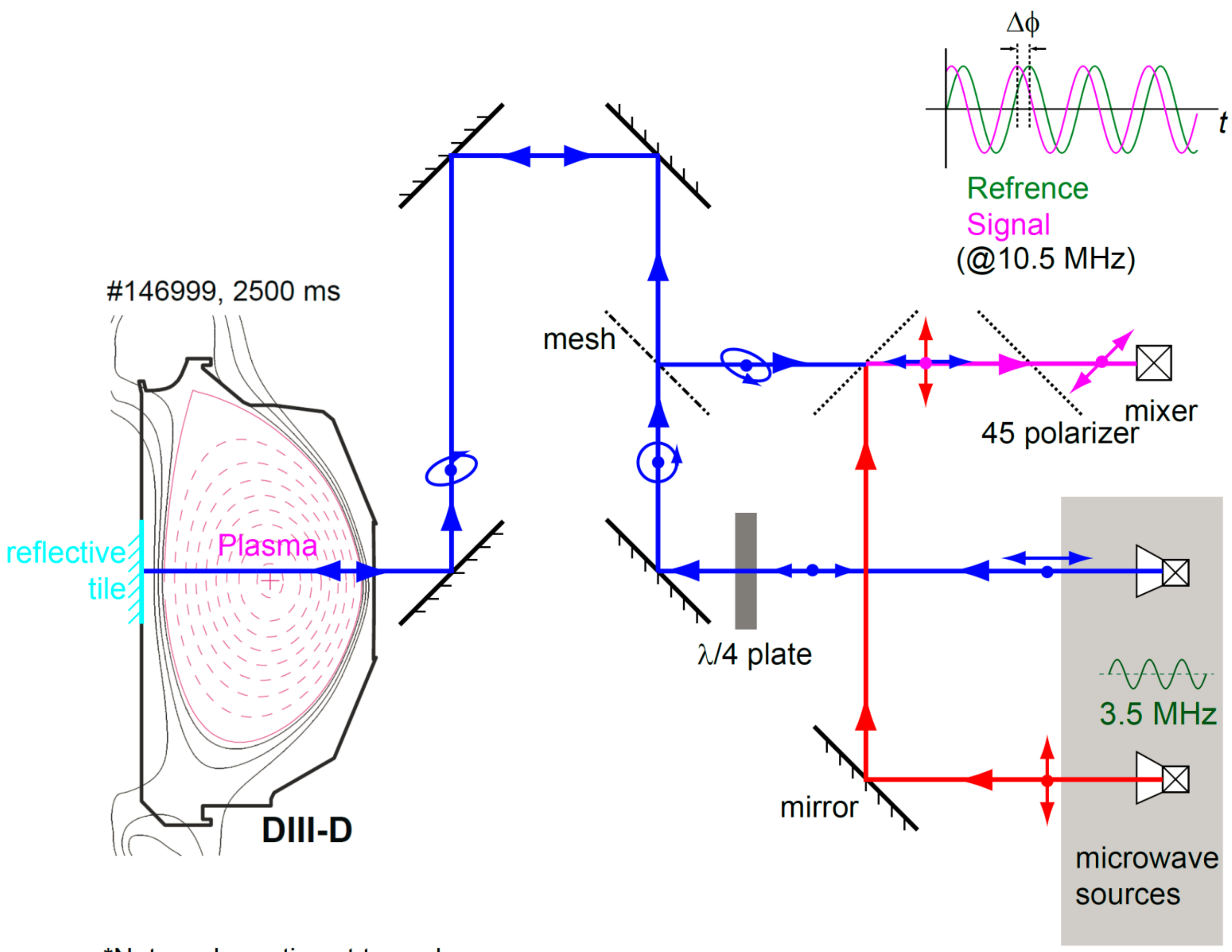
- Name and Email ;)

Backup#1: Polarimeter/interferometer sources



SSB--Single Side-Band modulator

Interferometer configuration initially used to test hardware



*Note: schematic not to scale