Abstract

The ALTAR C-Mod 3-DOR FIR polarimeter, with a 2 MHz bandwidth, is capable of responding to fast changes in the plasma equilibrium and high frequency fluctuations. It operates under ITER-like plasma conditions and magnetic fields, and uses an optical layout similar to that proposed for ITER. After a short discussion of the system, the design of the upgrades we installed on ALTAR C-Mod will be presented. The laser has been relocated on the cell to a position closer to the plasma, and this re-located position is the location selected for the upgrade project. The magnets and beam paths have been moved to allow the optical polarimeter system to remain intact. In this paper, we describe some of the major features of this upgrade, which is currently in progress.

Possible Improvements

- Resonant beam probes by relocating optics and detectors on upper optics table
- New arrangement would allow for four simultaneous beam paths
- New vacuum flange to mount etalon windows to maximize transmission of laser radiation
- Coverage both above and below plasma midplane
- Horizontal probe beam near midplane to improve fluctuation measurements since it is perpendicular to JT among existing chord
- Fluctuation signal may be written as $\Delta \phi = \Delta \phi_0 + \Delta \phi_1 + \Delta \phi_2 + \Delta \phi_3$ for three-chord measurement path coverage
- Optical Path from Location 1 to Location 2 ≈ 3.736 m

Example Results from 2012 Run Campaign

- Largest Faraday rotation change during LHCD on each of the two mirrors, which is closer to the magnetic midplane
- LH off-Faraday rotation decrease, as current profile flattens
- Faraday rotation change (increase) current profile peaks
- Faraday rotation change (decrease) current profile peaks
- Note that the current relaxation times to $t_{\text{relax}} = 1.64 x 10^7 (\text{MHz})^2 / 2 T_{\text{c}}$

Upgrade Goals

- Improve Faraday angle measurement accuracy from several tenths of a degree to ~ 0.1 degree
- Improve humidity control and reduce beam paths
- Reposition beams and improve vacuum window transmission
- Lasers and associated optics moved from cell to external diagnostic pit to reduce induced magnetic field, acoustic and vibrational effects on lasers
- New lasers and associated optics will rotate the two linear laser polarizations into parallel and perpendicular to cell optics assembly
- Half-wave plate installed on laser table will rotate the two linear laser polarizations into parallel and perpendicular to cell optics assembly
- Lined-up laser table will be installed on laser table will rotate the two linear laser polarizations into parallel and perpendicular to cell optics assembly

Implemented Upgrades

- Faraday rotation measurements
- Poloidal magnetic field measurement
- Axial & magnetic fluctuation measurement
- Laser wavelength = 1.177 µm
- Laser power: 50 W
- Laser beam reduction in plasma < 1% using 2x2 cm beam expanders
- High power commercial lasers
- 3/4 inch wave plate
- High sensitivity commercial detectors
- Two lasers = 4 MHz IF and 25 MHz IF response
- Three-chord simultaneous measurements
- Division by three minimizes laser noise: Use any three of the six interferometers installed on laser table to increase measurement path coverage

Polynomial System installed on C-Mod

- Beam line and associated mounts fabricated and installed
- BEAM1 and BEAM2 mounted on laser table fully enclosed and humidity controlled using air dryer (supplemented by gas bottle) to 10% RH below 30% RH
- Possible Improvements
- Collinearity of FIR Beams Measured Using Temporary Folded Optical Path
- Alignment to C midplane
- Induced Phase Error
- Angle readout not available
- Improved humidity control along viewing, double pass, magnetic field
- Accurate FIR beam co-linearly achieved
- Anticipate plasma data during next run campaign (Feb 2016)

Faraday Angle Calibration Method

- Quartz half-wave plate mounted in free running motorized rotation stage
- Angle readout not available
- Three fixed (not rotating) measurements used to align rotation angles to time series
- Three under polynomials fit
- RMS residual = 7.6 x 10^{-4} deg

Faraday Angle Calibration

- Beam Centers Aligned to < 0.1 mm at Location 2 (x direction)
- Total Deviation (including x components) = 0.3 mm
- Measured Collinear error = 0.40 µrad
- Induced Phase Error = 0.04 degrees
- This error will lead to a fixed baseline shift which will be removed by processing
- Total Path Length to Detectors = 15.8 meters

Beams Collinear to Better Than 40 µradians

- Folded path on laser table (see previous plot)
- Effect of collimating mirror taken into account
- Motorized Pyroelectric Detector (2 mm X 2 mm)
- Induced phase error $\Delta \phi = 2 x 200$ µrad
- $\theta_0$ = angle between two laser beams
- For small angles $\Delta \phi = \frac{\pi}{2} (\theta_0)^2$