Toroidal Rotation Measurements of Tokamak Plasmas with Fast Time Resolution

A. Graf, M. May, P. Beiersdorfer, D. Q. Hwang, R. Horton, R. Evans, S. Howard, J. Terry and J. Rice 
University of California at Davis, Davis, CA; Lawrence Livermore National Laboratory, Livermore, CA; Plasma Science and Fusion Center, MIT, Cambridge MA

Abstract
A visible spectrometer has been designed and constructed to measure toroidal rotation velocities in the Alcator C-MOD plasma. The spectrometer will have a high throughput with a temporal response of 1 ms and a rotation velocity sensitivity of $\sim 10^{-9}$ cm/s. This diagnostic will have a tangential view and map out the plasma rotation at several locations along the outer half of the minor radius ($r/a > 0.5$). The plasma rotation will be determined from Doppler shifted wavelengths of D$_3$ emission from the radial Diagnostic Neutral Beam (DNB), electric and magnetic dipole transitions of highly ionized impurities in the plasma introduced through either gas puffing or laser blow-off injection. The fast time response and high spectral resolution are possible due to special LLNL 6" diameter circular transmission gratings that are capable of $\Delta \theta/\lambda = 30000$ at 3800 Å in conjunction with a 30 mm slit. Our spectrometer will have an f/3 yielding over ten times greater throughput than the f/10 in a conventional spectrometer. Also, poloidal rotation and ion temperature measurements from collisional broadening of the line widths should be possible. 2-D ion velocity images will be obtained on a compact toroid injector which acts as a calibration/test plasma.  

This work was performed under the auspices of the U. S. DoE by the University of California Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

Introduction

- Progress has been made towards the goal of a burning MCF plasma through the discovery of the pedestal or transport barrier just inside the Last Closed Flux Surface (LCFS) develops. 
- The pedestal or transport barrier just inside the LCFS is of interest because it represents the flattening of the density profile
- The pedestal or transport barrier just inside the LCFS is of interest because it represents the flattening of the density profile

High Throughput-High Resolution Doppler Spectrometer

- To further analyze the relation of Magnetohydrodynamic (MHD) phenomena and their relation to the changes in $I_e$ and its impact on the H-mode and particle transport, require a temporal resolution of the toroidal velocity between $10^{-3}$ to 1 ms. Present routine core rotation measurements are limited to a time resolution of $\sim 20$ ms.
- C-MOD is primarily KRF heated. There exists little contribution from external momentum sources such as Neutral Beam Injection (NBI).

CTIX-Compact Toroid Injection eXperiment

- CTIX is to be used as a test/calibration plasma.
- The spheromak like compact toroid (SCT) is self-contained structure of plasma with embedded poloidal and toroidal magnetic fields.
- Various targets to be installed in drift tube of CTIX.
- Gas injection for testing in plasma species and visible radiation.

CTIX-Compact Toroid Injection eXperiment

- Reproducibility of the SCT and controlled movement of the extraction optics between shots allow measurements of 2-D ion velocity images in a turbulent plasma.
- Various targets to be installed in drift tube to section the creation of MHD turbulence.
- Ion temperature $T_i = 2.4 \times 10^7$ K from spectral line broadening will be obtained during thermalization after collision of SCT and target.

Status

- Construction completed.
- Data acquisition via Labview code written and tested.
- Alignment and spectral calibration in progress
- Tests on the CTIX planned to begin shortly.

PLASMA PHYSICS A. Graf, M. May, P. Beiersdorfer, D. Q. Hwang, R. Horton, R. Evans, S. Howard, J. Terry and J. Rice 
University of California at Davis, Davis, CA; Lawrence Livermore National Laboratory, Livermore, CA; Plasma Science and Fusion Center, MIT, Cambridge MA

Abstract
A visible spectrometer has been designed and constructed to measure toroidal rotation velocities in the Alcator C-MOD plasma. The spectrometer will have a high throughput with a temporal response of 1 ms and a rotation velocity sensitivity of $\sim 10^{-9}$ cm/s. This diagnostic will have a tangential view and map out the plasma rotation at several locations along the outer half of the minor radius ($r/a > 0.5$). The plasma rotation will be determined from Doppler shifted wavelengths of D$_3$ emission from the radial Diagnostic Neutral Beam (DNB), electric and magnetic dipole transitions of highly ionized impurities in the plasma introduced through either gas puffing or laser blow-off injection. The fast time response and high spectral resolution are possible due to special LLNL 6" diameter circular transmission gratings that are capable of $\Delta \theta/\lambda = 30000$ at 3800 Å in conjunction with a 30 mm slit. Our spectrometer will have an f/3 yielding over ten times greater throughput than the f/10 in a conventional spectrometer. Also, poloidal rotation and ion temperature measurements from collisional broadening of the line widths should be possible. 2-D ion velocity images will be obtained on a compact toroid injector which acts as a calibration/test plasma.

This work was performed under the auspices of the U. S. DoE by the University of California Lawrence Livermore National Laboratory under contract W-7405-ENG-48.

Introduction

- Progress has been made towards the goal of a burning MCF plasma through the discovery of the high confinement mode (H-mode) and transport barriers. These phenomena reduce anomalous transport and increase tokamak confinement.
- The L-H transition (see right) has been correlated with a reversal in the core velocity direction.
- The pedestal or transport barrier just inside the Last Closed Flux Surface (LCFS) develops during the L-H transition and is thought to be the result of a reversal in $I_e$ which creates a shear in the E x B velocity.

High Throughput-High Resolution Doppler Spectrometer

- To further analyze the relation of Magnetohydrodynamic (MHD) phenomena and their relation to the changes in $I_e$ and its impact on the H-mode and particle transport, require a temporal resolution of the toroidal velocity between $10^{-3}$ to 1 ms. Present routine core rotation measurements are limited to a time resolution of $\sim 20$ ms.
- C-MOD is primarily KRF heated. There exists little contribution from external momentum sources such as Neutral Beam Injection (NBI).

CTIX-Compact Toroid Injection eXperiment

- CTIX is to be used as a test/calibration plasma.
- The spheromak like compact toroid (SCT) is self-contained structure of plasma with embedded poloidal and toroidal magnetic fields.
- Various targets to be installed in drift tube of CTIX.
- Gas injection for testing in plasma species and visible radiation.

Status

- Construction completed.
- Data acquisition via Labview code written and tested.
- Alignment and spectral calibration in progress
- Tests on the CTIX planned to begin shortly.