Motional Stark Effect with Laser-Induced Fluorescence Diagnostic Development

Jon Hillesheim, Elizabeth Foley[1], Fred Levinton[1]

University of Wisconsin—Madison; [1]Nova Photonics, Inc.

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MSE-LIF Background

• The motional Stark effect with laser-induced fluorescence (MSE-LIF) diagnostic is being developed to measure the magnetic field pitch angle and magnitude in a variety of plasma conditions; in particular, at low magnetic fields (< 0.5T).

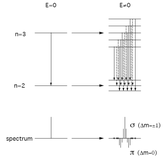
• When passing through a magnetic field, the H-alpha emission from a neutral hydrogen beam is split and polarized by the linear Stark effect due to the **v**x**B** electric field. The pitch angle can be determined from the polarization and the magnitude from the line splitting.

• The axial energy spread of the neutral beam causes line broadening. The neutral beam source has been modified since its original construction in attempts to minimize the energy spread. One remaining possible source of energy spread, variation of the plasma potential within the source, has been investigated.

• A plasma of ~10^{12} cm^{-3} density with a diameter over 10 cm is required to collect an observable MSE-LIF signal above ~.01T. To that end, a spiral antenna helicon plasma source has been constructed.

Atomic Hydrogen in an Electric Field

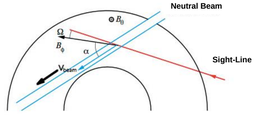
Linear Splitting of Energy Levels:



Lorentz Electric Field

$$E = V \times B$$

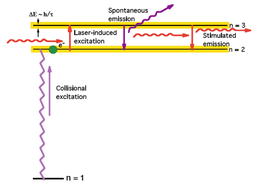
Typical MSE Viewing Geometry



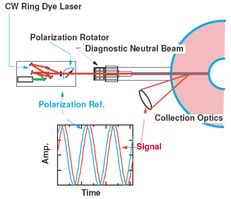
Polarization Angle

$$\tan(\gamma_m) = \frac{v_b B_\theta \cos(\alpha+\Omega) + E_r \cos(\Omega)}{v_b B_\phi \sin(\alpha)}$$

Addition of Laser-Induced Fluorescence



Proposed MSE-LIF Layout



Advantages of Adding Laser-Induced Fluorescence

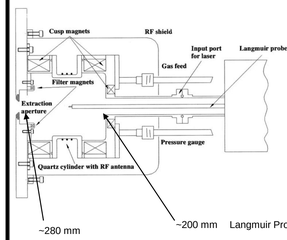
• Traditional MSE limited below ~.75 T by overlap of spectral lines, MSE-LIF allows measurement of the magnetic field pitch angle from ~.001 T and up

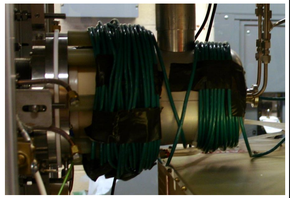
• Also allows measurement of magnetic field strength

• Polarization angle set by laser, no need for polarimetry

• In conjunction with an additional MSE system, can infer radial electric field

Diagnostic Neutral Beam





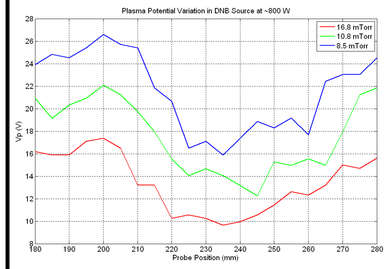
Langmuir Probe positions on the plot shown below

• Axial energy spread in the neutral beam causes line broadening

• Increase in the axial energy spread of the neutral beam observed at low fill pressure of ~15 eV

• Variation of the plasma potential in the region where ions are born causes energy spread in the neutral beam

• Is the observed increase in energy spread due to an increased variation of the plasma potential at low pressures?



• Observed increase in plasma potential only ~3-4 eV

• Similar results for other values of RF power

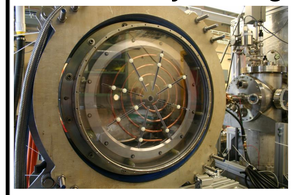
• Results are from Hydrogen

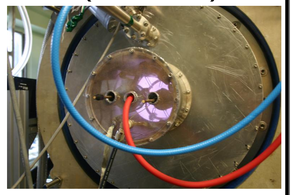
• The greens coils pictured above were an attempt to reduce the plasma potential variation. They did not have the desired effect.

• Measurements inside DNB source made with a Langmuir probe system, plasma potential determined by hand-fit

• Increased variation of the plasma potential not sufficient to account for observed increase in axial energy spread

Spiral Antenna Helicon with High Intensity Background (SAHHIB)





Motivation for the construction of SAHHIB:

• No LIF signal above ~.01 T detected in previous experiments

• Understood to be the result of 2s state depopulation due to decreased lifetime with applied field

• Approximately 10 cm of plasma at a density of ~10^{12} cm^{-3} required for a sufficient population of hydrogen atoms in an n=2 state

Helicon Waves

• Superposition of low frequency whistler waves in a bounded container

• Efficient way to create a sufficiently hot and dense plasma for a test bed

• Helicon wave equations:

$$\frac{k k_\parallel}{k_0^2} = \frac{\omega_{pe}^2}{\omega \omega_{ce}} \Rightarrow k k_\parallel = \frac{e \mu_0 n_0 \omega}{B_0};\ n_0,\ B_0\ scale$$

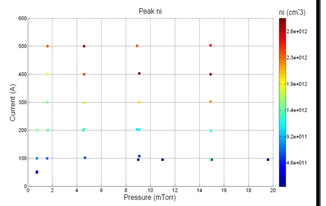
• As expected, the density is higher at stronger fields

• Magnetic field strength is ~1 Gauss/Amp

• Radial density profiles of top row shown in plot below

• Top three rows all at 400 W

• All data points here are from Argon

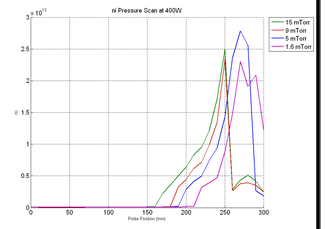


• Radial density profiles at 500 Amps (limit of available power supply)

• Center at ~280 mm

• High density core modes are knocked out due to the incursion of the Langmuir probe

• Design goals appear to have been met



Interesting Observations and Forthcoming Research

• Pictured to the right, Argon (top row) and Helium (bottom row)

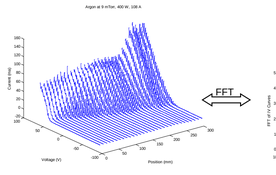
• Multiple operating modes observed

-High density core modes ~10^{12} cm^{-3}

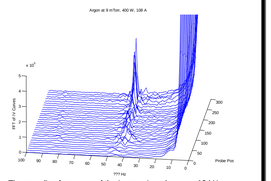
-Hollow core or doughnut modes

-Electron cyclotron operation

Instabilities were picked up on the Langmuir probe, as well as with a photodiode and an antenna:

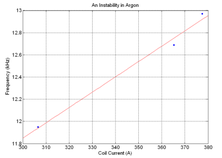


FFT

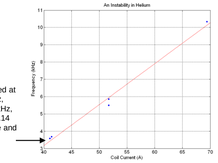


A set of Langmuir probe sweeps, radially, from the edge to the center.

The sampling frequency of the Langmuir probe was ~12 kHz



Harmonics observed at 3.68 kHz, 7.38 kHz, 11.06 kHz, 14.76 kHz, 18.42 kHz, and 22.14 kHz on Photodiode and Antenna



Summary:

• Increased variation of the plasma potential not sufficient to account for observed increase in axial energy spread

• The design goals for SAHHIB of 10 cm of 10^{12} cm^{-3} plasma appear to have been met

Forthcoming Research:

• MSE-LIF

-If successful, install on NSTX

• Additional coils and power supplies for stronger fields and different field configurations

• Further study of SAHHIB instabilities