MSE Diagnostics on the HSX Stellarator

for simultaneous measurement of radial electric field and bootstrap current

S. T. A. Kumar, C. Ruiz, F. S. B. Anderson, D. T. Anderson

Department of Electrical and Computer Engineering, University of Wisconsin-Madison, USA

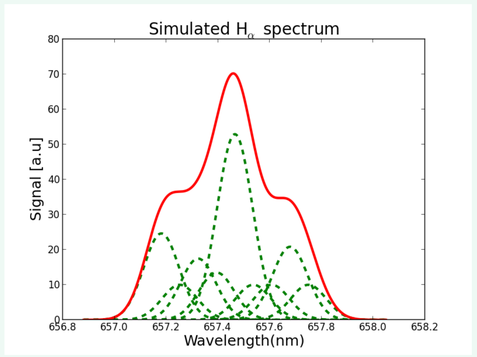
1. Abstract

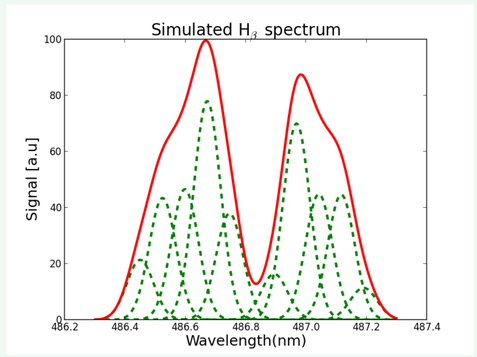
- Understanding of the bootstrap current and its temporal evolution is crucial in stellarators as it can significantly affect the magnetic topology and plasma confinement. One of the parameters which could determine the evolution of the bootstrap current is the radial electric field (E_r).
- The Motional Stark Effect (MSE) diagnostic is capable of making simultaneous E_r and bootstrap current measurements, and is under investigation on the HSX stellarator.
- Simultaneous H_α and H_β measurements are currently underway on HSX, and MSE polarimetry is planned for the near future.

2. Experiment

HSX diagnostic neutral beam: 30 keV, 3 ms Hydrogen. ~80-90% full energy component. Beam radius ~1.5 cm.

HSX B field: 1 Tesla. E_{MSE} ~ 2.5 MeV/m. Calculated E_r near the plasma core ~50 kV/m

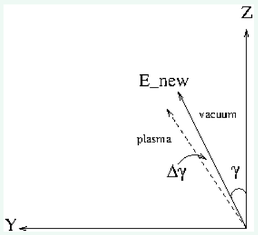




i. Spectral method

- Neutral beam atomic energy levels do not equilibrate in the low density (~1-4e18 /m^3) and small (<a> ~12 cm) HSX plasmas.
- Beam modeling and MSE simulation for non-equilibrated beam are required for a traditional spectral analysis.
- Line ratio method is presently pursued. Taking ratio of emission intensities from same upper level avoids non-equilibration issue – Data fitting allows fine-structure separation.

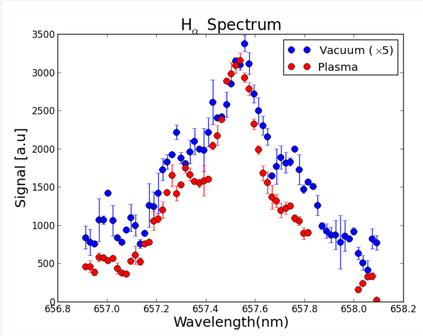
ii. Polarimetry



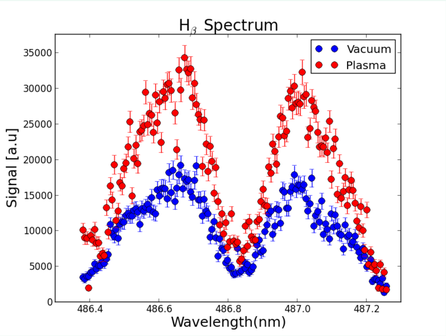
- Total electric field, $\mathbf{E_{tot} = EM_{SE} + Er}$
- $E_{new} = Et_{ot}$ transformed into a coordinate system where the sight-line is along the x-axis.
- $tan(\gamma) = {}^{E_{new}\hat{Y}}/_{E_{new}\hat{Z}}$
- γ is also the direction of polarization of one of the Stark emission components.

- Change from vacuum to plasma case gives the effect of E_r and bootstrap current.
- Measurements with two beam energies at the same location separates E_r and bootstrap current effects.

3. Preliminary experimental results



f=1m Czerny-Turner spectrometer, 19x200 micron fibers, 2160 g/mm grating

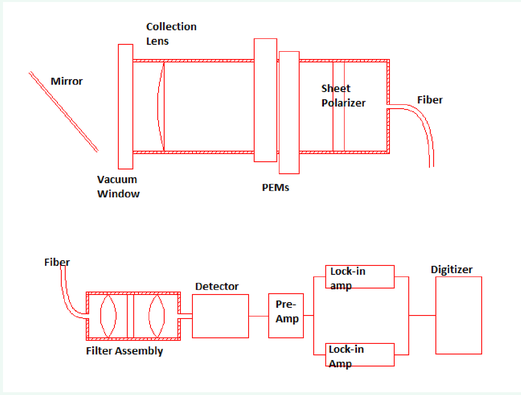


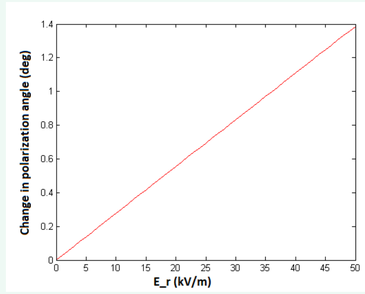
f=0.75 m Czerny-Turner spectrometer, 600 micron fiber, 2400 g/mm grating

- Simultaneous measurements of H_α and H_β spectra are made near the magnetic axis.
- Modeling underway to extract individual Stark components from both H_α and H_β spectrum.

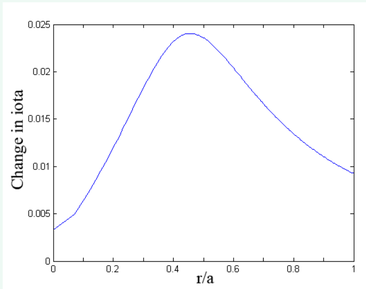
4. MSE polarimetry

A single channel dual photo-elastic modulator (PEM) polarimetry system has been designed.





Calculated change in polarization angle ($\Delta\gamma$) of the Stark component from its vacuum value.



Change in rotational transform due to 400A bootstrap current – a VMEC calculation. $\Delta\gamma_{max} \sim 1.4^o$

- Ratio of the output signals from the lock-in amplifiers at twice the modulation frequency gives a direct measurement of γ.
- Change in polarization angle ($\Delta\gamma$) from vacuum to plasma cases gives E_r and bootstrap current effects.
- Typical measurement resolution of the polarimetry is ~ 0.1 degree.

5. Summary

- MSE diagnostic is employed on the HSX stellarator for simultaneous E_r and bootstrap current measurements.
- Both spectral analysis and polarimetry are pursued.
- Simultaneous H_α and H_β Stark emission measurements are made. Data-fitting underway to extract individual Stark components.
- A single channel dual PEM system has been designed for Stark polarization measurements.

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