Measurement needs for the alternates, with broader connections

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17 March 2009

Improved and increased diagnostic capability is an urgent need for alternates research.

- Diagnostic capability called out as one of two urgent needs in TAP report
  - Vital for developing physics understanding of less-mature concepts
  - Some of this need due to lack of resources necessary to implement standard diagnostics
  - But alternates also have measurement needs not addressed by straightforward application of standard diagnostic techniques

- As a cross-cutting action item, alternates community should identify needed developments in diagnostic capability
  - Examples: need analogs of ECE and MSE diagnostics

☛ Proposed diagnostic developments will have increased resonance if they relate to burning plasma research needs

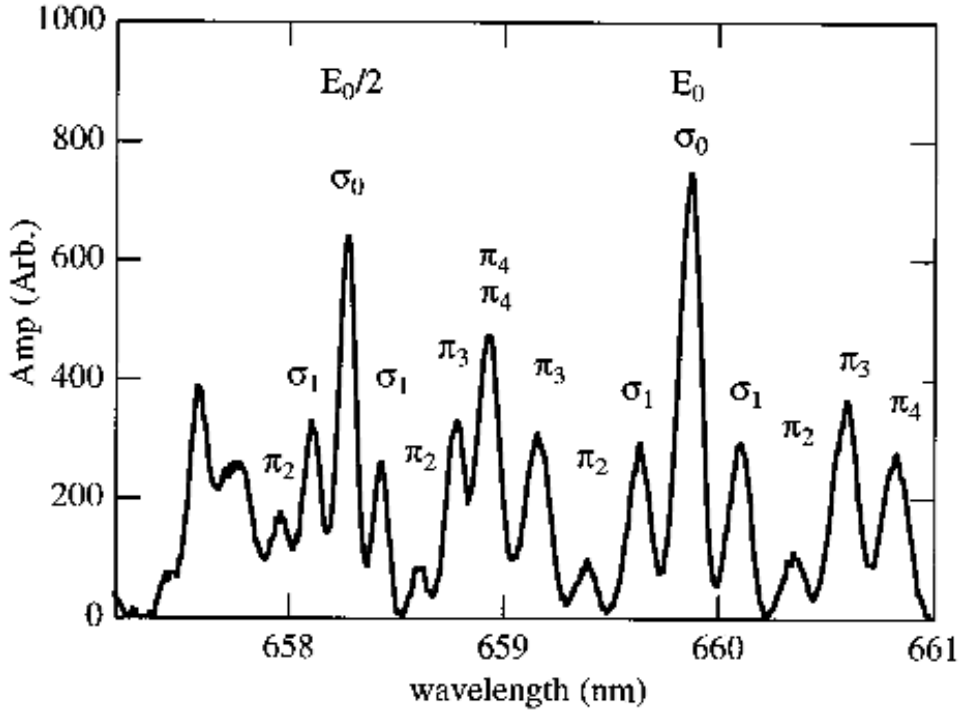
The plasma in alternates often has some characteristic that renders standard diagnostic techniques inapplicable.

- Example: ST, RFP, and CT are all relatively low-field compared to tokamak
  - Typically electron cyclotron emission (ECE) does not propagate because plasma is overdense ($\omega_{pe} >> \omega_{ce}$)
  - Electron temperature diagnostic based on ECE will not work
  - In present-day tokamaks, ECE diagnostic provides good spatial and temporal resolution of electron temperature
    - Even used for fluctuation measurements
    - No analogous tool available to low-field alternates

- Specific cross-cutting opportunity for development of diagnostic to provide spatially and temporally resolved *Te*
  - Possibilities: electron Bernstein emission, soft x-ray, ….

Motional Stark effect (MSE) is a relatively common diagnostic technique in high-B (>1 T) plasmas.

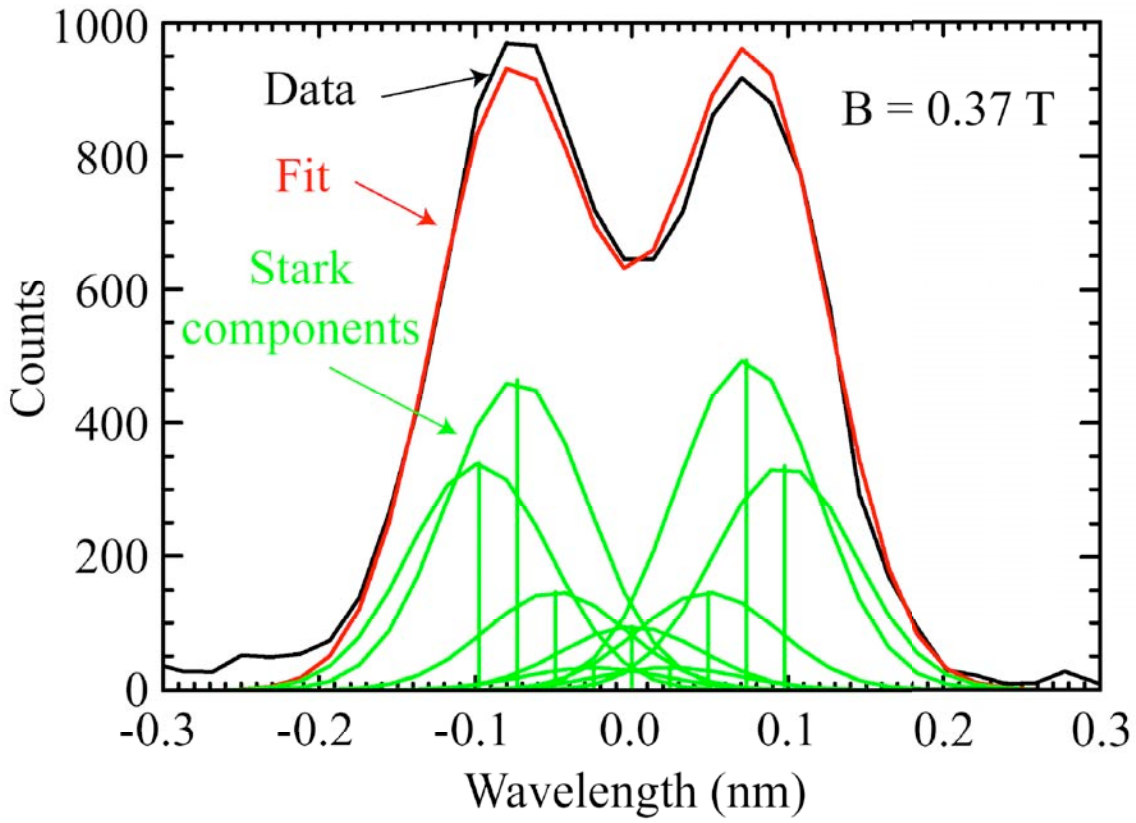
- Stark manifold is composed of
  - π transitions polarized parallel to **E**
  - σ transitions polarized perpendicular to **E**
- For most fusion research devices, $\mathbf{E} = \mathbf{v}_{beam} \times \mathbf{B}$ is large (~10 MV/m)
  - π and σ components can be isolated because Stark splitting is large
  - polarimetry of the direction of the component emission gives the magnetic field pitch angle



F. M. Levinton, Rev. Sci. Instrum. **70**, 810 (1999)

In low-field plasmas, $v_{beam} \times B$ is small (~1 MV/m), so Stark components overlap.

- One solution: measure full Stark spectrum
  - Fit with model assuming statistical population of excited levels
  - Spectral MSE technique measures $|\mathbf{B}| \geq 0.2$ T

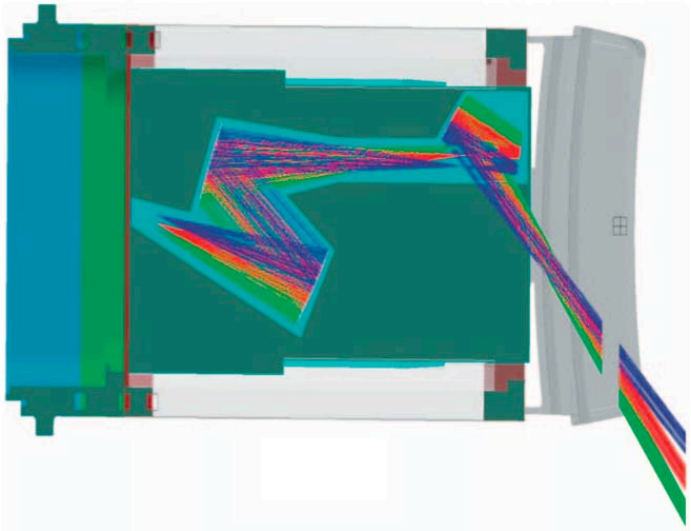


Spectral MSE technique is being considered for ITER.

- Standard polarimetric MSE technique may not work in ITER
  - Mirror characteristics will change during a discharge
  - Polarization analysis may be difficult
- Possible solution: measure Stark splitting for |**B**|
  - |**B**| is input for equilibrium reconstruction

➨ Development and use of spectral MSE technique on alternates may influence implementation of this technique on burning plasmas.

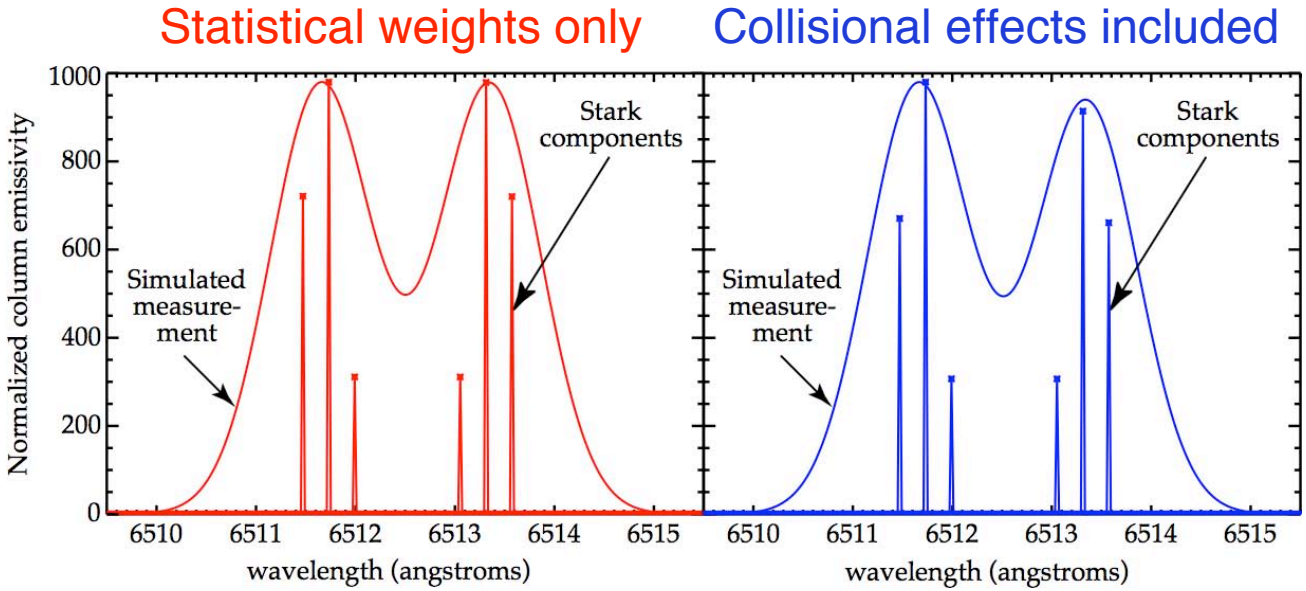
ITER MSE light collection system



M. A. Makowski *et al.*, Rev. Sci. Instrum. **79**, 10F519 (2008)

An atomic model for MSE is being developed and tested by an MST/ADAS/DIII-D collaboration.

- This model will include:
  - Stark effect (primary mechanism for energy-level splitting)
  - Zeeman effect
  - fine-structure (important because of low B)
  - collisional-radiative population model
- C-R effects may generate structural asymmetries in the MSE spectrum



- Improved MSE model will increase measurement accuracy
  - Possible benefit ranging from low-field to burning plasma research

Summary

- As a cross-cutting action item, alternates community should identify needed developments in diagnostic capability
  - Need new diagnostic physics to address some high-priority measurements
  - Diagnostic developments may have impact beyond alternates research
  - In addition to examples in this talk, needs in
    - Turbulence and fluctuation diagnostics
    - Fast ion diagnostics
    - Internal measurements for equilibrium reconstruction
    - Other areas

☛ Proposed diagnostic developments will have increased resonance if they relate to burning plasma research needs