Motional Stark Effect Measurements

CCFE CULHAM CENTRE FOR FUSION ENERGY

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ABSTRACT

A key research theme for MAST-U is pedestal physics, particularly with the introduction of new divertor configurations which will give access to ITER relevant pedestal structures. The motional stark effect (MSE) diagnostic provides a radial measurement of magnetic pitch angle, used to constrain equilibrium reconstruction codes such as EFIT++. From MSE measurements, it is possible to infer a radial toroidal current density profile and q profile. We present preliminary results on edge current measurements on MAST. The effect of radial electric field on polarization angle, and subsequently on the Current profile is shown.

THE MOTIONAL STARK EFFECT

MSE is a **passive beam spectroscopy** diagnostic.

Hydrogen atoms injected into plasma, experience strong **Lorentz E field and Stark effect** splitting energy levels.

Doppler shifted emission away from $H\alpha$ and **polarised parallel (π) and perp (σ)** to E field.

MSE measures polarisation angle γ, in absence of Er proportional to pitch angle γp:

$$\tan\gamma = -\frac{\cos\beta}{\sin\alpha}\tan\gamma_p$$

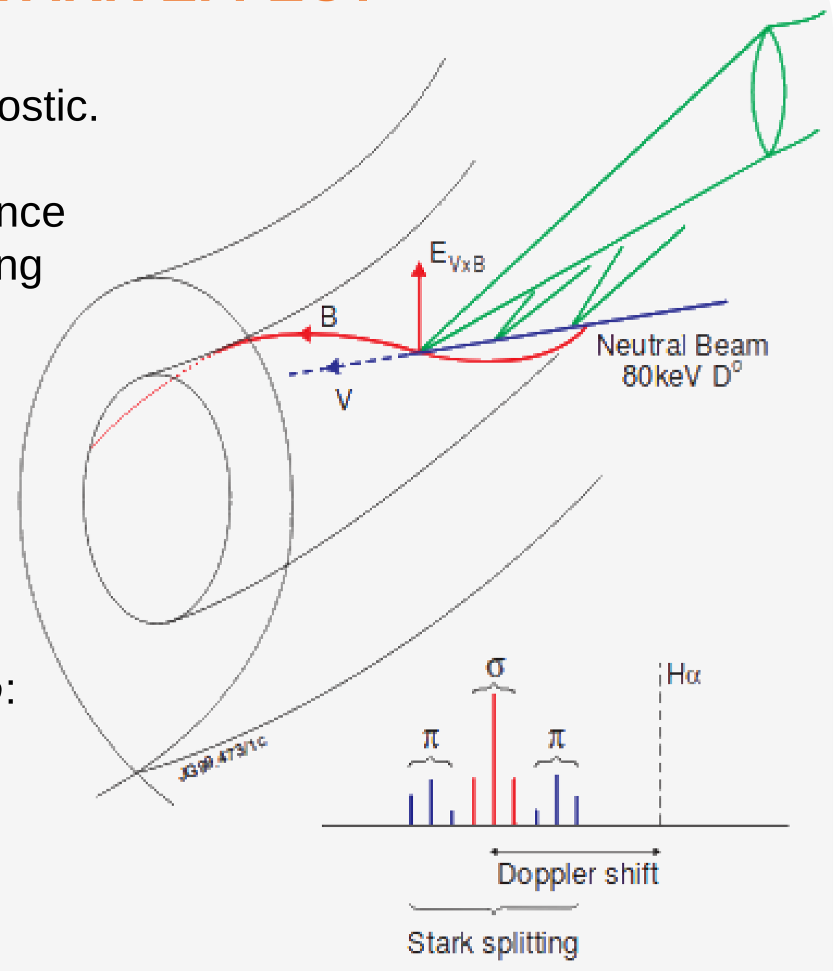


Fig. 1: *Geometry of the MSE measurement, etendue of each line of sight and Doppler shifted measured spectrum.* [1]

MAST-U MSE DIAGNOSTIC

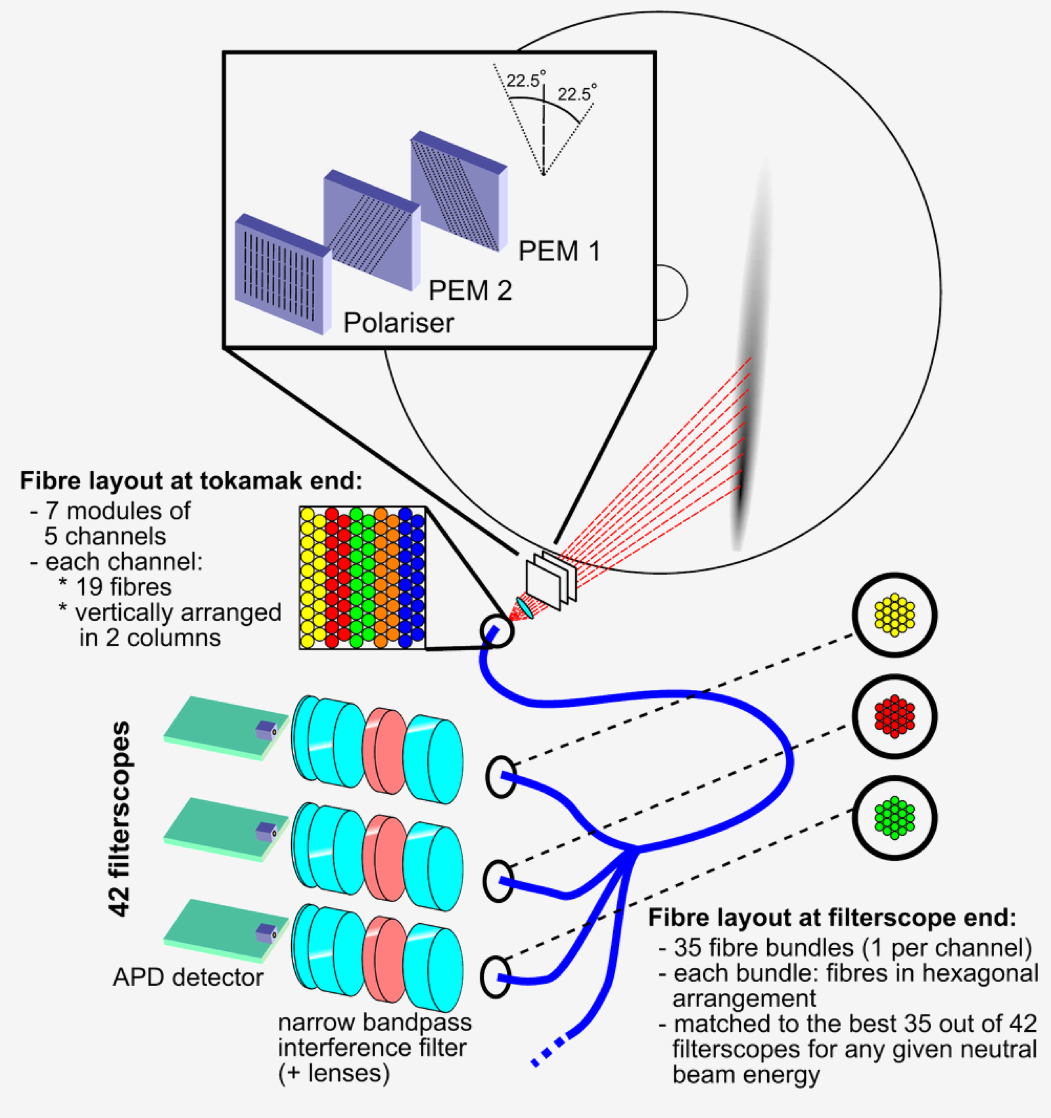


Fig 2: *Schematic of the MAST MSE diagnostic.* [2]

Capabilities

2.5cm spatial resolution
~1ms time resolution
$\Delta\gamma \leq 0.5$ angular noise at $\Delta\gamma \leq 1$ms
MSE-constrained EFIT available inter-shot

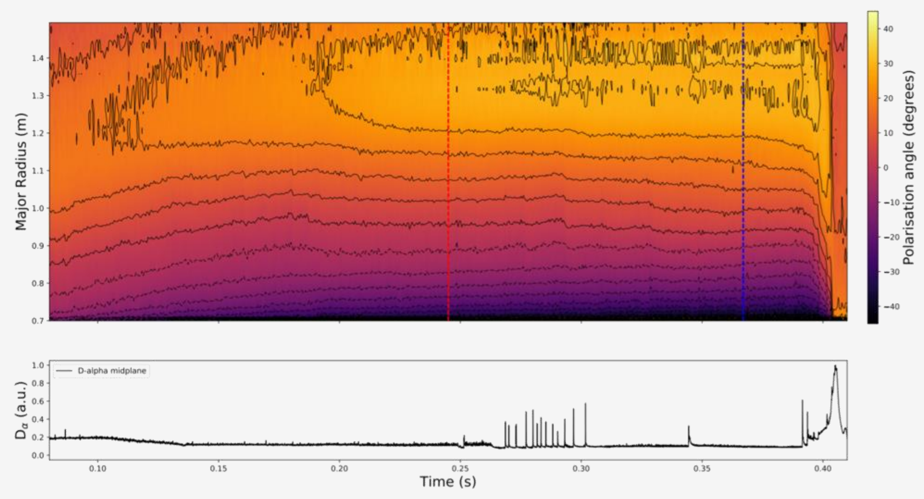
»*Narrow bandpass filters*
- »Overlapping π and σ spectral lines due to **low B field → less Stark splitting**
- »Narrow interference filters select either π or σ line (0.1nm FWHM)
- »Require wavelength matching to account for beam voltage variation

»*Photoelastic Modulators (PEMs)*
- »Encode **polarization as intensity modulation**: Dual PEM operation at 20kHz, 23kHz.
- »Allow for synchronous detection of the second harmonic of each PEM to recover **γ.**

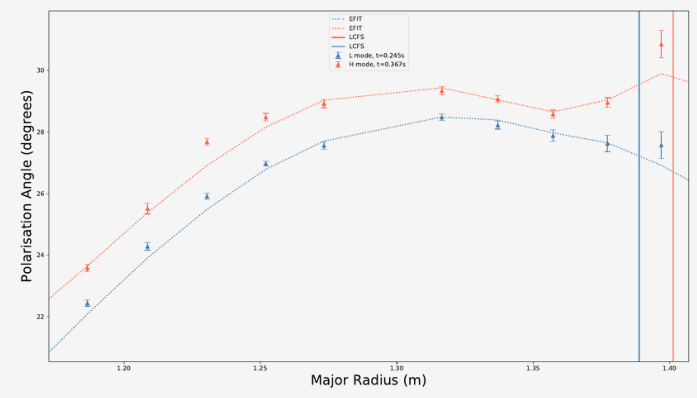
» *Fibers*, *Filterscopes and Detectors*
- »Image fiber bundles onto avalanche photodiodes (APDs)
- »Fibers arranged in hexagonal packing to minimise broadening of filter bandshape.

EDGE CURRENT AND Q PROFILE MEASUREMENTS ON MAST

Polarisation angle profiles



Observed peaked γ inside LCFS in H mode (#24409).



Inferred q and current profiles

Calculate Bz from γ and j using Ampere's law:

$$\mu_0 j_\phi = \frac{\partial B_R}{\partial Z} - \frac{\partial B_Z}{\partial R}$$

2D COHERENCE IMAGING MSE

Principle: *Imaging polarisation interferometer using whole MSE spectrum.*

IMSE Advantages:
- ✓ *Obtain 2D profile of Bz*
- ✓ *Insensitive to broadband polarised light*
- ✓ *Operate over range of beam energies*

Future work:

Assess feasibility of IMSE on MAST-U given small Stark splitting through diagnostic forward modelling.

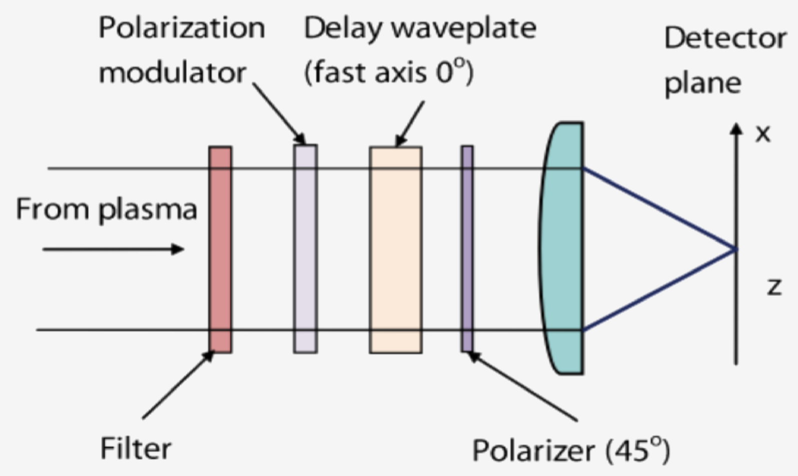
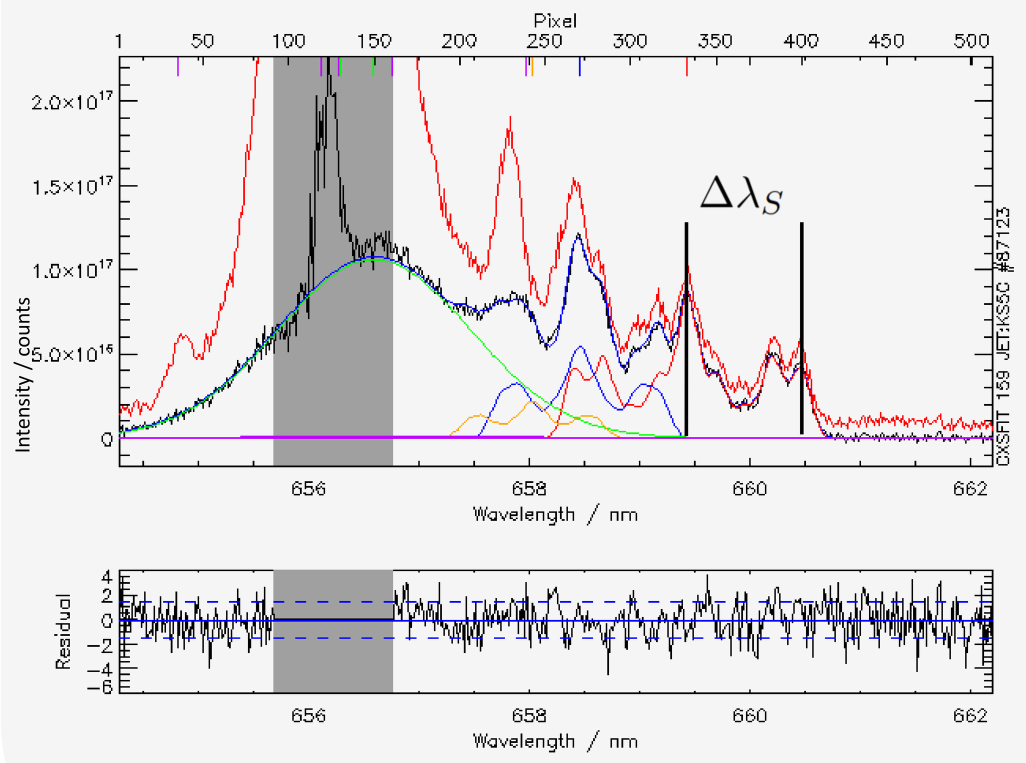


Fig 6: *Optical setup for IMSE. Waveplate thickness is optimised to maximise contrast between π and σ polarised light.* [3]

TOWARDS ITER RELEVANT MSE



Plasma deposition degrades conventional MSE optics.

Background polarised light significant on **ITER – alternative approach required** [5]

Line splitting proportional to |B|:

$$\Delta\lambda_S = \frac{3ea_0}{2hc}\lambda_0^2 m\,|E|$$

- ✓ **Polarisation free measurement**
- ✓ **High B field → well defined π / σ**
- ✓ **Ready to be tested in ITER relevant JET DT campaign**

References
- [1] N. C. Hawkes, Rev. Sci. Instrum. **70**(1), 1999
- [2] N. Conway, Rev. Sci. Instrum. **81**(10) 2010
- [3] J. Howard, K-STAR presentation, 2010
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- [5] M. De Bock, ITER System Design Description, 2014