Motional Stark Effect Measurements On MAST-U

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A multichannel MSE system is employed on MAST-U which is used to measure the pitch angle of the magnetic field. These measurements constrain equilibrium reconstruction codes and measure edge current density and q profiles. These are important parameters for understanding and mitigating Edge Localised Modes (ELMs).

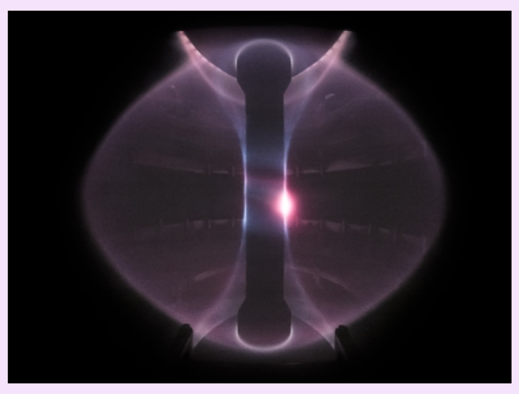

Fig 1: A MAST plasma.

Motional Stark Effect

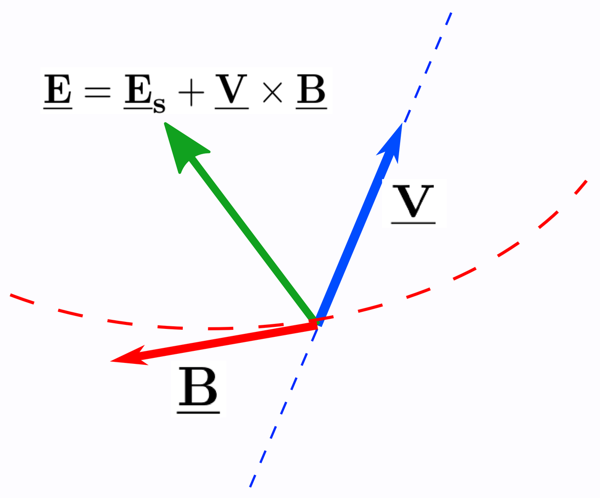

Fig 2: Geometry of the Lorentz VxB field.

Neutral heating beam atoms (blue) move at high velocity through the magnetic field **B**.

They experience a large Lorentz electric field, which induces Stark spliting in the Balmer-α transition. The light emission is polarized with respect to the radial E field $\mathbf{E_R}$.

Transition lines split into π and σ lines; polarized parallel and perpendicular to the E field respectively.

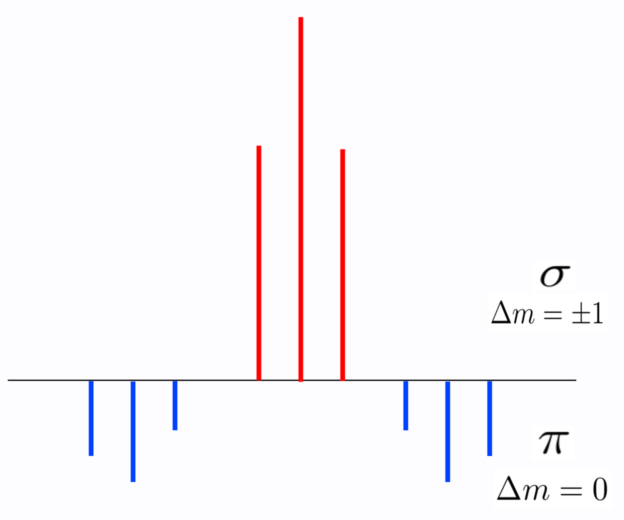

Fig 4: Intensity of π and σ lines.

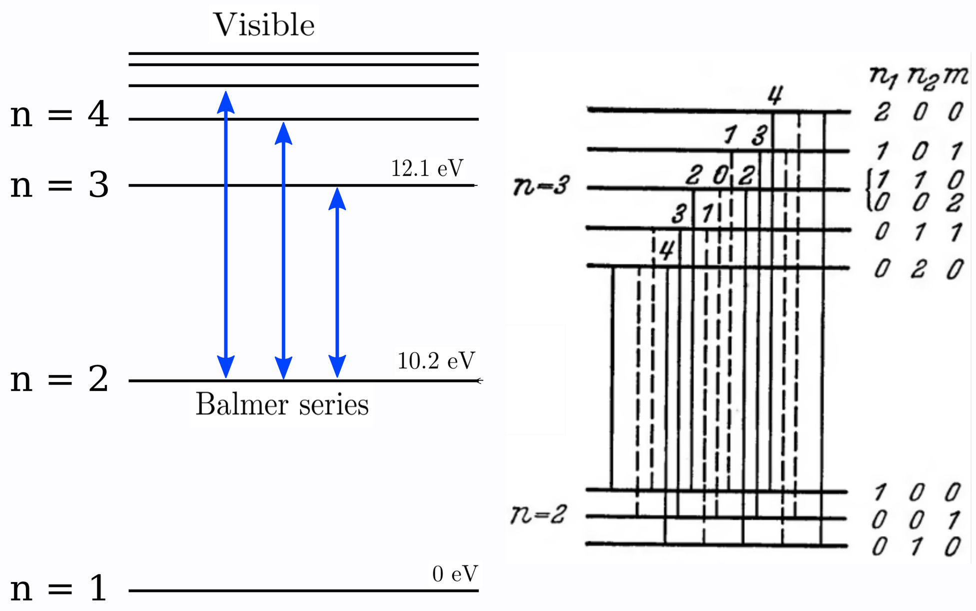

Fig 3: The Balmer series includes transitions from above n=3 to n=2. Stark split states shown with parabolic quantum numbers. [4]

MSE System on MAST-U

Birefringent photoelastic modulators (PEM) and polarizer encode polarisation state as modulated intensity signal, as optical fibres do not preserve light polarization.

Polarization angle is obtained from a ratio of amplitudes of the second harmonics (40kHz and 46kHz) from each PEM. [1]

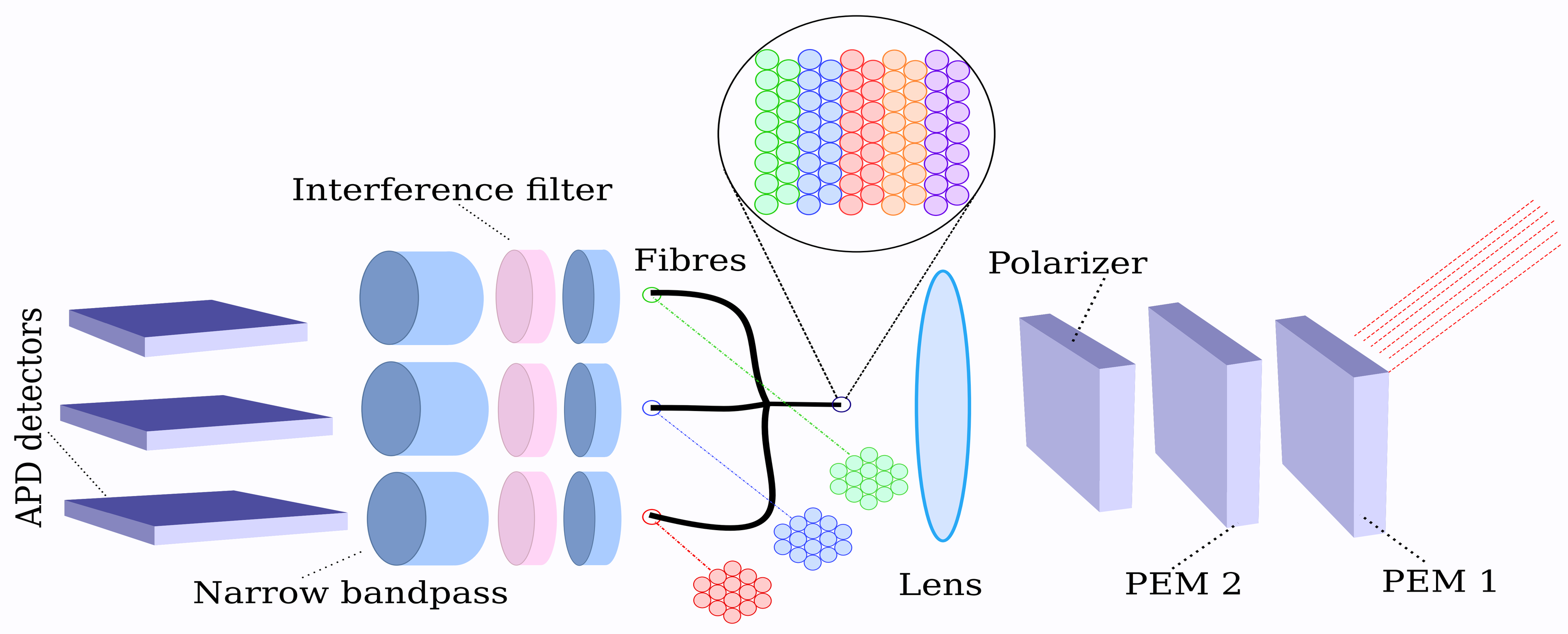

Fig 5: Hardware and optical arrangement for the MSE system on MAST-U. The PEMs are mounted with their axes at 45° apart, followed by a linear polarizer at 22.5° from each PEM.

- 35 spatial channels at R = 0.71m - 1.5m
- Resolution: ~2.5cm
- Filterscopes optimised for NBI voltage range (65kV-75kV)
- Time resolution: 0.5ms
- Statistical noise in polarization angle: 0.5° at 1ms

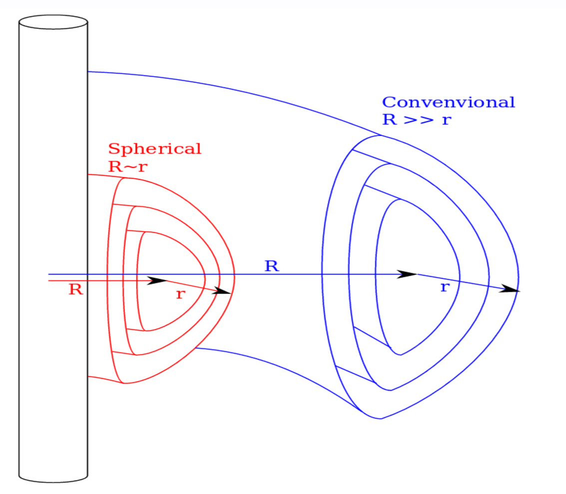

Fig. 6: Comparison of a tight aspect ratio tokamak such as MAST and large aspect ratio tokamak. [3]

There are added challenges when employing MSE in a spherical tokamak:

- The magnetic field strength is lower.
- Curvature of the magnetic field is larger.

MSE spectrum suffers from spectrum broadening and overlapping pi/sigma lines due to:

- Variation in **B** and $\mathbf{E_S}$ over the collection volume.
- Beam velocity distribution causes Doppler broadening.

Edge Current Evolution using MSE

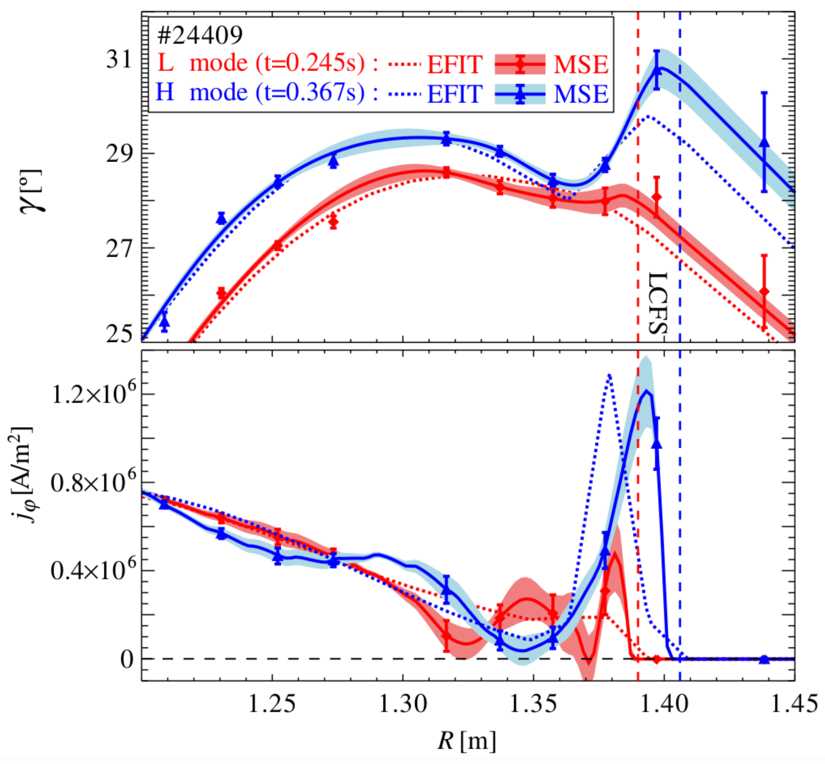

Fig. 7: Profile of pitch angle γ and current density j_ϕ during L and H mode. A peak in j_ϕ and γ is observed at the edge of the plasma. [2]

Edge current density $\mathbf{j_\phi}$ is derived from the magnetic pitch angle,

$$\Delta\gamma_m = \frac{B_\phi \Delta B_\theta}{B_\theta^2 + B_\phi^2}$$

where $\mathbf{B_\theta}$ and $\mathbf{B_\phi}$ is the poloidal and toroidal magnetic field respectively. The current density is given from Ampere's law,

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

$\mathbf{B_Z}$ can be calculated directly from the polarization angle measured by MSE and $\mathbf{B_R}$ calculated from $\mathbf{E_R}$.[2]

Stability and the Evolution of j_ϕ

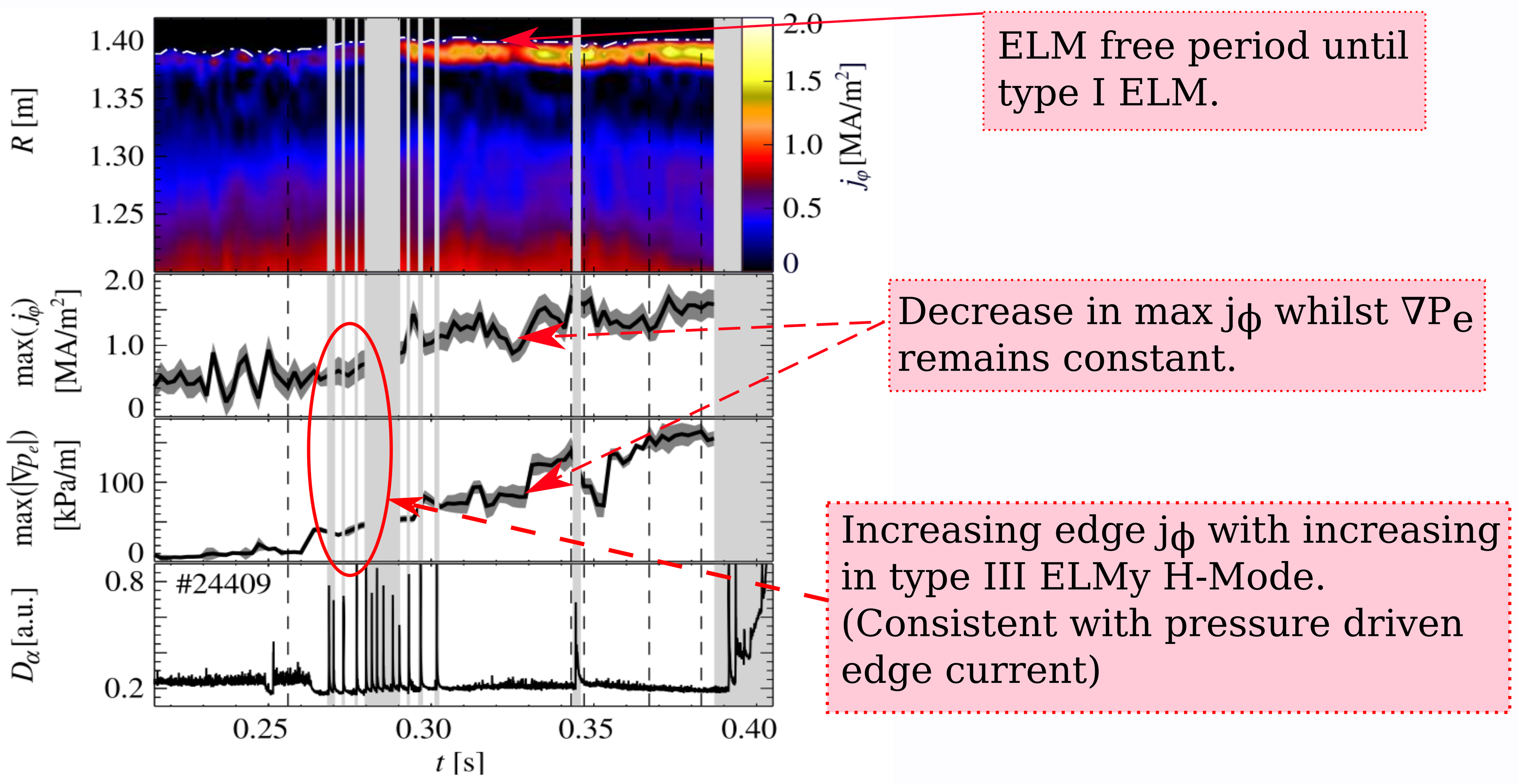

Fig 8: Evolution of current density and pressure gradient, with Dα emission peaks. The grey sections denote a time when ELMs occur, at which no reliable MSE data is attained. [2]

Independent measurements of j_ϕ provide information for:

- **Improving pedestal profiles** to fit meaured T_i, N_i, T_e, N_e and γ. This would give a more accurate description of the pedestal.
- Understanding **the role of current diffusion** with respect to the stability of the H mode pedestal.

References

[1] Conway, N. J., et. al, Rev. Sci. Instrum. **81**.1, 10D738, (2010)
[2] De Bock, M. F. M. et. al, Plasma Phys. Control Fusion, **54**.2, 025001 (2012)
[3] Walkden, N. R., Properties of Intermittent Transport in the Mega Ampere Spherical Tokamak, University of York Thesis, (2014)
[4] Kat, J., Beam Emission Spectroscopy Motional Stark Effect diagnostic on TEXTOR, Eindhoven University of Technology Thesis, (2013)

Acknowledgements

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