Measurement of the current profile in Alcator C-Mod with Lower Hybrid Current Drive using an upgraded Motional Stark Effect diagnostic*  

R. T. Munguard¹, S. D. Scott², S. Shiraiwa¹, G. M. Wallace¹, R. R. Parker¹, J. W. Hughes¹, R. S. Granetz²  

¹*Plasma Science and Fusion Center, MIT, Cambridge, MA, USA  
²Princeton Plasma Physics Laboratory, Princeton NY, USA  

This work is supported by the U.S. DOE, OES awards DE-FC02-03ER54512 and DE-AC02-09CH11466.  

Key points:  
- LHCD system on Alcator C-Mod capable of coupling ~1MW of power to plasma for several current relaxation times  
- Upgraded Motional Stark Effect (MSE) diagnostic used with within-shot calibration technique and kinetic profiles to constrain magnetic reconstructions  
- System used to study reconstructed current profile in plasmas with strong Lower Hybrid Current Drive (LHCD):  
  - Current profile evolution consistent with sawtooth suppression/reappearance; timescales correct  
  - Non-inductive discharges show broad current profile with significant on-axis current drive  
  - Increasing density decreases driven current faster than expected, consistent with previous results  
  - Profile may move slightly outward with increasing density  
  - Decreasing LHCD launched n reduces MSE pitch angles  

Lower Hybrid Current Drive on Alcator C-Mod at ITER relevant field, frequency and density[1]  
- 12 Krysts provide 2.5MW source power, 1MW coupled to plasma  
- 4.6 GHz (ITER at 5GHz [2])  
- 16 active columns of 4 rows  
- Pulse lengths up to 1s achieved (5-10 current relaxation times)[3]  
- All six fully released current profiles  
- Extendable up to 5s in future  
- Variable phasing allows launched n from 1.4 to 3 within a pulse on a millisecond time scale  

Upgraded Motional Stark Effect diagnostic for constraining magnetic reconstructions[4]  
- Thermal stress-induced birefringence not completely eliminated in the MSE optics.  
- The diagnostic calibration drifts due to shot (1-2min time scale)  

Within shot Ohmic calibration technique used to compensate for MSE diagnostic drift[5]  
- Thermal stress-induced birefringence not completely eliminated in the MSE optics.  
- The diagnostic calibration drifts due to shot (1-2min time scale)  

Within MSE calibration technique:  
- Reconstruct Ohmic pre-LHCD portion using magnetic, sawtooth inversion radius (SIR) and pressure constraints  
- Determine MSE calibration offset using reconstructed pitch angles  
- MSE, magnetic and kinetic profiles then used as constraints in LHCD reconstructions  

Key points:  
- MSE response is constant throughout a discharge  
- MSE response is linear  
- An offset correctly characterizes the MSE calibration drift  
- LHCD neutral beam, magnets do not affect the operation of the diagnostic  
- MSE, magnetic and kinetic profiles then used as constraints in LHCD reconstructions  

Within shot Ohmic calibration technique used to compensate for MSE diagnostic drift[5]  
- Thermal stress-induced birefringence not completely eliminated in the MSE optics.  
- The diagnostic calibration drifts due to shot (1-2min time scale)  

Within MSE calibration technique:  
- Reconstruct Ohmic pre-LHCD portion using magnetic, sawtooth inversion radius (SIR) and pressure constraints  
- Determine MSE calibration offset using reconstructed pitch angles  
- MSE, magnetic and kinetic profiles then used as constraints in LHCD reconstructions  

Key points:  
- MSE response is constant throughout a discharge  
- MSE response is linear  
- An offset correctly characterizes the MSE calibration drift  
- LHCD neutral beam, magnets do not affect the operation of the diagnostic  
- MSE, magnetic and kinetic profiles then used as constraints in LHCD reconstructions  

Within shot Ohmic calibration technique used to compensate for MSE diagnostic drift[5]  
- Thermal stress-induced birefringence not completely eliminated in the MSE optics.  
- The diagnostic calibration drifts due to shot (1-2min time scale)  

Within MSE calibration technique:  
- Reconstruct Ohmic pre-LHCD portion using magnetic, sawtooth inversion radius (SIR) and pressure constraints  
- Determine MSE calibration offset using reconstructed pitch angles  
- MSE, magnetic and kinetic profiles then used as constraints in LHCD reconstructions  

Key points:  
- MSE response is constant throughout a discharge  
- MSE response is linear  
- An offset correctly characterizes the MSE calibration drift  
- LHCD neutral beam, magnets do not affect the operation of the diagnostic  
- MSE, magnetic and kinetic profiles then used as constraints in LHCD reconstructions  

LHCD N discharge scans show only mild dependence of driven current location on launched n; future work includes further analysis of shots and comparison to simulations of LHCD  
- Decreasing n decreases current drive slightly outward  
- Increases the current drive efficiency, qualitatively consistent with theory through n dependence is not as strong as expected  

Assumptions used in this technique have been verified:  
- MSE response is constant throughout a discharge  
- MSE response is linear  
- An offset correctly characterizes the MSE calibration drift  
- LHCD neutral beam, magnets do not affect the operation of the diagnostic  
- MSE, magnetic and kinetic profiles then used as constraints in LHCD reconstructions  

Next steps include further analysis of shots and comparison to simulations of LHCD  
- Mechanical in-situ between shot MSE calibration system has been installed to obtain an absolute pitch angle calibration for each shot  
- Eliminate the need for within-shot Ohmic calibration technique  
- Refine data analysis  
- Investigate systematic errors in the MSE calibration technique  
- Develop uncertainty estimates for the reconstructions  
- Simulate the discharges using RF codes to determine the contribution from DC electric field – RF fast electron coupling to better estimate the LHCD current profile  
- Compare to time dependent RF-equilibrium codes  
- Future upgrade to Alcator LHCD system including an additional advanced poloidal polarimeter measurement[6]  

References:  