Active and Passive MHD Spectroscopy Diagnostics for ITER

Alcator C-Mod

J A Snipes

MIT Plasma Science and Fusion Center, Cambridge, MA USA

MIT PSFC

What is MHD Spectroscopy?

Diagnosing the properties of MHD modes in the plasma can provide information on other plasma properties through the dispersion relation of those modes, e.g., for Toroidal Alfvén Eigenmodes (TAE's):

$$\omega_{TAE} = v_A / (2qR) \propto B_T / \sqrt{m_i n_i} / (2qR), \;\; q = (m + \frac{1}{2}) / n$$

- Passive MHD spectroscopy uses naturally occurring unstable modes in the plasma measured with pickup coils, ECE, PCI, reflectometry, ...
- Active MHD spectroscopy uses antennas close to the plasma to excite stable modes swept across a controlled range of frequencies to actively measure the characteristics of these stable modes
- Through a comparison of theoretical calculations with the analysis of the measured frequency spectra and phase differences in time and space, plasma properties can be inferred like in optical spectroscopy

A Fasoli et al *PPCF* (2002) **44** B159

Potential Uses for MHD Spectroscopy on ITER

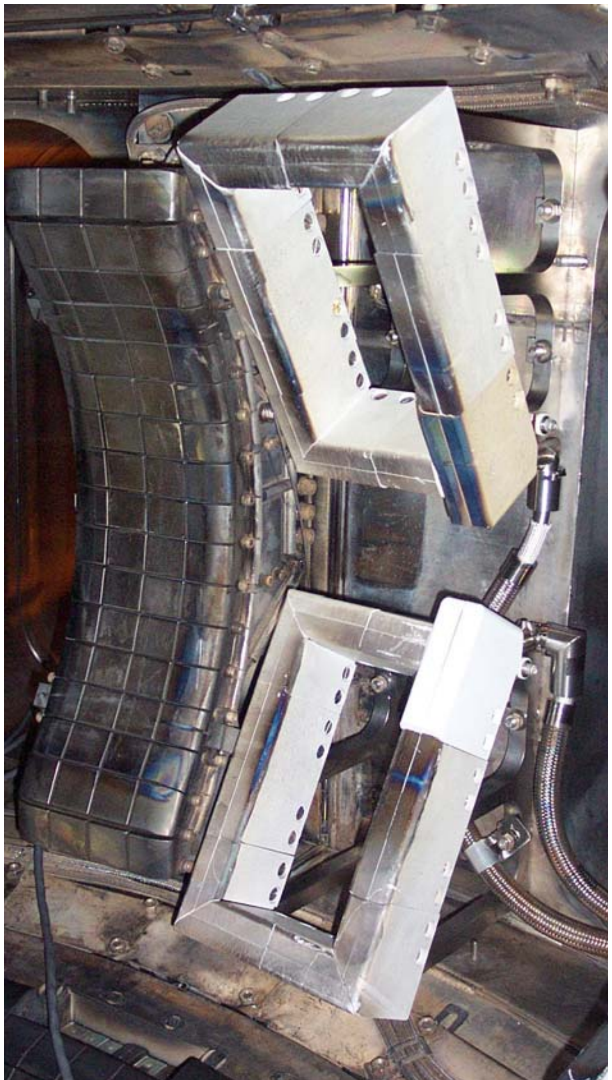
Determine the properties of fast particle driven modes to:

- Passively infer the time evolution and radial location of fast particles
- Passively infer the rapid evolution of the central q profile and better constrain equilibrium q profile calculations
- Passively measure plasma rotation at various rational q surfaces
- Actively provide a measure of the relative tritium concentration
- Actively determine the damping rate of Alfvén eigenmodes as a function of plasma conditions
- Provide a feedback control signal for Alfvén eigenmodes to help maintain stable plasmas and avoid substantial fast α-particle losses

MIT/JET/CRPP Collaboration on Active MHD

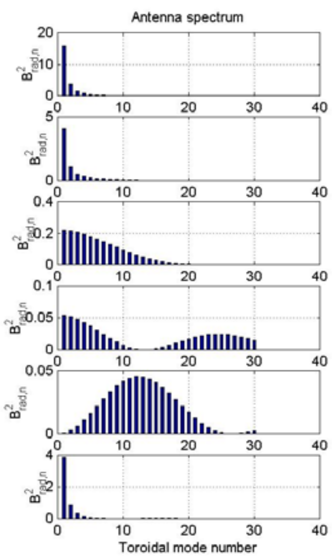
- Prof. A. Fasoli came to MIT from JET/CRPP and started an Active MHD Spectroscopy collaboration with DOE funding in 1999 based on his pioneering work in this area on JET
- We then initiated Active MHD Spectroscopy also on Alcator C-Mod to compare results in a high field, high density regime
- Prof. Fasoli is now at the CRPP-Lausanne on leave from MIT continuing a three-way collaboration between MIT/JET/CRPP
- Combining our efforts rather than competing leads to a better understanding of fast particle driven modes in different plasma regimes

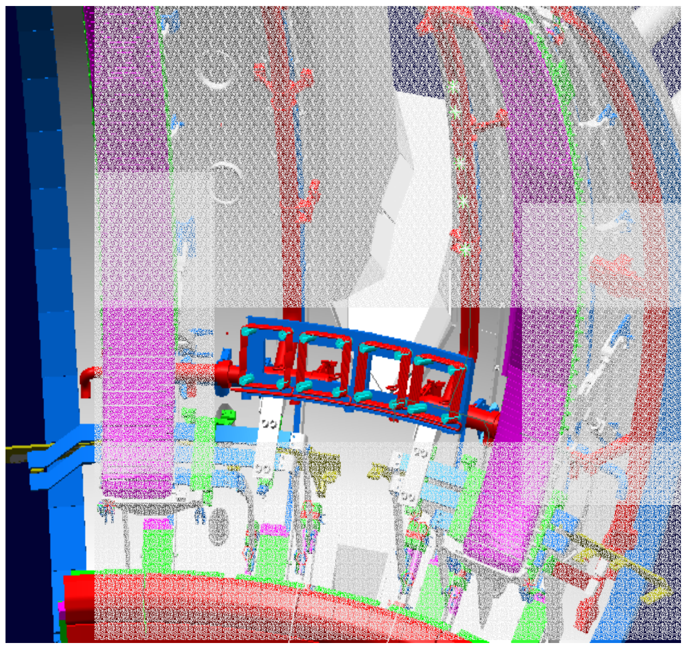
Active MHD Antennas on Alcator C-Mod



- Presently two operating Active MHD antennas above and below the midplane
- Each antenna is 0.15 m × 0.25 m × 5 turns
- Drive up to 25 A across the frequency range 1 kHz < f < 1 MHz
- Excite core Toroidal Alfvén Eigenmode resonances ~ 400 – 500 kHz
- Antennas are within 2.5 cm of the plasma and are protected by boron nitride tiles to allow high frequency field penetration

New Active MHD Antenna Design for JET





A Fasoli, D Testa, CRPP
C Boswell, J A Snipes, P Titus, MIT

- MIT and CRPP-Lausanne are collaborating to design new high n Active MHD antennas for JET
- 4 closely spaced antennas in two locations 180° apart toroidally
- Each antenna is 0.25 m × 0.25 m × 18 turns
- Uses 3 kW, 10 A power supply to drive frequencies 10 kHz $< f <$ 500 kHz

Ideas for MHD Spectroscopy on ITER

High n toroidal distribution of excitation antennas and pickup coils

- Need to excite and measure modes with $n < 15$ and $f_{TAE} \sim 100$ kHz
- Requires high frequency response pickup coils close to the plasma distributed every 12° toroidally preferably above and below the outboard midplane (60 pickup coils to include redundancy)
- Similar toroidal distribution of driving antennas separated by 12° with at least 8 antennas close to the plasma along the outboard wall
- Each driving antenna should cover 1.5 m × 1.5 m × 10 turns
- Antenna conductors and power supplies should be designed to drive 125 A of current across the frequency range 1 kHz < f < 250 kHz
- Antenna and pickup coil protection tiles must be non-conducting to allow high frequency flux penetration

University Involvement in ITER

- Universities can provide valuable expertise to ITER research
- Ongoing experiments in Active MHD Spectroscopy on C-Mod and JET need to be assessed before proposing this diagnostic for ITER
- Pickup coils for passive MHD Spectroscopy up to at least 100 kHz should be included now in the design of the ITER first wall
- Joint collaborations instead of competition between different ITER parties will strengthen ITER and should be encouraged at least in areas where strong collaborations already exist
- The lower costs of university projects provide a high return on investment by maintaining extensive scientific expertise in important research areas throughout the ITER program