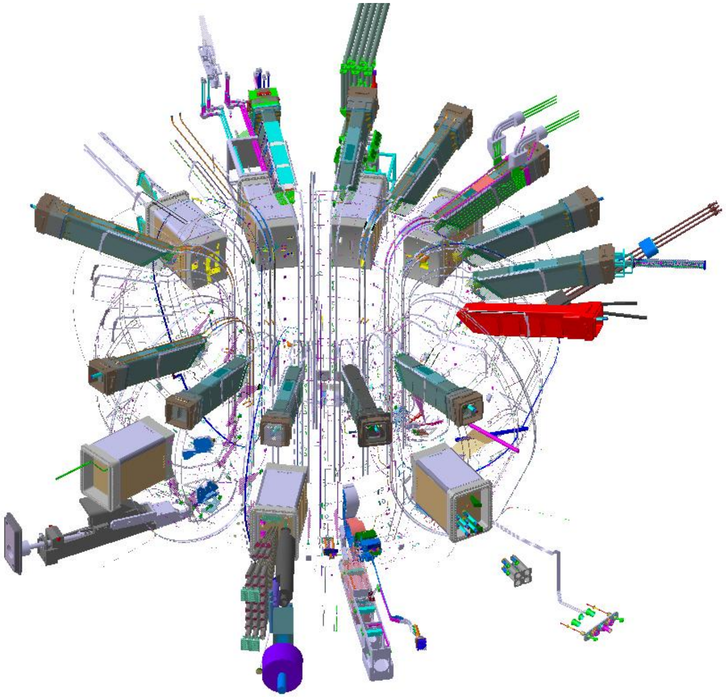
# EC-16 Workshop: ITER ECE Session



Victor S. Udintsev on behalf of ITER Team

All EC-16 Participants

# Agenda

- 10:30 - Session starts
- 10:30 - Max Austin: *"ITER ECE and the Three R's: Resolution, Reliability, and Rightness"*
- 10:50 - Key questions to ask
- 11:00 - Open discussion
- 12:00 – Session closed

# ITER ECE: measurement requirements and hardware

• **Measurement range: $T_e$ = 0.5 – 40 keV**

**Radial resolution from the present Project Requirements:**

• **Edge resolution: r/a > 0.85, 5 mm**

• **Core resolution: r/a < 0.85, 70 mm (~ a/30)**

• **Detection of MHD, TAE, NTM, turbulence**

**4 instruments: Michelson interferometry (X- and O-modes) and Heterodyne Radiometers (O (122-230 GHz) and X (244 – 355 GHz) modes; $B_t(0)$= 2 – 5.3 T)**

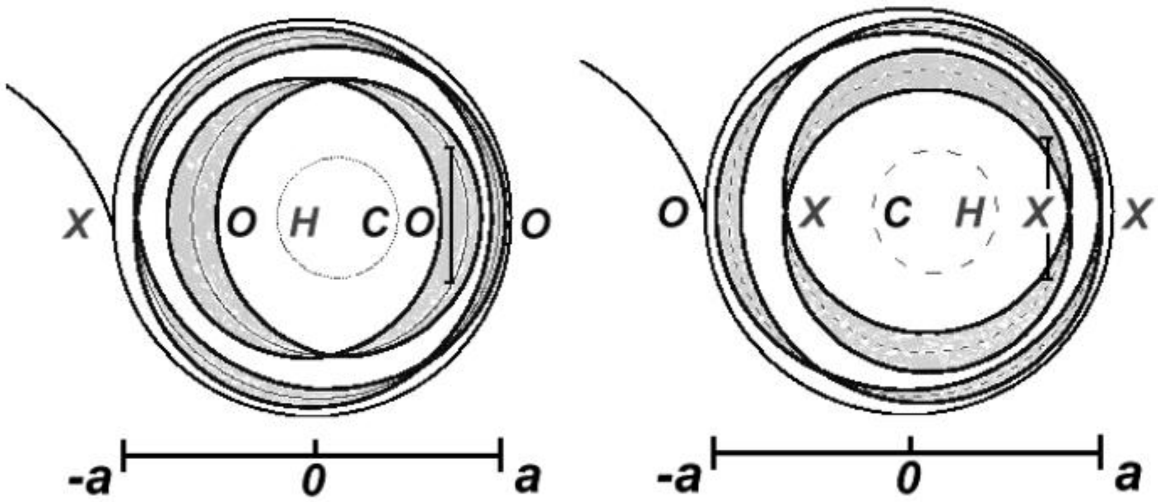
**2 lines-of-sight are for:**

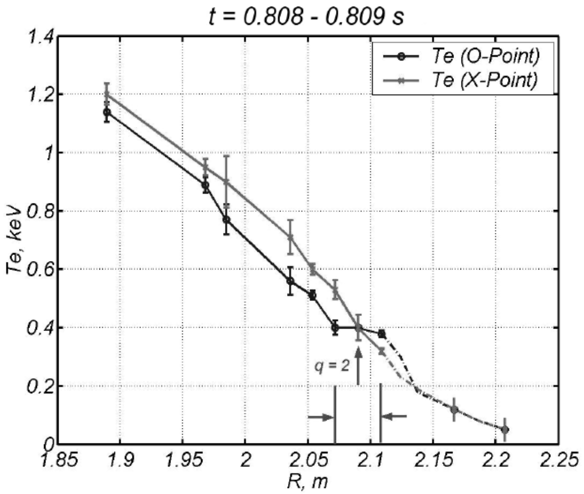
- **Redundancy**
- **Lower losses when both running**

**$2^{nd}$ line of sight can be oblique if these missions are not compromised**

# ECE: Requirements for the Spatial Resolution

• Present requirements for NTM detection:
$\Delta Te/Te = (0.1 - 5.0) \times 10^{-2}$, $\Delta r = 50$ mm
*Is this enough, or higher radial resolution is needed?*




**TEXTOR; Udintsev, NF 2003**

$$\Delta r = \frac{\Delta T_e}{dT_e / dr}$$

The critical island width on ITER is 20 – 40 mm; ECH deposition is 30 – 70 mm

This may affect the number of channels and their separation at NTM radii

Feasibility of using real-time ECE to control MHD/NTMs in ITER. What do we learn from the present machines? In particular, the experience of TEXTOR, AUG, TCV and others can help a lot in understanding the technique and thinking of similar one for ITER real-time control.

Other control uses of ECE ($T_e$ profile)?

Oblique ECE on ITER. What can we expect?

Transmission line choice. Corrugated waveguides? Degraded performance above 300 GHz. Oversized waveguides for Michelson? Quasi-Optical transmission lines?

Confinement barrier strategy on ITER: two windows or window + isolation valve to provide confinement function in all situations

First confinement must withstand 2 bar peak pressure

Windows design should take into account the diagnostic requirements and should not degrade their performance

Experience from existing machines; dedicated tests and mock-ups for ITER microwave diagnostics could be important; any additional R&D required?

# ECE and Thomson scattering: discrepancy at higher $T_e$

At $T_e > 7$ keV, discrepancy between ECE and TS were observed at TFTR (G. Taylor) and later on JET

On JET, both 2nd and 3rd harmonics were optically thick, and the temperature deduced from 3rd harmonic ECE is closer to TS results

Possibilities:

- High-energy electrons which raise the average electron energy? But observations were made from LFS
- Result from the strong coupling from the energetic ion beams used to heat plasma with the plasma electrons in the low-energy range (Taylor)? But what about e-e collisions which are effective to restore the Maxwellian velocity distribution? Can this distortion therefore exist quasi-statistically?
- What about ECH-heated discharges for ITER? ECH may affect both diagnostics in different ways (Krivenski)
- Do we need to re-assess our understanding of the basic physics of the heating systems if the distortion is indeed due to the energy input from them?

# ECE and Power Loss

The critical parameter for power loss due to ECE is the effective reflectivity of the vacuum vessel. All experimental determinations of this parameter so far have been at the few hundred GHz level. But for ITER at full power, DEMO etc, the ECE will peak at about one THz. What will $R_{eff}$ be there? The calculations being done of the ECE power loss for these machine usually take $R_{eff}$ as 0.7 or 0.6 but is this is based on current experiments.

An experimental determination of this parameter on one of today's machines (a high field machine such as FTU or Alcator would be best) at high frequencies is needed. The best way to do this is to measure the ECE spectrum with a well calibrated system of a well diagnosed plasma and then fit the measured and calculated spectra using $R_{eff}$ as a variable.
NOTE: today’s machine have a higher ratio of hole to wall.

Any codes to aid this estimation? Good model of $R_{eff}$ in the ITER vessel would be a benefit.

# 2D ECE and Calibration

There is a little information available on system calibration in imaging systems. Any developments and/or updates from the community?

Fluctuation measurements by 1D and 2D systems. There has often been too much emphasis on the plasma measurements but this is only half the story. The measurements have value if the system is appropriately calibrated and that maybe an absolute calibration or a relative calibration depending on the measurement that is being made. But what is the significance of this for fluctuation measurements?

What are the benefits of fluctuation studies on ITER? What can we learn from them?

# Open Discussion

| | | |
|---|---|---|
| **1.** Electron Cyclotron Emission ECE | | |
| O & X-mode Michelson | 70 GHz – 1 THz | Quasi-optic |
| O-mode Radiometer | 122 – 230 GHz | 4 bands: F, D, G + |
| X-mode Radiometer | 244 – 355 GHz | 4 bands. QO? |
| **2.** Reflectometers | | |
| O-mode plasma position | 15 – 60 GHz | 3 bands: K, Ka, U |
| LFS O-mode profile | 15 – 60 GHz + | 3 bands as above |
| LFS O-mode profile | 40 – 160 GHz | 4 bands: U, E, F or W, D |
| LFS Xu-mode profile | 76 – 180GHz | 2(or 3) bands: W, D, (G) |
| HFS Xl-mode profile | 8 – 78 GHz | 3-5 bands: (X), K, Ka, U, (V or E) |
| HFS O-mode profile | 15 – 127 GHz | 5-6 bands: K, Ka, U, E, F |