FOM-Institute for Plasma Physics Rijnhuizen
Association Euratom-FOM

Imaging Meso-scale structures in TEXTOR with 2D-ECE

Abstract

The combination at TEXTOR of:

- an innovative 2D imaging technique for temperature fluctuations,
- a versatile ECRH/ECCD system and
- a unique possibility to externally induce modes in the plasma,

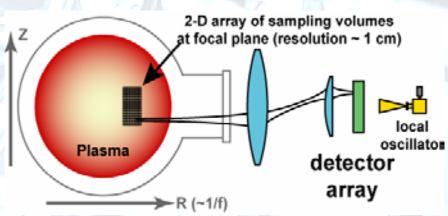
allows to detect and control instabilities.

Three examples of meso-scale structures detected by ECEI are shown:

- the edge structures induced by the external perturbation coils
- the suppression of m=2/n=1 tearing modes
- temperature fluctuations in the QC-mode

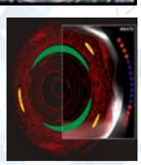
ECEI

- 16 element array of heterodyne receivers
- each a radiometer with 8 frequency channels → 16x8 matrix
- corresponds to 16x7 cm² in plasma



TEXTOR & DED

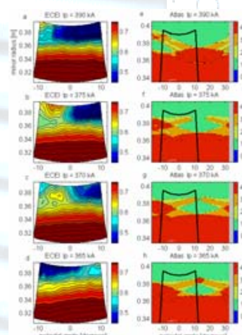
- R_0= 1.75 m
- a = 0.46 m
- I_p < 0.8 MA
- B_t < 2.8 T
- P_{NBI} = 2 x 1.5 MW
- P_{ICRH} = 2 x 2.0 MW
- P_{ECRH}= 0.8 MW
- Circular cross-section
- pulse length < 10 s



16 perturbation coils HFS (DC and 1kHz AC)
Strong 2/1 and 3/1 field components
→ locked 2/1 TM

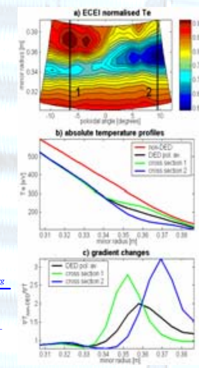
Edge structures

DED in 12/4 mode gives rise to structures in the plasma edge. Te in these have been visualized with ECE-I



ECEI measurements <-> Laminar plots

$$\frac{\nabla T_{e,non-DED}}{\nabla T_{e,DED}} \approx \frac{\chi_{erg}}{\chi_{\perp}}$$



Significant transport enhancement in laminar zone. Ergodic region not much affected

Fluctuations

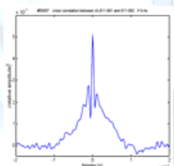
Quasi coherent modes have been observed with reflectometer (n_e) before.

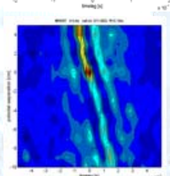
Here it is shown that also ECE can detect these fluctuation, but now in T_e

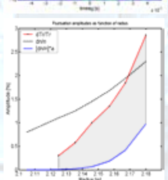
- Poloidal velocity: 6 km/s
- Poloidal wavelength ~ 7 cm
- mode number: m==40
- frequency 90 kHz ± 50 kHz
- T_e fluctuation level ~ 1 %
- detection liomit 0.1 %.

Correction for optical thickness:

$$\frac{dT_R}{\langle T_R\rangle} = (1+a)\frac{dT_e}{\langle T_e\rangle} + a\frac{dn_e}{\langle n_e\rangle} \quad with \quad a = \frac{\tau\cdot\exp(-\tau)}{1-\exp(-\tau)}$$







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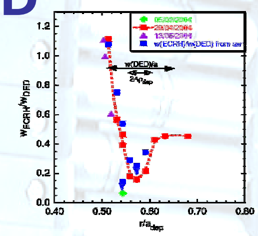
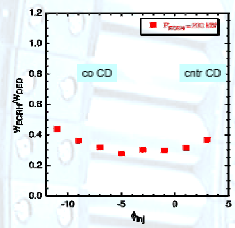
Island Suppression By ECRH/ECCD

- suppression only effective is power is deposited at q=2 with accuracy comparable to power deposition.
- deposition around O-point has larger effect than at X-point
- most effective if all ECRH power deposited inside island
- modulation same effect as CW, but more efficient
- Effect of current drive negligible here
- Dominant effect: heating inside islands

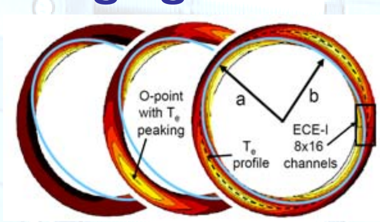


Island suppression vs deposition in case of ECRH



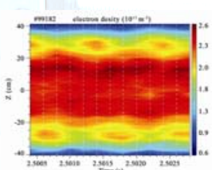
Effect of ECCD (Toroidal Inj. angle) on Island suppression

Imaging of Island Dynamics

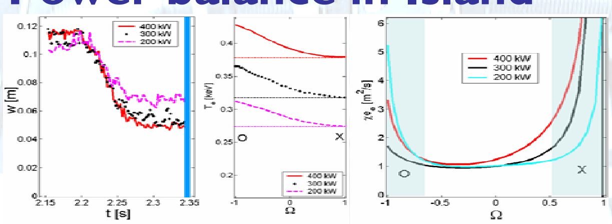


a) No ECRH, b) ECRH on → T_e peaking, c) suppressed island

Density *peaking* in island, measured by TS

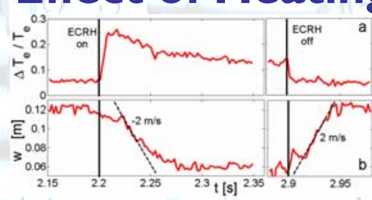


Heating: Power balance in Island



Heat diffusivity in island and ambient plasma comparable

Effect of Heating

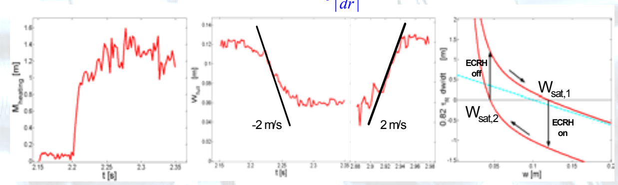


Two step process: first heating by ECRH, then suppression. Island reduced (but not disappeared)

Rutherford equation

$$0.82\cdot\tau_r\frac{dw}{dt} = r_s^2\Delta' + M_{ext} - M_{heating}$$

$$M_{ext} = 2mr_s\left(\frac{w_{vac}}{w}\right)^2; \quad M_{heating} = \frac{32\mu_0 R r_s^2 q}{B_\theta\left|\frac{dq}{dr}\right| R w^2}\cdot\frac{j_{sep}}{T_{e,sep}^{3/2}}\int_{r_s-w/2}^{r_s+w/2} dy \oint T_e^{3/2}\cos(m\xi)\,d\xi$$



Extrapolation to ITER: 30% bootstrap fraction to be replaced: 20% Te peaking needed

Scaling of T_e peaking: $q_e = -n\chi_e\nabla T_e = \frac{P_{ECRH}}{r_s R}A_1$; $\frac{\Delta T_e}{T_e} = \frac{w\nabla T_e}{T_e}A_2 = \frac{wP_{ECRH}A_1A_2}{r_s R n\chi_e T_e}$

➔ Needed: $\chi_{e,ITER} \le \frac{1}{6}\chi_{e,TEXTOR} \approx 0.2\, m^2/s$ (for χ_e=0.5 m²/s, 20 % effect)