Overview on high frequency quasi-coherent modes at Wendelstein-7X

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Motivation

Wendelstein 7-X (W7-X) is the world's largest stellarator, optimized to minimize neoclassical transport. Anomalous transport governs heat- and particle-transport, driven by the gradients in the electron-, ion- and density profiles, expressed by the ratio $\eta_e = L_n/L_{T_e}$ and $\eta_i = L_n/L_{T_i}$. Certain constraints on η_e and η_i determine which kind of turbulence dominates. Most important types are the ∇T_i driven turbulence (ITG) and the trapped electron mode (TEM) driven turbulence. The latter is excited within magnetic wells along a magnetic field line and is stabilized with increasing collisionality. TEMs, separated in ∇T_e-TEMs and ∇n_e-TEMs, reveal strong QCM activity. This poster discusses (i) the observations from turbulence diagnostics and (ii) the profile analysis allowing to identify regions where TEM turbulence is expected.

Conclusions:

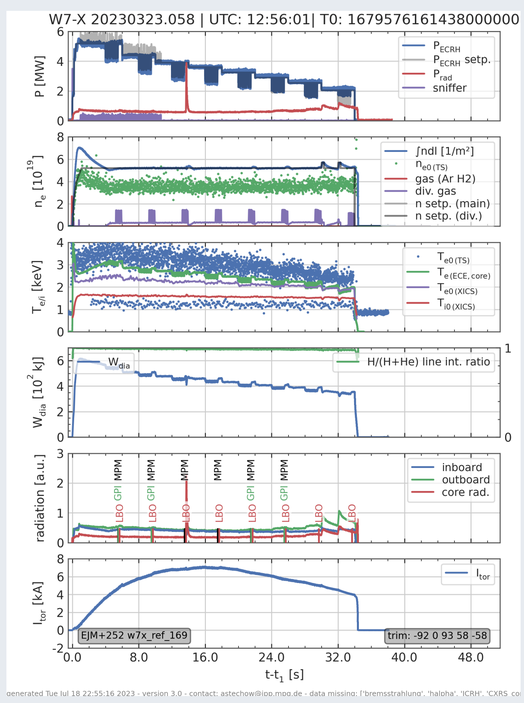
∇T_e-TEMs

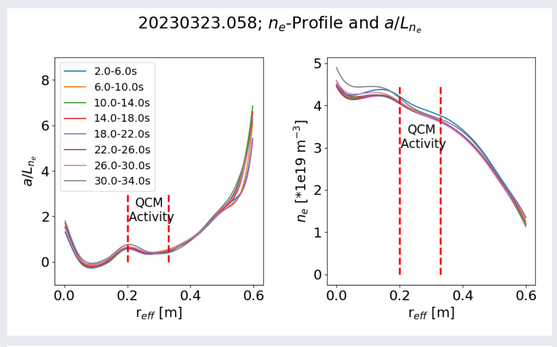
- Power scan experiments – QCM at mid-radius
- Increase of f_{QCM} with ∇T_e; $f_{QCm} \geq 100$ kHz
- QCM-velocity in e^- drift direction
- Poloidal correlation length 25 mm; $k_\perp \rho_s \geq 1$ consistent with ∇T_e-TEMs
- From profiles: $8 \leq \eta_e \leq 10$ confirms ∇T_e-TEMs

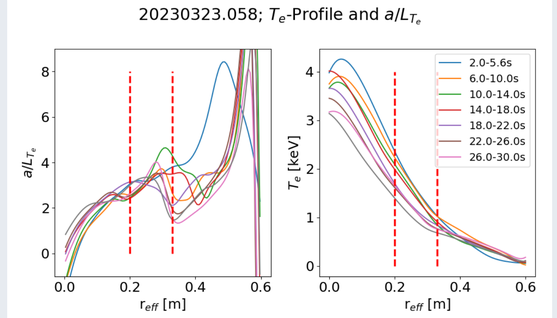
∇n_e-TEMs

- Experiments with NBI-fuelling – QCM at the outer third of the plasma
- Mode frequency scales with a/L_{n_e} and P_{ECRH}; $f_{QCm} \geq 400$ kHz
- QCM-velocity in e^- drift direction
- $k_\perp \rho_s \approx 1$ and $1 \leq \eta_e \leq 1.3$ consistent with ∇n_e-TEMs
- Steeper n_e-profile - reduction of η_i and suppression of ITG-turbulence

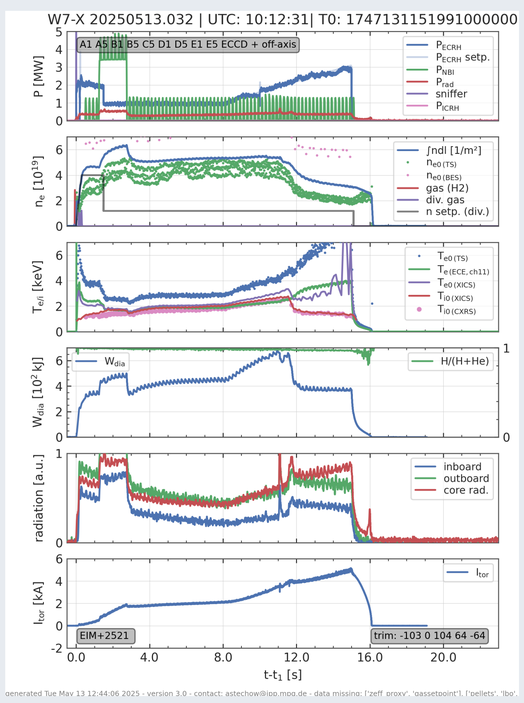
Experiments in standard configuration – ∇T_e-TEMs

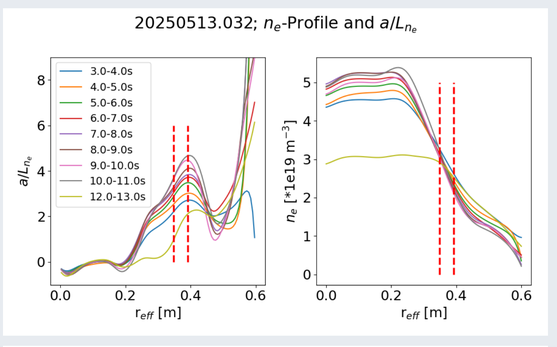


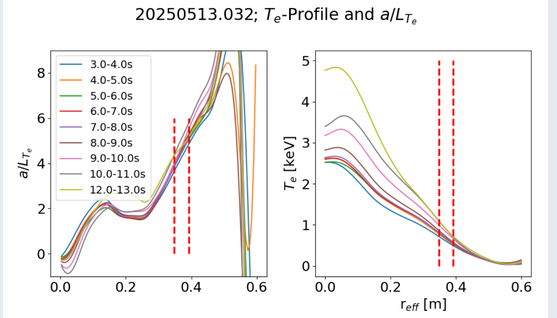




Experiments in standard configuration – ∇n_e TEMs

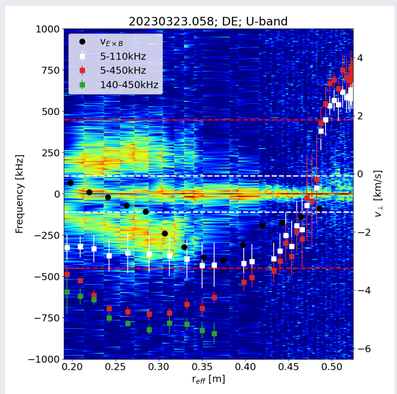




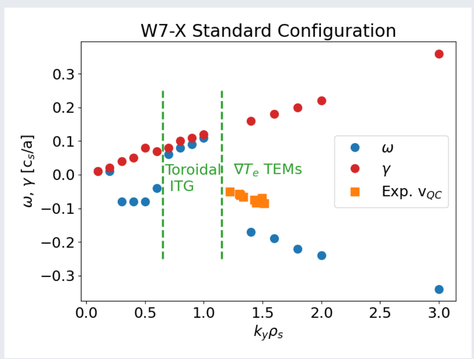


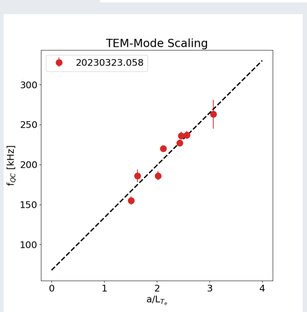
Mode observations

Coherence spectrogram for an antenna pair versus r_{eff}; QCMs for $f \leq 400$ kHz; $v_\perp$-profile for different frequency intervals reveals faster QCM rotation; Good agreement between $E \times B$-rotation from NC and $v_\perp$, outside mode radii.

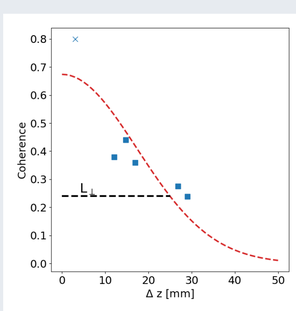


Gyro-kinetic simulations for γ and ω support the existence of ∇T_e-TEMs for $k_\perp \rho_s \geq 1$; Experimental values agree in $k_\perp \rho_s$ with simulations; Frequency mismatch, but right tendency observed.





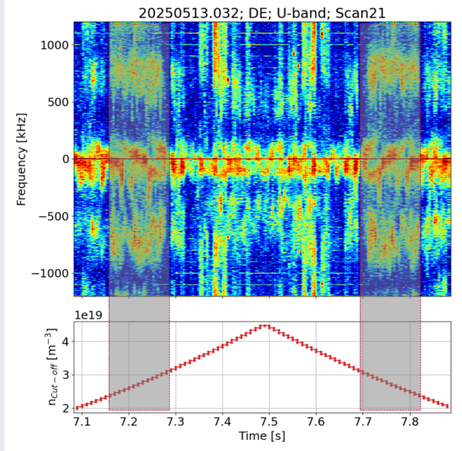
- Scaling of f_{QC} with a/L_{T_e}
- Linear increase of f_{QCM} with a/L_{T_e}
- Estimation of $L_\perp$ from relevant antenna pairs
- Calculated $L_\perp = 25(2)$ mm
- Yields $k_\perp \approx 2.7\,\mathrm{cm}^{-1}$



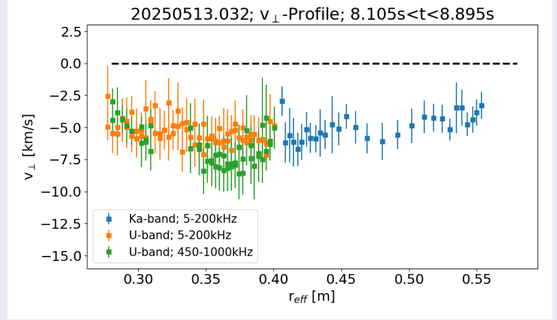
$8 \leq \eta_e \leq 11$ for the radii with QMC supported ∇T_e-TEMs; $3 \leq \eta_i \leq 5$ obtained from profiles; Large values of η_i indicate no stabilization of ITG; W_{dia} is unaffected.

Mode observations

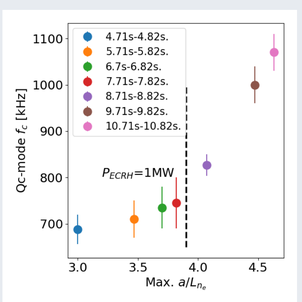
Coherence spectrograms obtained from an antenna pair show broad mode structures (grey area) for 400 kHz to 900 kHz at electron density: $2.4 \times 10^{19}\,\mathrm{m}^{-3}$ to $3 \times 10^{19}\,\mathrm{m}^{-3}$; Intermittent structure in low frequency turbulence



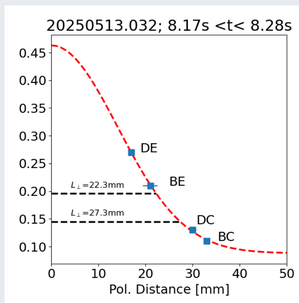
Velocity profiles for different frequency intervals; Different velocity for regions with QCM; Phase velocity of QCM in e^--drift direction; Evidence for TEMs



Mode frequency in the plasma frame: $f_{Pl} = f_{Lab}(v_{Lab} - v_{E\times B})/v_{Lab} = 240$ kHz



- Scaling of f_{QC} with a/L_{n_e}
- Increase of f_{QC} at $P = const$
- f_c increases with P_{ECRH}
- Coherence for different distances
- $L_\perp$: 22 mm $\leq L_\perp \leq 27$ mm
- Within the range of $\leq 10\rho_s$ for TEMs



$\eta_i \approx 0.3$ dominated by TEMs; ITG likely stabilized; Agrees with increased W_{dia} and reduced turbulence level; $\eta_e \approx 0.4$ expected for ∇n_e-TEMs in the edge.

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