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Turbulence measurements using Doppler reflectometry on ASDEX Upgrade

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Latest results on core and edge turbulence properties are presented from the multi-channel O and X-mode Doppler reflectometers on ASDEX Upgrade using adjustable tilt antennas with W-band (75–110 GHz) and fixed tilt antennas in V-band (50–75 GHz) frequency ranges. The antenna tilt induces a Doppler frequency shift $f_D \approx u_\perp . k_\perp / 2\pi$ in the reflected microwave signal proportional to the perpendicular rotation velocity of the turbulence moving in the plasma, $u_\perp = v_{E\times B} + v_{ph}$, from which the radial electric field E_r, flow perturbations (ie. GAMs) or turbulence phase velocity v_{ph} variations can be extracted with sub-millisecond temporal and sub-cm spatial (radial) resolution. The spectral peak amplitude $S(k_\perp) \propto |\delta n|^2$ is proportional to the turbulence strength at the probed perpendicular wave-number, $k_\perp = 2k_o N_\perp \sim 2k_o \sin(\theta_o)$, and the radial cutoff position ρ_{pol} (obtained via beam-tracing & experimental density profiles). With the variable antenna tilt θ_o and W-band k_o range the turbulence $5 < k_\perp < 25$ cm^{-1} from the tokamak mid-radius to the separatrix can be probed. In L-mode the turbulence amplitude rises towards the edge together with a substantial flattening of the k-spectrum. However, in H-mode the comparative $S(k_\perp)$ spectra show a decrease at all wavelengths and spectral steepening for $k_\perp \rho_s > 1$ across the edge region. Initial attempts to measure an ETG signature using localized ECRH deposition show indications of enhanced fluctuation amplitude at high $k_\perp \rho_s \sim 2$ also across the edge. The diagnostic response is contrasted with V-band fixed tilt measurements at low $k_\perp$ and at high $k_\perp$ using 2D full-wave simulation codes.