The impact of inverted density gradients on density profiles measured by reflectometry: an experimental and numerical investigation at ASDEX Upgrade

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At ASDEX Upgrade (AUG), the detachment of the inner divertor is associated with the existence of a high-field side high-density (HFSHD) region in the divertor [1]. The HFSHD region expands to the high-field side midplane, leading to strong poloidal asymmetries in the scrape-off layer (SOL) density [2]. This HFSHD region has been recovered in the modeling of AUG plasmas with SOLPS 5.0 [3], also showing a clear in-out asymmetry of the SOL density profiles. SOLPS modeling has also predicted an inverted density gradient at the inner midplane separatrix leading to a hollow profile with a density peak outside the separatrix.

In principle, O-mode reflectometry is unable to probe the hollow part of the density profile due to wave reflection at the higher density in front of it. Hence, the existence of a hollow region leads to discrepancies between the real and the reconstructed density profiles. If present, the HFSHD region may also block the reflectometry systems from accessing the separatrix under some operating conditions due to the high density of the SOL. Therefore, a procedure for profile reconstruction under such conditions should be developed. Important phenomena occurring in the hollow part of the profile such as wave tunneling and trapping should also be analyzed.

This contribution investigates - via simulation and experiment - the existence of hollow density profiles at AUG associated with the HFSHD region. On the simulation side, a synthetic O-mode reflectometry diagnostic was implemented based on a 1D full-wave code. On the experiment side, our work leveraged the unique capability of the AUG O-mode reflectometer to measure radial density profiles simultaneously at the low-field and high-field sides. This study is a step toward better understanding the signature of a hollow profile in the group delay of the reflected signal.

Simulation results were compared with experimental data obtained in AUG discharges with an L-mode density ramp, focusing on the low-density phase of the discharge where the midplane SOL density is within the measuring range of the current diagnostic (limited to n_e = 3e19 m-3). This investigation has found experimental confirmation that inverted gradients do exist at the high-field side. This is evidenced by a large discontinuity in the group delay together with signal characteristics compatible with wave tunneling in agreement with the simulation results. Finally, this work assesses the uncertainties in the density profile reconstruction as a consequence of the inverted gradient.

[1] S. Potzel et al. 2015 JNM 463 541-545 [2] L. Guimarãis et al. 2018 NF 58 026005 [3] F. Reimold et al. 2017 NME 12 193–9