First measurements of an imaging heavy ion beam probe and validation of the synthetic diagnostic

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A new diagnostic concept, the imaging heavy ion beam probe (i-HIBP) [1 – 4] has been commissioned at the ASDEX Upgrade tokamak and first measurements have been obtained, demonstrating the diagnostic working principle. The i-HIBP injects a primary neutral alkali beam, either $^{85,87}Rb$ or ^{133}Cs with currents up to 1.5 mA and energies in the range of 50 – 70 keV. This beam ionizes when reaching the plasma forming secondary singly-ionized beams that gyrate until impigning on a scintillator plate. The emitted light pattern which encodes information on the density, electrostatic potential and magnetic field of the plasma edge, is then collected by an optical system and a fiber bundle into a camera.

The first experimental i-HIBP footprints have been obtained at the ASDEX Upgrade tokamak in a wide variety of plasma scenarios, with magnetic fields in the range of 1.9 T – 2.5 T and plasma currents of 0.2 – 0.8 MA. The light emitted by the scintillator forms a characteristic strike-line pattern that moves as expected when changing the magnetic field and plasma current in the experiments [5]. Signals have been obtained in low density L-mode plasmas, up to line-averaged densities around $\sim 2.0 – 3.0 \cdot 10^{19}\ m^{-2}$, limited by the secondary beam attenuation due to electron-impact ionization.

These experiments have been analyzed using the iHIBPsim code [6, 7]. This code simulates the detector response by taking into account a realistic finite beam width, beam divergence and a 3D model of the optical head, allowing the simulation of the beam blocking by the optical head, as observed in experiments. The optical model of the diagnostic, including magnification, photon emission and distortion has been included, allowing a more realistic comparison between experimental measurements and simulated signals. Sensitivity analysis was conducted with the synthetic diagnostic demonstrating that the diagnostic is mostly sensitive to density perturbations in the scrape-off layer [5]. Simulations of different experiments with currents in the range of 250-750 kA show that the strike-line shifts can be reproduced with the synthetic diagnostic with an excellent agreement, including 3D effects from the scintillator optical head. Cut-off effects from the optical head observed in experiments are reproduced and can be used to determine the plasma current and current density estimates. An iterative fitting algorithm has been implemented that allows the signal inversion into physical characteristics, such as the density profiles.

The proof-of-principle of the diagnostic has been demonstrated, showing the capabilities of the diagnostic of capturing variations in the plasma edge which may help to shed light in the investigation of L-H transition and SOL filaments, among others. The diagnostic may be particularly attractive for smaller devices, where the signal level is not be expected to be limited by the attenuation of the secondary beam.

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