Plasma perturbation by active probes in the SOL of W7-X

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Electric (Langmuir) probes are a common diagnostic tool for the investigation of plasma edge physics in magnetized fusion plasmas. While they offer several advantages, such as highly localized measurements and typically good temporal resolution, they have the inherent drawback of being an invasive diagnostic, potentially perturbing the plasma.

Experiments involving electrically biased reciprocating probes in the test divertor operation phase of the Wendelstein 7-X stellarator (2017-2018) reveal a variety of (unintended) phenomena attributed to perturbations by the probes:
Firstly, negatively biased probes, drawing ion saturation current, affect the fluctuation characteristics in the 100kHz range of nearby unbiased probes.
Secondly, a single swept Langmuir probe can strongly affect the signals of all nearby electric probes while it is at electron collection (positive) bias. The effects include a strong modulation of both time-averaged values and fluctuation characteristics. In particular, electron collection currents of ~1A by the swept probe at positive bias voltages can clearly affect plasma conditions measured by divertor target probes on flux tubes passing closely nearby the reciprocating probes at a parallel distance of ~10m.
Finally, the insertion of a reciprocating probe head into a magnetic island can redistribute heat and particle fluxes within the island, causing factor 2 changes (both increases and decreases) in density and temperature at the divertor targets, presumably by acting as a field-line limiting object.

This contribution summarizes these observations, infers scenarios to minimize perturbations in future experiments, and explores potential exploitations of perturbations: As an example, the clear response on target probes due to a reciprocating swept probe can help in mapping magnetic field lines. Furthermore, the propagation of active perturbations provides insight into the SOL plasma physics. Finally, modification of plasma conditions and particularly E_r shear by biased electrodes with the goal of tailoring SOL heat and particle fluxes has been attempted in several fusion devices, e.g. [Zweben PPCF **51** 105012 (2009), Grenfell NF **59** 016018 (2019)].