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Highly electronegative plasma conditions in the SPIDER negative ion source

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Neutral Beam Injectors (NBIs) based on negative ions will be the workhorses of the ITER experiment, where they are expected to provide up to 33MW of power to heat the fusion plasma. The negative hydrogen ions are extracted from a RF plasma, in which a magnetic filter field cools down the electrons reaching the so-called expansion region allowing the formation of negative ions near the apertures in the plasma grid. To further improve the production of negative ions, cesium is usually evaporated inside the source and deposited onto the plasma walls, reducing the work function of the surfaces. This dramatically increases the density of negative hydrogen ions near the surfaces, causing the transition to a highly electronegative plasma in the vicinity of the plasma grid.
In this paper, the emergence of this condition in SPIDER, the prototype ion source of ITER NBIs, is assessed starting from the results of the Langmuir probes embedded in the plasma grid and bias plate electrodes in the expansion region, whence negative ions are extracted. These sensors were extensively used during the last SPIDER campaigns with the injection of cesium, and a reduction of the electron saturation current was observed, indicating that the plasma is moving towards an ion-ion plasma. We present here the characterization of the occurrence of this condition, its dependence on machine parameters such as the RF power, the polarization of the plasma grid and bias plate electrodes with respect to the source walls, and its dependence on the cesiation procedure effectiveness as evaluated in terms of negative ions density measured by the cavity ring-down and laser absorption diagnostics, and in terms of the beam and coextracted electrons currents.

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