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Plasma Properties in Giant Negative Ion Sources for Fusion

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Giant negative ion sources are used for neutral beam injectors in fusion devices. A high density of cold negative hydrogen ions is required over the large extraction area of the caesium-seeded plasma source, to provide the required negative ion current, distributed uniformly over thousands of extraction apertures. In this regard, it is expected that the expansion of plasma and neutrals from the driver region provides as uniform as possible plasma properties at the extraction region, for adequate compensation of the space charge of such large negative ion density, and relatively slow precursors for the negative ion conversion at caesiated surfaces. These conditions are difficult to achieve in the presence of the transverse magnetic field necessary to filter the diffusion of electrons to the extraction region. The driver region can be either a large volume multi-cusp filament-arc plasma, or an inductively-coupled plasma discharge realised in multiple drivers with external radiofrequency antennas: neutral beams based on filament sources for negative ions reached impressive performances in the recent decades, and an intense development program is in progress for the rf-driven source plasma to bridge the gap in view of the ITER neutral beam injector. The optimization of the ITER beam source plasma, aiming at extracting 350/290 A/m^2 of H^-/D^- with low-divergence at the low filling pressure of 0.3 Pa, is challenging.

A review of the ITER beam source physics is provided, based on experimental measurements obtained until now also on the one-to-one prototype SPIDER, and on results of numerical models. This is in the line of the massive work done until now towards the development of negative ion sources, based on both filament arc and rf sources. An overview of the ongoing R&D physics program for SPIDER is also proposed and results of experiments performed at other test facilities are presented.

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Yes

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