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USE OF ELECTRICAL MEASUREMENTS FOR NON-INVASIVE ESTIMATION OF PLASMA ELECTRON DENSITY INSIDE THE DRIVER OF SPIDER

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SPIDER is a full-scale prototype of ITER HNBI radio frequency (RF) negative ion-source equipped with a 100 keV particle accelerator system. It has 4 RF circuits, each composed of an RF generator operating at a frequency of 1 MHz, rated power of 200 kW on 50 Ω load whose RF load is composed of a transmission line feeding a capacitor-based impedance matching network connected to two driver coils in series. The plasma in the source is initiated in the drivers through a filament and is heated via inductive coupling with the 8 driver coils. The plasma then expands into an expansion region towards the extraction and acceleration grid system.

To improve the performance of the SPIDER ion source, the characterization of plasma behavior in the driver region is necessary during experiments. In this regard, one of the key input parameter is plasma electron density. Its knowledge is also important for the methodology developed (in another work) for the estimation of power transfer efficiency to the plasma.

Experimental measurement of the electron density inside the driver of SPIDER is however a challenging task. The present main tool for its estimation is based on non-invasive optical emission spectroscopic measurements but the associated collisional radiative loss model is still under development. A more direct approach for the electron density estimation is via Langmuir probes measurements but permanent probes are not present in SPIDER. In this regard, some work was done in 2020, where Langmuir probes were temporarily inserted inside the drivers. This campaign provided some information about the electron density in SPIDER in several experimental conditions.

The paper discusses the performances of complementary non-invasive diagnostic tools for the estimation of electron density applied to SPIDER. This alternative diagnostic tool could be beneficial for ITER HNBI too, where a stringent criterion has to be maintained and no diagnostics inside the driver are foreseen due to high neutron flux and possible material damage from its radiation. In this work, two methods are considered, both are based on a plasma model, an electrical model of the RF circuit, and electrical measurements (like the voltage, current, etc) available at the output of the RF generators. The first one uses the modified power balance model on a driver (considering the losses in the passive structures), while the second one is an alternative method proposed by M. Bandyopadhyay et al and is based on the classical plasma conductivity and skin depth models. The stochastic heating collision frequency is also considered in this approach and its effect is discussed. The first results obtained from the two methods in terms of electron density for different drivers in SPIDER are presented and discussed in this work under a wide set of experimental conditions like RF power, gas pressure, PG current, type of gas, etc. The results obtained are also compared with preliminary estimations of plasma density obtained from temporary Langmuir probe measurements performed in 2020.

Primary author: Dr JAIN, Palak (Consorzio RFX)

Co-authors: RECCHIA, Mauro (Consorzio RFX (CNR, ENEA, INFN, Università di Padova, Acciaieri); SARTORI, emanuele (unipd); Dr SERIANNI, Gianluigi (Consorzio RFX); ZANIOL, Barbara (Consorzio RFX (CNR, ENEA, INFN, Università di Padova, Acciaierie Venete SpA))

Presenter: Dr JAIN, Palak (Consorzio RFX)

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