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A Novel Plasma Source Concept for Negative Ion Generation in Neutral Beam Injectors for Fusion Applications

The negative ion sources currently used for Fusion applications produce tens of Amperes of Hydrogen or Deuterium ion current from a low-temperature (few eV) plasma. Being the negative ion current typically limited below 200 - 300 A/m2 at the extraction apertures, these sources can be quite large and their input power ranges from some tens to hundreds of kW. Two source types are currently used: the Japanese "kamaboko" sources, and the radio-frequency (RF) plasma-driver sources, mainly developed in EU. The former exploits an arc discharge produced by hot filaments biased w.r.t. the containing chamber, whereas the latter uses cylindrical coils operating at about 1-2 MHz. The generated plasma expands towards a cesiated Plasma Grid (PG), where some of the impinging particles are converted into negative ions and then accelerated through the grid apertures. In both types a power of about 2-4 MW/m2 is necessary for achieving the required negative ion current.

The main reasons for this are: (1) the low-temperature plasma is confined just by the cusp-shaped magnetic field produced by permanent magnets located outside the plasma chamber; (2) a large fraction of the electric power of the RF coils is dissipated by eddy currents induced on the surrounding metallic structures.

In principle, a current-free plasma (such as the one considered in these sources) could be confined using a purely poloidal magnetic field configuration. In fact, a dipole configuration allows to achieve an efficient plasma confinement, without requiring a net plasma current. This concept has already been applied in the LDX device [Garnier et al., Nucl. Fusion 49 (2009) 055023] and a similar configuration has been proposed for the Polomac device [F. Elio, Fusion Engineering and Design 89 (2014)].

In the paper we propose a novel Ion source, based on the Polomac configuration, estimate the particle trajectories so as to assess the equilibrium and low-temperature plasma confinement capabilities of such device.

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Email Address

giuseppe.chitarin@igi.cnr.it

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Presenter if not the submitter of this abstract

Primary author: CHITARIN, Giuseppe (Univ. of Padova and Consorzio RFX)

Co-authors: Dr ABATE, Domenico (Consorzio RFX); ELIO, Filippo (deutelio); SARTORI, Emanuele (Consorzio RFX - Università degli Studi di Padova); Dr SPIZZO, Gianluca (CNR-ISTP and Consorzio RFX)

Presenter: CHITARIN, Giuseppe (Univ. of Padova and Consorzio RFX)

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