Contribution ID: **1054** Type: **Regular Poster**

Progress on NIO1 ion source and on energy recover tests

Friday 14 May 2021 12:10 (20 minutes)

The current drive and heating system is fundamental for prolonged tokamak operation, so that development of adequate Neutral Beam Injectors requires: high current density (>200 A/m2); long operation (1h pulse) and durability (years); good beam quality[1.,2]. Moreover, if net energy production is required, high energy efficiency is required, perhaps with some energy recovery system.
As a complement to Neutral Beam Test Facility, Consorzio RFX and INFN developed a Negative Ion Optimization-1 source (NIO1), installed in 2014 and routinely used for daily operation, and several concepts for ion energy recovery.
NIO1 ion source has 9 beam extraction holes, and is installed on a 2 m long 350 mm diameter vacuum vessel, with plenty of other ports (CF200 or CF250 size) available for pumps, optical and beam diagnostic (including Beam Emission Spectroscopy and calorimeters); currently we have two turbopumps (for prolonged H2 operation, and comparison with other gases) and two cryopumps (for H2 operation with vessel pressure $p_v < 40$ mPa). The source plasma chamber wall (a 0.21 m long 0.1 m diameter cylinder), except for the borosilicate radiofrequency (rf) window, the plasma grid and auxiliary CF16 flanges, is covered by 0.5 mm Mo liners, which are more durable than a simple Mo covering. Most CF16 flanges are equipped with optical diagnostics, and we have 3 gas input points. A compact Cs oven was recently attached to the NIO1 lower CF16 flange and is being commissioned.
The status and time evolution of surfaces, also in relation to Cs coverage[4], during long time plasma discharge (feasible in NIO1) is of extreme technological importance, and the need to clean or condition the oxide layers (tungstate or molybdate) is very well known[5]. Conditioning with large H2 pressure in the source p_s and large rf power Pk is being investigated, as a preliminary phase to H− beam production at lower $p_s \in [0.3, 0.8]$ Pa. During a typical NIO1 run, for protection, cryopumps are indeed used only after the plasma is turned on and maintained for a convenient time (1 h), which is about twice the settling time of H− current.
An interesting conditioning effect was noted in NIO1 even before Cs coverage, namely the H− production of a run was enhanced by a previous run with oxygen[3]. Note that plasma atomic content is continuously monitored by Source Emission Source, both to exclude that the effect is due to plasma impurities and to measure the cleaning time of surfaces. Apparent beam divergence (including fluctuation in columns of beamlets) can be easily observed by lateral cameras, as shown in fig 1.(a). The coextracted electron current is strongly decreased with increasing filter field (maximum tested strength was 12 mT) , while H− slightly increases, provided that field straying inside rf driver does not exceed 3 mT. Optimal filter direction was found to be crossed to extraction grid (EG) field direction.

.

Indico rendering error

Could not include image: [404] Error fetching image

Inside diagnostic vessel, part of H− are converted to H0 and to H+, depending on local pressure p_v, eventually enhanced by a gas cell. Traditional approach is to deflect residual H− and H+ by a magnetic field towards two collectors, respectively biased to voltages $-\eta_1 V_s$ and $\eta_2 V_s$, where V_s is the absolute source voltage, η_1 and η_2 are recovery efficiencies. In our new concept, see Fig. 1.(b), the first is a cup with a 'repel'electrode on its end, where H+ and H0 pass through, while H− are driven to cup side wall by their own space charge, enhanced by the collector deceleration. With K_i the kinetic energy of each H− ion, $K_a(z)$ its average at a given z, $V_a = K_a/e$ the equivalent acceleration voltage and I_b the beam current, the local perveance is $P(z) = |I_b|/V_a^{3/2}$; the space charge expansion regime is $P(z) \gg 2k_0$ with $k_0 = (4\varepsilon_0/9)(2e/m_i)^{1/2}$ a reference perveance. Exploiting this regime, V_a can be greatly reduced at collector z_c with two advantages against the traditional collector (where $P(z) \leq k_0$): the lost energy fraction $V_a(z_c)/V_s$ is reduced; secondary particles are reduced and emitted not in the z direction. On the same beamline, a second collector recovers H+. After simulations and optimization to trap secondary particles inside cups, a compact collector finalized for test on NIO1 or other sources was designed and is under construction tender, see Fig. 1.(c).
Design was also discussed for rectangular beam geometries, relevant to MITICA.

Acknowledgements: Some parts of this research were financially supported by EUROFusion, commission INFN-5 (technological researches) or project INFN-E (energy).

References:
[1.] E. Speth et al., "Overview of the RF source development programme at IPP Garching,"Nucl. Fusion, 46, 2006, pp S220-S238 doi:10.1088/0029-5515/46/6/S03.
[2] M. Bacal1 and M. Wada, "Negative hydrogen ion production mechanisms,"Appl. Phys. Reviews, 2, 2015, 021305, doi:10.1063/1.4921298.
[3] M. Cavenago et al., "Beam and installation improvements of the NIO1 ion source,"Rev. Sci. Instrum., 91, 2020, 013316, doi:10.1063/1.5128658.
[4] R. Gutser, U. Fantz, and D. W¨underlich, "Simulation of cesium injection and distribution in rf-driven ion sources for negative hydrogen ion generation,"Rev. Sci. Instrum., 81, 2010, 02A706, doi:10.1063/1.3258607.
[5] I. Langmuir, "Chemical reactions at very low pressures. I. The clean-up of oxygen in a tungsten lamp,"J. Am. Chem. Soc., 35, 1913, pp. 105–127, doi:10.1021/ja02191a001.

Country or International Organization

Italy

Affiliation

INFN-LNL

Author: Dr CAVENAGO, Marco (INFN-LNL)

Co-authors: ANTONI, Vanni (Consorzio RFX); Dr BALTADOR, Carlo (INFN-LNL); Dr BARBISAN, Marco (Consorzio RFX, Corso Stati Uniti 4, I-35127 Padova, Italy; INFN-LNL, Viale dell'Università 2, I-35020 Legnaro, Italy); DELOGU, Rita (Consorzio RFX); Mr MARTINI, Denis (INFN-LNL); Mr MINARELLO, Alessandro (INFN-LNL); Dr PIMAZZONI, Antonio (INFN-LNL); SERIANNI, Gianluigi (RFX); Dr TACCOGNA, Francesco (ItISTP); Dr UGOLETTI, Margherita (Consorzio RFX); Dr VALENTINO, Vincenzo (INFN-BA); Dr VARIALE, Vincenzo (INFN-BA); Dr VELTRI, Pierluigi (Iter Organization)

Presenter: Dr CAVENAGO, Marco (INFN-LNL)

Session Classification: P7 Posters 7

Track Classification: Fusion Energy Technology