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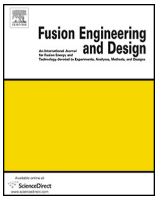

Installation and first operation of the negative ion optimization experiment

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HIGHLIGHTS

- Negative ion sources are key components of the neutral beam injectors.
- The NIO1 experiment is a RF ion source, 60 kV–135 mA hydrogen negative ion beam.
- NIO1 can contribute to beam extraction and optics thanks to quick replacement and upgrading of parts.
- This work presents installation, status and first experiments results of NIO1.

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ABSTRACT

Negative ion sources are key components of the neutral beam injectors for thermonuclear fusion experiments. The NIO1 experiment is a radio frequency ion source generating a 60 kV–135 mA hydrogen negative ion beam. The beam is composed of nine beamlets over an area of about 40 × 40 mm^2. This experiment is jointly developed by Consorzio RFX and INFN-LNL, with the purpose of providing and optimizing a test ion source, capable of working in continuous mode and in conditions similar to those foreseen for the larger ion sources of the ITER neutral beam injectors. At present research and development activities on these ion sources still address several important issues related to beam extraction and optics optimization, to which the NIO1 test facility can contribute thanks to its modular design, which allows for quick replacement and upgrading of components. This contribution presents the installation phases, the status of the test facility and the results of the first experiments, which have demonstrated that the source can operate in continuous mode.

1. Introduction

Negative ion sources are key components of the neutral beam injectors for thermonuclear fusion machines. NIO1 (negative ion optimization-phase 1) [1] source is being developed in Padova, Italy, by Consorzio RFX and INFN-LNL. It is a flexible test facility that allows testing several configurations and magnet layout, with quick replacement and upgrading of components. The work is carried out in the framework of accompanying activities in support to the ITER Neutral Beam Test Facility [2] that is under construction in Padova (Italy). NIO1 will produce a 60 kV–135 mA hydrogen negative ion beam composed of 3 × 3 beamlets over an area of about 40 × 40 mm^2 and the frequency of the RF source is 2 MHz. It relies on an inductively coupled plasma (ICP), with negative ion production enhanced by adding cesium vapour in the plasma. The installation of the service plants of NIO1 experiment is nearing completion and their commissioning has started. This contribution presents the latest activities on NIO1 and the status of the test facility, together with the first experiments. These preliminary experiments demonstrated that the source can operate reliably in continuous mode.

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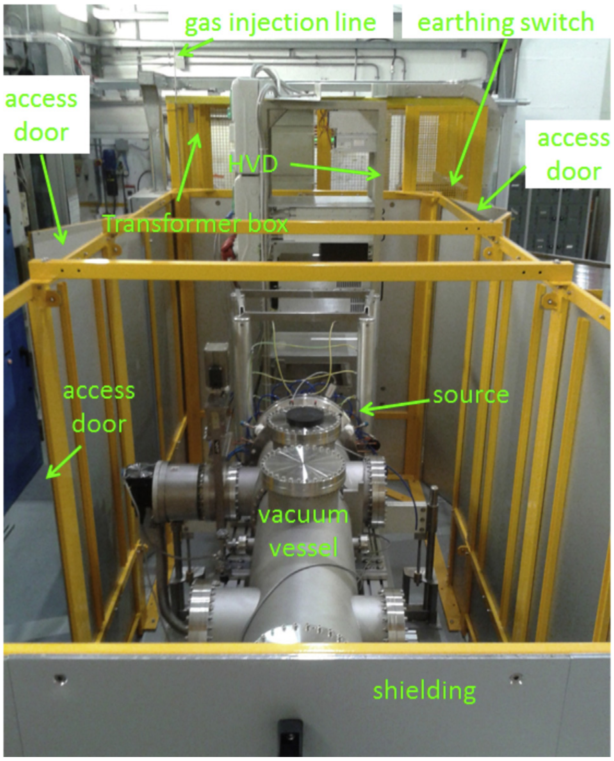

Fig. 1. NIO1 experiment layout.

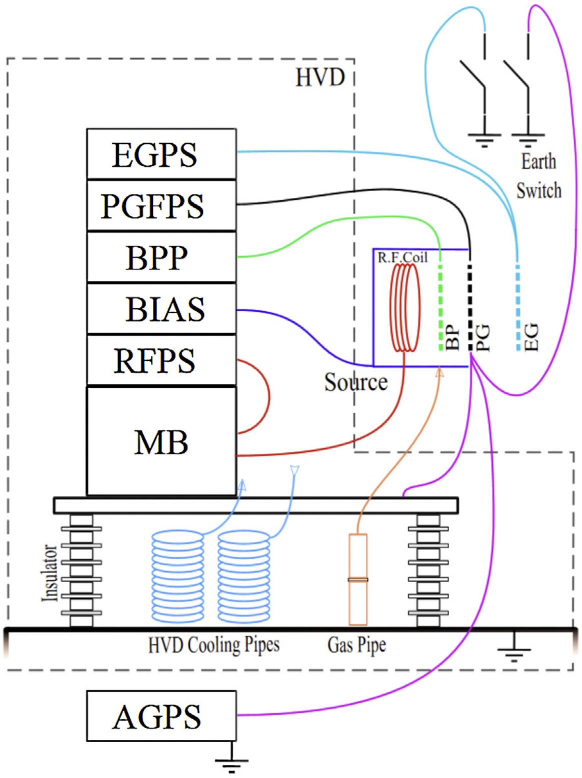

Fig. 3. Connections diagram.

2. Status of the experiment

At the end of 2013 the vessel support was assembled, fixed to the floor and leveled, and the vacuum vessel was installed on it. The source was assembled, aligned and mounted on the vessel. Fig. 1 shows the status of the NIO1 test facility.

The alignment of the source grids, satisfying beam optics requirements, was performed using a specific tool, provided with alignment bars: the tool allows also rotation of the source for final positioning (Fig. 2).

During the installation the yielding of the cantilevered source was measured and found negligible. However, the source was installed on a cradle, to guarantee the source alignment over time. The yielding of the cradle was verified: under the source weight of about 40 kg, a deformation of 0.1 mm was measured. The source was fixed to the vessel taking particular care to the parallelism of the mating flanges; then also the cradle was fixed to the source and to the floor. The pumping system, realized with a pre-vacuum scroll pump and a turbo-molecular pump, was installed and a base pressure of 2×10^{-5} Pa was achieved.

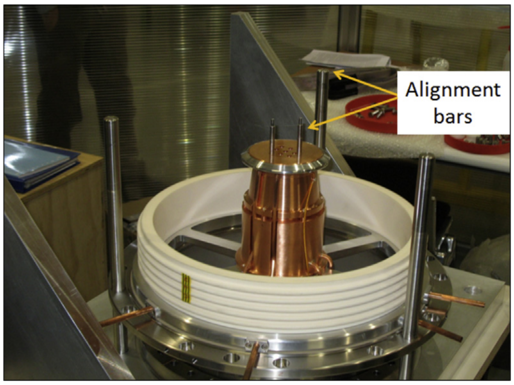

Fig. 2. Alignment of the source.

The box for the ion source insulator transformer [3] and the transformer were initially installed. Then the electric distribution board for the power supply of the experiment was installed and tested.

A diagram of the high voltage connections and earthing is shown in Fig. 3: Connections diagram. The high voltage deck (HVD) was assembled and installed on site, equipped with: matching box (MB), RF generator (RFPS, 2.5 kW), EGPS (extraction grid power supply, 4 kW 10 kV dc), high current power supplies (polarization of bias plate with respect to plasma grid – BPP – 50 A–30 V, polarization of source with respect to plasma grid – BIAS – 76 A–20 V and magnetic filter field – PGFPS – 400 A–8 V), feedback control of gas injection system and acquisition board of source thermocouple signals.

To design the radiation shield, the maximum acceleration voltage of 60 kV and 800 h/y expected operation time are considered. The acceleration of negative hydrogen ions also produces parasitic particles (electrons and positive ions), whose expected parameters are detailed in Table 1 [4]. All these particles are blocked by the 10 mm thick stainless steel vessel. The main source of radiation is due to bremsstrahlung (electron–wall interaction). The X-rays are shielded with a safety factor of 2 by 2.5 mm thick lead walls at 0.5 m from the source (the enclosed area is about 1.5×3.5 m^2). The lead

Table 1
Particle producing radiation in the NIO source.

Accelerated particle	Max energy (keV)	Max current (mA)
Negative hydrogen ion	60	150
Electrons	10	300
Electrons	60	10
Positive hydrogen ion	60	10