Neutral Beam Injectors (NBI) will have a relevant role in future fusion reactors. The NIO1 experiment [1-2] is devoted to optimize the production, acceleration and neutralization of negative ions, with the development and test of new concepts for the future NBI of the DEMO reactor.

NIO1 hosts a flexible RF H ion source; H ions are accelerated up to 60 keV for a max. total current of 130 mA (with future Cs deposition) by a set of grids: Plasma Grid (PG-facing the source), Extraction Grid (EG), Post Acceleration Grid (PA at ground voltage) and Repeller (REP). The grids have a square lattice of 3x3 apertures. The horizontal and vertical spacing between adjacent apertures is 14 mm, while the diameter of the final apertures on the repeller is 8.8 mm.

Source and acceleration system are connected to a vacuum vessel with several BEAM DIAGNOSTICS:

Beam Emission Spectroscopy (BES) IR thermography on CFC tile calorimeters 1D&2D CCD cameras and many others...

**BEAM EMISSION SPECTROSCOPY**

...collects the H_2 light produced by the beam along a line of sight (LOS), and analyzes its spectrum [3]. It allows to measure:

- Beam divergence
- Beam intensity (rel. variations)
- Beam direction
- Fraction of stripping losses (rel. variations)

**HARDWARE**

![Diagram of a vacuum system with labels for components such as Beam, Acceleration System, RF ion source, and others.]

**Optical fiber: 10 m long, 400 μm core diameter**

**Optic Head: collects He emitted by beamlets.**

**Lens: f=50 mm Cs4x6 mm Ø**

**Spectrometer: separates Doppler shifted He emissions.**


F=320 mm, grating: 2000 gr/mm Entrance slit width: 50 μm Plate factor @ Hc: 12.9 pm/pixel.

**CCD camera**


Pixel dim.: 15.5 μm

Typ. Exposure time: 8 s

**Theory**

![Graph showing properties of the spectrum against wavelength with labels for Full energy Doppler peak, Unshifted He peak, and Gaussian fit.]

**Doppler shift formula**

\[
\lambda' = \frac{\lambda_{0} - \beta c \cos \alpha}{\sqrt{1 - \beta^{2}}} \]

\(
\alpha = \arccos \left( \frac{1 - \lambda'}{\lambda_{0}} \right)
\)

\(\lambda':\) Doppler shifted wavelength

\(\lambda_{0}=656.28 \text{ nm}\)

\(\beta \approx 10^{-2}\)

\(\alpha: \) angle between beam particles and emitted photons

**Source pressure scan**

![Graph showing source pressure scan with labels for higher \(P_{\text{source}}\): 9.9% more gas density in the acceleration system and higher fraction of stripping losses.]

**Extraction voltage scan**

![Graph showing extraction voltage scan with labels for higher accelerated current: 9 higher beam compression and higher accelerated current: 9.]

**First results**

![Graph showing first results with labels for F. e. Doppler integral: 9 higher accelerated current: 9.]

**Conclusions & references**

The BES diagnostic has been successfully installed in the NIO1 experiment and is routinely working during NIO1 experimental campaigns. Beam divergence, beam horizontal aiming and relative variations of beam intensity and stripping fraction can be measured. As preliminary check, known relations between the BES results and the operational parameters have been successfully verified. In future, the diagnostic will be validated by comparing them with the output of the other beam diagnostics. Simulations of the beam will be also carried out in order to better interpret the BES and the accelerator’s electric measurements with which they are usually correlated.