Contribution ID: **70** Type: **25 min Oral**

Towards long-pulse and continuous positive-ion-based neutral beam injection

Wednesday 16 October 2024 14:35 (25 minutes)

While Neutral Beam Injection (NBI) with beam energies in excess of about 100 keV/amu (e.g. on ITER, JT-60SA, DTT) requires sources for negative ions ("N-NBI"), positive-ion-based ("P-NBI") systems have attracted renewed interest for smaller long-pulse fusion devices such as volumetric neutron sources (VNS). In these devices, like for instance the tokamak-based VNS currently studied by EUROfusion [1] or the high-field mirror BEAM proposed by Realta Fusion Inc. [2], D—T fusion is chiefly driven by fast ions from NBI. The several hours long pulses with high duty cycle or even continuous operation that these devices aim at sets unprecedented requirements for NBI.

The experience with inductively coupled radio frequency (RF) ion sources [3, 4] shows that they are already very reliable and, particularly for P-NBI, basically maintenance-free. Technically demanding solutions required for continuous operation, such as active water cooling of the sources'Faraday screens, have also been successfully implemented in the N-NBI derivatives of the RF ion sources. However, the gap between the maximum accumulated beam-on times per source on today's facilities and those foreseen at VNS devices still remains huge. This also means that so far irrelevant phenomena, such as erosion of the high heat flux components by physical sputtering, may very well determine the maintenance schedule of the beamline.

Another key aspect is pumping. NBI requires high feed gas flows to the ion source and neutraliser. In order to keep losses of the neutralised beam by re-ionization low in the beamline, this gas must be efficiently pumped by large area getter pumps such as cryo pumps. These pumps require recurring regeneration when the limit of the adsorbed hydrogen inventory is reached. The limit is usually determined by safety considerations. Continuous NBI therefore requires concepts of accommodating regeneration without interrupting injection, e.g. by cyclically operating N −1 out of N beamlines while one beamline regenerates. This in turn requires improvements in gas consumption and pump regeneration time.

Continuous operation also increases the relevance of NBI's overall energy efficiency, as NBI will be a dominant power consumer of a VNS. Developing concepts to improve the beamline's wall-plug efficiency, such as residual ion beam energy recovery, to maturity deserves increased attention.

The paper will give an overview of the challenges, strategies and development needs to make P-NBI meet the demands of continuously operated, NBI-reliant fusion devices. Many of the aspects are relevant to N-NBI as well.

[1] G. Federici, Nucl. Fusion 63 (2023) 125002
[2] C.B. Forest, IAEA FEC (2023)
[3] E. Speth et al., Fus. Eng. Des. 46 (1999) 383
[4] B. Heinemann et al., New J. Phys. 19 (2017) 015001

Primary author: HOPF, Christian (Max-Planck-Institut für Plasmaphysik)

Co-authors: HEINEMANN, Bernd (Max-Planck-Institute für Plasmaphysik); OROZCO, Guillermo (Max--Planck-Institute für Plasmaphysik); HAERTL, Thomas (EUROfusion Consortium, FTD)

Presenter: HOPF, Christian (Max-Planck-Institut für Plasmaphysik)

Session Classification: H&CD session

Track Classification: Long-Pulse Heating and Current Drive