PROGRESS OF CRAFT NEGATIVE ION SOURCE NEUTRAL BEAM INJECTION TEST FACILITY

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1. CRAFT NNBI TEST FACILITY

A test facility to tackle the key technology of the negative ion source neutral beam injection (NNBI) is under constructed in the site of the Comprehensive Research Facility for Fusion Technology (CRAFT) at Hefei, China. The CRAFT NNBI test facility includes two major test stands and their supporting systems (for example, the acceleration voltage power supply, cooling plant, cryogenic plant) [1]. One test stand is the Hefei Openfacility for Negative Ion Source (HONOR). It's specially formulated for the research of the negative ion source for fusion with various plasma and beam diagnostics [2]. Another test stand is the CFEDR Advance Neutral Beam Equipment (CAN·BE). CANBE will act as the prototype of the NNBI system for the Chinese Fusion Engineering DEMO Reactor (CFEDR). At this stage, the CANBE test stand is built to have the steady-state operation capability with the beam energy of \leq 400 keV and the accelerated ion current of \leq 28 A. For HONOR test stand, the operated high voltage is limited to 200 kV. Both of the test stands are put into operation and open for research proposals.



Figure 1. Composition of the CRAFT NNBI test facility.

2. MAIN EXPERIMENTAL RESULTS

Under the CRAFT project, four RF driven negative ion sources are planned to be developed. Their source sizes and acceleration voltages are increased one by one. During the 2^{nd} experimental campaign of the CRAFT test facility, a megawatt-class negative hydrogen ion beam has been repeatably accelerated for lasting above100 s from the CRAFT dual-driver negative ion source. The experimental waveforms and the operation conditions are indicated in Figure 2. This negative ion source is equipped with a one-stage accelerator of 200 keV and its extraction opening is around 748×300 mm². For high-power operation, the beam energy can reach 173 keV and the extracted ion current density is larger than 200 A/m². In those experiments, the plasma grid was only cooled by the room-temperature water, which means the Cs deposited walls were not in the best condition according to the previous studies.

The neutralization experiments were also carried out on the CANBE test stand, which has an ITER-like beamline structure. The achieved neutralization efficiency at different gas inlet rates was consistent to the beam-gas modelling. The first application of the electric residual ion dump (ERID) has verified that it can effectively purify the neutral beam. However, a new problem arose that the electric breakdowns on the ERID were more frequent than expected.

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3. CRAFT NNBI PHYSICS ACTIVITY

All the primary tasks and research plans of the CRAFT NNBI are arranged under the framework of CRAFT NNBI Physics Activity (CNPA). There are six topics: RF Plasma Discharge, Plasma Confinement, Negative Ions Production, Beam Optics, HV Holding, Neutralization & Beam Transport. The highlights of CNPA in the last two years are:

- Plasma parameters driven by the RF wave of 1.5 MHz were better than that of 1.0 MHz, in terms of higher plasma density, lower electron temperature, and lower plasma potential.
- A new RF driver for NBI was developed with the water-cooled ceramic tube, and it can attain a higher plasma density than the usual design with the internal Faraday shield.
- Magnetic cusp field around the expansion chamber can effectively improve the plasma density and its uniformity.
- Grid support and radiation shield can converge the whole beam due to the electric field shaping, which should be checked for the leading edges of the neutralizer.
- Plasma neutralizer prototype has been finished the physics design based on CANBE test stand; Photon neutralizer proof-of-principle has been completed the construction of the test bed.

4. FUTURE PLANS

For the HONOR test stand, the primary task is the long-pulse acceleration of the large-area negative ion beam at the level of 200 kV, hoping to form a complementary with the other test stands worldwide for the negative ion source research. On the CANBE test stand, the research focus is the beam neutralization and transport, especially the stable application of the ERID.

REFERENCES

- [1] WEI, J.L., et al., Comprehensive research facility for negative ion source neutral beam injection at CRAFT: design and first operations, Plasma Sci. Technol. (2024) doi: 10.1088/2058-6272/ad8da7.
- [2] XU, Y.J., et al., Progress on development of diagnostic system for negative ion source of CRAFT NNBI test facility, Fusion Eng. Des. **211** (2024) 114808.