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Diagnostics for a fusion grade neutral beam injector

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Neutral beam injector (NBI) is an important auxiliary heating and current drive system for a fusion reactor. An NBI system comprises of an ion source, a neutralizer, a residual ion dump (RID), a V-shaped beam dump or calorimeter and a long drift duct as an interface between the NBI unit and the fusion reactor vessel port. All these beamline components are housed inside a large vacuum vessel evacuated by large size cryopumps. The ion source consists of two parts: (a) plasma chamber where plasma is created using either filament arc discharge or radio frequency (RF) discharge or microwave (MW) discharge techniques and (b) ion beam extraction-acceleration system comprises of multiple grids having large number of ion extraction apertures. From the plasma required ions are extracted and accelerated up to a required velocity using the ion extractor system. The size of the ion source extraction area and the number of apertures is determined by ion beam current requirement. The need of beam energy for plasma heating and current drive determines the values of high voltage applied on different grids in the extraction-acceleration system. After beam extraction and acceleration, the ion beam is then neutralized while passing through the neutralizer, a gas cell due to collisions with the background neutral gas particles inside. After that while passing through RID un-neutralized ions from the neutral beam are filter out. The V-shaped beam dump is a retractable unit placed after RID to measure the beam power and profile when beam is not injected into the fusion reactor for plasma heating and current drive.

The characteristics of the ion source and its extracted ion beam followed by its neutralization and ion filtration determine the performance of an NBI. Therefore, a judicious selection of different diagnostics based on electrical, optical and thermal types at different locations on the beam path are required not only for evaluation of the performance of the beam but also for its safe operation. A number of diagnostics are being developed in IPR for Indian Test Facility (INTF) [1] to characterize the ITER Diagnostic Neutral Beam (DNB) [2], an Indian package to be delivered to ITER for its helium ash diagnostics. All the diagnostics for INTF are versatile in nature in terms of their working principles and their objectives. A schematic picture to show the planned deployment of different beam and plasma diagnostics for INTF is presented in figure1. For INTF ion source plasma characterization, multiple lines of sight optical emission spectroscopy (OES), cavity ring down spectroscopy (CRDS) [3] are envisaged for negative ion density measurements across the large extraction area ($1.6m \times 0.6m$). Multiple electrical probes will be used for plasma parameter measurements. On the other hand, Doppler Shift Spectroscopy (DSS) [4], Optical Emission Tomography (TOMO) [5], and carbon fiber composite target plates based infra-red (IR) thermal imaging are considered for INTF beam characterization. Thermocouple based calorimetric diagnostic on different beam line components are important to monitor the beam alignment and corresponding thermal management.

The talk will highlight those diagnostics and their prototype experimental efforts on different operational ion source setups (ROBIN [6], TWIN [7] and HELEN [8]) with a brief introduction of a fusion grade NBI system.

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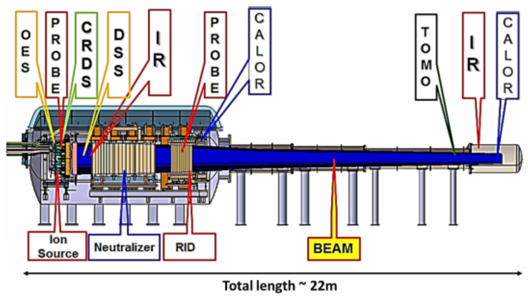

Figure1. INTF diagnostics and its planned deployment.

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