Technical Description

Lost Alpha Monitor - Development of the Final Design and associated tests and prototypes

1 Scope

ITER is designed to produce self-maintained burning plasmas dominated by alpha-particle heating with a fusion power amplification factor, Q ≥ 10. A good alpha-particle confinement is therefore of paramount importance for the ITER project. Fusion born alpha particles as well as other fast-ions generated by auxiliary heating systems are, however, subject to transport by a broad spectra of magnetohydrodynamic perturbations. A large fast-ion redistribution/loss could have a significant impact on their plasma heating and current drive efficiency compromising the machine fusion performance.

This Implementing Agreement (IA) covers the design of the ITER Lost Alpha Monitor, PBS 55.B9 – a diagnostic system using a reciprocating Fast Ion Loss Detector, to measure the energy, pitch angle and flux of fast ions during the tokamak pulse. The diagnostic is located in the ITER Diagnostic Equatorial Port No.8. The IA comprise the conceptual design, the preliminary design, the final design (including the closure of the design reviews), and the associated tests and prototypes.

The diagnostic consists of a detector head equipped with a scintillator and an array of Faraday cups, mounted on a reciprocating system. The signal from the scintillator is carried through an optical transfer system through the Port Plug and Interspace to fast-framing cameras and photomultipliers located inside a shielded cabinet located in the Port Cell.

The technical requirements for the design of the diagnostic are listed in the Lost Alpha Monitor sub-System Requirements Document 55.B9 [ITER_D_WYJUNZ].

The IA covers the design of the following components of the ITER Lost Alpha Monitor:

- Detector head including the protective housing, the collimator, the scintillator, the Faraday cup detector array, including the interface with the reciprocating system;
- Opto-mechanical design of the detector instrument inside the shielded cabinet in the Port Cell, including the cameras and photomultipliers, and mounts for optical components located inside the shielded cabinet.
- Software to operate the camera as well as the Physics analysis software.

The work includes the fast ion modelling activities in support of the design. The design of the reciprocating system, the optical transfer system and the Instrumentation & Control are outside the scope of this IA.

The IA comprises the support to the Conceptual, Preliminary and Final Design Reviews and the preparation of the corresponding Design Review closure out plan. The IA also comprises the closure of the FDR and the preparation of the manufacturing technical specifications.

2 Duration and schedule

The duration of this IA is 4 years. The main milestones of this IA are listed below, including the milestone due dates. The priority shall be given to the timely finalization of the interfaces.

Milestone	Due date
CDR	Q3/2023
PDR	Q1/2025
FDR	Q1/2026

3 Work Description

The work to be completed within this IA include the following tasks:

- Develop detailed, complete, and properly documented and IO-approved conceptual, preliminary and final design solutions for the diagnostic components listed in Section 1, compliant with all applicable requirements from 55.B9 sSRD;
- Support the update of interface sheets for Design Integration Reviews before the CDR, PDR and FDR and support the DIRs (presentation, closure of DIR actions);
- Prepare the Design Reviews documents and presentations;
- Support the preparation of the Design Review Close Out Plan;
- Resolve chits from the Design Reviews;
- Develop and maintain detailed schedule;
- Generate the manufacturing technical specifications and the associated drawings;
- Develop a Work Breakdown Structure (WBS) detailing the individual work packages and associated manpower resources;
- Develop a cost estimate for the procurement of the diagnostic components;
- Develop and regularly update the project Risk Register and propose risk mitigation;
- Perform assessments of the diagnostic's performance, in particular an assessment of the signal-to-noise ratio for ITER specific conditions (including nuclear radiation), an analysis of the instrumental effects and the impact of the environment and the lifetime of the detectors;
- Select the visible cameras and photomultipliers for the Fast Ion Loss Detector;
- Develop the alignment and calibration strategy for the diagnostic, and the corresponding engineering design;
- Conduct an engineering design to recognized codes and standards or acknowledged best practice;
- Quantitatively assess feasible design solutions;
- Perform design iterations;
- Coordinate the design with experts/specialists (e.g. ITPA Topical Group for Energetic Particles) and integrate their inputs;
- Conduct the engineering analyses in support of design development, including: studies; use and/or development of simulation tools/codes; modelling; calculations and expert qualitative assessments covering, but not necessarily limited to:

- Perform structural, thermal, hydraulic and electromagnetic engineering analysis using static and dynamic analysis to applicable codes and standards, including nuclear codes, following the System Load Specifications;
- Develop plans for the assembly, testing, installation, commissioning, maintenance and operation of the components listed in Section 1;
- Develop 3D CAD design of all diagnostic components listed in Section 1 in compliance with the IO CAD rules;
- Conduct a literature survey of suitable luminescence (scintillator) materials considering specific ITER environment conditions – in particular the radiation hardness and the tolerance to high temperatures – and propose for the CDR the scintillator materials for irradiation tests.
- Develop classification of the system components and assemblies;
- Perform RAMI assessment;
- Assess compliance of the design with applicable requirements;
- Perform manufacturability assessment;
- Regularly update the engineering diagrams;
- Support the integration of the Lost Alpha Monitor in the diagnostic ports;
- Manage physical and functional interfaces with other ITER systems;
- Perform assessment of the Lost Alpha Monitor measurement performance and the analysis of the instrumental effects;
- Assess and mitigate the impact of the environment on the Lost Alpha Monitor electronics;

3.1 Tests and Prototypes

This IA comprise the following tests and prototypes:

- Irradiation tests for selected scintillator materials in accelerator and/or neutron irradiation facilities.
- Prototype of the combined scintillator and Faraday cup sensor including irradiation tests, and electrical tests of the full signal path.
- Optical design breadboard to test the absolute calibration of the scintillator signal and the alignment.
- Thermal cycling and vibration tests of the detector head.

4 Specific requirements and competences

- Experience in the design and operation of the optical diagnostics and/or instruments containing cameras and/or photomultipliers;
- Experience in the scintillator materials;
- Experience in the fast ion modelling;
- Experience in the irradiation testing;
- Experience in the design validation through engineering analyses;
- Experience in the integration of diagnostics or instruments in complex environment;
- Experience in the design, manufacture, assembly, installation and operation of the fast ion loss detector diagnostics would be an advantage;
- Experience in generating technical documents;

5 Safety requirements

ITER is a Nuclear Facility identified in France by the number-INB-174 (“Installation Nucléaire de Base”).

For Protection Important Components and in particular Safety Important Class components (SIC), the French Nuclear Regulation must be observed, in application of the Article 14 of the ITER Agreement.

In such case, the candidates and potential subcontractors must be informed that:

- The Order 7th February 2012 applies to all the components important for the protection (PIC) and the activities important for the protection (PIA).

- The compliance with the INB-order must be demonstrated in the chain of external contractors.

- In application of article II.2.5.4 of the Order 7th February 2012, contracted activities for supervision purposes are also subject to a supervision and surveillance done by the Nuclear Operator.

For the Protection Important Components, structures and systems of the nuclear facility, and Protection Important Activities, the Implementing Agreement partner shall ensure that a specific management system is implemented for his own activities and for the activities done by any of his subcontractor following the requirements of the Order 7th February 2012.

This IA does not include the design of the Protection Important Components and the Protection Important Activities.