Overview of MITICA diagnostics design and procurement

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Introduction

MITICA, the full-size ITER heating neutral beam (HNB) injector prototype, is under construction in the ITER Neutral Beam Test Facility (NBTF) at Consorzio RFX. MITICA is based on an RF negative ion source, producing a 40A deuterium beam accelerated to 1 MeV; the beam is then gas neutralized with 60% efficiency, the residual ions are electrostatically removed, and it is finally dumped on a water cooled calorimeter. MITICA is required to validate the design and demonstrate the performance of ITER injectors: operate in stationary conditions for up to one hour, with low divergence, 3-7 mrad, intensity uniformity better than 10%, and low co-extracted electron fraction $e^- / D^- < 1$.

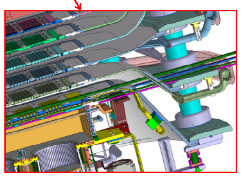
On SPIDER, the 100 kV full size prototype of the HNB RF source in NBTF, a complete set of diagnostics is proving essential to characterise the plasma in the source and the beam, also to understand the complex behaviour of the system especially in the first years of operations when different kind of anomalies were affecting the performance and required deep investigation.

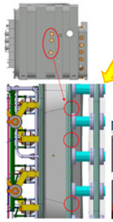
Similarly on MITICA we are expecting the need to have a comprehensive range of measurements, especially for the key parameters like beam uniformity and divergence, but in general to assist in the operation. Most of these diagnostics will not be available on the ITER HNB, equipped mainly with thermocouples, because of the restricting ITER requirements and the reduced accessibility. MITICA will then represent the best bench test for the solutions considered for HNB thermocouples and their layout, e.g. fixation methods, cabling, connectors and feedthroughs.

This contribution provides an overview of MITICA diagnostics (thermo-mechanical sensors, electrostatic probes, source and beam spectroscopy, beam imaging and tomography), a description of their current design, the status of procurements and some solutions that can be reproduced also in the ITER HNBs.

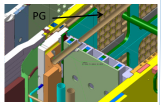
Source spectroscopy

MITICA source spectroscopy lines of sight (LOS)



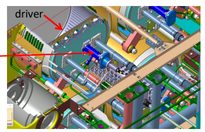


Parallel to the PG (horizontal), next to it: three pairs of opposite viewports are installed on the vacuum vessel to pass a reduced set of LOS, compared to SPIDER.



Few additional LOSs can be collected in-vacuum, using through-bushing fibers.

Perpendicular to the PG, through the drivers: collected in-vacuum by through-bushing fibers.

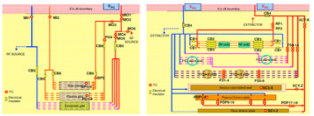


Source thermocouples

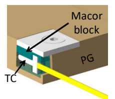
The source in MITICA is being equipped with a total 110 N type thermocouples:

- 66 grounded thermocouples with mineral insulation (MI) to be embedded onto the surface of the GG, PG, BP, PDP and the lateral walls of the source case
- 44 Kapton Insulated thermocouple cable: fluorine free Kapton tape; with exposed hot junction fixed to the source cooling pipes.

Distribution of thermocouples in the beam source cooling circuits and components

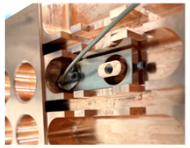


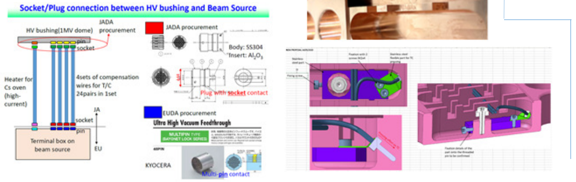
MIC thermocouple in the Plasma Driver PLate



MIC thermocouple in the Plasma Grid

Fixing of MIC thermocouple in the Grounded Grid





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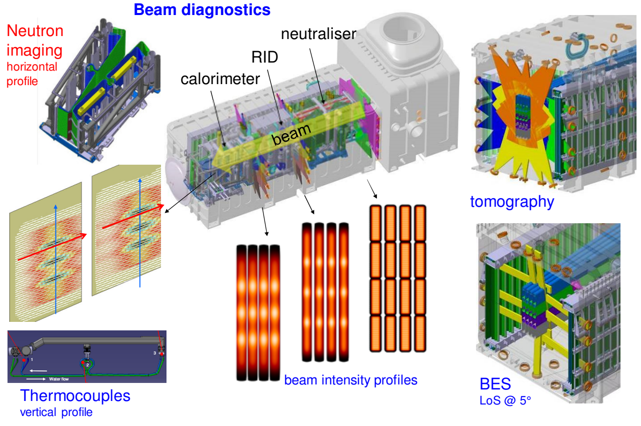
Beam diagnostics

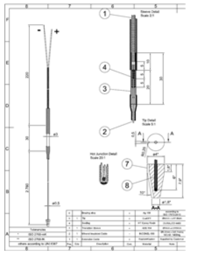


Beam Line Components thermocouples

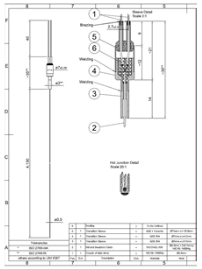
The sensors are distributed as follows:

- NED: 203
- ERID: 192
- CAL: 247

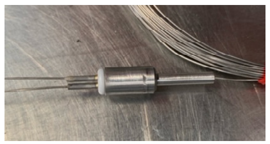
All are standard MIC cables, except 124 TC for the Calorimeter which are ITER-like.



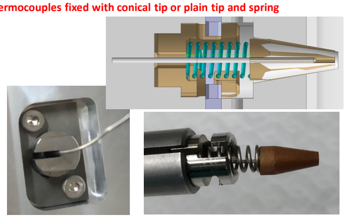
Standard MIC thermocouples
0.5 mm diameter
Transition to kapton insulated wires fluorine free



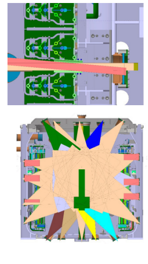
ITER-like MIC thermocouples
0.5 mm diameter
Termination with 2 pins to custom connector;
Brazed/welded vacuum seal



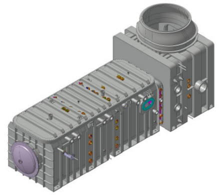
Thermocouples fixed with conical tip or plain tip and spring



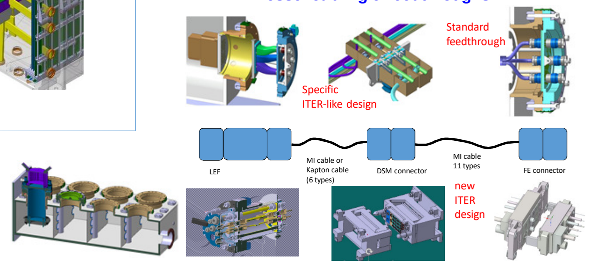
Spectroscopy and imaging Lines of Sight



80 viewports mainly between BLCs
Side view through 5cm wide slots on cryopanels
Tomography from 18 views all around the beam

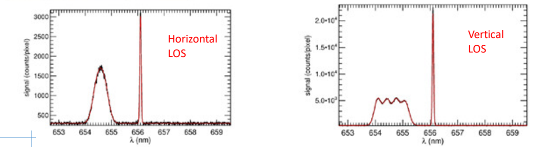


In-vessel cabling & feedthroughs

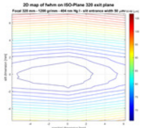


Beam Emission Spectroscopy

	MITICA SPEC	MITICA CCD
BES1	Isoplane 320 mm 150(bz 500)-1200 (bz 600)-2400 (holo 300)	Pixis B 1024x1024, 13mm
BES2	Isoplane 320 mm 150(bz 500)-1200 (bz 600)-2400 (holo 300)	Pixis B 1024x1024, 13mm
SES DRIVER	Isoplane 320 mm 150(bz 500)-1760(holo high mod)- 2400(holo 300)	Pixis 2kB 2048x512, 13.5mm
SES SOURCE	CT 750 mm 50(bz 600)-100(bz 450)-1200 (vis holo)	Pixis 400 BR Excelon 1340x400, 20mm



Simulated Dα BES spectrum along a vertical LOS in the Neutralizer-ERID section (50ms integration)



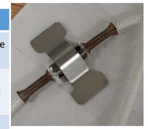
Comparison imaging capabilities of Isoplane 320 and CT 750

BLC thermomechanical sensors on optical fibers

MITICA BLCs will be instrumented with thermal and mechanical sensors to be used:
- for coolant calorimetry;
- for operational protection against beam-wall interaction;
- to verify the functional requirements of the injector and derive the beam condition: beam density, uniformity, divergence, and alignment.

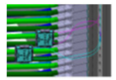
Local temperature measurements on panels of the beamline components will be carried out by thermocouples, except for high voltage panels (-20±5 kV @ 50 Hz) of ERID.
Optical fiber technology is used for **these temperature sensors** (dielectric strength 1 kV/cm).
The thermal expansion produced by the beam-wall interaction induces deformations of the component panels (reduction of the net channels cross section and reduction of beam transmission), in particular for the single-side heated side panels of the ERID: **strain gauges** will be installed on the grounded side panels to monitor these deformations.
Acceleration measurements detect vibrations produced by vapour bubble collapse in the cooling channels exhausting the thermal power in subcooled boiling conditions: **accelerometers** will be mounted at the cooling outlet regions of the high heat flux components.
Among available technologies, **fiber Bragg gratings (FBG)** has been selected for the wide range of parameters that can be measured.

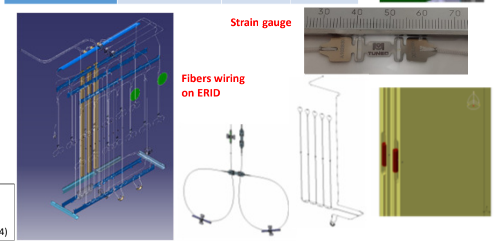
	T 10-300 VR-X-HT	os3120	AC1-ax8NT
Parameter	Temperature probe, double-ended optical fiber	Optical strain gage	Accelerometer
Operating Temperature Range:	20 to 300°C	-40 to 120°C (150°C short-term)	20 to 160°C
Operating Strain Range:	-	0-2500 μm/m	-
Response Time:	1 s	-	-
Mounted Resonance Frequency:	-	-	~2500 Hz
Weight (including cable):	2 g	3 g	300 g
Fiber Type:	SM1250SC(9/125) from Fibercore	SM1250BI(9.8/125)P from Fibercore	SM1250SC(9/125) from Fibercore
Cable Type:	1 mm Fiberglass Braid	1 mm Fiberglass Braid	1 mm Fiberglass Braid
Connector:	FC/APC	FC/APC	FC/APC
Fastening Methods:	epoxy mount	epoxy mount	Bolting hole
Number of sensors considered for BLCs	57	29	21



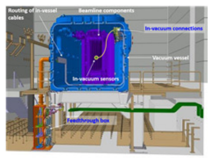
Temperature sensor

Accelerometer

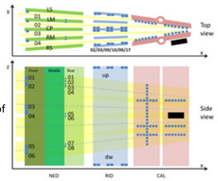




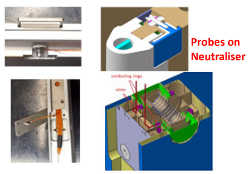
Electrostatic probes on Beam Line Components

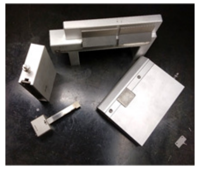


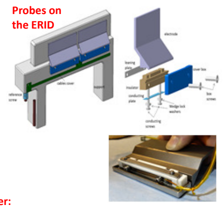
Cables routing in-vessel and ex-vessel to the CODAS cubicles

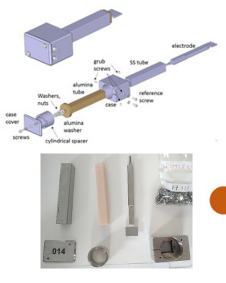


Spatial distribution of probes in the BLCs: top and side views



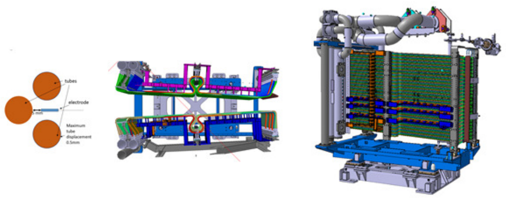






Secondary Electron Detectors on the Calorimeter:

RIGHT: 3 horizontal arrays of 14 sensors + 1 vertical array of 21 sensors
LEFT: 3 horizontal arrays of 14 sensors



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