LIBS preparation and plan for operation

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FSD Science CoordinationMeeting on JET decommissioning and FSD related activities

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Overview

Project Aims

- To develop a compact LIBS tool to be mounted on the JET Remote Handling System that can access as many of the JET Vessel Plasma Facing Components (PFC) as possible
- Deploy the tool within the JET Vacuum Vessel to measure fuel retention and concentration of contamination on PFC

Project Benefits

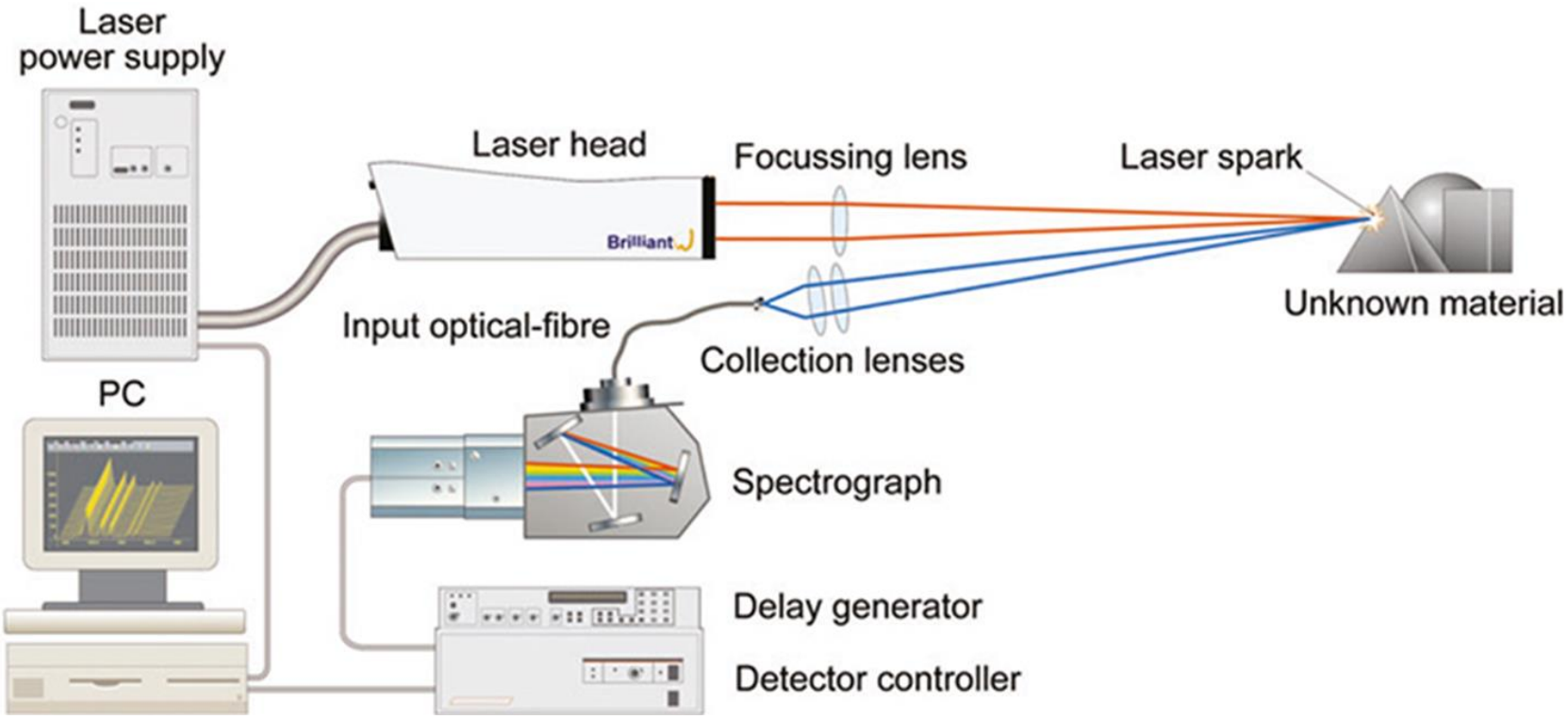
- Development of techniques for in-situ analysis of fusion vessel components
- Develop our scientific understanding of fuel retention and contamination in PFC
- Maximise the scientific benefits of the JET reactor during decommissioning
- Development of techniques that minimise human exposure to the fusion environment

Meeting aims

- Review current project status
- Outline work for the next months

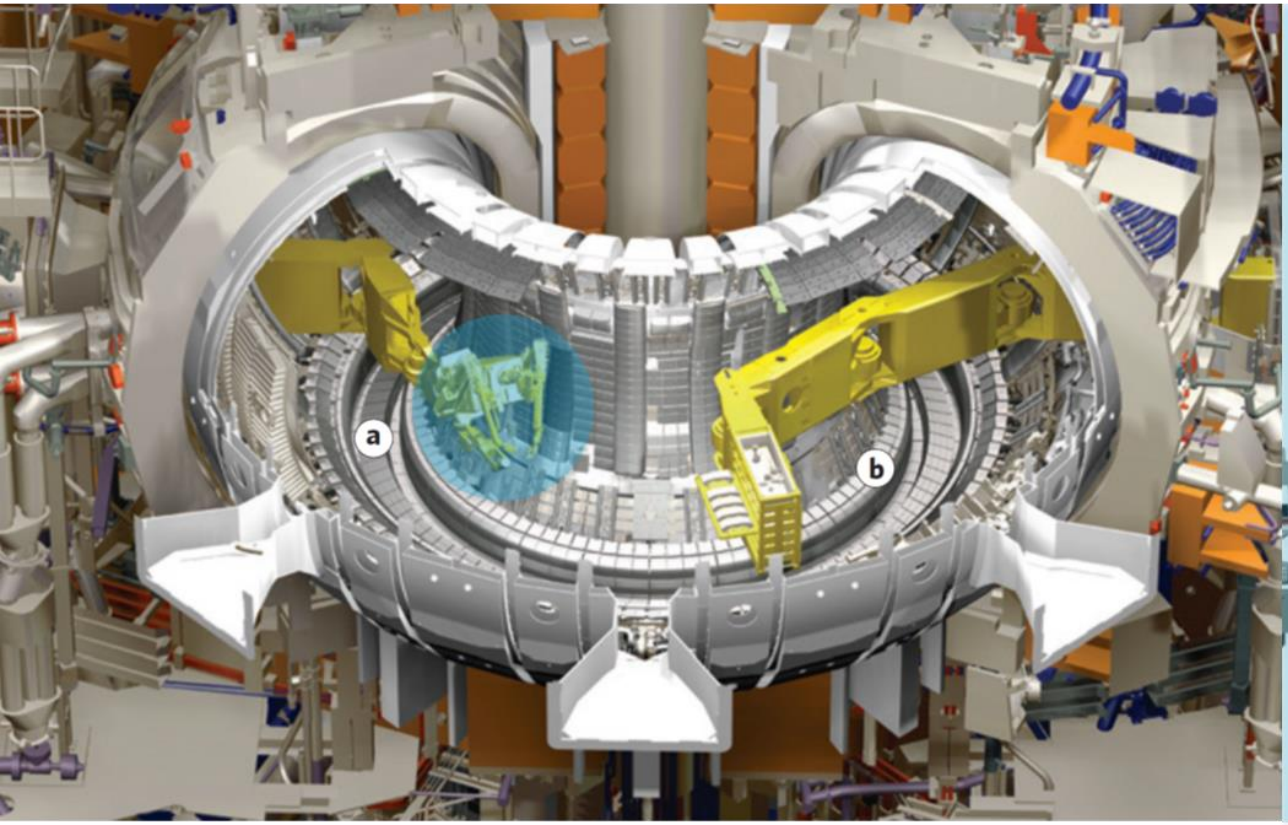
LIBS spectroscopy

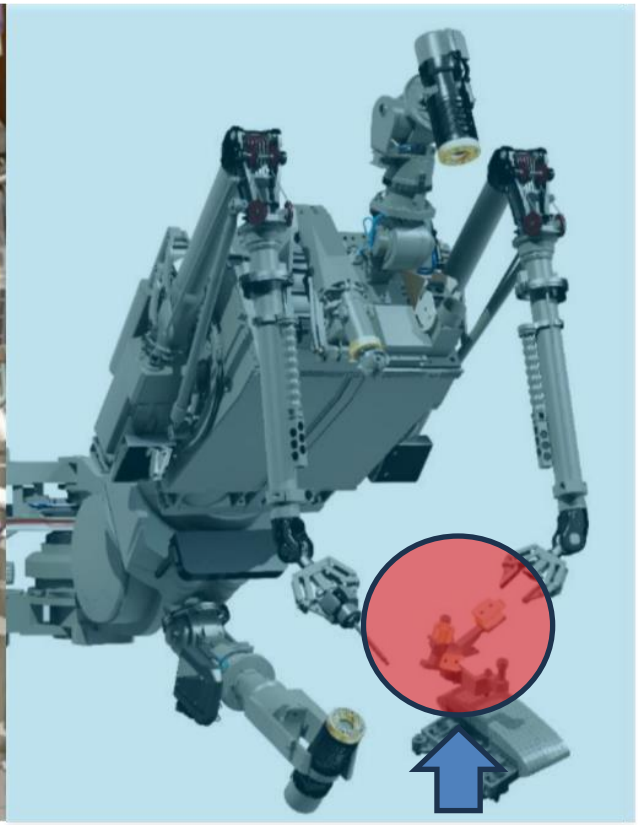
LIBS is a laser-based technique of chemical analysis delivering a focused short laser pulse (ns or ps) on the target, inducing its ablation and vaporization and creating a small plasma. Light from this plasma is collected and spectrally analysed to give the elemental composition of the target.



The JET Remote-Handling-System (JET-RHS)

The LIBS tool will be manipulated by the MASCOT telemanipulator robot, a two-armed machine with back-drivable actuators. The manipulator is remotely operated from a control room, where a kinematically similar master manipulator is used to control motions, and provide high-fidelity force feedback





Position of the LIBS tool

The current status of the project

The project is divided in two phases: a design phase and an implementation phase

Design phase	**Implementation phase**

Milestone No.	**Milestone Title**	Period	**Due Date [mm/yyyy]**
1	Definition of the components of the LIBS system	**T0* / 2022-Q4**	12/2022
2	Design of the whole LIBS system	**2022-Q3 / 2023-Q2**	06/2023
3	Test on the JET In-Vessel Training Facility	**2023-Q3 / 2024-Q1**	03/2024
4	Final measurements on JET tokamak, data analysis and interpretation	**2024-Q1 / 2024 Q2**	06/2024

Deliverable No.	**Deliverable Title**	% completion (30-09-2023)	**Due Date**
D001	Definition of the components of the LIBS system, based on their characteristics and properties suitable for use in JET after the conclusion of the D-T experimental campaign with ITER-LIKE PFCs	100%	12/2022
D002	Detailed design of the whole LIBS system and confirmation of readiness for scientific exploitation	100%	06/2023
D003	Procurement of the components and installation of the LIBS system on the JET-RHS. Test on the JET In-Vessel Training Facility	75%	03/2024
D004	Final measurements on JET tokamak by deployment on the MASCOT Manipulator	0%	06/2024
D005	Data analysis and interpretation	0%	06/2024

* T0 = start date 29/04/2022

Gannt chart

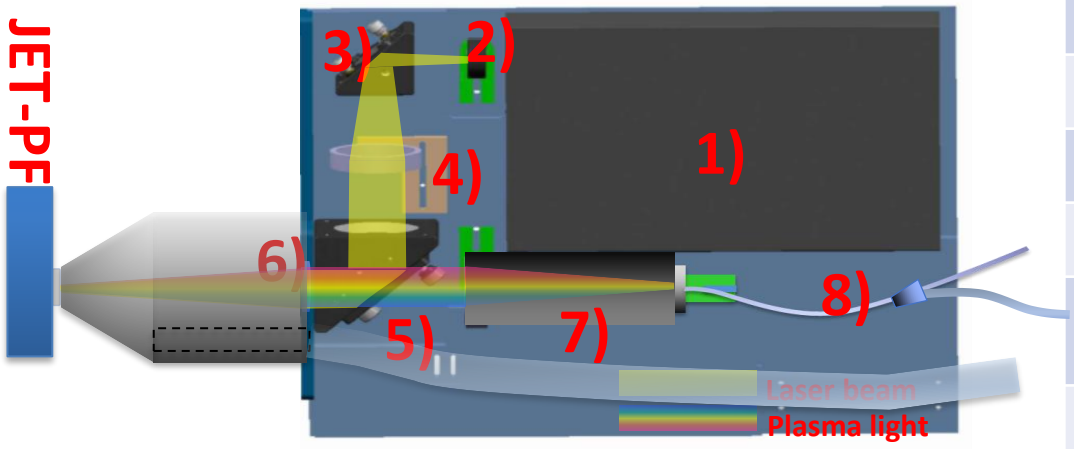
Design phase

Implementation phase

	2022-Q2	2022-Q3	2022-Q4	2023-Q1	2023-Q2	2023-Q3	2023-Q4	2024-Q1	2024-Q2
Definition of the components of the LIBS system									
Design of the whole LIBS system									
Procurement of the components and installation of the device on the JET-RHS.									
Test on the JET In-Vessel Training Facility									
Final measurements on JET tokamak, data analysis and interpretation									

Sketch of the LIBS tool

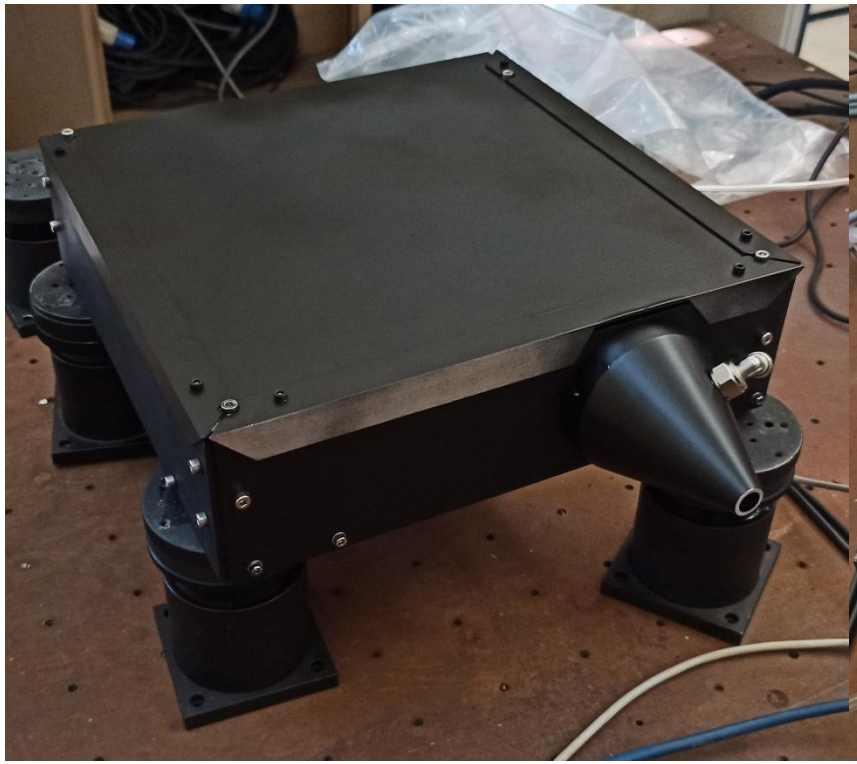
- Given the impossibility to effectively carry a picosecond laser pulse via an optical fiber 20 m length and more, the most reliable LIBS scheme is that in which a compact ps laser head must be fixed on the LIBS head and transported inside the VV.
- A vacuum cone has been put in contact with the JET PFC in order to ensure the correct focusing distance between the focusing lens and the JET-PFC.
- Background gases like Ar or He could be fluxed on the JET surface to reduce the Stark broadening of the Balmer alpha emission lines of T, D, H

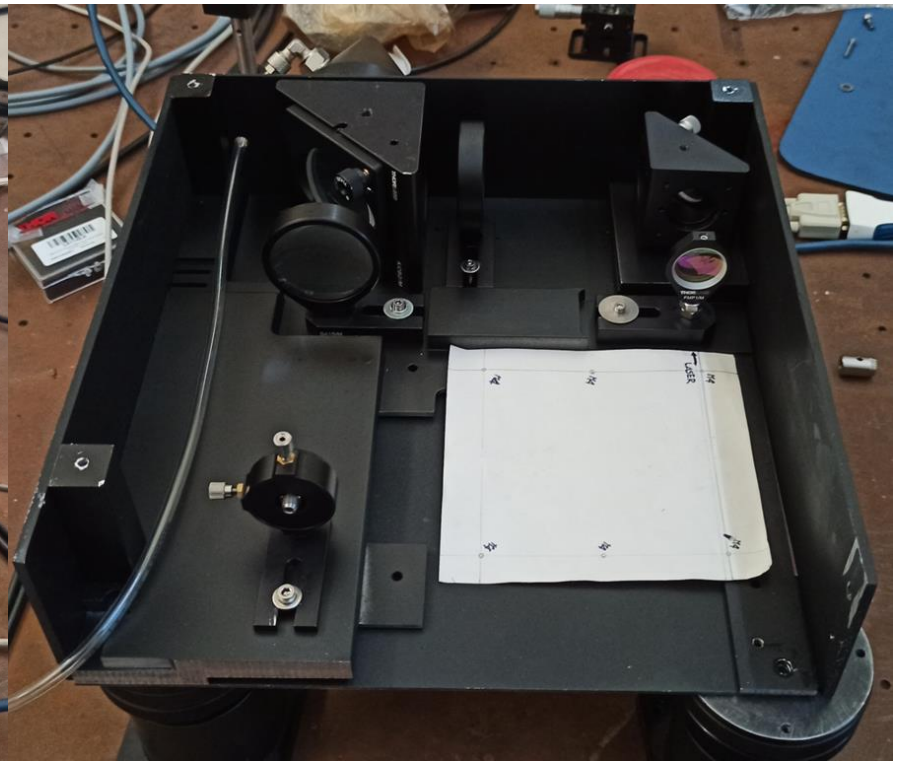


	Description
1)	Ps – laser (λ = 1064 nm)
2)	1'' dia. lens (f = -75 mm)
3)	1'' dia. HR-IR 45° mirror (45°)
4)	2'' dia. lens (f = 200 mm)
5)	2'' dia. HR-IR HT-VIS dielectric mirror (45°)
6)	2'' dia. lens (f = 75 mm) + vacuum cone
7)	2'' dia. doublet
8)	Optical fiber (≥ 20 m)

The LIBS tool

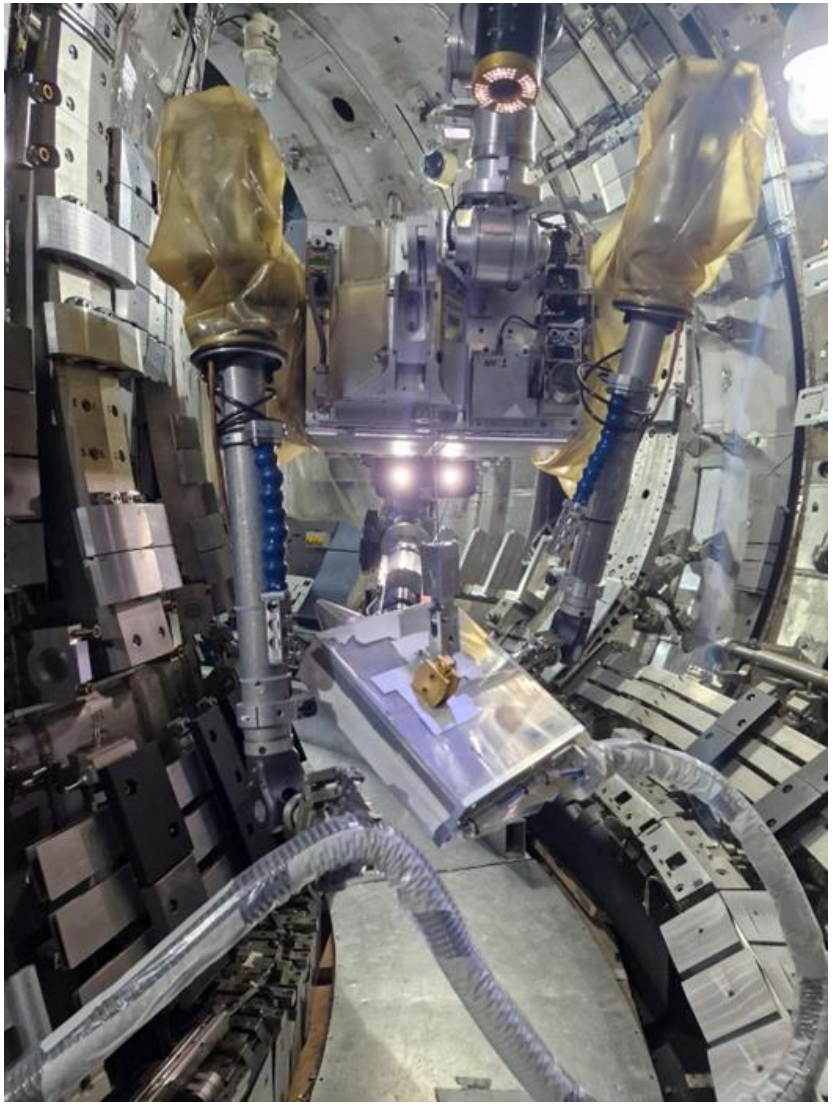
The tool was assembled and sent to the JET-RACE team: with all the optical elements mounted on the platform





The LIBS tool

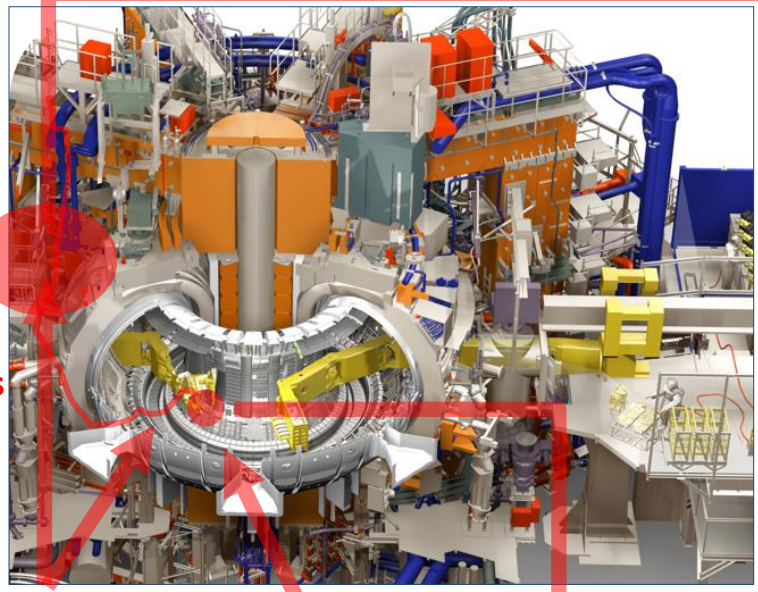
- The tool was sent at the JET-RACE team in late summer. A low fidelity tool was assembled and used for trials the JET-mock-up
- Trials proved the viability of the tool design and cable management system
- All points in vessel could be possibly reached
- Some minor modifications are need, including the addition of a winch point
- It is recommended that an additional camera is used.



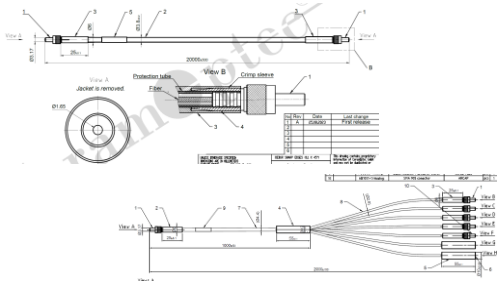
Scheme of operations

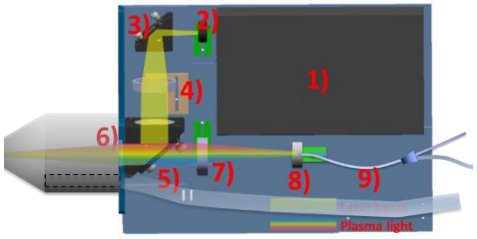
The detection devices (monochromators, spectrometers, photomultipliers) are connected to the LIBS tool via an optical fiber. This is enclosed, together with power and communication cables in an flexible tube that allows the movement of the tool. A top vessel platform is suggested to allocate the ex-vessel components (monochromators, cameras, laptops etc)

Ex vessel components



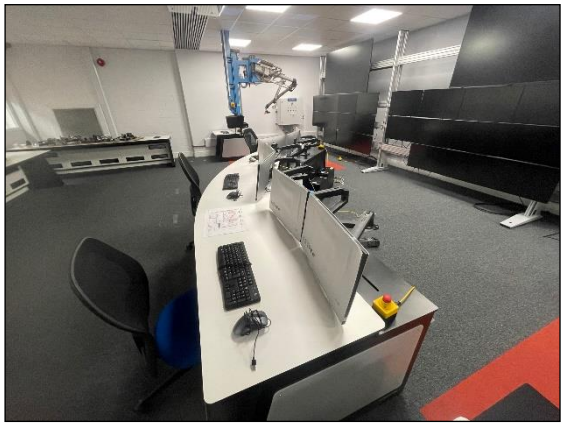
Optical fibers





LIBS tool

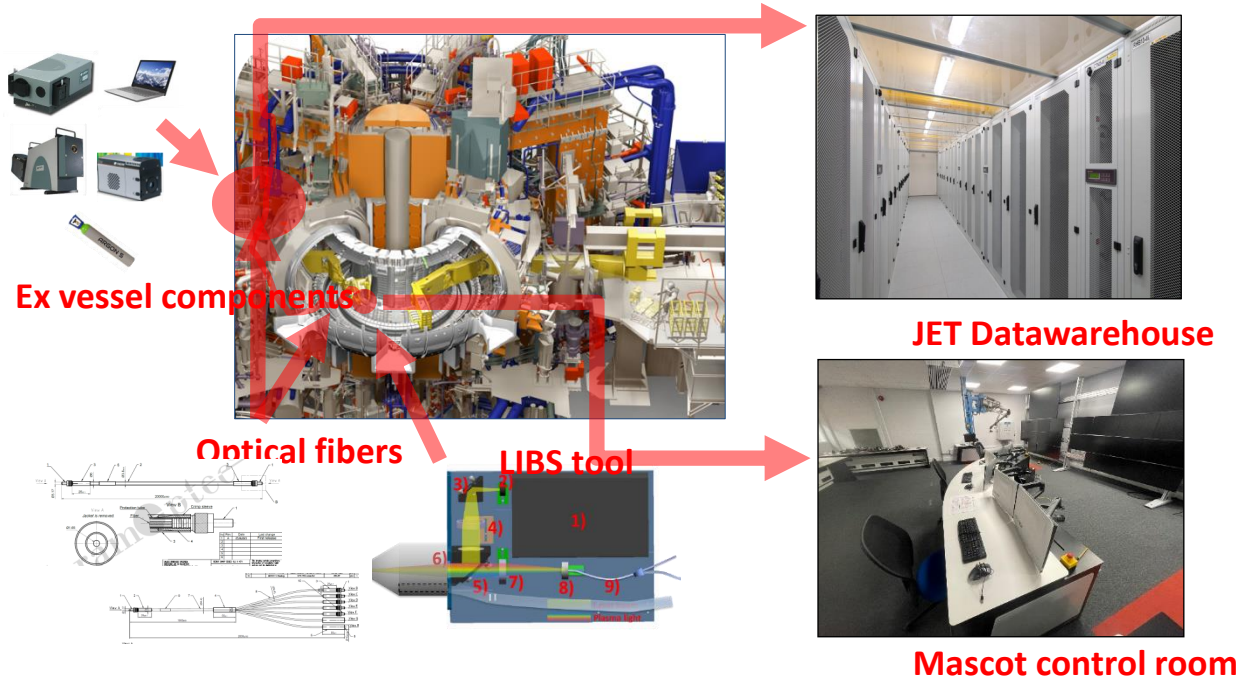
JET Datawarehouse



Mascot control room

Concept of operations

1. The LIBS Laser and diagnostics will be housed inside the ‘LIBS Tool’.
2. This tool will be positioned in vessel using the Mascot and RH System.
3. The tool will be connected to supporting equipment, set up in the ex vessel vicinity of J1T.
4. A penetration will be required to link the tool with the ex vessel equipment via an umbilical.
5. The LIBS Tool will be controlled from the RHCR via the RH fibre Network connected to the ex vessel equipment.
6. Data will be processed in J1T on an industrial PC.
7. Data will be relayed back to the RHCR via the RH fibre network.
8. Data will be relayed back to the Codas Data Centre via fibre to be processed and stored.

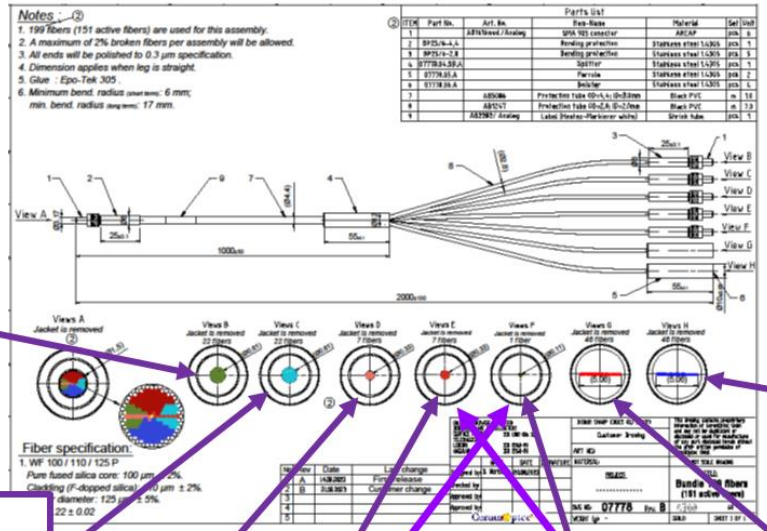


Proposal for using fiber ends for LIBS signals detection

380–635nm, 380–471nm,
467–541nm, 587–635 nm,
620–960 nm,
long gate (> 1.1ms)

JET
KS8
COS

AvaSpec-ULS2048L-USB2-RM



Photomultipier 1 with interference filter λ= 656.1nm $\Delta\lambda$=3.0nm

Photomultipier 2 with interference filter λ= 656.1nm $\Delta\lambda$=1.5nm

This is optional spectrometer

Littrow spectrometer 2

365–720 nm, long gate (>2ms)

JET
KS8
EOS

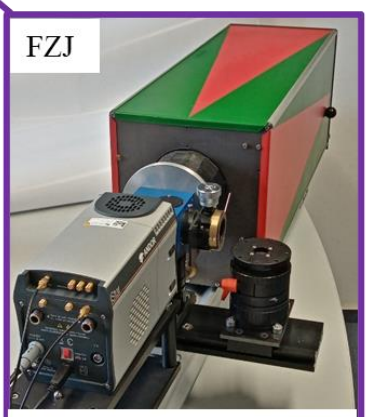
Spectrelle 20000p

Photomultipier 1

Photomultipier 2

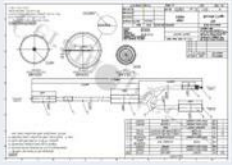
ENEA

Aryelle 200



Littrow spectrometer 1

Procurement of the components: current status

Element	Image	Owner	Status	Remarks
Laser		VTT	Ordered. Expected delivery time end of 2023 early 2024	The M-NANO-Nd: made by Montfort Compact lasers 3-4 month delivery time, Dec 23
Full-range spectrograph		ENEA	Available in ENEA Frascati	Trials in ENEA Frascati
High-Res spectrometer				Acton KS3 currently in use at JET (but it will be probably replaced by the Littrow)
Littrow Spectrometer		FZJ		Trials in FZJ
Optical fibres		IPPLM	Ordered. Expected delivery time: end of 2023, early 2024	Specification defined 10-12 weeks delivery time Will have 7 outputs

Procurement of the components: current status

Element	Image	Owner	Status	Remaks
ICCD		ENEA	Ordered. Expected delivery time February 2024	A twin camera is already available and it is currently used for trials
Optical components		ENEA	Already available and mounted on the LIBS tool	Spares have been ordered
Tool Structure		ENEA-UKAEA-CU	Complete	Nose Cone: Comenius University
		ENEA-UKAEA	Tool Housing:	Ongoing
		ENEA-UKAEA	MASCOT Grippers: UKAEA	Ongoing
		UKAEA	Strain Relief and Cable Management	In Design Phase
			RS232 Cable 20 long	A 20 m long cable will be delivered together with the power cable by the laser supplier

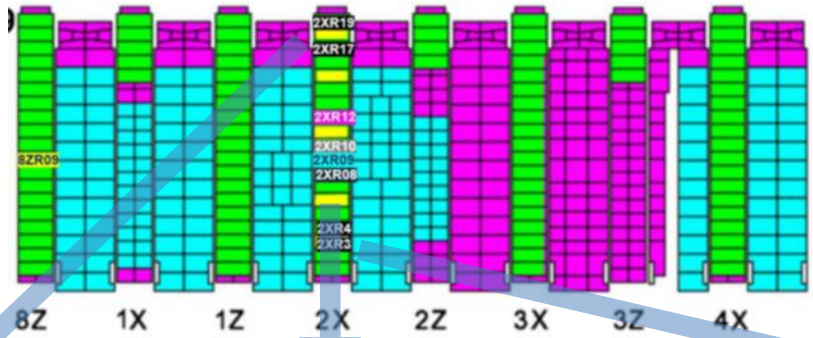
Procurement of the components: current status

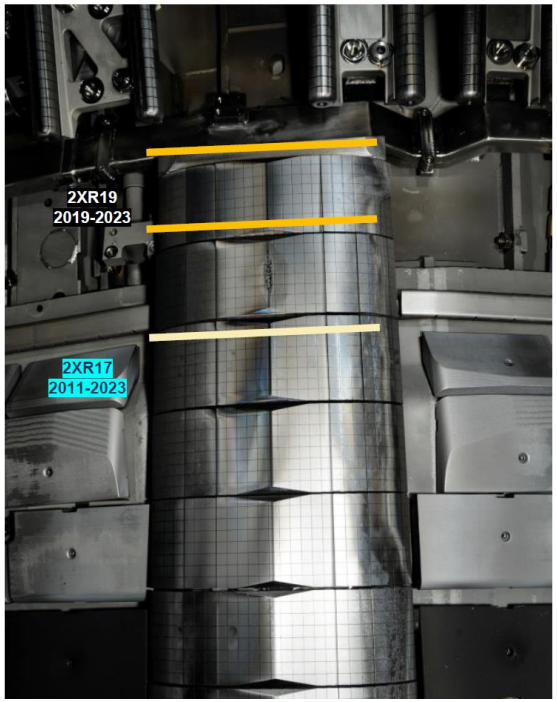
Element	Image	Owner	Status	Remarks
Argon(Inert) Gas		UKAEA	Ongoing	
Argon Flow Controller		UKAEA	Ongoing	Control the flow of Argon gas into the cone with a small device within the tool if weight allows.
Laptop(s)		UKAEA	Ongoing (complete)	Many alternatives. A new laptop with a management system is delivered with the Aryelle Spectrometer that we can consider. Alternatively an industrial PC could be considered. Or use CODAS laptop and add software
Low Fidelity Tool		UKAEA	complete	For use in the IVTF to confirm MASCOT Gripper locations.

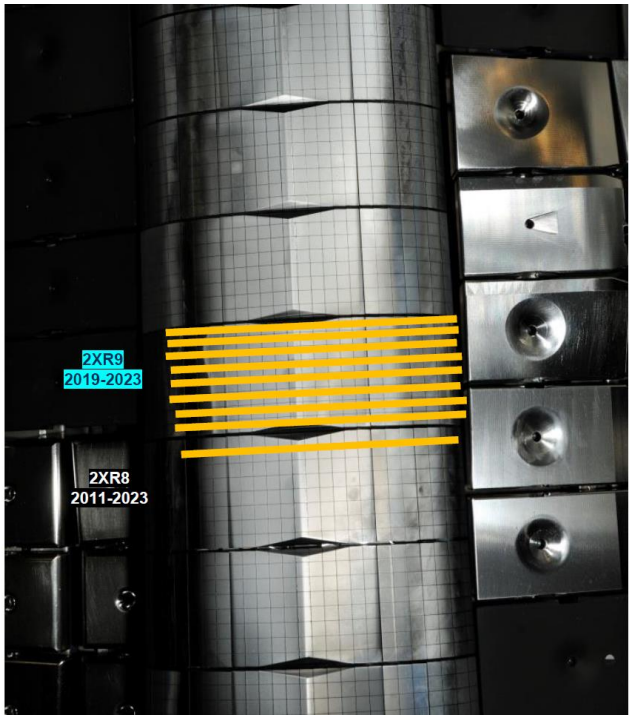
Definition and positions of the PFCs to sample

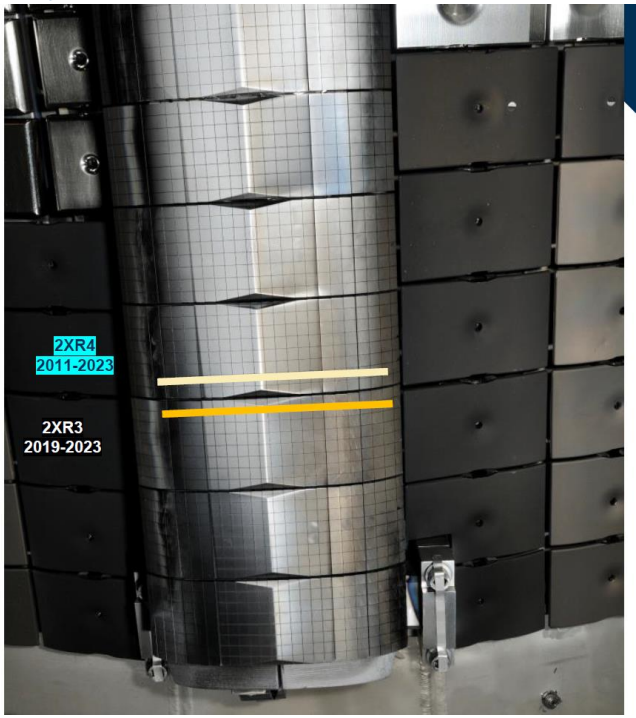
Area	Location	Required time (h)	Required time (days)	Spots
Inner and outer wall limiters	Second sector	49	3	288
Diagnostic coverage in main chamber	KS3, KS8	10.5	1	25
Divertor	First toroidal sector	21	1.5	144
Divertor	Second toroidal sector	21	1.5	144
Diagnostic coverage in divertor	LID-QMS spots	9	1	15
Upper dump plate (optional), rough scan		16	1	
total		126.5	9	616

Inner Limiter

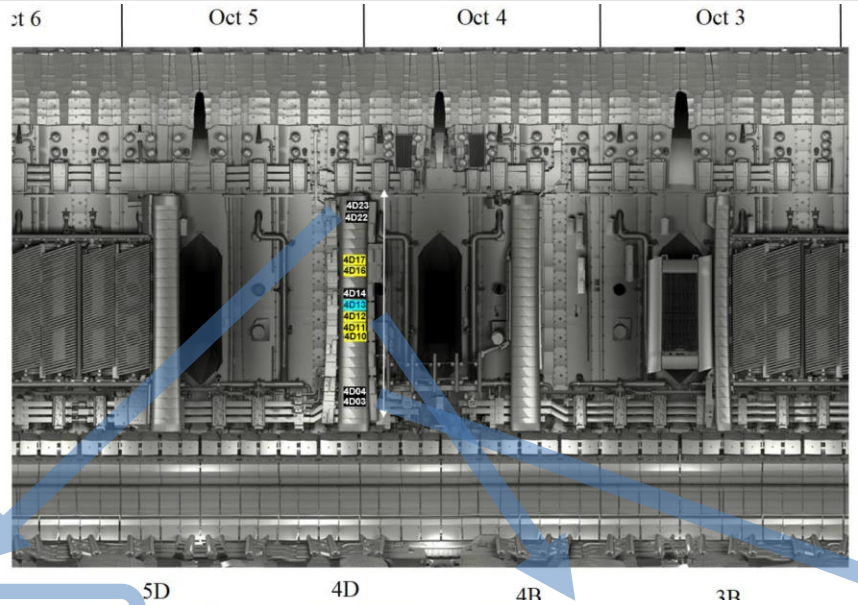


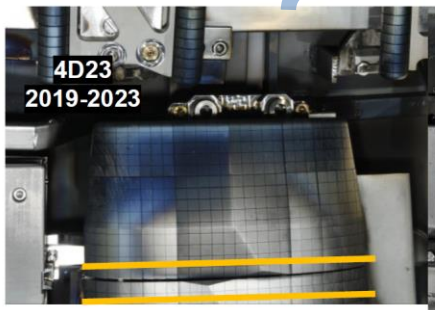


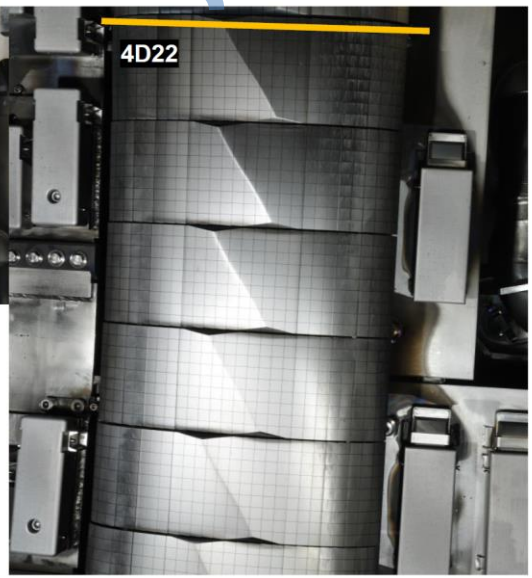


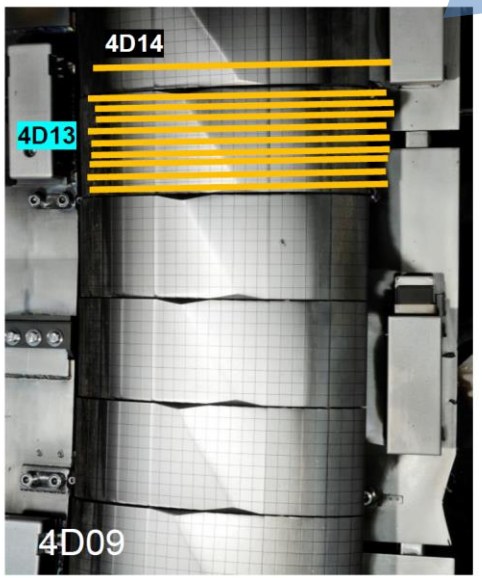


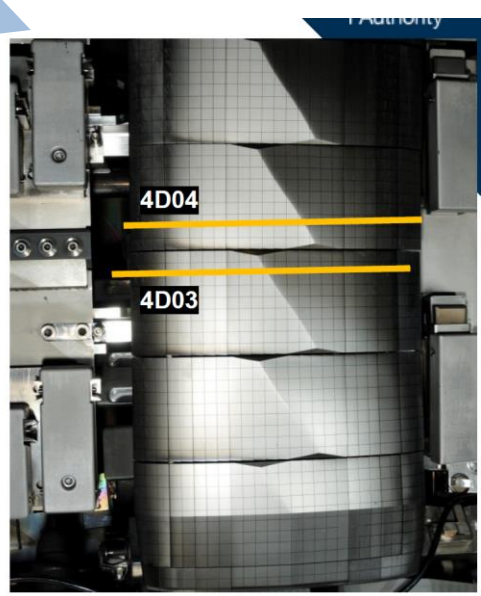
Outer Limiter



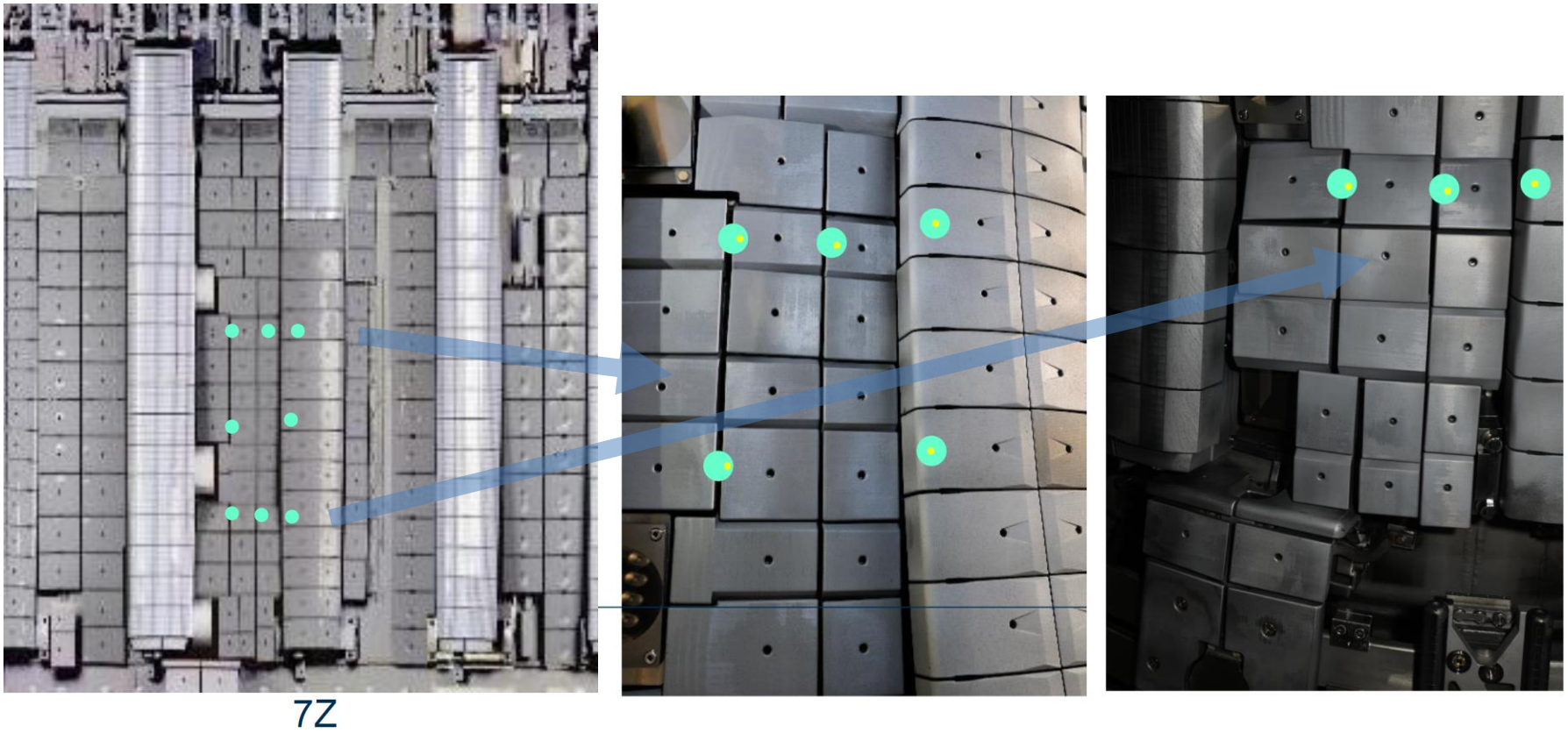




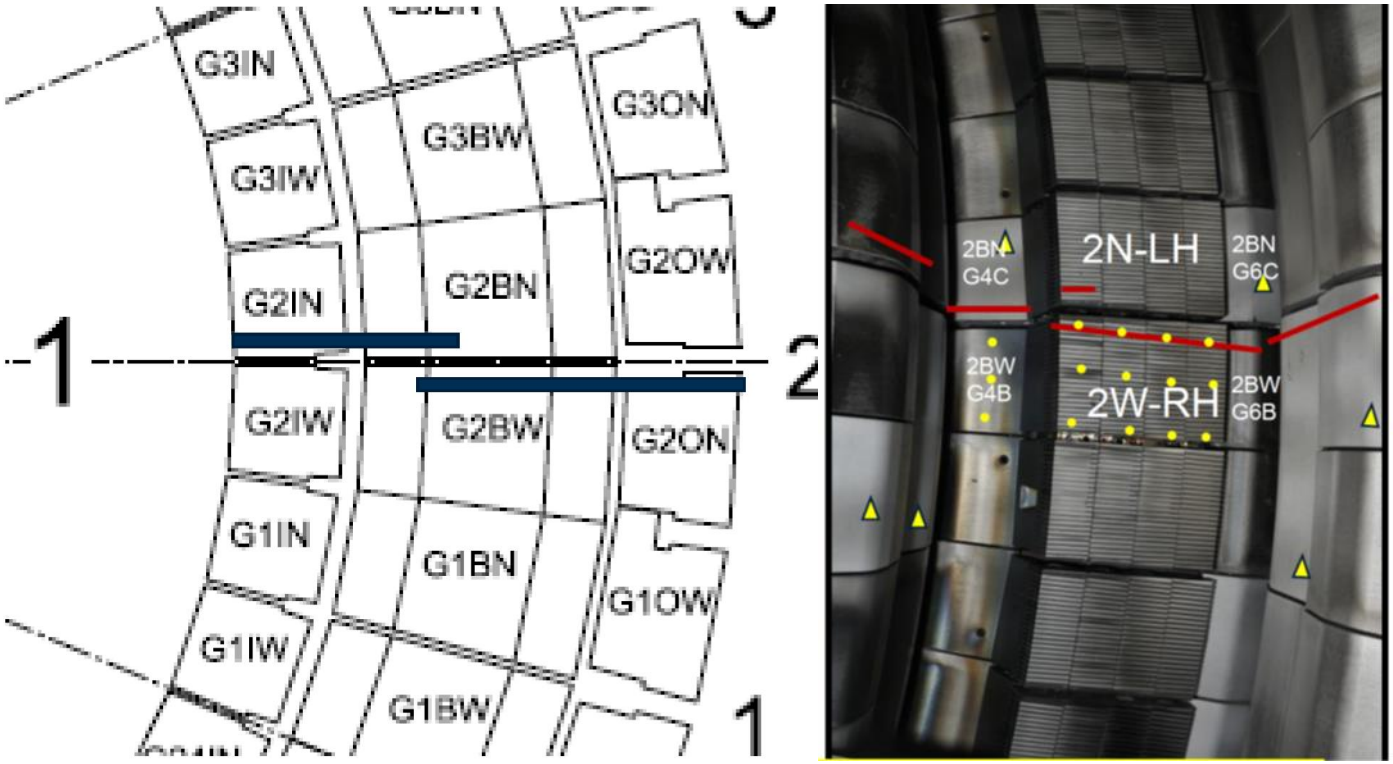




KS8



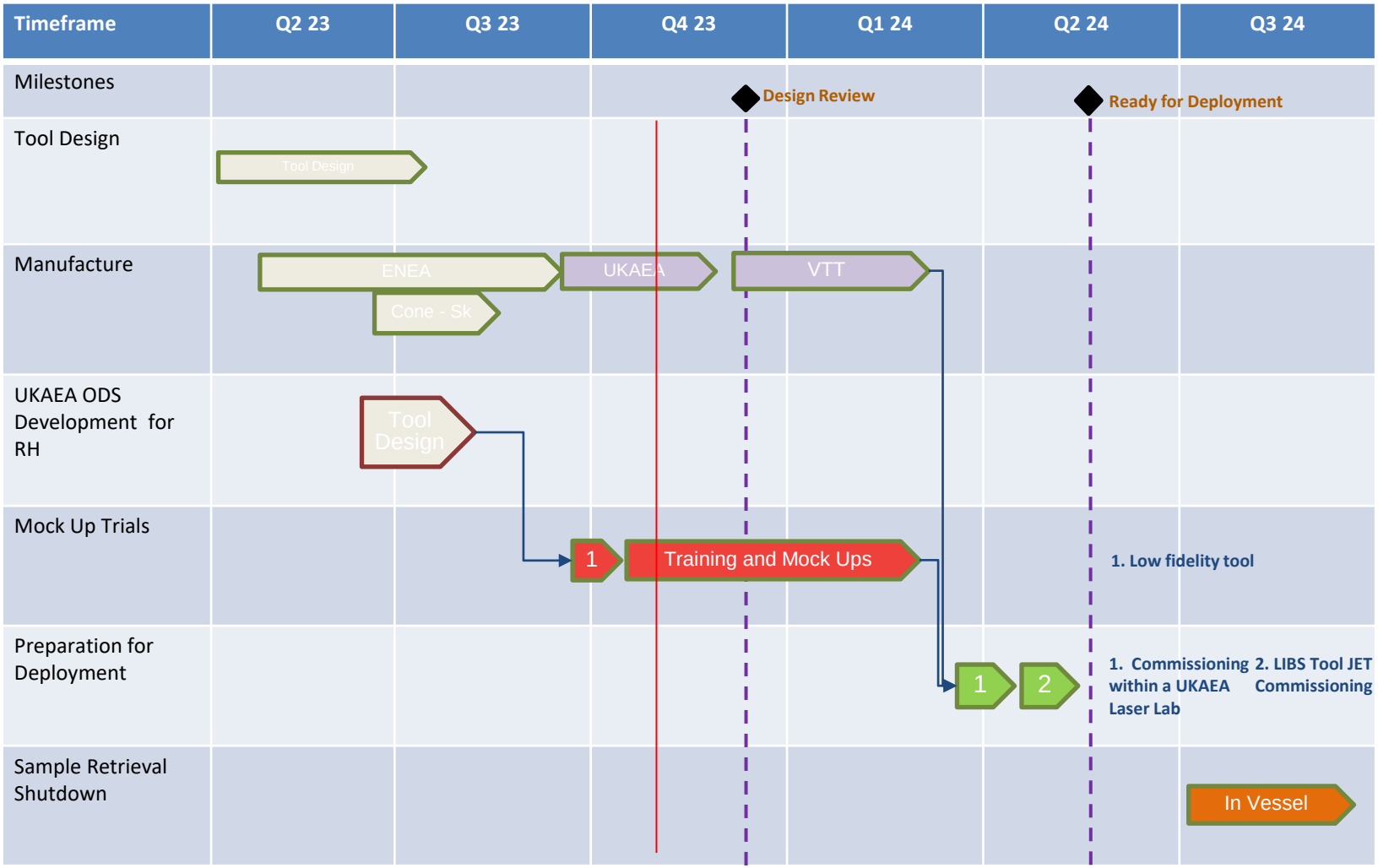
Divertor


G3IN
G3BW
G3ON
G3IW
G2OW
G2IN
G2BN
1
2
G2IW
G2BW
G2ON
G1IN
G1BN
G1OW
G1IW
G1BW
1
2BN
G4C
2N-LH
2BN
G6C
2BW
G4B
2W-RH
2BW
G6B

Main project requests, issues and risks

Request	Consequence
Data processing personnel	Data Processing Personnel: it is necessary have at least two onsite data processing personnel per work shift 1. EUROfusion to provide data processing personnel → call for personnel whitin the EUROfusion Consortium 2. Involve if available UKAEA colleagues in data processing training
Issues	**Consequence**
Change Request – Ex Vessel Equipment	Confirming the type, quantity, availability, required power supply and file type generated by the Ex Vessel Equipment
Risk	**Consequence and mitigations**
In Vessel Contamination	Contamination of the tool occurs in vessel and requires disposal of the tool and loss of the equipment, mostly the laser. 1. Design a sealed tool with lens providing a barrier between inner tool and cone 2. Investigate options for a plastic cover for the tool 3. Development of a cleaning plan with UKAEA Health Physics 4. Also provides an opportunity to study levels of contamination the tool collects as information for future use
A limited access to J1 to adjust set up and calibration of the Ex-Vessel equipment (Spectrometers)	1. Understand the degree to which this will be an issue 2. Generate bespoke safety case
Operation of the LIBS tool - insufficient EUROfusion LIBS experts to work double shifts	1. EUROfusion to provide training to the tool operators 2. Identify which Ops Eng will be on shift so they are familiar with the training

Schedule overwiew



Next months plan

Activity	Forecast date	Comments
Preliminary tests at VTT: tool + laser + Aryelle spect.	19/01/24	Ongoing - adaptation of the pre-existing LIBS setup to the new laser and spectrometer
All required LIBS Hardware delivered to UKAEA Site	15/03/24	
Bench Assembly of LIBS System Complete	25/03/24	
LIBS Tool Ready for Deployment On	17/04/24	
First Access granted to J1T	01/05/24	(Assumed date –TBC)
Start of LIBS Operations during SR24 shutdown	01/06/24	(Assumed date –TBC)
End of LIBS Operations during SR24 Shutdown	14/06/24	(Assumed date –TBC)