Kick-off Meeting for new Diagnostics Enhancements in the JT-60SA tokamak (3/June/2024)

Doppler reflectometer for turbulence and flow measurements

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- Where are we
- What happens next
- Open questions

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Proposal development (2019-2022)

Up to date, this project has undergone the following stages:

2019: Diagnostic scientific program definition:

- Turbulent model validation in intermediate plasmas (between current tokamaks and reactor conditions).
- Characterization of the formation and behaviour of both edge and core transport barriers.
- Complementary diagnostic to CXRS for the investigation of rotation (neoclassical viscosity, impurity transport, etc.)

2020: Search for a suitable location for the diagnostic.

- P-18 Horizontal port is provisionally selected.

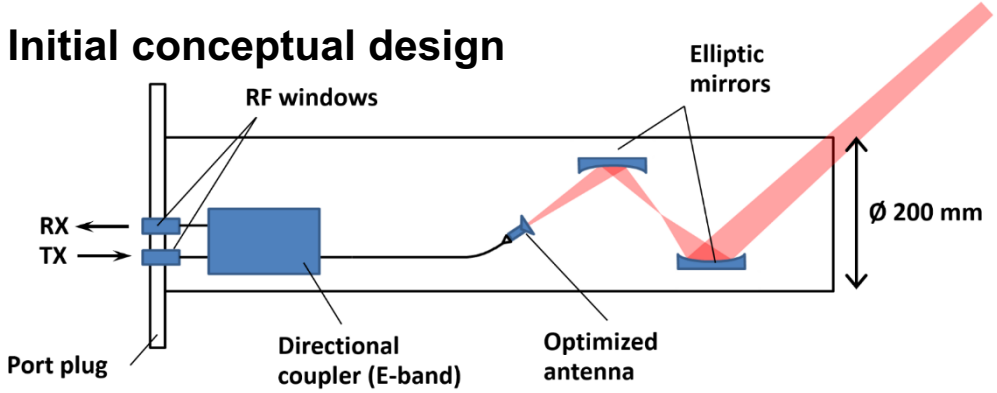
2021: Viability study, published in Fusion Eng. Design.

- An Initial Conceptual Design was defined to start exploring space allocation requirements.
- ***Not suitable for the realization of a significant part of the scientific program.***

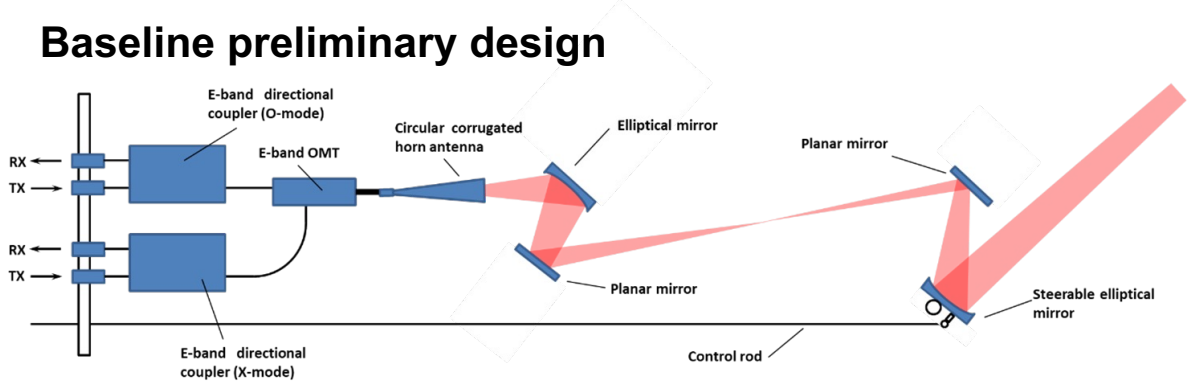
2022: Baseline preliminary design development.

- O/X mode operation + steering mirror (wavenumber spectra)
- **Can carry out the whole scientific program.**
- Requires additional space in the port (to be defined when port allocation is agreed upon and CAD drawings become available)

Initial conceptual design

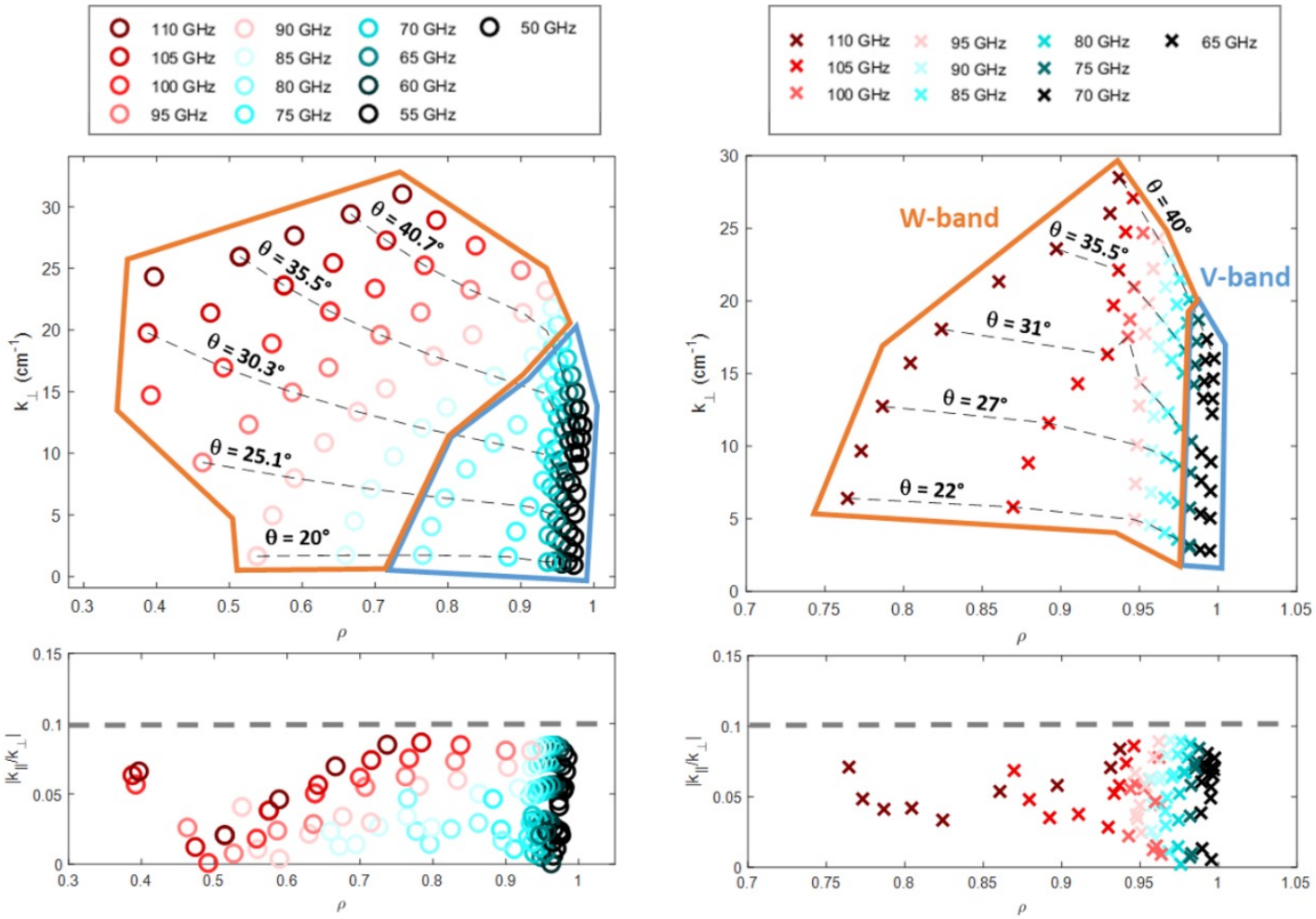


Baseline preliminary design



Main Features of the proposed DR system

Feasibility study results (high density scenario)



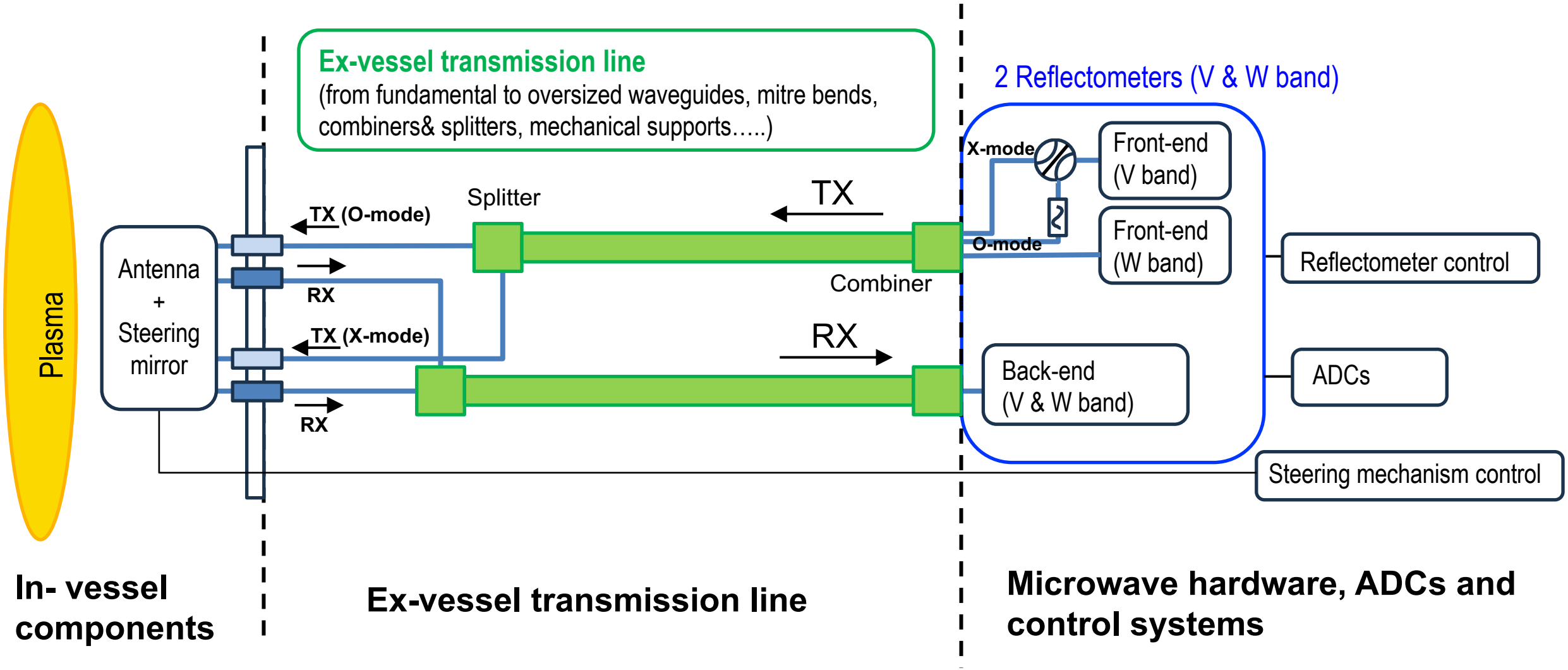
D. Carralero (WPSA meeting, 2022)

Two reflectometers, one mirror solution:

- By using an steerable mirror, a range of $k_\perp$ values can be probed. Typical values are in the $k_\perp \rho_s \sim$ 1-10, appropriated to observe ITG and TEM turbulence.
- Good radial coverage: Pedestal region (up to SOL) can be covered by V-band in X-mode. Central region can be covered using O-mode polarization with W Band.

Doppler reflectometer selected as priority 1 diagnostic by the JT-60SA experimental leaders

‘Simplified’ functional diagram for the DR



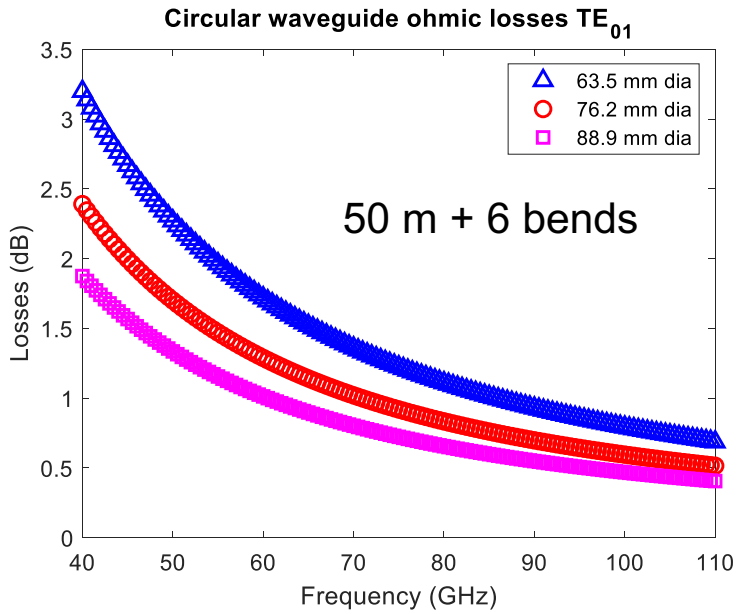
V band (50-75 GHz), W band (75-100 GHz)

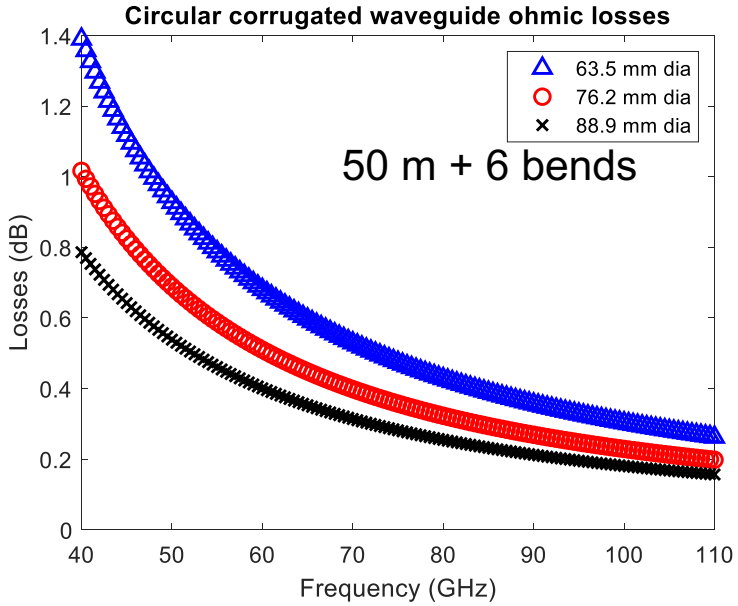
What do we need to start the work?

- To translate the ‘baseline’ conceptual design into a realistic design of a working diagnostic, the following information is needed:
  - ❖ **In–vessel components**
    - Diagnostic port and launching position for the DR needs to be confirmed (essential for the design of the optimal geometry of the DR, input information to determine the steering mirror requirements)
    - Volume available for the diagnostic components inside the diagnostic port (antenna + mirrors set)
    - Mechanical/volumetric constraints associated with the component inside the diagnostic port
  - ❖ **Ex–vessel components**
    - Are the DAQ and reflectomer installed inside or outside Torus Hall? If inside, when will the diagnostics be accessible during operation?
    - Distance from the vacuum window to the place where the reflectometer and the DAQ system will be installed (essential to evaluate transmission losses, which strongly impact the selection of transmission line components)
    - Mechanical/volumetric and any other constraints associated with the installation of components outside the vacuum vessel

Ex-vessel transmission line

- Transmission losses must be kept as low as possible → oversized waveguides with quasi-optical coupling. Separate transmission and reception paths (to avoid unwanted parasitic reflections)
- Existing examples:
  - W7-X: outside Torus Hall, transmission path= 24. Oversized circular waveguides (D=27.8 mm). A second system installed inside the Torus Hall (fundamental waveguides)
  - JET: outside Torus Hall, transmission path = 40 m. Oversized circular corrugated waveguide (D=37.5 mm). (more expensive option)





Expected timeline for implementation

Timeline proposed in 2023:

Y1 (2024)	Y2 (2025)	Y3 (2026)	Y4 (2027)	Y5 (2028)
Finalize baseline design & Mechanical design	Design validation	Final design & Call for Procument agreement	Procurerment, manufacturing & testing ???	

JT-60SA timeline						
Maintenance and Enhancement 1		OP2 (9 months)	ME2	OP3 (9 months)	ME3	OP3 (8 months)

Work in 2024 has not yet started, pending a decision on the port allocation for the DR

Two main uncertainties affect the timeline:

- port allocation not yet decided. This decision will mark the starting point for the mechanical design work (for in-vessel and ex-vessel components)
- the time needed for manufacturing and testing (although many of the components are off-the-self, some components, in particular the antenna and mirrors set, must be manufactured to specific requirements)
- it must be noted that no provision has been made for neutronic analysis (tbd)

Estimated budget

Estimated budget (staff):

Year	Staff by activities (PM)			Total PM
	Management	MW design & system specifications	Engineering & CAD	
2024	2	4	6	12
2025	2	3	7	12

To be noted that, by our initial estimations, a minimum of 18 person-months per year was needed to complete the necessary tasks !!!!

Estimated hardware costs:

Hardware components	Cost
Front & back end MW components (V/W bands, O/X polarization) Antenna + Steering launching mirror	230 k€
Ex-vessel components (cost dependant on the choise of waveguide)	

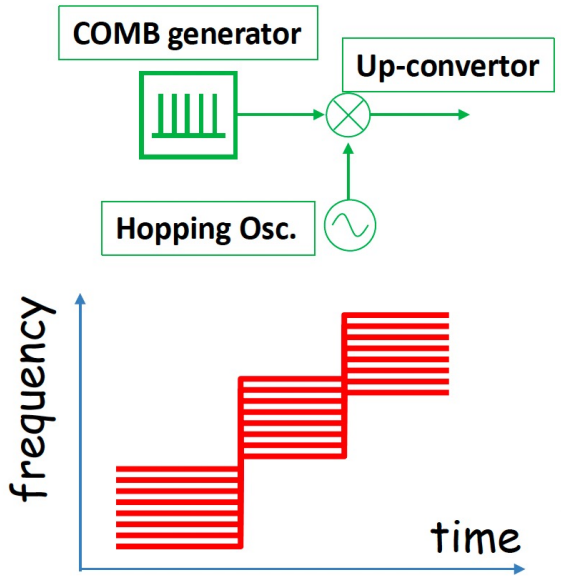
Team members (compencies and availability)

People involved:

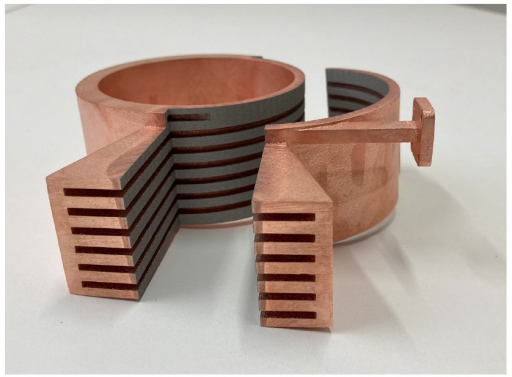
- E. de la Luna (Project Leader)
- D. Carralero & T. Estrada, (MW design and project management)
- J. Martínez (MW design)
- S. Cabrera (Engineering, full time 2024, 2025)
- Engineer #2 (Engineering, 2025, 50% (tbc))
- CAD specialist

Japanese proposal for JT-60SA

In parallel to the conceptual design proposed by CIEMAT, a complementary proposal is being developed by T. Tokuzawa (NIFS)



Phased array



T. Tokuzawa is advancing in his own concept for a JT60SA DR system. Current status presented in the 16th Reflectometry Workshop (13-16 May, 2024):

- This system would allow simultaneous $u_{\perp}$ and fluctuation amplitude measurements in multiple radial locations at the SOL and edge of JT60-SA.
- It combines a frequency comb system with a phased array antenna (manufacturing tests are currently ongoing)
- Radial coverage more focused on the pedestal and SOL region (Band Q, band V)

The Japanese proposal could be an excellent complement to CIEMAT proposal, providing a complete coverage of the plasma and allowing toroidal turbulence asymmetries and zonal flows studies if it is installed in a different toroidal location

Additional questions/comments

- Is there any news about when the decision about the port allocated to DR will be taken?
- Can the unused staff budget be transferred from 2024 to 2025?

- What is the formal review process that allows us to start the Procurement Agreement?
  - We note that the system specification for the ex-vessel MW components (V and W band reflectometers) could be ready as soon as the final baseline design is accepted. There is no need to wait for the mechanical design of the in-vessel components or the ex-vessel transmission lines to be completed.
- Is there a minimum list of required documentation that needs to be prepared, or is this flexible?
- Is there a repository with the input data (space availability, load requirements, safety issues,…) needed to start the mechanical design for both, in-vessel and ex-vessel components?