Diagnostica THz per WEST: obbiettivi, progetto, programmi futuri.

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- WEST contact person: Didier Mazon

- *Diagnostic contextual basis: measurements, advantages, characteristics*
- *Laboratory tests: results and status*
- *Machine interface and installation*
- *Timeline & tentative budget*

Advantages of THz diagnostics to traditional devices

- THz plasma diagnostics displayed an increasing level of interest in the last few years. Published papers related to specific table-top experiments.

- This is the chance to test the first tokamak THz diagnostic *ever*.

- The diagnostic will summon up the measurements done by Interferometry, Reflectometry, Polarimetry and in perspective ECE.

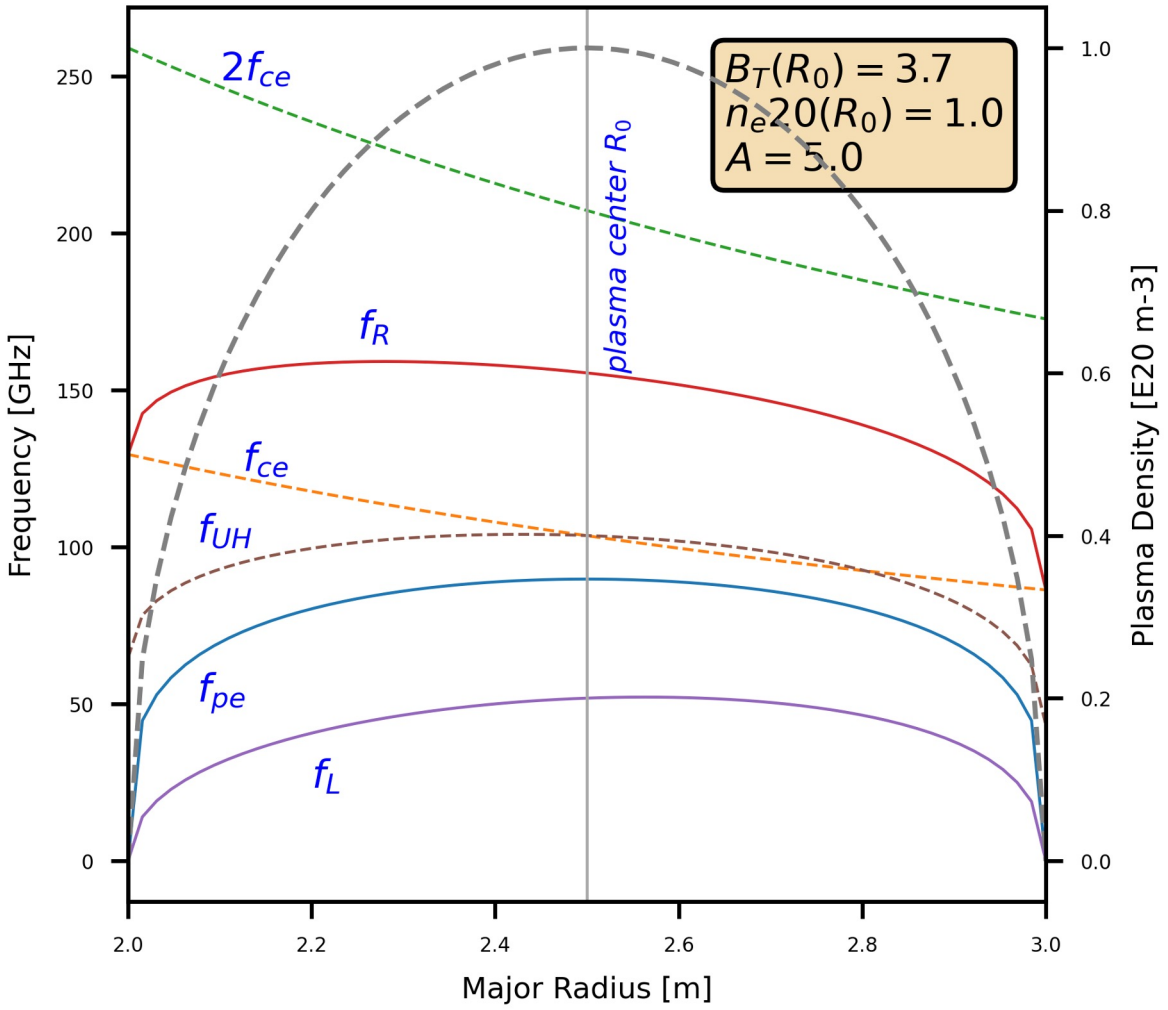
- The hardware, although technologically advanced, will be compact and easier to manage. For example no cryogenic devices neeeded.

Diagnostic frequency pattern

(WEST general parameters)

Range 0-250 GHz

A THz Spectrometer in the range 1-2 THz will cover the range for standard FIR measurements

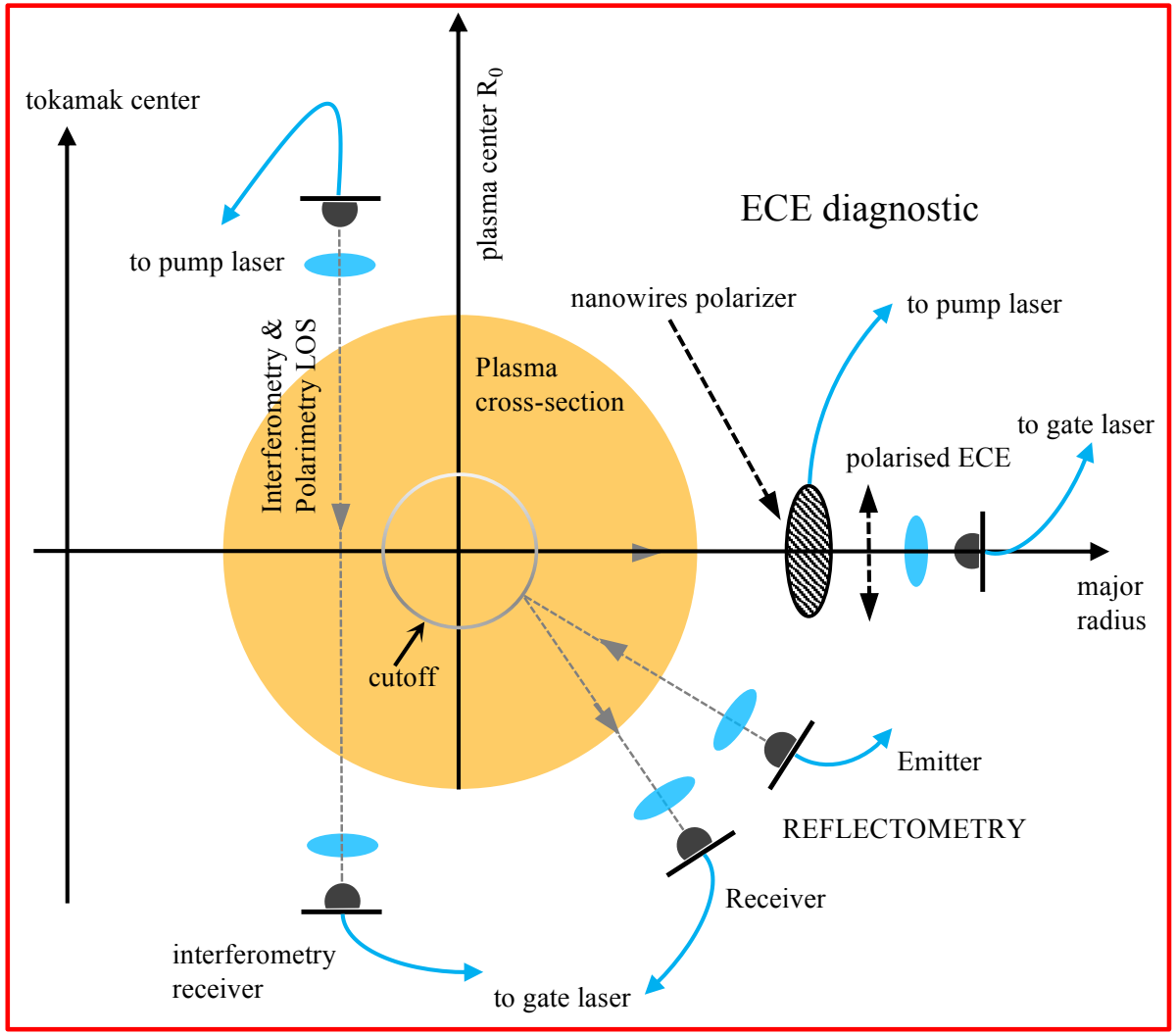


The diagnostic will be based on the industrial THz spectrometer **TeraFlash smart SN 3025** which has been acquired last year by ENEA Frascati and customised for plasma diagnostics applications.

Access required: 2 vertical equatorial ports, one oblique and/or equatorial port (size < 20 cm).

Initial tests on the machine to check alignment criticity, achievable signal to noise ratio, stability of measurement on long-pulse WEST operation (ex. #61299, ~minutes) AND results validation with WEST corresponding diagnostics.

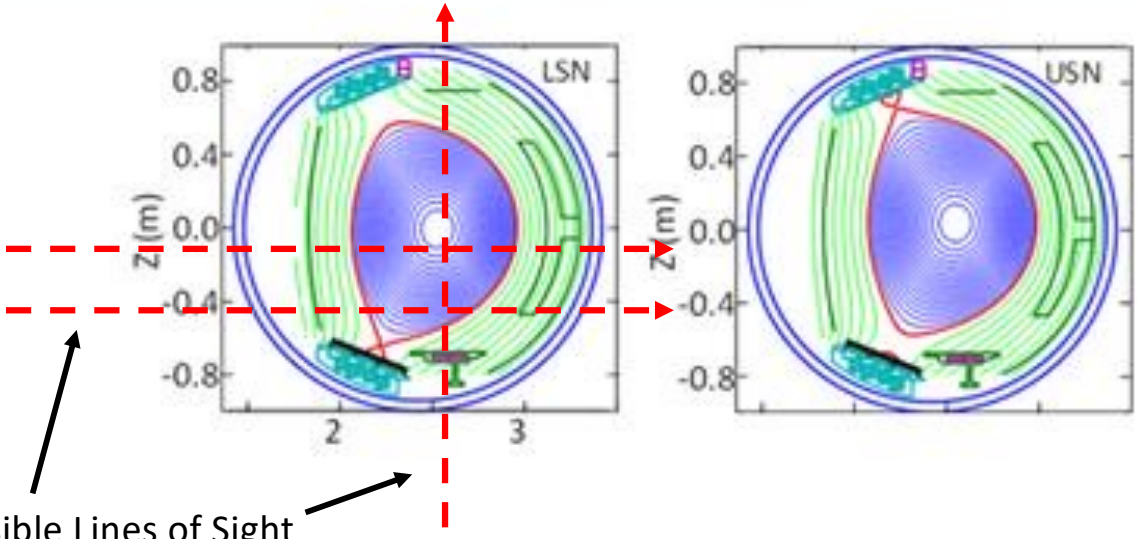
Based on the results it will be devised how to move towards more complex measurements, such as Polarimetry and nanowire modulator-based ECE.



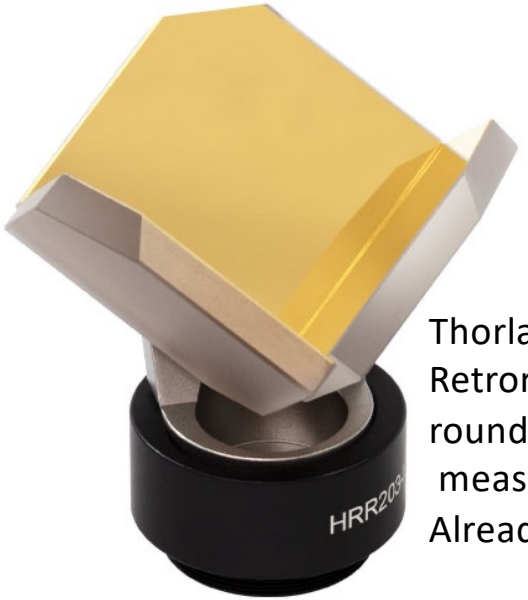
Teraflash full optical path can be tuned between 180 and 300 cm, using a tailored zero-dispersion-fiber. Optical fibers lengths is 10m.

WEST Layout & Parameters (courtesy D. Mazon)

B	I_p	R	A	V_p	κ / δ	P_{RF}	Magnetic conf.
3.7 T	1 MA	2.5 m	5-6	15 m^3	1.4 / 0.5	16 MW	LSN, USN, DN



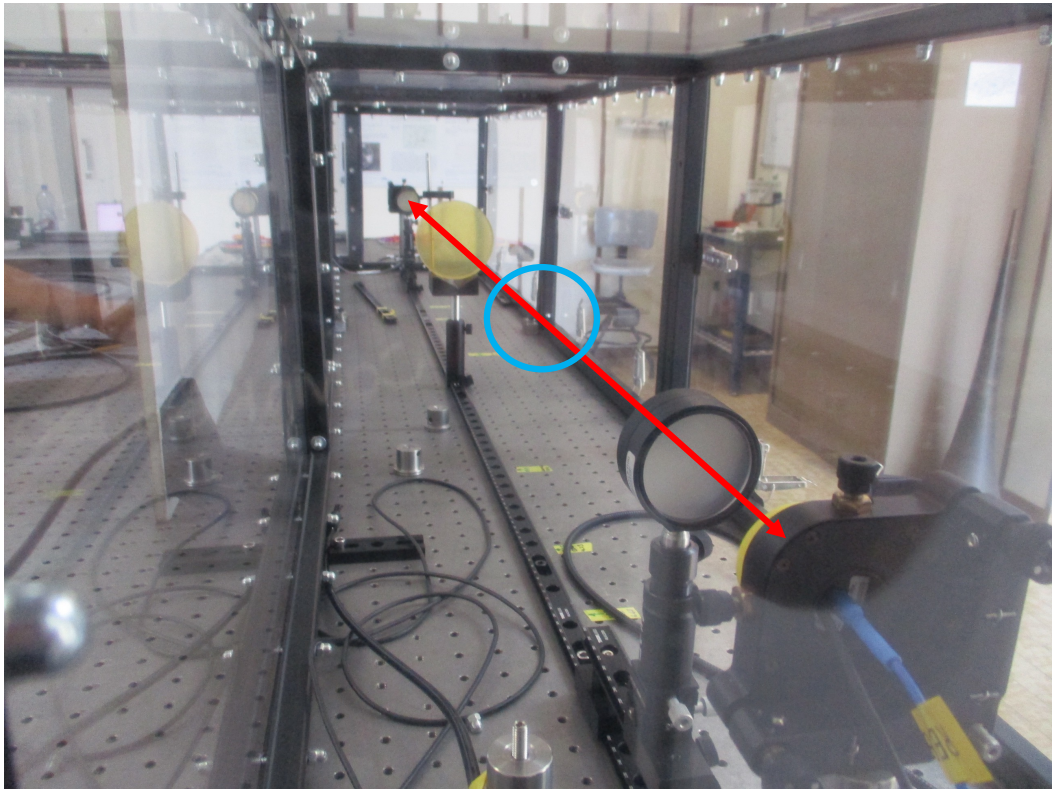
Possible Lines of Sight



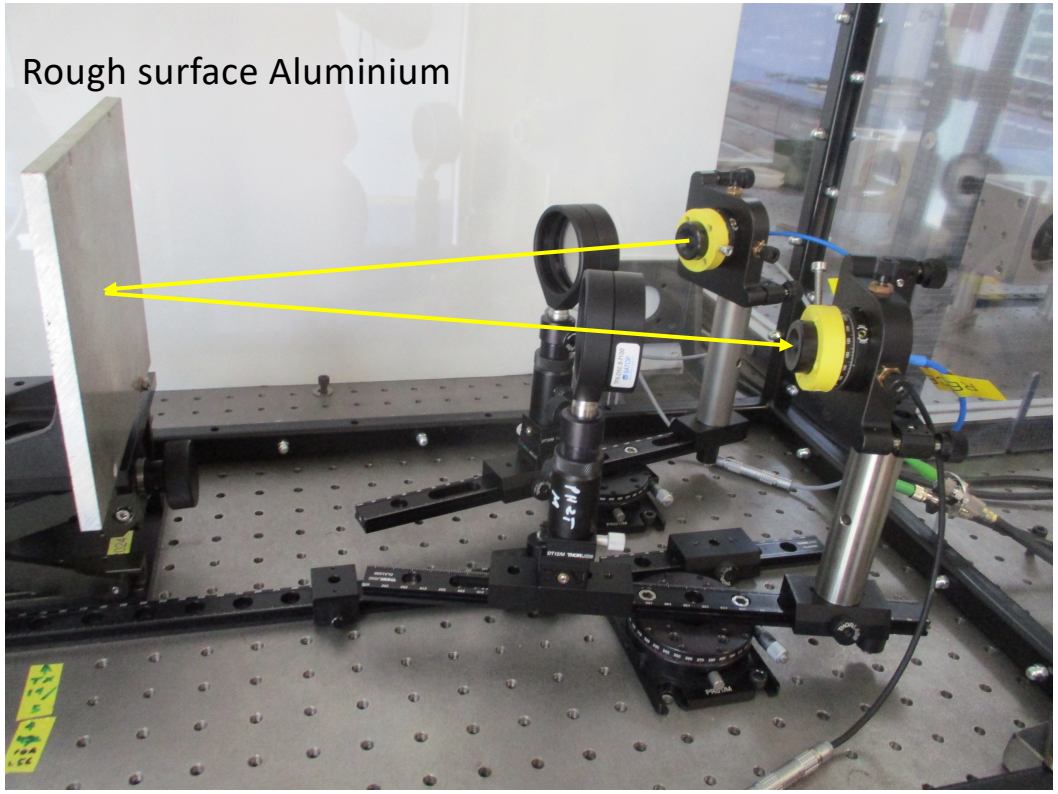
HRR203-M03

Thorlabs Hollow Retroreflector for round trip interferomet measurements. Already acquired.

Table top configurations



Interferometry: with dummy sample (TPX). LOS=2m. The beam is tubular (collimated) with 90% intensity within 45mm diameter (lens diameter 50mm)



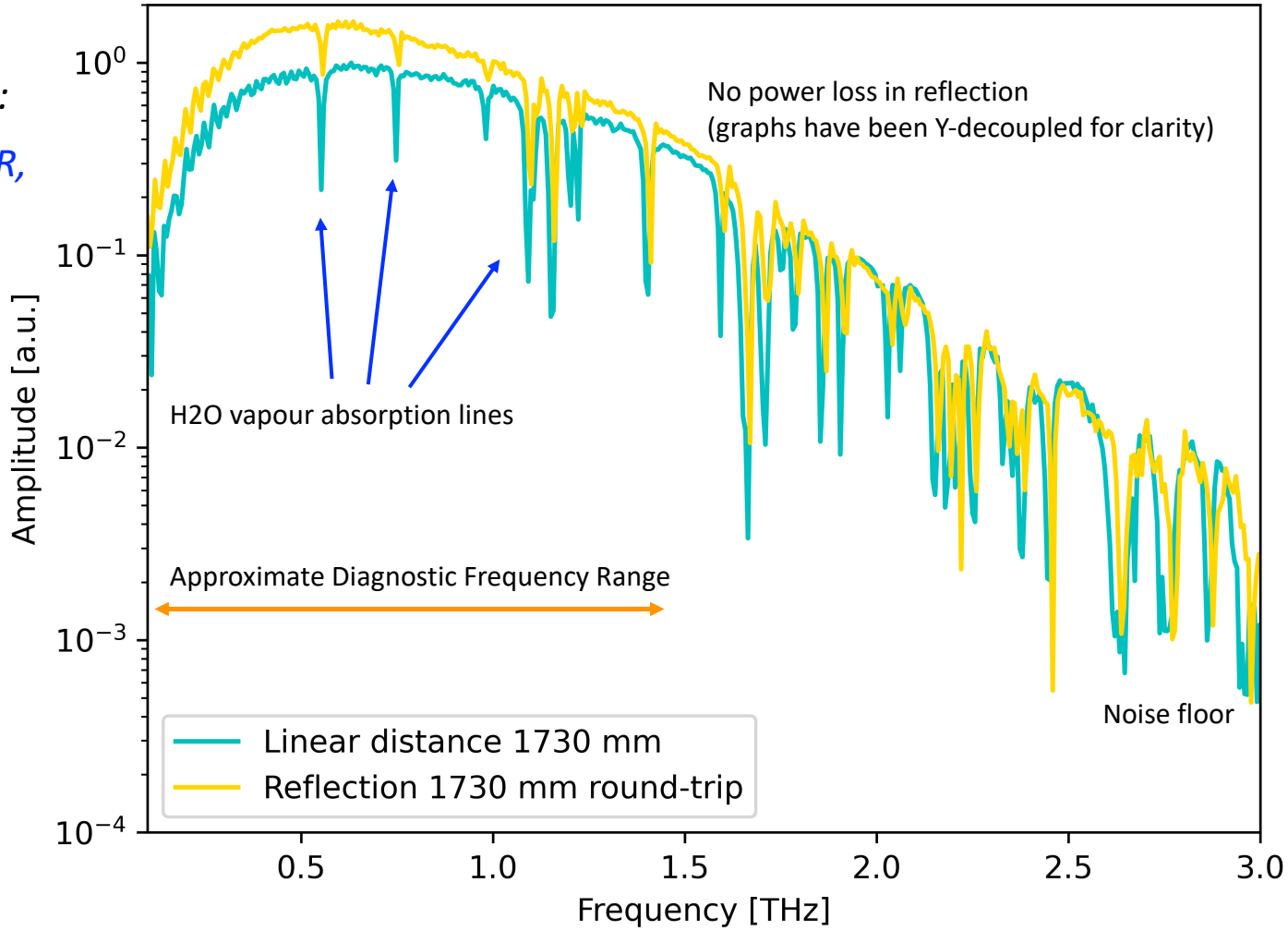
Reflectometry: successful at distances WEST-relevant

Example of Table-Top Tests Results

Laboratory tests completed in THz-TDS laboratory in Frascati:

long range measurements, SNR, Reflection, alignment criticity.

Many different arrangements and configurations geometrical and optical,with different samples and various type of THz generation and detection have been tested. A paper on this subject is under preparation.



Details to define

- Work out the available access and plasma Lines of Sight on WEST
- Design the Diagnostic-Machine interface (flanges, windows)
- Available timing of installation and measurements (machine vent etc.)
- DAQ – CONTROL: Teraflash has its fully on-board acquisition system. It can be TTL externally triggered for synchronization with WESTBOX. Data can be then transferred from internal ADC to WEST pulsefile.

Timeline of the project: next steps

- *Laboratory tests – Completed*
- *Diagnostic conceptual design completion – 2 months. Instrumental choice and engineering - 5 months*
- *WEST «dummy» noise test with detectors near the machine - 1 month*
- *Start installation of the full system: 8 months after kickoff*
- *Tentative manpower: ENEA 6-8 PM x 2, 4-8 weeks missions. CEA: as required, for interface implementation*
- *Tentative budget: ENEA ~20keuro (on top of existing already acquired hardware). CEA, as above for manpower*

Frascati selected publications on the subject

Zerbini, M. (2025). *Plasma diagnostic techniques based on terahertz radiation.* **Applied Physics Reviews**, *12*(3), 31314.

Galatola Teka et al., (2024). *A thorough experimental assessment of THz-TDS plasma diagnostic techniques for nuclear fusion applications.* **Review of Scientific Instruments**, 95(10), 103519.

Zerbini, M. (2022). *Sailing on Far Infrared and Submillimeter Waves Plasma Diagnostics, towards THz-TDS and beyond*. 2022 47th International Conference on Infrared, Millimeter and Terahertz Waves **(IRMMW-THz)**. **Invited paper.**

Zerbini et al, (2016). *From FIR and millimeter waves to THz plasma diagnostics applications.* 41st International Conference on Infrared, Millimeter, and Terahertz Waves **(IRMMW-THz)**. Copenhagen (Denmark).