Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

The potential of THz-TDS diagnostics for next step Fusion experiments

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- THz Time Domain Spectroscopy
- Diagnostic layout & Features
- Measurements examples
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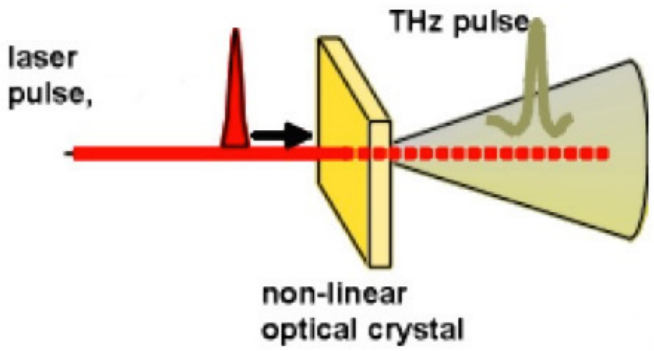
Prolegomenon

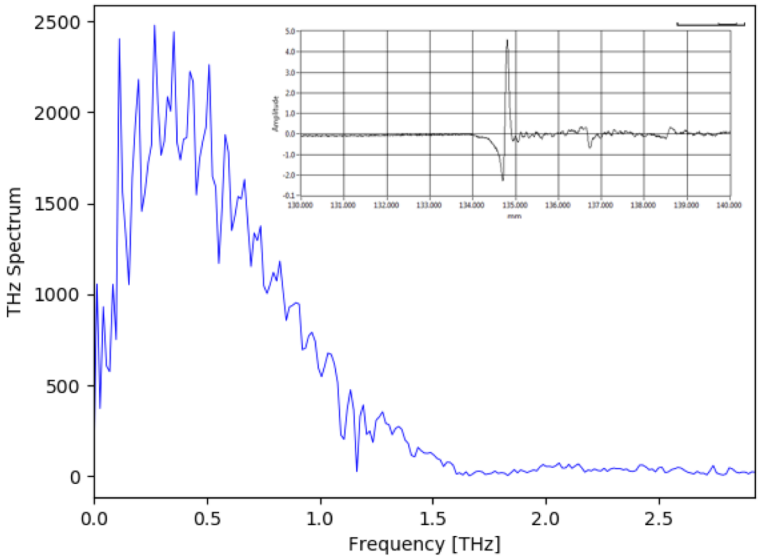
- The optical properties of plasma in the Far Infrared Radiation band (100 GHz to 2 THz+) are extremely fortunate. A vast landscape of plasma parameters can be smoothly and effectively detected from the electromagnetic waves response, both in transmission and in reflection.

- Since the early days, this paved the way to a large number of fundamental diagnostics, based on interferometry, radiometry, polarimetry, with the development of many optical and quasi-optical spectroscopic systems.

THz-Time Domain Spectroscopy

• THz-TDS is a now well established spectroscopic technique, based on laser-driven broadband emitters (0.1 THz – 4 THz+), providing the transmission and reflection properties of many materials, through simultaneous detection of amplitude and phase of the probe signal.

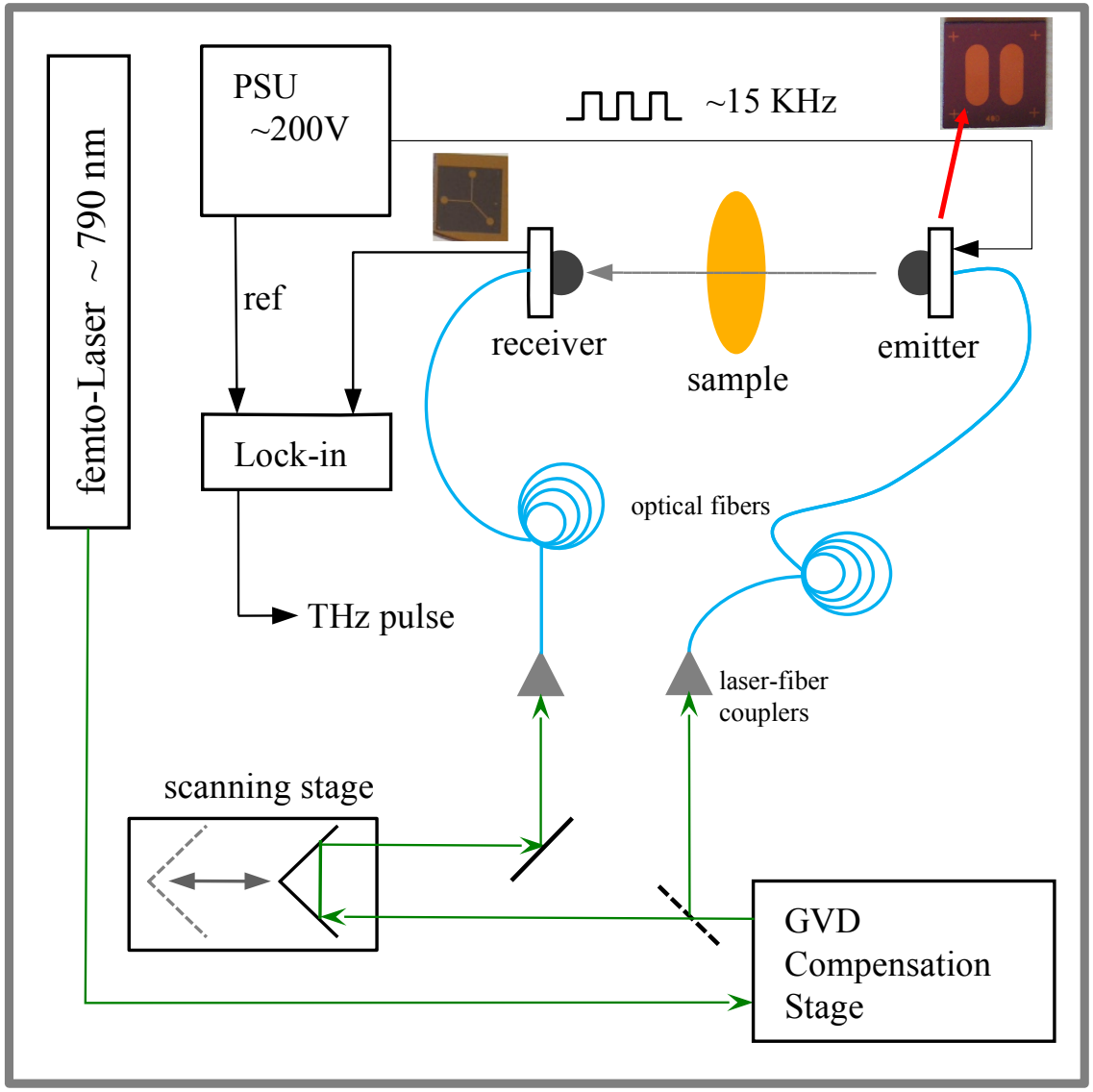




• It is a promising candidate for plasma diagnostics applications, since one single instrument can potentially provide reflectometry, interferometry and polarimetry mesurement, from the spectral analysis of the plasma response to the broadband THz pulse.

Diagnostic layout

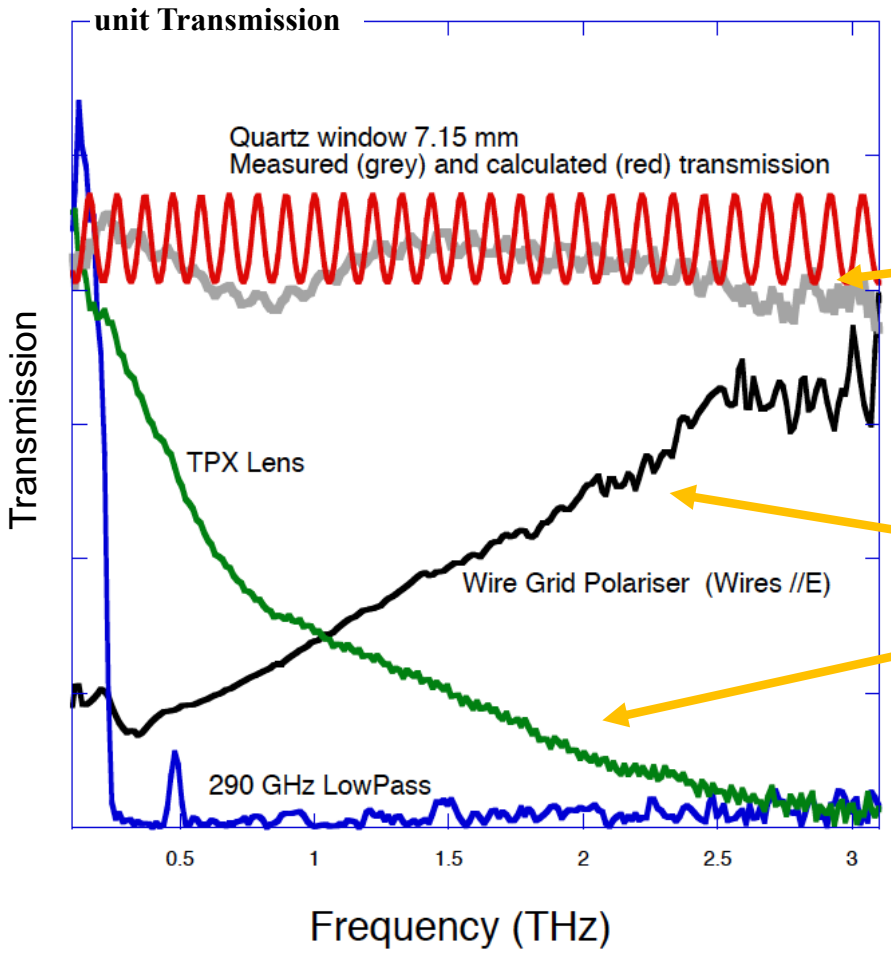
A THz-TDS spectrometer with emitter and receiver located at the opposite ends of a vertical chord, using several spectral components of the THz beam, will provide the same information of a classic interferometric and in addition a straightforward implementation of the combined measurement of interferometry and polarimetry.

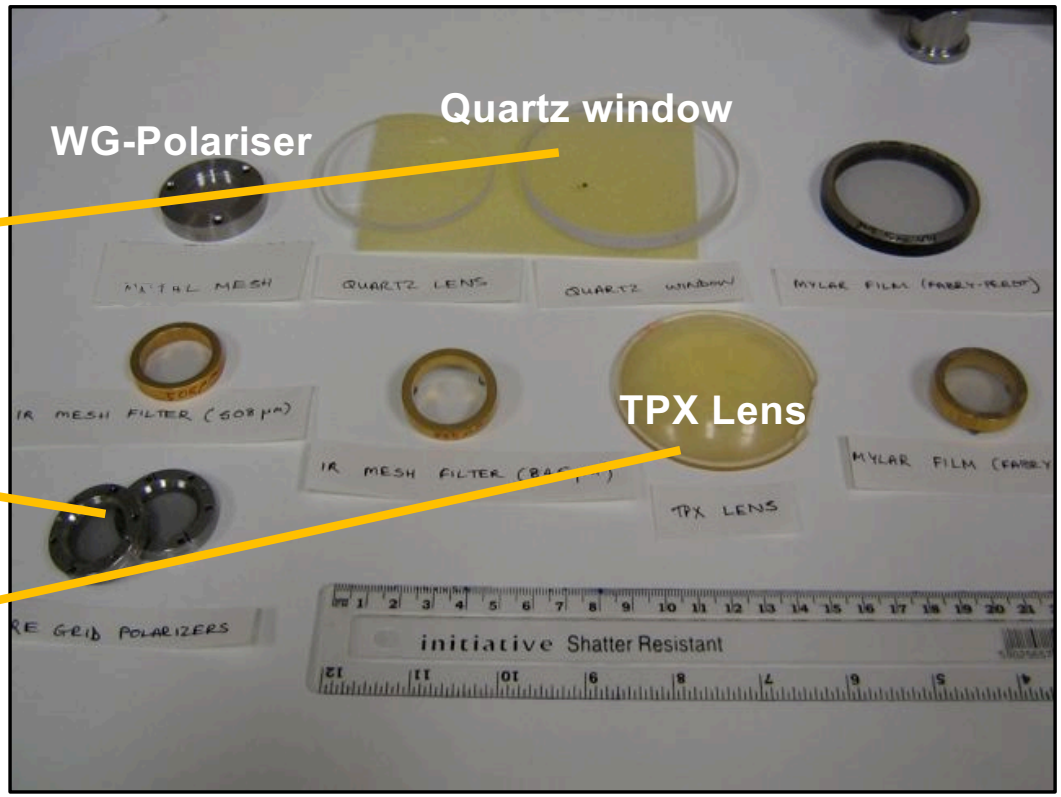


Features of a Novel Broad-Band THz Diagnostic

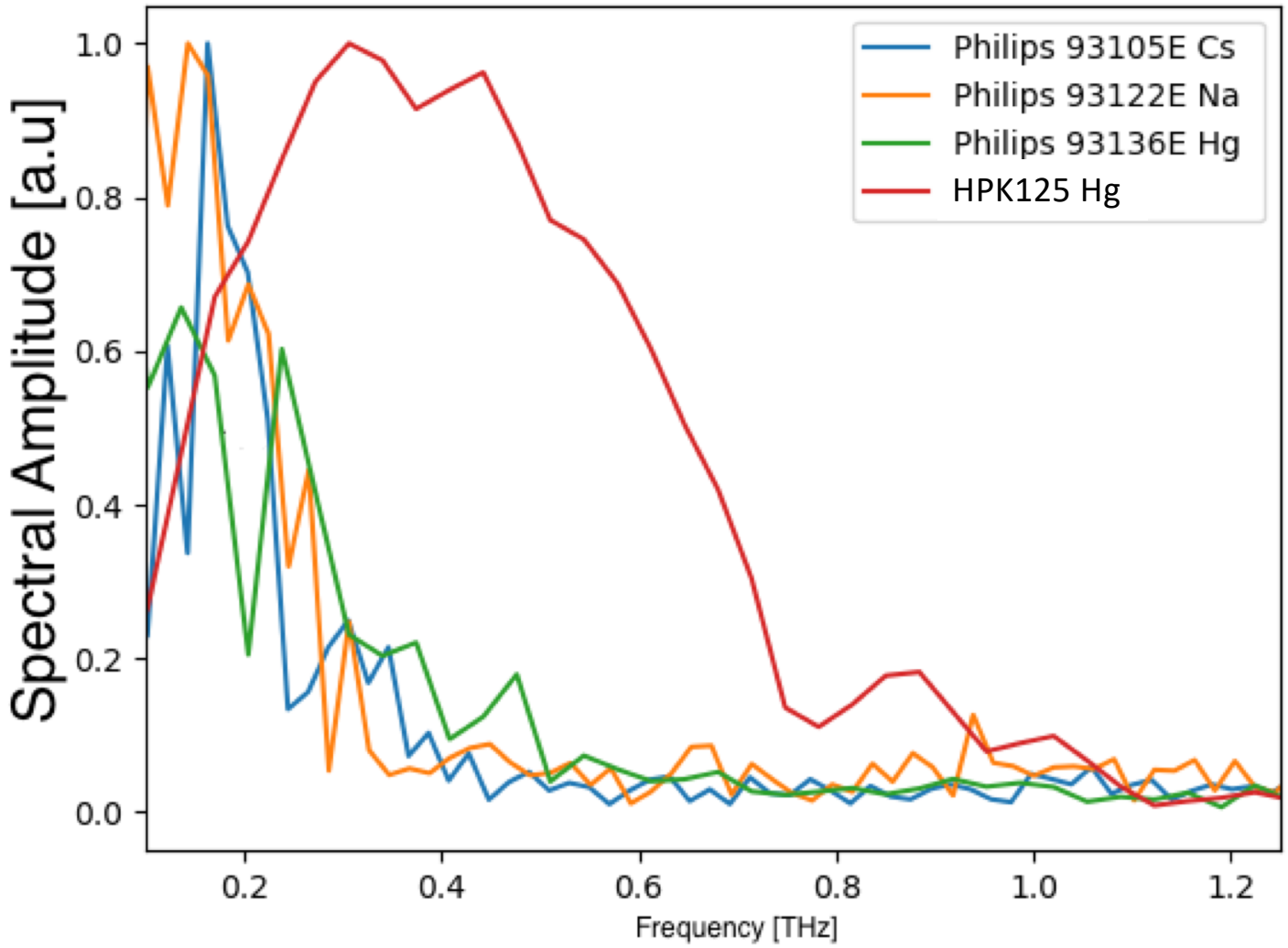
- THz-TDS makes use of ***compact, room-temperature solid-state devices & optical fibers, ideal*** to ease access and match Tokamak plasma harsch environment requirements (*limited space, radiation, thermal stress*).
- ***High resolutions & sensitivity*** (background rejection) can be reached with appropriate choice of emitters, detectors and synchronous detection systems (basic estimate SNR~100)
- ***Multiple plasma measurements with a single instrument are foreseable:*** Interferometry, Reflectometry, Polarimetry, to measure density, magnetic field, charge density, conductivity and current profile.
- **In addition, possibility of THz-TDS « cold test »** for many kind of diagnostics and heating systems, components and materials.

Plasma-Relevant THZ-TDS Test Results





Examples of plasma transmission measurements



A path to the THz-TDS diagnostic

- Transition from table-top THz-TDS spectroscopy to plasma diagnostics on a tokamak will require a complete change of layout and geometry:

THz beam path ~meters. ”Sample" is a large plasma column

- Measurement time will necessarily be short (*milliseconds*), hence sophisticated techniques will be necessary to achieve diagnostic-grade signal-to-noise-ratio (ASOPS, piezo-scanners).

- Tailored Gaussian optics for Emitter - Receiver coupling across the tokamak paths (m). Accurate management of plasma refraction effects

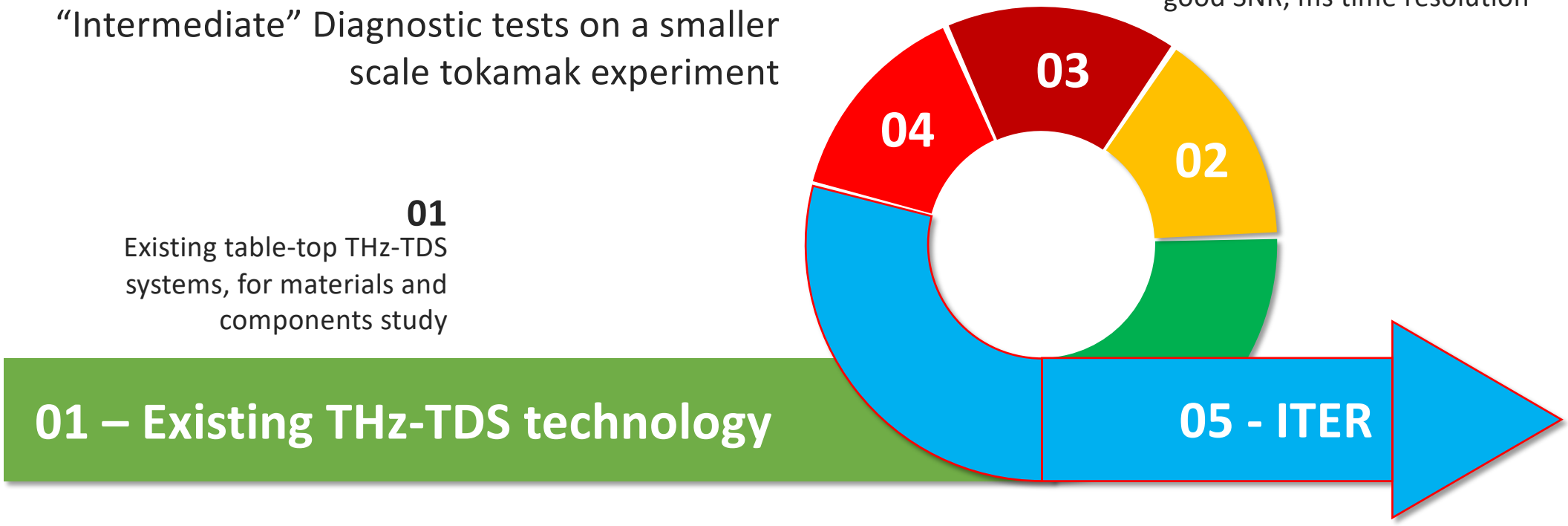
→ Combination of technological and plasma challenges

From table-top THz-TDS to ITER diagnostics

02-03
laboratory demonstration of long distance measurements, good SNR, ms time resolution

04
"Intermediate" Diagnostic tests on a smaller scale tokamak experiment

01
Existing table-top THz-TDS systems, for materials and components study



THz-TDS has great potential for evolution of FIR diagnostics capabilities towards a next-generation class of measurements for ITER: moving beyond routine plasma density and temperature measurements, to provide a range of plasma parameters with unprecedented flexibility and reliability, by using a single multi-functional instrument.