Compact in-situ LIBS device for material characterization

ENEA - Centro Ricerche Frascati developed a compact Laser-Induced Breakdown Spectroscopy (LIBS) diagnostic for the in-situ characterization of fusion and non-fusion materials. The compact system has been assembled on the Frascati Tokamak Upgrade (FTU) robotic arm to sample several sites of Plasma Facing Components (PFCs) and determine their elemental surface composition. The technology is designed to take measurements both on-site and in the lab for post-mortem studies. It works at atmospheric pressure or in vacuum and is suitable to perform measurements with different background gases (Ar, He, etc) and on different materials: metals, polymers, liquid and gases. The technology is available for further use where detailed surface material characterization is needed, e.g. metallurgical laboratories and industries, nuclear plants, aerospace applications, cultural heritages, archeology and life sciences.

Description of the technology

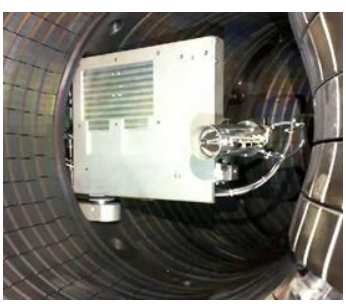
Laser-Induced Breakdown Spectroscopy (LIBS) is a rapid chemical analysis technique that employs a short laser pulse ($\leq 10^{-9}$ s) to produce a micro-plasma on the sample surface. The LIBS plasma is spectrally analysed to identify the sample's chemical composition. A single pulse can reveal the presence of all the chemical elements of surface materials.

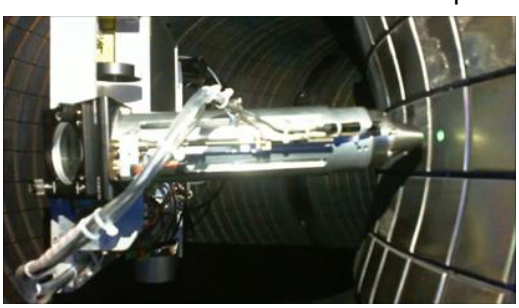
ENEA-FSN developed a specific compact configuration to be able to perform in-situ characterization of Plasma Facing Components (PFCs) within the Frascati Tokamak Upgrade First Wall (FW) and analyse elemental surface composition. The technology was also used in laboratory for post-mortem analysis.

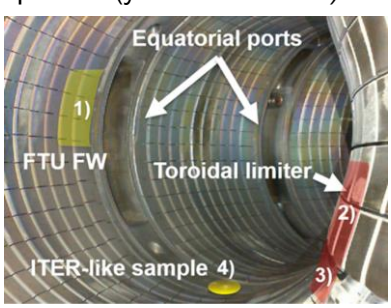
The end module of the robotic arm was designed to accommodate the LIBS system, incorporating a Nd:YAG DP laser. The Nd:YAG DP laser (λ=1064 nm, max pulse energy = 70 (+70) mJ, pulse width 10 ns, beam Ø ≈200 μm, max repetition rate 20 Hz) emits towards a 1" negative lens (f = −75 mm) and a 1" 45° mirror. The beam is then directed onto a 2" lens (f = 200 mm) and focused on a pair of 2" 45° mirrors; the first is a semitransparent beam-splitter that allows plasma light to pass from the sample to the collecting optics. Finally, the beam is focused onto an extendable telescopic tube with a focusing 1" lens (f = 50 mm).

As we can see in figures below, the FTU First Wall (FW) was sampled in air at different points along the axial section of the vessel with a compact LIBS probe, mounted on a remotely operated robotic arm :

1. the FW of the vessel (light yellow area #1)
2. some tiles of the toroidal limiter light red area #2)
3. the area of the inner wall underlying the limiter (light red area #3)
4. the bottom of the vacuum vessel where an ITER-like sample was placed (yellow circle #*4)*







Compact LIBS probe on the FTU remote handling system

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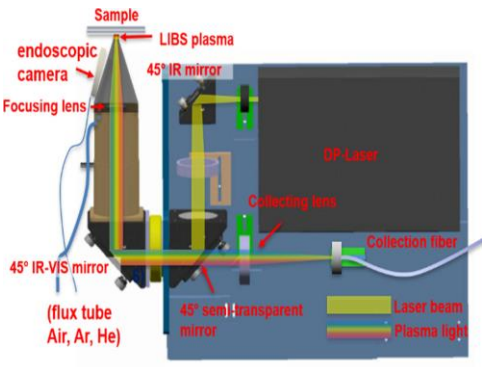
Innovation and advantages of the offer

The technology developed by ENEA-FSN can simultaneously perform a multi-element detection, having a wide spectral range but in low resolution or, in the opposite, it can find a single molecule in a small spectral range but with a high resolution. Moreover, the LIBS micro-destructive characterization technique only needs few µg of sample and there is not the necessity for sample preparation. LIBS has depth profiling capabilities, thus can analyze multilayered materials. In addition, it can detect trace elements with high sensitivity. Finally, this process can be used in hostile environments, can perform semi quantitative and quantitative analysis and remote detection either from optical ports or miniaturized robotic probes and online data analysis for in situ cleaning procedures.

Non-fusion Applications

This technology can be declined in fields where surface material characterization is needed, in the presence of hostile environments, also through remotely operated systems. In addition, the compact LIBS can be used in environments where the continuous monitoring of surfaces is fundamental without the need of samples preparation. The technology is available for material characterization in different fields, e.g. metallurgical laboratories and industries, nuclear plants, aerospace applications, cultural heritages, archeology and life sciences.



How LIBS works and its layout

EUROfusion Heritage

The LIBS compact technology has been developed and applied in the framework of EUROfusion research activities to characterize the materials and as a suitable diagnostics for PFCs. The technology was installed in FTU (Frascati Tokamak Upgrade) and it was designed to be a compact LIBS able to work in-situ in hostile environments and able to be controlled remotely.

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