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STONE 2025 Paris

CALLOSLASER-ASSISTED REMOVAL: ASSESSING OF EPILITHIC BIOLOGICAL ATTACK FROM STONE BY MEANS OF LED-IF

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CALLOS

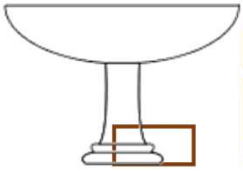
FORTH

Co-financed by Greece and the European Union

AIM

Development of customized methodologies for:

- Laser-assisted removal of epilithic biological formations on marble.
- Assessment of the cleaning efficiency on the basis of LED-IF signals.

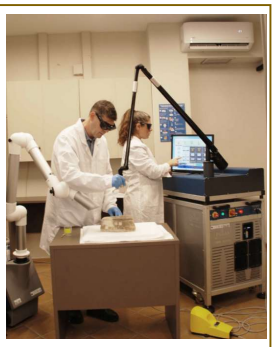


Sketch of a typical archaic ***perirrhanterion*** *(an ancient Greek basin used in religious ceremonies to hold holy water)*

A series of preliminary spot tests (to define the critical parameters) and areas of various cleaning levels (to test the methodology)

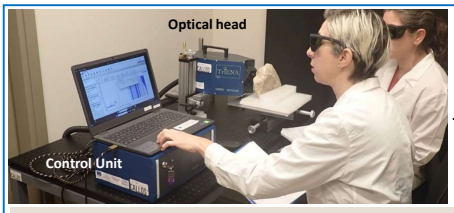
Paλλas Laser cleaning system

PAλλAS is an innovative laser cleaning system designed & developed by FORTH-IESL for safely and precisely removing pollution deposits and biodeterioration from archaeological stonework. The system can emit 3 laser beams (Infrared-1064nm, visible-532nm, and ultraviolet-355nm), which can be used individually or in combination, to address specific conservation challenges.



Conservators can easily direct the beam/beams at the specific cleaning area using a flexible, articulated mechanical arm. The system is equipped with user-friendly software that enables adjustments to operational parameters, providing tailored cleaning methods for different weathering phenomena and substrate types. This design was developed during the CALLOS project.

The TriENA Portable Analytical Instrument



TriENA is a hybrid analytical device that combines 3 spectroscopic analytical techniques for the direct identification and characterization of construction materials and their deterioration phenomena.

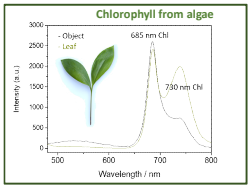
TriENA is a user-friendly, portable instrument that can be operated both in laboratory & *in-situ* settings, such as on monuments and excavation sites, without the need for sample collection or preparation.

TriENA is designed in 2 individual modules to ensure accurate measurements, ergonomics, & flexibility. It consists of:

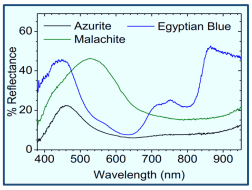
- an easy-to-use optical head that collects visual information using appropriate optics, and
- a control unit that houses sensors for signal capturing and power supply devices for the subsystems.

The system is controlled by a portable computer & a tailor-made software which allows data processing and results extraction. TriENA comes with a specially designed optical head holder, providing flexibility and ease of access to the surface under study.

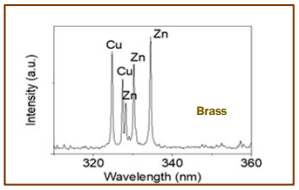
LED-IF — LED Induced Fluorescence → Detection of **Biodegradation**



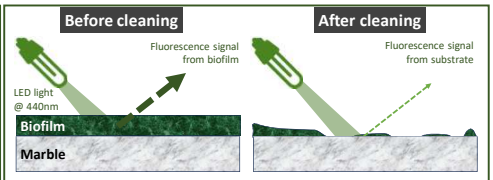
DR — Diffused Reflectance → Identification of **Paints**

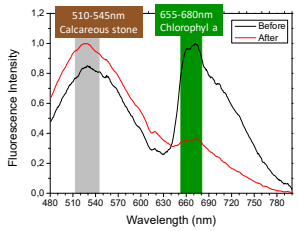


LIBS — Laser-Induced Breakdown Spectroscopy → Elemental analysis of **pigments, metals,** etc



Assessment of cleaning using LED-IF Analysis





Photons are absorbed **mainly by the crust** → the recorded fluorescence signal is attributed to the biodeterioration rather than the stone substrate

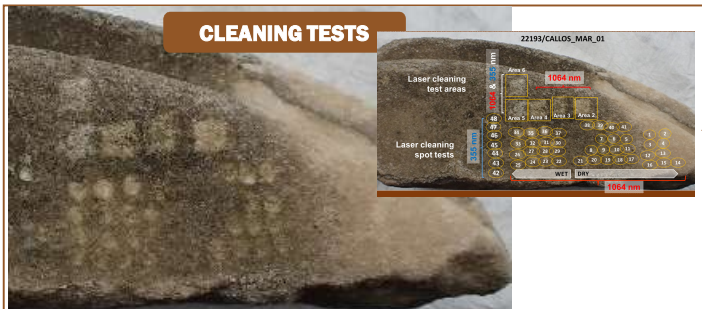
When the biocrust is partially removed, the **fluorescence signal from the biofilm decreases**, while the signal from the marble increases

$$R = \frac{I^{fluo}_{substrate\ (510-545nm)}}{I^{fluo}_{biofilm\ (655-680\ nm)}}$$

R is a quantitative indicator to evaluate the cleaning result

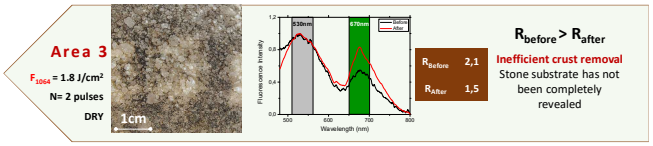
RESULTS & CONCLUSIONS

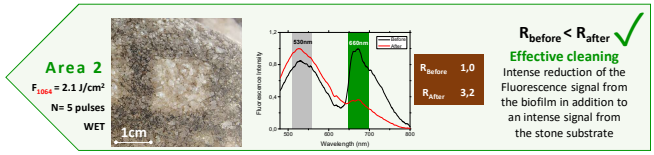
CLEANING TESTS



Crust / substrate	laser beam λ (nm)	Critical Fluence values F (J/cm²)	wetting
Deteriorated marble surface	1064	Spot 14: F_{marble_1064}= 1.2	✓
	355	F_{marble_355}= 0.6	✓
Biofilm/ deteriorated marble	1064	Area 2: $F_{biofilm\_1064}$ = 1.2	✓
	355	Spot 45: $F_{biofilm\_355}$ = 0.6	✓
	1064 & 355	Area 5: F_{1064}/F_{355}= 3/1 → effective cleaning	✓
		Area 6: F_{1064}/F_{355}= 6/1 → under-cleaning	✓
Pollution crust/ deteriorated marble	1064	$F_{επικάθησης\_1064}$ = 1.2 - 2.3	✓

LED-IF CLEANING ASSESSMENT





CONCLUSIONS & FUTURE STUDIES

- ✓ Laser cleaning tests indicated the critical F thresholds for removing biofilms and pollution crust
- ✓ Evaluation of cleaning effectiveness was tested using LED-IF signals before and after cleaning
- ✓ The introduced Ratio R, which quantitatively assesses the removal outcome, has proven to be a handy tool for informed decisions
- ✓ The assessment methodology is under optimization to other substrates and types of biofilms

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