Lasers are considered a highly selective cleaning tool offering unique advantages and attributes (localised action, immediate control and feedback, environmental and user friendly approach etc.). Pioneer research at IESL -FORTH aims at addressing demanding conservation problems focusing on the:

Cleaning Artworks with Lasers

- ✓ development of laser cleaning methodologies and portable instrumentation for restoration,
- ✓ systematic research on laser-material interaction allowing the implementation of innovative technologies in the laser conservation practice, including the use of femtosecond lasers for the cleaning of Cultural Heritage objects.

A novel laser cleaning methodology that relies on the simultaneous use of infrared and ultraviolet radiation from a Q-switched Nd:YAG laser was pioneered by IESL-FORTH and has been successfully applied in the preservation of the Parthenon West Frieze and other sculptures on the Athens Acropolis. This proprietary technique produces impressive results and was chosen among over 40 other methods that were evaluated to meet the strict criteria for a restoration intervention on a world renowned monument. Recently, in a symbolic connection between ancient and modern Greece, an advanced laser laboratory has been set up on the visitors' floor at the Acropolis Museum, where the Caryatids are exhibited. Removal of surface pollution accumulations takes place in this laboratory, allowing museum visitors to watch the conservation interventions that until now took place only inside restricted access laboratory environments.

Detail of the Parthenon West Frieze during the laser cleaning process

Laser cleaning of one of the Caryatids is taking place in situ at their exhibition site inside the Acropolis Museum

Laser assisted varnish removal from oil painting (National Gallery of Athens)

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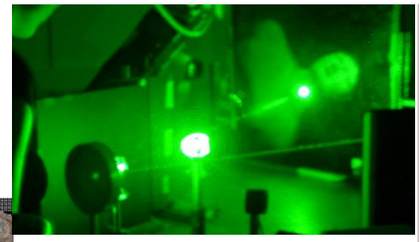
FORTH

Institute of Electronic Structure & Laser



Lasers for Cultural Heritage

FUNDED PROJECTS

EU Projects

CHARISMA	Cultural Heritage Advanced Research Infrastructures: Synergy for a Multidisciplinary Approach to Conservation/ Restoration (FP7-INFRA-2008-228330 / 2009-2013) *http://www.charismaproject.eu*
SYDDARTA	SYstem for Digitisation and Diagnosis in ART Applications (FP7-ENV-2010-265151 / 2011-2013)
CLIMATE FOR CULTURE	Damage risk assessment, economic impact and mitigation strategies for sustainable preservation of Cultural Heritage in the times of climate change (FP7-ENV-2008-1-226973 / 2009-2013) *http://www.climateforculture.eu*
ATHENA	A scientific training for high education initiatives in art conservation, (Marie Curie EST, FP6 MEST-CT-2004-514567 / 2004-2008)
PROMET	Innovative conservation approaches for monitoring and protecting ancient and historic metals collections from the Mediterranean basin (INCO-CT-2004-509126 / 2004-2008)
LASERACT	Laser multitask non-destructive technology in conservation diagnostic procedures (FVK4-CT-2002-00096 / 2003-2006)
MultiEncode	Multifunctional encoding system for assessment of movable Cultural Heritage (SSP1-CT00-6427 / 2005-2008)
	Advanced on site laboratory for European antique heritage restoration (CLT 2003-A1-RO-515 / 2003-2004)
Laser cleaning	Modeling and diagnostics of pulsed laser-solid interactions: application to laser cleaning (TMR Network FMRX-CT98-0095 / 1998-2002)
COST Action G7	Advanced artwork restoration and conservation methods using laser techniques (2000-2005)
	Advanced workstations for controlled laser cleaning of artworks (EESD CRAFT ENV4- CT98- 0787 / 1998-2001)
RESTORE	Facade cleaning with lasers, EUREKA project (1997-1998)
Laser ART	Non-intrusive laser measurement techniques for diagnostics of the state of conservation of frescoes, paintings and wooden icons (SMT4-CT96-2062 / 1996-1999)

Other National and International Projects

LASTOR	Lasers for stonework restoration (GSRT* / 2003-2006)
OLOTEK	Holographic method and system development for structural assessment of artworks (GSRT / 2003-2006)
MOBiLART	Mobile laser art conservation laboratory (GSRT / 2005-2007)
LATECA	Laser technology in conservation of artworks (GSRT / 1995-1998)
EMERIC II	Risk Map for the assessment of wall paintings of the Byzantine monuments in Crete (CRINNO- Crete Innovative Region / 2004-2005)
The ACROPOLIS MUSEUM	Launch of an "open common laboratory" in collaboration with the Acropolis Museum in which modern laser based diagnostic and imaging techniques will be used for expanding the historic knowledge of the artifacts and deciding the best conservation practices for the exhibits
ATHENS ACROPOLIS MONUMENTS	Development of a methodology and a laser system for the cleaning of the Parthenon West Frieze and other Acropolis Sculptures and Monuments. Bilateral collaboration with the Committee for the Preservation of the Acropolis Monuments (ΕΣΜΑ), (Greek Ministry of Culture and Tourism/ 2002-2011)
LMntl	Development of a laser induced breakdown spectroscopy instrument for the analysis of archaeological samples (INSTAP, USA / 1999-2002)

**GSRT: General Secretariat for Research and Technology, Greek Ministry of Education, Lifelong Learning and Religious Affairs*

Structural Diagnosis

Analysis and Imaging

Cleaning and Restoration

Laser Diagnostics - Conservation - Restoration of Artworks

IESL - FORTH is among the leading centers worldwide for research and development of innovative laser and optical technologies for the diagnostics and conservation of works of arts and antiquities.

Emphasis is placed on laser ablation methodologies for cleaning and restoration, laser spectroscopy for compositional analysis, multi spectral imaging and holographic metrology techniques for structural diagnosis.

Numerous collaborations exist between IESL-FORTH and museums or other organizations, focusing on the use of laser and optical technologies for addressing a broad spectrum of challenges in art conservation and archaeology. These collaborations have had significant technological output, for example mobile LIBS instruments for the analysis of works of art and archaeological samples, laser cleaning systems, currently in use on the Parthenon sculptures, mobile laser interferometry instruments for structural characterization of artworks and monuments and versatile imaging systems for mapping and discrimination of materials.

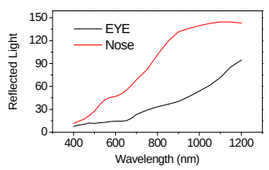
Spectral Imaging Technologies

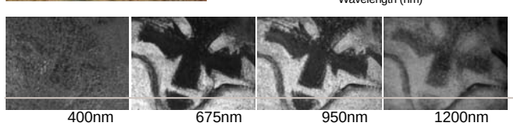
Optical imaging techniques play an important role in the non-contact, non-invasive, in-situ examination and continuous inspection of Cultural Heritage objects.

Applications include: mapping of varnish and paint layers, visualization of underdrawings, assessment of past conservation treatments, on-line monitoring of cleaning interventions etc.

Research at IESL-FORTH aims to investigate, quantify and expand the potential applications of spectral imaging on Cultural Heritage objects, while continuous technical development both in hardware and software targets to improve the analytical capabilities of the technique.

The versatile mobile instruments, IRIS-I and IRIS-II, developed at FORTH are used for research campaigns in museums, rural churches and other Cultural Heritage sites





Spectral Imaging provides combined analytical information which allows the differentiation and/or identification of pigments with similar hue

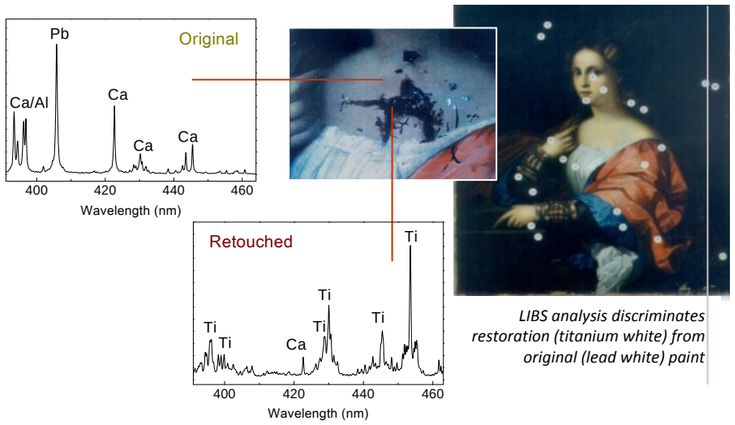
Laser Spectroscopic Analysis

Laser techniques such as Laser Induced Breakdown Spectroscopy (LIBS), Laser Induced Fluorescence (LIF) and micro- Raman spectroscopy provide insight about the identity and composition of materials in Cultural Heritage objects.

Research at IESL-FORTH focuses on:
- ✓ laser analytical methodologies
- ✓ development of novel portable instrumentation

The goal is to produce flexible, user-friendly tools that will enable archaeologists, art historians and conservators to obtain vital information about objects of Cultural Heritage, through chemical analysis of materials. Identification of pigments in paintings, icons and illuminated manuscripts and analysis of archaeological metal, glass and pottery objects are just a few examples. Instrumentation produced at IESL-FORTH includes LM^{NT}I, a mobile LIBS analytical instrument, and LM^{NT}II a fully-portable LIBS system. LM^{NT}I is currently used for analysis of archaeological objects at the Conservation Laboratory of INSTAP-SCEC in Eastern Crete, while LM^{NT}II is used for research campaigns in museums and archaeological sites.

LIBS mobile instruments, LM^{NT}I (top) and LM^{NT}II (bottom)



LIBS analysis discriminates restoration (titanium white) from original (lead white) paint

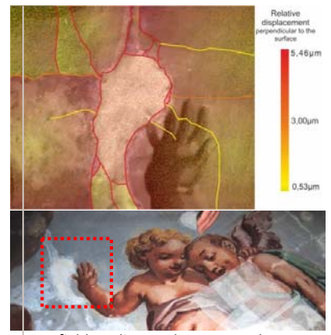
Laser Interferometry for Structural Diagnostics

Physicochemical deterioration affects slowly but steadily artwork mechanical integrity. Structural deformation becomes visible when its effects are irreversible and weak areas, detachments or hidden cracks have accumulated within the construction.

Holographic technology utilizes expanded laser beams to illuminate remotely the art surface and uncover, from the surface responses, the effects of deterioration within the structure. Effects and defects which are not visible by the naked eye or other methods, such as X-ray imaging, axial tomography, coherent tomography, IR and reflectography imaging, become visible and quantifiable. The exact position, structure and size of defected areas, as well as, deformations arising from environmental and climate changes, conservation treatments, natural or provoked ageing, transportation or handling, can be traced. The whole-field non-contact recording procedure allows temporal differentiation of reactions among layered composites providing real-time deformation monitoring of complex structures. The influence and magnitude of subsurface defects becomes evident on the surface allowing the prioritization of the restoration works and optimum planning.

Research at IESL-FORTH aims to conceptualise and exploit novel solutions for preventive conservation and restoration strategies, such as:
- ✓ development of novel dedicated instrumentation
- ✓ study of deterioration mechanisms
- ✓ deformation monitoring
- ✓ assessment of long- or short-term effects.

Studies on the structural integrity of a wooden icon by El Greco ("the Baptism") indicated areas of high risk necessitating for immediate restoration actions



Far-field studies on the structural condition of a wall painting at the 16thC castle in Brezice, Slovenia

The DHSPI instrument operating on-site at the Crypt of Dubrovnik Cathedral in Croatia