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LASERS IN THE CONSERVATION OF ARTWORKS

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ABSTRACTS

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MULTI-ANALYTICAL MOLECULAR MAPPING FOR ASSESSING THE QUALITY OF NATURAL ULTRAMARINE BLUE PIGMENT IN PAINTING CROSS-SECTIONS

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Keywords: multi-analytical, molecular mapping, paintings, cross-sections, ultramarine

Natural ultramarine is a well-studied pigment due to its precious and unique blue colour as well as its complex composition. Several papers have been published regarding its use in the past, the trading network and provenance. Interesting considerations regarding the discrimination between the synthetic and natural pigments, as well as their conservation state in paintings, have been made in the literature. However, literature lacks answers regarding the quality and purity grade of this pigment in works of art. Purity grade and compositional details provide information on the origin and production process. Moreover, high purity and deep blue are typically associated with the Afghan mines of Sar-e-Sang. Aspects of great relevance in authentication studies and conservation interventions.This work aims to address this issue, establishing an innovative analytical protocol for the analysis of micro-samples from paintings containing ultramarine, using a combination of spectroscopic data generated by different analytical techniques (Raman, FTIR and Fluorescence) to gain more detailed compositional information. The purpose is to overlap the information contained in each map, consisting of large spectroscopic data sets, using modern algorithms to enable a complete statistical compositional evaluation. The experimentation has involved the analysis of several standards of natural ultramarine pigment powders from Afghanistan with different purity grades used to train each spectroscopic technique in mineral identification. The study has been focused not only on the identification of the mineral lazurite, which is responsible for the blue colour, but also on the associated silicates, carbonates, oxides, phosphates and sulphides. This multi-analytical and holistic approach has allowed for the first time the selection of a few minerals as purity markers of the pigment. Preliminary and promising results in this sense have been achieved on some cross-sections from old master paintings of The Courtauld's Easel Painting Conservation archive collection, which have been subjected to this analytical approach for the first time. This research brings a significant contribution from Prof. Austin Nevin, who passed away last year. This talk is also the occasion to celebrate his memory as a point of reference for the scientific community working in the Cultural Heritage field, as well as a valuable member of the scientific committee of this conference.

Acknowledgements
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MATERIALS AND PAINTING TECHNIQUES OF ANCIENT WALL PAINTING FRAGMENTS FROM ROMAN DACIA: CURRENT STATE OF RESEARCH

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Keywords: Roman wall painting; Roman Dacia; painting technique; pigment; multi-analytical investigation; heritage science

Renowned for their aesthetic beauty, Roman wall paintings have long captivated both scholars and the general public. Although extensively studied, these artworks continue to spark interest and inspire new avenues of research. A substantial body of data exists on wall painting materials and techniques from well-known sites such as Rome and Pompeii, and similar studies have been conducted in other regions of the Roman Empire, including Northern Italy, Spain, and France. In contrast, the frontier provinces—such as Roman Dacia—remain underrepresented in scientific studies of mural painting practices. Preserved examples of mural painting in Dacia are scarce, typically consisting of isolated fragments associated with monumental buildings, setting the region apart from other Roman provinces in terms of available material and scholarly attention.

This lecture presents on overview of the most significant results obtained in recent years from the scientific investigation of Roman wall painting fragments uncovered at key archaeological sites in Dacia—most notably *Ulpia Traiana Sarmizegetusa* and *Alburnus Maior*—as well as recent, unpublished findings from *Buridava* and *Histria*. The material composition of the pictorial layers and the production techniques behind Roman wall paintings are examined and discussed through several surviving examples of decorative polychrome plaster fragments. The results are derived from several interdisciplinary studies conducted by CERTO INOE 2000, in collaboration with key stakeholders in the cultural heritage field, including museums and archaeological institutions. Given the rarity of the findings, the research prioritized non- and minimally-invasive methods to ensure preservation. Analytical techniques used to explore the pigments, stratigraphy, and painting techniques included X-ray fluorescence (XRF), Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy, laser-induced breakdown spectroscopy (LIBS), scanning electron microscopy with energy-dispersive X-ray spectrometry (SEM–EDS), and X-ray diffraction (XRD), complemented by advanced imaging methods such as hyperspectral imaging. These investigations form part of the first interdisciplinary studies dedicated to Roman wall paintings from the former province of Dacia, an ongoing series exploring the technical know-how behind decorative wall paintings found in Roman archaeological sites in Romania.

STUDY OF THE ACTIVE FIBER LASERS: INFLUENCE OF THE SELECTABLE PARAMETERS IN THE CLEANING PROCESS

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Keywords: active fiber laser, design of experiment, laser ablation processes, parameter influence

The use of active fiber lasers for cleaning purposes is in rapid expansion in the field of cultural heritage. One of the main potentials of this laser is the possibility to combine a wider range of parameters than traditional lasers, enabling different types of interaction with the materials. [1] In addition, the possibility to choose from a variety of scan shapes and sizes accelerates the cleaning process. [2]

This study takes into consideration the ytterbium doped active fiber laser Smart 300 (El.En Group). The aim is to evaluate the effect and the influence of each parameter in the cleaning process by investigating the cleaning performed on mockups that replicate the roman *fresco* technique with two different overlapping layers: a *stacco* glue and a *scialbo.*

A Design of Experiment (DoE) approach was implemented to evaluate the role of power, scan speed, repetition rate and pulse duration in the cleaning process. The evaluation focused on changes of surface roughness and colour before and after the treatment, along with the analysis of the cleaning rate and of the different damages induced on the materials. This article aims to increase our understanding of how active fiber lasers operate and the role and contribution of each parameter in the cleaning process.

Acknowledgements

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CONTACT-LESS CLEANING METHODS FOR SOOT REMOVAL FROM HISTORICAL SILK: Nd:YAG vs PLASMA-GENERATED ATOMIC OXYGEN

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Keywords: Nd:YAG, AO plasma-generated atomic oxygen cleaning, historical textiles, Pyrolysis and Mass Spectrometry, thermostability

In the field of textile conservation, the cleaning of historical silk remains a significant challenge, particularly when dealing with soot contamination from fire-damaged collections, a problem that has yet to be fully resolved [1]. The complexity of this cleaning stems from both the nature of soot and silk itself: aged protein-based fibers are highly water-sensitive and easily damaged by mechanical or chemical treatments. Over the last two decades, tailored cleaning strategies have been developed, with laser cleaning emerging as a promising contactless technique [2,3]. This work investigates a comparative approach between two Q-switched Nd:YAG laser systems (532 nm and 1064 nm) and an innovative contactless method based on plasma-generated atomic oxygen (AO) [4], developed within the MOXY project (2022–2026, Horizon Europe). AO acts by selectively oxidizing carbon-based contaminants into volatile byproducts (CO, CO_2, H_2O). Experiments were carried out on pongee silk mock-ups, both aged and unaged, artificially soiled with soot from hot combustion. Cleaning tests were assessed through a comprehensive multi-analytical protocol, which includes 3D digital optical microscopy, fiber optic reflectance spectroscopy (FORS), and colorimetric measurements. Damage thresholds and morphological alterations were assessed using scanning electron microscopy (SEM). Moreover, Evolved Gas Analysis-Mass Spectrometry (EGA-MS) together with Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GC-MS) were employed to investigate the thermostability and potential damage of the treatments, delving into the degradation pathways at a molecular level.

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GHOSTLY IMAGES IN A 19TH CENTURY WALL PAINTING EXPLAINED BY SCIENTIFIC INVESTIGATIONS

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Keywords: spectroscopy, microscopy, metal-soaps, painting conservation, wooden church

Deterioration phenomena in wall paintings are a usual presence in any conservation project. Among the diversity of them, the most common ones relate to the stability and integrity of the pictorial layer and of its support, the amount and type of deposits including dirt, changes in color appearance. A part of them are generally explained by physical and chemical changes due to environmental conditions (such as microclimate instability), internal chemical processes or former restoration additions. It is less common to find a painted surface on which the usual dirt and smoke do not set, with a perfectly clean appearance. This is the case of a small wooden church in northern Transylvania (Romania), built in 1671 by the local community of Orthodox christians and completely repainted at the end of 19th century. Only recently the existence of an older painting has been discovered, during preliminary research for the painting conservation project. Both paintings are made in distemper technique, on their major part, and oil painting technique for skin areas.The team documented white shapes of figures and garment folds, having no connection with the iconography of the scene, which loomed on the blackened ceiling of the altar. Why and how this phenomenon happened and how it is possible that in more than 100 years of use, candle smoke does not set on certain areas are some questions to which this paper tried to answer.
Microbiological research has not identified microbiodeteriogens and reactions between microbial metabolites and substrates were excluded.
The methodology included on site examination and laboratory techniques applied on minute samples (ATR-FTIR, SEM-EDX, optical and digital microscopy). The results indicated interesting properties of the overpaintings in relation with the underlayer, that prevented setting of candle smoke on the pictorial surface.

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CLEANING OF FRESCO AND TEMPERA MOCK-UPS BY MEANS OF A Nd:YAG at 1064 nm

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Keywords: laser cleaning, wall painting, conservation, binder, pigment

This study focuses on the application of a QS Nd:YAG laser (wavelength: 1064 nm, pulse duration: 6 ns) on tempera (egg yolk binder) and fresco mock-ups, crafted following ancient recipes. Three colors—green, blue, and red—were selected, with two pigments chosen for each color: one representing historical authenticity (Verona green earth, Egyptian blue, and cinnabar) and the other reflecting industrial production (chromium oxide, ultramarine blue, and mars red). The mock-ups were artificially aged by soiling with diesel powder and exposure to SO_2 in a climatic chamber for 40 days.

The study first established damage thresholds for the painting mock-ups. Subsequently, cleaned areas were analyzed using stereomicroscopy and color spectrophotometry to evaluate physical changes, while chemical alterations were assessed with Fourier-transform infrared spectroscopy (FTIR), and microtextural modifications were examined using scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX).

Results showed that both binders provided a protective effect on pigments. Blue and green paints demonstrated resistance to laser radiation, while cinnabar and mars red-based mock-ups were more vulnerable, exhibiting color changes even at low fluences. Cleaning was not successful for cinnabar-based paintings, because darkening was not avoided. In general terms, irradiation with the damage threshold caused damage to the pictorial layer, requiring an intense fluence reduction, with exception of red mars-based paintings with both binders. Instead, blue pigments in fresco show barely colorimetric changes.

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MORPHOLOGICAL DIAGNOSTICS USING 3D LASER SCANNING, 3D MODELLING, AND 3D PRINTING FOR THE REPLICATION AND PRESERVATION OF HERITAGE ARTEFACTS

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Keywords: Morphological diagnostics, 3D modelling, 3D scanning, Digital reconstruction, Heritage replication

The integration of digital technologies in cultural heritage preservation enables non-invasive diagnostics and high-fidelity replication of artefacts that are often too fragile, incomplete, or valuable for handling or display [1-3]. This study explores a multidisciplinary approach combining 3D laser scanning, 3D modelling, and metal 3D printing to support morphological diagnostics and replication, using a cast iron artefact as a representative case. The research was conducted in three sequential steps. In Step 1, the artefact was documented using high-resolution 3D laser scanning and photogrammetry to capture its geometry and surface. In Step 2, the missing part was 3D modelled and reconstructed based on morphological symmetry and stylistic cues. This virtual restoration not only predicted the likely original form but also rebalanced the artefact, enabling it to stand upright. In Step 3, the completed digital model was fabricated using metal 3D printing and compared with the original artefact (Geomagic Control X). Results showed that the 3D-printed replica can achieve high morphological accuracy. This structured approach enabled the restoration of an incomplete object, the creation of a stable, display-ready replica, and an evidence-based evaluation of replication quality. By combining precise 3D scanning, 3D modelling and 3D printing, this three-step workflow provides a robust, scalable method for digital restoration and replication. It supports not only faithful reproduction but also informed conservation decisions, contributing to the advancement of heritage science and the practical preservation of historical artefacts.

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ASSESSMENT OF VISIBLE OR NEAR-INFRARED HYPERSPECTRAL IMAGING FOR EVALUATING LASER CLEANING EFFECTIVENESS ON TEMPERA MOCK-UPS

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Keywords: hyperspectral imaging, laser cleaning, visible, NIR, non-invasive technique (max. 5)

Wall paintings are so fragile, thus non-invasive or non-contact technologies are necessary for their analysis and/or evaluation of their conservation state. The use hyperspectral imaging (HSI), which combines the advantages of spectroscopy and imaging techniques, provides high resolution spectral and spatial information on samples and obtain their physical and chemical properties in a quickly and non-destructive ways [1]. The most often used hyperspectral cameras in heritage conservation operate in different regions of the electromagnetic spectrum: visible (V), near-infrared (NIR), V/NIR, short-wavelength infrared (SWIR). The efficacy of laser cleaning has been also assessed using this technique [2]. Besides, it is interesting to know which wavelength is the most suitable for determining cleaning processes.

In this work, two HSI cameras working in different ranges (V and NIR) were used for the assessment of the cleaning of an artificial soiling on tempera wall paintings mock-ups. These mock-ups were made of different pigments (azurite, malachite, lead white, orpiment and cinnabar) mixed with different binders (egg yolk or rabbit glue). The cleaning was carried out by two different lasers: LQS Nd:YAG (1064nm and 100ns) and Nd:YVO_4 (355nm and 25ns). Reflectance results were compared with those obtained through analytical techniques conventionally used to assess cleaning effectiveness: stereomicroscopy and color spectrophotometry. Overall, V or NIR ranges provide similar information, but in the case of AZ-based mock-ups the differences in the cleaning achieved by both laser were clearest with the NIR assessment. Lead white and orpiment-based mock-ups suffered the higher color differences and LQS offered the best performances.

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CHARACTERIZATION OF COMPLEX LAYERS IN CULTURAL HERITAGE USING A MULTIVARIATE AND MULTIMODAL ANALYTICAL APPROACH

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Keywords: spectroscopy, imagistic, stratigraphy, multivariate, multimodal

The characterization of complex stratigraphic layers in cultural heritage objects is critical for understanding their construction, history, and degradation processes. This study presents a multidisciplinary approach combining Laser-Induced Breakdown Spectroscopy (LIBS), Fourier-Transform Infrared Spectroscopy (FTIR), X-Ray Fluorescence (XRF), hyperspectral imaging, and digital X-ray radiography to analyse heritage objects non/micro-invasively. Spectral data acquired from LIBS, FTIR, and XRF were processed using chemometric methods to classify and differentiate material compositions. Concurrently, hyperspectral and digital X-ray imagistic data were processed using supervised and unsupervised classification techniques, to map surface and subsurface features. The integration of spectral and imagistic datasets was achieved through correlation analysis, where chemometric classification results were spatially aligned with image-derived maps. This synergistic approach enabled the identification and mapping of underlying layers and hidden features not visible to the naked eye. The spectral signatures of specific pigments or materials were correlated with corresponding regions in the hyperspectral and X-ray images, revealing concealed artistic details, restoration interventions, or structural anomalies. The combined methodology demonstrated its efficacy in uncovering complex stratigraphies, providing new insights into the material composition and historical context of the analysed heritage objects. This integrated framework offers a powerful tool for conservators and researchers, enabling detailed non-destructive analysis and preservation planning for cultural heritage artefacts.

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THE SCREAM MOTIF: NEW PERSPECTIVES TO ITS STUDY AND COLORS PERCEPTION

Irina Crina Anca Sandu, PhD

Abstract:
This presentation will show the latest results around the studies of the most iconic motif in the collection of Munch Museum in Oslo and how these researches brought new perspectives in understanding the Scream and its change in appearance over time.
Main projects presented here are the Dating Scream, still ongoing, and the PERCEIVE ((PERCEIVE - Perceptive Enhanced Realities of Colored collEctions through aI and Virtual Experiences) project, a EU-funded initiative, where AI and digital technologies are used to showcase the color change and propose tools and services for monitoring and simulation.
The Dating Scream is an internal project considered priority for the research agenda of MUNCH museum and involved different partners and scientific tools aiming to define the date of the iconic Scream, that nowadays still las a question mark on it (1910?). Started at the initiative of the art historian Petra Pettersen in 2023, the first part of the project involved the use of two scanners (MA-XRF and MA-XRPD) in a campaign run in Spring 2024 with the support of AXIS group at Antwerpen University. The research involved until now 7 paintings (on cardboard and canvas) from the early period (1893-1895) and also around 1907 and it considers to further access MOLAB facilities for analyzing other paintings in the MUNCH's collection from a later period (from 1910 onwards).
MUNCH museum made available for the PERCEIVE project two versions of the Scream, highly sensitive to light and relative humidity: the painting on cardboard dated around 1910 and the hand-colored lithograph dated from 1895. These versions are case studies in the Scenario 2 dealing with color change in paintings and works on paper.
The main research questions around the Scream fading (or darkening, for those colors prone to this phenomenon) that support the creation of novel tools and services based on AI algorithms and color science processes are:

- How a Scream without colors would look like and what this would mean for the European CH?
- Can we recreate the original appearance of the Scream?
- What is the main input data that we need in order to safeguard the memory of these iconic art-objects?
- Are we able to simulate how the objects will look into the future, if we do nothing to mitigate the color fading?
- How can we better transfer to a large public the complex knowledge around sensitive colored materials for painting and print making?
- What kind of experiences (digital, immersive, hybrid) can be designed to enhance perception, authenticity and sense of care of colored collections?

The scientific methodology of PERCEIVE around the Scream case study will be presented along with first results from the combination of analytical results and simulations.
The presentation will resume the main challenges and findings coming from these 2 projects and also the contribution of Heritage science in advancing knowledge and improve conservation practices in important art collections.

LASER CLEANING OF HISTORICAL COPPER ROOFING

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Keywords: copper patina, laser cleaning, diagnostics, conservation

Laser cleaning presents itself as a conservation intervention technology for stone, ceramics, paintings and heritage metals [1-3]. It can play a beneficial role particularly in the cleaning of outdoor bronze monuments and architectural elements, such as copper roofs [4,5]. There exists a wealth of experiences with laser cleaning for outdoor bronzes [6,7]. The optimal conditions for laser cleaning of bronze patina surfaces would be the case “black over green” areas because a black crust would absorb in most of the used laser wavelengths and would be evaporated. Whereas a green patina phase mainly absorbs radiation in the blue and violet range. Actually, cleaning of patinated copper surfaces with ultraviolet and green laser wavelengths resulted in discolouration and darkening, whereas infrared wavelengths allowed cleaning without side effect [4,6,7].

In this study, of historical roofing sheets served as examples. Cu sheets from 1928 of the St. Egyd parish church tower, Klagenfurt, Austria, were removed as part of the church renovation in 2021. Another sample was a Cu roofing sheets from 1947 of the Melk Abbey church dome, Melk, Austria. The removal of this sheet metal was undertaken on an area of ca. 700 m² in 2020.

Laser fluence *F* and pulse number *N* are the overruling parameters controlling the irradiation dose volume density which is the total photon energy absorbed in the material [8]. Therefore, laser treatments of clean patina surfaces, naturally contaminated, and artificially contaminated patina surfaces were undertaken by varying *F* and *N*. The thresholds of cleaning and substrate modification were carried out by colorimetry addressing the patina colour depending on the [Cu(I)]/[Cu(II)] ratio and the layer thickness [9]. Further diagnostics were z-scan digital light microscopy, XRD, and SEM/EDX.

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LASER CLEANING FOR GILDED POLYCHROME SURFACES: A CASE STUDY ON A 16TH-CENTURY RELIEF

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Keywords: laser cleaning, gilded polychrome surfaces, cultural heritage restoration, photoablation.

The use of laser technology for controlled and gradual cleaning of gilded surfaces represents a significant advancement in the conservation and restoration of cultural heritage. This study presents an innovative approach combining laser and solvent-based cleaning techniques applied to a previously unstudied 16th-century polychrome and gilded relief, belonging to the Cathedral of Madonna della Bruna and Sant' Eustachio in Matera.

The artwork, an Annunciation carved in relief, exhibited extensive stratification of foreign substances, including incoherent deposits that obscured the original brightness of the gold leaf. Preliminary analysis revealed that the gilding was composed of highly hygroscopic materials, including a preparatory layer of casein, gypsum, and lime, making traditional cleaning methods unsuitable. The presence of organic finishing layers, such as oil, waxes, and resins, along with pigments like madder lake and smalt bound in oil, required an extremely selective cleaning approach.

Given the heterogeneous nature and fragility of the materials, initial tests with solvent-based cleaning were conducted on detached fragments. Various solvents, including ligroin, white spirit, and cyclohexane, were tested under controlled environmental conditions (21°C, 50% RH). While some deposits were successfully reduced, the risk of weakening the preparatory layers necessitated an alternative, more precise method.

Laser cleaning was then explored as a complementary approach. Several laser systems were tested, including Nd:YAG in Q-Switched and Free Running modes and Er:YAG in Very Short Mode. Parameters were optimized to minimize thermal and mechanical stress on the gilded surface. Due to the high reflectivity of the gold leaf, a humidification strategy was employed to control heat transfer. In thicker deposits, a hydroalcoholic solution was nebulized, whereas thinner layers and fragile areas were treated with ligroin applied via Japanese paper interposition.

The laser cleaning tests determined damage and ablation thresholds, demonstrating that a combination of photoablation (EOS QS Nd:YAG, Q-Switched mode) and solvent-based pre-treatment (ligroin) provided the most effective, controlled, and minimally invasive cleaning method. For fragile, thin layers, a weak acrylic dispersion was applied to consolidate the gilding before laser treatment.

Results confirmed that a combined approach allowed for selective removal of concreted deposits while preserving the delicate polychrome and gilded layers. The cleaning process ultimately restored the luminosity of the gold leaf, revealing intricate details previously obscured. The study highlights the effectiveness of integrating laser and chemical cleaning methodologies to address complex conservation challenges in gilded polychrome sculptures, setting a precedent for future restoration projects.

CHOICE OF LASER ABLATION SYSTEM AND EVALUATION OF RESULTS DURING THE CLEANING PHASE OF THE 16TH-CENTURY GROTESQUES IN THE PRINCE'S PALACE OF MONACO

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Keywords: cleaning, laser ablation, diagnostics, conservation, frescoes

This study aims to establish an effective and controlled laser cleaning protocol by evaluating the impact of four laser ablation systems on the 16th-century grotesque frescoes adorning the ceiling of the Antichambre Room in the Prince's Palace of Monaco. The project focused on understanding the composition and condition of both the original painted layers and the successive overpaintings before and after laser cleaning.

Several test areas were selected and analysed to assess the cleaning effectiveness of four laser systems: Nd:YAG-based EOS QS®, EOS 1000 LQS®, INFINITO® 50W (EL.En. Group), and Thunder Art® (Quanta System). These tests were supported by extensive diagnostic analyses, before and after laser intervention, conducted in collaboration with the Epitopos-Mescla laboratories. Analyses employed included in situ Laser-Induced Breakdown Spectroscopy (LIBS), Fourier Transform Infrared Spectroscopy (FTIR) in DRIFT mode, and Scanning Electron Microscopy (SEM) on micro sections. [1]

The primary challenge of this intervention stemmed from the stratigraphic complexity of the painted surfaces. Multiple superimposed grey layers, differing in origin, composition, and date, complicated both the diagnostic process and the intervention strategy. Alterations such as oxalate layers, carbonated lime wash concretions, and general surface soiling obscured the original polychromy and compromised the legibility of the grotesques. These factors made it difficult to differentiate between degradation, overpainting, and authentic 16th-century paintings through visual inspection alone.

Comparative evaluation of each test area revealed significant variations in the grey tones' response to different laser parameters. Selecting the optimal pulse duration and energy levels for each laser system was critical to achieving effective cleaning while preserving the integrity of the original materials.

The pre-cleaning analytical campaign was essential in establishing a scientifically grounded cleaning protocol. This was followed by rigorous control of the process using spectrophotometric monitoring, along with CIElab and delta E measurements before and after cleaning, to quantify chromatic variations. A final post-cleaning analytical campaign verified the removal or attenuation of altered and repainted layers, thereby confirming the precision and appropriateness of the selected conservation approach.

Acknowledgements
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LEAD ISOTOPIC RATIO INVESTIGATION OF GLAZED CERAMICS USING INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY

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Keywords: glazed ceramics, ICP-MS, lead, isotopic ratio

This study investigates the isotopic composition of lead (Pb) in glazed ceramic artifacts from the Dacian region through the application of quadrupole inductively coupled plasma mass spectrometry (ICP-MS). By analyzing the stable lead isotopes (^{204}Pb, ^{206}Pb, ^{207}Pb, and ^{208}Pb) the research aims to find patterns in isotopes composition can act as provenance indicators. These isotopic ratios are highly valuable in archaeometry, but in the same time they can help identify the geological origin of the lead used in the glaze, provide insight into technological choices made during ceramic production and may also offer clues about ancient trade routes or resource procurement networks. To ensure the integrity of the results, a refined sample preparation method was developed, allowing efficient lead extraction from the ceramic glaze thereby minimizing contamination risks, alteration of the glaze matrix, and matrix-induced analytical interferences. Although quadrupole ICP-MS instruments offer lower mass resolution than sector field mass spectrometers and lower precision than multicollector ICP-MS, in some particular scenarios they can be used for isotopic analysis, when operated under optimized conditions. Instrumental parameters were carefully adjusted, and data correction strategies were applied to account for isobaric interferences and instrumental biases. The obtained isotopic data reveal clear patterns that can be attributed to samples' shared origin (most likely corresponding to specific lead ore sources) and thus demonstrate that quadrupole ICP-MS, despite its limitations, is a powerful tool in archaeometric studies.

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INTEGRATED IMAGING AND CLEANING STRATEGIES FOR THE DIAGNOSIS AND RESTORATION OF DAGUERREOTYPES: ACCESS TO ADVANCED INFRASTRUCTURAL RESEARCH FACILITIES

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Keywords: research infrastructure, laser ablation, imaging, spectroscopy, daguerreotypes

Daguerreotypes, the earliest form of commercial photography introduced after 1839, pose significant conservation challenges due to their metallic nanostructure, high image resolution, and sensitivity to environmental contaminants and inadequate conservation treatments [1,2]. Addressing these challenges requires an interdisciplinary approach based on advanced scientific tools and scientific collaboration. This project presents an integrated methodology for the diagnosis and conservation of historical daguerreotypes, including examples damaged by traditional restoration treatments. Developed within the framework of several national projects and European research infrastructure, the approach exemplifies how shared scientific resources can support innovative and efficient conservation practices.

The methodology combines advanced imaging and chemical analytical techniques with laser-based cleaning strategies. Non-invasive, multimodal imaging, particularly reflectance imaging spectroscopy (RIS) in the visible to near-infrared range (400–2500 nm), was employed to assess image condition and the potential visual recovery, particularly in plates with extensive degradation layers over the entire surface. Laser microprofilometry recorded the microscale topographic features of the plate, while vibrational spectroscopies, including μ-Raman and μ-FTIR in reflection mode, characterized the degradation compounds distributed over the daguerreotype surfaces. These datasets informed condition assessment and guided treatment protocols, allowing detailed evaluation of cleaning outcomes even months after the treatment.

In the second phase, laser cleaning protocols were optimized. Four laser wavelengths were tested: 532 nm, 355 nm (Nd:YAG), 248 nm (KrF excimer), and 193 nm (ArF excimer), operating in both nanosecond and femtosecond regimes, depending on the laser source. In particular, UV lasers demonstrate high selectivity in removing metallic sulfides and calcium carbonate layers without damaging underlying image features.

This methodology, developed through Transnational Access to advanced laser research laboratories at the Institute of Electronic Structure and Laser (IESL), FORTH in Greece, as part of the LaserLab-Europe research infrastructure (RI) [3], is adaptable and scalable for broader applications, for example, to other photographic materials or metal-based heritage objects. By integrating a deep understanding of artefacts from the macro to the microscale, the proposed framework contributes to the development of minimally invasive, evidence-based conservation protocols.

Beyond the scientific contribution, the project also explored access mechanisms to European research infrastructures. In particular, the Aria platform, used by LaserLab RI and developed by Instruct ERIC, was evaluated as a tool for managing research proposals and fostering user-provider collaborations. Its functionalities were useful in building the new Catalogue of Services for the European Research Infrastructure for Heritage Science (E-RIHS) ERIC [4] and are implemented as part of the H2IOSC (Humanities and Cultural Heritage Italian Open Science Cloud) project [5,6].

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RESEARCH OF THE ARCHITECTURAL SURFACES AT THE CHURCH OF "ST. MARTIN" IN THE VILLAGE OF MOTIŞ, SIBIU COUNTY

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Keywords: *mural paintings, microscopy, spectroscopy, diagnostics, conservation*

This article presents the results of interdisciplinary scientific research carried out at the Church of St. Martin in the village of Motiș, Sibiu County, a representative monument for the Romanian medieval heritage,

The investigations started in 2017, included art history studies that involved establishing the dynamics of the history of the Motiș community and stylistic influences. Archaeological research provided data on the layers of previous habitation and the historical stages of construction.

3D scanning was used to create architectural surveys for all buildings that are part of the fortified complex at Motiș.

Through architectural studies, successive interventions of the church and the fortification from the 15th to the 20th centuries were identified. With the help of dendrochronology research, it was possible to date the wooden material from the roof structure and other artistic wooden components. The stratigraphic research of the architectural surfaces highlighted mural paintings in the choir of the church.

Scientific investigations of the interior and exterior materials: optical microscopy, SEM, EDX, FTIR and XRF provided important data about the constituent materials of the masonry structure but also of plaster and paint layers.

Microscopy studies allowed the identification of biodeteriogens (algae, microscopic fungi, lichens and bryophytes) with a major impact on the state of conservation respectively on architectural surfaces.

The results allowed time-framing of different layers, both at the interior and exterior of the church, based on the presence of some specific materials and reactions highlighted at microscopic level.

Acknowledgements

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2017-2021

NON-INVASIVE OPTOACOUSTIC IMAGING FOR IN-DEPTH CULTURAL HERITAGE DIAGNOSTICS

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Keywords: photoacoustic, cultural heritage, diagnosis, imaging, ageing

In the recent years, photoacoustic (PA) techniques have been steadily gaining ground in cultural heritage (CH) diagnostics, demonstrating a remarkable potential for the detailed analysis of complex objects, such as paintings and murals. These methods rely on signal generation through the PA effect, which can be simply described as the formation of acoustic waves following the absorption of intensity-modulated (typically pulsed) optical radiation. The detection of PA signals through spectroscopic and imaging approaches is not only non-invasive, but also provides exceptional optical absorption sensitivity at high depths, especially when compared to the established pure optical techniques in the field. In this study, we present a novel reflection-mode PA prototype that utilizes near-infrared (NIR) excitation light and a spherically focused air-coupled ultrasonic transducer to detect emitted PA waves. This system is designed to investigate in-depth ageing effects in painted mock-ups and to reveal hidden pencil sketches beneath opaque paint layers [1]. To demonstrate the capabilities of the system as regards the detection of degradation effects, we have measured the PA response from various pigmented layers following thermal or photo-ageing procedures. We have observed a gradual increase of the detected PA amplitude as a function of ageing time, revealing also variable deterioration rates for different types of paint. Furthermore, we have additionally employed the second harmonic wavelength at 532 nm and estimated the ratio of PA amplitudes for the two excitation lines, in an attempt to increase the detection sensitivity of the method. In this manner, we have identified the degree of corrosion in various metals and alloys, and distinguished among different types of inks and pigments with similar color characteristics. These findings confirm the effectiveness of PA detection as a complementary diagnostic method to traditional techniques, offering highly sensitive in-depth insights into degradation processes and differentiation of features in a wide range of CH artefacts.

Acknowledgements

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VINCENT DETALLE'S AUGMENTED HERITAGE OBJECT - A VISIONARY APPROACH TOWARDS A UNIFIED FRAMEWORK IN CULTURAL HERITAGE STUDIES

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Cultural Heritage encompasses a multitude of discipline, disparate in their applied methodologies and approaches, spanning from humanities and social sciences, such as art history, archaeology, cultural anthropology or sociology, to natural and experimental sciences, including chemistry, physics, earth sciences or biology, and exact sciences, such as mathematics, engineering or data sciences. Their aims are to have a better grasp on past socio-cultural or economic events, understand how artefacts, monuments or sites have been constructed, used and discarded, or characterize their materiality and conservation state today. Some objects are musealized, other archived, while unfortunate ones perish or buried under modern developments. While the effort on working in a cross-disciplinary way has been long recognized as a priority, there are effectively few attempts at offering sustainable and realistic solutions to this challenge. Among them, the visionary approach advanced by the late Vincent Detalle, suggesting the definition of a new framework for data integration, and thus a new digital object, the Augmented Heritage Object, outstands.

His main suggestion was to align data along three main axes: historic, conservation and mediation, and thus bring together the disciplines associated with them into a unified framework, generating the augmented heritage object. Consequently, this idea frames the foundation for ESPADON, one of the French national flagship projects in Heritage Science, and influenced further developments in major EU-funded initiatives, such as the recently launched European Research Infrastructure for Heritage Science (E-RIHS – ERIC) and its DIGILAB and the European Collaborative Cloud for Cultural Heritage (ECCCH) and its main implementation project ECHOES.

The talk will detail the fundamental principles guiding the developments in DIGILAB and the core principles framing ECHOES's digital commons and advancing its digital continuum.

METHODS AND TECHNIQUES IN DIAGNOSTICS, CONSERVATION-RESTORATION OF CULTURAL HERITAGE

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Keywords: spectroscopy, laser ablation, diagnostics, conservation, painting (max. 5)

The conservation and understanding of cultural heritage rely on the integration of scientific research, advanced technologies, and conservation practices. This paper provides a multidisciplinary overview of recent developments in heritage science, emphasizing innovative diagnostic tools and conservation/restoration treatment methods. Analytical techniques such as X-ray diffraction (XRD), X-ray fluorescence (XRF), optical and electron microscopy (OM, SEM-EDS, TEM), FTIR and Raman spectroscopy, all these enable non-invasive, high-resolution characterization of materials, including pigments, binders, stratigraphy, and previous restoration layers, thereby supporting informed conservation strategies. Furthermore, the application of nanomaterials—such as hydroxyapatite, and carbonated hydroxyapatite—offers compatible and reversible consrervation/restoration treatments. Case studies, including the **Micia fort** - large Roman fort for auxiliary troops and an important part of the western Dacian limes (limes Dacia), used for defense of Ulpia Traiana Sarmisegetuza, **Sacidava Fortress** - Geto-Dacian settlement and Roman castrum, from the Roman era (Trajan era), known as Danube harbour, **Roman Mosaic of Constanţa**, and **Trophaeum Traiani Roman fortress, Adamklissi** - founded by Trajan on the site of the old Geto-Dacian settlement, are discussed in this paper. For all these monuments, the characterization of materials, degradation status and preliminary conservation/restoration tests with nanomaterials, including 3D reconstruction of some of them, will be discussed.

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LIBS Stratigraphic and Elemental Analysis for Evaluating Conservation Treatments in Fossils

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Keywords: LIBS, in-depth analysis, alteration, conservation, heritage science

Conserving paleontological material, particularly fossils affected by pyrite decay, is challenging due to internal chemical degradation and the requirement for minimally invasive analysis. In emergency excavation contexts such as at the Santa María de Ariño mine (Spain), rapid assessment tools are essential for stabilising and preserving fragile specimens. This study presents the first application of Laser-Induced Breakdown Spectroscopy (LIBS) in the field of fossil conservation, with the aim of characterizing the chemical composition and degradation processes in pyritized dinosaur remains. This study evaluates the potential of Laser-Induced Breakdown Spectroscopy (LIBS) as an *in situ* diagnostic tool for assessing fossil stability a guiding conservation strategies. Using a mobile multi-spectral characterization system for cultural heritage analysis (SYSPECTRAL), which enabled high-resolution depth profiling through sequential laser ablation. LIBS revealed layered chemical stratigraphy, distinguishing between surface residues, intermediate altered zones, and core fossil material. These results demonstrate the value of LIBS in evaluating the effectiveness of treatments, providing a powerful tool for making real-time conservation decisions in paleontological fieldwork.

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ASSESSING THE INFLUENCE OF HEAT TREATMENT AND QUENCHING ON CARBON QUANTIFICATION IN ANCIENT STEELS BY LASER-INDUCED BREAKDOWN SPECTROSCOPY (LIBS)

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Keywords: LIBS, carbon quantification, quenched steels, matrix effects, laser ablation

Laser-Induced Breakdown Spectroscopy (LIBS) techniques have been employed in the analysis of cultural heritage materials. In our previous studies [1], we achieved the quantification of carbon in ancient ferrous alloys. However, quenching, defined as a metallurgical process involving the rapid cooling of metal after heating, has been demonstrated to modify the crystalline structure of steel [2]. This modification may consequently increase the hardness of the steel, potentially resulting in a change to the ablation process and, by extension, affecting the reliability of LIBS-based quantitative analysis and especially the one of the calibration curves. Therefore, the objective of this study is to assess whether the LIBS technique can provide accurate and reproducible quantification of carbon in steels that have undergone post-reduction hardening treatments. This work represents a methodological advance in the application of LIBS to the study of ferrous alloys, particularly historical alloys that have undergone complex thermal histories, where precise elemental analysis is crucial for understanding manufacturing and transformation techniques.

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THE REPETABILITY OF TWO LIBS SYSTEMS TO CLASSIFY GILDINGS

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Keywords: On-site laboratory, Laser-Induced Breakdown Spectroscopy (LIBS), Non-invasive methodology, Gilding, Principal Component Analysis (PCA)

Gold leaf has been used in painting for a long time, and its preservation remains a major concern. Current methods for identifying gilding are often visual and require destructive sampling. An initial study program was launched in 2022 to characterize gilding using a laser (LIBS, Nd: YAG 1064 nm, spectral range) in order to reduce the impact. Tests were conducted on samples to determine the composition of different gold leaves. Then, they were statistically classified using Principal Component Analysis (PCA) according to their gold (Au), silver (Ag), and copper (Cu) content. The resulting database was then tested on-site at the Palais des Rohan in Strasbourg, allowing researchers to distinguish restoration gilding from historical gilding.

A second phase of the study was launched to validate the established protocol. Another analysis laser (LIB-z903, ultra-portable, Nd: YAG 1064 nm, spectral range) was used to verify the repeatability. This laser offers higher precision and a larger spectral range (250–950 nm). The analysis spot size is smaller too: 50 µm against 200 µm for the first system used. Same samples (gold, orange, white and yellow leaves) from Eytzinger were studied with the same protocol. Results obtained were consistent with those of the first study and helped refine the model.

HOW TO CLEAN TAGGED PICTOGRAPHS ? ON FIELD AND EXPERIMENTAL RESULTS

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Keywords: pictographs, tags, laser ablation, LIBS, painting

Red ocher pictographs from an Indian site have been recently tagged in Canada using a black spray paint. The aim of this study was to find how to clean them. Chemical cleanings were tested first on a sample coming from the tagged rock, but the results were not good. Based on previous results (Labouré and al., 2022), the laser cleaning seemed then to be the most appropriate technic.
The first “in situ tests” on the rock supporting the pictographs showed the suitability of the laser cleaning. More, its application on the tagged pictographs gave good results comparing images of the pictographs before they were tagged and after the cleaning. The observations using an infield microscope did not allow detecting any change on the red ocher painting compared to the untagged one. To better understand the effects of this technique, laboratory tests were performed on experimental magmatic stones samples modelling the Indian site rock. These stones have been painted using a red ocher that is supposed to be used to create the pictographs according two techniques: application of red ocher mixed in water without or with rabbit skin glue.
The first onsite results show that some residues of the black painting remain on the bottom of the quartz and felsdpar grains. The observations of the experimental samples reveal similar results. The laser cleaning of the samples also leads to a light yellowing of the experimental stone. It seems that this effect was not detected on site maybe because of the rock patina.
Complementary analyses where also performed to understand the effects of this cleaning. These tests include LIBS analyses, colorimetry, SEM and IR camera observations.
The analyses using LIBS and colorimetry have shown their complementarity. Colorimetry shows the evolution of the darkening parameter (L*) with the degree of cleaning. It allows detecting chromatic variations (a*, b*) that can help to assess the efficiency of the cleaning.
LIBS analyses have been focused on the comparison of C and Fe content in the different case studies. They both proved to be good tracors of the cleaning efficiency.
The other analyses are in progress.
In conclusion, the use of an e-microscope, a colorimeter and a LIBS are convenient portable techniques that allow evaluating the efficiency of Nd-YAG cleaning laser to remove a tag that affects red ochre paintings on outdoor granitic stone.

Acknowledgements
The financial support of this work in Canada has been provided by the Osoyoos Indian Band. Logistical support on site was provided by Angela Clyburn, independent archeaologist.

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LASER CLEANING OF VANDALIC GRAFFITI PAINTS ON CONTEMPORARY WALL PAINTINGS

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Keywords: laser, street art, urban art, conservation, sustainable cleaning

Contemporary wall paintings constitute an essential contribution to modern art in urban space, reflecting societal values, cultural expressions, and artistic innovations. Their preservation is paramount, not only for aesthetic appreciation but also for historical documentation and for preserving cultural heritage. Suitable cleaning ensures the durability and integrity of these artworks, safeguarding them for future generations to enjoy and study. Accumulation of gaseous pollutants and dirt, and the uncontrolled graffiti application are ones of the most common deterioration forms, hiding the true colors and details. As occurs when cleaning any artwork, the cleaning of such contemporary paintings must ensure the removal of deposits without causing damage to the paint underneath. This is critical when it comes to removing vandalic graffiti from paintings, given their similar nature. Due to its advantages, the application of laser technology needs to be studied for this purpose and optimized to enhance the process.

To the best of our knowledge, there is no research on the use of laser cleaning for contemporary wall paintings made with modern paints (such as alkyd, acrylic, vinyl, etc.). In this study a solid-state ns Nd:YAG laser working at 1064 nm was applied to extract a blue alkyd paint from samples painted with pink and green paints of different nature (alkyd and polyvinyl acetate paints). Cleaned surfaces were examined with stereomicroscopy, color spectrophotometry, Fourier-transform infrared spectroscopy (FTIR) and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM/EDX). The chemical composition of the vandalism paints and their compatibility with the paint to be preserved are the main factors for satisfactory results.

Acknowledgements
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SUSTAINABLE COATING MATERIAL ENHANCES LASER CLEANING SELECTIVITY ON CONTEMPORARY MURAL AND STREET ART

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Keywords: laser cleaning, contemporary murals, Py-GC/MS, spectroscopy, protective coating

Contemporary murals and street arts are now valued for their accessibility, social impact, and role as platforms for activism, which makes them vital components of modern urban landscapes. However, the conservation of these murals faces persistent challenges from unwanted graffiti and environmental wear.

Recovering the original appearance of murals from undesired graffiti is a critical task. The similarity of synthetic painting materials presents a significant challenge in removing these vandalized surfaces without causing damage to the original paint layer. Addressing this challenge, within the SuperStaAr project (Sustainable Preservation Strategies for Street Art, https://prin2020superstar.dcci.unipi.it/) and based on our previous empirical criteria for evaluating laser cleaning [1], we investigated whether a sustainable, water-based alkoxysilane coating can act as barrier and improve laser selectivity.

Mock ups comprising various spray-paint systems (original + graffiti) were prepared fresh and after accelerated ageing. Samples were either left uncoated or coated with the water-based alkoxysilane, then cleaned with Q-switched and Long Q-switched Nd:YAG lasers under identical fluence regimes. Cleaning performance was analyzed through an integrated approach: colorimetry measurement, ATR-FTIR, Py-GC/MS, laser scanning confocal profilometry, and optical coherence tomography. In both ageing conditions, in most cases, the coating promoted a "peeling" ablation mechanism: the graffiti layer detached cleanly while the underlying paint was minimally altered — even on critical samples where both layers were identical alkyd-based sprays.

These results demonstrate that a water-based alkoxysilane coating not only protects mural surfaces but also enhances the efficiency and safety of subsequent in situ laser cleaning. The study offers a practical route toward more sustainable conservation protocols for urban artworks.

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A PRELIMINARY INVESTIGATION OF DRY CLEANING PLASTER CASTS AND MOULDS WITH COATINGS USING LASER AND PLASMA METHODS

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Keywords: Plaster objects, laser cleaning, cold plasma treatment, original coatings, evaluation

Plaster casts and moulds have been used for hundreds of years in the process of making sculpture and reproducing works of art, and the residues and stains from materials such as oils, resins, shellac, soap and waxes on their surfaces represent important testimony of their physical and technical histories [1,2]. Cleaning their surfaces of subsequent staining, dust, coatings, and dirt from use, exhibition, storage, fire, and/or floods is always a challenge. However, lasers have proven to be an effective tool in cleaning plaster in a selective and modulated way [3-8], and developments in laser technologies offer ever more effective ways of dry cleaning unwanted deposits while respecting original materials. This paper presents a comparative study of different laser techniques applied to cleaning plaster to evaluate established and new technologies. A selection of laser systems (Nd:YAG laser operating at 1064 nm and 532 nm, and Er:YAG laser operating at 2094 nm), and HF Dielectric Barrier Discharge plasma [9,10] were used to perform selective cleaning tests on plaster mock-ups featuring traditional materials as reported in the literature. The surfaces were investigated before, during and after cleaning tests with technical photography, Hi-Res VIS and IR imaging, and microscopy techniques, to identify and evaluate potential colour, chemical and morphological changes. Methods exhibiting the best results were then used on historical plaster objects to judge their effectiveness in selectively removing dirt and deposits while preserving original coatings.

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INFUENCE OF THE PIGMENT AND BINDER ON THE LASER CLEANING OF GRAFFIT IN CAVE PAINTINGS MOCK-UPS WITH AN Er:YAG

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Keywords: laser cleaning, archeological heritage, conservation, kaolin, quartzite

Cave paintings are complex systems composed of inorganic materials and pigments (such as hematite, red earth, or charcoal) mixed with a binder. The identification of these binders is often uncertain due to degradation caused by atmospheric agents, anthropogenic activities (e.g., graffiti), etc. Recent studies on megalithic art have identified binders such as vegetable oils, fatty acids, or casein [1]. These mixtures are applied either directly onto the stone or onto a preparation layer that homogenizes the surface; in NW Iberian megaliths, this layer is typically composed of kaolin [2].

This research investigates the suitability of an Er:YAG laser (150 µs pulse duration, 2940 nm) for removing blue alkyd graffiti from cave painting mock-ups. A mixture of a pigment (hematite, red earth, or carbon black) with an organic binder (butter or casein) was applied to two different substrates: a kaolin-butter mixture or quartzite. Preliminary tests to optimize the laser parameters were performed on reference samples composed of pigments (tablets) and painting mock-ups without graffiti. The damage thresholds for pigments and paintings were identified using stereomicroscopy and spectrophotometry. In addition, the cleaned areas were analyzed using Fourier-transform infrared spectroscopy, pyrolysis–gas chromatography–mass spectrometry, and high-performance liquid chromatography coupled with a tandem quadrupole-time-of-flight mass spectrometric detector. Microtextural changes were further investigated using scanning electron microscopy with energy dispersive X-ray spectroscopy.

The damage thresholds were identified for pigments and paintings, except for that with red earth and butter. Casein provided superior pigment protection compared to butter. In terms of cleaning performance, the most satisfactory graffiti removal was achieved on butter-based painting with carbon black.

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SPECKLE-BASED IMAGING TECHNIQUES FOR THE DIAGNOSTICS OF HISTORICAL VIOLINS

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Keywords: speckle interferometry, ESPI, shearography, speckle pattern imaging, violins

Diagnostics of historical violins is demanding given their dual nature of an artwork and a functional music instrument, subjected to structural and material degradation, and being played for centuries. Nondestructive testing techniques based on laser interferometry may play a crucial role in violin analysis as they provide non-contact and real-time measurement with high sensitivity, allowing to evaluate the material and the acoustic behavior. Example of detected features that impact acoustic properties are structural deformations of the wood or varnish in the sound board, such as microcracks, surface distortions, delaminations, as well as deeper bulk damages, due to aging factors - environment and playing habits.

In this presentation we discuss the use of different speckle-based imaging techniques for violins diagnostics sin full-field, i.e., Electronic Speckle Pattern Interferometry (ESPI), Speckle pattern shearing interferometry, Laser Speckle pattern Imaging (LSI), with a laboratory customized setup. ESPI allows a dynamic analysis by detecting displacements and strain at submicrometer scale, and vibration modes. Shearography enhances the speckle pattern sensitivity, e.g., for the local analysis of small defects in the varnished top plate. LSI allows to optimize a portable setup for measurements in an out-of-lab environment, thus enabling a more versatile - at lower sensitivity - real-time imaging of surface deformations and vibration patterns.

Such techniques are the core of the AMATI VI(H)OLIN suite, developed in the framework of a Next GenerationEU funded research, aimed at giving the proof-of-concept of a novel integrated approach for structural analysis of violins instruments and vibroacoustics features. The measurements from laser interferometric imaging are fused together with data from consolidated diagnostic allowing the integrated inspection of the violin dataset.

The holistic approach is demonstrated on an Italian historical violin by Alfredus Contino.

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TEXT RECOGNITION IN HISTORICAL MANUSCRIPTS: A COMPARATIVE STUDY OF CLASSICAL DEEP LEARNING AND OBJECT DETECTION-BASED APPROACHES

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Keywords: text recognition, damaged manuscripts; object detection, intersemiotic translation, deep learning.

For automatic text recognition, well-established methods such as Optical Character Recognition (OCR) based on deep learning techniques are commonly employed. These approaches perform effectively on manuscripts that are legible with minimal signs of degradation. However, recognising text in ancient manuscripts damaged by events such as floods, e.g. Verona in 1882 and Florence in 1966, remains an ongoing challenge. These documents show various forms of deterioration, including water and mud stains, ink fading, and partial or total loss of textual content, conditions that significantly hinder the performance of conventional OCR algorithms. Nevertheless, beyond the physical medium, the material data retains essential informational value: each remaining trace, even if degraded, may convey historical, cultural, or linguistic content of considerable importance. This underscores the need to develop tools capable of interpreting, ~~and~~ recovering and "translating" such information, even under severely compromised conditions, in order to make them readable to the machine – thus demonstrating that, as M. Bulgakov put it, "Manuscript don't burn" – namely from a semiotic, i.e. interepistemic, point of view.

Recent studies have introduced approaches based on Generative Adversarial Networks (GANs) for restoring degraded documents, improving legibility and enhancing OCR performance. For instance, the DE-GAN model has significantly improved the quality of restored images, facilitating more accurate text extraction [1]. In parallel, integrating text recognition techniques using bounding boxes has demonstrated potential in improving OCR precision. Studies such as that by Tang et al. [2] have proposed using reinforcement learning to optimise bounding boxes, achieving enhanced performance in text recognition tasks within complex visual scenes.

Despite these advancements in text recognition and digital restoration, the combined application of imaging techniques and object detection-based text recognition on flood-damaged manuscripts remains underexplored. Advanced deep learning methods for text localisation and recognition could offer a more robust and accurate solution for digitising and preserving damaged historical documents, thereby contributing to cultural heritage protection and improved information accessibility.

In this exploratory study, we propose a comparative evaluation between well-established traditional OCR methods and an innovative object detection-based approach using deep learning with bounding boxes. The analysis is conducted on two types of manuscripts: one damaged by natural events and one in pristine condition, to highlight the strengths and limitations of each method in different scenarios. Further developments will focus on the analysis of texts in Cyrillic, opening up new perspectives for intercultural analysis and theorisation.This research emphasises the importance of developing integrated frameworks that combine advanced imaging techniques with state-of-the-art text recognition methods and theoretically based interepistemic approach, to effectively address the challenges posed by the degradation of historical manuscripts intended as complex multi-layered semiotic texts.

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COMPUTER VISION MACHINE LEARNING TOOLING FOR CULTURAL HERITAGE

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Keywords: machine learning, model versioning, tooling orchestration, IoT.

During the last years machine learning models have been developed for a large variety of computer vision architectures solving, in a flexible way, different problems in Cultural Heritage. While these models provide accurate and reliable results, they are developed and applied using task focused workflows where each model has its own particularities in terms of the ingestion pipeline and results consolidation. This work focuses on the development of a standardized, consistent and reliable model orchestration for both computer vision transformers and estimators (regression, classification). While models can be developed using a large variety of frameworks that a not interoperable there is a need for a common ground related to the model inference. During the last years such a standard appeared (ONNX[1]). While the system needs to support several types of data ingestion techniques, its main process consists of an orchestrations service allowing for data to be feed through it from physical full-scale devices and IoT. The orchestration service needs implement the specific preprocessing pipeline [2] and capture the model results. As these results, at least in the case of classification [3] is numeric and it has to be translated in plain text. Other models perform vision transforms and similarity search [4] that need to be then converted towards an interpretable output.

Both the input and the output are even structured or unstructured data meaning that the final result needs to be converted in a human readable form while unstructured data (images, media files a.s.o) needs to be attached or referenced from the output result.

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MULTI-DISCIPLINARY RESEARCH AT THE NATIONAL INSTITUTE OF RESEARCH AND DEVELOPMENT FOR OPTOELECTRONICS: THE ROAD TO EXCELLENCE AND SUSTAINABILITY

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Keywords: optoelectronics, research infrastructures, sustainability

Optoelectronics is essential in heritage sciences, facilitating non-invasive analysis, documentation, and preservation of cultural artifacts. Methods including multispectral imaging, laser scanning, and fiber optics enable specialists to assess the composition, condition, and authenticity of artifacts without threatening their integrity. Heritage sciences and optoelectronics are intrinsically multidisciplinary fields that integrate knowledge from various domains, including physics, chemistry, materials science, archaeology, art history, engineering, and computer science.

At the National Institute of Research and Development for Optoelectronics, we incorporate optoelectronics into heritage sciences [1] while also focusing on research and development in Earth sciences [2], technologies and processes for nanostructured materials and sensors, renewable energy sources, food security, and high-pressure fluidic actuation systems.

This paper outlines the trajectory to success and recent accomplishments across all research domains under the institute's mission, alongside the challenges in maintaining the sustainability of these activities. We show how, over time, the emphasis shifted from small collaborative projects with limited scientific aims to extensive multidisciplinary initiatives, where the coordination of activities and the aggregation of resources are essential for optimizing the implementation process. The extensive array of research contracts undertaken by the institute, covering a wide range of topics, coupled with a notable success rate in both national and particularly international competitions, illustrates a strong alignment with current trends in the field, as well as the researchers' excellence and efficiency. Furthermore, the institute's active participation, including leadership roles, in European infrastructures such as E-RIHS ERIC and ACTRIS ERIC ensures the preservation of its long-term association with global research.

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KEEPING KNOWLEDGE IN CULTURAL HERITAGE USING LARGE LANGUAGE MODELS

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Keywords: knowledge respresentation, machine learning, RAG, cultural heritage, data processing flows.

While time passes through, even in the case for common analysis and assessments, knowledge is highly affected by entropy often leading towards mistakes or late responses. This is an important topic especially when users are working with point-and-click tools (like Microcal Origin, Matlab or other visual statistics tools. Simple operations become more time consuming due to the remembering phase in data analytics. Moreover, due to natural evolution, knowledge is hard to pass by between humans and often require several years for a consistent information transfer. With this work we propose a system for knowledge representation based upon one of the leading machine learning tools available. This tool is based upon a Retrieval Augmented Generation [1] - RAG – pattern enhanced for our use case. The RAG encodes information using an text based note taking system (Org-Roam), one of the most established tools for managing information [2]. This representation allows for storing links between topics and this links have to be represented within the RAG's Vector Database thus allowing the topic context required for better results.

Using point-and-click solutions requires the user to learn specific workflows for each of the tools involved in processing raw data. In order to overcome this issue, the raise of common programming languages like [3] allows for data processing using scripts that are more verbose than the close methods hidden behind the user interface menus. Also, using tools like Jupyter Notebook and ORG mode allow for the implementation of *Literate Programming* [4] techniques for writing processing flows scripts for humans rather than focusing on the computer.

One advantage for using Large Language Models while representing knowledge is related to the fact that LLM's can interact with external systems using the Model Context Protocol (MCP). This allows model expansion using other models or scripts.

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POSTER SESSION

ABSTRACTS

LACONA XIV, 2025

INSIGHTS IN MANUFACTURING TECHNIQUE AND MATERIALS OF DOWRY CHESTS FROM NORTH ROMANIA

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Keywords: FTIR spectroscopy, X ray fluorescence, dowry chest, painting

Dowry chests represent important pieces of cultural heritage, as they were an intrinsic part of family life until the beginning of 20th century. However, in the literature, there is a scarcity of information about the nature of materials and techniques. Within the Romanian territory we can find several stylistic typologies specific to the main regions of the country and deeply connected to the tradition. Aside from stylized floral elements found in most of the cases, in Bucovina County appears the motif of rooted heart.

For this study, seven chests from the end of 19th and beginning of 20th century were selected. They are all made of wood, featuring painted decorations, five of them similar in what concerns the style and even decorative patterns. However, previous study [1] highlighted important differences in technique. The aim of this study was to shed light on the question if tradition was taken into consideration only for the decorating motifs, while the materials and technique varied with the artists or time.

A combination of non-invasive techniques - examination with portable microscope under different spectra and portable X ray fluorescence, together with infrared spectroscopy and staining technique for micro-samples, were used to obtain a complete panel of the materials and techniques employed by the artists to decorate these pieces.

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BUILDING FAIR DATA SERVICES: RECENT DEVELOPMENTS OF THE INFRA-ART SPECTRAL LIBRARY

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Keywords: data service, database, FAIR data, open science, heritage science

The INFRA-ART Spectral Library [1,2] is an open-access spectral database tailor-made to fit the necessities of the heritage science specialists that work with (portable) spectroscopic techniques. The database has been designed, developed and optimized during several years and it currently houses a curated multi-analytical dataset of over 2,000 spectra from more than 1,000 reference materials commonly encountered in artworks and archaeological objects.

This presentation provides an overview of recent and upcoming developments, including the integration of new data types, the design of web-based analytical tools, and the implementation of structured educational content. Additionally, it addresses ongoing challenges related to metadata standardization, long-term data curation, and repository sustainability, reinforcing INFRA-ART's role as a dynamic, community-driven platform for the heritage science sector.

Originally conceived as a standalone data service, INFRA-ART has evolved into a FAIR-aligned digital repository through sustained development efforts. Key challenges addressed during this transformation included the enhancement of metadata quality and the improvement of interoperability with the European Open Science Cloud (EOSC) ecosystem. This progress has been significantly supported by participation in FAIR-IMPACT support actions, leading to measurable improvements in the repository's FAIR maturity. Beyond its function as a scientific resource, INFRA-ART is also expanding into an educational platform through the OPEN-SciART project. It now offers a growing body of openly accessible learning materials designed to foster digital and scientific literacy across disciplines. These resources include tutorials, case studies, and articles covering topics such as spectral data analysis and interpretation, material characterization, FAIR data practices, and research data management.

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AIR POLLUTION IN URBAN AREAS AND IMPLICATIONS ON CULTURAL HERITAGE DEGRADATION

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Keywords: particulate matter, ultrafine particles, air quality, historical buildings

Urban air pollution poses a significant threat not only to public health and environmental quality but also to cultural heritage assets [1]. Urban air pollution in Bucharest, capital city of Romania, presents a growing threat to the city's rich architectural heritage, including historical buildings date back to the 19th and early 20th centuries [2]. Major pollution sources such as heavy traffic, outdated automobiles, heating, and illegal waste burning contribute to elevated levels of nitrogen oxides (NO_x) and particulate matter (PM). The pollutants represent a double stressor for historical buildings, as primary degradation of the outdoor facades and infiltration to the indoor environments becoming agents of photo-oxidative degradation (surface blackening, corrosion, and loss of structural integrity), especially when exposed to natural light and high indoor temperatures.

This paper examines the exposure of several Bucharest city's historical buildings to the urban air pollution, which determines acceleration of their degradation. Seasonal particle matter concentration on different size distributions are analyzed using mobile measurements along the same route passing the proximity of several prominent historical buildings in the city: Triumph Arch, Palace of Justice, National Museum of the Romanian Peasant, Grigore Antipa National Museum of Natural History, New "Saint Spyridon" Church. In the summer, particulate matter concentration displays a variety of sources of particles, with transportation being the most significant source. In the winter, however, particulate matter concentration in Bucharest exhibits a more even distribution of sources, but elevated levels. A higher stress due to particle pollution could be evidenced for Triumph Arch, Palace of Justice and New "Saint Spyridon" Church comparing to the rest of analyzed buildings.

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Possibilities of Reflectance Transformation Imaging (RTI) and imaging techniques as useful tools for the evaluation of conservation treatment in panel paintings

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Keywords: reflectance transformation images, diagnostics, conservation, panel painting, multispectral images

Non-invasive imaging techniques play an essential role in diagnosing and monitoring works of art, providing valuable information without affecting their integrity. Reflectance Transformation Imaging (RTI), a relatively recent method of examination and documentation, allows the observation of surface details, through multiple illuminations combined digitally. This method has been used for the evaluation and monitoring of the consolidation treatment on a 19th century Russian icon painted on wood, which had the paint layer severely detached. As a first step in the project, multispectral imaging (VIS, IR, UV, IRFC) combined with radiographic images, FTIR, XRF and OM were used for the identification of painting stratigraphy and materials. Not only the structure of the paint layers has been analyzed, but also the wooden panel which has been shown was the main reason for the detachments. The X-ray image showed inconsistencies in the structure of the wooden panel. Based on the findings, the consolidation treatment could be planned. Due to the specificity of the case with high elevation of the detachments, and richness of details of the painting, it became evident that a monitoring of the consolidation was needed. RTI has been the method employed for the documentation and evaluation of the results.

REVEALING THE ORIGINAL ICONOSTASIS OF ST. GEORGE WOODEN CHURCH FROM IONEŞTI (ARAD COUNTY-ROMANIA). A NON-INVASIVE STUDY BASED ON COMPLEMENTARY SPECTROSCOPIC TECHNIQUES

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Keywords: Hyperspectral imaging, spectroscopy, wooden churches, underdrawings

Wooden Churches from Romania represent a special category of built cultural heritage [1], closely related with the development orthodox Christians rural communities. For the past 30 years the villages in which these churches were built became heavily depopulated, leaving the religious monuments exposed to an accelerated process of degradation due to the lack of interest and financial support. Recently, "The Wooden Churches Association" started to raise awareness and to increase the visibility of these vulnerable type of buildings. St. George Wooden Church from Ionești village (Arad County) is a fortunate case study where the local community supported the efforts for documentation and restoration. As part of the documentation process, a data field campaign was carried out on-site at the beginning of Spring 2024, reuniting a diverse range of specialists such as: architects, restorers, art-historians, and science conservators. The main task of our collective research was to demonstrate the presence of a previous painting layer, which at the end of 19th century was covered by another decoration following the same iconographic pattern but in a different style [2]. Short-wave Infrared hyperspectral imaging (HIS-SWIR), Laser-induced breakdown spectroscopy (LIBS), X-ray fluorescence spectrometry (XRF), Raman spectroscopy (RS) and Fourier Transform Infrared Spectroscopy (FTIR) were complementary applied in order to reveal the initial decoration and to highlight the technological features of both stages of decorations. A HySpex 384 hyperspectral system was used in order to record the iconostasis and part of the wall painting decorations. The results of this inspection were spectacular, revealing a different style and qualitative approach. It also pointed out that in some areas a different iconographic representation was used. The correlation between Raman, XRF, FTIR, and LIBS analysis highlighted, as well as the hyperspectral imaging, a clear difference between the two pictorial layers. The molecular and elemental analysis were further corroborated with the hyperspectral data in order to select with high accuracy the endmembers for supervised classification and mapping of the various materials on the surface [3].

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THE ARTMAP LIF SYSTEM: A CUSTOM IN-HOUSE LASER-INDUCED FLUORESCENCE SCANNING DEVICE FOR THE STUDY OF CULTURAL HERITAGE SURFACES

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Keywords: laser-induced fluorescence, chemical surface mapping, heritage science

Laser-induced fluorescence (LIF) spectroscopy has emerged as a powerful tool in the heritage science field, offering high specificity and sensitivity across a wide range of materials. Originally developed as a point-based method for chemical analysis, LIF has evolved with the integration of scanning systems, leading to the development of LIF imaging instruments [1]. Despite its many advantages and strengths, LIF remains relatively underutilized compared to other analytical techniques, largely due to the limited availability of commercial equipment. At this moment, most reported applications in the field rely on custom-built in-house LIF instruments [2]. This paper presents a recently upgraded, custom-made LIF scanning device developed and patented by CERTO-INOE 2000 [3]. Key updates include the integration of a new ultra-compact flexible laser unit and a critical review of the optical scanning system. Additionally, the electronic and software components have been completely redesigned for optimized functionality. These upgrades, carried out within the frame of the artMAP project [4], aim to support a broader range of applications while improving performance in terms of data acquisition and speed. The system is lightweight, cost-effective, and easily portable, making it well-suited for examining large-scale painting surfaces. Furthermore, high-resolution LIF images at different wavelengths can be obtained by adjusting and recombining the modular harmonic generation units. To demonstrate the effectiveness and reliability of the artMAP LIF system, the examination of several mockup samples and historical artworks are also discussed as representative case studies.

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THE USE OF OPTOELECTRONIC TECHNIQUES FOR THE INVESTIGATION OF MEDIEVAL WEAPONS

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Keywords: medieval weapons, non-destructive analysis, spectroscopy

The present work describes the application of chemometric techniques to the analysis of medieval weapons from the area of Romania. Nine weapon heads, dated between the 10th and 17th-century, were included in the study, from the inventory of the National History Museum of Romania. For the characterization of these weapon heads, a non-destructive analysis protocol was applied, involving elemental and molecular analysis and unsupervised learning algorithms for data post-processing. The results pointed out the main factors influencing the variability of the dataset are given by a combination between the chemical composition of the bulk material, and that of the patina.

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WHEN DEGRADATION PRESERVES: THE PTAH STATUE CASE STUDY

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Keywords: laser cleaning, carbonate concretions, egyptian blue, multispectral imaging

The statue of the god Ptah (1386-1349 BCE), housed at the Museo Egizio di Torino, presents a unique conservation challenge. Originally fully painted, traces of polychromy remain visible, particularly on the right side of the throne, now crystallized within carbonate concretions. Over the centuries, a layer of atmospheric deposits has penetrated the porous structure of the limestone.

The restoration of the Ptah statue is part of a broader interdisciplinary research project that combines 3D scanning, multispectral imaging, and epigraphic survey. These techniques enabled both the monitoring of the statue's condition throughout the restoration process and the identification of the original execution techniques and types of degradation. In particular, the detection of Egyptian blue through multispectral analyses—hidden beneath coherent deposits and invisible to the naked eye—highlighted the need to adopt an extremely selective and gradual cleaning methodology. Moreover, a significant challenge arose from carbonate concretions, which trapped both polychrome traces and dirt particles, resulting in a unique coexistence of material to be preserved and material to be removed.

Traditional cleaning methods proved ineffective. After optimizing fluence and defining an irradiation protocol, laser technology emerged as the only viable solution for removing unwanted deposits while preserving the underlying stone and pigments.

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A LASER-BASED BOTTOM-UP APPROACH FOR THE CHARACTERIZATION AND CONSERVATION OF HISTORICAL TEXTILES

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Keywords: Spectroscopy, Laser ablation, Conservation, Dyes, Textiles

Lasers are versatile tools applied across fields such as nanofabrication, spectroscopy, and conservation of cultural heritage. Their broad applicability and selective action make them especially valuable in conservation studios for cleaning delicate materials like paintings, paper, textiles, and ethnographic artifacts. The present study highlights the multifunctionality of laserbased techniques through a multi-step investigation involving the material characterization and laser cleaning of three historical tapestries (16th–18th century) provided by the Royal Tapestry Factory, Madrid. A multi-analytical approach, comprising Optical Microscopy (OM), Diffuse Reflectance FourierTransform Infrared Spectroscopy (DR-FTIR), Fibre Optics Reflectance Spectroscopy (FORS), Colorimetry and UV-induced fluorescence photography, was used to characterize materials and assess surface changes following laser treatment. The latter was performed using a 1064 nm Long Q-Switched Nd:YAG laser (120 ns pulses), as proved to be the most effective and safe wavelength for cleaning textile materials dyed with organic colorants. Key findings of this study include the identification by DR-FTIR of silk and wool as the primary textile materials. μ-Raman and Surface Enhanced Raman Spectroscopy (SERS) were used to identify organic dyes. SERS was performed by extracting dyes via acid hydrolysis and enhancing the signal with silver nanoparticles synthesized by laser ablation in water (1064 nm, Q-switched, 20 Hz). The SERS protocol successfully revealed the presence of weld, alizarin, and cochineal dyes, while μRaman confirmed the presence of indigo in blue regions. Preliminary laser cleaning tests demonstrated that, within the optimal fluence range of 0.5–1.0 J/cm², efficient dust removal was achieved without inducing optical or chemical alterations to the substrate. This work represents a meaningful step forward in the field of textile conservation, demonstrating the potential of laser technologies for the safe and effective cleaning of dyed historical fabrics.

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WOOD SURFACE MODIFICATION FOR SUSTAINABLE AND SAFE USE

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Keywords: hydrogels, conservation, flame retard, antibacterial effect,

Wood is one of the oldest and most versatile materials used in construction and everyday life, appreciated for its beauty, resistance and natural properties. However, a major disadvantage of wood is its flammability, and in this context, wood stands out for its particular vulnerability to fire. In this work, new flame retardant hydrogels based on cellulose-derived polymers (HEC and MC), silica nanoparticles and calcium carbonate were developed and tested in order to improve the flame retardant properties and the antimicrobial, antifungal and antibiofilm properties of wood. Silica nanoparticles with an amorphous structure were synthesized by the Stöber method, and HEC/MC/SiO_2/$CaCO_3$ hydrogels were obtained by the sol gel process, at room temperature and applied by brushing. FTIR and SEM analyses confirmed the integration and uniform distribution of the hydrogels on the surface and inside the wood, and TG-DSC analysis revealed an increase in thermal stability. The treatments demonstrated a moderate antibacterial effect without affecting the appearance or integrity of the wood. This surface modification technology has the potential to significantly improve the safety and durability of wood used in construction and restoration.

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INNOVATIVE CROSS-DISCIPLINARY STRATEGIES IN DEVELOPING MODERN CONSTRUCTION MATERIALS

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Keywords: nanomaterials, built heritage, conservation, natural compounds

In recent years, there has been a noticeable rise in the search for novel biocidal agents, with most efforts directed toward enhancing human health through new compounds, while comparatively less attention has been given to the protection of culturally significant structures and artifacts. The widespread application of conventional synthetic biocides (pentachlorophenol (PCP), tributyltin oxide (TBTO), zinc carboxylate, boro-esters, etc.) present numerous challenges, including their high toxicity, limited effectiveness, and elevated production costs. An example of this phenomenon was observed at the San Martiño Pinario Monastery in Santiago de Compostela, where different products were used to eliminate *Apatococcus lobatus* [1].

In this context, the aim of the study is to present synthesis and characterization protocols for different innovative materials, integrating new concepts, formulations and strategies, in order to enhance the antibacterial properties of the construction material, thus decreasing significant gaps in knowledge on the sustainability of building materials enriched with metal nanoparticles.

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HYDROXYAPATITE-BASED TREATMENTS FOR THE CONSERVATION OF TRADITIONAL BUILDING MATERIALS

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Keywords: hydroxyapatite, materials, built heritage, conservation

The use of hydroxyapatite (HAP), a calcium phosphate compound structurally similar to the mineral components of traditional lime-based materials, has emerged as a promising approach in the conservation of historic buildings [1, 2]. This work investigates the potential of hydroxyapatite and selected HAP derivatives for the protection of architectural substrates.

The study focuses on formulating application protocols suited to the diverse nature of traditional construction materials. Treatment performance was assessed through a multidisciplinary methodology combining physicochemical characterization (FTIR, SEM-EDX, XRD), microstructural analysis, and mechanical testing. Obtained results suggest that hydroxyapatite-based treatments can enhance surface integrity and resistance to environmental and microbial-related decay, maintain the visual and physical authenticity of the original materials, thus supporting the integration of HAP systems in conservation strategies tailored to the needs of built heritage.

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CONTRIBUTIONS TO THE KNOWLEDGE OF PAINTINGS MATERIALS OF LATE RENAISSANCE TRANSYLVANIAN MURAL

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Keywords: wall painting, Transylvania, late Renaissance, orpiment, conservation

This paper presents the results of material investigations carried out on a 17th century wall painting from Sibiu, Transylvania. These paintings made in 1628, by an anonymous painter, for the Saal of the Stamp House in Sibiu, are considered unique within the Transylvanian iconography. Recent studies suggest that the iconographical depictions of the house can be seen as a visual testament commissioned by the owner of the house, the merchant Gregor Stamp, for his young sons, as they are illustrating antithetical images with an educational purpose [1].

The investigations were carried out within the framework of the restoration project (still ongoing), with the aim of getting a better understanding of the composition of the plaster, the pigments, the binders and painting technique. The onsite preliminary examination revealed technical characteristics similar to *Kalkmalerei* technique, a version of fresco technique used by artists in Central Europe. In depth identification of pigments, painting stratigraphy as well as possible organic materials introduced during previous interventions were further investigated by laboratory means. Non-invasive (portable X-ray fluorescence) and micro-invasive (SEM-EDX and FTIR) analyses conducted on samples taken from representative areas of the painting were combined with advanced microscopy examination of cross sections. Although traditional inorganic pigments, compatible with alkaline environment of *Kalkmalerei* technique were expected, results showed the extensive use of orpiment and red lead. The occurrence of orpiment in the wall painting decoration in Transylvania can be connected with its natural abundance in this region.

This valuable data offers the opportunity to contribute to the knowledge of techniques and materials used by Transylvanian artists for secular painting in a period when Western influences were still present.

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DOCUMENTATION OF EASEL PAINTINGS – CASE STUDY OF TWO 19TH-CENTURY PAINTINGS BY UNKNOWN AUTHOR

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Keywords: spectroscopy, conservation, painting (max. 5)

Two paintings coming from the main nave of a family crypt in the Jewish cemetery of Alba-Iulia, in Romania, have been evaluated prior to restoration, through a multi-analytical analysis protocol. Although they had been the subject of previous documentation interventions, the paintings were in a poor state of conservation, which impinged a very delicate approach, so as to not extend the damage to these fragile paintings.

The results indicated that the paintings were, most probably, made by the same painter, as the similitude between the materials of the two paintings was very high. Both paintings showed the use of Prussian blue for the blue areas, and iron oxide, along with a natural mineral pigment for the brown areas, vermilion for the red hues, and a chromium-green pigment for the green and amber areas. Both paintings showed various calcium, zinc and lead degradation products. The results of the analysis protocol were useful in contouring the most appropriate restoration intervention.

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MORTARS CHARACTERIZATION BY LIBS

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Keywords: Mortars characterization, on-site LIBS, hydraulicity, Statistical analysis (PCA)

The Church of Saint John the Baptist of Abbetot in La Cerlangue is a building that has undergone numerous phases of construction and restoration between the 11th and 20th centuries. The construction of the first church began in 1050, but no traces of it remain today. The crypt, choir, and chancel were newly built around 1060, and at that time, the building did not feature any painted decorations. The nave was built in the 13th century, and the transept underwent changes in the 15th century, including the reinforcement of the crossing and the removal of the north and south arms. In the 18th century, the north wall of the nave was rebuilt in brick. Since 1835, the church was then abandoned. Repairs of the masonry, the vault, and the crypt became necessary. Around 1855, Dauvergne intervened to restore certain decorations in the crypt and the upper church. Finally, the 20th century was marked by several phases of restoration work, including mortar consolidation and biological treatments.

As part of the material study, Epitopos was commissioned by restorers Céline Maujaret and Mélodie Bonnat to characterize a large portion of the mortars. On-site laser analyses with a LIBS system z-903 were carried out on June 12, 2024. Then, statistical analysis (PCA) on LIBS data were performed and linked with observations and microscope (SEM-EDS) results in order to characterize and compare them.

Visual observations allows us to classify mortars in function of the color and the granulometry. Given the limited study budget, only a few samples were selected to be analyzed by SEM-EDS microscopy, serving as reference. LIBS characterization permit us to highlight several groups based on the hydraulicity of binders. Furthermore, this study allowed the development of a method for comparing mortars on-site using LIBS technology.

CHARACTERIZATION OF HISTORICAL FAÇADES WITH MULTIMODAL IMAGING TECHNIQUES

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Keywords: spectroscopy, laser ablation, diagnostics, conservation, painting (max. 5)

The characterization of historical façades involves advanced imaging techniques to assess materials composition, deterioration and previous repairs of architectural surfaces. This paper presents a non-invasive approach combining advanced imaging techniques such as photogrammetry, thermal imaging and UV fluorescence.

The results are processed and optimized for online presentation on a dedicated web platform, which allows users to interact with 3D visualizations of the data. This allows comparing various aspects of the façade and evaluating its condition without the need for specialized software.

A case study of a Romanian church from the 17th century demonstrates how this method can be an efficient way to document and preserve historic buildings. This approach improves accessibility, promotes interdisciplinary collaboration and supports informed decision-making in cultural heritage conservation.

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LASER ABLATION INDUCTIVELY COUPLED PLASMA MASS SPECTYROMETRY (LA-ICP-MS) APPLICATIONS IN HERITAGE SAMPLE INVESTIGATIONS

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Keywords: numisatics, ICP-MS, laser ablation

This study investigates the applicability of quasi-nondestructive laser ablation analytical technique for the elemental analysis of archaeological artifacts and numismatic items. Laser ablation was paired with an inductively coupled plasma mass spectrometry (ICP-MS) equipment (with a quadrupole mass filter), in order to provide a powerful tool for analysis with lower detection limit than conventional non-destructive techniques such as X-ray fluorescence (XRF). While XRF is widely used due to its portability and ease of use, it is often limited in sensitivity and unable to detect trace elements with high accuracy. Nevertheless, laser ablation introduces specific analytical challenges, particularly in relation to the geometry and surface irregularities of historical samples, the heterogeneity of archaeological materials, data acquisition from surface layers only, and the complex calibration procedures. Proper calibration, often using matrix-matched standards or carefully selected reference materials, is critical for obtaining meaningful quantitative data and often impossible in certain scenarios. The technique enabled precise determination of elemental ratios with only minimal alteration to the sample surface, while avoiding the need for specific calibration in this particular case. Furthermore, with optimized instrument settings and calibration protocols, the method shows strong potential for broader applications, such as pigment identification and even isotopic ratio determinations, in cultural heritage applications.

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NEW APPROACH TO LAYERS REMOVAL IN GILDING CONSERVATION FOR BETTER CONTROL OF Er:YAG LASER SURFACE ABLATION ACCOMPANIED BY ANALYSES FOR SCIENTIFIC DIAGNOSIS

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Keywords: laser ablation, LIBS, diagnostics, oxydation, gilding, metallical layer

The conservation of the gilded surfaces of the console of Verbeckt, dating from the 18th century and from Versailles' palace, was carried out in the gilding workshop of the C2RMF by Stéphanie Courtier.

The preliminary study of the gilded wood surface by the conservator has revealed the presence of two gildings. The water gilding is original and composed of the mats and brunishes. We observe that the invasive conservation resulted in a second gilding of this surface. The original mats gilding surface is covered by the oil gilding with a chemical pigment.

The removal of the original decorations was then considered and led to a discussion on the feasibility of such a removal of two layers with the same binder. It should be noted that the conservation-conservation of original surfaces generally begins with the research of bibliographic sources, the knowledge and understanding of techniques, traces and the materiality of the object. During the conservation of gilded wooden works, cleaning and mechanical and/or chemical removal are commonly performed. These choices of intervention are related to the problem encountered and are influenced by the conditions of the original surface. Although the range of tools available to the restorer is nowadays wide, in some cases, the physico-chemical properties of the materials make the choice of a satisfactory method challenging.

Following the Lacona XIII conference, which presented the laser in the sciences of cultural heritage and associated current research, a conservation was carried out on gilded ivory using a pulsed Er:YAG laser (2940 nm, µs regime). This new approach to gilding in decorative art treatment has made it possible to overcome the limits of traditional methods. The physical parameters of the laser (coherence, selectivity, energy and high precision) make it an appropriate tool for this type of application. It enables the layers concerned to be cut physically and/or thermally, without direct contact with the material and with micrometric or even sub-micrometric precision. The laser treatment coupled with OCT was accompanied by analyses under X-ray Fluorescence, under ion beam on AGLAE, by SEM analysis and by ultraviolet and composite absorption Fluorescence (CAF) imaging at the Research Department and the Imaging Group of C2RMF.

These pulsed laser removals required sophisticated work, in particular the implementation of laser cleaning protocols monitored and controlled by optical coherence tomography (OCT) and LIBS (.....). Following trials and validation of a protocol, the combined use of Er:YAG, OCT and LIBS on twisted and gilded columns enabled the gradual and controlled removal of the thickness of the gilding at different levels, using different laser repetition rate and energy settings. Firstly, the oxidised metallic overpaint and the metal foil were removed, then the No. 2 oil layer, and finally the preparatory layer was completely removed. This work was obtained during the conservation by Stéphanie Courtier, Head of the workshop and conservator of the gilding surface on the wood and Xueshi Bai, head of the laser lab the OCT to C2RMF and Vincent Detalle.

A technique was used to remove an oxidised metallic overpaint and a modern gilding. The laser treatment and OCT were accompanied by LIBS, SEM and ultraviolet analysis in C2RMF's Research Department and Imaging Group.

We will present in detail the process, the experimental methodology and the results obtained during conservation.

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INTERPRETING THE MATERIALS AND EXECUTION PROCESSES OF THE ARRINGATORE FROM PILA USING ADVANCED PHOTONIC TECHNIQUES

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Keywords: LIBS, Raman, Archaeometallurgy, Large bronze, Etruscan

The Arringatore (Orator) is the celebrated life-size (height: about 180 cm) Etruscan bronze portrait of Aule Meteli, a prominent public official in late Republican Etruria, which is exhibited at the National Archaeological Museum of Florence. This large bronze masterpiece was found in Pila, near Perugia, Italy, in July 1567 and soon after (August 1567) it was bought by Duke Cosimo I de' Medici and brought to Florence. During 2008-2009 the statue underwent thorough investigations and overall restoration intervention including laser assisted removal of late patinations and construction of new mechanical support. In a previous work [1], the main aspects of the successful laser treatment of such a non-gilded ancient large bronze was reported. Here, we present and discuss for the first time the results of the complex and extensive archeometallurgical investigation carried out during this intervention. It included metallotechnical examination based on digital 2D/3D imaging and X-ray radiography to recognize features supporting the interpretation of casting, repair, finishing, and past restoration processes, along with LIBS elemental depth profiling of stratified mineralizations and alloy substrate. At the same time, laboratory material characterizations were carried out on several minute samples by means of optical and SEM-EDX micrography and XRD analyses. Finally, Raman and FTIR insights have been recently carried out on some of the available stratification samples, which provided additional information on copper minerals and organic components. The comprehensive multianalytical results achieved will be here presented and thoroughly discussed within the framework of very debated knowledge problems concerning the Etruscan and Roman alloy recipes along with their casting, assembling, and patination techniques. Besides unveiling peculiar compositions and construction features, special emphasis will be dedicated to important analytical evidences, which substantially support the thesis the Arringatore formerly had a rather dark appearance given by the application of an intentional patina whose traces were formerly pointed out by micrography, XRD, and confirmed by Raman mapping.

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Depth Profile Analysis of 19th Century Electrotype Artefacts by Laser-Induced Breakdown Spectroscopy

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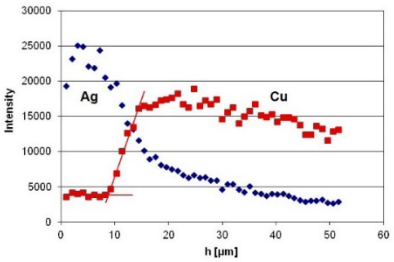
Keywords: LIBS stratigraphy, galvanic coatings, laser ablation, diagnostics

A collection of electrotype objects from the 1840s and 1850s containing Ag- or Au-plated copper plates and medallions (Technisches Museum Wien, Vienna, Austria) has been manufactured by the first commercial laboratory for electrotyping in Austria, established by Franz Theyer in the period 1839–1851 [1,2].

The present work focuses on the potentials of depth profiling analyses by Laser-Induced Breakdown Spectroscopy (LIBS) to supports conservation interventions. All tests were conducted on samples that simulated the original artefacts.



The graph shows an example of a depth analysis of a galvanic Ag film on a Cu substrate employing LIBS with a Nd:YAG laser (7 ns pulses, 532 nm). This resulted e.g. in a Ag film thickness of 8,78 µm in excellent agreement with X-ray fluorescence (XRF) results of 8,88µm.

Even in cases where the ablation rate per pulse is close to the layer thickness (<1 µm) quantitative depth profiling is accessible by a stratigraphic LIBS model assuming near-Gaussian beam profiles [3,4]. This model has been successfully applied to various film systems by means of empirical fitting functions, where discontinuities indicated layer boundaries. This mathematical algorithm was designed to even resolve thin intermediate layers. Further, it was pointed out that the wavelength plays a decisive role in the ablation rate (depth/pulse) when plasma shielding sets in.

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THE USE OF ACTIVE FIBER LASER SYSTEMS IN CULTURAL HERITAGE: CASE STUDIES ON SANDSTONE MATERIALS

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Keywords: laser cleaning, conservation, active fiber laser, sandstone, graffiti removal

In recent years, active fiber laser (AFL) systems have increasingly emerged as a promising technology in the field of cultural heritage conservation. Their effectiveness, rapid action—especially on large surfaces—and environmental friendliness make them attractive alternatives to traditional cleaning methods, such as mechanical and chemical processes, as well as to conventional laser systems.
Since 2018, the Centro per la Conservazione ed il Restauro dei Beni Culturali (CCR) "La Venaria Reale", Italy, has conducted extensive studies on this technology, applying it to various case studies [1, 2, 3, 4] and participating in both national and international research projects. These include the LASERING-PH project, led by the University of Vigo in Spain [5]; the "SUPERSTAR - Sustainable Preservation Strategies for Street Art" project [6], led by the University of Pisa and involving several research groups from Italian universities and the National Research Council (CNR); and a Ph.D. project titled "Innovation in laser cleaning for cultural heritage: increasing the knowledge of active fiber laser systems and optimizing the use of Er:YAG systems with chemical agents", led by the University of Turin in collaboraration with the El.En. Group.
This contribution aims to highlight the effectiveness of AFL systems in addressing complex conservation challenges, through the presentation of two successful case studies: the Temple of Ellesiya (originally from Nubia, ca. 1430 BCE), now part of the collection of the Museo Egizio in Turin, Italy; and the Hegra UNESCO World Heritage Site (6th century BCE) in Saudi Arabia. Despite the remarkable differences in historical context and chronology, both artifacts share a similar stone substrate—namely, a very fragile and porous sandstone. In the case of the Temple of Ellesiya, the intervention aimed to remove deteriorated vynil, acrylic, and polyester resins, which were no longer suitable for preserving stone. The cleaning was performed using a Smart 300 system by the El.En. Group and was supported by a multi-analytical campaign aiming to characterize the materials and monitor the cleaning process. In the case of the Hegra UNESCO archaeological site, the focus was on evaluating the effectivness of active fiber laser thecnology for removing graffiti vandalism, using the Infinito 100-Watt laser by the El.En. Group. Multiple tests were conducted on spray paints of various colors, some of which had naturally aged by being exposed to outdoor conditions for up to 20 years, resulting in deep penetration of the paint into the stone substrate. The treatment, carried out during a laser training session for the Royal Commission for AlUla (RCU) conservation team, posed additional challenges due to its on-site nature. The cleaning results were monitored using a USB portable optical microscope, which demostrated the effectiveness of laser cleaning compared to other methods, particularly in terms of spatial control.

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LASER CLEANING OF WOODEN PAINTED ARCHEAOLOGICAL FINDINGS FROM THE EGYPTIAN TOMB OF KHA AND MERIT

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Keywords: painted wood, ancient Egypt, laser cleaning, spectroscopy, gas-chromatography

This project presents the laser cleaning assessment of seven painted wooden boxes belonging to the collection of the Museo Egizio of Turin. The Centro Conservazione Restauro "La Venaria Reale" (CCR) carried out the study and conservation treatment of part of the funeral equipment of Kha and Merit, discovered in 1906 in Deir El Medina, Egypt. The boxes originally contained several goods they are painted on the outer surface with geometric decorations and figures. A multi-analytical investigation focused on the characterization of painted layers, overlapping materials, non-original coatings and of degradation phenomena that occurred over time, aiming to develop appropriate conservation protocols.

Based on the previous experience of the CCR on the conservation treatment of archaeological artifacts, laser cleaning was compared to traditional dry-cleaning methods [1, 2]. The treatment, performed using an Nd:YAG system in Long Q-Switch mode (Eos 1000 LQS by El.En group), was challenging because of the high sensitivity and the de-cohesion of the paint layers as well as the heterogeneous nature of dirt deposits. The results were monitored by combining surface observation with optical microscopy (OM) and analysis of ablated material by means of Fourier Transform Infrared Spectroscopy (FTIR) and Pyrolysis Gas Chromatography-Mass Spectrometry (Py-GC/MS). For the latter analysis, an innovative passive method was tested to collect the material, placing a quartz filter on the micro-aspirator during laser cleaning [3]. In conclusion, it was possible to define a specific cleaning method for each object that allowed the removal of dirt and non-original overlapping layers, well preserving the original paint.

Acknowledgements
Our sincere thanks go to the members of the Museo Egizio in Turin for their ongoing collaboration in the field of cultural heritage conservation and to the TT8 project partners for their support in the study of the finds. We would also like to extend our gratitude to the University of Turin. Special thanks to Light for Art, El.En. Group, for their longstanding collaboration.

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Objectification of Er:YAG laser-assisted chemical cleaning : example of a glue patina removal from a tempera painting

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Keywords: laser cleaning, chemical cleaning, repaints, layers of glue, tempera painting on panel.

The cleaning treatment of paintings involves gradually reducing or removing exogenous layers that have accumulated on the surface, without damaging the original materials.
As part of a thesis on the removal of overpaint using an Er:YAG laser, a hybrid protocol combining this laser (2940 nm) with slightly basic buffer solutions was tested on the *Saint Etienne et Sainte Lucie* (16th century, Figure 1), which is conserved at the Musée Jacquemart-André in Fontaine-Chaalis. Combining chemical and physical methods reduces the number of times the solution-soaked cotton needs to be passed over the surface, minimises friction and speeds up the work.
FTIR analyses were carried out to characterise the materials making up the paint and the layer to be removed. Infrared images with false colour computer processing were used to obtain information about the pigments. In the Italian tradition, the paint was applied over a layer of calcium sulphate-based primer and was painted in tempera and oil. The paintwork had been restored several times and was covered with a layer of animal glue, wax inlays, oil and water repaints as well as a thick layer of oxidised varnish. The surface layers were removed using chemical methods involving solvents and emulsions. However, it was very difficult to solubilize the protein glue layer, in contact with the original paint. This could only be achieved using sligthy basic buffered water, but several passes were necessary, so a hybrid protocol was tested in a small area.
Cleaning tests were perfomed by comparing two laser systems: an EOS Combo Nd:YAG (El. En. S.p.a), with a wavelength of 1064 nm in LQS (100 ns) pulse mode and a Light Brush 2 Er:YAG (El.En. S.p.a), with a wavelength of 2940 nm in Very Short (150 µs) mode.
We will present the promising results of these tests and the scientific methodology developed to evaluate this hybrid protocol.

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Our thanks to the Fontaine-Chaalis for the concrete collaboration.

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