CULTURE 2000
"SAVING SACRED RELICS OF EUROPEAN MEDIEVAL CULTURAL HERITAGE"
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Radiation Science in the Service of Art

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The introduction of laser divestment and diagnostic technologies into the field of art conservation has paralleled similar events that took place in laser application to the entertainment, science, manufacturing, military ordnance, communication, and medical disciplines (to name a few). Similarly, numerous conservation applications for lasers have been shown to be feasible in art conservation practice. During the early years of laser art conservation, scores of technical papers reported on projects that had developed some of these into practical conservation tools. In many cases this involved producing models for the laser-ablation processes, advancing the associated laser technologies, or determining optimum laser parameters for particular circumstances. In recent years this maturing research has focused on case histories, refinements and adaptations in technique, and the broadening of databases.

Much remains to be accomplished along these veins and will continue to advance the state of the art. However, the great breadth of materials and circumstances encountered in the conservation of antiquities suggests a potential for a much broader range of scientific endeavor within the art-conservation community. (This is not to say that there is not already considerable technical diversity within the field including new cutting edge efforts to incorporate nanotechnology.) Specifically, there are numerous new and emerging technologies that could either be useful in conservation or could be employed more broadly and extensively. Scientifically, they have a great deal of commonality with laser technology, except for their operation outside of the visible portion of the electromagnetic spectrum.

A few examples of these are nm ultrasonic imaging, X-ray holography, surface penetrating radar, millimeter wave imaging, portable and free-induction nuclear magnetic resonance, micro CT scanning, and x-ray and UV backscatter imaging. In addition there are laser technologies such as photoacoustic spectroscopy, matrix-assisted ablation, and photodynamic chemistry that hold promise for conservation science, but have yet to be applied to any great extent. Consequently, with the considerable array of new conservation problems that are likely to be encountered with the diverse historic sites in Sucesva County, this may be a propitious time to consider advanced technologies that may further this conservation program as well as serve to disseminate the results to the larger community.

Key words: laser conservation, millimeter wave imaging, radar imaging, x-ray backscatter, nuclear magnetic resonance imaging, photoacoustic spectroscopy, photodynamic chemistry.

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Microscopic Analysis of the Fibers from the Isachta Mummy Fabrics

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The article presents the results of the microscopic and qualitative fibre analyses of Egyptian Isachta mummy dating from the 7th to the 6th century A.C., housed in the National Museum of Slovenia.

Prior to the conservation and restoration of the textile part of the mummy it is important to identify the kind of material that was used, its texture and origin. On Egyptian Isachta mummy the analyses of the weft and warp thread, have been executed. The analyses were performed on two cloths and several kinds of bandages used for wrapping mummies during the mummification process.

Over centuries, the fibers were ageing. Slowly, various textile degradation degrees were attained due to the dust loading on the textile. The degree of the pathological degradation process on the textile part of the mummy that had been attained since the moment the mummy came into existence has also been analysed. It has been found that the degree of lightning and the degree of relative humidity and temperature, to which the mummy textile had been exposed, contributed to fiber degradation.

Key words**:** archaeological textiles, ancient textiles, fibre analyses;

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Investigations performed to point out the interactions between artworks and microclimate variability within the European Project Friendly-Heating

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Churches have been utilised for centuries without heating, and when they have been heated, artworks suffered or were dramatically damaged. If the Temperature (T) is kept constant throughout the whole cold season, the Relative Humidity (RH) drops to very low levels which are dangerous to wooden artworks, tapestry and paintings, for the loss of bound water. Humidifying the air would inevitably led to condensation on cold walls and ceiling with growth of moulds and fungi. The worst case is with sporadic heating, when the largest variations in T and RH occur. The T peaks during services cause drops in RH, and paintings on canvas and other artefacts with low thermal inertia, dehydrate and shrink. Conversely, frescoes, which have high thermal inertia likely remain below the Dew Point raised from people breathing in crowded conditions and suffer from moisture condensation. The EU Friendly-Heating project (i.e. both comfortable for people and compatible with conservation of art works preserved in churches) is aimed to warm people leaving the church and artworks in their natural, unaffected microclimate. The solution is based on a local heating from a number of radiant elements strategically located in each pew, in order to optimize the physiological needs for thermal comfort. The altar area is heated with heating carpets, altar cloth and remote quartz tubes.

The project has studied the problem with physical models, CFD simulation and then on the site with a global approach. In particular, it carefully monitored the air indoors (e.g. microclimate, droughts) and outdoors, the structures (e.g. surface temperature), the energy dissipation and the air leaching, the actual response of artworks (e.g. dimensional changes) to microclimate variability and the human thermal comfort (e.g. infrared equilibrium temperature, average skin temperature). Thermal comfort and conservation have conflicting needs, and an adequate compromise between the two should be achieved. The measurements, carried out for a three-year period, were fundamental to reach the goals, i.e. to fully respect conservation needs and to provide an acceptable comfort level.

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Lasers in Conservation: Analysis and Diagnosis with Laser Induced Breakdown Spectroscopy and Laser Induced Fluorescence

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Laser-based analytical applications in cultural heritage (CH) date back to the early 1980´s. This talk presents two optical laser spectroscopic techniques: laser induced fluorescence, LIF, and laser induced breakdown spectroscopy, LIBS, implemented for the analysis of artworks.

LIF, a molecular emission spectroscopic technique, was first applied by Miyoshi *et al* for the identification of pigments in paintings. More recently, remote application of LIF in a LIF lidar configuration (light detection and ranging) and the application of fluorescence lifetime imaging (FLIM) to CH surfaces (frescoes and statues) have enormously expanded the potential of the technique. LIF lidar is a remote sensing technique that enables to study a remote object by analysing from a distance the light emitted when illuminated by a pulsed laser of the appropriate wavelength. On the other hand, FLIM is based on the measurement of the temporal properties of the fluorescent emission in every point of a sample, thus allowing the reconstruction of the lifetime map of the analysed region. FLIM enhances the capabilities of fluorescence imaging by providing effective discrimination among different fluorescent substances.

LIBS, is an atomic emission technique, yielding information on the elemental composition, on the basis of the spectral analysis of the micro-plasma produced by focusing a high-power laser on the material. While LIF is totally non-destructive, LIBS consumes a microscopic amount of sample. LIBS can applied in situ and in a remote configuration (LIBS lidar) and additionally allows stratigraphic analysis of the sample. Recent advances include the remote analysis using femtosecond laser-generated filaments. In the talk the basic principles, main features, instrumentation and applications to CH objects of these two techniques will be presented.

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Thin Films, Nanostructures and New Optical Devices for Environmental Sensing

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The effect of the indoor or outdoor environment on cultural heritage items is the subject of increasing awareness. While light exposure, for indoor objects, relative humidity and temperature are usually monitored and controlled, gas pollutants and atmospheric particulates have received much less attention despite their deleterious effect on artworks.

Additionally the new multi-pollutant situation makes mandatory to consider the synergistic relationship of all kinds of pollutants.Therefore sensors are required to improve environmental monitoring and decision making and these have to be simultaneously cheap, fast, reliable, selective, sensitive (detect pollutants at very low concentration-at the molecular level), robust, and easy to use. Particularly interesting are the devices that offer the possibility of remote, in situ, and continuous monitoring although these are often conflicting requirements.

In these talk I will review emerging strategies for environmental sensing based in optical interference, technologies at the nanoscale and new laser systems and techniques including cavity ring down spectroscopy (CRDS), pulsed-laser deposition (PLD) methods to fabricate nanostructure-based sensors and nanoparticle enhanced spectroscopies such as SERS (surface-enhanced Raman spectroscopy) and SEIRA (surface-enhanced infrared absorption).

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Compact scanning LIDAR fluorosensor for investigations of biodegradation on ancient painted surfaces

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A compact scanning lidar fluorosensor apparatus has been realized and employed in the diagnosis of stone samples and wall frescos relevant to the preservation and valorization of European cultural heritage.

A detailed spectroscopic investigation was performed in laboratory on different cleaned and dirty stones, and on different painted surface, before the participation to the Advanced On-Site Laboratory for European Antique Heritage Restoration, held in Constanta (Romania), April 15-30, 2004.

The scanning LIF prototype was utilized during the campaign to investigate painted walls of a Byzantine crypt. Scanned images at different spectral channels and their suitable combination, showing the effectiveness of the technique to reveal the occurrence of biodegradation from different microorganisms, are presented. Results are discussed in combination with successive laboratory measurements on micro-organisms cultures on fresco's substrates.

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Analysis of bronzes by single and double pulse LIBS

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Although the laser induced breakdown spectroscopy presents many advantages with respect to other spectroscopic techniques and can be utilized for a variety of applications, the processes involved in it, such as plasma formation and evolution, atomization of species and material ablation result complex. The overall process is sometimes difficult to reproduce due to its strong correlation to the experimental conditions, thus preventing an accurate control of the signal intensity dependence on the experimental parameters, and possibly limiting analytical applications of the technique. Further limitations in this respect are related to the strong dependence of emission signals on sample matrix composition and to the fractionation problem.The so-called double-pulse approach to LIBS is investigated in order to address these problems.

In this work, single and double pulse laser induced breakdown spectroscopy was applied for the analysis of bronze samples, in order to investigate the material ablation process in two different experimental conditions.The same Nd:YAG laser at the fundamental wavelength, with a fixed value of total energy and pulse width, has been used for both set-up configurations. The craters produced by the laser on the samples surface were analysed by a contact profilometer to estimate the ablated material quantity and to study the effect on the crater morphology of the single and of the double pulse respectively.

The behaviour of some peculiar intensity ratios, that can be used to build calibration curves, has been studied in order to evaluate the trend in fractionated evaporation by using the double pulse technique with respect to the single pulse one.

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Non Invasive Analyses of Coptic Fabrics from the Early Christian Era

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The authors deal with non invasive analyses of the "Coptic" fabrics from the early Christian era dating from the 3rd till the 10th century A.D. Clothes and fabrics contained in this collection were worn and used by Copts and are originating from the Egyptian territory. The researched collection, containing 52 artifacts, is housed in the National Museum of Slovenia and the non invasive analyses on the fabrics from this collection have been performed jointly by the Department of Textiles, University of Ljubljana and the National Museum of Slovenia.

The investigation of archaeological or/and ancient textiles is multilevel. The aim is firstly to gain more information about the material and technology used at the time of production of artefacts and secondly to choose the proper method of conservation. Archaeological or/and ancient textiles can be damaged due to different reasons and conservation conditions are one of them. Damage can be on fibre structure level, visual level (colour), fabric structure level etc.

The analyses comprise basic textile properties such as raw material origin, yarn structure (linear density, diameter of yarns) and fabric structure determination. The analytic methods used were optical microscopy and photography and FT-IR spectroscopy.

Key words: Coptic fabrics, archaeological textiles, ancient textiles, FT-IR analyses;

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Amplitude-modulated Laser Range Finder (LRF) for 3D imaging with multi-sensor data integration capabilities during field operation

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A high performance Amplitude Modulated Laser Rangefinder (AM-LR) is presented, aimed at accurately reconstructing 3D digital models of real targets, either single objects or complex scenes. The scanning system enables to sweep the sounding beam either linearly across the object or circularly around it, by placing the object on a controlled rotating platform. Both phase shift and amplitude of the modulating wave of back-scattered light are collected and processed, resulting respectively in an accurate range image and a shade-free, high resolution, photographic-like intensity image.

The best performances obtained in terms of range resolution are ~100 µm. Resolution itself can be made to depend mainly on the laser modulation frequency, provided that the power of the backscattered light reaching the detector is at least a few nW. 3D models are reconstructed from sampled points by using specifically developed software tools, optimized so as to take advantage of the system peculiarities. Special procedures have also been implemented to perform precise matching of data acquired independently with different sensors (LIF laser sensors, thermographic cameras, etc.) onto the 3D models generated using the AM-LR. The relevance of this technology in cultural heritage applications is discussed in special detail, by providing results obtained in different campaigns with an emphasis on the system's multi-sensor data integration capabilities.

A laboratory instrument for 3D fast scanning and model reconstruction of small objects, which contemporarily collects images from 3 different views will be also presented for its application relevant to artwork cataloguing.

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Surface protection of wall paintings: laboratory test methods for the evaluation of the performance of water repellent product

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Protection of porous inorganic materials is very important to preserve the mural paintings in a good state of conservation and to protect damaged works of art during restoration.

The use of appropriate water repellents products can slow down the alteration processes and the chemical, physical and mechanical damages caused by water.

The evaluation of protective agents should be carried out by determining their performance in relation to the kind of materials and according to a series of durability tests.

The following steps should be defined:

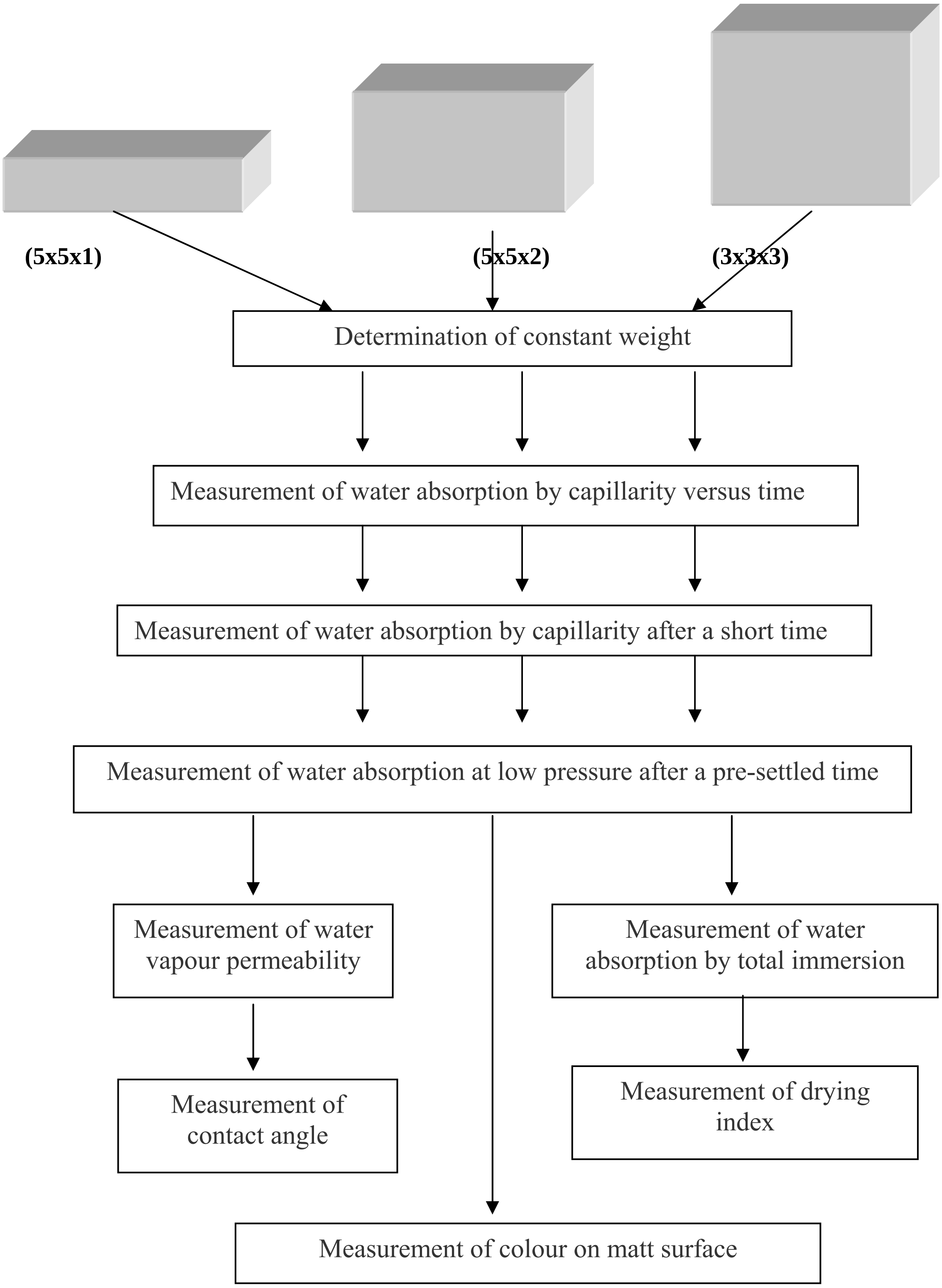
- ✓ criteria for the choice of the parameters to be taken into consideration;
- ✓ methods to determine the parameters.

The parameters useful for a correct evaluation of a protective product are related to the changes of the artefact features as well as to the changes of the behaviour of inorganic porous materials when they are subject to water action. In fact, it is well known that water is the most important physical-mechanical agent of decay and the most important carrier of atmospheric pollutants into porous inorganic materials.

1. Measurement of water absorption by capillarity (WAC) (UNI 10859)
2. Measurement of water absorption by total immersion (WA_{TI}) (Normal 7/81)
3. Measurement of drying index (DI) (Normal 29/88)
4. Measurement of water vapour permeability (WVP) (Normal 21/85)
5. Measurement of contact angle (CA) (Normal 33/89)
6. Measurement of colour on matt surface (Normal 43/93)
7. Measurement of water absorption at low pressure (WA_{LP}) by pipe method (Normal 44/93)

The evaluation of water repellents products applied on porous inorganic materials is carried out according to the following procedure:

- specimen preparation
- measurements of the parameters indicated in clause 2 according to the sequence reported in the figure 1
- determination of the duration of the treatment,
- treatment procedure with the product under evaluation
- measurements of the parameters listed in clause 2 after the treatment, according to the sequence reported in the figure 1.



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Experimental results on the protection of outdoor mural paintings of Feltre

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In order to evaluate the performance of different products suitable for the application as water repellents on mural paintings of painted surfaces in the Feltre town some laboratory and field tests were carried out as final step of the conservation process.

Among the protective coatings, commonly used as water repellent, were chosen the most suitable which could be applied on painted surfaces according to the experience of the *"protective testing group"* operating inside the Italian National Commission for the standardization of the conservation procedures to be applied on Cultural Heritage.

The following products were chosen:
-two oligomeric siloxane solvent soluble Rhodorsil 224 and Wacker 290 L;
-a water soluble silane Dynaylan BSM 100W;
-a siloxane in micro-emulsion Wacker SMK 1311,
-the acrylic co-polymer Paraloid B72
-the ammonium oxalate.

The evaluation of the chosen products has been carried out on test area previously determined, and simulating the behaviour of painted and not painted plasters.

The parameters measured were:
i) water absorption by capillarity, according UNI 10859,
ii) drying index, according to Normal 29/88,
iii) water vapour permeability, according to Normal 21/85,
iv) colour, according to Normal 43/93,
v) ratio of protection calculated on water absortion by capillarity

Regarding the water absorption the results obtained shows that the siloxane solvent-soluble, Rhodorsil 224 and Wacker 290L, are the best both on painted and not painted plaster.

As regards the water vapour permeability a reduction of 45% for the two siloxane solvent-soluble on painted plaster, while the minor reduction of 17% and 32 % has been measured on Rhodorsil 224 and Wacker 290L respectively. The water soluble silane and the ammonium oxalate show a very low water vapour reduction, but they have worst performance regarding the water absorption. The best combination, lowest water absorption and lowest water vapour permeability, occurred for Rhodorsil Rh 224.

In field measurements confirm the same behaviour.

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Advantage and limits of the use of surface analysis in the individuation of ancient working processes

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The comprehension of the ancient working processes employed in the realization of ancient objects by precious metals, is an important element for its collocation in an historical period or in a geographic area, but also it means to recognize characteristic marks. These last also allow to produce an accurate diagnosis on the conservation state of the item, either in terms of integrity of the object, either in terms of readability of the ancient technology employed in its realization.

In this field, the use of scanning electron microscopy coupled with energy dispersion microanalysis (SEM-EDS) is widely utilized in the surface analysis as well as the x-ray fluorescence (XRF) analysis is able to detect signals coming from the bulk, this suggested their integration in a unique instrumentation whose peculiarity will be illustrated and discussed.

Any way, any analytic results cannot be resolutive in the understanding of the whole process, if they are not interpreted in terms of the accordance with the thermodynamic principles.

In this optics, a series of studied cases will be illustrated by selecting those involving the investigations of different material, as well as jewellery products, bronzes and smelting products. The results will be furnish not only informations on the historical contextualization of the object or its related working process, but mainly will give indication on the reliability of the application of the instrumental methodology in a wide spectrum of applications.

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The Medieval Graphite Mural Sketches of holy Spirit Chapel – Sesimbra. New Techniques in Monument Analysis

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The paper describes the conservation and digitalization works of the graphite mural sketches depicting strange ships and sea scenes from the 17th and 18th centuries, attributed to seafarers that stayed in the building for recovering reasons, discovered during the restoration of The Holy Spirit Chapel (Capela do Espírito Santo) in Sesimbra. Special focus is given to the use of Artworks Digitalization techniques and environmental analysis in order to achieve a better understanding of building's capacities in art conservation.

The fact that the building was of typical construction with thick masonry walls and poor environmental conditions was not a handicap for modern techniques to be applied and it showed the usefulness of these systems in historical and documental conservation.

The work carried on also showed the collaboration of tree different teams of experts, one from the Sesimbra Municipality, and the other two collaborator teams being the DGEMN team, which supplied the project, and the INETI team, as invited specialists, with the modern techniques know how and up to date equipment.

The paper presents an example of simple works of consolidation and preservation of the mural sketches and relates the restoration process of the chapel itself with the use of traditional materials and construction methods.

INTRODUCTION

The former medieval Hospital of the Holy Spirit on the Sesimbra seafront, based in a 15th century structure founded by Sesimbra fishermen and seafarers, the Confraternity of the Holy Spirit (Confraria do Espírito Santo or Corpo Santo), was hidden after the 1755 earthquake on the aftermath of the greatest loss of buildings in Portugal.

Later, the Casa do Espírito Santo, was built completely anew and in the early seventies the remaining structures were rediscovered and brought to surface by the team of Gonçalo Lyster Franco, architect of DGEMN, during an intensive excavation campaign leaded by Sesimbra municipality between the years 1979 and 1981 (Figure 1).

The Chapel of Holy Spirit of Seafarers is a listed monument comprising two different areas: the Chapel on the upper floor and the Hospital on the bottom floor. The absence of an intervention program that could have opened the building to public use, following the previous utilization as a church and the consequent abandonment with lack of maintenance during more than three decades, were responsible for the collapse of the ceiling in 1945 and the poor conservation conditions in witch the sketches were brought to analysis. It must be said that the protective scaffolding built by Sesimbra Municipality in the late nineties prevented even more damage to the building and the irremediable loss of this patrimony (Figure 2).

The chapel served its worship purposes until the collapse of the roof and then the *Associação de Socorros Mútuos Marítima e Terrestre da Vila de Sesimbra* rented the ruins of the chapel to Sesimbra's Town Council so as to convert it into a library with works completed in 1961 and the installation of a fixed Calouste Gulbenkian Foundation library in December, 1962 (Figure 3).

It was only in 1973 however that Sesimbra´s mayor envisaged the possibility that underneath the library on level floor an existing empty space could have been used to extend the existing library or even install the Municipal Archaeological Museum. This as a result of the suddenly revelation of a stone ogee arch in what was the former main door of the ancient Hospital and two stuccoed walls, one of which had a dark-ink outline of a three-mast Latin Caravel (Figure 4)!

The interest of the building was immediately perceived and an extensive cultural program was schedule for what would be the first nucleus of the Sesimbra Museum dedicated to the sea. Some insight of the conditions of this museum and the reconstruction works carried on the building in order to preserve the sketches, as well as the remaining art pieces, were developed in the following years by the team of DGEMN with the main concern of maintaining the original characteristics for future use.

The origin of the building, connected with the sea and the seafarers, and its significance to the development of the zone as a fisher village, is the main reason for the public interest and represent the principal curiosity of its visitors.

Having as it main contribution the 17th and 18th century's inscriptions, the visitor has the opportunity of travel in time to that ancient period, using the sketches interpretation and the given information about those charitable institutions that served the population in times of distress.

Presently the building is open to the public with a Religious Art exhibition, with painting and sculpture works from the 15th and 18th centuries as well as the graphite sketches and the structures of the primitive Hospital of the Holy Spirit Confraternity (Hospital da Confraria do Espirito Santo) which forms Sesimbra Municipal Museum.

The valorisation of this element is important for the cultural fruition of a municipal net of several museums, with all the welcome and interpretation conditions for every kind of public (Figure 5).

REHABILITATION PROGRAM

Restoration of the chapel and conversion into a museum were carried out between 1999 and 2004 within the Sesimbra Municipal Museum project, thanks to a close collaboration between the Sesimbra Town Council and the *Direcção-Geral dos Edifícios e Monumentos Nacionais*/ Lisbon's Regional Office. The work specification that would have been necessary to avoid the complete destruction of the sketches and the utilization program of the building were developed by DGEMN-DRML involving specialist in different areas such as architecture, archaeology, engineer, history, art and design. It was intended that the intervention would include the final presentation of the collection and so, a museum layout program was established, including pieces display structures and interpretation guidelines.

The works itself started with the interior definition and structural consolidation of walls and ceilings in order to maintain the existing construction system and use the remaining material for public view. That was the case of some foundation material of the post-earthquake construction that was suddenly discovered below one of the walls with the excavation of the sub level of the building and the original mortars of the partition walls that were consider by that reason as archaeological walls (Figure 6).

The former ceiling trusses were also reutilised with the use of metal plates connected to the wood and support point consolidation (Figure 7). When the architectural program was established an acoustical metal ceiling was fixed on a second metal truss, parallel to the first, with two steel cables along the bottom chords, for anchoring proposes (Figure 8). This system proved well due to the consolidation injections of lime based mortar in the supporting walls.

To support the wooden floor, a steel structure was conceived, with columns and beans next to the archaeological walls with no loads transmitted to their surfaces. The inferior ceiling and all the electrical cables and apparatus were subsequently fixed to this system in a convenient manner and no visible objects were obtained below the "Cor-ten" steel sub ceiling. The utilization of normal concrete was limited to the foundation of this steel structure (Figure 9).

The works carried on this ancient structure were obviously of great delicacy and care. Apart from the risk of loosing the remaining sketches and covering materials, witch were intended to preserve, there was the risk of loosing the structures during the work itself. It was a frequent observation during the meetings - great concentration of loads and materials on the wood floor, intended to resist only to weight and people.

SKETCHES CONSOLIDATION PROGRAM

For sketches conservation during the works, a protection system of paper tissue, plastic sheet and plywood were built on the three zones of the building which contained the graffito's and special care was taken in order to stop all the circulation near the area. Previously, all the support mortar was clean and consolidated with lime based material. The architectonic project, based on Sesimbra Municipality program, was conveniently adapt by DGEMN to protect the sketches until the end of the work and took advantage of this unexpected item in the interior layout for the future museum.

The idea of public access to this "archaeological crypt" consisting in the remaining sketches of ships implied a special planning and conservation procedures during the early hours of intervention. Techniques and methodology involving new approaches were intended to be applied and some credit must be given to the owner's openness to this idea.

The interest and adequacy of this object to the use of a modern tool in documentation and preservation were not immediately understood and, after a preliminary protection of plastic sheet and plywood, the sketches gained a new significance to the museum interpretation.

Obviously the final protective structure was not immediately conceived and some discussion whether or not the graphite sketches could be directly observed or some multimedia explanation should be given instead, took place, until finally the solution suddenly came: the sketches would be seen and a digitalization program for future study would be carried.

This meant that the poor condition of the sketches had necessary to be dealt with, and so a conservation team was invited to develop the consolidation and restoring of the original sketches, using suitable techniques and materials.

The previously stabilization operations (cleaning of surfaces and placing of facings) conducted by the *Instituto Português de Conservação e Restauro* followed the completion of civil engineering Works in which mural paintings underwent conservation and restoration operations between October/November 2004 and July/August 2005 significantly improved their condition, apart from making extant sketches more perceptible. A diagnosis of their condition was followed by a thorough consolidation and filling of void areas in the support structures, so as to ensure cohesion of underlying mortar layers. A consolidating injection compatible with the original materials solved the first problem, whereas void areas (deep cracks or cracks between layers) were filled with a PLM A injection – desalinated hydraulic lime – that reinstated cohesion and adhesion to the supporting structure. Once stabilisation of this structure was complete, facings were removed with the solvent used for applying the fixative. Surface cleaning of graffiti was done by means of chemical and mechanical procedures, with resort, only in particular cases, to chromatic reintegration using compatible and reversible materials such as water-colours (Figure 10).

During different intervention stages, there was concern to strictly identify pre-existing materials and technologies used. Cement based mortars were removed and so were hollow masonry partitions; consolidation of archaeological walls was made by injecting lime with pozzolanic additive; stone material that came out of excavations (both from archaeological and height adjustment operations) was reintegrated in the construction; every wall was protected with a lime and stone plaster using traditional techniques and was later white washed; diwidag steel bars were used to reinforce the cohesion of the whole building, reducing the risk of collapse in case of an earthquake.

ARTWORKS DIGITALIZATION

To register the finding for future analysis, considering to probable loss of the inscriptions, a Artworks Digitalization work was carried by INETI with the use of a ShapeGrabber SG-1000 portable system. The obtained image containing information concerning the graffito and the inscriptions detected in the surrounding area enabled a high performance digitalization procedure and an easy solution for images storage. All the system proved well, due to its portability, design and simplicity of use (Figure 11).

Following the digitalization of the sketches, a stone piece of the ancient door was brought to analysis and, with the obtained data; a virtual reconstruction of the door frame will be possible for study purposes (Figure 12).

ENVIRONMENTAL CONTROL

Some further work involving weather conditions in the interior was subsequently developed, since the earlier stages of the work in order to control the conditions for the exhibition of the sketches and the art pieces in the future museum. Data concerning temperatures and humidity was obtained and some interesting conclusions were achieved relating the human presence in the building with the increase of the humidity level, after the public opening.

The humidity and temperature behaviour monitorization in different parts of the building since the end of the first stage of the works implied that a simplified system of forced ventilation had to be introduced allowing air to be renovated. This was reinforced by a carefully integrated temperature and humidity monitoring meant particularly for the ancient hospital, since it is a basement and the height is low.

This work proved the applicability of new techniques in monument analysis and opens new possibilities for documentation and utilization of existing patrimony.

COST CONTROL

Costs were strictly controlled throughout this process. There was an almost daily monitoring of the works progress *in situ*, and a weekly forum involving the whole work team for discussing future strategies. Total costs of the intervention were mainly incurred by the Sesimbra Town Council and the *Direcção-Geral dos Edifícios e Monumentos Nacionais* as follows:

1st stage147.330€ | 2nd stage 289.000 € | 3rd stage 60.785 €

It is worth mentioning that most of the sacred arts collection was kindly made available by the Sesimbra Town Council/Municipal Museum and *Santa Casa da Misericórdia de Sesimbra*.

The intervention was also financed by the *Instituto Português de Museus/ Rede Portuguesa de Museus* – 18.600€ – through a 2003 programme designed to encourage the qualification of Museums. This amount covered the cost of producing one book, one exhibition tour /catalogue, conservation/restoration of the archaeological collection and study of the numismatic collection.

ACHIEVED RESULTS

Apart from the satisfaction of rescuing a medieval hospital structure that had been buried since 1755, the people of Sesimbra were very much involved in the whole project from the outset. They frequently visited and proudly showed this monument that was, more than ever, theirs by right.

The Museum educational services have responded to the interest of a number of teaching and museum-related institutions, by promoting conferences focussed on the meaning of 500 years of history and the value of its collections.

This project has been a political and cultural reference from the beginning, and will undoubtedly set the example for future heritage restoration operations in the area. It proves that with both rigour and simplicity, it is possible to rescue and perpetuate a memory, no matter how extinguished it seems to be (Figure 13).

CURRENT AND FUTURE USE

A sacred arts exhibition integrating some of the region's most valuable works of art from the 16th and 17th centuries has been opened to the public since December 2004. The ancient hospital has an interpretation route including the most significant archaeological findings of the 1979/81 and 2002 excavations, apart from a temporary display of coins also found in the same period.

The Museum's sacred arts collection has recently been increased, thanks to the generosity of institutions owning this particular form of heritage. The new specimens will soon be available to the public.

The Sesimbra Town Council inaugurated the Museum with a temporary exhibition and has plans for organising some more in the coming years.

The study of archaeological collections as well as conclusions of recent historic research on medieval hospitals, and this one in particular, conducted by Dr. Sílvio Conde from the University of the Azores, have opened the possibility of reconstituting the ancient beds and the main artefacts constituting the daily life in these social assistance institutions.

This is the first nucleus of the Sesimbra Museum but it expects to have, among others, a second one near the Castle on the pre-medieval period, and a third one dedicated to fishing and seafaring traditions in Sesimbra.

FUTURE MAINTENANCE AND ADDITIONAL WORKS

Apart from annual routine inspections to be made within the next ten years, provisions have been made for a campaign for conservation of façades, roof coverings and external openings.

The discovery of human burials under the chapel's front yard postponed resolution of the moisture problem affecting one of the hospital's boundary walls. Despite constant monitoring and the introduction of ventilation and air-conditioning during the intervention, exhumation of human remains is expected to take place within the next few months, with monitoring from experts in anthropology and archaeology, so that a cut-off drain is built outside and the affected wall is duly insulated.

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Humidity Analysis and Control

José Gonçalves

Civil engineer

Humidity is probably the worst enemy of constructions and we can relate its multiple appearances with the majority of degradation processes in traditional buildings. Is also difficult to deal with the real origins of humidity in buildings when some far easier solutions (like hiding their final results) usually achieve a cheaper alternative.

The best way to tackle humidity problems is always by preventing its final contact with the building or, when that proves impossible, to conceive a method to reduce that contact with efficient draining systems. The ways to solve this problem are synthesise in this report with examples of practical solutions in traditional buildings and monuments by using ancient techniques that proved particularly well in actual rehabilitation works.

SUMMARY

1 – Introduction

Humidity problems in constructions are the worst scenario when the restoration experts came on site for damage evaluation. The causes of degradation are usually disguised with cover material problems which are far easier to deal with in a rehabilitation process. If far simpler to show a new appearance to an ancient surface, or apply an authentic finishing to an old object, than to look for the origin of the damage in that object or artefact. Normally technicians involved in diagnosis and restoration using modern methods and techniques of evaluation tend to create a different approach for the problem and sometimes have not the necessary background to ear what the other have to say about the situation.

Problems relating humidity in constructions are not only the cause for the interaction of these different mentalities but a reason for establishing common principles in modern conservation practice. Is therefore important to study these scenarios for evaluations proposes and modern techniques appliance. The organization of recovered information in work surveys is the basis for the correct evaluation and establishment of protective measures, and that is the aim of this report considering the possible loss of existing patrimony due to bad decisions based on deficient evaluations.

2 – Construction humidity

The manifestation of humidity due to the construction is a problem that is apparently overcome by the passage of time and its consequences on the construction behaviour and response. This is not ultimately true because is always possible that the building have been repaired with a modern material using ancient techniques or have suffered from an important alteration in its constitution or organization. That is the example of new floor rehabilitation in which the wood planks had not conveniently dry before application and start to adjust due to water loss, or even some mortar application in old surfaces with water transmission inside the walls and consequent moisture migration to their exterior layers. (Pictures *Teatro São Carlos*)

The appearance of humidity in the walls or the degradation of the wood on floors are the major consequences of that problem and the repairing solutions are not always easy because usually involve possible substitution of material or moisture control inside the building with all the evident consequences for its inhabitants or visitors. Is much preferable to prevent the problem itself during repairing with simple solutions like interposition of impermeable paper beneath the wood floor before final application of the material or improve the ventilation in certain zones on the repaired walls.

All solutions however need some discussion beforehand with the intervention team because of all the implications on the final aspect of the surfaces or their economic repercussions for the overall budget and management.

3 – Ground humidity

Ground humidity is a far worst scenario when it comes to deal with humidity in an existing building that have obviously been subject to alterations or degradation in its environment.

The humidity from the ground beneath the building is always the consequence of hydraulic changes in the foundation that causes the migration of water trough the walls and foundation materials until the water reach the higher levels of the walls inside the building or the floor elements at ground level (Pictures *Igreja São Miguel*).

A usually alteration in the moisture content of the ground is when the conditions around the building change due to the application of impermeable materials like bituminous surfaces or hydraulic tiles in the area around the exterior walls in a urban intervention. That alteration prevents the water from the rain to infiltrate to the ground in the same way as it used to and may conduct the same water for certain zones on the walls with the known consequences.

The solution, in this case, is an easy one. All we have to do is dig a water barrier around the exterior walls of the building and, with the application of water proof solutions like polyethylene membranes or geo textile materials to block the access of water in its way to reach the outer layers of the walls. This solution must be completed with an efficient method of conducting the water to an existing draining system, with convenient drilled tubes placed in the lower level of the water barrier and the use of small rock sand to facilitate the water migration to the draining tubes (Pictures *Capela São Sebastião*).

Another situation comes with the presence of water around the exterior walls in a sub level of the building with no access on the outside, like the above mentioned situation. In this case one must seriously consider a construction of a second wall on the inside with an efficient draining system in the space between the two walls.

A third solution could be achieved with the use of a chemical solution of silicone resins, or other water repellent product, injected with a pump system in predetermined holes on a level below the affected zones of the walls.

Each of these solutions must be used with great care due to the obvious difficulty in an exact determination of the water origin and its future effect on the building. Some of the mentioned techniques also involve the use of expensive machinery and equipment and so a carefully planed intervention must be carried and each solution conveniently adapt to the building because of its singularities or specifications.

4 – Rain humidity

Rain humidity if perhaps the first preoccupation in the design phases of the intervention and can be, by that reason, one of the only reasons for water prevention systems to exist. That is not obviously correct and a global study of this problem can be achieved with the consideration of all elements of the exterior enclose of the building.

4.1 – Exterior walls

Exterior walls are the first element in a building where humidity related damages are best perceived in a visual inspection or survey. Normally, considering the permeable materials of walls constitution, the visual aspect of humidity in the interior of an element, signifies that the entire wall is humid and a special protective treatment must be applied.

Also the great thicknesses of monument walls, with heterogeneous materials and sometimes problems of structural origins, facilitate the water migration trough dangerous regions where its presence is a major handicap to building preservation and interior protection.

The water migration inside a wall is not only a cause for major alarm and concern due to the consequences for the existing materials but also because of the long time effect of salts dissolution and future crystallization in the outer layers of the walls that causes the premature degradation of the element (Pictures *Café Barreiro*).

All solutions based in mortar applications must be conveniently study and adapt considering the existing elements and materials in the walls. Also, modern composites namely hydraulic products, cement materials and non expansive solutions should carefully chosen or alternatively a lime based mortar with a limited portion of Portland cement can be applied with a limited risk for the existing walls. That is an option to each case as there is no universal solution for all historical buildings and monuments.

However must be considered the execution of at least two layers, following the first consolidation (or in some cases reinforced) layer, with mortar compatible materials, preventing the migration of water, or in other cases, allowing water migration to the exterior of the wall.

Special care must be taken also with the use of modern water repellent painting systems that, as well as preventing the water passage to the inner layers of the walls, prevent the migration of the water vapour to the exterior, and, consequently became non adherent to the wall and fall after some time (Pictures *Café Barreiro*). In this case, lime based inks are preferably a better option for ancient walls because allow a certain hydraulic equilibrium in both sides of the element, exposed to climatic conditions.

4.2 – Horizontal construction elements

Horizontal construction elements formed with ceramic cover tiles or terraced cover elements represent the principal problem in dealing with water access to buildings and monuments. The singularities of the respective draining elements like pipes, gutters and all sorts of accessories related with water conduction to inferior levels of the building are a major concern in humidity prevention design and the solutions should be reached from the first sketches of the project until the final phase of construction.

Is therefore of great significance the rehabilitation of all the horizontal elements that support the draining systems, like trusses, ceiling beans or structural frames, because its deformation or collapse leads to water problems in the building and the future loss of the remaining elements (Picture *Convento São Francisco*).

There are some ways to prevent this problem and normally involves the interposition of a water barrier material underneath the cover elements with no alteration of the final aspect of the building. These solutions are relatively easy to adjust to existing structures and modern water proof materials are generally of great quality in humidity prevention if all the actions concerning its maintenance are taken along the way (Picture *Convento São Francisco*).

Is also necessary to think of all the exterior parts of the building elements like chimneys, salient walls, ventilation pipes, joints between buildings or dilatation joints in which case special isolation elements and connections must be considered in water prevention systems.

Modern methods are based in water proof painting systems easily applied with normal brushes and other tolls in which a good adhesion is achieved with satisfactory results in rehabilitation programs.

Its interesting to compare the value of all water prevention systems with the loss of the building and its interior valuable pieces due to water damage or humidity related problems. Is a far better solution to prevent things to happen than to repair what went wrong in building design or maintenance.

4.3 – Window frames

All the exterior elements in a façade are singular points in which humidity problems can occur if there is that possibility. Window frames in historical buildings represent a problem itself because its materials, like wood and iron, have some characteristics that change due to climatic exposition and that alteration can bring humidity problems to the interior of the building (Pictures *Convento São Francisco*).

The major problems related with the presence of water in these elements are the attacks by insects or other bugs, in the case of wood, and the corrosion problems, in the case of iron.

Both put a delicate problem in water prevention analysis because the maintenance of existing materials in exterior widows and doors of historical buildings, are generally imposed as a preliminary condition and so an easy method for its rehabilitation must be achieved.

Protective elements in monument windows and doors have obviously been subject to exterior actions along the life of the building and some importance due to that fact they had had. The substitution of these elements must made with identical materials and using the same techniques as the original ones. The intervention should be programmed to achieve a good integration and response in the building percieveness because no other solution could be easily justifiable.

Generally is far cheaper to build identical new elements in a window and door frame rehabilitation program then to treat existing ones in site, even if the degradation is not prohibitively significant. The first question is to know whether treatment products and methodology are well tested in similar conservative processes, considering the risk of future degradation due to the same phenomena. The second one is to evaluate the degradation level of the element and to compare between its integral substitution value and the restoration value with all the factors involved.

That can be achieved for a particular case not meaning that the same result can be achieved for a different one.

5 – Humidity from damage installations

Installations in historical buildings are not generally original due to the evolution of our necessities in the building fruition process. The number of different installations inside an existing monument is a consequence of the historical value of that monument as a cultural object and a signal of its importance for the visiting public.

It must obviously be assume the risk of water leakage in a fire security pipe system but not the risk of loosing the monument because the fire security system inexistence. The same can be said of the bathroom water systems or the draining systems mentioned before.

Another completely different problem is the existing systems that have suffered from bad interventions in previous alteration processes or pretence reparations with non adequate materials or mixing modern techniques with ancient concepts (Pictures *Teatro São Carlos*).

That is the case of modern materials like plastic tubes in hot water supply systems that need a considerable dilatation space when applied in existing walls which have not been devised to receive those elements. In this case, a special technical duct should be considered and all the systems easily placed there for conservation and maintenance purposes.

The problems related with new installations or new supply systems should similarly be considered and all the materials carefully chosen to prevent future problems due to the presence of water sometimes in different places of the building.

6 – Condensation humidity

Humidity problems related with condensation phenomena are generally of great difficulty to solve and even, in cases where its occurrence is considered as natural, to assume as a problem.

Condensation derives of the fact that air, in contact with cold environments turn into water, damaging the support material that was supposed to stay dry. This is apparently easy to solve applying insulation materials on the walls or by heating the interior of the zones where this occurrence is significant. The problem derives of the fact that with any changes in the moisture degree of the place, for example in kitchens, bathrooms or rooms with great number or people, the dryness capacity of the interior air is easily achieved and all the remaining moisture turn into water, with the known consequences for the material surfaces.

Is also possible to ventilate the places where condensation problems are expect to happen, and allowing a certain amount of water to evaporate before its concentration is perceived or generate any damage. That is not always possible because monuments and traditional buildings are not usually easily adapted to modern ventilation systems. Is this case, it must be considered small ventilation systems or strategically placed openings functioning according to convection laws and exploring existing air movements to permit a certain evaporation capacity and reducing the risk of condensations.

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UV Irradiation of Organic Artwork Materials - Color Changes

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Electromagnetic radiation is a common cause of much damage of most artworks material and dyes. Organic dyes and materials of artwork are particularly damaged by electromagnetic radiation, especially by UV radiation. It can cause the color change and consequently it directly affects the appearances of the organic artwork.

Thus, the goal of our study was to evaluate the effects of UV artificially and accelerated ageing of certain organic artwork material as leather.

The leather samples were directly exposed to UV radiation under constant environmental and room conditions. All samples were divided in three areas (chromatic homogenous), which have been exposed to UV radiation for two periods.

The reflectance spectra were acquired for both reference and UV irradiated samples. The color changes induced by UV irradiation in leather samples were quantified in terms of color parameters, lightness (L*), color coordinates (a*, b*) and color difference (ΔE*ab), using the CIE L*a*b* model. The results were recorded in a database which permits to monitor the color changes accordingly the leather type and processing. Thus, has been show that accelerated and artificial UV ageing yields to a strong color change of the organic artwork materials as leather.

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Laser cleaning on easel paintings

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UV laser cleaning means thinning down the varnish layers.

Understanding about varnish for paintings is essential.

Varnish means resin. There are two main groups. Natural and synthetic resins (second part of the 20the century).

Beside of varnish you can find Patina and Glacis on a painting.

When oil paint is drying, the pigments will sink in and an oil film will appear as a skin on top of the paint -the Patina-. Bright colours can contain only la bit of oil medium and dark colours a lot.

This results in uneven appearance after drying. (glossy and mat parts). After drying an applied varnish can equalize the surface and intensify the deepness of the colours. Beside of the esthetical value, the varnish will work as a protecting layer on the painting.

Glacis can be found on paintings too. These are transparent (for example Lake-madder) paint layers on bright colours between the solid paint and the varnish.

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Controlled laser cleaning of fire-damaged paintings

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Modern technology, such as lasers, can offer valuable tools to support conservators and restorers in their work. In Europe, an innovative laser restoration tool for non-contact cleaning of painted art objects has been developed. This laser workstation has proven to be a valuable tool to solve the problem of fire-damaged paintings.

Soot deposit, often a serious problem for conservators, can easily be removed from the surfaces using an ultraviolet (UV) laser. Since only low laser energies are needed for efficient removal, the effect of the UV laser light on the residual material is minimal.

European research supports the viability of the UV laser technique as an additional tool in conservation practice. The ability to gradually remove the damaged top layers of a painting with minimal influence on the remaining material opens new possibilities for conservators.

Keywords: Laser, cleaning, paintings conservation, fire damage, varnish removal, process control

Introduction

Though in industry lasers are a well-accepted method for the removal of material from surfaces [Miller1994], the application of lasers in art conservation is subject of more recent developments and studies [König1997, Salimbeni2000]. The utilisation of lasers for cleaning provides a method to remove layers that cannot be removed using conventional methods. Furthermore, the laser enables controlled removal of (part of) a thin layer, while the conservator can choose when to stop.

The feasibility and value of laser cleaning techniques have been demonstrated mainly for surfaces like sculptures, stone and marble [Cooper1998]. Application of lasers for the cleaning of more delicate surfaces, such as paintings, only occurs on a relatively small scale. The use of lasers for the conservation of painted artworks is more demanding, due to the high sensitivity of the delicate paint layers to light. Several studies over the last five years have focused on the identification of the (damaging) effects of mainly infrared laser light on pigments [Salimbeni2000, LaconaIV2001, Zafiropulos2001]. Researchers at the Foundation for Research and Technology-Hellas (FORTH) in Greece carried out pioneering work on laser cleaning of paintings and icons [Fotakis1997, Zafiropulos1998]. They showed that a UV (248 nm) excimer laser could be applied in a safe and efficient way for the removal of e.g. old varnish layers from painted artworks. In contrast to infrared light that penetrates the paint layers, UV light is absorbed in the surface layer of a painting, enabling the removal of surface material with minimal thermal or photochemical effects on the underlying layer. The Greek researchers used Laser-Induced Breakdown Spectroscopy (LIBS) as a diagnostic tool to control the cleaning process [Anglos1997].

Using the Greek expertise on this subject, the Dutch company Art Innovation has developed a professional laser cleaning station for the restoration of paintings [Scholten2000]. To further the knowledge on the boundary conditions under which laser cleaning can be safely applied, a large European research project, "Advanced workstation for controlled laser cleaning of artworks" (ENV4-CT98-0787, funded by the European Commission, 1999-2001), was initiated. A multidisciplinary team of conservators, scientists and engineers collaborated to apply the innovative laser restoration tool on a wide range of samples and real artworks. The research focused on the identification of molecular changes in paint materials (pigments, binding medium) induced by UV radiation with varying intensities [Scholten2000, Teule2001]. The activities evolved around a series of well-defined egg tempera paint samples, which were carefully characterised before and after laser treatment and solvent cleaning. This effect study has confirmed that the effects, observed in case of direct irradiation of paint with 248 nm laser light, are largely constrained to the top few μm of the layers, and that even a very thin layer of material blocks the UV photons. This means that, in case of e.g. varnish removal, a thin layer of residual varnish acts as a protective layer for the underlying paint. If required, this very soft layer of organic material can subsequently be removed using mild solvents.

The abovementioned European research work also included the application of the developed UV laser workstation in the conservation of real art objects. In the removal of surface layers, such as aged varnish, the laser technique often provides a better control of the cleaning process compared to solvent or mechanical cleaning. Using the laser, a varnish layer can be partially removed, and no contact with the original paint layers is necessary. Furthermore, the technique has proven to be a valuable tool in for example the (partial) removal of varnish layers and the treatment of fire-damaged paintings. This paper focuses on the results with regards to several paintings that were severely damaged in a fire.

Methodology

For the cleaning of delicate objects like paintings, with variable properties, accurate control of the laser cleaning process is essential. The laser workstation at Art Innovation consists of a UV excimer laser (Lambda Physik Compex 205, KrF 248 nm), a motorised 'optical arm' to direct the laser beam accurately to the painting surface, and an on-line detection system based on LIBS for on-line control of the cleaning process. The workstation was designed to be able to accurately scan the laser beam over the paintings surface, without having to move the often very delicate artwork. The optical arm employs parallel mirrors in a configuration similar to that of a periscope. Since the mirrors are mounted as complementary pairs, the rectangular laser beam profile and orientation of the spot are guaranteed during a rotation of the arm. The optical path is of constant length, which simplifies the task of maintaining the necessary constant laser spot properties. The positioning accuracy of the optical arm is ~40 μm.

The LIBS detection system allows the on-line, immediate identification of the material that is removed from the surface. At elevated laser fluences, atoms and molecular fragments are ablated and ejected in a plasma plume. Light emission from these energetically excited particles is spectroscopically analysed using a spectrograph with a fast ICCD (Oriël MS260i, Instaspec V ICCD). The resulting LIBS spectra are characteristic of the material that is removed, and hence can be used for on-line monitoring.

When applying the UV laser system for the cleaning of painted artworks, it is very difficult to define a general cleaning procedure. Hence, each restoration case has to start with a feasibility study, to establish the laser parameters, and define a specific data algorithm for process control.

In this study, the laser workstation was used to treat three paintings that were severely damaged in a fire. Thin layers of soot, especially when deposited directly on the painting surface, can cause serious problems for conservators. The grime does not easily dissolve in solvents, and the rubbing when using a swap causes the particles to disperse into the surface. However, when using a UV laser, only low energy fluences are needed for the removal of these particles. Moderate laser energies were employed (0.38 – 0.43 J/cm^2) to minimise the influence on the residual paint layer.

Case studies / Results

A bright spring landscape (1942, oil paint on masonite, 53x37 cm^2, artist unknown) was seriously damaged in a fire. The combination of high temperatures and soot has caused severe discolouration of the surface layers, and consequently the original image was largely obscured. The thickness of the discoloured layer is ~10-20 μm and is located directly on top of the paint layer.

Using conventional techniques, it appeared very difficult to clean the fire-damaged painting. Several tests were done using different solvents. Most solvents were not able to remove the dark superficial layer completely. Others removed the dark layer, but damaged the underlying paint layers at the same time. The removal of the darkened layer did appear to be possible with a kind of soap. However, traces of this soap could be left in the remaining material causing damage on the long term. Chemical analysis of some paint samples is being performed to determine whether traces of soap can be identified.

To remove the darkened layer, the laser was tuned to a moderate amount of energy (0.38 J/cm^2) and focused in the x-direction to a 1.5 x 3.5 mm^2 spot, scanning with 80% overlap in the x-direction and 75% overlap in the y-direction. Using only four pulses, the very top layer of the painting was removed and the bright colours of the original paint layer appeared (Figure 21).

The laser was able to ablate the discoloured layer while leaving the paint surface texture intact (see Figure 20). Only deep into the holes of the hardboard support, residues of dark material remain. However, the in-depth cleaning of the surface with conventional methods was unsuccessful in this respect as well. Despite of direct contact of the laser light with the paint surface, the original paint layers were not visibly discoloured by the light. This can be explained by the limited amount of UV light (energy) that was used in the cleaning process. Furthermore, the oil binding medium seems to behave differently on short term compared to the egg tempera that was used in the test samples.

The conservators were very enthusiastic about the final cleaning result. This cleaning procedure will also be applied on a similar painting on Masonite, damaged in the same fire. During this conservation treatment, the various stages will be carefully documented. Cross sections will be made to show the layer structure before and after treatment.

Figure 22 shows another painting, painted by the Dutch artist Jan van Vuuren around 1925 (50 x 40 cm^2) that was damaged in a fire about 30 years ago. The heat of the fire has caused the paint to detach from the support, and numerous small and large blisters are formed. Also, soot was deposited over the whole surface, darkening the picture. With conventional techniques, it is not possible to restore this painting. The blisters are very hard, and strong solvents would be needed for softening the paint in order to push it back on the support. The use of solvents would inevitably mean that soot particles can penetrate more deeply into the painting, causing more damage. Also, the physical contact with the painting surface creates unacceptable danger for further delamination of the paint layer. The laser technique can offer a solution to this problem, because it allows the removal of surface material without physical contact with the artwork.

After a few initial tests, an area of 11x39 cm^2 was treated with the UV laser, focused to a laser spot with a width of 2.5 mm. Using an energy of 0.41 J/cm^2, the laser was scanned over the area with 75% overlap in x-direction and 65% overlap in y-direction. First, the area was treated with 2 laser pulses per position. This resulted in a significant lightening of the image, and the village view became visible. Because the surface was still darkened, another two pulses were applied over the whole area. The result is visible in Figure 23: The recovery of the original colours beautifully reveals details of the village view, such as a person sitting on the doorstep.

The cleaned painting surface still shows many small craters and blisters, that seem unaltered upon laser treatment. However, now that the soot has been largely removed from the surface, the use of solvents once more becomes an option to soften the paint and push it back. In this case, a combination of laser treatment with conventional methods offers the solution to a problem that is otherwise very difficult to solve.

Conclusions

Application of the UV laser workstation on fire-damaged paintings shows that the laser technique, often in combination with conventional techniques, offers a good solution for this category of conservation problems. The darkened top layer of these paintings can be removed in a fast and efficient way, and the original paint colours are revealed beautifully. No physical contact with the artwork is needed, making the technique suitable for the treatment of extremely vulnerable objects.

The long-term effects on these real artworks needs to be evaluated. Also, further research is necessary to account for the absence of discolouration upon direct UV irradiation. Since the results on real artworks with different binding media (than used in the test systems) indicate a different short-term behaviour upon laser treatment compared to the test samples, future research will study the effects of UV laser light on naturally aged artworks with different binding media.

Acknowledgements

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Laser Cleaning of Organic Materials

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Pulsed lasers are becoming new tools in the hands of restorers [1-3]. Most activities, however, were concerned with the laser cleaning of stone artefacts, wall paintings, and facades. The contactless laser cleaning of biopolymeric, such as varnishes on paintings, and biogenetic surfaces such as parchment, on the other hand, has been approached only in recent years [4-15]. By now, laser beam delivery has been realized either via an optical fibre or an articulated optical arm to a hand-held output optics common in facade laser cleaning, or it is immobile relying on the movement of a scanning mounting supporting the work piece.

The cleaning objects painting varnish, tempera paintings, paper and parchment belong to the chemically most fragile substrates exposed to high-power laser radiation. The main constituent of paper e.g. is cellulose. The overall structure is of aggregated fibrils with extensive pores capable of holding relatively large amounts of water by capillarity. Collagen forms long ropes and tough sheets.

One of the first examples of laser cleaning of organic materials was demonstrated at paintings and icons [4-6]. Ultraviolet (UV; 248 nm) excimer lasers were used to remove old varnish layers from painted artworks. In contrast to infrared light that penetrates the paint layers, UV light is absorbed in the surface layer of a painting, enabling the removal of surface material with minimal thermal or photochemical effects on the underlying layer. Laser-induced breakdown spectroscopy (LIBS) was used as a diagnostic tool to control the cleaning process.

The laser was able to ablate the discoloured layer while leaving the paint surface texture intact. Residue of dark material remained only deep into the holes of the hardboard support. However, the in-depth cleaning of the surface with conventional methods was difficult as well. Despite the fact that the laser light was in direct contact with the paint surface, the original paint layers were not visibly discoloured.

Paper and parchment on the other hand was cleaned according to a completely other strategy: there, maximum contrast between contaminant and substrate was exploited in employing visible laser light (532 nm, Q-switched Nd:YAG) were the substrate exhibited minimum interaction. That guaranteed a minimisation of cellulose and collagen deterioration (7-13). The cleaning process was programmed for automatic laser beam scanning operation. The pulse duration was c. 8 ns and the repetition rate could be chosen up to 1000 Hz. The workstation featured on-line diagnostic tools such as visible, ultraviolet and fluorescence imaging for the identification and documentation of visible and chemical changes of the irradiated substrate areas. The multi-spectral imaging system operated in a spectral range from 320 nm up to 1550 nm]. Several imaging modes are possible: visible reflection, infrared reflection, visible fluorescence, and ultraviolet reflection.

One of the major challenges of precision cleaning is to avoid areas of ink, printed letters or pigments. A section of an old office document on rag paper was contaminated with pencil scratching almost to unreadability. The area to be laser-cleaned was drawn on the computer screen by the mouse movement as a customized lithographic mask. Then, the system automatically scanned the intended area.

The cleaning system also proved successful on originals, such as a sheet of music of a psaltery from 15th century, which was heavily soiled during a bombing attack at very end of Second World War. There, hand-written ink letters, notes, and lines of the staff often have to be preserved from the converting action of the laser beam.

Model experiments for the dry laser cleaning of fibrous materials such as textiles contaminated with organic and inorganic micro-particles on silk fabric (tabby crepe, provided by Prevart GmbH, Karin von Lerber, Winterthur, Switzerland) were undertaken. A silk fibre is made up of spidroin proteins whose structures provide silk with unique properties. Silk fibres get their stretchiness from the disordered, loose, coil-like protein chains of glycine peptides (amino acids) that stretch when pulled, giving silk its elasticity; and it gets stiffness and strength from highly ordered, 'brick-like' protein crystals of alanine peptides that are spread throughout the silk line.

The composition and the size of the micro-spheres have been varied. The evaluation was undertaken microscopically by a computerized imaging system. Detailed scanning-electron-microscopical evaluations allowed an insight into possible morphological modifications due to the phase separation process and near-field optical complications.

Currently, special efforts are undertaken to develop process modes to speed up the scanning of larger areas. It has to be remarked that an efficient exhaust system is not only vital for the operator's safety but also to avoid redeposition of already vaporized contaminants. Further research on the molecular understanding of the influence of laser radiations with various photon energies is under way.

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Multispectral Image Analysis Applications

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Art objects are usually considered from a historical and aesthetical approach, but modern human society emphasizes also the care for their material condition and composition. The material aspect of the Cultural Heritage is the solid base which sustains the complete artistic message and this concrete pedestal is a key factor in understanding also the refined meaning which the art objects posses. Any modern scientific approach related to art study must face both aspects of the cultural heritage: his material and immaterial condition and existence. Conservation/restoration of Cultural Heritage targets directly material compounds but there is a strong connection with aesthetical and historical message as their relation proves it.

Multispectral image analysis is a technique based on simple principles. Its application has some history already but certain steps have to be carried out in order to offer a full access to the advantages of this technique to specialists from other areas. Based on a simple observation that different materials absorb the light in different way, it is possible to measure the amount of light absorbed and reflected and to establish precise spectra of absorbancy or of reflection for substances that compose art objects. It is also possible to record these spectra not for visible waves, but also for UV and NIR waves. Approaching this idea from a different angle we can consider that electromagnetic waves from UV range to NIR range, including of course visible spectra, go through artwork materials in different ways. If it is possible to analyze the way that materials behave at electromagnetic radiation exposure with a handy mobile device a lot of valuable data will be available to art evaluation, conservation or restoration specialists without support from specialized laboratories.

Such device consists in a high resolution digital camera which can record in separate modes images in UV, visible and NIR spectra. These images are processed, compared and stored using dedicated software. Certain databases offer electronic version of classic conservation-restoration documentation. These databases can be shared via internet with other specialists for further cooperation. They also can be printed and used in various requested documents related to authentication, conservation or restoration of art objects.

Another aspect regarding artwork materials behaviour at different ranges o UV-VIS-NIR spectra is related to identification of differences between almost the same coloured materials. If the most trained human eye can hardly see any difference between two materials and these materials are chemically different somewhere from UV spectra to NIR spectra these materials will look different on computer screen due to selective mode operation of digital camera. Varying dependant on working mode selection it is possible to identify a complex range of degradations and modifications that art work materials suffered in time.

Based on some years of experience, the paper will resume some of the actual investigations performed by our specialists together with dedicated departments from well known museums and private enterprises form Romania. The results prove the reliability and usefulness of the multispectral imaging system combining convenient adaptation, rapidity and quality of acquired information.

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The use of lasers in the field of conservation in Austria

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The Beginning:

Since the early 1970ies, laser technology was successfully applied for cleaning of artefacts. The first cleaning treatment with a laser was done on stone works in Venice by an interdisciplinary team leaded by J. Asmus in 1972. A ruby holographic laser was modified and used for cleaning of the lions portal at Palazzo Ducale in Venice and other pieces of art made in marble. Although the cleaning results were convincing, for a longer time laser was only used seldomly. In some single cases C. Calcagno used the laser technology for cleaning some sculptures or ornaments made in bright marble or limestone. Up to the middle of the 1980ies the interest for this technique increased in Europe. In France, Italy, Greece, Germany and Great Britain interesting cleaning projects with laser tools started to be carried out. Basic research was done improve the laser tools and to test it on a wide range of applications. Because of these efforts the laser tools became easier to handle and today they are suitable for work on scaffolding. From this moment the possibilities for cleaning have not focused only on stone materials. Laser cleaning technologies were also tested on metals, wood, ceramics, ivory, paintings, textiles and many other inorganic and organic materials. In Austria the use of laser cleaning in the field of conservation was introduced in 1993. During the last 10 years a lot of different stone monuments and historical facades were analysed, documented, cleaned or reconstructed by laser technique (e.g. Romanesque and Gothic parts from St. Stephens Cathedral, marble sculptures from the parliament and public gardens, Gothic outdoor sculptures and facades from many other churches and buildings). Four different types of modified Nd:YAG-lasers were used. Some conservator-restorers and the Federal Office for Care and Protection of Monuments are responsible for the acceptance of the lasers in the restoration works. Only in this combination the laser work was successful.

A hard way to convince:

The responsible institutions in the field of care and protection of monuments and artworks are very careful and critical with new conservation techniques and so a lot of preliminary examinations and tests were carried out by scientists and conservator-restorers. In the field of stone conservation the laser cleaning technique is usually compared with other traditional techniques (e.g. micro sandblasting, paper pulp pad impregnated with an aqueous solution of ammonium carbonate and ion exchange resins. In many cases laser cleaning showed advantages and therefore some very interesting conservation projects could be done with Nd: YAG- lasers (e.g. Romanesque portal of Cremona, the portals of the Cathedral of Amiens and Notre Dame in Paris, etc.). Especially on very delicate surfaces with thin scaling or brittle parts the laser offers the better alternative cleaning method, however problems have been observed in connection with some pigments and some binding media. In some cases the yellowing of some stone surfaces after laser treatment represents an esthetical problem.

Subsequently, a scientific platform was founded in Heraklion, Crete which was called LACONA (Lasers in the Conservation of Artworks), but there are also other national and international associations which are working in the field of laser technology for artworks (e.g. COST G7, LACONA).

Laser tool and function

At the moment there is a concentration of producing Nd: YAG lasers for stone conservation, although other laser types could also be successful for special cases. Presently, approximately five companies have YAG-Lasers in their production. Common parameters of Nd:YAG-lasers are: wavelength (λ): 1064 and 532 nm, energy pulse energy (E): 250 – 1000 mJ and more, pulse width (t1): 6ns and more, repetition frequency (fp): 5 – 20 Hz and more, peak power (Ppk), average power (P) (W), beam diameter (non focused): 2 – 20 mm, different lenses, beam delivery: mirrors or cables made from glass fibre, focusing devices (e.g. zoom optics). Recently the colleagues in Greece developed a modified laser system which combines ultraviolet and infrared laser radiation (4).

The process of cleaning with laser is done by evaporation (photo thermal ablation mechanism) and ablation/spallation (photo mechanical and photo chemical ablation mechanism) effects.

The intensity of absorption or reflection of the laser light, which is manly caused by the shooted substrates (stone, dirt, layers of over paintings etc.) is responsible for the quality of cleaning.

In the simplest case, a bright white stone is covered by a black dark crust. After the evaporation of all black crust there is no dark material for absorbing the laser light and the light will be reflected without producing any damage for the white stone. This is also a reason why wet dirt is easier to remove because it is darker. In reality such clear simple cases are rare and difficult situations are making the process of laser cleaning quite complex.

Base for laser cleaning

In the field of conservation (= cleaning) the most important parameters defining the conditions are the stone type and the nature of its surfaces as well as the presence of historical paint layers. The characteristics of the patina layers including black crusts, dust, soot and salts to be removed with the laser device are also important concerning the effect and speed of the cleaning process.

In principle every cleaning has to respect the signs of history and time because they are documenting the periods between creation and today. The task of laser cleaning is also connected with the "value of age" and other aesthetic values.

Sandstone, calcareous sandstone, marble, red limestone as well as other bright stone types have shown very successfully excellent results after laser treatments. The risk of undesirable cleaning effects has been reduced through foregoing appropriate cleaning samples and permanent scientific controlling. For special cleaning problems e.g. white marble surfaces with sandy scaling the laser tool can preserve even delicate surface details, which are often identified as last preserved original stone surfaces. A big advantage can also be the possibility to clean without pre-consolidation (e.g. ethyl silicate, acrylic resins, silicon resins and other mixtures). In this case laser cleaning can often be faster than other cleaning techniques.

Stone material where Laser was applied successfully:

bright marble: Carrara marble, Laaser marble, Penthelicon marble, Carinthian marble,…

sandstone: Types of quartz sandstone (e.g. Wienerwald-Flyschsandstein), types of calcareous limestone (e.g. Margarethner or Zogelsdorfer stone

compact limestone: Istrien stone, Untersberger limestone, Verona red, Adneter red.

Concrete, artificial stone and different types of mortars

Material that could be removed from stone surfaces:

black crusts, thin concrete layers, dust and soot,old acrylic and epoxy layers from old treatments,

casein layers from former conservation treatments

From the economical point of view the comparison between traditional and high tech cleaning systems is very important. Often the best cleaning result can be achieved by combining three or more cleaning techniques, including also laser treatment for special purposes (table 2).

However, if there are monochrome or polychrome layers, cleaning with Nd-YAG lasers is possible only in rare cases. Example: Comparison of different methods of cleaning at the Romanesque West portal of St. Stephen's Cathedral in Vienna.

It is also very important for the conservator-restorer to follow safety regulations thoroughly. Protection with special glasses for the eye, gas-mask, appropriate cloths, exhauster and a right isolation with a sign for danger of the working place (studio, scaffolding, workshop) where the laser is used are an absolute mandatory.

Applied to stone conservation the laser technique is not only used for cleaning but also for laser diagnostics (e.g. holography, vibrometry), 3D-measurements for monuments and artworks (documentation tool) and spectroscopy for monitoring and identification (e.g. RAMAN, LIBS, LIF).

Prospects

There is a great attention to side effects caused by laser cleaning (short- and long-term), including the behaviour of pigments and binding media, removal of former conservation layers, fundamentals of laser-artwork interaction (yellowing), recent laser developments for cleaning (e.g. uncommon wavelengths, short/long pulse), laser cleaning stations for practise (in situ/atelier/lab), standardization, safety and health aspects and many other connected contents.

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3D Images of Artworks by Laser Scanning

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Laser systems are used to illuminate at low levels, in scanning mode, artwork surfaces.

The detection of the reflected light, using different techniques, provides the acquisition of information of the spatial coordinates of each scanned point on the artwork surface, allowing the construction of digital models and 3D imaging of the original surfaces.

Principles of operation and different applications to Rupestrian Art, Roman Ruins, Easel Paintings and decorative Architectural Elements will be presented.

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lication of the amplitude-modulated Laser Range Finder (LRF) for 3D imaging in campaigns aimed to model ancient0 caves tombs and crypts

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ENEA – FIS-LAS

The high performance Amplitude Modulated Laser Rangefinder (AM-LR) realized in order to accurately reconstruct 3D digital models of real targets, either single objects or complex scenes has been utilized fro archaeology. Small and large subterranean room have been scanned in order to obtain a precise model of the drawings and fresco's there contained.

Results collected in Italy on a Palaeolithic painted cave (grotta dei Cervi, Porto Badisco) will be presented, together with those collected in a palaeo-Christian Church (S. Marina Antiqua in Rome) and an Etruscan tomb (Tomba dei Demoni Blu, Tarquinia).

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Laser Investigations on Organic Artworks

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The paper is part of a large systematic investigation on the effects induced by the laser radiation on particular organic materials that may be found as artworks' substrates. The results of the study are designed as a useful guide for future laser applications that are expected on this category of materials and also, as a useful instrument that will ease up the embrace of laser methods by the current practice of Romanian restorers and conservators.

The experimental results and related comments are structured into a database that contains investigations such as: colorimetry, LIBS - single scan and stratigraphy spectra - for the evaluation of the laser cleaning efficiency, the depth of laser penetration corroborated with depth of different materials' layers, as well as their chemical compounds, emissivity informations, microscopic images related to any modifications that may have occurred on the surface relief.

The test series have been carried out using a Q-switched Nd:YAG laser working at 1064nm, 532, nm, 355nm and 266nm, being real time monitored by microscopic and thermographic techniques.

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Laser Cleaning Strategies spring up Historical Buildings

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The main goal of the team was to develop a proper cleaning solution that will offer the best protection for the original stone layer but with a complete removal of the dark encrustations from the surface. Several methods were compared to laser cleaning, such as combined chemical and mechanical removal. The results proved that laser cleaning has a higher speed, precision and selectivity compared to other traditional methods. The interventions envisaged two of the most important Romanian religious places Lady's Church and Stavropoleos Church, buildings with great historical, cultural and architectonic significance.

The **Lady's Church** is located in Bucharest city center; it was built in 1683 by Princess Maria Cantacuzino on the site of a former wooden church. It was painted in fresco technique by the famous Greek painter Constantin Mina. Due to the wrong urbanism development strategy combined with the pollution generated mostly by high traffic, this historic and artistic site was severely deteriorated. The poor stone conservation status does not allow the traditional cleaning methods application. This stone laser cleaning application was the first one done in Romania with special support of the national authority for historical monuments attendance.

Cleaning stone decorations at **Stavropoleos Church** in Bucharest was the second on site application of laser cleaning in conservation in Romania. It demanded a special attention because of the complex palette of materials that have been used to build it up. Very fragile decorations, affected by environmental degradation, address a challenge for stone restoration. The church was restored following an all together vision of the architecture and decorations under a common strategy. That's why the final aspect of the columns must look at the end of laser cleaning stage according to the image of the newly applied exterior plaster on the church walls.

A complex study was accomplished comprising a synthesis of the most important published papers on this field, important laboratory experiments on different types of stone, as well as in situ experiments. In both buildings, the laser employed for stone cleaning was a Q-switched Nd:YAG laser set at 1064nm wavelength with 0.6 J energy.

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