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PREFACE

The volume of proceedings includes the selected papers and abstracts presented at the 2nd International Conference "Modern Methods of Testing and Evaluation in Science" NANT 2015. The Conference takes place every year and this year was held on 14-15th December 2015. at Faculty of Mechanical Engineering, University of Belgrade.

The main aim of this Conference is to provide a Forum for researchers and experts from different country to exchange their ideas and achieved results, but also to include young people and students in scientific research and acquaint them closer with the methods of testing and evaluation in science. Having that in mind, we put additional emphasis on active participation of students and young researchers, so the idea is that all papers will be presented by students who previously contributed to these papers with their older colleagues.

The Conference brought together the participants from institutes and universities from different countries: Croatia, Romania, USA, Bosnia and Herzegovina, Macedonia, Sweden, Libya, Iraq, Spain, Montenegro, Ukraine, Belarus, Poland, Slovenia, India and others.

The aim of the conference is, also, to connect different fields of science, because we can find many common points between different research areas, and by doing that, to open possibilities of developing new technologies or improving the old ones. Therefore, the Conference covers various topics from the following fields: mechanical science, transport and traffic engineering, material science, metallurgy, electrical engineering and other engineering areas, but all other sciences as well, including for example medical science, which uses different techniques of experimental examination and testing.

The program of the Second Conference consists of keynote lectures, oral and poster presentations.
Co-organizer of the Conference is Innovation Center of Faculty of Mechanical Engineering in Belgrade and main sponsor is BAS from Belgrade. We would like to kindly thank them for their help.

We would like to thank all authors who have contributed to this volume and also to the Scientific Committee, Organizing Committee, reviewers, speakers, chairpersons, and all the conference participants for their support for a successful scientific meeting.

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POTENTIAL AND CONTEMPORARY LASER APPLICATIONS WITH PARALLEL TECHNIQUES IN THE PROCESSES OF MONITORING, PROTECTION AND RESTORATION OF CULTURAL HERITAGE OBJECTS

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Abstract: Laser applications in processes of monitoring, protection, restoration and cleaning of the objects of cultural heritage still attract attention, inspite of relatively long tradition. Although numerous mutual problems are resolved, each precious object of cultural heritage is unique and needs specific characterization before exact laser operation. Contemporary generation of laser scanners along with competitive techniques accelerated the processes of data collecting and storing in the form of 3D digital models, irreplaceable in modern informative space.

Key words: *Laser, cultural heritage, 3D digital models, cleaning, material characterization*

1. INTRODUCTION

Laser application covers a wide range of fields, practical as well as scientific. Accomplishments were significant for the purposes of industry, medicine, communications, Space research, military, etc. where their requirements overlapped. Similar tasks of laser applications are present in diagnostics, various technical processing, telecommunications, remote control and energy supplying as well. Counting of technical disciplines would connect the same global tasks starting from products marking in vacuum conditions, to marking of samples for SEM and TEM (electronic microscopies), as well as marking in civil engineering and architecture [1-5].
Since the definition of cultural heritage includes the human beings, besides the cultural monuments made of various materials, the palette of laser tasks significantly spread. Historical overview of laser application in cultural heritage starts from the first days of the Second World

War and Heddy Lammar's ideas, nuclear explosions and plasma with *serendipity* (belongs to the most difficult category of words for translation in English speaking area). The opposite term for *serendipity* is *zemblanity,* which fortunately did not overcome. Without pretentions, practically there is no area where the lasers (in general) have no use. We will remain to some categories*:*

coherent illumination gives different impression in opposite to the incoherent;

laser coherency offers applications of various holographic methods for data storage object view or object monitoring in time and space;

starting points could be laser dash cleaning from the paintings (very small power);

cleaning tasks, multitasks demands for ablation processes of various organic/ inorganic layers, encrustation, etc. Different materials for conservation tasks demand very different power, frequency repetitions and incident wavelengths. The cleaning process could be applied on the field sculptures, sensitive museum objects, as well as massive walls of big palaces, bridges, etc.

laser scanning tasks concerning various problems in architecture and civil engineering [5] are technically ready for successful replacement of more classical methods, such as drawings based on measurements, or photogrammetry;

authenticity determination [6];

the tasks with commonly used acoustical methods were replaced with Brillouin scattering methods in defining the material performances state for studied objects (stone performances, anisotropy, cracks, etc.);

by accepting the laser induced breakdown spectroscopy - LIBS techniques, laser microscopic analyses - LAMMA techniques, Raman's scattering, etc. numerous chemical analyses were replaced.

Some selected tasks will be presented in this paper along with adequate laser functions (currently in use or potentially of significance).

2. LASER SYSTEMS APPLICATION IN CULTURAL HERITAGE - CLEANING ON THE BASIS OF ORGANIC MATERIALS AND PAPER

The laser application for the materials in printing technology, graphic arts [7,8] and for objects (materials) of cultural heritage is very well known due to possibility to provoke transformations to/of surface states, operations of material cutting (or separation) as well as for techniques of proper storage of valuable papers (and data) or cleaning of objects of cultural heritage [7, 9, 10]. It exists for a long time in common life and in theoretical consideration. Selected samples (i.e. paper based samples) are exposed to different laser beams in respect to laser wavelength as well as laser working regimes. The samples were of different age with various histories. These should be defined before and after expositions, with standard and less conventional techniques. Other possibilities should be analyzed with respect to potential laser applications considering special cases (water mark [11], confirmation of authenticity, etc. or possible and at-the-moment-impossible material cleaning processes). Laser printouts were not considered in study presented although the influence of lasers for further cleaning processes of materials and documents, produced in different manners, including laser printed samples, offset printed materials, etc. are non negligible. It means that paper [8] was used, as well as cardboard, parchment, textile, fabrics [12, 13], insulation paper - used in electrical devices, oil transformers, and surface changes o material and material characteristics (performances) obtained by contemporary thin coatings (single or multiple thin films) [14, 15]. It is very known that metal coatings are replaced by dielectric multicoatings.

There is an urgent need for coordination of standards concerning laser application in the domain of cultural heritage. This task needs multidisciplinary approach, because any larger project requires consent of the responsible institution, while from the intervention point of view the acquaintance with several factors is necessary: interaction of coherent radiation with material, IT approach, area definition for chosen object, etc.

Elements for interaction and productivity are always actual topics. Only the laser number will be here considered. It defines the material feasibility for laser methods processing.

2.1. The laser number definition

The laser number definition is linked to the ease of the material laser cutting (Tab.1).

$$N = \text{integer } T^2_v/(I+1)^2\ 100, \qquad (1)$$

where N is laser number, T_v - Vicat temperature and I- incandescence resistance.

Since Vicat temperature definition is holding under 200°C this definition is limited for use. The N value is linked to the possibility of cutting processes.

In the Table 1, a short categorization of the material after N is given.

Table 1: Laser number and classification of material for laser processing efficiency

N value	Cutting process with laser
20<N<100	excellent results
9<N<20	enough
4<N<9	poorly
N<4	very poorly

2.2. Material performances

Serbian standards (with respect to the other countries, ex SFRY and Montenegro) concerning paper, as the example here given, define general regulations about quality testing, sampling and air conditioning.

Classification in general: grammage, format, fiber direction, thickness, specific gravity, volume, ponderability and humidity.

Structural performances of the fibers concern composition of the fibers, other components, porosity and purity.

Capillary and hygroscopic properties: absorption of moisture and grease or odor and leakage.

Optical properties: whiteness of the paper, opacity and transparency, fluorescence, color, brightness, light resistance.

Printing properties: scalability, smoothness, roughness, hardness and softness, strength and elasticity, dusting and cleaning.

Dielectric properties: conducting, electrical isolation, static electricity.

Mechanical properties: resistance to tearing, splitting, punching, bending, compression pressure, dimensional stability.

Chemical properties: content and composition of fillers, ash, lignin, glue, paraffin waxes, fats, oils, determination of pH.

Specific properties: ageing resistance, inflammability, and biological processes on gasses, steam, fats and light.

All material performances should be defined by adequate measuring techniques and modern interpretation of measuring uncertainties. In some of them laser measuring methods are implemented.

Traditional paper conservation along with old parchments were the objects of investigations in many institutes. These investigations are crossing with palimpsest [16].

In Figs. 1 (a-f) are presented some of the pages from old books with characteristic parts which deserve laser cleaning. Some tests were performed with graphite pencil or ball point pen traces, where 1060 nm (or harmonics) of laser cleaning devices wavelenghts were used for their removal. Also, we tried whitening (decoloring) of the old pages color. The experiments were performed for organic and inorganic stains. Depending on the material type, some wavelengths were more efficient than the others.

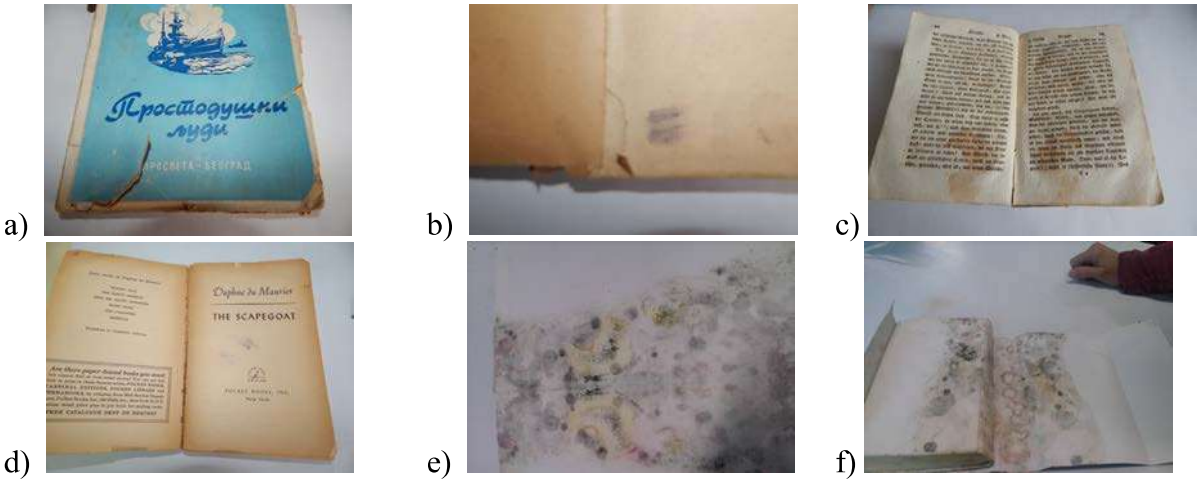


Figure 1: a-d The pages of old books (printed more than 50 years ago) partially cleaned with different laser wavelenghts; **e-f** The pages with organic stains aimed for laser cleaning by Nd^{3+}:Yag and its harmonics

2.3 The role of excimer lasers

Excimer lasers are used to remove biological waste from substrate - original artifacts. KrF laser [17,18] is often used for removing Aspergillus niger mold, which could be find in filer-paper. The air in close environment, as well as the role of aperture size is investigated. It is found that filter paper is sterilized by laser treatment. Spores and mold fragments are sent in the atmosphere and represent relative risk disregarding to all professional working conditions.

Excimer lasers [18] are also used for sterilization purposes of inner side of cardboard & container before filling processes as nonchemical sterilization methods which enable longer life of products of different kinds (wood, ivory, ebony, mahogany). Papillomas caused human viruses.
Laser application on paper cleaning [18, 19, 20] was successfully made for the books of the beginning of 20th century. Besides that many technological steps concerning cutting and drilling of paper and fabrics material are performed, as for the sterilization, too. All these processes are of interest for restoration and conservation of cultural heritage.

2.4 Laser damages on ceramic artifacts from the Pločnik area

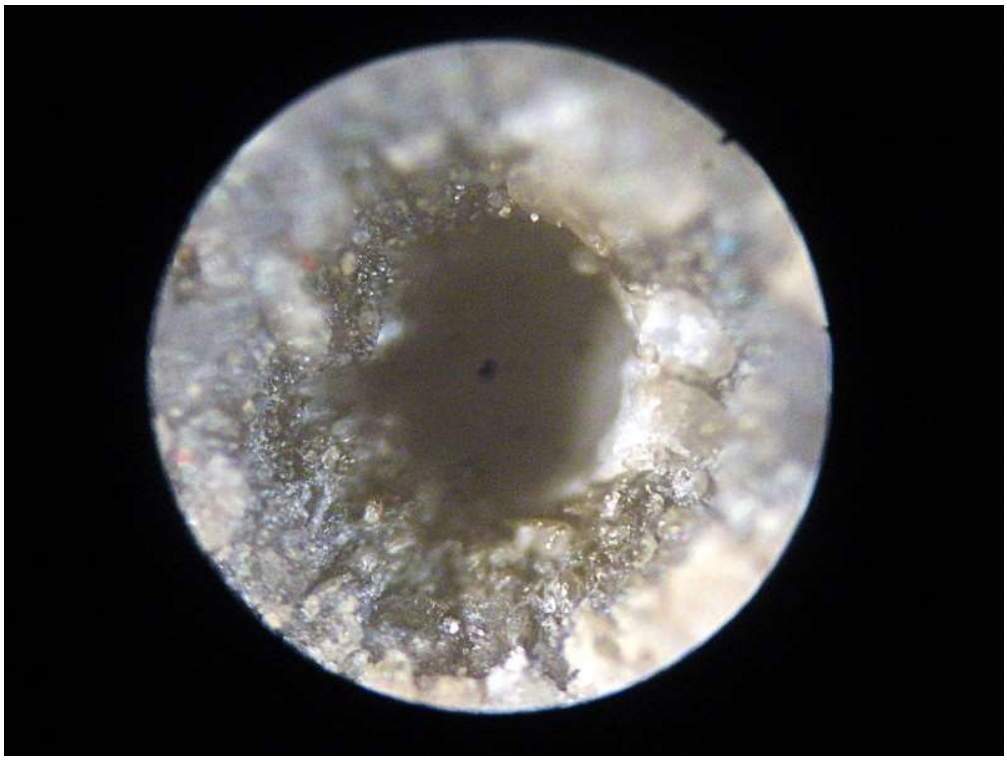
In the testing processes of ceramic artifacts from Pločnik area, we exposed some samples to Nd^{3+}:YAG laser operating on the principal transitions, i. e. λ=1060nm. After the exposition we performed microscopic analyses (Fig.2).

Nd^{3+}:YAG
E_I=40mJ/pulse
1000 pulses
OM 56x

a)

Sample 1, front , crater 1

Nd:YAG
E_1=40mJ/pulse
1000 pulses
OM 120x



b)

Sample 1, front , crater 1

Figure 2 - a,b Details of laser interaction with artefacts from Pločnik area in testing process

3. CONTEMPORARY TASKS IN CULTURAL HERITAGE CONCERNING LASERS AND OTHER PARALEL TECHNIQUES FROM ARCHITECTURAL AND CIVIL ENGINEERING POINT OF VIEW

Cultural heritage protection and revitalization of significant historical monuments recently accomplished serious results in development of methodologies when processing of collected data, documentation and presentation are concerned.
New results are presented in virtual reality surroundings by 3D technology. Laser scanning, radar surveying and photogrammetry offer accurate point clouds, for generation of 3D digital models (triangulated meshes), or orthophotos with photo realistic textures. The CAD/CAM and CNC technologies enabled materialization and mass production of archeological replicas in the form of 3D models. The applications of all these techniques cover a wide range of disciplines: scientific, historical or educational research, tourism, architecture, media, etc. starting from small artefacts to the monumental complexes.
The tasks in the area of restoration and conservation depend on precise information about original material. Whether the ancient or newer objects are concerned in the surveying process

or repairment of the monument, the laser techniques are highly confident. The small samples of the material are sufficient for reliable results in material identification when the laser techniques with minimal destruction LIBS- laser induced breakdown spectroscopy are applied. Current tendencies in measuring techniques are concerning nondestructive *in citu* measurings (Fig. 3), microscopic samples and remote sensing where the lidar techniques and extensive experience offer precise description of the particular material.

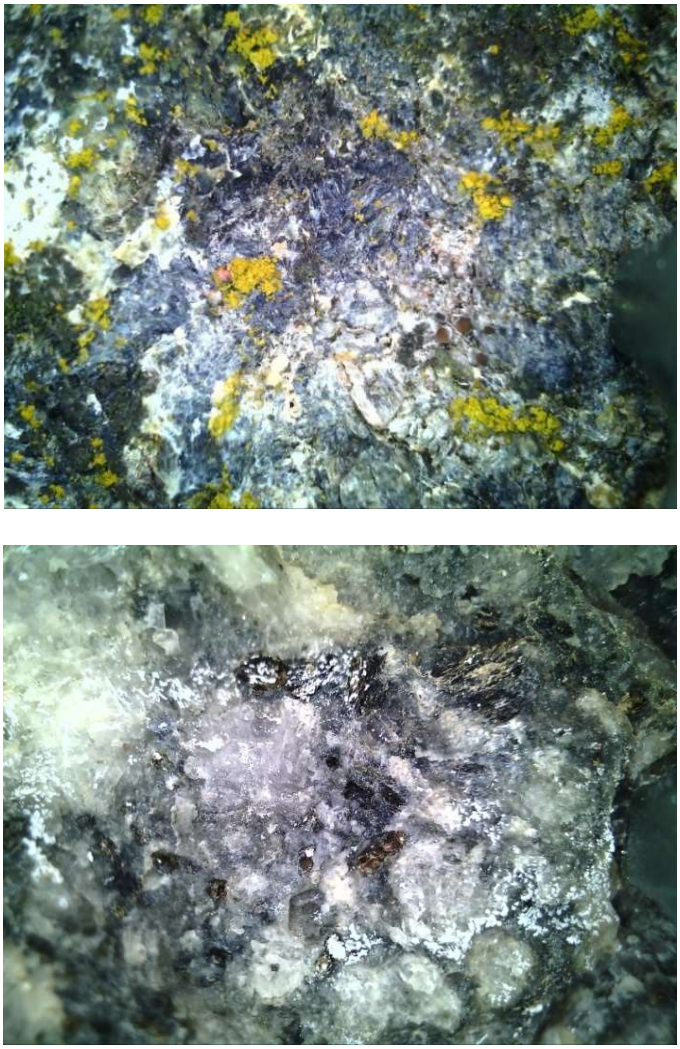


Figure 3: Microscopic images of the stone samples from monastery in Slavkovica village

Thermal imaging is one of the parallel techniques [21] for diagnosis with respect to the remote control, lidar and radar, while including mm wave remote methods, triangulation [22], etc. methods are in constant competitions. The principal reason for exact choice could be the price of commercial devices.

3. 1 Revitalisation process of Serbian medieval monasteries

Serbian historical, cultural and identity representatives among other are monasteries and churches of the medieval time. Most of them, like Slavkovica, Kastaljan and Pavlovac (Fig. 4a-c) were witnesses and the "victims" of the wars on Serbian teritory during Ottoman empire. As

the representatives of the significant historical period, along with their architectural, spiritual and other social values, they deserved special attention. Their concept and location were thoroughly chosen, in order to achieve quiet oasis for the pilgrimers or travelers positioned nearby the main medieval roads. The process of revitalization for such monuments requires thorow analyses in dimensions (proportions), style and building techniques, material, reconstruction and final presentation concept [23]. Temporary state of the remains dictates the scientific approach and adoption of strict regulations of cultural heritage institutions. However, the valuable data collected *in citu* may be of interest for different kind of interventions – building, architectural design, artistic, etc. Severely damaged objects need all the phases of restoration and revitalization and require adequate technical documentation of the existing state.

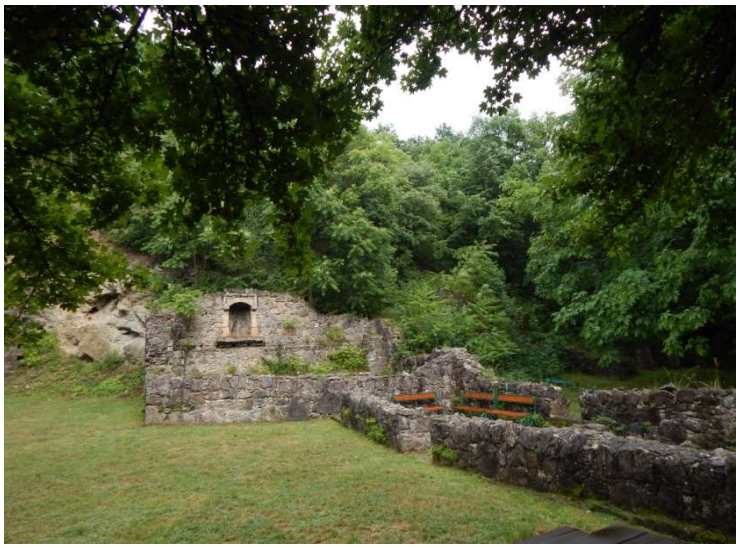


Figure 4a-b: Monastery complexes Kastaljan and Pavlovac near mountain Kosmaj, 14th century

Figure 4c: Inner space of the monastery church in village Slavkovica, near Ljig

The authors presented results of the research carried out in the central Serbian region on the medieval monastery devoted to the Introduction of the Holy Theotokos (God's Mother) located in village Slavkovica near Ljig. The accent on the first phase of the project was on accurate technical documentation. 3D digital model of the monument's current state (Fig. 5) is obtained by terrestrial photogrametry methods. For the modeling phase, high computer preferences were required, because of the processing of 300 photos. Camera preferences: Canon EOS 5D, lens - Canon EF 24mm f 1:2:4. Software support was the Agisoft Photoscan, very reliable and high ranked in this area.

Figure 5: Ortophoto image – north facade view of the monastery church in Slavkovica (point cloud image made by *Agisoft Photoscan* software)

Since photogrametric method is competitive and severely cheaper regarding laser scanning (scanner itself and other equipment, including the adequate software solution) it was chosen in this project. The location of the monument was convenient for the photo shooting, due to the absence of the barriers. The difficulties concerned overlaping of the images in vertical sense,

so the higher parts (the roof) of the object were poorly presented in the final model. When comparing this method with laser scanning, it needed a lot of manual positioning of markers (approximately 80) on the inner and outer walls [23], while laser scanning required just a few (3 visible markers for each scanning position).
Final 3D model (Fig. 5) resulted with significant accuracy in dimensions and high quality of the image texture. The project had its educational and practical purposes, since the students were involved in the realization, while the results were used for precise architectural technical documentation (view and cross sections of the object) of the existing state of the monument, with significant level of details. Further actions with 3D model imployed GeoMagic Studio software, for corrections of the model, dimensional analyses and cross sections. Current reconstruction of the monastery church is in the elaboration phase of the main project.

4. CONCLUSION

Laser cleaning has its tradition for more than 20 years. Rather simple cleaning procedures for the materials such as paper are often successful, but the prior material characterization (original material and encrustation) is necessary for the choice of adequate working regime of laser cleaning devices.
Available technology possibilities concerning 3D digital models obtained by laser scanning or parallel methods (photogrammetric) enabled high time efficiency and geometric accuracy of technical documentation, as well as high performance presentation on damaged cultural heritage objects, such as historical remains of medieval monasteries. Simultaneously, various software products compatibility, opened wide range of investigations concerning accuracy, model corrections and further architectural design.

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