LASER CLEANING OF THE HERITOLOGICAL ARTEFACTS IN NANOSECOND REGIME

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Lasers have been employed as cleaning tools for historical objects and artworks for the last few decades. Lasers provide noncontact and nonchemical interaction. In this work, the papers from the end of XIX century and artefacts made of brass and bronze are cleaned by Nd:YAG laser that operates in nanosecond regime, with different time of exposition. Cleaned samples are investigated by light microscope and spectrophotometer and results are analyzed and discussed. The laser proved to be successful in cleaning of the heritological artefacts.

Key words: laser, paper, copper alloy, conservation, cleaning, light microscope, spectrophotometry

1. INTRODUCTION

Laser cleaning of artefacts has been successfully employed worldwide over the last few decades [1]. Cleaning of cultural artefacts, especially fragile materials like paper, is part of the conservation process [2].

The cleaning of historical documents on paper requires the elimination of existing stain, dirt and damage without further damage to the paper [3, 4]. Removing contamination from the artefact without altering the sample and the authenticity is an essential part of the conservation process [5—7]. Laser cleaning has been applied in many different historical mediums such as stone, painting, sculpture, textile, etc. [8]. Laser cleaning is non-contact and non-chemical process. Lasers have a number of control parameters, such as wavelength, pulse duration and power which can be adjusted in order to efficiently dispose of the dirt layers with a minimum damage to artifacts.

This paper presents the method of measuring the performance of cleaning paper, as well as the results of the preceding studies and suggestions as to further research.

2. EXPERIMENTAL

In this experiment, a Thunder Art – Quanta System Nd:YAG laser model was used. The specification of the laser is given in Table 1.

A digital thermal imager FLIR E6, used in the study, is based on an uncooled microbolometer detector and forms a thermal image by measuring the infrared radiation of a particular body or the entire scene. Software contained in the camera performs the necessary corrections during the conversion of the thermal image in a thermogram, which represents an estimated temperature of an exact recording of the object, or a temperature distribution in the scene. Postprocessing of the results was done using FLIR Tools Plus professional software which allows performing analysis of the temperature field distribution, monitoring overruns in the zones of interest, viewing weather depending on temperature, viewing the temperature profile along a given line, etc.

The set-up of the experiment is shown in Fig. 1.

Table 1

Specification of Nd:YAG laser model Thunder Art – Quanta System

Energy wavelength 1064 nm wavelength 532 nm wavelength 355 nm	 900 mJ 450 mJ 150 mJ
Output beam diameter	10 mm
Pulse duration	≤ 8 ns, 1064 nm
Beam spatial profile Near-field (fit to Gaussian) Far-field (fit to Gaussian)	 ≥ 0.7 ≥ 0.9
Beam delivery	7 mirrors articulated arm
Operating temperature	10+5ºC

Fig. 1. Set-up of the experiment

The following artefacts were treated by laser:

1. Book "Žitje Gerasima Jelića", Serbian Literary Association, printed in the State Press of the Kingdom of Serbia, Belgrade, 1900;
2. Sample of corroded brass.

The experiment was performed with the following parameters:

wavelength 532 and 1064 nm,
pulse energy E_1=0.5 mJ, E_2=1 mJ;
time of exposition 1, 2, 3, 4, 5, 6, 7, 8, 10, 20, 30, 40, 60 s.

Treated samples were analyzed using a light microscope and a spectrophotometer.

3. RESULTS AND DISCUSSION

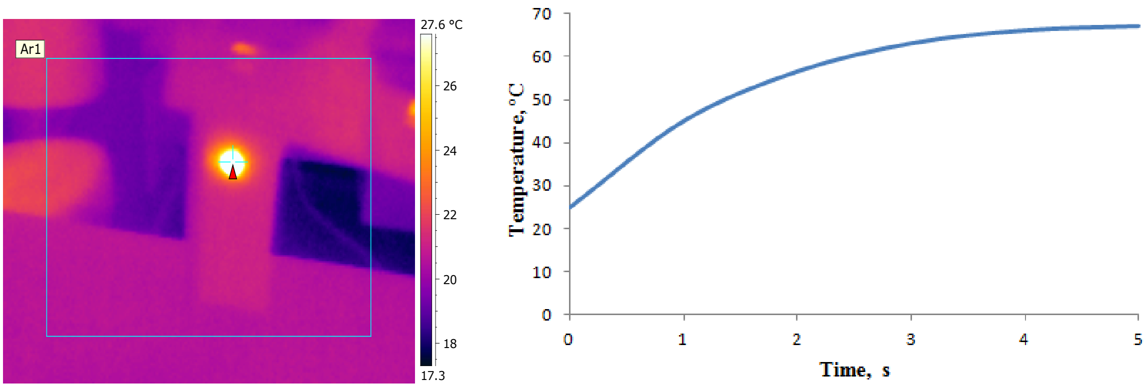

Fig. 2. Thermograms obtained during the cleaning of the paper

Fig. 2 presents thermograms obtained during the cleaning of the paper. The resulting thermograms show that the incident laser beam does not heat the target beyond permissible limits, so the energy of the laser pulses is mostly spent on evaporation of the materials on the surface of the cleaned sample.

The irradiated surfaces were investigated by a light microscope and a spectrocolorimeter and compared with untreated paper. Fig. 3 shows the result of cleaning off of the seal from the paper.

Fig. 3a shows the result of the cleaning carried out with the following parameters: wavelength 1064 nm, frequency 20 Hz, pulse energy 0.9 J, oval shape focus 3×2 mm, and exposure time 3 s. From the Fig.3a it can be noticed that the lower right part of letter "A" is cleaned off, i.e. the ink is totally removed. The upper part of letter "A" was cleaned with a smaller focus and the paper was damaged. Fig. 3b presents a letter "N" cleaned with the wavelength of 532 nm, frequency 20 Hz, focus diameter 3×2 mm, and exposure time 50 s. The cleaning in both wavelength regimes gave successful results; the 1064 nm regime required less time but easily damaged the paper. The cleaning with 532 nm turned out to be safer for the paper but the ink was not removed completely, ink microtracks could be found.

a) b)

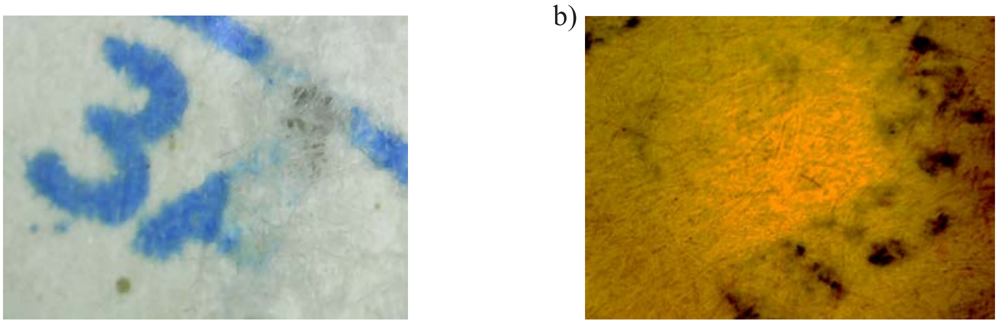

Fig. 3. Results of cleaning off of a seal from the paper using laser with different wavelength regimes: 1064 nm (*a*) and 532 nm (*b*)

Fig. 4 presents the results of cleaning of corroded copper alloys: bronze (Fig. 4a) and brass (Fig. 4b). Corroded brass was irradiated by laser with the following parameters: wavelength 1064 nm, frequency 20 Hz, oval shaped focus 3×2 mm, and exposure time 1, 2 and 4.5 s. The damages were analysed using an optical microscope and a colorimeter. Fig. 4b presents the damage caused by the irradiation during 4.5 s. Table 2 shows CIE L*a*b* results for non-irradiated area, and areas irradiated for 1, 2 and 4.5 s.

Table 2 and Fig. 4b show that the cleaning regime with the longest exposure time provided the best results.

a) b)

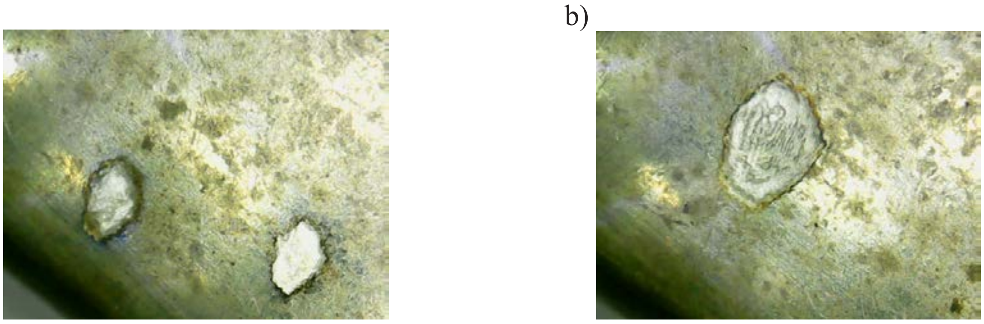

Fig. 4. Results of cleaning of corroded brass during 1 and 2 s (*a*) and 4.5 s (*b*) by laser with the wavelength of 1064 nm (magnification 5×)

Table 2

*CIE L*a*b* results for non-irradiated and irradiated brass*

	*L	*b	*a	chroma	hue
corroded brass	75.30	10.233	0.3	10.24	88.31
cleaned for 1 s	57.93	7.582	–0.186	7.58	–88.59
cleaned for 2 s	70.90	6.789	1.337	6.92	–78.85
cleaned for 4.5 s	73.51	5.826	0.136	5.83	88.65

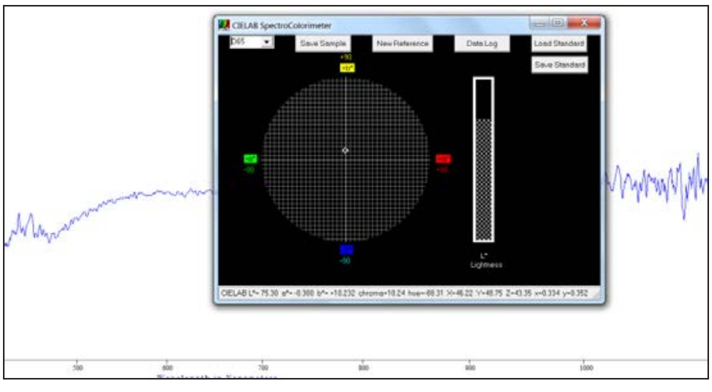

Fig. 5. Spectrocolorimetric results of the cleaned corroded brass

4. CONCLUSION

Laser interactions can be very effective in cleaning of the artefacts of heritological importance.

Optical microscope images show that the surface of the samples is successfully cleaned.

Optical microscopy demonstrated that ink (ink seal) can be successfully cleaned off of the 19th century paper.

CIE L*a*b* analyses proved that the laser removed the ink from the paper with the wavelength of 1064 nm, while with the wavelength of 532 nm some ink microtracks remained on paper.

Corroded brass and bronze were also successfully cleaned. Colorimeter analysis showed the best results with the longest exposure time.

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Лазерная очистка геритологических артефактов в наносекундном режиме

Лазеры используются для очистки исторических объектов и произведений искусства в течение последних нескольких десятилетий. Лазеры обеспечивают бесконтактное и нехимическое взаимодействие. В этой работе бумаги конца XIX века и артефакты из латуни и бронзы очищаются лазером Nd:YAG, работающем в наносекундном режиме с разным временем экспонирования. Очищенные образцы исследуются с помощью светового микроскопа и спектрофотометра. Исследования показали возможность успешного использования лазера для очистки геритологических артефактов.

Ключевые слова: лазер, бумага, медный сплав, консервирование, очистка, световой микроскоп, спектрофотометрия.