File: 25

Cleaning performance of femtosecond and nanosecond laser pulses for artificially soiled papers with sizing

Selçuk Aktürk[1*], Canan Yagmur Boynukara[1], Tansu Ersoy[1], Mehmet Uguryol[2], Gurcan Mavili[3], Havva Yagci[3]

[1]*Faculty of Science and Letters, Physics Engineering Department, Istanbul Technical University, Maslak, TR-34469, Istanbul, Turkey*

[2]*School of National Palaces & Historical Buildings, Department of Technical Programs, Architectural Restoration, Yıldız Technical University, Yildiz Campus, Z Block 34349, Yildiz / Istanbul, Turkey*

[3]*Mimar Sinan Fine Arts University, Findikli Campus Meclis-I Mebusan Street 34427, Findikli/ Istanbul, Turkey*

*akturks@itu.edu.tr

Laser cleaning is becoming of increasing practical use in cultural heritage conservation. The method has significant advantages over more conventional alternatives. Yet, due to strong dependence of performance on variations of materials and laser parameters, it has to be carefully investigated for each novel application. Nd:YAG lasers are used very commonly and efficiently for cleaning of mechanically strong materials such as stones. However, high penetration depth and high laser fluences may become problematic for application in more fragile artifacts such as papers, textiles and parchments [1][2]. At UV wavelengths, laser irradiation can also cause photolysis of cellulose. Furthermore, colour obtained after laser irradiation has to be very close to authentic colour of paper (e.g. colour of clean/uncontaminated parts of a historical document). Side effects such as yellowing or bleaching should be avoided.

Ultrashort-pulsed lasers offer more reliable method to clean delicate materials [3]. At such pulse durations, heat deposition to background material is minimal, eliminating the possibility of deterioration of fiber network. In our recent work on femtosecond (fs) laser cleaning of paper samples with sizing, we determined that the sizing layer provides some degree of protection to the underlying fiber network. As a result, it is still an open question to whether longer (e.g. nanosecond, ns) pulse durations might still be applicable to this particular type of paper material.

In this study, we present comprehensive and comparative experimental results including fs ns laser cleaning of paper samples with various sizing types. Sizing is a protective layer applied to paper surfaces. It prevents water or ink from spreading into paper. Various substances have been used for sizing in Ottoman papers, and we prepared a range of paper samples using various sizing types. The samples were artificially soiled with graphite and graphite - kaolin mixture. For aging, all of the samples were exposed to air at 90 ˚C and 50% relative humidity during 16 days. In laser cleaning treatment, two different methods and lasers were used. In the first method, Yb:Glass fs laser beam (1030 nm) was focused on paper surface by using cylindrical lens (25 mm focal length). Square regions were cleaned through scanning the samples under laser light. Laser power was varied in the range of 100-200 mW. In the second method, Q-switched Nd:YAG ns laser was operated at fundamental wavelength (1064 nm) and second harmonic (532 nm). Laser fluence is varied from 0.24 to 1.24 J/cm^2. Each sample was cleaned by means of 10 laser shots. Effectiveness of cleaning was investigated through measurements of colour variations and microscopic observations.

As a result of our evaluations, we conclude that fs laser cleaning is still superior in performance as compared to ns. Yet, the latter might still be of acceptable and significantly lower cost use in certain sizing types.

We gratefully acknowledge funding from TUBITAK (grant no 114f376)

[1] Krüger, J. et al., Appl. Phys. A **92**, (2008) 179-183.

[2] Rudolph, P. et al., Appl. Phys. A **79**, (2004) 181-186

[3] Ersoy, T. et al., J. Cult. Herit. **15**, (2014) 258-265