An optical surface measurement for laser removal of graffiti

Phumipat Kittiboonanan*, Jidapa Rattanarojpan, and Amarin Ratanavis

Department of Industrial Physics and Medical Instrumentation, Faculty of Applied Science, Lasers and Optics Research Group (LANDOS), Science and Technology Institute. King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

**Corresponding author. E-mail: phumipat.landos@gmail.com*

Abstract

In this paper, we present the creation of a new class of an optical surface measurement based on laser scattering principle. This technique is aimed to serve as a non-destructive testing tool for laser removal of graffiti. This study intends to design, build and demonstrate a simple and inexpensive online diagnostic system. The laser scattering system consists of a weak HeNe laser beam that can be used as the probe beam. The diffuse reflection of the scattering light from the inspected surface is projected on a screen. The image of the screen is then captured by a CCD camera. The image is analyzed by using an image processing program. The scattering image can be used to identify the laser cleaning threshold. In this study, an experiment on the angular laser removal of graffiti was setup as an example to testify the diagnostic system under practical conditions. A Q-switched Nd:YAG laser operating at 1.06 microns was used to remove graffiti from mortars. The pulse duration of the laser is 10 ns. The laser cleaning procedures were performed by changing the incident angle of the laser beam. The rate of application of pulses was remained at 1 Hz. The laser fluence was varied from 0.1 J/cm^2 to 7 J/cm^2. After the application of individual pulse, the assessment of quality of laser cleaning was performed with the laser scattering measurement. The laser fluence of the cleaning threshold varies between 2 J/cm^2 and 3 J/cm^2 according to the sample properties. This laser scattering measurement provides the simplicity of the optical setup and allows the further development of an online surface inspection potentially exceeding the performance of the current optical inspection technology.

***Keywords*:** Laser cleaning, Angular laser cleaning, Online surface inspection

Introduction

Graffiti can be appreciated as an art form or it can be seen as nothing else but vandalism of someone else's property. Regularly, Bangkok, the heart of Thailand, has been notice of graffiti. Heritage sites in Bangkok have been associated with increased risks of graffiti. The effect of such damages can be devastating. This study involves the methodology of the graffiti removal by using Nd:YAG laser equipped with an online inspection.

The use of laser graffiti removal has been proven as the alternative effective approach [1-13]. For the laser graffiti removal, the painted surface is meant to be removed preferably using non-contact, non-invasive laser beams. Several laser types have been used to the cleaning procedures [14]. The capability of pulse lasers on graffiti removal has been intensively studied. For short pulse lasers, the ablation mechanism governs the cleaning process. In addition, the CW laser cleaning has been tested in order to evaluate of cleaning effects of the evaporation and combustion processes. The technological advances in CW lasers have provided an attractive approach to the current laser cleaning procedures.

This work combines the inspiration of the angular laser cleaning and the scattering surface inspection. The marriage of these techniques allows the optical inspection during the laser cleaning process which is applicable to the practical cleaning situation on the catastrophic site caused by graffiti.

Materials and Methods

The advantages of the angular laser cleaning can be combined to the laser scattering inspection. Figure 1 shows the schematic diagram of the setup. The target material is the painted mortar (Figure 2). The weak HeNe laser beam and a high fluence laser beam are sent to the painted surface at glancing angle. These two beams are overlapped perfectly to each other. The Q-switched Nd:YAG laser performs as the cleaning beam. The emission of 1.06 μm is meant to be used in the cleaning process. The laser configuration offers the high-quality TEM_{00} output beam. The laser cavity is adjusted to ensure single-frequency operation. The stable single-frequency operation of a flash-lamp

pumped Nd:YAG laser with 10 ns pulse was performed during the cleaning procedures.

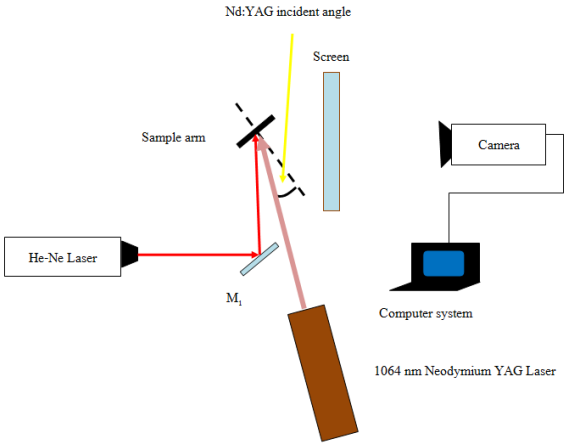


Figure 1. A simplified diagram of the experimental setup.

(a)

(b)

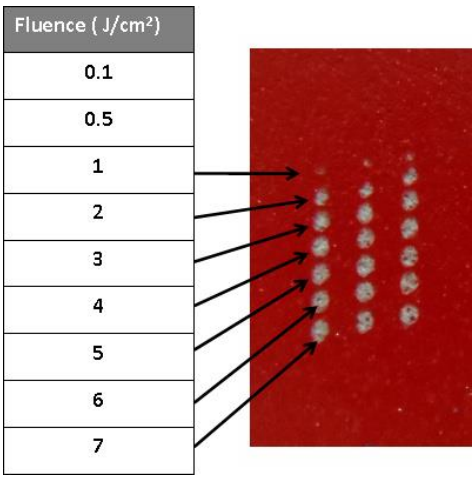
(c)

Figure 2. The prepared mortars used in the experiments. (a) The unaffected graffiti. (b) The green-painted sample. (c) The red-painted sample.

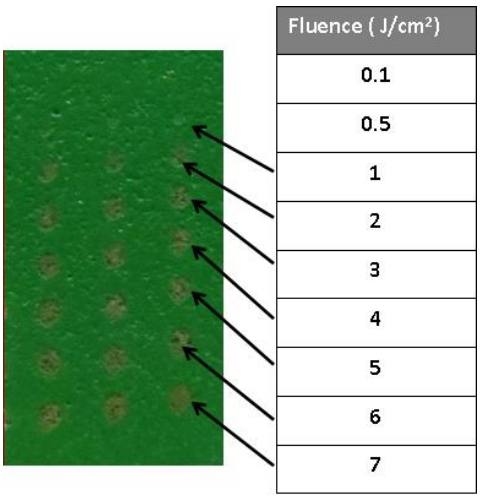
The laser scattering from rough surfaces enhances the possibility of an online inspection during the cleaning process. A weak He-Ne laser beam is allowed the scattering detection appeared on the detection screen. A CCD camera captures the screen image. The scattering images of the pained surface were compared to the image of unaffected graffiti surface. The mean difference of such images is calculated using an image processing program. The calculation can be used to establish the cleaning threshold. Using described approach, the performance of the laser cleaning can be evaluated.

Results and Discussion

The Nd:YAG laser was operated to deliver Q-switch pulse output. The laser fluences were adjusted from 0.1 J/cm^2 to 7 J/cm^2. Figure 3 shows the cleaning results with varied laser fluenced.



(a)

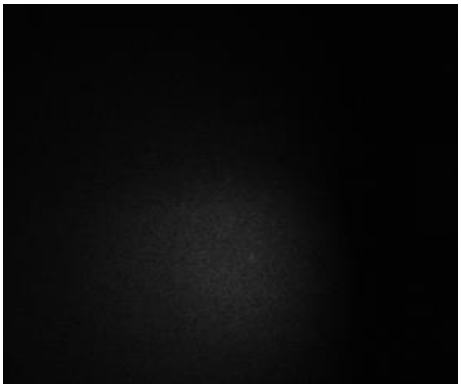


(b)

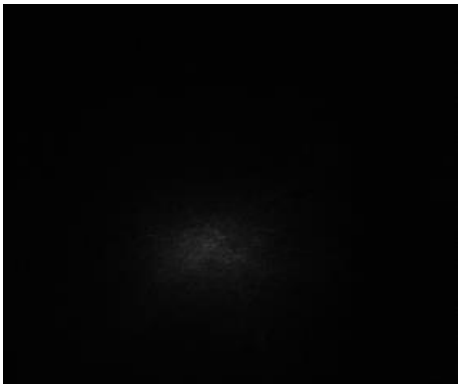
Figure 3. The laser treated mortars used in the experiments. (a) The green-painted sample. (b) The red-painted sample.

It is evident that the cleaning threshold can be estimated by naked eyes. The fluence of 2 J/cm^2 is sufficient to remove the painted surface. As shown in Figure 3, the laser treatments were repeated for three times to ensure the obtained results.

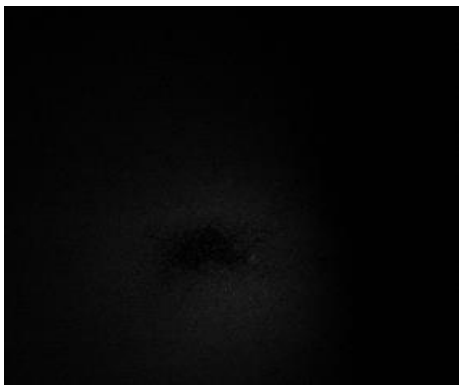
The experimental investigation of the laser scattering described in the previous section can be shown in Figure 4. It can be understood the difference of the scattering patterns between the unaffected graffiti sample and the pained sample. The regular mortars show strong scattering power compared to the painted surface.



(a)



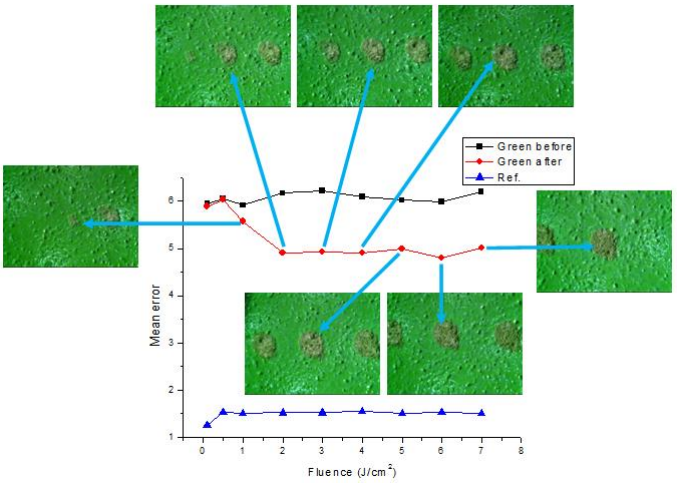
(b)



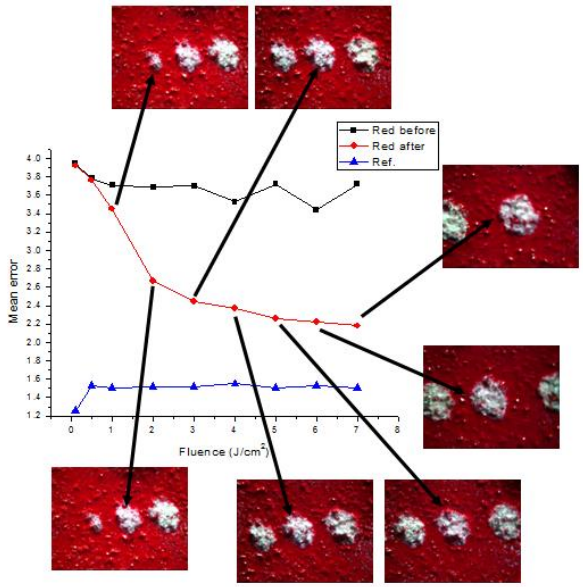
(c)

Figure 4. Example of the scattering patterns captured by CCD camera . (a) The unaffected graffiti sample. (b) The green-painted sample. (c) The difference between the unaffected graffiti sample and the green-pained sample.

The mean error of the unaffected graffiti image and the laser treated image is meant to determine the cleaning efficiency. Figure 5 shows the relation between the laser fluence and the mean error.



(a)



(b)

Figure 5. Photographs of laser treated surfaces along with the plot between the laser fluence and the mean error. (a) The green-painted sample. (b) The read painted sample.

The mean error should fall to zero for the perfect cleaned surface. However, it is impossible to achieve such desirable results. It should be stressed that the laser beam with sufficient energy can lead to the paint removal but only the pained surface and the bulk of the sample. The porous nature of the mortars allows the deep painted layer that is impossible to be removed by the laser beam. The penetration of the HeNe laser beam into the porous area still produces the scattering pattern. According to Figure 5, it can be suggested that the fluence of 2 J/cm^2 is capable of the graffiti removal.

Conclusions

The trials carried out were divided into two groups, the green-painted and red-pained samples. The cleaning threshold is 2 J/cm^2. In trials, the laser cleaning approach proved successful at removing the graffiti from the surface of the mortars. The representative samples were further investigated by means of laser scattering method. The captured scattering images of the laser treated images and the unaffected image were compared. The mean errors are calculated by using an image processing program. The scattering inspection reveals the porous nature of mortars prevents the satisfaction of the completed cleaning. Parts of the paints are still alive in the porous. To alleviate this problem, it can be suggest that water can be used immediately prior to laser radiation to increase the cleaning efficiency.

Acknowledgments

This research work is financially supported by King Mongkut's University of Technology North Bangkok, Contact no. KMUTNB-GEN-57-26.

References

1. Yayun Ye, Yang Qi, Xiaodong Yuan, Xia Xiang, Haijun Wang, Weiqiang Zhou, Xiaofeng Cheng, Xiaoyu Luan, and Runping Zhang, “Laser cleaning of contamination on sandstone surface in Yungang Grottoes”, Optik **125** (2014), 3093.
2. M. P. Fiorucci, A. J. López, A. Ramil, S. Pozo, and T. Rivas, “Optimization of graffiti removal on natural stone by means of high repetition rate UV laser”, Applied Surface Science **278** (2013), 268.
3. T. Rivas, S. Pozo, M. P. Fiorucci, A. J. López, and A. Ramil, “Nd:YVO_4 laser removal of graffiti from granite. Influence of paint and rock properties on cleaning efficacy”, Applied Surface Science **263** (2012), 563.
4. K. G. Watkins, Carmel Curran, and Jong-Myung Lee, “Two new mechanisms for laser cleaning using Nd:YAG sources”, Cultural Heritage **4** (2003), 59s.
5. Poologanathan Sanjeevan, Agnieszka J. Klemm, and Piotr Klemm, “Removal of graffiti from the mortar by using Q-switched Nd:YAG laser”, Applied Surface Science **253** (2007), 8543.
6. Y. F. Lu, W. D. Song, M. H. Hong, Y. W. Zheng, and T. C. Chong, “Laser surface cleaning and potential applications in disk drive industry”, Tribology International **33** (2000), 329.
7. Pedro Gaspar, Manuela Rocha, Aileen Kearns, Ken Watkins, and Rui Vilar, “A study of the effect of the wavelength in the Q-switched Nd:YAG laser cleaning of gilded wood”, Cultural Heritage **1** (2000), 133.
8. M. P. Mateo, G. Nicolas, V. Piñon, A. Ramil, and A. Yañez, “Laser cleaning : an alternative method for removing oil-spill fuel residues”, Applied Surface Science **247** (2005), 333.
9. P. Ortiz, V. Antúnez, R. Ortiz, J. M. Martín, M. A. Gómez, A. R. Hortal, and B. Martínez-Haya, “Comparative study of pulsed laser cleaning applied to wethered marble surface”, Applied Surface Science **283** (2013), 193.

10. N. Carmona, M. Oujja, H. Roemich, and M. Castillejo, “Laser cleaning of 19th century Congo rattan mats”, Applied Surface Science **257** (2011), 9935.
11. Piero Mazzinghi and Fabrizio Margheri, “A short pulse, free running, Nd:YAG laser for the cleaning of stone cultural heritage”, Optics and Lasers in Engineering **39** (2003), 191.
12. J. Ravis, A. J. Lopez, A. Ramil, S. Pozo, M. P. Fiorucci, M. E. López de silanes, A. García, J. R. Vazquez de Aldana, C. Romero, and P. Moreno, “Comparative study of ornamental granite cleaning using femtosecond and nanosecond pulsed lasers”, Applied Surface Science **278** (2013), 226.
13. Pagona Maravelaki-Kalaizaki, Vassilis Zafiropulos, Paraskevi Pouli, Dimitrios Anglos, Costas Balas, Renzo Salimbeni, Salvatore Siano, and Roberto Pini, “Short free running Nd:YAG laser to clean different and evaluation of the effects”, Cultural Heritage **4** (2003), 77.
14. J. Penide, F. Quintero, A. Riveiro, A. Sánchez-Castillo, R. Comesaña, J. del Val, F. Lusquiños, and J. Pou, “Removal of graffiti from quarry stone by high power diode laser”, Optics and Lasers in Engineering **51** (2013), 364.