Feasibility study of a dual wavelength laser cleaner

K Chongcharoen*, P Kittiboonanan and A Ratanavis

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

*E-mail: Chong.Kanokwan@gmail.com

Abstract. A dual wavelength laser system providing emissions of 1064 nm and 532 nm was developed for cleaning applications. In this study, cleaning of surface layers of paints with the dual wavelength laser system was demonstrated. The results reveal that the laser system was able to control the depth of material removed. The cleaning efficiency was evaluated with varied conditions. With several advances, the dual wavelength laser cleaner operating in infrared and visible region will become an establish tool in non-contact cleaning applications.

Keywords: Laser cleaning, Dual wavelength laser, Paint removal

1. Introduction
Nd:YAG lasers are regularly used for cleaning applications [1-2]. The cleaning tasks have been carried out using nanosecond pulse Q-switch Nd:YAG lasers [3]. In recent years, the use of free running Nd:YAG lasers (microsecond event) has been proposed to diminish the aggressiveness occurred by the nanosecond pulse [4].

It is a well-known problem that the use of IR lasers for laser cleaning applications leads to the effect of yellowing alteration [5-6]. However, it was suggested that the combination of laser wavelengths may overcome such a problem [7].

The dual wavelength laser cleaning was introduced as the combination between IR and ultraviolet (UV) wavelengths [7]. The combination of these two laser beams allows an opportunity of an optimum cleaning without discoloration or other alterations [7].

It remains a challenge to investigate the combination between IR and visible laser beams for cleaning applications. In this study, a free-running Nd:YAG laser emitting simultaneously in 1064 nm and its 2nd (532 nm) harmonic frequency was developed to testify the capability of laser cleaning process. In addition, the synchronous use of the two-wavelength laser beams is spatial overlapping.
2. Methodology
The use of a free-running Nd:YAG laser was investigated for cleaning procedures. The Nd:YAG laser was developed to provide the wavelengths at 1064 nm and 532 nm with the pulse length of 200 microsecond. Maximum pulse energies are 100 mJ and 1 mJ for the 1064 nm laser and the 532 nm laser, respectively. The repetition rate of 1 Hz was carried out. Figure 1 shows the optical arrangement that is meant to provide the laser cleaning process using laser pulses at 1064 nm and 532 nm. To investigate the effect of the particular wavelength, a harmonic beamsplitter is used to split the IR laser beam and the visible beam.

![Optical setup for the dual wavelength laser cleaning.](image)

3. Results and Discussions
Figure 2 shows the SEM image of the paint removal using only the IR laser beam at the laser fluence of 6 J/cm². At this fluence value, the paint can be completely removed. The long pulse event of the IR laser results the burn pattern as expected.
Based on the observation, the IR laser beam can be used as a tool for cleaning most pigments while the 532 nm laser beam attains for less of colors. Low fluences of the IR laser beam allow the safe cleaning condition without mechanical damage. Based on the optical setup, the two laser pulses are naturally delayed. The burn area initially produced by the IR laser can absorb the delayed 532 nm pulse laser. Due to its smaller wavelength at 532 nm, the smaller focus beam can be achieved providing the advancements in the dual wavelength laser cleaning in which the selective process to obtain different cleaning levels is controllable. Figure 3 reveals the microscope image of the removal paint using the two-wavelength beams. This determines the feasibility of the dual wavelength laser as a cleaning tool.

![SEM image of the paint removal using IR laser beam.](image1)

**Figure 2.** SEM image of the paint removal using IR laser beam.

**Figure 3.** Microscope images of samples using the dual wavelength laser cleaning approach. The experiments were carried out at 300 J/cm² and 10 J/cm² of the 1064 nm and 532 nm laser beams, respectively.
4. Conclusion
A dual wavelength laser was developed to serve as a cleaning tool. The paint removal was demonstrated as an example. The results show that the use of the dual wavelength laser is much more selective than the traditional laser cleaning system. The cleaning can achieve at an efficiency comparable with the single wavelength laser cleaning technique.

5. References
[1] Siano S et al. 1997 Cleaning processes of encrusted marbles by Nd:YAG lasers operating in free-running and Q-switching regimes Appl Optics. 36:7073
[2] Klein S et al. 2001 Discoloration of marble during laser cleaning by Nd:YAG laser wavelengths Appl Surf Sci. 171:242
[3] Sanjeevan P, Klemm A and Klemm P 2007 Removal of graffiti from the mortar by using Q-switch Nd:YAG laser Appl. Surf. Sci. 253:8543
[4] Mazzinghi P and Fabrizio Margheri 2003 A short pulse, free running, Nd:YAG laser for the cleaning of stone cultural heritage Optics and Lasers in Engineering vol 39 pp 191-202
[5] Jasinska M, Nowak A, Łukaszewicz J W and Sliwinski G 2008 Colour changes of a historical Gotland sandstone caused by laser surface cleaning in ambient air and N₂ flow Appl Phys A 92:211
[6] Klein S, Fekrsanati F, Hildenhagen J, Dickmann K, Uphoff H, Marakis Y, et al. 2001 Discoloration of marble during laser cleaning by Nd:YAG laser wavelengths Appl Surf Sci 171:242
[7] Pouli et al. 2016 The two-wavelength laser cleaning methodology; theoretical background and examples from its application on CH objects and monuments with emphasis to the Athens Acropolis sculptures Herit Sci 4:9

Acknowledgments
This work was totally supported by Lasers and Optics Research Center (LANDOS), Science and Technology Research Institute, King Mongkut’s University of Technology North Bangkok.