International Journal of Technology and Engineering Studies
volume 7 issue 2 pp. 1-7 doi: https://dx.doi.org/10.20469/ijtes.7.10001-2

The Influence of Nanosecond Fibre Laser on the Removal of Paint on Metallic Surface

R. Linggamm
Joining, Welding and Laser Processing Lab (JWL), Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia, 26600

M. M. Quazi *
Joining, Welding and Laser Processing Lab (JWL), Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia, 26600

M. Nasir. Bashir
Department of Engineering Science, National University of Sciences and Technology (NUST), Islamabad, Pakistan

M. Ishak
Joining, Welding and Laser Processing Lab (JWL), Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia, 26600

M.H. Aiman
Joining, Welding and Laser Processing Lab (JWL), Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia, 26600

Abstract: This research aims to study the effect of nanosecond laser parameters on the paint removal process and obtain a set of parameters that would result in the highest paint removal efficiency. In this study, the effect of laser paint removal parameters such as power, defocus distance, and the number of loops are studied with an optical microscope to observe surface features. The laser paint removal process is conducted using the IPG YLM 200/30 - Q pulsed fiber laser machine. The process sample was examined with an optical microscope to analyze the effectiveness of this laser paint removal process. The results indicated that the power and number of loops significantly enhance the paint removal process. The selection of correct frequency, power, hatching distance, scanning speed, and defocus distance also play a significant part in the efficiency of the laser paint removal process.

Keywords: *Laser paint removal, stainless steel, conventional technique, laser mechanism*

Received: 2 December 2020; ***Accepted:*** 11 July 2021; ***Published:*** 24 August 2021

I. INTRODUCTION

In the recent technology era, laser cleaning is high-efficient and newly emerging environmentally-friendly technology. This technology can be widely applied to many fields, such as cleaning electronic elements, removing oil dirt, and painting [1, 2]. Therefore, paint removal by laser technique, where the laser parameter is a key factor that decides the paint removal efficiency of the surface cleaning process. Until recently, many researchers have been investigating the efficiency of the laser paint removal process to be widely replaced by the conventional technique for various industries applications [3]. Moreover,

*Correspondence concerning this article should be addressed to M. M. Quazi, Joining, Welding and Laser Processing Lab (JWL), Joining, Welding and Laser Processing Lab (JWL), Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia, 26600. E-mail: moinuddin@ump.edu.my

© 2021 The Author(s). Published by KKG Publications. This is an Open Access article distributed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 .

through the glance of few papers, the selection method of laser parameters can be in categories such as based on the experiment, which needs to conduct repeated experiments on a different type of paint with different thicknesses of coated thickness [4]. By applying this method, it is easy for us to understand the physical behavior of each parameter on the effect of the paint removal process.

The processing parameters decide the output of the product produced 26, which further translates to the failure characteristics exhibited27 The variation of the laser parameter such as power, scanning speed, hatching distance, frequency, pulse width, and defocus distance could be affecting the efficiency of the paint removal process by laser [5, 6]. Besides, the critical effect of the laser incident parameter is the laser power and defocus distance; this is due to the different effects of this parameter could be damage the mechanism of the paint removal process [7]. Based on this consideration, many kinds of research on changes of paint removal mechanism and the corresponding paint removal caused by different laser power intensities can be beneficial to the laser parameter for the paint removal [6, 8]. Furthermore, the paint removal process can be revealed by quantitatively investigating the relationship between the physical effects and the laser power [9]. Finally, in the field of manufacturing engineering, processing parameters play an important role [10]. According to a disciplinary perspective, the current application is experiencing the absence of actual intensive investigations for improving biomedical and modern utilizations of laser removal is essential.

Furthermore, the usage of lasers is now being optimized [11, 12] in different fields and applications such as in welding [13], and hard surfacing [14]. Hence, the usage of lasers has become a viable approach as an emerging rapid and robust technology. This study aims to study the effect of nanosecond laser parameters on the paint removal process and obtain a set of parameters that would result in the highest paint removal efficiency.

II. LITERATURE REVIEW

Laser cleaning is defined as removing unwanted layers or the extended contamination of the unwanted layers from a solid substrate [15]. It involves cleaning off foreign organic impurities, namely coatings over a solid or metal substrate [16].

Laser cleaning is the most dependable and effective solution in many sectors because it cleans without affecting the surface shape, is non-contact, has high efficiency, and is appropriate for a wide range of materials [17]. Regardless of the spearheading works tracing back to the mid-1970s, this inventive method began to be methodically examined and afterward widely applied just 20 years after the fact. Several logical examinations were accounted for in the course of the last two decades, meeting procedures, and books, zeroing in on the productivity, selectivity, and afterward adequacy of laser removal, just as on the potential benefits it can furnish concerning conventional cleaning methods [18, 19].

Laser cleaning addresses the main commitment of physics to the preservation of social legacy. This measure is the interaction between light and the substrate. By illuminating the substrate surface with a laser, the limiting power between the substrate and the poisons connected to the substrate surface is disturbed, and the toxins on the substrate surface are isolated from the substrate surface by dissipation, breakage, and vibration [20].

Laser removal offers novel prospects in surface cleaning as it involves exact control, material selectivity, and quick criticism [21]. Laser removal furnishes critical benefits for mechanical and substance approaches as far as slowness, selectivity, self end, and repeatability of the material expulsion measure, just as far as an ecological effect [22]. Specifically, existing research highlights that laser cleaning is a better alternative for the conventional chemical cleaning process in coating/paint [23, 24].

III. METHOD AND MATERIALS

The laser paint removal process is conducted using the IPG YLM 200/30 Q pulsed fiber laser machine, as shown in Fig. 1. Thus, this machine can be used in Continuous Wave (CW) and Pulse Wave (PW) modes. However, the maximum power capacity of this machine is 30W. This fiber laser machine is attached by the laser source, focal plane, and Ezcad- Software. The software is a major part of the machine which the other parameter can be adjusted as illustrated in Table 1. Therefore, the influence of the paint removal process depends on the machine adjustable parameter, whereby with a slight change of this parameter, the effect of the paint removal process can seem to affect the metal surface.

Meanwhile, the laser source in the machine is transferred to the laser head by using fiber optic, where the distance between the focus lens and the laser focus spot is 200 mm. This focal distance can be varied according to the need during the experiment. Moreover, the stainless steel SS404L was used as substrate material. This stainless steel has been coated with the paint to start the process of removal.

Then the process sample was examined with an optical microscope to analyzed the effectiveness of this laser paint removal process.

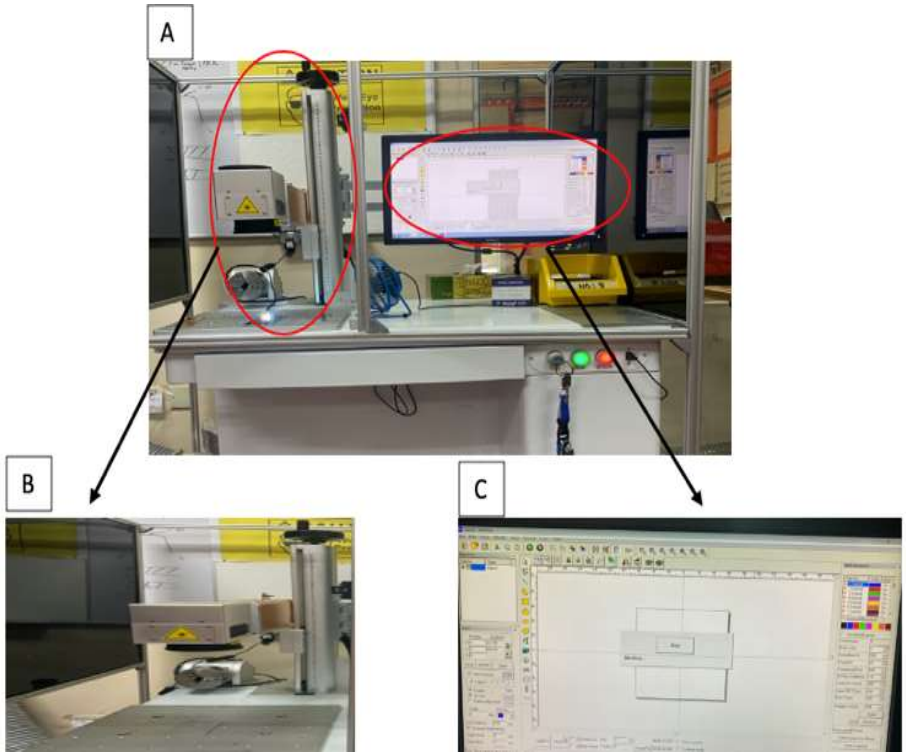


Fig. 1. (a) Fiber laser machine, (b) Laser source with focus plane, and (c) EZCAD-Software

TABLE 1
RANGE OF ADJUSTABLE PARAMETER OF THE MACHINE

IPG Fibre Laser Machine	
Parameter	Range of Parameter
Power	30W
Frequency	300KHz
Scanning speed	10000mm/s
Pulse width	300ns
Focal plane	–
Hatching distance	–
Workpiece dimensions	150mmx150mm

IV. RESULTS AND DISCUSSION

The maintenance work of removing paint always requires a period with conventional methods such as sandblasting, paint removal solvent, and sanding process [25, 26]. Thus, the application of laser for paint removal work is promising for this purpose. Fig. 2 shows the optical microscope images of the samples (a) Received sample and (b) painted surface. In the process of paint removal by lasering, the significant parameter is the power rate required to remove the paint as a key role in surface processing quality.

In addition, Table 3 displays the different power parameters and multiple marking loops set on the laser for the paint removal process with an optical image shown. The defocused distance has been set at 184mm. Then the surface has been heated with the adjustment of the power with the marking loop, which the other parameter remains fixed. The paint is roughened but not fully removed at the lower power, as shown in experiment number 1. When the slight increment of the laser power, the paint removal starts, indicated from the optical images in the 2nd experiment. As the laser power increases, much more paint is detached with two times the marking loop. However, the paint is still not completely removed from the surface of the substrate. Therefore, the steel subtracts show a bright background to the naked eye. Thus, under the microscope, the brighter spot tends to connect into a larger bright area. Where we can examine the paint removal efficiency by looking at the surface profile of the process area. With the large removal area, the efficiency is better than the smaller removal area. Likewise, with incremental laser power density to 60% with 2 times marking loop, the paint is removed, but the surface is highly rough compared to an original surface.

In experiment number 5, an incremental power of 70% with three times marking loops has been made to smoothen the surface. Hence, the optical image shows the paint has been removed completely with a smoother surface. In conclusion, the power density of 70% with multiple marking loops a are significantly good parameter for the Laser paint removal process. Table 2 presents the power variance with a single marking loop when the other parameter remains fixed. In this set of experiments, we have increased the defocus distance to 186mm. It was observed that the significant increase of the defocus distance causes the paint removal process to be started at the power of 20%. As the power increased, the paint started to detach slowly, where the intensity of the laser is increased dramatically due to the increment of defocus distance. A further increase of power did show the paint was removed, but a small amount of paint was observed on the metal surface with a single marking loop. In contrast, an increase of power to 70% with three times marking loop, the paint has been fully removed and back to the received sample illustrated in Fig 2. This could be due to the change in intensity of the laser power due to the incremental defocus distance.

Fig. 2. Optical image of (a) As received sample and (b) painted surface or SS304L

TABLE 2
EFFECT OF LASER PARAMETERS ON MULTIPLE PASS PAINT REMOVAL ON SS304L WITH 184MM DEFOCUS DISTANCE

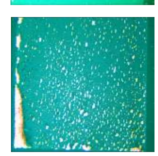
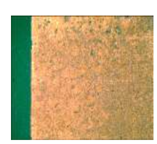
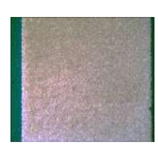
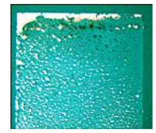
Sr. No	Power	Frequency	Speed	Pulse with	H. D	Loops	Optical Images
1	30	20	1000	300	0.05	1	
2	40	20	1000	300	0.05	1	
3	50	20	1000	300	0.05	2	
4	60	20	1000	300	0.05	2	
5	70	20	1000	300	0.05	3	

TABLE 3
EFFECT OF LASER PARAMETER ON SINGLE PASS PAINT REMOVAL ON SS304 WITH 186MM DEFOCUS DISTANCE

Sr. No	Power	Frequency	Speed	Pulse with	H. D	Loops	Optical Images
6	20	20	1000	300	0.05	1	
7	40	20	1000	300	0.05	1	
8	55	20	1000	300	0.05	1	
9	65	20	1000	300	0.05	1	
10	70	20	1000	300	0.05	3	

After observing the effect of power, defocus distance, and loops, the significant parameter for a laser paint removal process was decided by IPG YLM 200/30 - Q pulsed fiber laser, as shown in Table 4. The incremental power being with higher energy and the ensuing number of marking loops as a smoothening phase. Additionally, a comparison of the painted sample and surface areas of the removed sample is shown in Fig. 3. It is to be noted that the painted surface can be removed partially, and the removed part is quite uneven under the irradiation with low power, as in Fig. 3(b). With the increase of power and marking loop and lower defocus distance, the paint can be removed completely without any obvious damage mark on the metal substrate, as in Fig. 3 (c). Furthermore, a review[3] concluded that the higher increment of the power could affect the paint removal area will expand with obviously serious, and ablation and the substrate have also been damaged.

TABLE 4
LASER PARAMETERS FOR MULTIPLE PASS LOOPS FOR THE PAINT REMOVAL PROCESS

Loop	Power (W)	Frequency (Hz)	Speed (mm/s)	Pulse width (9ns)	H.D (mm)	Defocus Distance (mm)
1	40	20	1000	300	0.05	184
2	50	20	1000	300	0.05	184
2	60	20	1000	300	0.05	184
3	70	20	1000	300	0.05	184

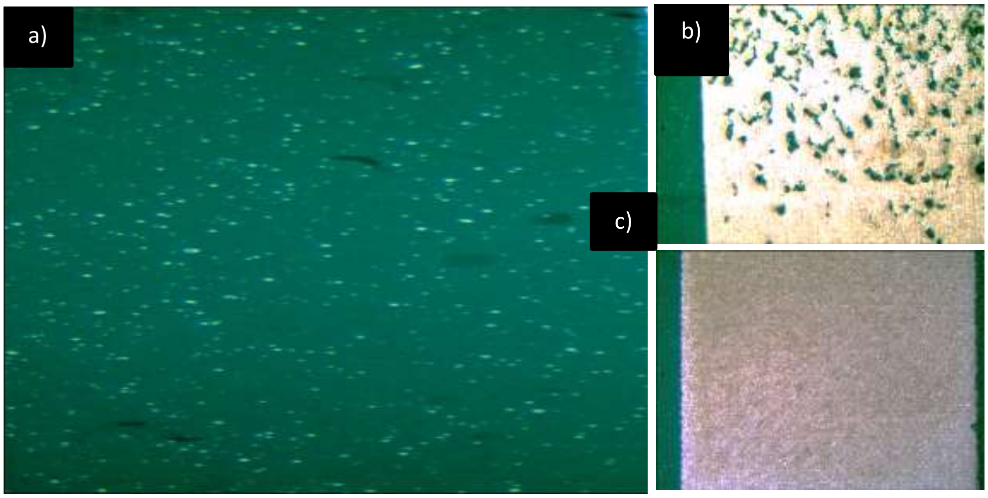


Fig. 3. Optical Image of (a) Paint surface SS304L, (b) LPR Process not fully remove and (c) Fully remove paint surface

V. CONCLUSION AND RECOMMENDATIONS

In this work, a process of paint removal by laser can be considered complex. It involves the heat effect, thermal stress effect, vaporization, and ionization effect towards the process. Thus, the laser irradiation of different irradiation power can affect dissimilarly the ablation process. Under the lower irradiation of power and defocus distance, the laser ablation is only focused on the surface which the paint is partially stripped off from the metal surface. This is due to a thermal stress effect on the substrate. Therefore, the observation shows that the paint is removed tearily by increasing irradiation power, marking loop, and defocus distance. This condition is due to the thermal stress between the metal substrate, and the paint coat is higher than the adhesive force between them, where the paint will be removed effectively without causing any damage to the substrate. So, in the research, it is concluded that the power, marking loop, and defocus distance parameter alters the paint removal quality and rate.

Declaration of Conflicting Interests

There are no conflicts of interest.

Acknowledgment

The work was supported by University Malaysia Pahang Research grant RDU1903119.

REFERENCES

[1] X. Li, Q. Zhang, X. Zhou, D. Zhu, and Q. Liu, "The influence of nanosecond laser pulse energy density for paint removal," *Optik*, vol. 156, pp. 841–846, 2018. doi: https://doi.org/10.1016/j.ijleo.2017.11.010

[2] G. George and H. Shaikh, "Introduction to austenitic stainless steels," in *Corrosion of Austenitic Stainless Steels*. Sawston, UK: Elsevier, 2002.

[3] G. Chen, T. Kwee, K. Tan, Y. Choo, and M. Hong, "Laser cleaning of steel for paint removal," *Applied Physics A*, vol. 101, no. 2, pp. 249–253, 2010. doi: https://doi.org/10.1007/s00339-010-5811-0

[4] R. S. Kappes, F. Schonfeld, C. Li, A. A. Golriz, M. Nagel, T. Lippert, H.-J. Butt, and J. S. Gutmann, "A study of photothermal laser ablation of various polymers on microsecond time scales," *Springerplus*, vol. 3, pp. 1–15, 2014. doi: https://doi.org/10.1186/2193-1801-3-489

[5] Z. Wang, X. Zeng, and W. Huang, "Parameters and surface performance of laser removal of rust layer on A3 steel," *Surface and Coatings Technology*, vol. 166, no. 1, pp. 10–16, 2003. doi: https://doi.org/10.1016/S0257-8972(02)00736-3

[6] E. Di Francia, R. Lahoz, D. Neff, V. Rico, N. Nuns, E. Angelini, and S. Grassini, "Novel procedure for studying laser-surface material interactions during scanning laser ablation cleaning processes on Cu-based alloys," *Applied Surface Science*, vol. 544, pp. 14–20, 2021. doi: https://doi.org/10.1016/j.apsusc.2020.148820

[7] P. Flanigan and R. Levis, "Ambient femtosecond laser vaporization and nanosecond laser desorption electrospray ionization mass spectrometry," *Annual Review of Analytical Chemistry*, vol. 7, pp. 229–256, 2014. doi: https://doi.org/10.1146/annurev-anchem-071213-020343

[8] C. Zhang, C. Yao, and C. Wang, "Modulations of nonideal repaired damage sites irradiated by CO2 laser at different parameters," *Optik*, vol. 127, no. 8, pp. 3750–3754, 2016. doi: https://doi.org/10.1016/j.ijleo.2015.12.139

[9] S. F. Haider, M. M. Quazi, J. Bhatti, M. N. Bashir, and I. Ali, "Effect of Shielded Metal Arc Welding (SMAW) parame-ters on mechanical properties of low-carbon, mild and stainless-steel welded joints: A review," *Journal of Advances in Technology and Engineering Research*, vol. 5, no. 5, pp. 191–198, 2019.

[10] A. Zaifuddin, M. Aiman, M. M. Quazi, M. Ishak, and T. Ariga, "Effect of Laser Surface Modification (LSM) on laser energy absorption for laser brazing," *IOP Conference Series: Materials Science and Engineering*, vol. 788, no. 1, pp. 12–13, 2020.

[11] S. Wakeel, S. Bingol, S. Ahmad, M. N. Bashir, M. S. M. M. Emamat, Z. Ding, and F. Hussain, "A new hybrid LGPMBWM-PIV method for automotive material selection," *Informatica*, vol. 45, no. 1, pp. 105–116, 2021. doi: https://doi.org/10.31449/inf.v45i1.3246

[12] M. M. Quazi, M. Ishak, A. Arslan, M. Nasir Bashir, and I. Ali, "Scratch adhesion and wear failure characteristics of PVD multilayer CrTi/CrTiN thin film ceramic coating deposited on AA7075-T6 aerospace alloy," *Journal of Adhesion Science and Technology*, vol. 32, no. 6, pp. 625–641, 2018. doi: https://doi.org/10.1080/01694243.2017.1373988

[13] M. M. Quazi, "An overview of laser welding of high strength steels for automotive application," *International Journal of Technology and Engineering Studies*, vol. 6, no. 1, pp. 23–40, 2020. doi: https://dx.doi.org/10.20469/ijtes.6.10004-1

[14] I. Ali, N. Lin, M. M. Quazi, M. N. Bashir, H. Sadiq, and F. Sharaf, "Investigating the wear characteristics of metal matrix composite coating deposited on AA5083 Al-alloy by laser surface engineering technique," *North American Academic Research*, vol. 3, no. 1, pp. 138–146, 2020.

[15] M. K. A. A. Razab, M. S. Jaafar, N. H. Abdullah, F. M. Suhaimi, M. Mohamed, N. Adam, N. A. A. N. Yusuf *et al.*, "A review of incorporating Nd: YAG laser cleaning principal in automotive industry," *Journal of Radiation Research and Applied Sciences*, vol. 11, no. 4, pp. 393–402, 2018. doi: https://doi.org/10.1016/j.jrras.2018.08.002

[16] J. P. Nilaya and D. Biswas, "Laser-assisted cleaning: Dominant role of surface," *Pramana*, vol. 75, no. 6, pp. 1087–1097, 2010. doi: https://doi.org/10.1007/s12043-010-0192-7

[17] A. Kumar, R. Bhatt, P. Behere, M. Afzal, A. Kumar, J. Nilaya, and D. Biswas, "Laser-assisted surface cleaning of metallic components," *Pramana*, vol. 82, no. 2, pp. 237–242, 2014. doi: https://doi.org/10.1007/s12043-013-0665-6

[18] A. Sansonetti, M. Colella, P. Letardi, B. Salvadori, and J. Striova, "Laser cleaning of a nineteenth-century bronze sculpture: In situ multi-analytical evaluation," *Studies in Conservation*, vol. 60, no. 1, pp. 28–33, 2015. doi: https://doi.org/10.1179/0039363015Z.000000000204

[19] G. Zhu, S. Wang, W. Cheng, G. Wang, W. Liu, and Y. Ren, "Investigation on the surface properties of 5A12 aluminum alloy after Nd: YAG laser cleaning," *Coatings*, vol. 9, no. 9, pp. 578–580, 2019. doi: https://doi.org/10.3390/coatings9090578

[20] D. Bäuerle, *Laser processing and chemistry*. Berlin, Germany: Springer Science & Business Media, 2013.

[21] C. Rodriguez-Navarro, K. Elert, E. Sebastian, R. M. Esbert, C. M. Grossi, A. Rojo, F. J. Alonso, M. Montoto, and J. Ordaz, "Laser cleaning of stone materials: An overview of current research," *Studies in Conservation*, vol. 48, no. 1, pp. 65–82, 2003. doi: https://doi.org/10.1179/sic.2003.48.Supplement-1.65

[22] J. Foster, "Thermal effects in a NdYAG laser," *Journal of Applied Physics*, vol. 41, no. 9, pp. 3656–3663, 1970.

[23] X. Li, T. Huang, A. W. Chong, R. Zhou, Y. S. Choo, and M. Hong, "Laser cleaning of steel structure surface for paint removal and repaint adhesion," *Opto-Electronic Engineering*, vol. 44, no. 3, pp. 340–344, 2017.

[24] Y. K. Madhukar, S. Mullick, and A. K. Nath, "Development of a water-jet assisted laser paint removal process," *Applied Surface Science*, vol. 286, pp. 192–205, 2013. doi: https://doi.org/10.1016/j.apsusc.2013.09.046

[25] G. Li, W. Gao, L. Zhang, X. Wu, L. Zhang, Z. Wei, B. Li, Y. Xue, J. Wang, and X. Wang, "The quality improvement of laser rubber removal for laminated metal valves," *Optics & Laser Technology*, vol. 139, pp. 67–85, 2021. doi: https://doi.org/10.1016/j.optlastec.2020.106785

[26] K. Lotfy and M. Gabr, "Response of a semiconducting infinite medium under two temperature theory with photothermal excitation due to laser pulses," *Optics & Laser Technology*, vol. 97, pp. 198–208, 2017. doi: https://doi.org/10.1016/j.optlastec.2017.06.021