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Surface Profiling Of Paper Radiated With Focused Infra-Red Nd:yag Pulsed Laser

Ahmad Hadi Ali[a*], Noriah Bidin[b]

[a]Science and Mathematics Department,
Faculty of Science, Arts and Heritage, Universiti Tun Hussein Onn Malaysia,
Johor, Malaysia.

[b]Laser Technology Laboratory, Physics Department, Faculty of Science,
Universiti Teknologi Malaysia, Johor, Malaysia.

Corresponding email: ahadi@uthm.edu.my

Abstract

A Nd:YAG pulsed laser with wavelength of 1.06 µm can cause a tremendous damage when interacts with material. In this study the effects of Nd:YAG laser interactions onto paper are reported. A combination lens technique was used with different focal length of lens. The target material that is a photographic paper was positioned at a focal spot of the laser beam. IR laser pulsed with peak power up to megawatt (MW) is brought to focus thus interacts with the photographic paper. This high-power impact of the laser pulsed shockwave caused a tremendeous damage on the photographic paper. Measurement of the impact was base on the surface size of the damage. From the observation result it shows that the maximum damage diameter for short lens system is 0.613 mm at peak power of 21.93 MW, whereas the maximum damage diameter for long lens system is 1.224 mm at 22.25 MW peak power.

Keywords: Laser, plasma, damage, paper, peak power.

1. INTRODUCTION

The interaction of a pulsed laser beam with solid materials is very practical in scientific research experiment as well as in industry [1]. It offers wide potential application in different areas of research relevant to material treatment, physical analysis, photo deposition, depth profiling and many other areas [2]. In industry laser is extensively used to cut and drill solid targets [3]. Laser provides high accuracy, precision and most important is it provides un-contact processes with the target material [4].

Lasers such as Nd:YAG pulsed laser is generally used for micromachining operation. The laser pulse duration ranging from nanosecond to femtosecond provides laser peak power of up to tens of gigawatts [5]. It is easily achieved by producing laser pulse energy up to multi-kilojoules in a single shot or multishot pulses. This high peak power irradiance of laser pulse can induce an optical breakdown when brought to focus by lens [6].

When high peak power of laser pulsed is focused by a lens onto the material's surface, the beam makes contact with the material consequently heating the material. This results in the ablation of the target material [7]. The temperature at the heated region can be achieved up to thousands of Kelvin [8]. All of these processes occurred in a very short time and can be observed by the formation of bluish spark or optical breakdown at the focal region [9].

The aim of this work, based on the use of image analysis method for the diagnostics of the laser pulsed irradiation on a photographic paper. The influence of laser peak power on damage size created on photographic paper was also investigated. The comparison of short with long lens system on the damage area was also carried out.

2. EXPERIMENTAL SETUP

The experiment layout is shown in Figure 1. The laser source is a Nd:YAG from Lumonics emitting at 1064 nm, which is capable of operating in single pulse. In single pulse regime, only one laser shot is emitted with time width of 8 ns and energy adjustable in the range 172 – 178 mJ/ pulse. A photodetector with photodiode model BPX 65 connected to the digital energy meter from Melles Griott used to measure the pulse energy. The energy is divided by time width resulted in peak power of laser pulse up to tens of megawatts. In this experiment a combination lenses technique is employed. Laser pulsed is directed to -25 mm focal length of biconcave lens, refracted thus diverged up to 10 x or more, depending where it been tested. A camera lens was introduced to focus the divergence beam. Two types of camera lens were utilized; that are, a short focal length of 28 mm and a long focal length of 50 mm. A photographic paper is placed at the focal region, where the interaction with the focused laser pulsed occurred at atmospheric pressure.

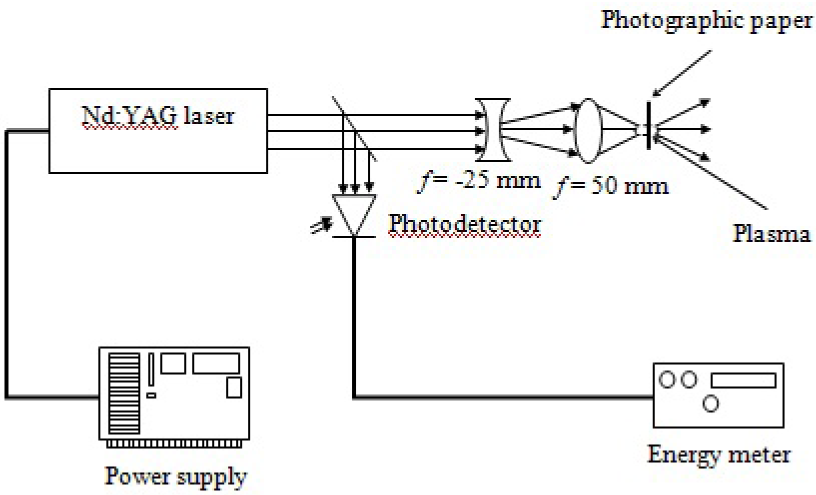

Figure 1: Pulsed laser induce damage on photographic paper when brought to focus by a combination lens technique.

The damage formed on the photographic paper was analyzed with the aid of photomicroscope model Q-520 LEICA in conjunction with image processing system. In this case Matrox Inspector version 2.1 image processing software was utilized. In order to measure the damage diameter, the burning area was firstly segmented and then selected using region of interest, ROI, as discussed in other paper [10].

3. RESULTS AND DISCUSSION

In qualitative and quantitative analysis of the laser pulse irradiation effects on photographic paper, we studied the damage area under different laser peak power and focusing lens. The damage area was visualized and magnified using a photomicroscope. The images then were stored in personal computer for analysis purposes using image processing software.

Figure 2 shows damage area on the photographic papers. The dark circular area at the center is the burning area, where laser pulse impinges on the papers surface. The brighter area around the dark area is the light rays used to illuminates the burning spot during magnification process using the photomicroscope. The images were arranged in the increasing order of laser peak power from 21.61 MW to 22.25 MW. The images were magnified 22x from its original sizes. The first six frames show that the damage or burning area increases with the peak power. However the damage area is reduced as the peak power gets higher.

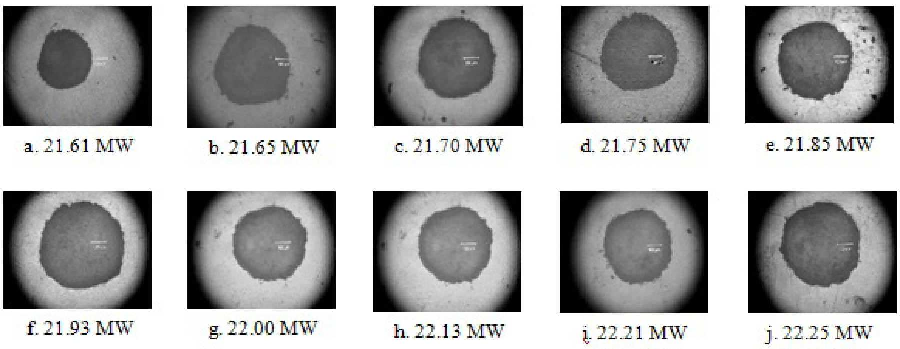

Figure 2: Damaged area produced from a combination of short lens system. Magnification is .

In conjunction with short lens of combination system, Figure 3 shows the arrangements of damage area of long lens system. The magnification of the images is 46x than the actual size. The burning area formed almost in circular shape, similar with short lens system. But the major difference can be seen from the size of the damage area. The damage sizes from the long lens system were observed much greater than the size from short lens system. The first three frames shows that the damage sizes increases with peak power, but as the peak power getting higher, the damage area were decreasing.

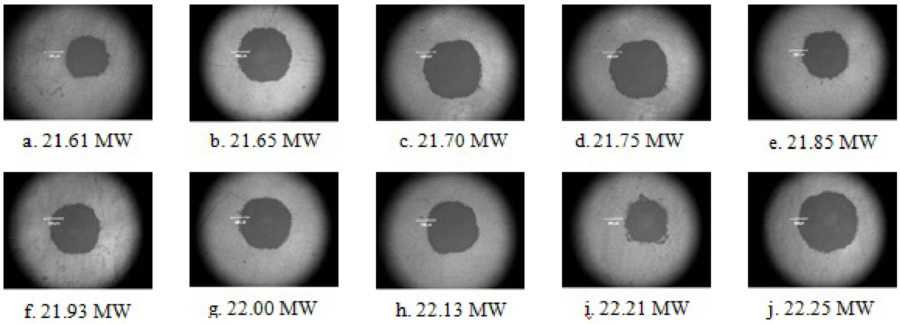

Figure 3: Damaged area produced from a combination of long lens system. Magnification is 46 x.

The damage area is the burning spot on the photographic paper when the laser pulse was focused on the surface. When the beam is deposited in matter during a time span which is short compared to the thermodynamic response times of the paper, a state of high-energy density is induced. The paper melts and the heat begins to dissipate into the paper. Pieces of melted debris were thrown out from the paper surface. The surface of the paper begins to deform due to shock waves generation during the laser impact. Adjacent objects may undergo deformation due to the changing surface of the paper. Heat continues to propagate through the paper. Debris begins to fall around the craters. As the debris lands, it may bond to the surface before it begins to cool. The melt phase stops and begins to cool into a recast layer, possessing different properties than the original material.

The relationship of the damages diameter with peak power is shown in Figure 4. The diameter was measured in the unit mm, whereas the peak power was calculated in MW. Two curves were plotted in the graph. The upper one is the curves plotted for a long lens system, and the lower one is the curves of short lens system. From the graph it is clearly shown that the size of the damage area for long lens system is larger than the short lens system.

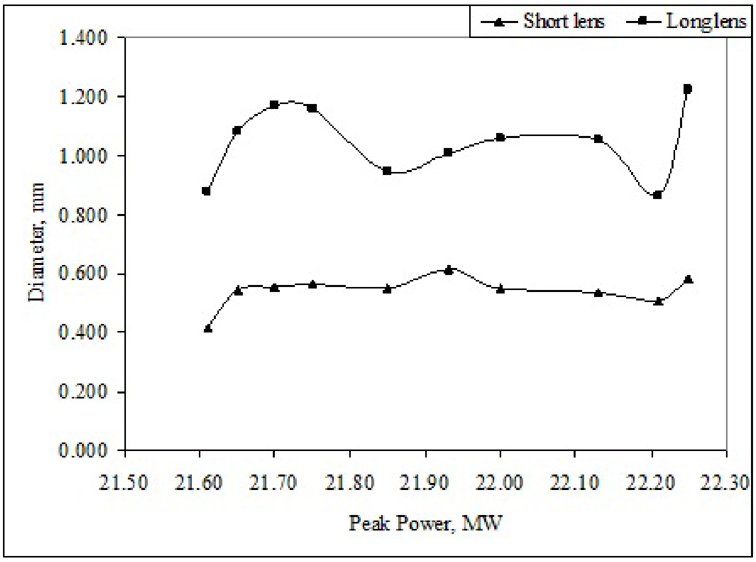

Figure 4: The relationship between damage diameter on photographic paper for short and long lens system as the peak power are increasing

For the short lens system, initially the damage diameter was gradually increasing from 21.61 MW to 21.93 MW. After this stage, the size of the damage was decreasing as the peak power getting higher. The minimum damage diameter was measured as 0.414 mm at peak power of 21.61 MW, whereas the maximum was achieved is 0.613 mm at peak power of 21.93 MW.

The long lens system which is represented by the upper graph shows drastically increases of diameter at the initial state until the peak power of 21.70 MW. But as the peak power getting higher, the size was decreasing before it jumps to the maximum diameter of 1.224 mm at highest peak power of 22.25 MW. The minimum diameter size was obtained as 0.862 mm at peak power of 22.21 MW.

4. CONCLUSION

Laser pulse interaction with photographic paper produces circular damage with different diameter size depending on the peak power of the pulse. At the initial stage, the short and long lens systems shows increasing size of damage area, but as the peak power gets higher the damage diameter were decreasing. Compared to short lens system, the long lens system produces larger damage size. The maximum damage diameter for short lens system was measured is 0.613 mm at peak power of 21.93 MW, whereas for the long lens system was 1.224 mm at highest peak power of 22.25 MW.

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