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# LASER PLASMA INDUCE DAMAGE ON BURNT PAPER

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**Abstract**

*High intensity laser pulse can cause damage on material when brought to focus. In this paper the effects of laser induce damage on burnt paper is reported. A Nd:YAG solid-state laser was used as a laser source. The peak power of the laser pulse was varied from 21.61 MW to 22.25 MW. Two-lens technique is used in order to focus the laser beam. Burnt paper was placed at the focal region. The focused laser beam generates an optical breakdown accompanied with plasma formation, thus induce damage on the burnt paper. For viewing purposes, a photomicroscope model Q-520 LEICA was used to magnify the damage. The image was processed and analyzed with the help Matrox Inspector version 2.1 software. The results show that the laser plasma induces quite a symmetrical and uniform configuration of damage. In addition, observation result shows that the maximum damage arear was measured as* 0.150 ± 0.008 mm *at peak power of 21.93 MW.*

***Keywords***
*Laser, plasma, damage, burnt paper, peak power.*

## Introduction

Plasma is an ionized state [1]. In plasma, electrons have freely dissociated from their atoms, which then become positive ions in a process that occurs in the presence of photons. High power laser such as Q-switched Nd:YAG laser is usually used as a source in order to induce plasma [2]. This nanosecond long pulse laser beam will generate an optical breakdown when it is focused by lens [3]. When focused to a small spot, usually less than 50 microns (μ) in diameter, Q-switched Nd:YAG lasers can produce adequate irradiance to induce optical breakdown. The optical breakdown is adequate to initiate plasma in the focal region through the mechanism of electron avalanche or cascade [4].

Laser induced plasmas have a variety of applications and a variety of experiments are possible, most experiments consist of directing a high power laser beam at a solid [5]. In typical laser plasma induce damage experiments, a multi-megawatt laser pulse is brought to a focus. The plasma that is ionized will expanding with temperatures up to kilo-electron-volts thus producing damage on the material. In this present paper, we report an experimental work on the laser plasma induce damage on burnt paper. A combination lens technique is used in order to brought the laser pulse to focus.

## Experimental Setup

In this study, a HY200 Nd:YAG laser manufactured by Lumonics with a wavelength of 1.06 μm and 8 ns pulse duration was employed as a laser source. The peak power of the laser was varied from 21.61 MW to 22.25 MW. The laser beam was focused by two lenses, that are a combination of negative lens of –25 mm focal length and Ricoh camera lens of 50 mm focal length. The plasma induced damaged was studied by introducing a target material at the focal region. The target material that is used is a burnt paper made of IC FORD photographic paper. The paper was cut into small pieces. Each specimen was used to test the plasma effect at different delivered peak power of laser pulse. Since the area affected by laser plasma interaction is very small (micron size), therefore a photomicroscope model Q – 520 LEICA was used to magnify the damage. The microscope has the ability to magnify the sample in the range of 5 to 150 times. This microscope has the ability to capture the image. In this case a Nikon Coolpix 995 CCD digital camera was used. The damaged can be observed by interfacing the digital camera to the personal computer. The image was processed and viewed by using Nikon View software; in addition the image was analyzed with the help of Matrox Inspector version 2.1 software. The images were selected and printed out for permanent recorded. The experimental setup is shown in Figure1.

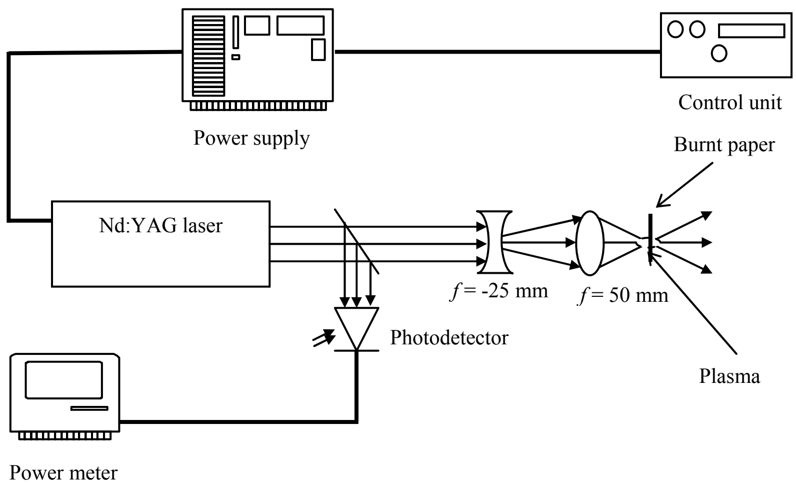


Figure 1 Experimental setup of laser plasma induce damage on burnt paper .

**Result and Discussion**

Typical results obtained from this experiment are depicted in Figure 2. The damaged frames are arranged in the increasing order of peak power delivered to the focal point. The first six frames indicate that the damage increased with the increasing of peak power. However the damaged area is reduced, as the peak power gets higher.
Entirely different shapes of damage area are generated by this combination lens technique. The damage patterns are almost in uniform circular shape. That means that the combination lens system resulted in a very uniform damaged area.

The damage on the burnt paper produced from plasma created by a combination lens system was measured and analyzed. The uniformity of damage configuration offers much easier work for measuring the damaged area. The precise measurement was made via the Matrox Inspector version 2.1 software.

The relationship of the damage area produced upon the peak power is shown in the graph of Figure 3. There are big differentiation damage occurred at both initial and latter stage of the graph. Initially the damage area is increasing drastically from peak power 21.61 MW to 21.65 MW. Then the area is gradually decreasing to the peak power 21.85 MW. The maximum damaged area occurred at peak power of 21.93 MW is $0.150 \pm 0.008$ mm$^2$. As the peak power is increasing, the damage area were found fluctuating until the maximum peak power of 22.25 MW. This shows that the combination technique contributed toward very unpredictable damage. However, quite consistence damage still can be achieved within the range of 21.65 MW to 21.85 MW of the peak power. The first few power setting and the midpoint tested power setting, result in very drastic increase of damaged area. These also indicate that the plasma produced from this system, at higher powers are very unstable. The plasma induced by this system was very large and strong enough to cause very dramatic damage.

Burnt paper is a sensitive material. When plasma is heated on such a sensitive paper, it could easily be burned and following the contoured of the heat source. As consequently a combination lens technique used to focus the high power laser beam possibly generates quite ellipsoid plasma. Thus it produces quite circular and uniform shape of damage on the burnt paper.

This suggests that, cutting, drilling welding and many other materials processing which required precise, and clean cutting edge should employ combination lens technique. The size of drilling or the diameter of a hole on the sample is determined by the peak power of the laser pulse

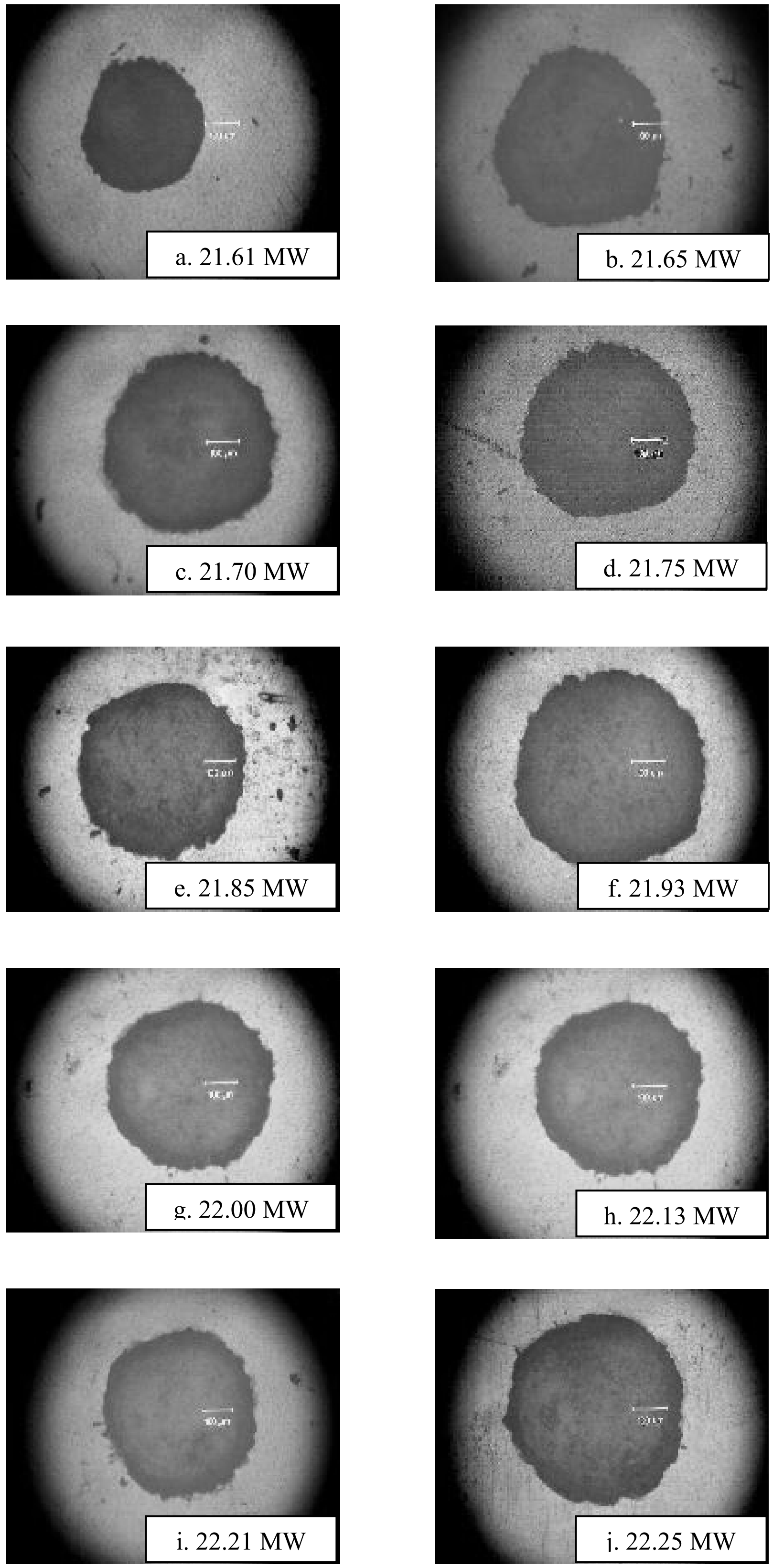


Figure 2 Damaged area produced from a combination of short lens system. Magnification is $50\times$.

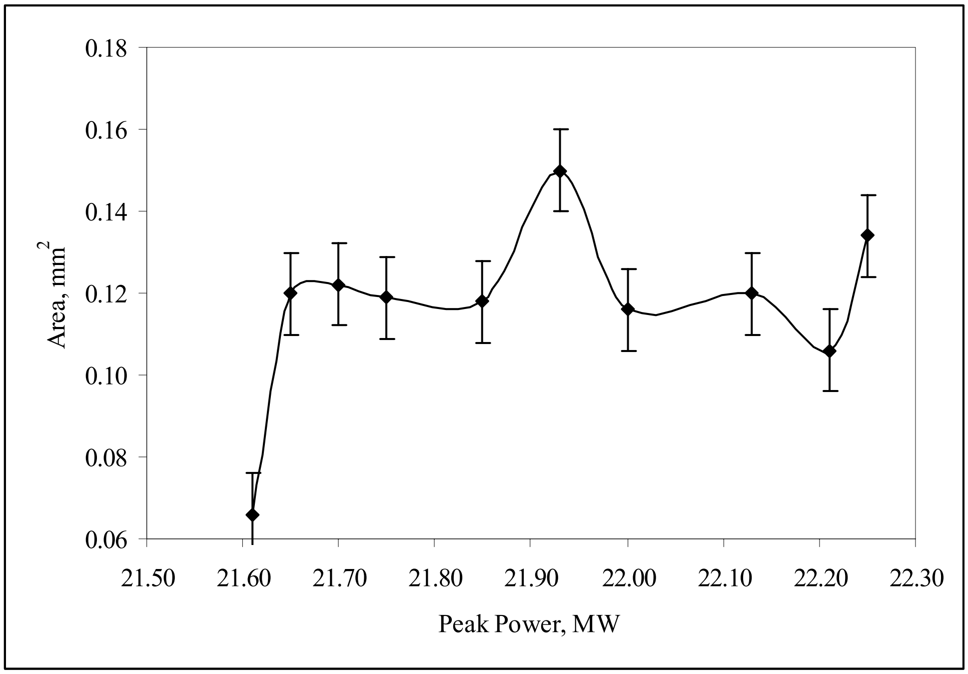


Figure 3 Graph of damge area as a function of peak power.

## Conclusion

As a conclusion, the laser pulse can induce plasma when brought to a focus by using a combination lens technique. The laser plasma can cause damage when interacts with burnt paper at the focal region. The area of the damages were determined by the peak power delivered at the focal region. The damage area was drastically increasing at the initial stage and quite fluctuating at higher peak power. The maximum damage area was observed at peak power of 21.93 MW is $0.150 \pm 0.008$ mm$^2$.

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