Controlling the overlapping of laser pulses

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Abstract

An overlap and separation between the laser pulses was sufficiently controlled. The 800-picosecond pulse width laser system that have a repetition rate of 40 KHz have been engaged to implement this path. The system with 532 nm wavelength was focused with a 0.75 NA lens to a 1.83µm diameter spot. Two parameters were used to separate/overlap on sample using the pulses from laser system: the pulse repetition rate and the sample scanning speed. An electric current was supplied to the laser diode driver (LDD) to control the repetition rate of pulsed laser. The second parameter was implemented to control the train of pulses and the speed of scanning stage under computer-control. The distance or overlap between the pulses have been successfully controlled for an arrange from separate the pulses with distance) all to get 90% overlap between pulses. The aim of this method was to get a single pulse from high repetition rate pulsed laser and to scale down the damage of material that result from applied multi pulses. This method was studied and implemented to make the price more reasonable and simpler to use comparing it with using the complex and expensive optics equipment.

Key words: Overlap/Distance, Repetition rate, Scanning speed.

Introduction

In recent years, pulsed laser as a tool for materials processing development has become an extraordinary field. Pulsed laser beams can be used to remove very small areas of material from a substrate (workpiece) with high accuracy in a process called ablation [1]. The ablation process results from various light-matter interactions but, principally, from a material absorbing sufficient laser energy in a short period of time.

Light that is incident upon a material can be reflected, absorbed and/or transmitted by the material. The manner in which laser light interacts with the material is dependent upon the laser wavelength and frequency, the material's optical properties, surface finish and, for thin films and structures, and sample dimensions (e.g. film thickness) [1].

To determine the energy applied on irradiated area of the material is required a sufficiently acceptable parameter number of pulses. The number of laser pulses can be used to reduce the ablation/melting threshold [1] or to reduce a thermal damage of material by using less number of pulses per length unit [2]. There are some techniques that need only single pulse for example laser induced forward/backword transfer (LIFT/LIBT) to transfer accurate quantity of material from a donor substrate to acceptor substrate[3], [4].

Several devices and procedures are used periodically to control the optical power or control pulse separation time of a laser beam such as; generate a single pulse using polarization-gating technique [9], a high-speed rotating chopper [5], acoustic optic modulator [6], disc chopper [7], light modolator [8].

By controlling the scanning speed and electric current supplied to the laser diode driver we can report a technique for controlling the distance/overlap or sorting a single pulse from laser pulses.

Experimental

The pulse duration of 800 ps, TEM_{00} beam profile, and (Alphalas; PULSELAS-P-1064-700-HP) is a (Sub-ns Passively Q-Switched Microchip Solid-State laser system). A 0.75 NA objective lens was used to focus the laser beam of 532 nm wavelength to produce a 1.85 μm diameter spot on sample.

After that, the samples were mounted on a high-precision three-axis (x, y, z) computer controlled linear stage. The used laser system has been described in one of our earlier publications [10] Fig. 1 describ the laser system setup.

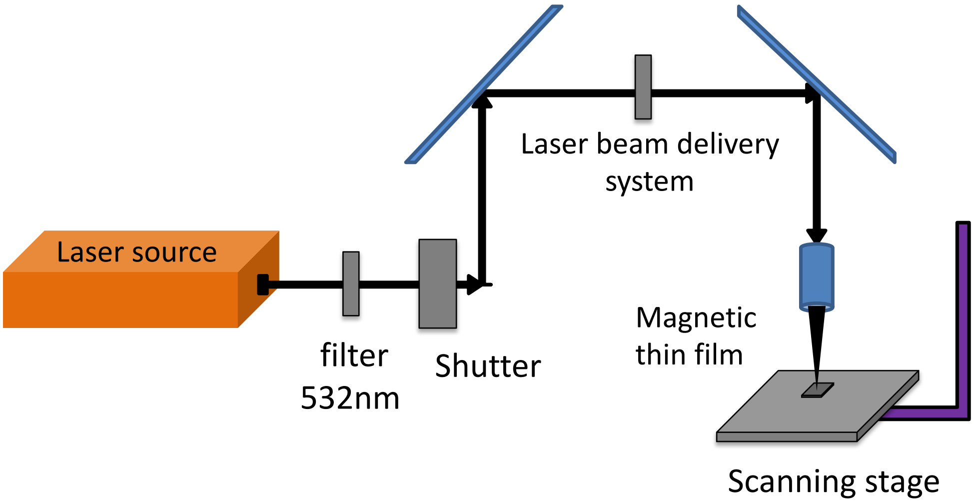

Fig. 1: *Scheme of the laser system setup.*

By controlling the scanning stage speed, *v,* we can control the number of pulses per unit length for the selected repetition rate, *f* and It can be calculated by:

$$N = \frac{f}{v} \qquad (1)$$

We can also calculate the distance/overlap *D* between ablation spot edges with a laser ablation spot diameter, *d*:

$$D = \frac{1}{N} - d \qquad (2)$$

D can take one of the following values:

$$D = \begin{cases} > 0 & pulses\ separated \\ \dots\dots\ 0 & pulses\ contiguous\ (just\ touching) \\ < 0 & pulses\ overlap \end{cases}$$

Figure 2 describe these cases.

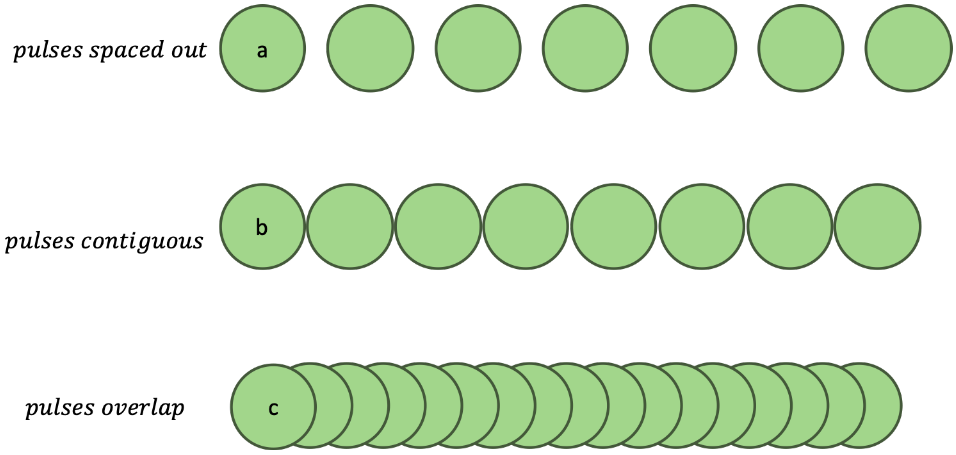

Fig. 2: *The three possibilities of distances between ablated pulse edges: a) separated, b) contiguous and c) overlapping.*

We can control the number of pulses per unit length with the second parameter and to scan speed depending on the diameter of laser spot, *d,* and the required distance/overlap *D* between ablation spot edges. it can be calculated the required scanning speed by:

$v = f(d + D)$ (3)

For Additional explanation about previous equations in [11].

on a glass substrate with thickness of 90 nm, the thin film was deposited using a thermal evaporator. Using SEM and the AFM the specimen were characterized.

RESULTS AND DISCUSSION

Figure 3 shows the change of the laser repetition rate, *f*, and average power with changing the electric current supplied to the laser's pump diodes. The repetition rate and average power increased linearly with increasing of laser diode current. The average power values have been measured just after objective lens without use attenuator or filter. Using variable attenuator, the average power has been attenuated.

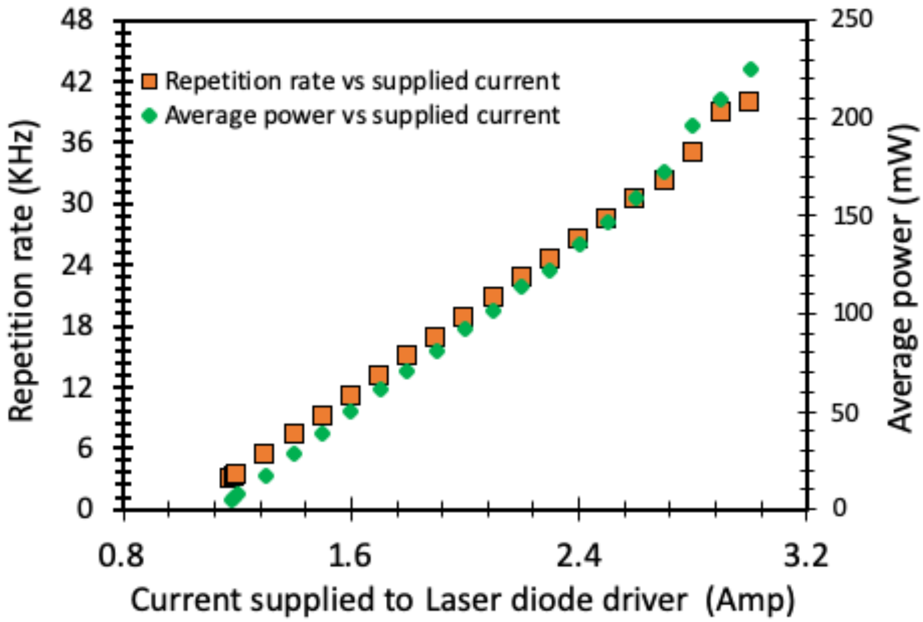

Fig. 3: *The repetition rate and average power of the picosecond laser as a function of laser diode driver current.*

By applying an electric current of 1.30 Amp to the laser diode driver, it can be reduced the Heat-Effected Zones (HAZs) and to generate the smallest spot ablation possible. With 1.3A, , repetition rate of 6 kHz with pulse energy of 10 nJ, the ablation spot diameter achieved was 1.85µm.

As shown in Figure 4 and according to equation 3 and based on the previous data, the first attempt to separate the laser pulses using a scan speed of 24 mm/sec to realize a space between pulses of around 100% of the spot diameter.

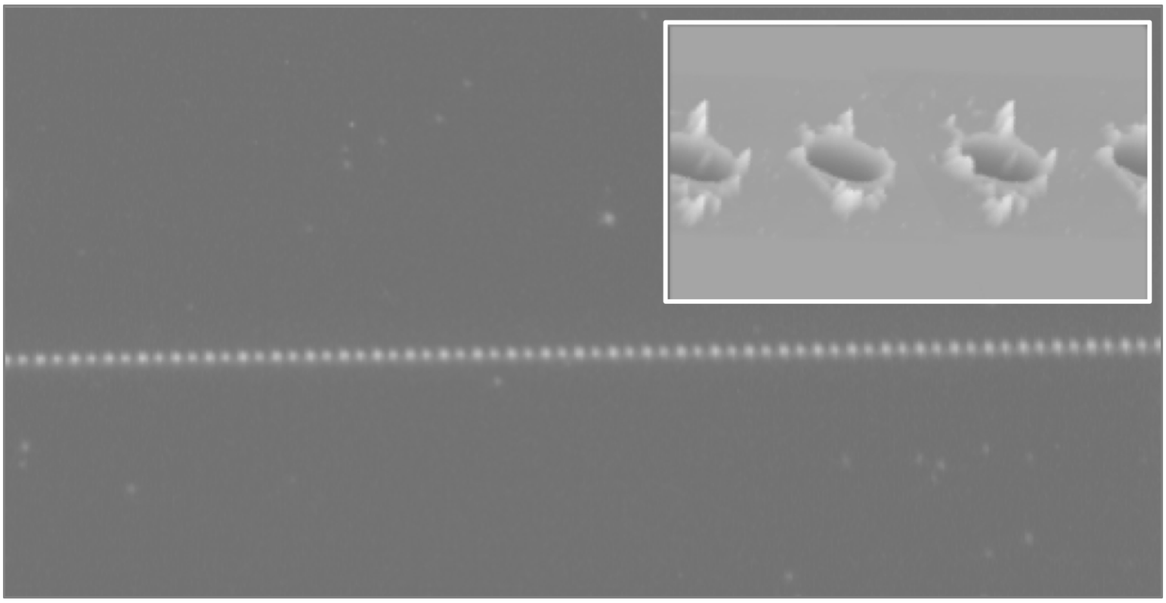

Fig. 4: *Optical microscopy image and Interior AFM image of separated pulses with distance of 100% of ablated spot diameter*

However, and as shown in fig 5 we achieved contiguous pulses by reduction the scanning speed to 12mm/sec.

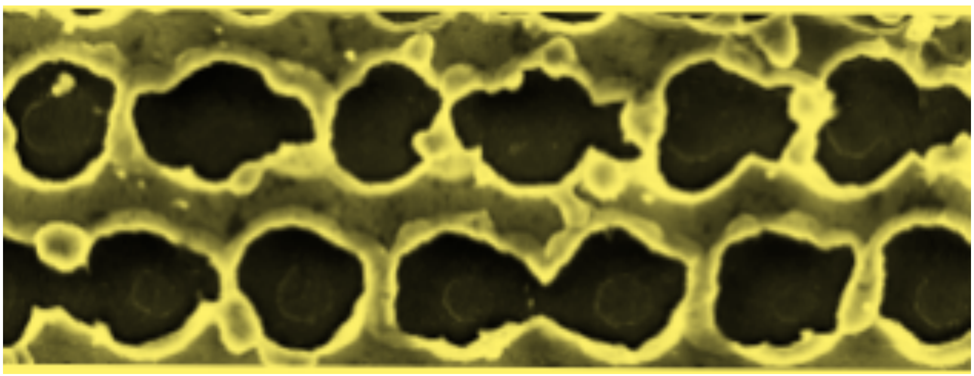

Fig. 5: *Scanning electron micrographs of contiguous pulses.*

Figure 6 shows samples of structures with overlap ratios of -16, -31, -51, -71 and -91% between pulses controlled by decreasing the scanning speed from 10, 8, 6, 4 and 2 mm/sec.

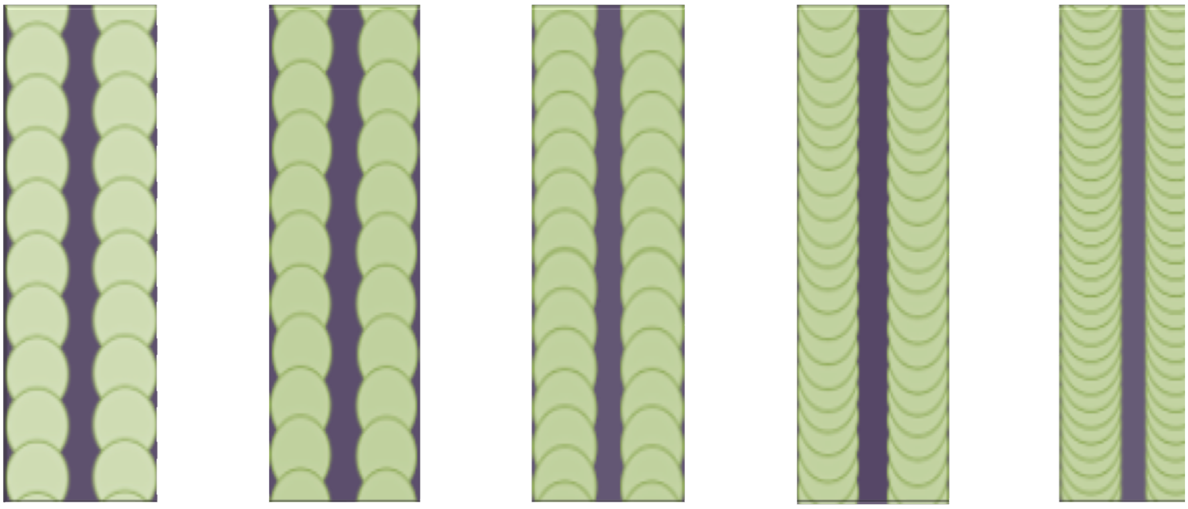

Fig. 6: *Micrographs of overlapping pulses of: a) -11%, b) -31, c) -51%, d) -71% and e) -91%.*

In the calculation of the previous equations shown in Fig 7, we obtained an actual result that is identical to the theoretical results. However, the slight difference between the hypothetical results and actual results is possibly because of the return of some of the melted material to the substratum and re-deposited on the thin film.

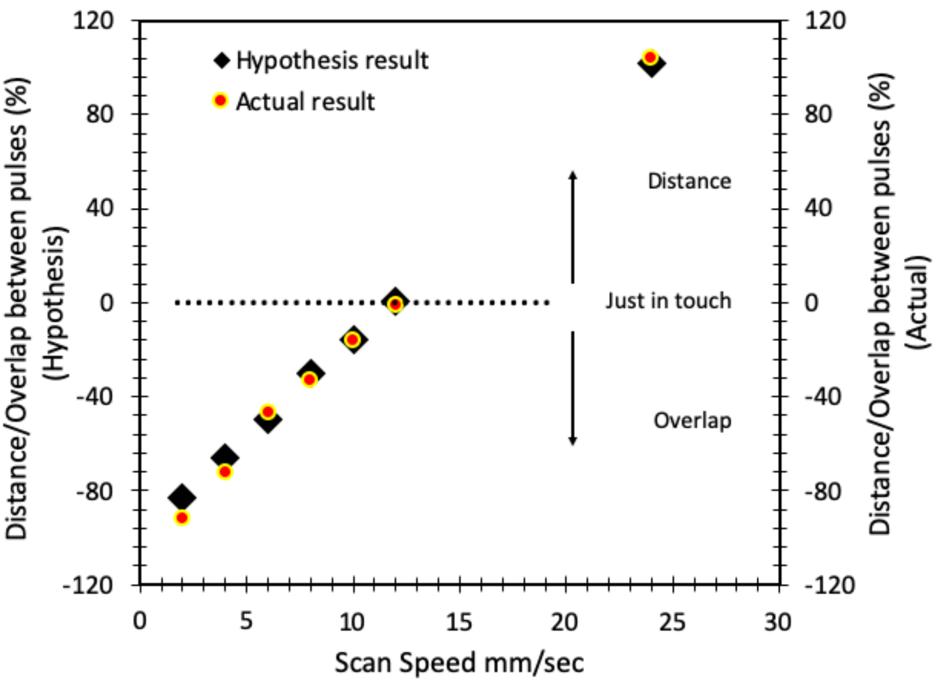

Fig. 7: Actual and hypothetical overlap or distance between laser pulses vs. scanning speed.

CONCLUSION

The laser pulses have been controlled through control the current provided the laser diode driver and specimens scanning speed. Single pulses were achieved with 100% of the diameter of the ablation spot and pulses overlap was achieved from 0 to -90% based on a mathematical calculation to determine the needed scanning speed. This technique can provide a simple and low-cost way for producing single pulses from a high repetition rate or to determine the necessary number of pulses per length unit to avoid sample damage.

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