Laser shutter control to thermal diffusivity measurements

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Abstract

There are several applications that use lasers lately and to do so it is necessary to control the total or partial beam blocking to better direct the heat flow. One example is the laser sintering of new metal alloys that require a controlled flow of heat. Another application that is necessary is measuring the thermal diffusivity of certain materials using the Flash laser method developed by Parker in 1961. This article presents two types of shutters, mechanical devices for controlling the electromagnetic signal, and a control for they use the Arduino Atmega328P microcontroller to control a laser beam to measure thermal diffusivity.

keywords: laser, difussiviy, flash laser method, shutter, arduino.

Resumo

Há várias aplicações que utilizam laser ultimamente e para tal faz-se necessário um controle do bloqueio do feixe total ou parcial para melhor direcionar o fluxo de calor. Um exemplo é a sinterização de novas ligas metálicas à laser que necessitam de um fluxo controlado de calor. Uma outra aplicação que se faz necessária é a de medição da difusividade térmica de determinados materiais por meio do método Flash Laser desenvolvido por Parker em 1961. Neste artigo é apresentado dois tipos de obturados, dispositivos mecânicos para ajuste de sinal eletromagnético, e um controle para os mesmos utilizando microcontrolador Arduino Atmega328P para ajuste de um feixe de um laser para medir a difusividade térmica.

Palavra-chave: laser, difusividade, método flash laser, obturador, arduino.

1. Introduction

Shutters are used to control electromagnetic signal or block completely the signal, they can be used as a security system where the light can cause damage or used to add precision in an experiment[1]. Shutters are used in a great number of applications that require some laser intensity control.

An application that uses a laser in their system is an ink sinterization using a laser that has the addition of control tha laser heating to a better result a laser ink deposition, a laser fluence is important to sinterinze in a sufficient temperature, this is a Additive manufacturing process.

Another application is a diffusivity measurement by flash laser method that uses a laser and needs a high precision on a gaussian opening. This method was developed for Parker et. al. in 1961[2] and was made to have a high precision and in a low time, differentment of other methods the method flash laser requires some seconds to have a measure. This method has a high accurate determination of thermal properties of ceramic materials or metallics.

The method flash laser consists of giving a high pulse of energy in the frontal part of a sample in disc format[3].

To control the type of laser opening, two types of shutters were considered so that the sample received the appropriate amount of heat, an opening that cuts the laser laterally, guillotine shutter, and an opening that allows the center of the laser to pass first, diaphragm shutter.

This paper presents a laser shutter control to processes that requires temperatures precision low cost, in this case was used for diffusivity measurements.

2. Methodology

The guillotine shutter uses a simple logic to block the laser's signal, a ceramic board is positioned in the front of the optical path of the laser, used a ceramic board because it doesn't transmit the laser's heat, this board was fixed in a solenoid to put him in front of the laser.

a) b)

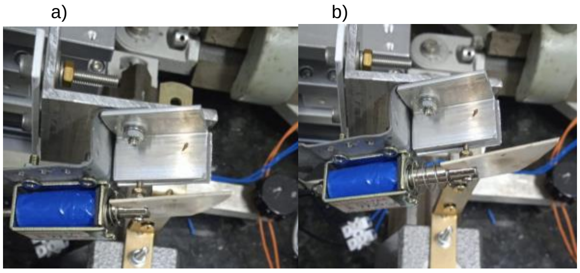

Figure 1: a) guillotine shutter activated; b) guillotine shutter deactivated.

A mechanical diaphragm shutter that was utilized uses a path that is from an analog camera photography that open when a lever is pulled, therefore, was used a solenoid as a actuator to pull the lever

Figure 2: diaphragm shutter

It utilized a board with an Atmega328P microcontroller arduino platform programmed in C++ language to control the both shutters solenoids.

The solenoid used needs 12V to work correctly and the arduino only has 5V in your output digital ports, therefore, relays are necessary to activate the solenoids.

2.1 Logic

The diaphragm shutter is made of metal and therefore cannot be exposed to the laser for a long time, otherwise the heat from the laser will cause damage to the diaphragm, therefore, to control the laser aperture there is a ceramic board(guillotine shutter) that supports the heat of the laser, this plate blocks the laser path before it reaches the diaphragm shutter.

Therefore, to control the laser opening, the board must be removed from the optical path, the path taken by the laser beam, so that the laser reaches the diaphragm and the diaphragm must be activated so that it rotates the laser. Therefore, first a guillotine shutter is used and then a diaphragm shutter.

To activate the diaphragm and remove the ceramic plate from the optical path, a 12V solenoid will be used, which will perform the mechanical movement when powered, and a button to start the system.

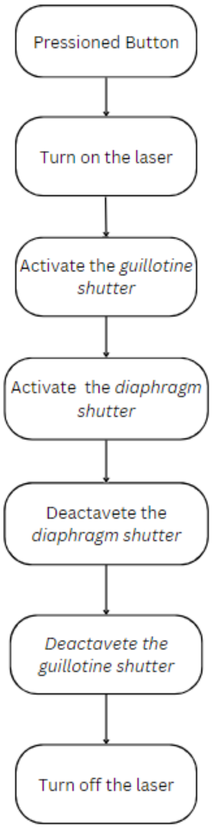

Figure 3: flowchart

2.2 The Flash Laser method

The shutters were used to control a CO_2 laser that is being used to a measurement system of diffusivity, in this case, the laser is used as a high pulse of energy and two type J thermocouple are used to measure the sample's temperature. Parker et al.[2] disregarded heat losses, but, with the experimental conditions can't be ignored[6] so is necessary to use a correction factor.

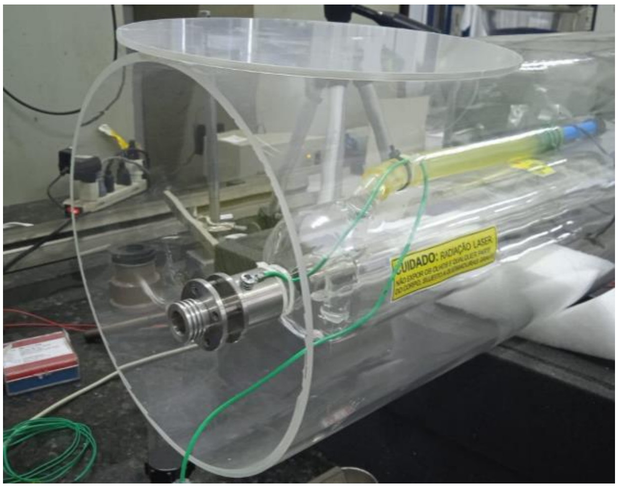

Figure 4: CO2 Laser

It utilized aluminum samples with 2 mm, 2,76 mm, 4,31 mm and 5,7 mm thickness in a disc form. The aluminum thermal diffusivity is 97,7x10^{-9} m^2/s, so it is possible to compare the samples diffusivity to compare with the expected value and find the correction factor.

3. Discussions and Results

According to the theoretical solution, with α = thermal diffusivity[m^2/s], d = thickness sample an $t_{1/2}$ is the time required to the temperature rise the half maximum value[4]. The α is given by Equation 1:

$$\alpha = 1{,}38\frac{d^2}{\pi^2 t1/2} \quad (1)$$

Using the Equation 1 was found the α of each sample as show in Table 1.

Table 1: sample's thermal diffusivity

Sample thickness[mm]	α[m^2/s]
2,00 ± 0,05	(8,97 ± 0,01).10^{-6}
2,76 ± 0,05	(1,7 ± 0,1).10^{-5}
4,31 ± 0,02	(3,8 ± 0,2).10^{-5}
5,7 ± 0,1	(6,3 ± 0,3).10^{-5}

As the aluminum thermal diffusivity is known so we can find the relation between the correction factor and the thickness of the sample. Being γ the correction factor and 97,7x10^{-9} m^2/s the thermal diffusivity of the aluminum:

Table 2: correction factor for each sample

Sample thickness[mm]	γ
2,00 ± 0,05	10,8 ± 0,8
2,76 ± 0,05	5,7 ± 0,7
4,31 ± 0,02	2,2 ± 0,5
5,7 ± 0,1	1,6 ± 0,4

With the Table 2 we obtained a graph as shown in Figure 5:

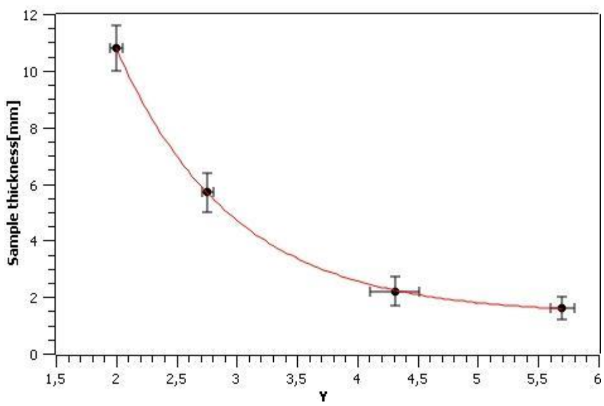

Figure 5: trend line of the function

With the Table 2 is possible to found the function that relates α and d using the graph trend curve. The trend curve is show in Equation 2:

$$\gamma = 1{,}38 + 75.e^{\frac{-d}{1{,}38}} \quad (2)$$

Where d is the thickness and γ is the correction factor.

4. Conclusion

The laser flash method is the easier method to measure the thermal diffusivity of materials. The obturators proved to be efficient for controlling the laser flow and for measuring the diffusivity of materials so this system can be used for thermal diffusivity measurements. Was find the correction factor of the experimental conditions, Equation 2.

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