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Practical analysis of laser beam parameter in Z-Scan technique

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Abstract

The z-scan is an important optical technology that is used to diagnose the optical behavior of different materials and optical elements and to verify their parameters by defining their linear and non-linear optical properties, this technique is based on the principle of the interaction of the laser beam with the material within tunable ranges of power, During the research, this technique was employed in a research and experimental manner to determine its capabilities and record its ability to be a database that can be adopted in future research in this field. The solid-state laser type (Nd: YAG) continuous wave (CW) 100mW @ 1064 nm was calculated intensity of the beam, depending on the approved engineering distribution was calculated intensity of the laser beam were observed harmony wonderful ability within the ranges of the optical axis can be employed in the experiments to determine visual qualities of linear and nonlinear materials.

Keywords: Z-Scan, Laser power, Laser beam, power density

تحليل عملي لخصائص شعاع الليزر في تقنية مسح المحور البصري

الخلاصة

تعتبر تقنية المسح المحوري البصري (Z-Scan) من التقنيات البصرية المهمة والتي تستخدم في تشخيص السلوك البصري للمواد المختلفة والعناصر البصرية والتحقق من معلماتها من خلال تحديد خصائصها البصرية الخطية واللاخطية، تستند هذه التقنية الى مبدئ تفاعل الشعاع مع المادة ضمن مديات متناغمة من القدرة، تم خلال البحث توظيف هذه التقنية بصورة تجريبية بحثية لتحديد إمكانياتها وتسجيل قابليتها لتكون قاعدة بيانات يمكن اعتمادها في البحوث المستقبلية في هذا المجال.

تم خلال البحث استخدام ليزر الحالة الصلبة نوع (Nd:YAG) مستمر بقدرة (100mW) وبالطول الموجي (1064 nm) وتم احتساب شدة الشعاع، بالاعتماد على التوزيع الهندسي المعتمد تم احتساب شدة شعاع الليزر وتم ملاحظة تناغم رائع للقدرة ضمن مديات المحور البصري يمكن توظيفه في تجارب تحديد الصفات البصرية الخطية واللاخطية للمواد.

Introduction:

The laser beam has many unique properties that have made it the ideal solution for all problems, as this beam is characterized by monochrome wavelength and is very similar and has a high direction, so this beam can be super focused to obtain very high focus intensity.

Many medical, industrial, and scientific applications of the laser are concentrated on one side, which is the shortening of the laser pulse width for the purpose of obtaining high laser output as in the following equation:

$$P.P(W) = E(J)/\tau(\text{sec}) \text{ .... } (1)$$

Where

(P.P) is the peak power of laser pulse with power unites (Watt).

(τ) is laser pulse width with time unites (sec)

(E) Is laser pulse energy with Joule that can be written as:

$$E(J) = n \times h \times \upsilon \text{ .... } (2)$$

Where:

(n) Is number of photons

(h) Is Plank constant

(υ) Is the photon frequency with (Hz) unites

Among the various applications of laser, especially scientific ones, there is a need for high power density or high energy density, which is described as obtaining the highest concentration of the laser beam in the area for the purpose of questioning and knowing the properties of materials and what is the interaction between the beam and matter and the role of power density or energy density in this phenomenon.

The power density equation for a laser can be represented by the following equation:

$I(W/cm^2)=P(W)/A\ (cm^2)$....... (3)

Where:

(I) Is laser power intensity

(P) Is laser power

(A) Is laser spot size

The optical axis scanning technology (Z-Scan) is considered one of the most important techniques to study the effects of the laser beam and its role in interacting with the material, as this technology provides a large area of harmony of power density or energy density, thus providing the possibility and a wide range of tests in the employment and study of the effects of the laser interaction with matter.

Figure (1) show a diagram of the z-scan technology.

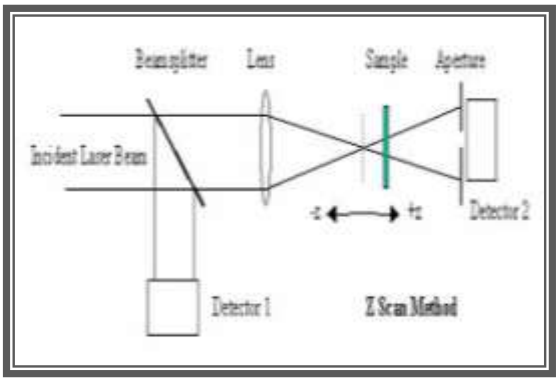


Fig (1): Basic diagram of the z-scan technology

The system generally consists of a laser source with a fixed optical ability that shines a beam onto an optical beam segment with a ratio of (10: 1). Directed towards the power meter for the monitoring the stability of the system.

The system contains a collimation lens located on the optical axis aiming to focus the beam in order to obtain the highest focus within the optical axis, the optical element to be examined is moved on the optical axis within the focus range, which is known as the "Rayleigh range", which is the extent to which the beam maintains the highest focus.

The effective radiation from the optical material is measured by an sensor located at the end of the optical axis. This technique is based on the change and harmony of the focus of the laser beam according to the radius of the beam where it is less at the focal length in the middle of the Rayleigh range and is less at the ends of this point and as shown in the figure No. (2) below:

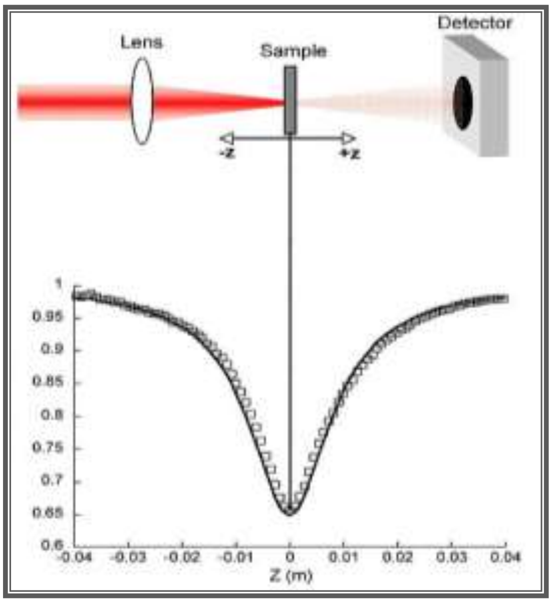


Fig (2): Sample transmission at the Rayleigh range

This technology acquires its value through the many distinguished scientific and research applications for it in the fields of non-linear optics and various medical and life applications.

Practical side:

During the research we had used the following devices and supplies provided in the lab:

- Solid state laser continuous wave (CW) Nd: YAG with wavelength (1.064nm) and output power (100mW).
- A digital power meter to measure the output power of the laser and indicate the stability of the system.
- Collimation lens with focal length (10 cm).
- Silicon cross-section imaging system with a silicon sensor operating within the spectral range (350-1100nm).

The stability of the laser output power was measured by operating the laser system for 30 minutes, and the output power was measured by means of the constant periodic power meter and the system stability was shown as shown in Figure 3 and they were as follows:

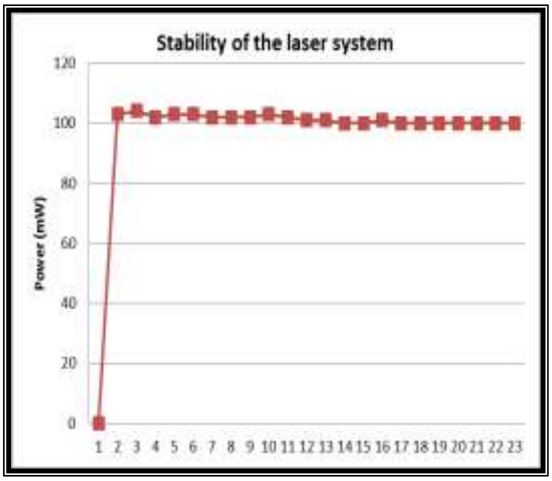


Fig (3): Laser power stability

The diameter of the laser beam before its fall onto the blinding lens was calculated by means of a laser beam cross-sectional imaging system that was (4 mm) and as shown in Figure (4) below:

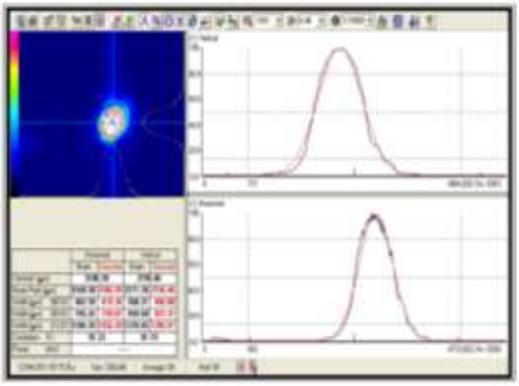


Fig (4). Laser beam profile

Five points were taken on the optical axis to measure the diameter of the laser beam and calculate the power density for each point.

Results:

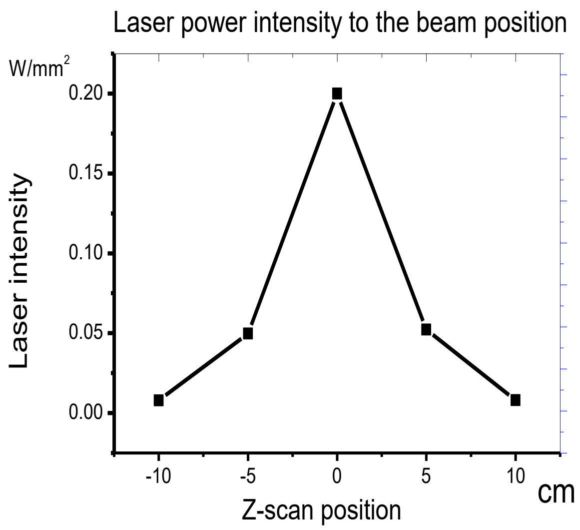
The laser beam in the solid-state lasers is characterized by its regular, circular shape, where the area of the laser spot can be calculated by applying the law of the circle's area. The results of the research were as follows:

Position	Beam Dim	Beam Area
-10	2 mm	12,566 mm^2
-5	0,8 mm	2,01 mm^2
0	0,39 mm	0,477 mm^2
5	0,78 mm	1,911 mm^2
10	1,98 mm	12,31 mm^2

The laser power density is calculated on the optical axis of the points indicated above:

Position	power density
-10	0,00795 W/mm2
-5	0,04975 W/mm2
0	0,2 W/mm2
5	0,0523 W/mm2
10	0,00812 W/mm2

By drawing the relationship that represents the relationship in harmony of the laser power intensity with the laser spot size change:



Conclusions:

1. This technique is of great importance in studying all the linear and non-linear spectral phenomena.

2. The experiment can be developed by adding a number of power metrics related to data automation software.

3. The use of high-resolution optical tripods that are driven by high-precision motors gives the ability of the system to obtain the best results.

4. By controlling the focusing power of the laser beam, the power density can be multiplied by more than twenty times.

5. It is preferable to use mobile optical platforms with high-precision computer-controlled capacity to obtain good results.

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