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Original article

Investigation of the semiconductor laser beam propagation through air and pure water (stable and turbulence)

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Abstract

Transforming the laser beam toward a mass flow has been a stimulus for both scientifically and technologically. As a foundation of estimating output laser performance, advancing exceptional beam quality is important for beam analyzing. we seek in this study to explain the beam characteristics of the laser in different conditions. By using an optical system consisting of a semiconductor laser with (λ= 650 nm, P= 4.64 mW). The attenuation and turbulence of the beam with different environmental conditions in the air and in the pure water (stable, turbulence) at different distances were studied and laser beam parameters (spot, shape and intensity) were included. The measurements were obtained by using a CCD camera and silicon detector type (Silicon PIN) in fast response (0.4-0.7A/W). The amount of the absorption coefficient of different conditions of the water was determined.

Keywords: Semiconductor laser, Beam propagation, Beam characteristic, CCD

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Introduction

Laser technology is widely used in various fields of human activity, for its excellent monochromatic (single wavelength), coherence (tightly focused) and directionality (no directivity)(1,2). The most widely used type of laser beam has a Gaussian intensity distribution at planes normal to the propagation direction. A Gaussian laser beam was completely characterized for all distances from the source by only couple parameters, smallest beam waist radius and its location (3,4).

Laser beams with intensity profiles other than Gaussian or with specific multi-mode distributions have attracted much interest in laser application such as in laser processing, lithography, fibre needle, medical treatments and laboratory experimentation (5,6).

Innumerable accurate measurements including fast analyses of the beam width are captured with (CCD) camera which, presents a straightforward and a real time appearance of the beam characterisation (7,8).

Many beams of lasers emit amidst Gaussian distribution. In the state, the laser is assumed to be producing on the significant (transverse mode) or (TEM00) mode of the laser's optical resonator(9,10). Beam shaping is a process of a redistributing irradiance and phase of optical beam radiation. Irradiance distribution defines the beam profile, such as Gaussian, multi-mode, annular, rectangular and circular (11,12).

A phase of the output beam delimits its proliferation characteristics. The entrance of a coherent beam within a pure medium in turbulence issues in a variety of light velocity which in turn generates distortion in the intensity and phase of the beam(8,13).

Distribution of the optical waves inside the arbitrary media like biological constituents is extremely essential in numerous administrations (14,15). In these locations, the temporally and spatially varying media change the amplitude and phase of propagating optical fields in both time and space(16).

These effects can cause attenuation or loss of the transmitted information and energy because of their directionality and high-energy concentration. Laser beams are widely used in modern optical communications in, remote sensing, and laser weapon systems. Turbulence effects restrict the fulfilment of all those systems (17).

Materials and Methods

Two techniques were appropriated to circumscribe the spot, shape and intensity of the beam within the air and pure and salt (stable, turbulence) water, through using a semiconductor- laser system with (λ=650 nm, P=4.64 mW). These methods are presented in figures (1,2).

CCD, camera was located in the exterior of laser beam that was focused at the centre of the camera at different distance 10, 20, 30 and 40 cm. A CCD Camera - Beam Profiler with software program to analyse the laser has been used to choose the best spot.

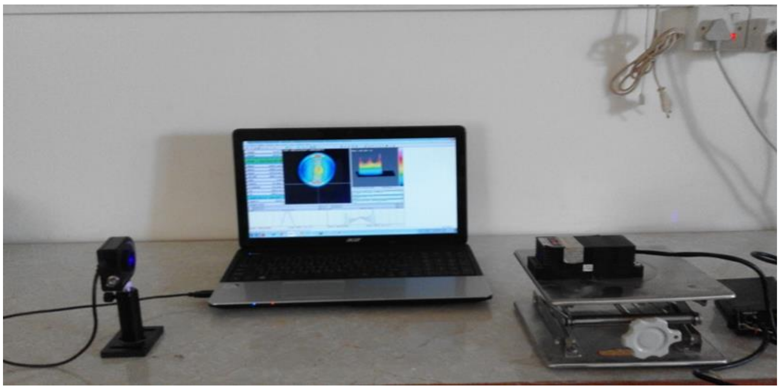

Figure1: Setup of the laser beam in air

In pure (Stable, turbulence) water, the method was used to measure spot, shape, and intensity as presented in fig (2). A laser was placed on the one side of a glass tank dimensions (d1=150 cm, d2=15 cm) and in the second side an optical window B7 type with diameter 30 mm and transmission of 0.8% placed exactly in front of the CCD camera. After filling the glass tank with pure water (stable), the laser beam was passed into the water and focused at the centre of the camera by using an electric motor. The flow rate was 3 L/min so as to generate turbulence in the pure (stable, turbulence) water, as shown in fig (2). The most suitable spot was marked at CCD Camera - Beam Profiler with software program to analyse the laser within a various distance of (10, 20, 30, and 40 cm).

The determination of the absorption coefficient for pure and salt water was done according to Beer-lambert law, with an incident intensity of (I_0) and a transmitted intensity of (I). A silicon detector type (Silicon PIN) has been used to record the intensities of the incident and transmitted laser beam.

The transmittance (T), of the water is defined as the ratio of (I/I_0). Absorbance (A) of water is linked to a transmittance and incident intensities by the following :

$$A = \log_{10} (I_0/I) \ldots (1)$$

$$A = - \log_{10} T \ldots (2)$$

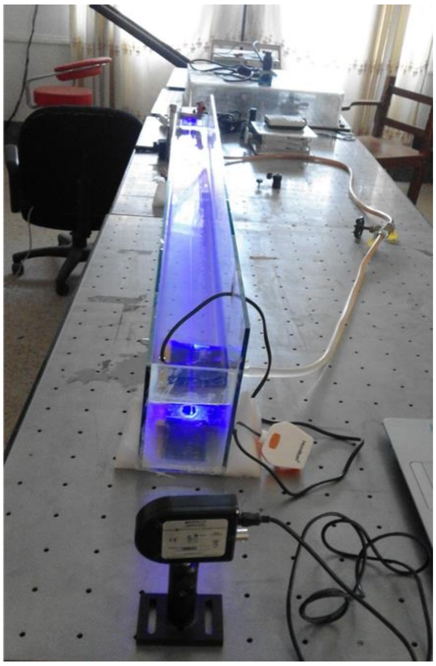

Figure2: Setup of the laser beam in water

In addition, the relation linking between the absorbance and the concentration with an absorption coefficient is as provided here:

$$A= \varepsilon\ c\ x \ldots (3)$$

Where (ε), is a molar absorption coefficient, while (c) is a concentration and (x) is a distance that laser travels through the water. From eq. (2, 3), one can get:

$$\varepsilon=A/c\ x \quad \ldots (4)$$

In this experiment, the concentration (c) for the salt water was (30%) and for the pure water was (100%) and the (x) distance was (150 cm).

Results

1. **Measurements of Absorption Coefficient**

Table (1) represents the result of the absorption coefficient for pure and salt water. The maximum absorbance was in salt water. Pure and salt water are transparent for visible light where there is not absorption peak in the range of (180-680 nm) which is a part from UV and visible light (14, 15). The incident intensity of (I0) was (0.5 W/cm2). The value of absorption coefficient in pure water was (0.009625, 0.010352) cm-1 for stable, turbulence water respectively and in slate stable and turbulence water they were (0.029306, 0.030594) cm^{-1} as shown in the table below.

Table (1): Result of the Absorption Coefficient for Pure and Salt Water

Water Type		I	T	A	ε
Pure	Stable	0.018	0.036	1.443697	0.009625
	Turbulence	0.014	0.028	1.552842	0.010352
Salt	Stable	0.024	0.048	1.318759	0.029306
	Turbulence	0.021	0.042	1.376751	0.030594

2. Laser Beam Semiconductor Laser (λ= 650nm) In Air

Figure (3) shows the spot which is elliptical and that the intensity was decreased with the distance. The distribution of the beam intensity is changed on Gaussian distribution in the air, while it changed irregular with different distances 10 cm, 20 cm, 30 cm, and 40 cm in the air. The following beam intensity was absorbed with these distances were (87.9, 93.2, 93.2, and 83.7 %) as showed in figure (3). When the beam passes through a medium, a small increase in temperature was noticed inside the medium which result in a little increase in kinetic energy of molecular medium that absorbed laser leading to affect the intensity and the distribution shape of the beam. When the kinetic energy rises, the molecular turbulence will increase which affects all properties of the beam. However, the spot is changed to almost elliptical shape (18,19).

Table (2) show the change of beam intensity and spot diameter with distance, the intensity increased until it reaches a distance of 30 cm and then decreased. The mean decrease is at distance of 20 cm and then increase a little at distance of 30 cm then decreased.

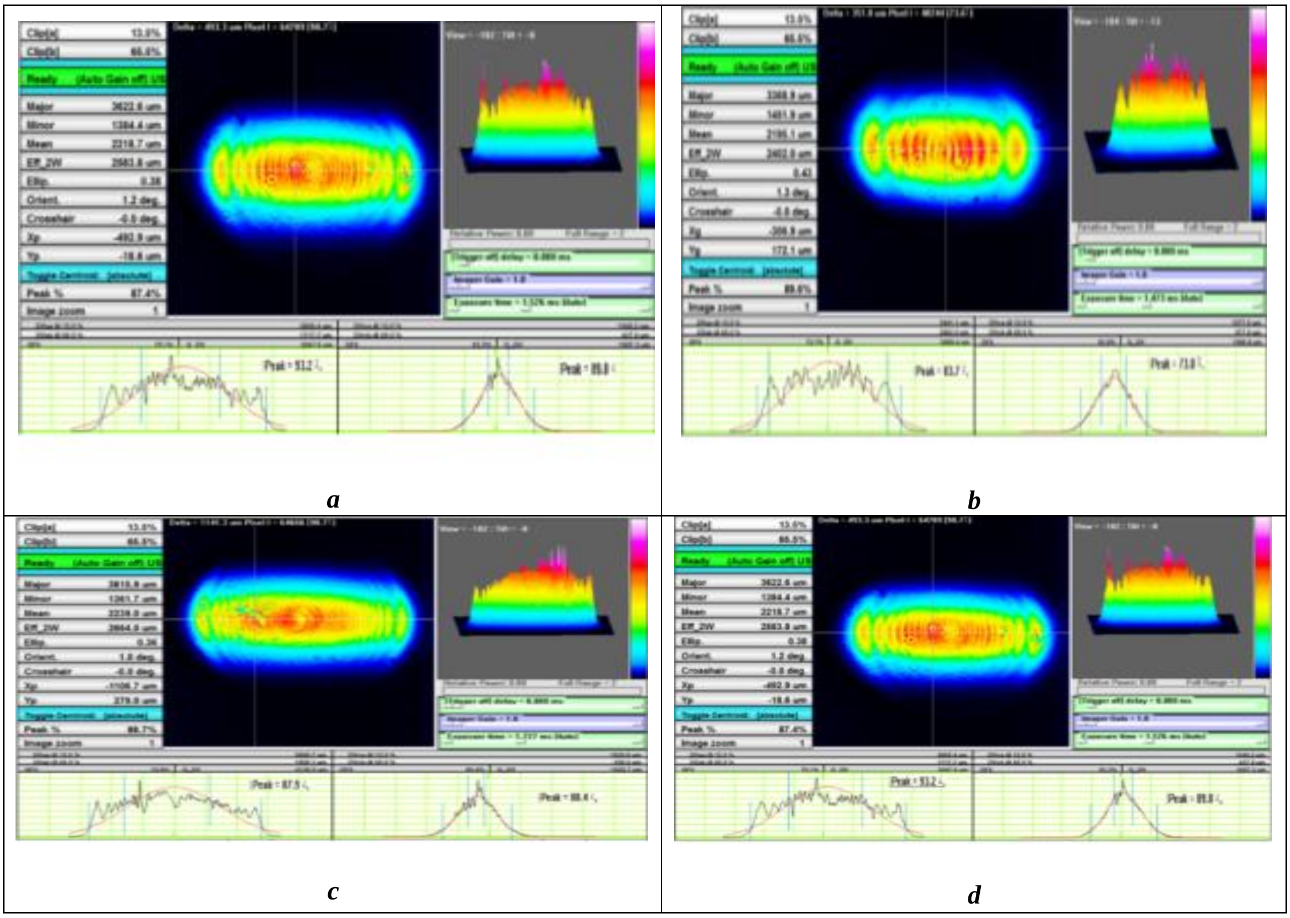

Figure 3: beam spot and profile of semiconductor 650 nm at different distances. (a)10 cm, (b)20 cm ,(c)30 cm and (d) 40 cm in the air

Table (2): The changing of the diameter and peak intensity within the distance of Semiconductor Laser (650 nm) in Air

X cm	Peak% (Spot Shape)	Peak% (Distribution Shape)	Mean (Diameter) µm
10	87.9	88.4	2239
20	93.2	89.8	2218.7
30	93.2	89.8	2218.7
40	83.7	73	2195.1

3. Laser Beam Of Semiconductor Laser (λ=650) In Pure (Stable) Water

Figure (4) (a,b,c,d) shows different laser beam spot on elliptical form when practicing pure water, which shows a little different in intensity distribution shape on Gaussian shape, noticed that intensity changed wasn't regular (87.9,93.2,93.2,83.7%) at different distance.

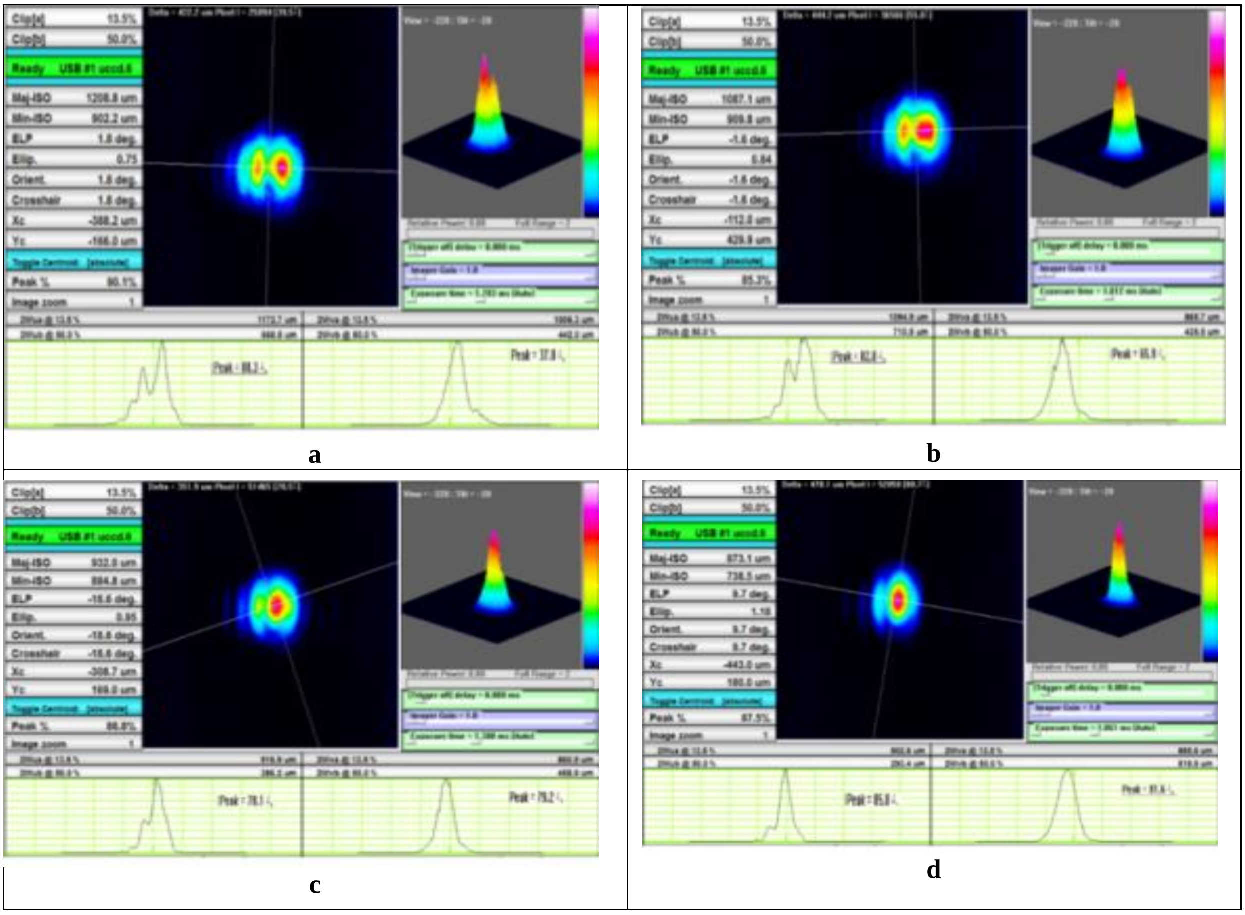

Figure 4: Laser Beam Spot And Profile Of Semiconductor 650nm At Different Distances (A)10cm (B)20cm (C)30cm (D)40cm In Pure (Stable) Water.

Table (3) shows a change in beam intensity and spot diameter with distance. Intensity increase until reached maximum value at distance of 30 cm and then it decreased. Notice that the mean diameter isn't changed with the distance until it reached the distance of 30 cm and then decreased.

Table (3): The changing of the diameter and peak with a distance of semiconductor laser (650nm) in pure water

X cm	Peak% (Spot Shape)	Peak% (Distribution Shape)	Mean (Diameter)µm
10	87.9	88.4	902.2
20	93.2	89.8	909.8
30	93.2	89.8	884.8
40	83.7	73	738.5

4. Laser beam of semiconductor laser (λ=650nm) in pure (turbulent) water

Figure (5) shows different laser beam spot on elliptical shape when using turbulent pure water, which shows a large difference within the shape and intensity distribution of Gaussian beam ,while it changed irregular (78,91.9,91.9,97.2%) with different distance

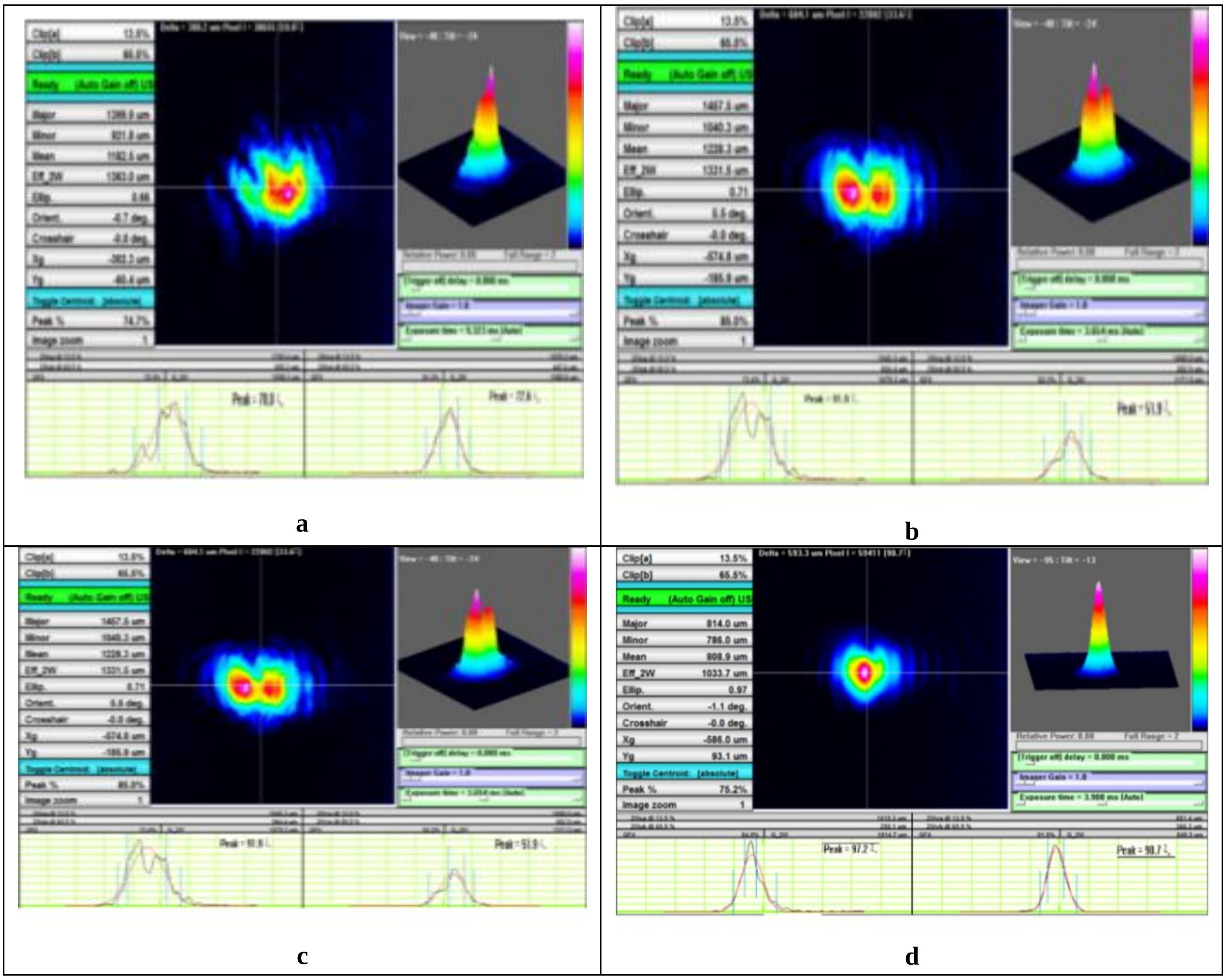

Figure 5: The spot & profile of 650nm at a different distance.
(a)10cm, (b)20cm, (c)30cm and (d)40cm in pure (turbulent) water.

Table (4) shows the change beam intensity and spot with distance. Intensity is increased until it reaches a distance of 30 cm and then a little change is shown. Notice that mean diameter is not change with distance until reached at distance of 40 cm then it decreased. Intensity is observed to be decreased at distance of 30 cm and then it is increased.

Table (4): Peak and Diameter Change with Distance of Semiconductor Laser (650nm) in Turbulence Pure Water

X cm	Peak% (Spot Shape)	Peak% (Distribution Shape)	Mean (Diameter)μm
10	78	72.6	1182.5
20	91.9	51.9	1228.3
30	91.9	51.9	1228.3
40	97.2	90.7	808.9

Conclusions

The results for managing the (650 nm, 4.64 mW) laser through pure and slate water were studied. The spot beam has shown relatively regular circuit and the shape of the distribution intensity was Gaussian shape in the air. While the peak values adjusted with different distance, and reduce the intensity with increase the distance. Also, we have marked a different spot on the circular shape during using pure, slate (turbulence) which shows a little difference in the shape of intensity distribution for Gaussian shape intensity and the largest change was in a slate (turbulence). it was remarked the intensity wasn't regular at a different distance. The absorption coefficient values were changed according to a type of solution. In usual, absorbance there was a manner of light interacting with a matter. The light, of course, is not lost, but it is transformed into heat or chemical energy. In biology and chemistry, the absorbance is utilised to quantify absorbing molecules in a solution.

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