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Optic large deflection cantilever beam (OLDCB) method

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In this experimental study, "Optic Large Deflection Cantilever Beam, OLDCB" method has been developed for calculating laser beams bending. OLDCB method is mathematically correlating and methodizing the information obtained from experimental results. OLDCB is defined regardless of wavelength and phase shift. In the experiment, lenses with a special geometric structure, which are independent of the wavelength and phase shift made of glass, were used. Semiconductor single mode green laser source was used as the source in the study. The optical output power of this laser source is 5-50 mW and the spectral bandwidth is 100KHz. There is no special condition for bending the magnetic field, electric field or laser beam in the experimental environment and it was carried out in the laboratory under atmospheric conditions. Only lenses that have been developed have been used for laser beam bending. We think that this experimental study result should add new terms as a contribution to the science of optics. These new optical terms are; bending limit value of laser beam optical power, laser beam critical minimum optical power, laser beam critical maximum optical power, laser beam critical bending resistance, optic resistance, critical laser beam diameter, maximum laser beam diameter, minimum laser beam diameter, laser beam bending critical conditions, optic surface area resistance and laser beam bending angle, laser beam minimum bending angle, laser beam bending range, laser beam boundary angles and laser beam bending in special conditions can be added. These terms have been defined as dependent on optical variables and have been added to optical science.

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1. Introduction

Many scientist have made many different studies dealing with the bending of light. Some of these scientists have studied that light bends as it passes through a high gravitational field [1] and magnetic field [2]. In addition, different studies and theorems related to bending of light are discussed in the literature [3].

Even if the light is diffracted, it normally tends in order to propagate along a straight path. Optical devices such as wave guides, lenses and mirrors are used to gather plenty of lights. Hence, different studies have been carried out in various situations where light bends even in vacuum [4].

Using the exact solution of Maxwell's wave equations, it was revealed that light could rotate left and right in the form of an arc without refraction [5-8]. In addition, the behavior of water and sound waves can also be calculated in detail, like the equations that clarify the light waves. Specially shaped beam of light without acceleration have been proposed in the reference [9].

The results of experimental studies carried out over the last decade have demonstrated that without accelerating, packets of airy waves could bend themselves [10-14]. Thus, airy wave beams are described as self-accelerating. Researches have also indicated that airy wave beams can be used for different purposes such as micromanipulation [15], plasma [16-17] and manipulation of surface plasmon [18-20]. The sources also show that Bessel waves have the same characteristic apart from airy beams [18-21]. Airy beams travel in their direction as parabolic trajectories because of the influence of gravity. They propagate as paraxial approach at large angles by losing their characteristics and appearances [21-22].

In the experiments on paraxial regimes and accelerating beams, the solutions of Maxwell's wave equation were used as the actual solutions for nonparaxial air beams [22-23]. In another research, accelerating beams "caustic-design" are described as caustic method since they can not maintain their shapes like non-paraxial regime [24-26].

In several studies, Airy wave packets can cause the creation of curved plasma tunnels by filamenting ultra-intense Airy beam waves in air [27]. Some researchers have demonstrated how the extremely dense Airy beams of arcuate plasma tunnels and self-bending, femtosecond laser pulses, and filamentation are used and what their properties are [27–33].

In comparison to the preceding studies, the present study was actually carried out using a lens under atmospheric conditions. As desired, the size of bending the laser beam can be regulated. Moreover, this bending is not an inherent bend that arise under certain conditions. The rad of bending beam can even reach meters. The remaining part of the paper continues as a mathematical model in section 2, experimental studies in section 3, and conclusion in section 4.

2. Mathematical models

The curvature of the bending moment is based on the Bernoulli-Euler's theorem. Curvature is directly proportional to the size of bending moment. This bending moment will be defined as the force for the physical quantities and as the bending moment of lens for the optical quantities. The bending process emerges in four different ways: Linear and nonlinear, and continuous and discontinuous. It is believed that the result of the bending process in four different ways requires different evaluations. In this study, “large deflection cantilever beams” method was only applied to the bending of the laser beam [34]. The units of the variables used in equations are determined as MKS units.

It is assumed that the angle in which the laser hits the lens does not change during the bending process.

B: The bending strength of the laser beam is determined as by $B = EI$ and E and I represent the size or sectional area of the laser. $B = (EI)/(I - v^2)$ is, on the other hand, defined for large-scale resources and v in the equation represents the Poisson's ratio.

Optical variables:

B: The bending strength of the light depending on the area cut that light strikes

M: Optical bending moment

ν: Poisson's ratio for large laser beams

ϕ: The angle of the laser on the lens or the tilt angle

L: Length of the beam in the Lens

Δ: Horizontal x-axis (X, horizontal) displacement

δ: the vertical y-axis (Y, vertical) displacement.

P: The laser optical power.

s: The arch length corresponding to the

$$B\frac{d\phi}{ds} = P(L - z - \Delta) = M \tag{1}$$

or

$$B\frac{d^2\phi}{ds} = -\frac{P}{B}\frac{dx}{ds} = -\frac{P}{B}cos\phi \tag{2}$$

maximum bending

$$\frac{1}{2}\left(\frac{d\phi}{ds}\right)^2 = -\frac{P}{B}sin\phi + C \tag{3}$$

C, are determined as fixed corresponding to the bending of the laser in any environment. The value is zero in these processes since no environment has affected the bending of the laser beam. In the following statement, ϕ_0 corresponds to the next slope and defined as the equality of

$$\frac{d\phi}{ds} = \sqrt{\frac{2P}{B}}(sin\phi_0 - sin\phi)^{\frac{1}{2}} \tag{4}$$

The solution of this equation is valid through the range of $-\pi/2 < \phi < \pi/2, \phi \neq 0$. The angle of the laser entrance into the lens is a special case of $\phi = 0$ and $X = 0$. In this case, the laser beam is limited to the right, which can be seen in Fig. 5. When the output of the laser beam is circular on in any other geometrical shape, the laser beam is converted towards the right part after it strikes the lens. During this conversion, the physical properties of the laser beam remain unchanged. Without being exposed to any bending, the laser beam turns into the right part and continues on its path as a vector at the axis of $\vec{Z}$.

The slope angle ϕ_0 cannot be calculated directly in this equation. However, the inclination angle of this elliptic integrals can be calculated directly.

$$\sqrt{\frac{2P}{B}}\int_0^{\phi_0}(sin\phi_0 - sin\phi)^{1/2}\,d\phi = \sqrt{2}\left(\frac{PL^2}{B}\right)^{1/2} \tag{5}$$

Substituting the variable, if α^2 is represented by PL^2/B and the following is defined,

$$1 + sin\phi = 2k^2sin^2\theta = (1 + sin\phi_0)sin^2\theta \tag{6}$$

$$\alpha = \int_0^{\pi/2}(1 - k^2sin^2\theta)^{1/2}\,d\theta \tag{7}$$

$$sin\theta_1 = \frac{\sqrt{2}}{2k} \tag{8}$$

In the next step,

$$\frac{dy}{d\phi}\frac{d\phi}{ds} = \frac{dy}{ds} = sin\phi \tag{9}$$

Equation (4) $d\phi/ds$ becomes Equation (4) $d\phi/ds$ from

$$\frac{dy}{d\phi} = \sqrt{\frac{2P}{B}}(sin\phi_0 - sin\phi)^{1/2} = sin\phi \tag{10}$$

Thus,

$$\delta = \int_0^y dy = \sqrt{\frac{2P}{B}}\frac{sin\phi d\phi}{(sin\phi_0 - sin\phi)^{1/2}} \tag{11}$$

With the help of Equation (6), if we obtain

$$\frac{\delta}{L} = \frac{\sqrt{2}}{2\alpha}\int_0^{\phi_0}\frac{sin\phi d\phi}{(sin\phi_0 - sin\phi)^{1/2}} = \frac{1}{\alpha}\int_{\theta_1}^{\pi/2}\frac{(2k^2sin^2\theta - 1)d\theta}{(1 - k^2sin^2\theta)^{1/2}} \tag{12}$$

This leads to the incomplete elliptic integral reflecting the first and second types. Jahnke and Emde

$$\frac{\delta}{L} = \frac{1}{\alpha}[F(k) - F(k,\theta_1) - 2E(k) + 2E(k,\theta_1)] \tag{13}$$

$$\alpha = [F(k) - F(k,\theta_1)] \tag{14}$$

so that

$$\frac{\delta}{L} = 1 - \frac{2}{\alpha}[E(k) - 2E(k,\theta_1)] \tag{15}$$

without any effect of forcing the laser beam, equation (1) is calculated when equation (4) is calculated from x = 0, and $\phi = 0$. This calculation can be written as either

$$P(L-\Delta) = B\left(\frac{d\phi}{ds}\right)_{\phi=0} = B\sqrt{\frac{2P}{B}}(sin\phi_0)^{\frac{1}{2}} \qquad (16)$$

or

$$\frac{(L-\Delta)}{L} = \sqrt{\frac{2P}{\alpha}} = (sin\phi_0)^{\frac{1}{2}} \qquad (17)$$

expressed as $sin\phi_0 = 2k^2 - 1$.

These statements are only valid to calculate the laser bending. It can be directly calculated from the polar coordinates if the bending is circular. The bending in the following Figs. 1, 2 and 3 was calculated using the method mentioned above. Figs. 4 and 5 reflect the special case. Using this method in calculating the values can reveal misleading results.

3. Experimental results

The CW laser was used in the experiment as an optical resource with an output power of 1 ... 5mW, semiconductor laser diode “CLASS-III” performing with two ordinary AAA 1.5V. This laser weld is a commercially produced electronic device without a special purpose. The photographs of the shapes were taken by a 16-megapixel resolution sensor. While the distance is 60 mm between the laser weld and the lens, it is 1300 mm between the lens and the plane. After going through the lens, the taken images are the ultimate images that propagate through the ambient air and are released into the atmosphere. In Figs. 1-5, the images have been obtained with the lens mentioned above by using a green laser source.

In the case shown as Fig. 4, the laser light is perpendicular to the lens. The laser beam moving as points are converted linear through bending and continues on its path as a vector. In our experimental studies, the laser beam was exposed to splitting and bending process at the same time [35]. It is an interesting finding in our experimental study that although the bending laser beam is expected to spread while moving away from the source, it, on the contrary, shrinks like free-flowing streams, or liquids. This is an interesting behavior of the beam [36]. In this situation, although the laser beam is expected to spread, it is believed that it changes depending on the environment. The case given in Fig. 5 is a particular case. It is converted into the linear part following the output of laser source. The spread of the laser beam is thus limited. The length of the linear part can be adjusted. The laser beam moves on this vector path in its direction of arrival. We work on the bending of light previous studies in the references numbered [35-36]. Laser source has a finite energy. Therefore, the laser bent also has a finite energy and it is weakened after reaching a certain length and time.

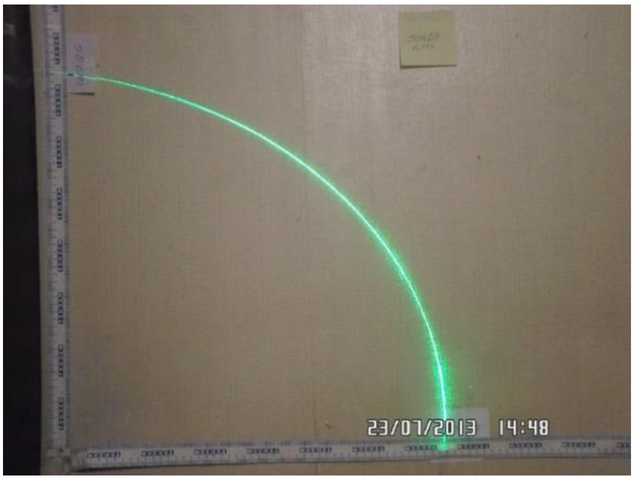

Fig. 1. Laser is bent towards the left as a quarter circle (color online)

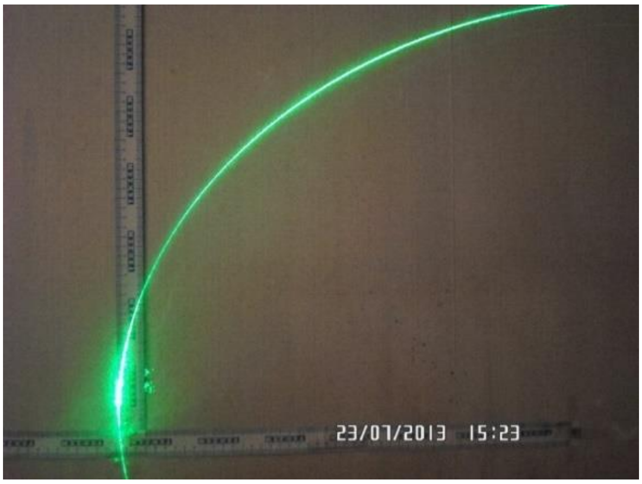

Fig. 2. Laser is bent towards the right as parabolic (color online)

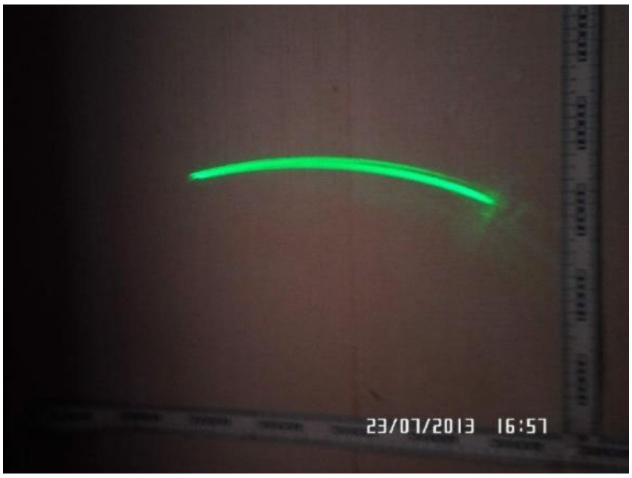

Fig. 3. Laser light at an angle limit. In this case, the spread of laser light is limited. It is possible to set the limits as desired (color online)

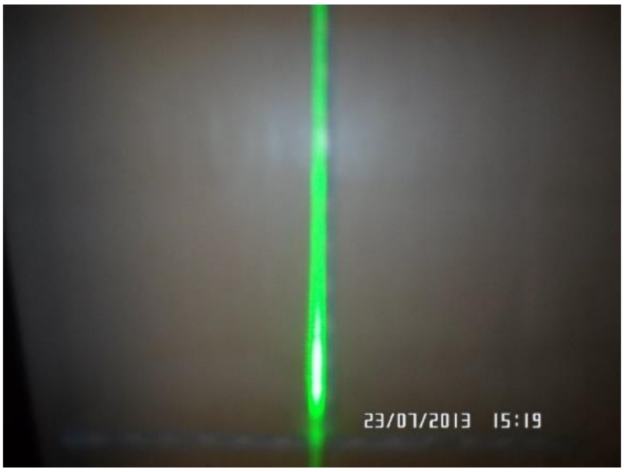

Fig. 4. Laser light obtained through bending (color online)

Fig. 5. Obtaining the laser beam as liner (color online)

The laser beam is characteristically nonlinear, and the bending and packaging of laser light is not uncommon [37]. If suitable conditions are created, bending occurs in the laser beam. In other conditions, the desired bending cannot be obtained in the laser beam and a detailed study on this subject is given in the patent [38].

4. Conclusion

In this experimental study, "Optic Large Deflection Cantilever Beam" method was developed for calculating laser beams bending. This “OLDCB” method is a theoretical model derived entirely from experimental results. In short, the results obtained as the product of an experimental study are made into a method. The method does not contain the theoretical part of the laser beam or any information about the structure of the laser. In contrast, it does not change any physical properties of the laser beam. This method does not directly give optical power losses. Optical power losses can be indirectly calculated by making use of the properties of glass used only in lens design. In this experimental study, a lens made of glass was developed. This lens glass does not have very special material. The lens has a special geometric structure. The lens used does not produce from new optical harmonics. In other words, while the laser used does not change the wavelength of the beam, it also works independently from the wavelength. The variable that the lens depends on is the laser beam diameter and optic power only depending on the physical structure of the lens. The lens used also prevents the formation of second-harmonic generation and higher-level harmonics due to its geometrical structure. In this study, semiconductor single mode green laser is used as an optical source. The spectral bandwidth of the laser source is 100KHz. Laser beam bending test was carried out using the laser beam obtained from the laser source with these features. The experiment was carried out under atmospheric conditions. The magnetic field, electric field and no special condition have been created in the medium for bending the laser beam. Only improved lenses are used for laser beam bending. These lenses are made entirely of glass and are not very special materials. The main features of the lenses are that they are homogeneous and the internal tension of the glass is homogeneously distributed. For experimentally bending laser beam, the “large deflection cantilever beams” method, which is used in the bending test of beams in civil engineering, was used as a mathematical model. This method is determined to be suitable for the mathematical model of bending the laser. All the variables of this method are the variables used in civil engineering science. It has no relation with optical systems. This method, namely “Large Deflection Cantilever Beams” variables, has been completely redefined and has been transformed into an appropriate form to be used in optic systems. MKS, CGS, or SI optic units are used for the standard unit system. This new “Optic Large Deflection Cantilever Beam, OLDCB” method was obtained under conditions. A new theoretical optic laser beam bending method has been obtained by combining OLDCB variables with optic variables and combining them with experimental results. We believe that this experimental study result should add new terms as a contribution to the science of optics. These new optical terms are; bending limit value of laser beam optical power, laser beam critical minimum optical power, laser beam critical maximum optical power, laser beam critical bending resistance, optic resistance, critical laser beam diameter, maximum laser beam diameter, minimum laser beam diameter, laser beam bending critical conditions, optic surface area resistance and laser beam maximum bending angle, laser beam minimum bending angle, laser beam bending range, laser beam boundary angles and laser beam bending in special conditions. These terms have been defined as dependent on optic variables and have been added to optic science.

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