International Journal of Scientific Research and Engineering Development-– Volume 9 Issue 2, Mar-Apr 2026
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Experimental Methodology for Obtaining the Waist Radius, Focus, and Radius of the Laser Beam

Josué del Valle-Hernández*, Mauricio Valtierra Domínguez**, J. Felix López Rocha***, José Alfredo Gasca González***, Adrián Pérez-Benavidez****, Carlos Alberto Trujillo Castellanos***, Alejandro García Trujillo***, and F. Alejandro Ramírez Díaz**

* (Dept. of Divison of Postgraduate Studies and Investigation, Tecnológico Nacional de México, Campus León
Email: josue.delvalle@leon.tecnm.mx
** (Dept. of Metal-Mechanical, Tecnológico Nacional de México, Campus León
** (Dept. of Basic Sciences, Tecnológico Nacional de México, Campus León
**** (Dept. of Metrology and Quality control, Instituto Politécnico Nacional, Campus León

--************************----------------------------------

Abstract:

Lasers have gained greater relevance over time, from communication and medical applications to metrology, holography, and industrial applications, among others. Therefore, in various applications, it is necessary to know one of the main characteristics of a laser when its beam is intended to be set up in an experimental arrangement, for which, in this publication, a traditional methodology to obtain the waist radius, radius, and focus of a laser beam in the infrared spectrum will be visualized and focused on.

Keywords — **Laser, waist radius, laser beam radius.**

--************************----------------------------------

I. INTRODUCTION

The laser is one of the discoveries and developments that have marked science and technology, whose phenomenology is based on Albert Einstein's theory of stimulated emission [1]. With it, it is possible to develop various applications across different fields and hazardous environments [2], as well as to serve as a support tool for the development of experimental setups to address real problems in Science and Technology.

There are various types of lasers with distinct characteristics, structures, operational mechanisms, and operating frequencies or wavelengths, including the pumping source. Among them, we find semiconductor lasers, gas lasers, carbon dioxide lasers, argon lasers, Helium-Neon lasers, among others, such as fiber-made sensors [3] commonly known as all-fiber sensors [4] to perform measurements in rotation, acceleration, electric and magnetic fields, temperature [5], pressure, vibrations, acoustics, linear and angular position, stress [6-7], humidity, viscosity, chemical measurements, among many other applications [8]. The laser, as its acronym suggests, is a device that amplifies light by stimulated emission of electromagnetic radiation to produce a highly directed beam and has a pure frequency or wavelength [9-10].

II. EXPERIMENTAL DEVELOPMENT

In order to obtain the lens focus, the waist, and the width of the laser beam, two experimental setups will be assembled. The first of these is shown in Figure 1; the detector is mounted on a lateral-displacement mount, and its position is varied using a micrometer. With the help of a voltmeter, the maximum voltage at the center of the detector and the minimum voltage at one of its edges were located in order to calculate the spot radius Wd_1 (radius in detector 1).

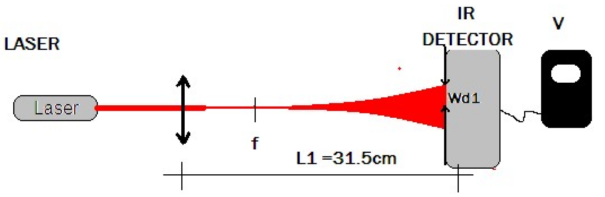

Fig. 1. Experimental setup for the measurement of the radius of the laser beam spot.

Subsequently, a table of experimental data is generated, and a Gaussian curve is obtained; an approximation is applied to have a cleaner graph (Figure 2).

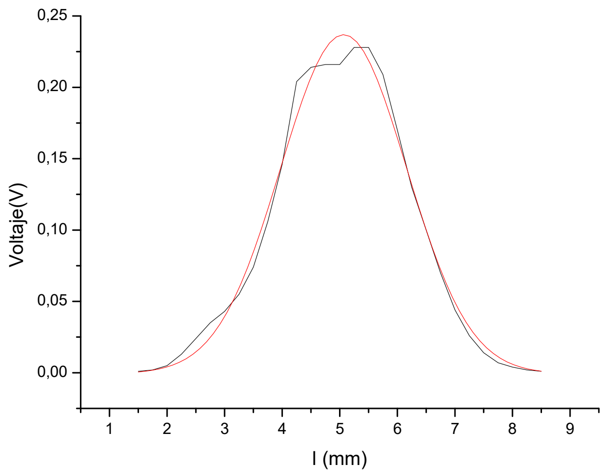

Fig. 2. Gaussian curve obtained by varying the voltage vs the variation of the detector position.

From the previous graph, a maximum voltage of $V_{max} = 0.2369\ volts$ is determined. Dividing this value by e^2 gives a voltage of $V = 0.03206\ volts$. Therefore, at this voltage, its abscissas (x) are determined at points P_1 and P_2 (Figure 3), in order to obtain the diameter of the spot, and consequently the radius of the spot ($Wd_1 = 2.135\ mm$) on detector 1.

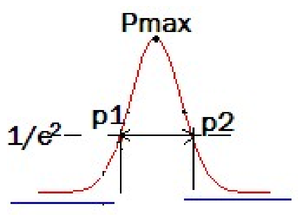

Fig. 3. Main parameters of a Gaussian curve

The second experimental setup is similar to the first; the only difference is that the detector is placed at a distance L_2=43 cm (figure 4), which makes the spot on detector 2 larger.

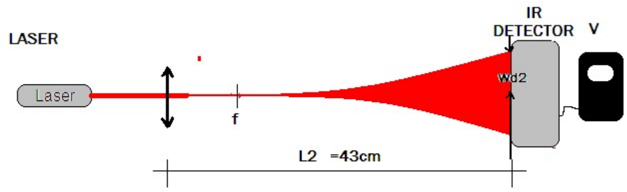

Fig. 4. Second experimental setup for measuring the laser beam spot radius.

Following the same procedure, a Gaussian curve is obtained (figure 5) and consequently the spot radius ($Wd_2 = 3.2452\ mm$) in detector 2.

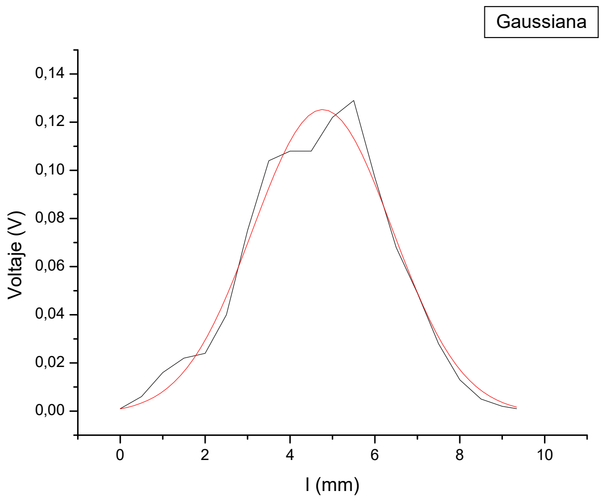

Fig. 5. Gaussian curve obtained by varying the voltage vs the variation of the position of detector 2.

The next step is to calculate the focus (f), the waist (Wo), and the beam width (Wo_1); for this, the following equations are proposed based on Figure 6.

$$f = L_2 - d \qquad ecs.1$$

$$Wo = \frac{\lambda f}{\pi(Wo_1)} \qquad ecs.2$$

$$Wo = \frac{\lambda d}{\pi(Wd_2)} \qquad ecs.3$$

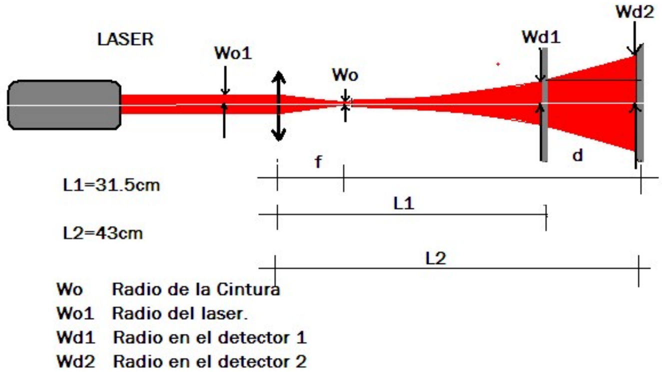

Fig. 6. Experimental setup for the measurement of the laser beam waist radius.

The distance d is calculated using similar triangles through the expression:

$$\frac{Wd_2 - Wd_1}{Wd_2} = \frac{L_2 - L_1}{d} \qquad ecs.4$$

$$d = \frac{(L_2 - L_1)(Wd_2)}{Wd_2 - Wd_1} \qquad ecs.5$$

By applying equations 1, 3, and 2, the value of the focal distance (f), the waist radius (Wo), and the laser beam radius (Wo_1) are obtained, respectively.

III. RESULTS

The results can be seen in the following table:

Variable	Descripción	(mm)
Wd_1	Spot radius on detector 1	2.135
Wd_2	Spot radius on detector 2	3.2452
d	Auxiliary distance to calculate f	336.34
f	Focal distance	93.66
Wo	Waist radius	0.021
Wo_1	Laser beam radius	0.898

Table 1. Values obtained experimentally.

The experimental determination of key parameters, such as waist radius, focus, and laser beam radius, was verified using the described methodology, which serves as a basis for solving various problems and applications across different areas of knowledge.

REFERENCES

[1] A. Einstein, (1917) On the Quantum Theory of Radiation.

[2] J. Villatoro, A.Díez, J.L. Cruz, and M.V. Andrés. : “In - line highly sensitive hydrogen sensor based on palladium- coated single-mode tapered fibers,” IEEE Sensors Journal, Vol. 3, No. 4, August 2003.

[3] E. Udd, “Fiber Optic Sensors: An introduction for Engineers and Scientists,” ed., Wiley, New York, 1991.

[4] Sait Khalil, Lulitkumor Bansal and Mahmoud, “ Intrinsic fiber optic chemical sensor for the detection of dimethyl methylphosphode” Opt. Eng. 43(11) 2683 -2688., Nov., 2004.

[5] A.Othonos and K. Kalli, Fiber Bragg gratings: fundamentals and applications in telecommunications and sensing, (Boston: Artech House, 1999), chapter 5.

[6] A.D. Kersey, T.A. Berkoff, and W. W. Morey, “Fiber-grating based strain sensor with phase sensitive detection,” Proc. SPIE, 1777, p, 61, 1992.

[7] W.W. Morey, “Distributed fiber grating sensors”, Proc. 7th Optical Fiber Sensor Conf., Iree Australia, Sydney, p. 285, 1990.

[8] J. Dakin and B. Culshaw, “Optical Fiber Sensors: Principles and Components,” Vol.1, Artech, Boston, 1988.

[9] Arthur Guenther, Leno S. Pedrotti y Chandrasekhar Roychoudhuri, "Lasers", William T. Silfvast.

[10] Maxim Thys and Eugene Desmet, (2011). Laser beams: theory, properties and applications.

