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INVESTIGATION OF THE LASER POWER ATTENUATION IN OPTICAL FIBER

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ABSTRACT

Attenuation characteristics of the power of the laser beam in the optical fiber of different lengths were investigated. Two continuous wave (CW) diode lasers of two different wavelengths, 532 nm, and 671 nm, in the visible spectral region, were used for the injection of the laser beam into the optical fiber. The output powers of both lasers can be varied over the range 0 - 50 mW. The attenuation coefficient (α) of the optical fiber was determined for the chosen wavelengths, 532 nm, and 671 nm. The attenuation coefficient (α) was measured as a function of the laser input power (Pin) and the optical fiber length. The obtained results show that the power attenuation of the laser beam is wavelength dependent. The power attenuation is significantly affected by changing the wavelength of the injected laser beam. It is observed that the increase in the laser input power (Pin) leads to an appreciable decrease in the attenuation of the laser power in the optical fiber.

Keywords: Optical Fiber, Laser Beam, Power Attenuation, Attenuation Coefficient

1. INTRODUCTION

Applications of the optical fibers have been grown enormously in many fields such as, optical communications, optical sensors, optical fiber lasers, photonic devices, computer networks, physics, medicine, biology, and engineering Mitschke (2010), Sharma et al. (2013), Senior (2014), Shi et al. (2014), Dasari (2015), Krohn et al. (2015), Dong and Samson (2017), Addanki et al. (2018), Correia et al. (2018), Ziyuan (2019), Guellar and Imani (2020), Pallarés-Aldeiturriaga et al.(2020), Haoxiang (2020), Meng et al. (2020), Tiwari et al. (2020), Agrwal (2021), Yuan and Cai (2021), Guellar (2021), Elliott (2021), Ferreira and Paul (2021), Fenta et al. (2021). The choice of optical fiber for these applications lies on its advantages such as, low cost, small size, light weight, large flexibility, high immunity to electromagnetic interference, higher bandwidth, which provides large carrying information capacity Senior (2014), Dong and Samson (2017), Addanki et al. (2018).

An optical fiber consists of three main concentric layers, a core, a cladding, and a protective outer coating, called the buffer. The core is made of glass or plastic polymer, while the cladding layer is made of a material with slightly lower refractive index (n) than the core. The difference in the indices causes the internal reflection process to occur at the interface between the core and cladding layers. The light is reflected back into the core and trapped within the core, keeping the light confined in the core and does not escape from the optical fiber. In this case, the optical fiber acts as a waveguide for the light beam Singal (2017), Guenther and Steel (2018).

Light signals suffer power attenuation (or reduction) during their propagation through the optical fibers, as a result of the light absorption, the light scattering, and the bending of the optical fiber, and other mechanisms Agrwal (2021). The attenuation or the loss of the power in the optical fiber reduces the performance of the optical fiber and consequently affecting the applications of the optical fiber systems, such as, the optical communications. Because of the high signal power attenuation in the optical fiber, scientific-technological research has been constantly developed in order to improve the properties and the performance of optical fiber Yuan and Cai (2021), Ferreira and Paul (2021). Optical fiber communication systems with a large capacity can be solved by improving the efficiency of the information transmission, raising the bandwidth of the optical fiber, and conducting research on low-loss optical fibers Elliott (2021).

Due to their unique properties, lasers were used as sources for the input signals of the optical fibers Meschede (2017), Ribeiro and Raposo (2018). To investigate the properties of the optical fiber, several experiments were carried out using different lasers with different wavelengths Agrwal (2021), Guellar (2021). The present work is limited to the range of the visible region of the electromagnetic spectrum. It is concentrated on the study of the laser power attenuation in the optical fiber, using two lasers with different wavelengths, 532 nm, and 671 nm.

In the present paper, the attenuation of the laser power in a single mode optical fiber was studied for different input laser powers, different optical fiber lengths, and two laser wavelengths.

2. EXPERIMENTAL METHOD AND MEASUREMENTS

Figure 1 shows the schematic diagram of the experimental setup used in the present work for the measurements of the attenuation of the laser power in the optical fiber.

A single mode optical fiber of different lengths, 2, 4, 6, and 8 m, was used in the experiments. Two diode lasers of different wavelengths, 532 nm (green light) and 671 nm (red light), were used for the injection of the laser beam into the optical fiber. Each laser is of a Gaussian beam and a variable output power over the range 0 - 50 mW. The output laser beam was split into two parts by the beam splitter (B.S.). The first part of the laser beam is directed toward the photodetector PD1, which was used to detect the input laser beam to the optical fiber, while the second part of the laser beam was injected into the optical fiber. The transmitted (output) laser beam from the optical fiber was detected by the photodetector PD_2. Each photodetector was connected to a power meter to measure the power of the input and the output of the laser beam.

Figure 1

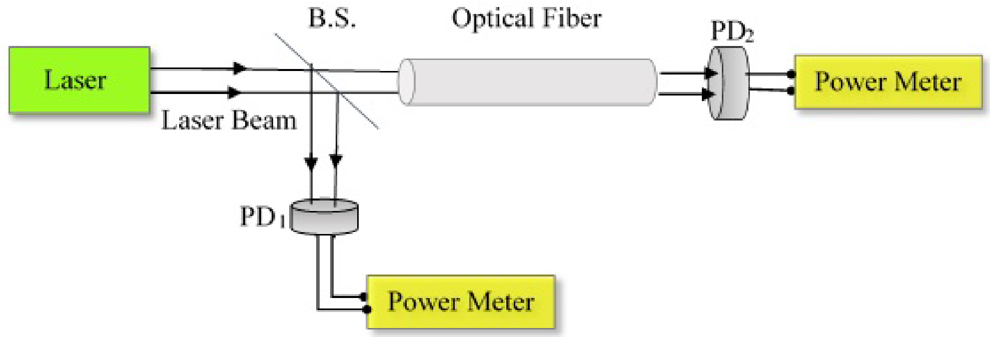

Figure 1 Schematic Diagram of the Experimental Setup for the Optical Fiber Attenuation Measurements

3. THEORY

The output power (Pout) of the laser beam, which is received at the optical fiber end, after the laser beam propagates along the optical fiber length (L), can be expressed in terms of the input power (Pin) of the laser beam, injected into the optical fiber, as follows:

$$P_{out} = P_{in}\, e^{-\alpha L} \qquad \text{Equation 1}$$

and the ratio of laser output power (P_{out}) from the optical fiber to the laser input power (P_{in}), or the laser power transmission through the optical fiber, is given by:

$$T = P_{out} / P_{in} \qquad \text{Equation 2}$$

where α is the power attenuation coefficient of the optical fiber. T is a measure of optical fiber ability to transmit optical power. Equation 1 is referred to as Beer's law Meschede (2017).

The attenuation coefficient (α) of the optical fiber is defined as the loss of the optical fiber per unit of length (L), and given by the following relation:

$$\alpha = (1 / L)\,[10 \log_{10} (P_{in} / P_{out})] \qquad \text{Equation 3}$$

The attenuation coefficient (α) of the optical fiber is usually expressed in decibels (dB) per unit length (L) of the optical fiber. The attenuation coefficient of optical fiber is one of the most significant parameters for optical fiber loss measurements.

4. RESULTS AND DISCUSSION

The attenuation coefficient (α) of the optical fiber was calculated by using the Equation 3, and then the obtained values of α were plotted as a function of the input power (P_{in}) of the laser beam, for two wavelengths, λ = 532 nm, and λ = 671 nm, as shown in Figure 2. It is seen that the value of α decreases with increasing the input power (P_{in}) of the laser beam. The obtained values of the attenuation coefficient (α) of the optical fiber using the laser beam with the wavelength 532 nm, are shown relatively larger compared to those obtained when the laser beam with the wavelength 671 nm used. This indicates that the power attenuation in the optical fiber is a wavelength dependence, and it is significantly decreased when the laser beam with the larger wavelength used.

Figure 2

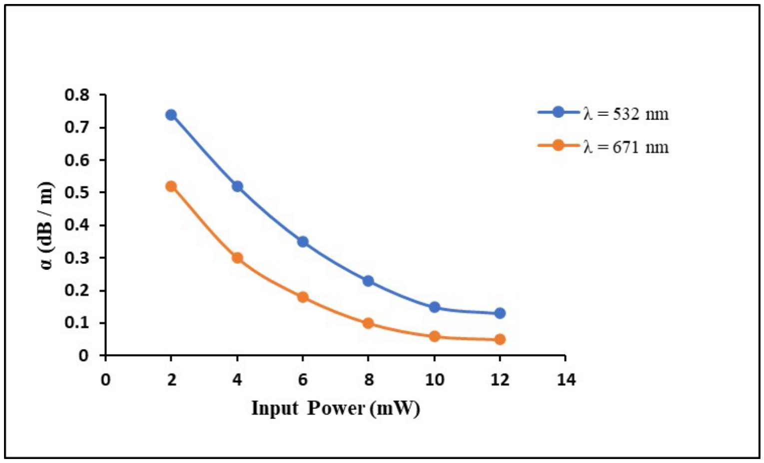

Figure 2 The Attenuation Coefficient (α) as a Function of the Laser Input Power (Pin), for two Wavelengths, 532 nm and 671 nm.

The length of the optical fiber is another factor affecting the power of the laser beam propagating through the optical fiber. The value of the attenuation coefficient (α) increases as the length of the optical fiber increases, as illustrated in Figure 3 and Figure 4. Figure 3 for the wavelength 532 nm and Figure 4 for the wavelength 671 nm. The attenuation coefficient (α) of the optical fiber was measured for two different laser input powers, 2 mW and 10 mW. It is clearly seen that the value of α decreased as the input laser power (P_{in}) increased. It is also seen that the value of α decreased when the laser of the wavelength 532 nm replaced by the laser of the wavelength 671 nm, and this is consisted with the previous findings. The attenuation of the laser power in the optical fiber decreased as the wavelength of the injected signal increased, when moving along the electromagnetic spectrum from short to long wavelengths.

Figure 3

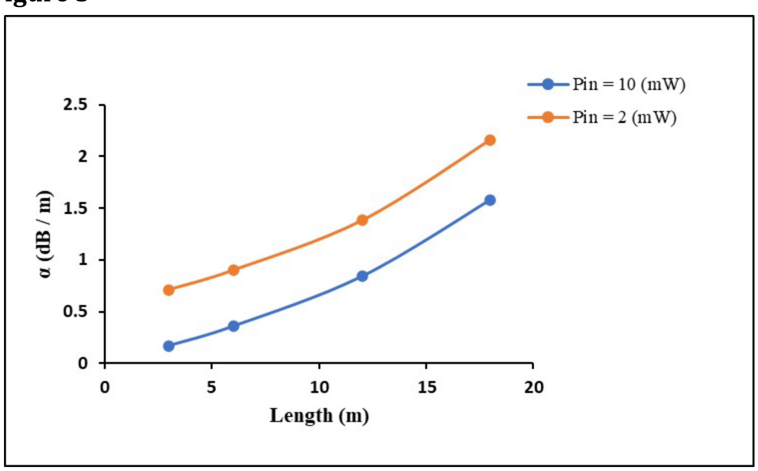

Figure 3 Variation of the Attenuation Coefficient (α) with the Optical Fiber Length, for two Values of the Laser Input Power, 2 mW and 10 mW, at the Wavelength 532 nm.

Figure 4

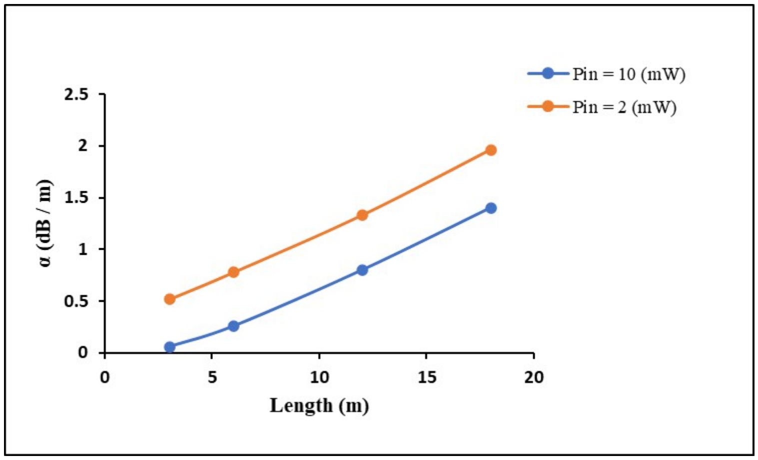

Figure 4 Variation of the Attenuation Coefficient (α) with the Optical Fiber for two Values of the Laser Input Power, 2 mW and 10 mW, at the wavelength 671 nm.

For a fixed laser input power, P_{in} = 10 mW, the output power (P_{out}) of the laser beam is plotted versus the length of the optical fiber (L), for the two wavelengths, 532 nm, and 671 nm. It is observed that the laser output power (P_{out}) decreases as the length of the optical fiber (L) increases. Replacing the laser of the wavelength 532 nm by the laser of the wavelength 671 nm leads to an increase in the laser output power (P_{out}), as shown in Figure 5.

Figure 5

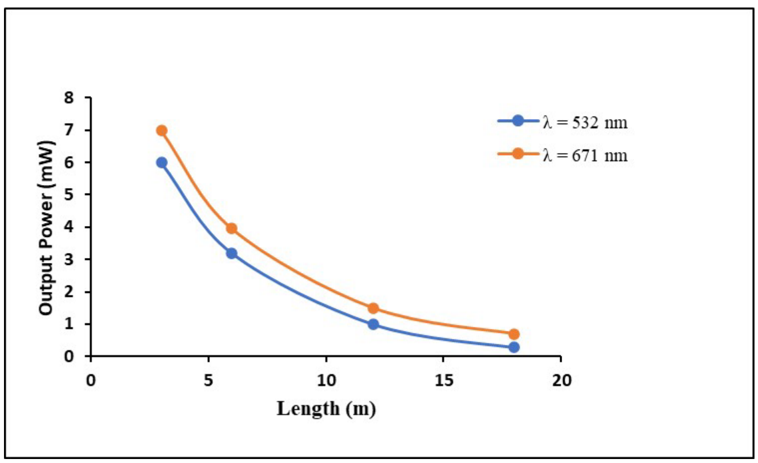

Figure 5 The Laser Output Power (Pout) Versus the Optical Fiber Length, for the two Wavelengths, 532 nm and 671 nm.

Figure 6 illustrates the relation between the output power (P_{out}) of the laser beam at the end of the optical fiber and the laser input power (P_{in}) into the optical fiber, for the two wavelengths 532 nm and 671 nm. It is obviously noticed that the laser output power (P_{out}) increases as the laser input power (P_{in}) increases. From Figure 6, it can be seen that there is a considerable increase in the output power (P_{out}) of the laser beam at the wavelength 671 nm as compared to that of the laser beam at the wavelength 532 nm, as a result of the reduction of the power attenuation for the laser beam at the wavelength 671 nm. Therefore, the longer the wavelength in the visible region, the lower the power attenuation.

Figure 6

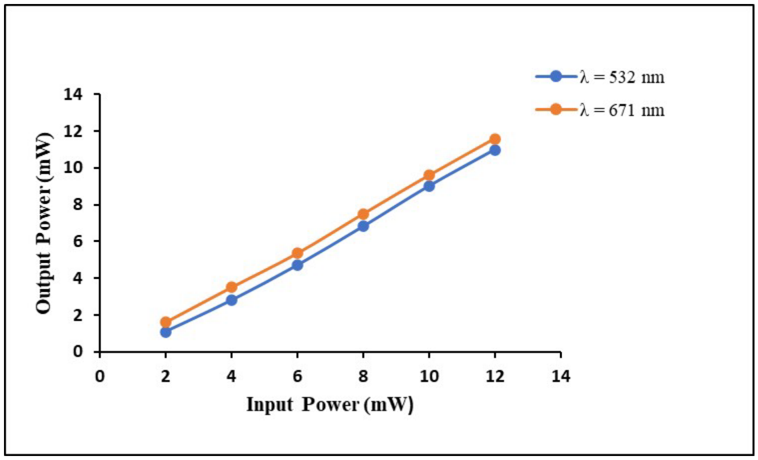

Figure 6 The Relation Between the Laser Output Power (Pout) and the Laser Input Power (Pin), for the two Wavelengths, 532 nm and 671 nm.

5. CONCLUSIONS

In this paper, we have investigated the laser power attenuation in the optical fiber. The attenuation coefficient (α) of the optical fiber is one of the most important parameters. This parameter was determined as a function of the laser input power (P_{in}) into the optical fiber, the length of the optical fiber (L), and the wavelength (λ) of the laser beam. It is found that the value of the attenuation coefficient (α) of the optical fiber is decreased with increasing the power of the injected laser beam (P_{in}). It is also found that the laser power attenuation is increased when the length (L) of the optical fiber increased. From the obtained results, it is noticed that the value of the attenuation coefficient (α) decreases with increasing the wavelength of the laser beam used. It is seen that the laser beam at the wavelength 671 nm is significantly less power attenuation compared to that of the laser beam at the wavelength 532 nm. This gives an indication that the attenuation of the laser power in the optical fiber is a wavelength dependence.

The optical fibers will continue to play a vital role in the development of the various optical applications. In order to prevent and reduce the losses of the optical fiber systems, continued research and developments on the materials composition and the fabrication process of the optical fiber are necessary for improving their performances.

CONFLICT OF INTERESTS

None.

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