

Rapid Prototyping of the Optical Fiber

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Abstract

The production of optical fibers through rapid prototyping may be useful for transmitting signals from one place to another. Combined with other factors, these parameters determine important fiber characteristics, including: attenuation as a function of wavelength, the light connection capacity, pulse spreading and transmission capacity as a function of wavelength, tolerance for splicing and connecting fiber, operating wavelength, tolerance to high temperature and environmental abuse, strength, flexibility, and cost. Models built with the stereolithography (SLA) resin and tested on the optical power meter were used to answer whether rapid prototyping could be used to transmit signal from one place to another. With the development of optical fiber through rapid prototyping for the first time and testing the same, for short distance communication a new frontier has been attempted. Different multi-mode fiber were created and tested in this project. one can come to the conclusion that rapid prototyping can be used to transmit signal. Creating and testing different multi-mode fibers, which are used for short distance communication, have proved this answer.

Keywords: Rapid Prototyping, Attenuation, Stereolithography, Optical Power Meter, Multi-mode

1. Introduction

At first glance, communication through optical fiber seems simple. Only a single fiber is needed to carry light signals between two points. However, the fundamental problem is transparency. An object is transparent when it absorbs very little light. Every material absorbs some light energy. The amount of absorption depends on the wavelength and the material. With the development of rapid prototyping technology such as the stereolithography (SLA) that uses transparent materials, optical fibers will have a great impact in communication and in the market. There are two major design variations (the single-mode fibers and the multimode fibers) for fiber optic as well as many secondary ones. Single-mode fibers are used for long distance and have a smaller core compared to multimode fibers which are also used for distance. The main focus of this paper is on multi-mode fiber.

2. Objective

The objective of this project is to determine whether or not an optical fiber built with stereolithography (SLA) resin can be used to transmit signal from one place to the other. An optical power meter was used to test the signal's strength of different fiber lengths.

3. Rapid Prototyping

Rapid prototyping is a broad term used to describe several related processes that create physical models directly from a computer aided design (CAD) database. Prototyping systems use a variety of techniques,

including stereolithography and fused deposition modeling (FDM). Rapid prototyping is used to create prototypes for concept modeling, injection molds, and investment casting.

3.1. stereolithography

Stereolithography, also known as SLA, is a three-dimensional fabrication process that builds a solid object from a computer image by using a computer-controlled laser to draw the shape of the object onto the surface of liquid resin, one layer at a time. The SLA used a UV-laser to cure the material layer by layer.



Figure 1: SLA Machine [1]

4. Optical Fiber

Optical fibers are flexible optically transparent fibers usually made of glass or plastic, through which light can be transmitted by successive internal reflections. This device is usually used to transmit signals from one place to the other. All optical fibers share the same fundamental structure. The center of the fiber is the core, which has a higher refractive index (1%) than the cladding that surrounds it. The difference in refractive index causes total internal reflection that guides light along the core.

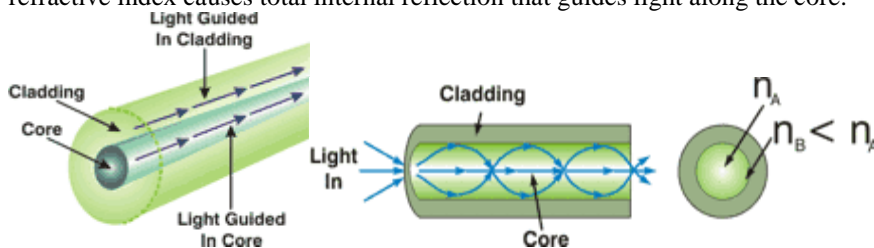


Figure 3: Fiber Characteristics[2]

4.1. optical fiber system

The optical fiber system consists of a transmitter, which transforms an electrical signal to be transmitted as optical signal to a receiver which then converts the optical signal back to the original electrical form, and a fiber transmission line which conduct the optical signal from the transmitter to the receiver.

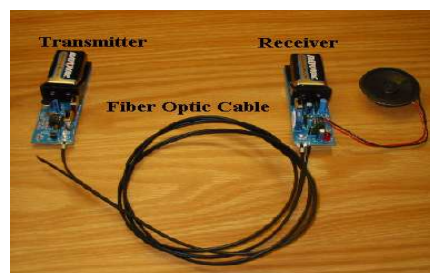


Figure 2: Optical Fiber Kit

4.2. plastic optical fiber

Glass fibers are extremely transparent because they absorb very little light at the wavelength that are used for communication but this is not true for plastic fiber. The bonds between atoms commonly found in plastic notably carbon hydrogen and carbon oxygen, absorb light in the visible and near infrared wavelengths.

4.2.1. attenuation

Attenuation or loss is the reduction of signal magnitude is normally measured in decibels. Fiber attenuation is normally measured per unit length in decibels per kilometer [3]. Attenuation can be categorized as either intrinsic or extrinsic. Substances inherently present in the fiber cause intrinsic attenuation whereas extrinsic attenuation is caused by external factors such as bending [4].

5. Testing

Several types fibers (7.62cm in diameter and 91.44cm, 76.2cm, 60.96cm, 45.72cm, 30.48cm, 15.24cm in length) were made to test the attenuation of different length. These models were built by injecting the SLA resin (Accura 10) into intravenous (IV) tubes by using a syringethen curing the resin with UV radiation. These models were tested with optical power meter to measure the power coming out of the end of the fibers.

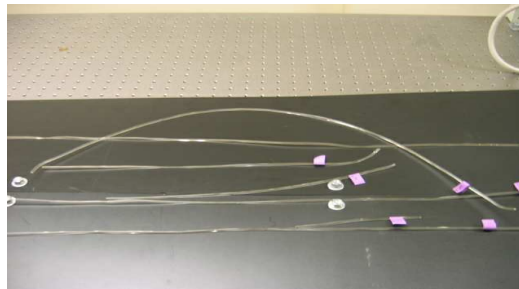


Figure 4: Fiber Models

6. Optical Power Meter

An optical power meter is an optical testing device designed to measure the amount of optical power of a continuous light beam [5]. The optical power meter has to be set to 650nm for it to measure the optical power coming out from the fiber since the optical fiber emits a red light.



Figure 5: Power Meter

7. Optical sensor

An optical sensor is an electronic device that responds to a physical stimulus such as light (e.g. an optical power) and converts it into an electronic signal of some kind [6]. Figure 6 shows the light coming out from the fiber to the optical sensor which transmits the light signal to the optical power meter. The optical fiber has to be placed at the center of the optical sensor to get a good power measurement.

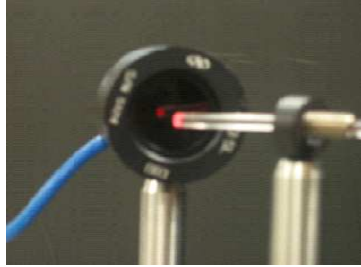


Figure 6: Light Reflection

8. Power Measurement

Figure 7 shows the testing setup used to measure the optical power coming out of the optical fiber. A transmitter, which transforms an electrical signal to be, transmitted an optical signal to an optical sensor. The optical sensor converted it back to the original electrical form to be measured by the optical power meter. The fiber transmission line to the optical sensor conducted this optical signal coming from the transmitter. These tests are usually made in a dark room otherwise; the optical sensor has to be covered so that the room light won't affect the signal power measurement.



Figure 7: Setup

Table 1

Length Cm	Pwo 1 μ W	Pwo 2 μ W	Pwo 3 μ W	Pwo 4 μ W	Avg Pwo μ W	Attenuation dB = $10\log(PWo/PWin)$
91.44	.0380	.0400	.0417	.0398	.0399	-35.57
76.2	.263	.261	.251	.256	.259	-27.45
60.96	1.30	1.27	1.26	1.26	1.27	-20.54
45.72	3.38	3.37	3.38	3.38	3.38	-16.29
30.48	13.60	13.70	13.81	13.77	13.72	-10.20
15.24	47.00	47.65	45.30	44.93	46.22	-4.93
PWin	141.13	144.00	151.57	138.62	143.83	

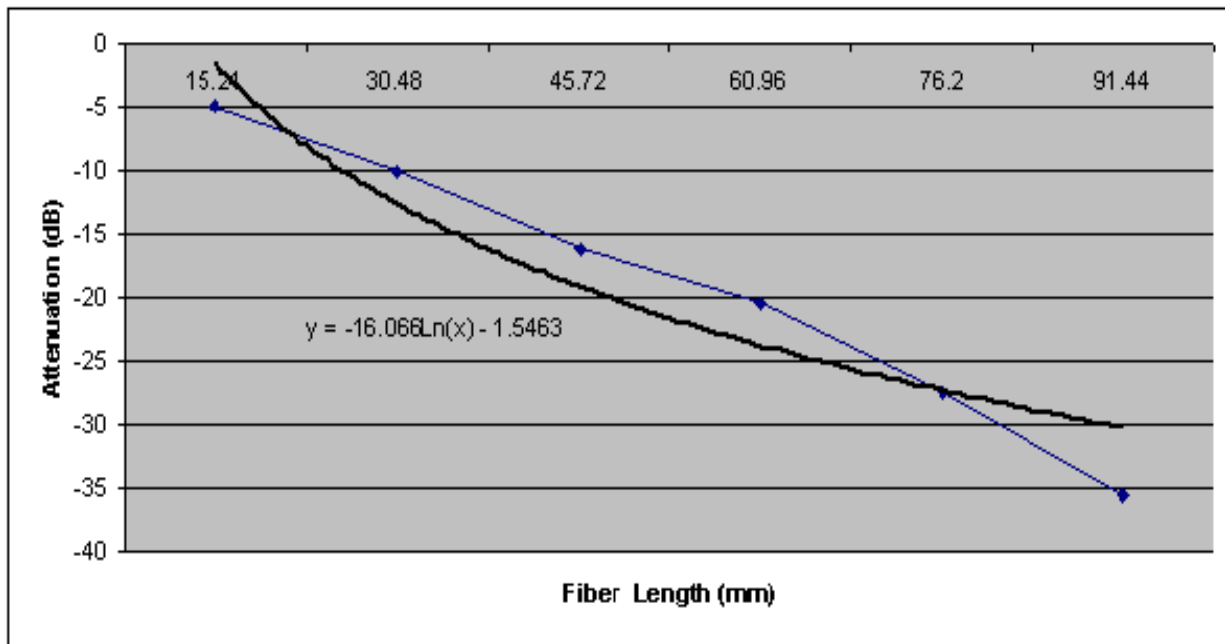


Figure 8: Attenuation vs Fiber Length

9. Discussion

Figure 7 shows the set up used to determine the amount of optical power present at the end of a fiber or power out (P_{W_o}). The input power signal ($P_{W_{in}}$) was determined by placing the light emitting diode (LED) from the transmitter very close to the center of the optical sensor, which transmitted the light signal to the optical power meter. The optical power meter then measured the actual input power of the fiber signal. This process was determined without using any optical fiber. An optical fiber was applied to measure the average optical power coming out at the end of it. This process was made several times with different fiber lengths. This process has been used to figure out the signal loss between the input signal and the output signal of each fiber. Because of different impurities from the fiber such as bubbles, transparency and microbending (imperfections in the cylindrical geometry) the attenuation per unit length may vary so and the attenuation vs. fiber length had more distortion points than expected. To prevent that that to happen a 91.44cm optical fiber was made to measure the attenuation. A length of 15.24cm has been cut from the fiber to measure the attenuation of the remaining fiber; this process was repeated six times. Table 1 shows the collected data of this process. From this table it can be noticed that the cutting of the fiber decreased the attenuation. Graph 1 displays attenuation as a function of fiber length. The black curve in the graph represents how the relationship would have looked like if there were no variations/length or distortion.

10. Conclusion

Initial testing shows that the optical fiber built with SLA resin can be used to transmit optical signals. Different procedures were used to increase the signal strength. A brush on electrical tape was applied to the optical fiber models to allow total internal reflection, but that did not work since this dark material absorbed light more than the transparent material. Therefore, when the light wave hit the material, the material absorbed the light instead of reflecting it back to the core. Since the core of the fiber has to have a greater refractive index than the cladding, the test was completed by removing the IV tube using the air as the cladding since the refractive index of air is 1. The results turned out to be better. The measured loss through the SLA resin is approximately 36 dB/m. This is the **first time** optical attenuation has been measured in the SLA resin (Acura 10). The loss of optical signals in the fiber are due to impurities,

bubbles, and microbending of the fiber . More research is needed to decrease the attenuation of these created fibers.

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