Study and implementation of effects of temperature, humidity and radiation on optical Fiber

Dr. Alaa A. Abdul-Hamead, Dr. Salah Aldeen Adnan Taha
Material Eng. Dept. , Laser & optoelectronics Eng. Dept.
University of Technology/IRAQ
aDr.alaa@yahoo.com , Salahadnan9999@yahoo.com

Abstract

In this paper there are two types of optical fiber has been used, the glass and plastic optical fiber(GOF , POF). with a length of (5 m) for each one to study the attenuation, by exposing them to the Iraqi weather conditions of temperature , humidity and radiation in the weathering acceleration system device.

These effects conditions were studied on the property of attenuation in the signal of power. In addition to the effect of these factors on the structure of the outer cover of the optical fiber.

The results shows that the higher temperature caused the appearance of cracks and external stresses on the outer surface of the optical fiber, This leads to increase the value of attenuation in the receiving signal of optical fiber and that the amount of this attenuation is the largest in the (POF) plastic optical fiber compared to (GOF) glass optical fiber.

Keyword: attenuation, Plastic optical fiber, glass optical fiber ,harsh weathering, SEM.

1. Introduction

Every day millions of optical fibers are developing communications in the industry. This science that deals with the transmission of light through extremely thin fibers of glass, plastic, or other transparent material. Optical fiber has a number of advantages over the copper wire used to make connections electrically. Optical fiber is immuned to electromagnetic interference, such as is caused by thunderstorms [1].Applications of optical fiber miscellaneous in Ordinary telecommunication cables ,Military , computers, railways, fire-retardant and heat-resisting wires oil fields, and oil factory, etc..[2].

Losses in the intensity of light as it propagates within the fiber is called "attenuation", There are four types of scattering loss for optical fibers Rayleigh scattering , Mie scattering • , Brillouin scattering, Raman scattering . Comparing to Rayleigh scattering, and the other three types of scattering loss is smaller, 1/100 of the Rayleigh scattering loss. So the Rayleigh scattering loss will be mainly discussed here. Rayleigh scattering accounts for the majority (about 96%) of attenuation in optical fiber [3].

Brillouin scattering depends on physical parameters of material such as, density, refractive index, longitudinal elasto-optic coefficient among others [4,5].

Loss of optical fiberglass (or sometimes plastic) can be caused by many factors, such as absorption of metal impurities, absorption of hydroxyl group , ultraviolet absorption and infrared absorption, scattering loss and bending loss both(Macro and Micro bending)[6,7,8].

Researches in this field are various. S.T. Kreger and others ,[9] study scatter in single- and multi-mode fused silica fibers to deduce strain and temperature shifts, yielding sensitivity and resolution similar to that obtained using plastic Fiber .C. Yan and others [10] ,studied radiation damage to polymer optical fiber the effects of radiation on mechanical strength and power transmission of polymer optical fibers were investigated . AEN[11] studied optical cables for shallow water applications ,the cable design here is for short-length for shallow water applications limited to water depths of no more than 300 feet. Those cables employ a special hermetically sealed copper tube to protect the fibers from the effects of deep-water environments. External physical forces and effects of hydrogen on the performance of the optical fiber in cables are used in such applications. Hydrogen can chemically react with dopants such as phosphorus to produce irreversible absorption peaks, resulting in a significant increase in the attenuation coefficient across various wavelength ranges. C. A. Galindez and Others[12] studied effect of humidity on optical fiber distributed sensor based on Brillouin scattering measure effect of temperature along an optical fiber , and the humidity on the fiber; therefore its effect must be minimized at 25C^o are reported. T. Ishigure and others[13] studied graded-index plastic optical fiber with high mechanical properties enabling easy network installations. Although the POF is generally believed to have a good mechanical flexibility even if it has a large-core diameter, such a high mechanical strength has been provided by making the polymer chains in the POF highly oriented in its axial direction .If such an orientation of polymer chains is eliminated, the POF becomes brittle, which is similar to silica-based fibers. R. J.Curry and others [14] studied the environmental effects on the attenuation of chalcogenide optical fiber they found that The attenuation of a number of chalcogenide glass optical fibers has been studied with regard to their exposure the environment. They demonstrated that gallium lanthanum sulphide (Ga:La:S) based glasses appear to be as resilient if not more so than arsenic sulphide (As_2S_3) glass to the attack of moisture when stored uncoated in ambient conditions for various periods exceeding 1 year. The increase in the characteristic OH- attenuation peak was (~3-4 dB/m) for all fibers following storage. The main purpose of this research is to study the effect of different conditions on the properties of multi-mode optical fiber, such as temperature ,humidity as well as radiation on the attenuation property of fiber in addition to the structural properties before and after exposure to the weather condition .

2. Experimental Part

Preparation of optical fibers: Multi mode glass and plastic optical fiber (GOF,POF) (5m) , YCT power-meter (850 nm) wavelength was used as power source and meter,(ST Type)connector was used.The glass and plastic optical fiber was cutting to small samples of of (3 cm) length to be used in optical microscopy test as it is shown in figure (1). Optical microscopy type PERMABLE, is also testing the samples with SEI electric device type 25e sumitomo .The microstructure of fiber is also tested with VEGA scanning electron microscopy from TESCAN. Exposing the fibers and the test samples to the weather conditions using a weathering instrument type QUV (Accelerated Weathering Tester). at the end, re-measuring all the tests after exposure, and conduct evaluation .
All fibers and fiber samples were kept in a temperature ,humidity and radiation controlled chamber, This conditions are shown in table (2).

Table (1) description of optical fiber

Nominal spectrum (nm)	Fiber Type Multimode (MM)	Fiber Size (µm)
850 ± 30 (short wavelength)	GOF	62.5/125
1550 ± 30 (extra-long wavelength)	POF	62.5/125

Figure(1) OF test samples

Figure(2)Accelerated weathering tester

Table (2) Weather condition of optical fiber

time hr	Cº	R%	RH%
1	0	0%	0
5	30	10%	20
10	40	50%	40
50	50	100%	60

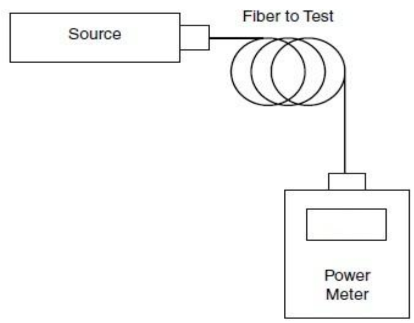


Figure 3 Fiber attenuation test

2. Result and Discussion

OPTICAL MICROSCOPY RESULTS: Figure (4) shows the outer polymer jacket surface of optical fiber casing before and after exposure to the weather conditions. in (a) it appears homogeneity and the absence of any defects, while in (b) the surface is under microscopy after exposure to all weather conditions effect ,it can be seen that grooves or cracks were accurate on the outer surface because its exposure to various harsh weather factors of temperature and humidity, radiation and its interaction with these conditions, and therefore the imprint of that interaction reflected in attenuation and property that are points of the focus of interest in the research, which will consider the following paragraph . This effect attention in this destruction is observed[15].

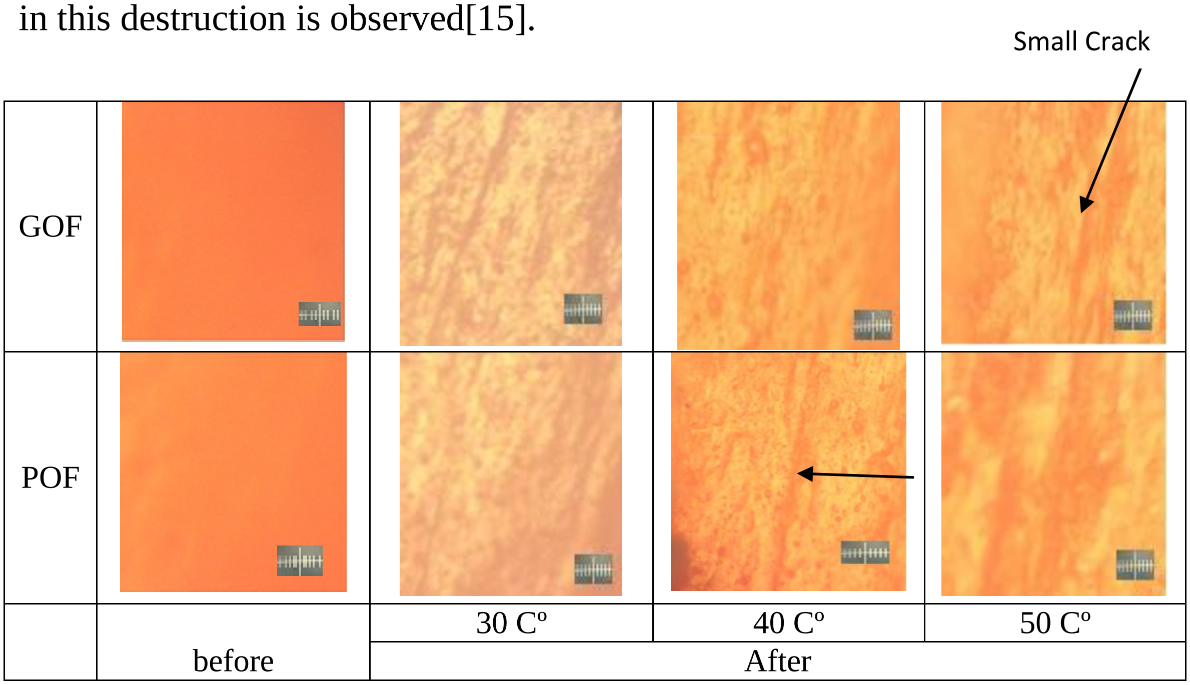
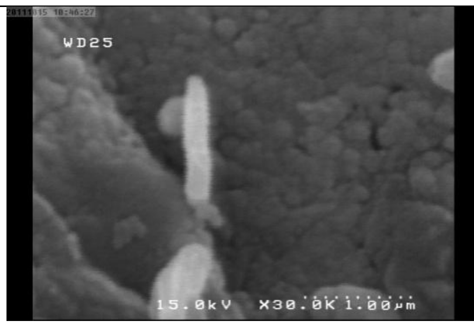


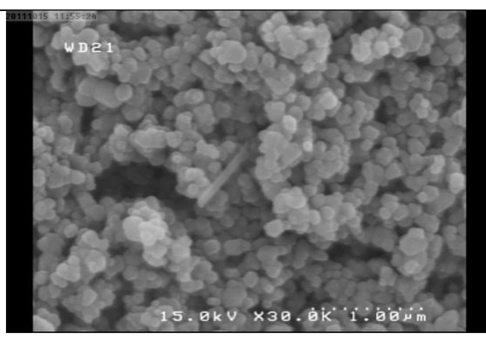
Figure (4) The jacket surface of Optical fiber before and after exposure at different conditions X50

The surface of Optical fiber before and after exposure at different conditions are shows in figure (5), the surface and the core of suffer change severe because of the heat and other conditions . In (a) a GOF have a conspecific structure seem to have a small regular growth because of invariant against weather vicissitudes as it can seen in (b). In (c) POF has a fine structure mutating in (d) confront irregular grow . So a physical stress on fiber, Core-cladding interface, irregularities diameter variations will take place , making GOF even at shorter distances more proper for weather vicissitudes deserts continental .

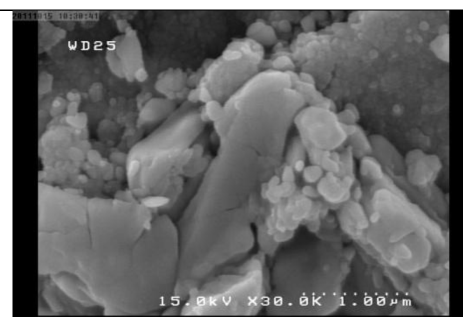


(a) GOF before

(b) GOF after



(c) POF before



(d) POF after

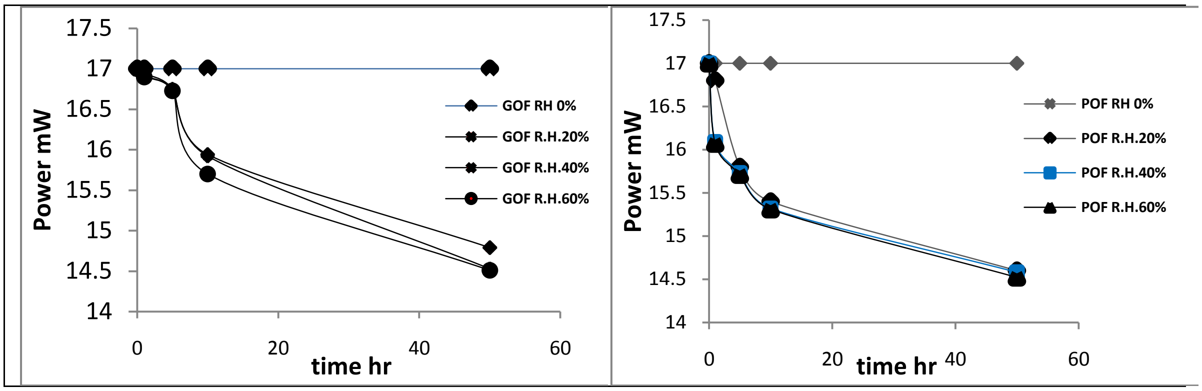
Figure (5) The surface of Optical fiber before and after exposure at different conditions

POWER RESULTS :

Figure (6) shows the relation between time of exposure to different humidity values(0 ,20,40,60 %) and received power. It shows that, as the exposure time increases, the received power value decreases. Dropping in value because of the stress attenuation . Assuming that some dissociation of an adsorbed water layer occurs, it may consider the following equilibrium:

$$H2O \leftrightarrow H^{+} + OH^{-} \qquad (1)$$

The OH^- effect on optical fiber. As a result, light traveling in the core dispersion, and loss occurs. This humidity effect in POF is more than in GOF glass optical fiber, the effect of humidity is agreed with [12] and [17].

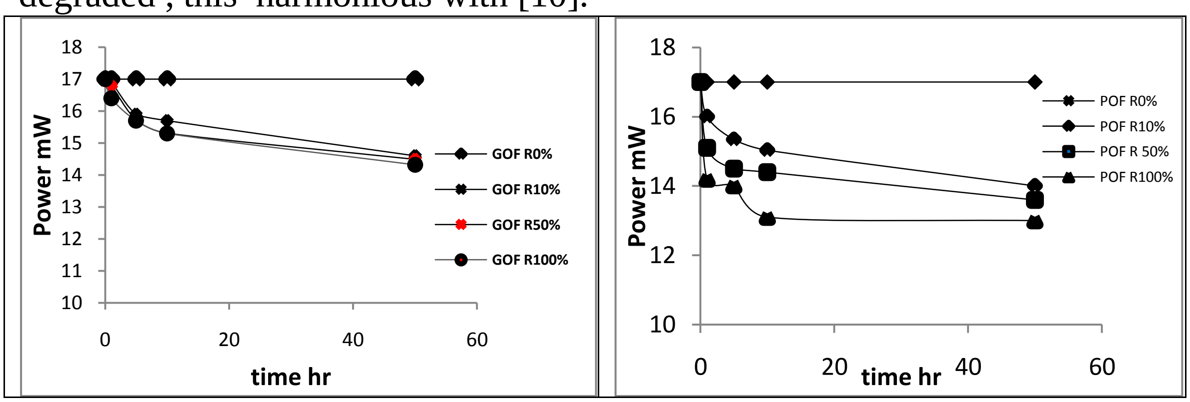


(a) GOF (b)POF

Figure (6) Effect of R.H. Relative Humidity on (a) G.O.F & (b)P.O.F

Figure(7) shows the relation between exposure time and received power value obtained for glass and plastic optical fiber at different irradiation values(0,10,50,100%) from source lamp ;maximum irradiance (1.55 W/m^2 at 340 nm).

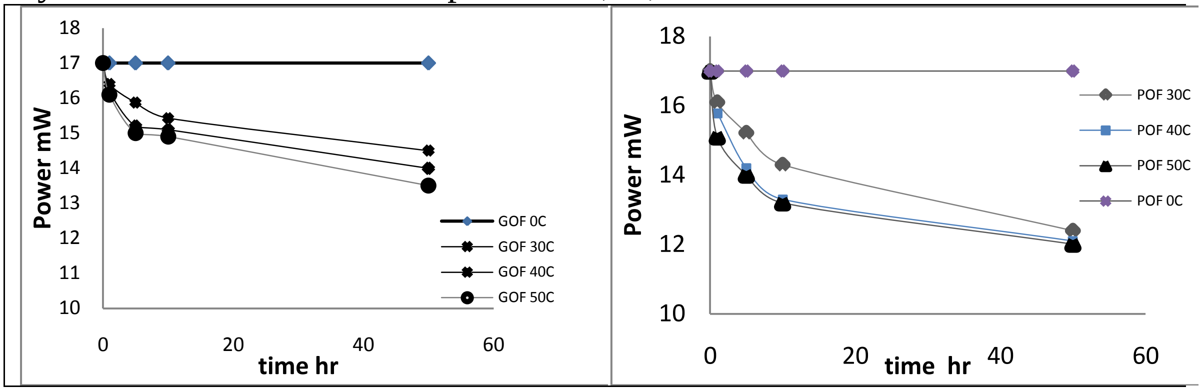
The effect of increase in radiation percentage for plastic optical fiber compared with a fewer effect on glass optical fiber. This is due to the detrimental influence of the irradiation on the fibers represented by degraded , this harmonious with [10].



(a)GOF (b)POF

Figure (7) Effect of irradiation on G.O.F& P.O.F

While figure(8) illustrates the effect of heat temperature on received power values which has the major effect in compared with the above figures (humidity & radiation). It shows the major effect on (b) plastic optical fiber is more than on (a) glass optical fiber, because of the effect of heat is more obvious on polymeric. And arrived the minimum value at about (12 mW), by the harmful effect of temperature[9,14,15] .



(a)GOF (b)POF

Figure (5) Effect of Heat on G.O.F & P.O.F

Attenuation Results: Beer's Law shows that transmitted power decreases exponentially with propagation distance through the fiber[1]:

$$P(x) = P(0)\, e^{-\alpha x} \qquad (2)$$

Input optical power, P(0) = 17mW, min. output power P(x) , light propagates distance, x, the result of POF and GOF without bending is shown in table (3) below by taking min. output powr.

Table (3) Attenuation Results

Factor	α (dB/km)	
	P.O.F	G.O.F
Heat	1.8	0.9
Radiation	0.35	0.2
Relative Humidity	0.12	0.1

4. Conclusion

We have shown results which question the stability of GOF in high temperature , radiation and humidity conditions. and have attributed this stability to the diffusion of the surrounding medium constituents into the glass core. This has great implications for the use any optical fiber sensors, especially in harsh conditions such as weather vicissitudes deserts continental.

5. References

[1] C. Lo ,Optical Fibers Manufacturing Techniques to Ensure Low Losses, Ph.D. Thesis , San Jose State University, 2003.
[2] http://www.mse.cornell.edu/courses/engri111/op-fiber.htm.
[3] Murata, Hiroshi, *Handbook of optical fibers and cables*, 1988.
[4] Boyd, R.W., Non linear Optics. Second ed. 2003, USA: Academic Press; Elsevier Science.
[5] K. Hotate, T. Hasegawa, “Measurement of Brillouin gain spectrum distribution along an optical fiber using a correlation based technique-proposal, experiment and simulation”, IEICE Trans. Electron E83 (3), 8, 2002.
[6] Robert G. Seippel, *Fiber Optics*, 1984.
[7] J.C. Baggett, T. M. Monro, K Furusawa, V Finazzi, D.J. Richardson, “Understanding the bending losses in holey optical fibers”, Optical communications, 227（2003）.
[8] K. Y., T. S., N.E., T.Y., H.H, and M.O, “Fabrication of low-loss optical fibers by hybridized process”, Electronics and communications in Japan, Part 2, 80, No. 2,（1997).
[9] S. T. Kreger, Alex K. Sang, Dawn K. Gifford, Mark E. Froggatt, Distributed strain and temperature sensing in plastic optical fiber using Rayleigh scatter, Fiber Optic Sensors and Applications, Vol. 7316 73160A-1(2009).
[10] C. Yan, S.H. Law2, N. Suchowerska3,4 and S.H. Hong5 Radiation damage to polymer optical fibres, ACAM, 2007 ,vol.10.
[11] AEN2, Optical Cables for Shallow Water Applications, Applications Engineering Note, 2002.
[12] C. A. Galindez, F. J. Madruga, M. Lomer, A. Cobo ,Effect of humidity on optical fiber distributed sensor based on Scattering, Proc. of SPIE Vol. 7004 70044W-1.
[13] T. Ishigure, Miki H., M. Sato& Y. Koike1, Graded-Index Plastic Optical Fiber with High Mechanical Properties Enabling Easy Network Installations, J. of App. Polymer Science, Vol. 91, 404–409 (2004).
[14] R. J. Curry, S. W. Birtwell, A.K. Mairaj, X. Feng, and D.W. Hewak , A Study of Environmental Effects on the Attenuation of Chalcogenide Optical fibre, Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK.
[15] B. Arvidsson, V. Cindro, B. T. Huffman, C. Issever, P. K. Teng, A. R. Weidberg & J. A. Wilson, A study of the effect of radiation on the mechanical strength of optical fibers, J.l of Instrumentation Vol. 8 ,2013.
[16] Girard, S. Kuhnhenn, J. Gusarov, A. Brichard, B. V. Uffelen, M. Ouerdane, Y. Boukenter, A. Marcandella, C.Radiation, Effects on Silica-Based Optical Fibers: Recent Advances and Future Challenges, Nuclear Science, IEEE Transactions on (Volume:60 , Issue: 3), June 2013.
[17] J. L. Armstrong, M. J. Matthewson & C. R. Kurkjian, Humidity Dependence of the Fatigue of High-Strength Fused Silica Optical Fibers, *J. Am. Ceram. Soc.*, 83 [12] 3100–108 (2000).