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Tapered Optical Fiber by Chemical Etching

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Abstract: ***Recently, Micro- Nano optical fibers have big interest in different fields especially sensing one due to their tremendous features. In this work chemical etching using hydrofluoric acid method have been used to reduce the diameter of single mode fibers and multimode fibers to several microns diameter 21.1 µm and 57.5 µm respectively.***

Keywords: Optical fiber, optical fiber sensors, optical fiber tapered, Chemical etching

1. Introduction

Optical fiber is a dielectric cylindrical shaped that works as a waveguide. It can be fabricated from low-loss materials like silica glass or plastic (polymer). It contain a core in the center which guide the light that emitted inside it with an outer low refractive cladding with a layer of protective coating to protects the fiber from dust and scratches and any outside effect. The incident light rays inside the core will undergo a total internal reflection through it without refraction at an angle that is greater than the critical angle[1].As shown in Figure (1).

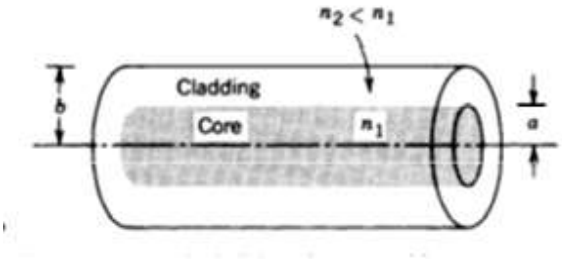


Figure 1: Optical fiber construction

Optical fiber can used in many applications such as medicine as an bio-medical sensor , communication networking system, etc.[2]. The features of the optical fiber can be boost by tapering method like: its sensitivity in the sensing usage. This method can be a way to access the fragile field in the optical fibers enabling to a strong interaction with analytic. It can be produced into two ways etching by chemicals or heat-pulling[3]. The heating it can be achieved with electric ARC, flames or high power laser as an outcome to this procedure, the structure of the core and cladding and interface are kept acting as a light guidance through a core, cladding and air structure[4]. The laser tapering assisting can create an excellent taper;tapers also can be manufactured by chemical etching[5]. The difference among the heat-pulled tapers and the chemically etched tapers it's in the index profile of the fabricated tapers and the tapers may have various optical characteristics[6]. The heat-pulled make a large index contrast in the strong confinement that can be reached its maximum in visible or near infrared range at a nanoscale dimension of waveguide. In the other hand the index reduced when the core is eliminating in the waist region through the chemical etching acting as a light guidance in the waist through the core and air structure, thus, the chemically etched fiber tapers are further used in fluorescence measurements.[7][8].As shown in the Figure (2)

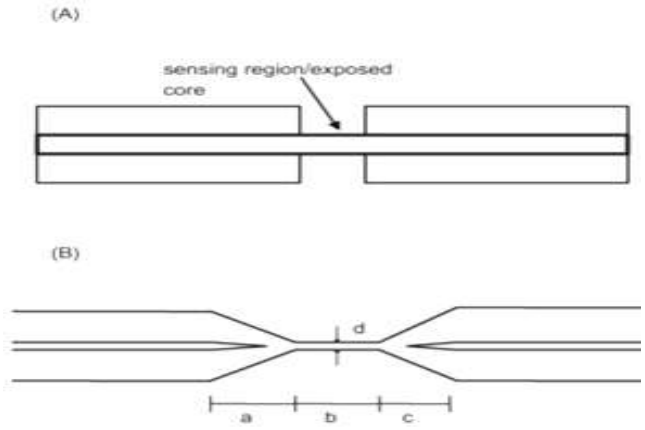


Figure (2): (A) De-cladded optical fiber. (B) Tapered optical fiber.

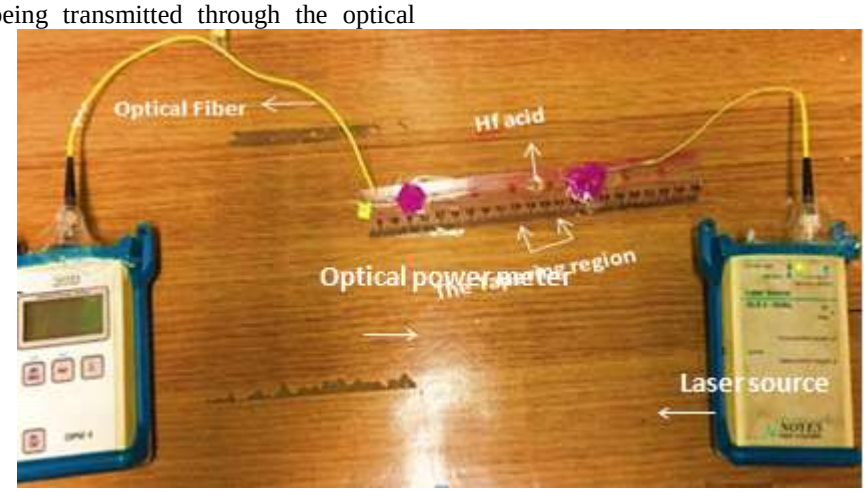
The fluorescence can be defined as the emission of light by substance that has absorbed light or other electromagnetic radiation in the form of luminescence [9]. The process of fluorescence consists of photon absorption by a molecule to go to an excited singlet state, relaxation from higher vibrational levels of that state to its lowest vibrational level, photon emission to a vibrational exited level of the ground state, and again relaxation of the molecule to the lowest vibrational level of the ground state [10].

2. Experimental Work

The optical fiber used in this work is glass optical fiber with refractive index~1.45. Two types of optical fiber have been used the single-mode with diameter of (125.3µm) and multi-mode with diameter (125.5µm).The first step of the work is the preparation of the fiber by using scissors that is specially made for optics fibers called (the Distributor,Type:Pro'skit8PK-326). To make sure the core of the fiber is completely clean by using ethanol alcohol concentration 96% and pouring amount on the core fiber for 15min.

The set-up of this work done on a plastic ruler because the HF acid interact with glass and iron with a Laser source (OLS 2-DUAL, At λ=1550nm) and the other end with optical power meter (NOYES, At λ=1550nm), By placing

the prepared optical fiber on the ruler .The next step is the optical fiber tapering by using 40% Hf acid (1:2, HF:H_2Odistilled water) pouring amount of the acid with plastic needle on the wanted area of the fiber core. The output power, that being transmitted through the optical fiber, can be determined by the monitor every 5 min for 90min.It depends on the amount of the reduced core diameter causing the loss in transmission of the input signal, as shown in the figure (3).



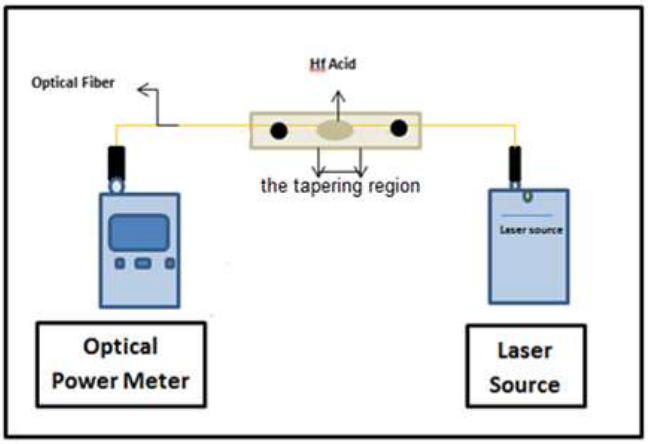


Figure 3: The Tapering Process.

To stop the tapering process by removing the acid and placing the optical fiber inside distilled water 15min and changing the water for 3 times. The next step is to measure the tapered core diameter by using microscope and it was found (21.1µm) for the single-mode fiber and for the multi-mode fiber it was established (57.5µm), as shown in the figure (4).

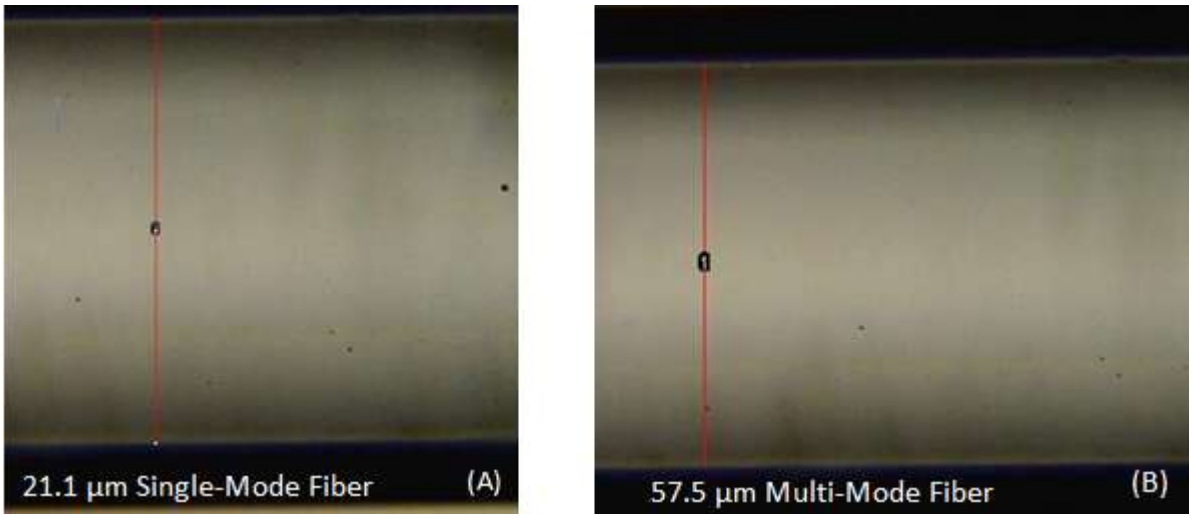


Figure (4): (A) The Tapered Core Diameter for the Single-Mode Fiber, (B) The Tapered Core Diameter for the Multi-Mode Fiber.

The next set-up shows the measurement of the tapered fiber`s fluorescence, As shown in the Figure (5), by connecting the end of the fiber with the spectrophotometer and the other end to source of laser light (Helium neon, λ=632nm).

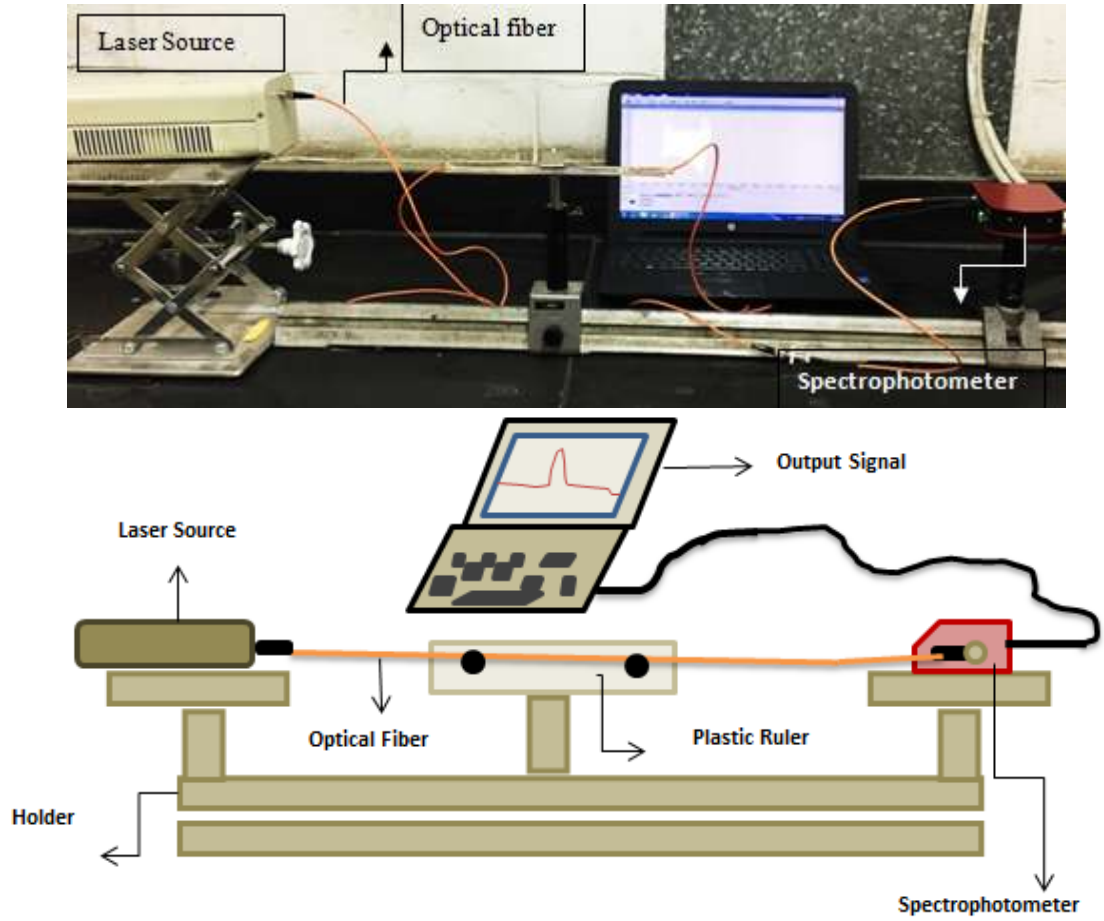


Figure 5: Measuring the Fluorescence

3. The result, Discussion and Conclusion

Optical tapered fibers can be manufactured by chemical technique that`s a simple and a low cost method by using Hf acid (40%, 1:2, Hf:H_2 Odistilled-water)to remove fiber cladding to decrease its diameter. Two methods were used in this work, the first one by using laser source and optical power meter to measure the output power transmitted through the tapered fiber. Fig.(6) shows the results of decreasing and loss in the output power with increasing of time, due to the interacting the (Hf) acid with the glass core causing the decreasing in the diameter, as shown in Figure (6).

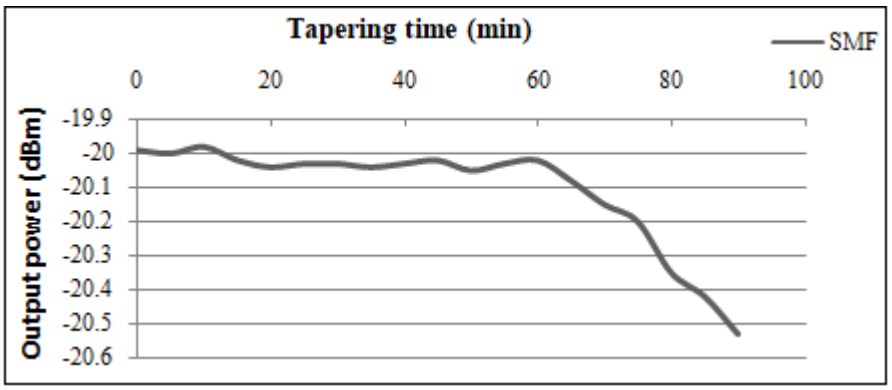


Figure (6) (A): Single-Mode Fiber Output Power (dBm) with Tapering time (min).

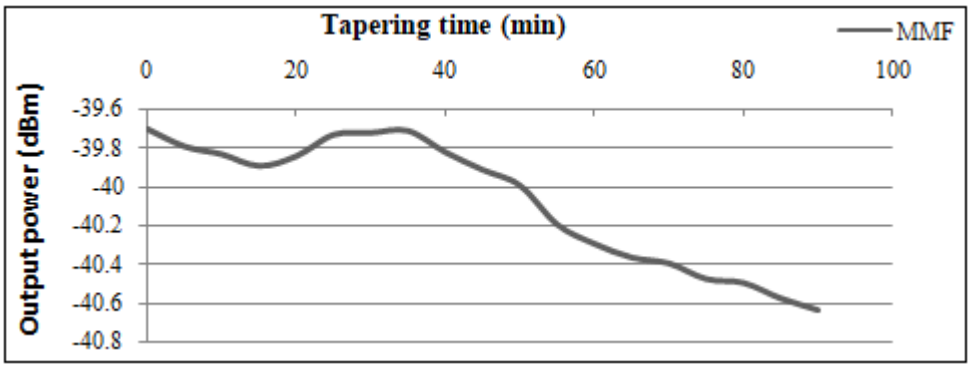


Figure (6) (B): Multi-Mode Fiber Output Power (dBm) with Tapering Time (min).

The second measurement is the fluorescence for the single-mode and multi-mode optical fiber by using spectrophotometer, to show the difference between them before and after the tapering process.as shown in the Figure (7).

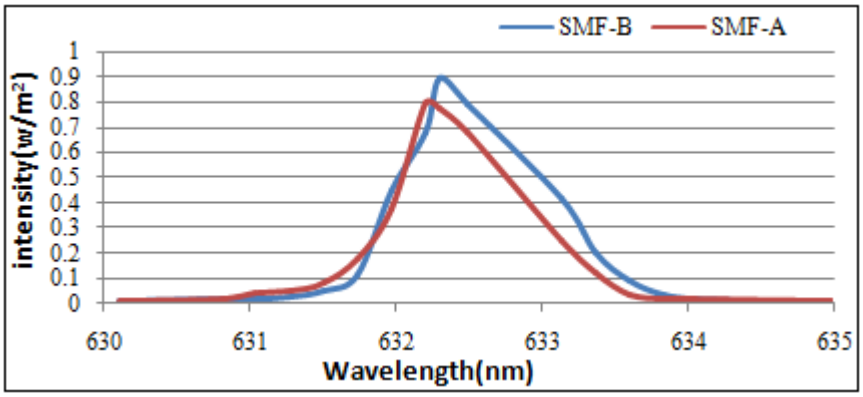


Figure (7) (A): The Intensity (Blue) SMF before Tapering (intensity=0.8968, wavelength=632.3005). (Red) SMF after Tapering (intensity=0.7968, wavelength=632.2030).

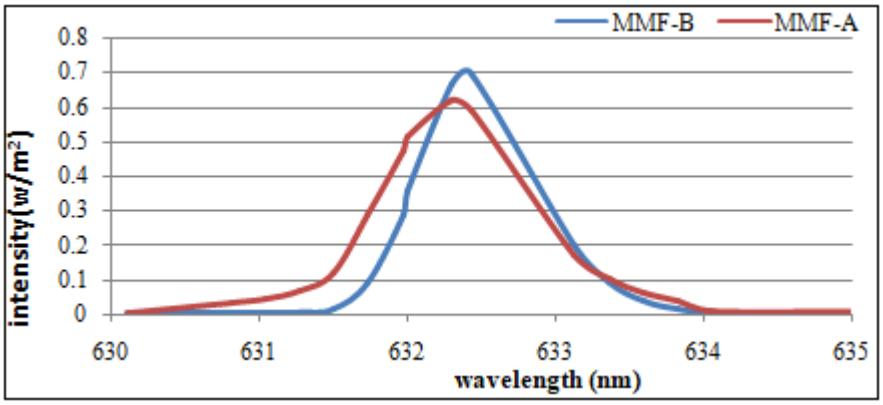


Figure (7) (B): The Intensity (Blue) MMF before Tapering (intensity=0.6958, wavelength=632.4366). (Red) MMF after Tapering (intensity=0.6199, wavelength=632.3005).

4. Conclusion

The core diameter of the optical fibers decreases with the increasing of time during the tapering process, due to the interacting of the Hf aid with core leading to its corrosion.

The Output power for the tapered optical fibers decrease with the loss in the transmission inside the fiber with the increasing tapering time due to the changes in the core diameter causing a less transmitted input single through the tapered optical fiber.

The change in the fluorescence's intensity between the two types of optical fiber single and multi–mode fibers due to their principle in transmitting the input signal , the single mode fiber only one mode can propagate through the core fiber ,it has a smaller core diameter than the Multi-mode fiber , and the difference between the refractive index of core and cladding is very small comparing to the multi-mode fiber and there is no dispersion i.e. no degradation of signal during travelling through the fiber .the multi-mode allows large number of modes for light rays travelled through it , it has a larger core diameter than the SMF, the relative refractive index is larger than the SMF, and there is signal

degradation due to multimode dispersion. These differences causing the changes in the input light rays of the laser.

References

[1] J. C. Dale, Fiber Optics, CRC Press, Boca Raton, FL, 1984.
[2] I. Chabay, Optical Waveguides, Anal. Chem. 5l, 1071A (1982).
[3] H. Latifi, M. I. ZibaII1, S. M. Hosseini and P. Jorge, "Nonadiabatic TaperedOptical Fiber for Biosensor Applications," Photonic Sensors 2, 340-356,(2012).
[4] W. J. Stewart and J. D. Love, "Design limitation on tapers and couplers in single mode fiber tapers," in Proc. ECOC 85, Venice, Oct. 1–4, 559–562, (1985).
[5] S. Pricking and H. Giessen, "Tapering fibers with complex shape," Optics Express 18, 3426–3437, (2010).
[6] E. J. Zhang, W. D. Sacher and J. K. Poon, "Hydrofluoric acid flow etching of low-loss subwavelength-diameter biconical fiber tapers," Optics Express 18, 22593–22598, (2010).
[7] R. J. Black, F. Gonthier, S. Lacroix, J. Lapierre and J. Bures, "Tapered Fibers: an overview," SPIE 839, Components for Fiber Optic Application II (1987).
[8] Suzanne Lacroix, Roch Bourbonnais, Francois Gonthier and J. Bures, "Tapered monomode optical fibers: understanding large power transfer," Optics Letters, 13, No. 5, (1988).
[9] Wygladacz, K.; Radu, A.; Xu, C.; Qin, Y.; Bakker, E. Fiber-Optic MicrosensorArray Based on Fluorescent Bulk Optode Microspheres for the Trace Analysis of Silver Ions. Analytical Chemistry 2005, 77, 4706-4712.
[10] Meadows, D. L.; Schultz, J. S. Design, manufacture and characterization of an optical fiber glucose affinity sensor based on an homogeneous fluorescence energy transfer assay system. AnalyticaChimicaActa 1993, 280, 21-30.