

# Preparation of Tapered Optical Fibers to utilize the Evanescent Field for Sensing Applications

Karra. Sony\*, Soumya. M\*\*

\*(Asst Professor, Department of ECE, K L University, Vaddeswaram, AP

\*\* (Asst Professor, Department of ECE, RNS Institute of Technology, Bangalore

## ABSTRACT

Optical fibers can be tapered in order to utilize the evanescent field present in the cladding region of the fiber. At the beginning of the taper region most of the power is present in the core. In the down taper region the light in the core region couples to the cladding region where the evanescent field is present. In the up taper region, light in the cladding region again couples back into the core region. Our experiment discusses about the process of tapering and the principle of tapered fiber and their optical spectrum.

*Keywords* – Bitaper , Evanascent field, Mode superposition, Sensors, V number

## I INTRODUCTION

An optical fiber is a cylindrically symmetric structure which consists of a core and it is surrounded by the cladding of slightly lower refractive index. The core and cladding are usually protected by a buffer layer. The core with the cladding is the basic optical system for transmission of light in optical fiber .

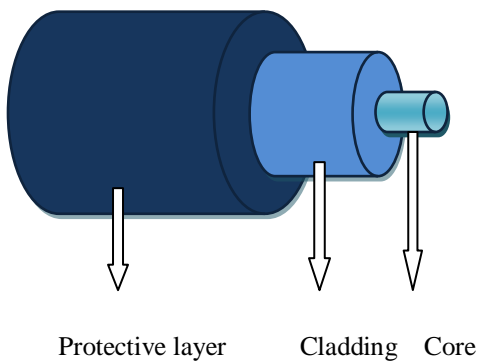


Fig 1: Basic Structure of Optical fiber

Total internal reflection is the phenomenon used to understand light guiding in multimode optical fibres.

When a ray of light is launched in the core of a fiber and it is incident at the core-cladding interface at an angle greater than the critical angle for that interface, it suffers total internal reflection at the interface. Because of the cylindrical symmetry of the fiber it makes repeated total internal reflection possible at upper and lower interface. This makes the ray to be trapped in the fiber and light emerges out from the other end.

Let  $n_1$  and  $n_2$  are the refractive index of the core and cladding respectively. Radius of the fibre core is assumed to be 'a' ,and let ' $\lambda$ ' be the wavelength of light propagating through the fibre ,these terms form the expression for a dimensionless parameter ' $V$ ' called the V number or the normalised frequency which gives the information about the modes.

## A EFFECT OF V NUMBER

In general a fiber can support a number of modes or only one mode depending on the geometry and the physical characteristics of the fiber , the former is called a multi mode fiber while the latter is called a single mode fiber. A fiber with  $V < 2.405$  supports only the fundamental mode  $LP_{01}$ . This is called the single mode condition.

Only fiber with its V value in the range  $0 < V < 2.405$  will be able to maintain propagation of a single fundamental mode  $LP_{01}$ . A fiber which

supports only this fundamental mode is known as a single mode fiber.

For very low values of  $V$ , the power of fundamental mode is confined within the core is very small and most of the power would effectively be propagated in the cladding as evanescent field.

In order to utilize evanescent field for sensing applications the core and the cladding diameters has to be reduced.

Hence ,the reduction of the core and cladding diameters can be done using the process known as fiber tapering ,so that large fraction of power of guided mode propagates in cladding as evanescent field.

## II PRINCIPLE OF TAPERED FIBERS

A bitaper consists of two tapered portions, uptaper region and downtaper region .

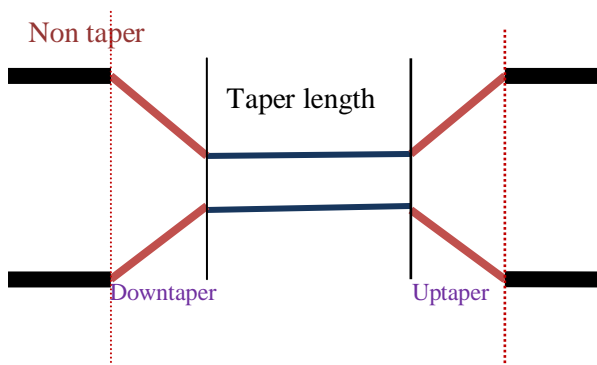


Fig 2. Schematic diagram of tapered fiber

The bitaper consists of a non tapered portion at the first end of the fiber and also at the last end of the fiber .It also contains a down taper transition region and a up transition region. In the down taper region the fiber core and cladding radius eventually decreases whereas vice-versa in the up taper region.

The non tapered region in the fibre support only the fundamental mode  $LP_{01}$  as we are considering the single mode fibre[7]. When the light enters into the down taper region as the fibre radius has been reduced because of the tapering, eventually the  $V$  number changes as we know that it depends on the core radius.

When  $V$  increases greater than 2.405, the fiber is no longer a single mode and fundamental mode couples into the cladding mode then the fiber will support multiple modes or the higher order modes  $LP_{11}$ [1].

As the higher order modes are excited , there will be interaction or coupling between the  $LP_{01}$  and  $LP_{11}$ . Mode superposition of the fundamental and higher order modes takes place when the optical field propagates into the taper waist. Overlapping of the two modes results in the beating process [2], because of which oscillatory behavior of the output light intensity from the tapered fibers can be observed with periodic optical intensity distribution.

In the down taper region, some of the higher order modes are no longer confined in the core region , but can be still guided by the fiber in the cladding region. Thus in the taper region there is evanescent wave related to the cladded modes in the fiber. At the end of the taper some of the cladding modes are coupled back into the core modes by the up taper region. Because of which the transmission intensity variation can be detected. Due to the presence of the evanescent wave related to the cladded modes in the fiber ,the taper fiber can thus be used for evanescent field applications[6].

## III PROCESS OF TAPERING

The fibre tapering is done using the fusion splicer Fujikura FSM 50-S either by first splicing and tapering the fiber or without splicing the fiber.In the former case two similar smf-28 fibers are stripped and cleaved properly and are kept in the fiber holders in the fusion splicer.We should set the amount of arc time and power and also the gap

between the electrodes which will inturn produce the arc.

It should be spliced such that the light when travels inside the fibre should not be scattered or reflecting in nature. The splice loss depends upon the cleavage angle and dust upon the fibres. So the fibres should be cleaned using ethanol. A proof test is done in order to ensure that the splicing is done properly. Prior to the operating of the splicer the parameters such as taper length, taper speed and arc time are fixed.

Once the proof test is done, then the fiber tapering is done by again giving the arc, the tapering of the fibre is done uniformly and the taper waist is reduced to approximately 20-30  $\mu\text{m}$  depending upon the taper speed what we had assigned to the fusion splicer before tapering.



Fig 3 Fusion Splicer

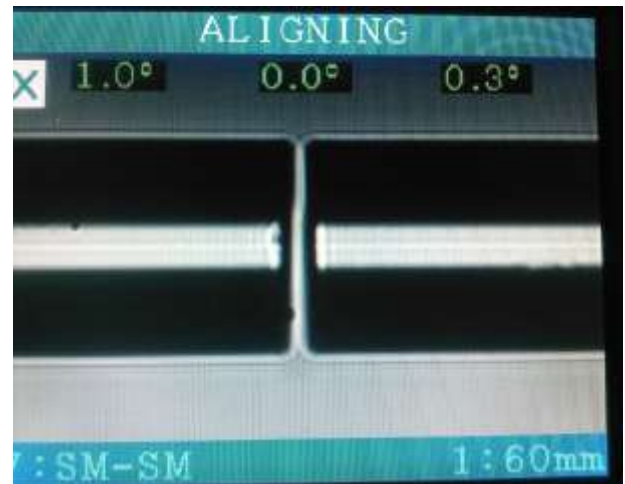


Fig 4 Fiber Alignment for Splicing

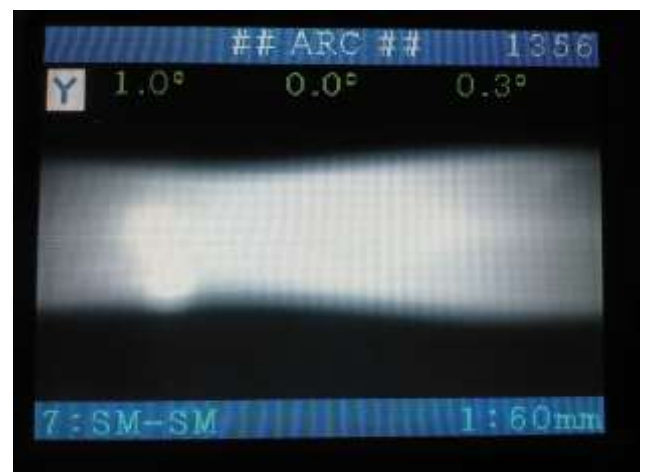


Fig3.3 Process of tapering

Tapering can also be done without splicing of the fibres where the fiber cleaving and cleaning remains the same, but we consider only a single SMF-28. The fiber is stripped in the middle and the same region is kept in the fiber folders of the splicer between the electrodes[3]. The ends of the fiber are held using the fiber holders and they are kept with magnetic weights. When the arc is given to the fibers because of the heat and also due to the weights of magnets the fibre will be pulled because of the force which inturn reduces its diameter and hence the uniform tapering of the fibers takes place.

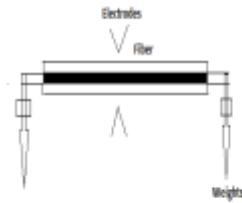


Fig 5 Heat and Pull Method

Fig 6 Taper waist of (28.8 $\mu$ m) with 10X Magnification



YOKOGAWA AQ6370 Optical spectrum analyzer(600-1700 nm) by using the bare fiber connectors where the optical spectrum is collected.

The data obtained from the optical spectrum analyzer were plotted using the ORIGINPRO which is a data analysis software, where the x and y axis are wavelength and power respectively.

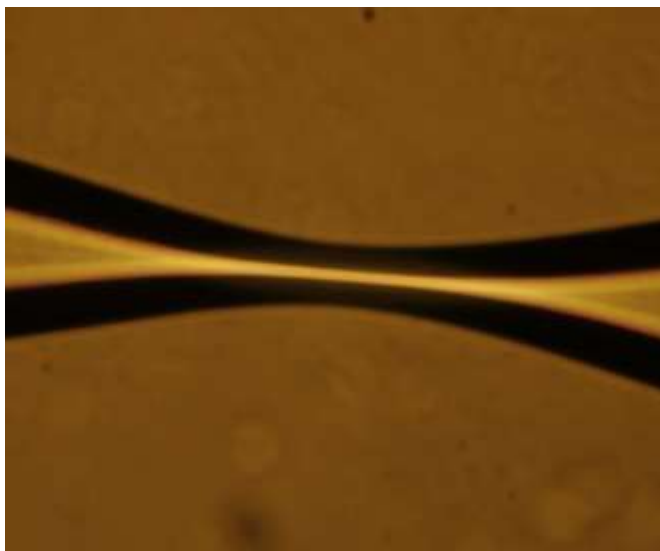


Fig 7 Taper waist of (28.8 $\mu$ m) with 40X magnification

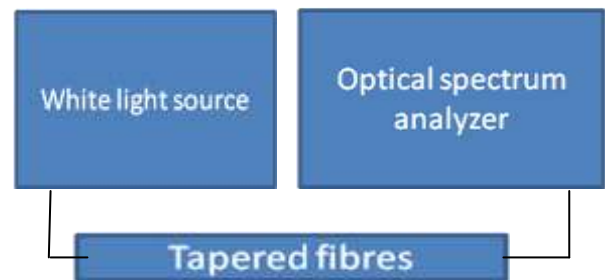


Fig 8 Experimental setup to obtain the tapered spectra

We can observe that at wavelengths ranging from 1100 to 1200nm the resonance condition is taking place which can be used for sensing of external forces onto the tapered fibre such as pressure, temperature, and evanescent field coupling between the tapered fibres and the liquid crystal micro droplets can also be done.

#### IV .RESULTS AND DISCUSSIONS

##### A TAPERED FIBRE SPECTRA

The Tapered fiber spectrum is obtained by sending a white light source YOKOGAWA AQ4305 (400-1800 nm) of light into one end of the tapered fiber and the other end is connected to the

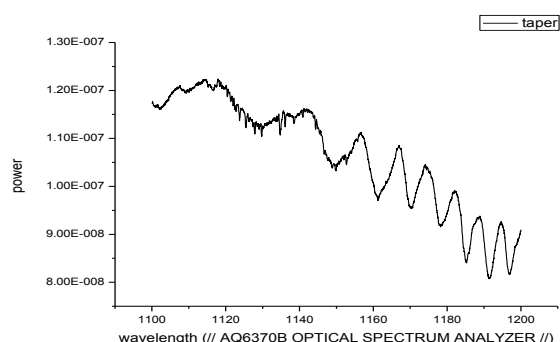


Fig 9 Tapered fibre spectra 2 with taper size 28.8  $\mu\text{m}$

## V. APPLICATIONS OF TAPERED FIBERS

Most optical fiber sensors are based on evanescent interactions. They are accessed by partial or total removal of the fiber cladding. In tapered optical fibers, the gradual change of core and cladding diameters makes the evanescent fields spread out more into the cladding as the fiber tapers down and thus it will reach the external environment and measure the external changes and [4]liquid crystal droplets[5].

## VI FUTURE WORK AND CONCLUSION

The tapered fibers with different taper waist sizes around 28  $\mu\text{m}$  are achieved and their transmission spectra is characterized for the evanescent field coupling. Observation of transmission spectrum of the tapered fibers with Liquid crystal micro droplets and also the dye doped liquid crystal droplet spectrum, will be carried out in the near future .

## REFERENCES

- [1] Lacroix , F. Gonthier , and J. Bures, Opt .Lett, Vol 13,No 5,MAY 1988.
- [2] FU Jian ,Chin .Phys.Lett.Vol .27,No 1(2010)014202.
- [3] A.Martinez-Rios, I.torres-Gomez, Revista Mexicana de fisica 56(1) 80-84.

[4] V. S. Ilchenko and A. B. Matsko, “Optical resonators with whispering gallery nodes—Part I: Basics ,” IEEE J. Sel. Topics Quantum Electron. vol. 12, no. 1, Jan./Feb. 2006.

[5] V. S. Ilchenko and A. B. Matsko, “Optical resonators with whispering gallery nodes—Part II: APPLICATIONS ,” IEEE J. Sel. Topics Quantum Electron. vol. 12, no. 1,PP 15-32, Jan./Feb. 2006

[6] F. Sporleder and H.-G. Unger. Waveguide Taper transitionsNew York: Peter Peregrinus,1979

[7] S. Lacroix, R. Bourbonnais, F. Gonthier, and J. Bures, “Tapered monomode optical fibers: Understanding large power transfer,” *Appl. Opt.*, vol. 25, no. 23, pp. 4421–4425, 1986.