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Cooperative Study for Power Spectral Towards Different Sizes Taper Optical Microfiber for Sensing Purpose

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ABSTRACT

Optical fibre, also referred to as fibre optics, is a method and medium of transmitting data using bursts of light through strands of glass or plastic. When light signals travel through fibre optic cables, they bounce off the core and cladding in a series of zigzag bounces, which is a phenomenon known as total internal reflection. Microfiber optic sensors have recently gained considerable attention due to their high sensitivity, quick detection, and adaptability to harsh environments. To produce microfibers in various diameters, a tapering technique is used. However, the sensor's performance may vary depending on the transmitted power levels produced by the different taper microfiber sizes. Several diameters of taper microfiber will be used as sensors to determine the sensing performance. The results indicate that the best performing sensors are those with smallest diameters.

1. Introduction

Modern sensors for many industrial applications, such as aircraft, infrastructure, transportation, biology, and so on, have emerged in recent years due to rising developments in optical sensing technology. Optical fiber sensors (OFS) have played an increasingly important role in the rapid development of sensors; to date, Corning has produced the first optical fiber with low attenuation, which has the advantages of being light in weight, compact in size, and low in cost, as well as electromagnetic immunity and excellent security [1].

Several optical fiber technologies have been developed in the past few decades to meet the various requirements of point-type optical fiber sensing, including fiber Bragg grating (FBG), long-period grating (LPG) assisted fiber, photonic crystal fiber (PCF), and multicore fiber (MCF) with surface plasmon resonance (SPR). However, their difficult fabrication, high cost, and low sensitivity limit their

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uses. Microfiber has been thoroughly researched in fiber optics as a combination of fiber optics and nanotechnology, with a diameter constrained to tens of nanometers to several micrometres[2-3].

Optical microfiber is another rapidly evolving fiber-optic sensor type with a crucial need for micro or nanophononics. Reducing sensing structures will improve performance, power, volume, and cost. The microfiber diameter is between tens of nanometers and micrometres smaller than that of standard optical fiber. As a result of the light diffraction limit for subwavelength scale microfiber, a significant portion of the evanescent field of microfiber is allowed into the environment, giving microfiber the capacity to interact strongly with its surroundings [4]. Microfiber has also been widely used in optical sensors, evanescent field coupling, particle trapping or manipulating, and quantum optics. The microfiber demonstrates flexibility in realising different microstructures as effective sensing heads, such as loops, knots, coils, and optical couplers[5-7]. This is made possible by their good flexibility and mechanical strength. Additionally, nonlinear optics are intrigued by microfiber's strong field confinement and tunable dispersion.

Various techniques for fabricating microfiber have been proposed throughout the evolution of microfiber research, depending on the precursor materials or optical fibers. The flame heating-pulling method was first reported to draw microfibers with a thickness of several micrometres from the standard optical fiber. Tong *et al.,* introduced a two-step drawing method to fabricate silica microfiber with atomic surface smoothness down to 50 µm[8-10]. Brambilla *et al.,* improved the flame tapering system configurations and demonstrated subwavelength silica microfiber with a loss of less than 0.01 dB/mm [11].

This research aims to develop the microfiber subclass of fiber optics as a sensor. The size of the taper microfiber affects the sensor's performance, creating various transmitted power levels. Different diameters of taper microfiber will be employed as sensors to determine the sensing performance. The best size of taper microfiber is generated towards the end of the study, and it performs capably as a sensor.

2. The Tapering Procedure

The procedure of the tapering process will be discussed further, and the diagram is shown in Figure 1. Firstly, 2 to 3 cm is removed from the Single-mode fiber (SMF) to fabricate the tapered microfiber. Furthermore, the SMF is placed horizontally in stages where two fiber holders hold the fiber. Using heat from the torch that moves along a short section of the fiber while simultaneously pulling the two ends of the fiber. The gas burner flame and oxygen are used as the heat source. Two stepper motors control the movement of the torch and the stage. In addition, when heated glass fiber is stretched, the diameter of the fiber is reduced. Along the heat region, the tapered fiber diameter is decreased uniformly.

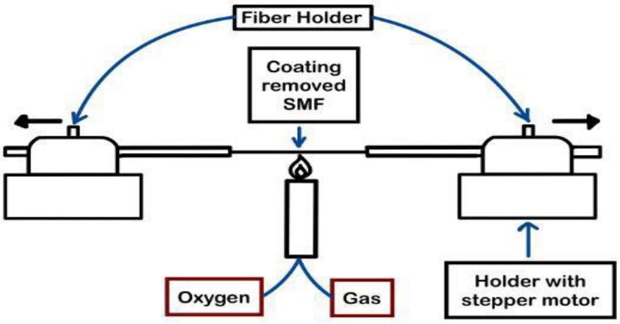

Fig. 1. The tapering procedure

During the tapering process, both the core and cladding diameters are decreased proportionally. The light is coupled from the fundamental mode of the untapered fiber to modes of the tapered section that can interact with the surrounding medium of this process. Another way to facilitate the interaction of light travelling through the optical fibre with the surrounding medium is to thicken the cladding of the optical microfibre while maintaining the same core dimensions. The tapered microfibre is essential to the sensor's functionality, as smaller diameter taper waists offer increased sensitivity.

3. Performance of Different Sizes of Optical Microfiber Sensor

The sensor's sensitivity demonstrates the performance of different sizes of microfiber optic sensors. This microfiber is developed using the tapering method. In Figure 2, the sizes developed are 28.5 µm, 21.7 µm, and 10.8 µm. Sizes are investigated by measuring the range of axis-y.

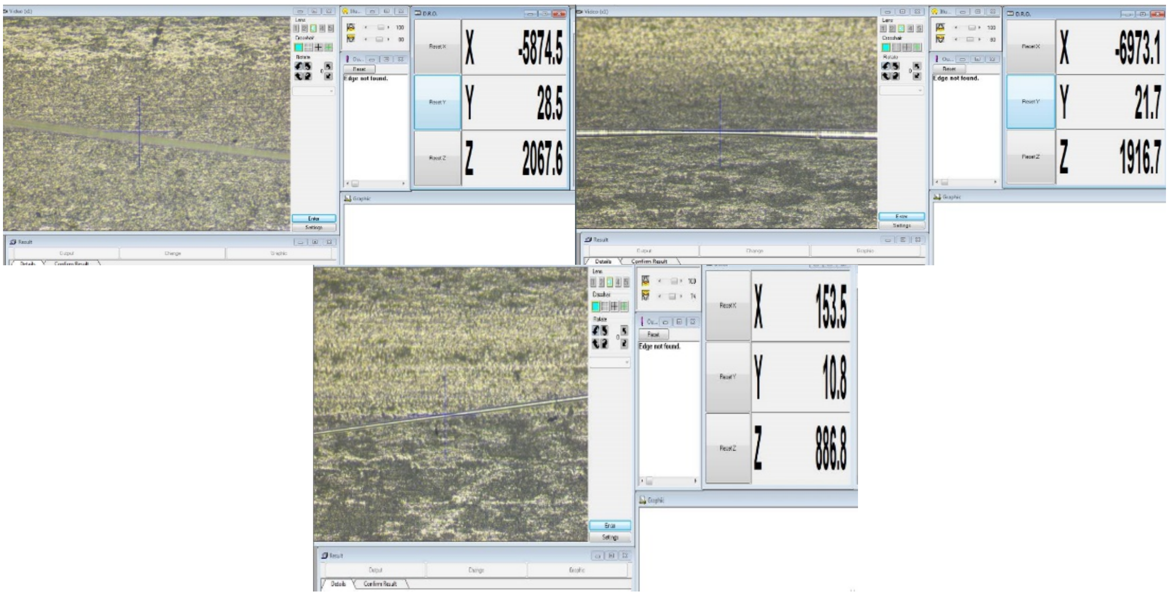

Fig. 2. Sample sizes (28.5 µm, 21.7 µm and 10.8 µm)

Table 1 shows sensitivity and linearity for the microfiber optics in three different sizes at wavelength 1550 nm. Sample 3 showed a higher sensitivity value than other samples, obtaining a reading of 0.1647dBm at wavelength 1550 nm, followed by sample 2 and sample 1 with a value of 0.1393dBm and 0.0672dBm, respectively. In terms of linearity, all samples have a very strong negative linear correlation. Based on the above table, we can conclude that the tapered microfiber's sensitivity increases as the sample size decreases. Furthermore, the linearity value indicates that the data have a good fit.

Table 1
Sensitivity and Linearity for Each Sample

Sample	Sizes	Sensitivity (Y)	Linearity (r)
1	28.5 µm	0.0672	-0.8697
2	21.7 µm	0.1393	-0.7803
3	10.8 µm	0.1647	-0.9351

Table 2 below shows the value of sensitivity and linearity in each minute with the total outcome percentage of power transmitted at 1550 nm wavelengths. The data is recorded every 1 minute for

9 minutes at wavelength 1550 nm, with the output measured in decibels (dBm). The optical microfiber acts as a sensor to detect the power transmitted and perform in different sizes of tapered fiber. Sensitivity and linearity are used as observed parameters. There is a distinct tendency where the cycle will go up and down before returning to its initial value.

Table 2
Sensitivity and Linearity for Each Minute

Minute	Sensitivity	Linearity
1	2.17	-0.9915
2	1.37	-0.9229
3	1.47	-0.9415
4	1.75	-0.9423
5	1.80	-0.9414
6	1.82	-0.9413
7	1.83	-0.9412
8	1.82	-0.9412
9	1.83	-0.9419

According to the investigation, the results obtained at a wavelength of 1550 nm show that the optical microfiber sensor performs better at the first minute. It has the highest sensitivity at the first minute compared to other times, with a value of 2.17. Furthermore, in terms of linearity, all values show strong negative linear correlations.

This experimental report investigated the effect of different sizes of microfiber using a power meter. The tapering method was applied to silica fiber SMF-28. Three different sizes of microfiber are formed. The result was monitored by the Optical Power Meter for 9 minutes, where the Optical Power Level measured the output in decibels (dBm) at a wavelength of 1550 nm. The smallest sample size obtained was 10.8 µm and became the most sensitive, and the largest sample showed the lowest sensitivity. The sensitivity depends on the size of the microfiber; the sensitivity increases as the core size of the microfiber decreases.

4. Conclusions

The method for developing fiber optic sensors with several sizes of fiber optic is presented in this paper. The proposed methodology is effective and robust for obtaining good results with only somewhat precise data and minimal network measurement information. Furthermore, the proposed analytical method obtains the correlation for each size by combining sensitivity and linearity. Overall, the research presented in this paper has improved our understanding of sensor relevance in fiber optics. The method presented uses a limited amount and type of data, employs simple mathematical manipulations, and necessitates fewer intensive calculations while producing quick, compelling, reflective, and somewhat accurate results. Furthermore, the study concentrated on developing approaches to facilitate the growth of low-cost sensors that rely solely on optical fiber sensing. As a result, it paves the way for the suggested additional research.

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