6. Microbending Loss and Application in Sensing

(Dated: January 20, 2021)

I. OBJECTIVE

To study a simple intensity modulated fiber optic pressure sensor based on microbending loss in multimode fiber

II. APPARATUS

1. Optical breadboard
2. He-Ne Laser and Laser aligner
3. Microscopic objective (20X) and holder
4. xyz-translational stage
5. Pin hole photodetector with multimeter and holder
6. fiber chucks
7. 2 post bases and 3 posts
8. Multimode Fiber of appropriate length
9. Fiber cleaver
10. Weight box
11. microbend deformers
12. weight pan.

III. THEORY

One of the main use of fiber optics is its application in sensing, i.e. optical sensors. These sensors are used to determine pressure, temperature, liquid level, refractive index, pH, antibodies, electric current, displacement, rotation etc. The sensors can be classified into two broad groups: intrinsic and extrinsic sensors. In an intrinsic sensor, one or more of the optical properties of guided wave, such as intensity, phase, or state of polarization, is modulated by the measurand, which is then detected at the output. In contrast to this, in an extrinsic sensor, the fiber itself serves as a conduit to carry light signal to and from the sensor head to be detected by a detector.

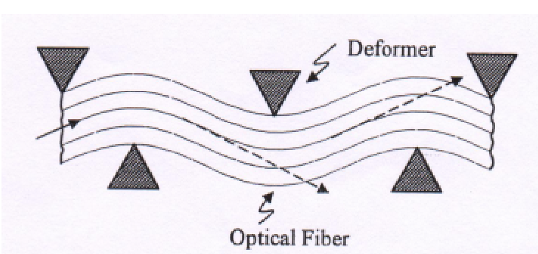

FIG. 1. Principle of microbend induced attenuation in an optical fiber

In this experiment, the sensor to be made is an intrinsic sensor based on the intensity modulation of light through fiber by inducing microbends in the fiber through a periodic deformer element. When the fiber is sandwiched between two deformers and pressure is applied to one of these deformer, the fiber undergoes periodic deformation in the form of micro-bends (fig.(1)). This causes higher order guided modes to radiate out of the fiber. Therefore the intensity drops and it is measured.

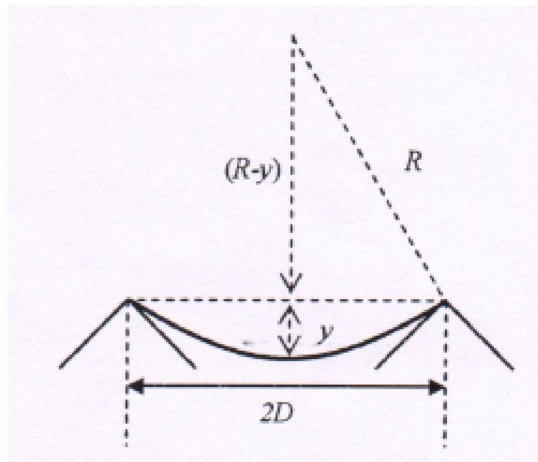

FIG. 2. Geometry of Microbend

The loss in the intensity for a bent fiber is given by:

$$loss = C\left(\frac{a}{R}\right)^2 \quad .....(1)$$

where R is the radius of curvature of the bend, a represents the fiber core radius and C is a constant. Thus, for a given fiber the pressure applied can be related to the bend radius; which is given by:

$$R = \frac{(y^2 + D^2)}{2y} .....(2)$$

where y is the displacement of the deformer and 2D is the distance between the contact points of the deformer element, which is the pitch of the element. Thus, transmittance T through fiber is:

$$T = 1 - loss$$

$$= 1 - \frac{Ca^2}{\left(\frac{y^2+D^2}{2y}\right)^2}$$

$$= 1 - C'\left(\frac{q}{1+q^2}\right)^2 \quad ....(3)$$

where,

$$C' = \frac{4Ca^2}{D^2} \quad .....(4)$$

and

$$q = \frac{y}{D} \quad ....(5)$$

The applied force and hence the pressure is proportional to the displacement y. Therefore, in terms of pressure, we have

$$q = \frac{PA}{kD} \quad ....(6)$$

where P is the pressure, A is the surface area of the deformer and k is a constant. We can change the equation in terms of mass, We know that PA = F = mg, therefore:

$$q = \frac{mg}{kD} \quad ....(7)$$

IV. PROCEDURE FOLLOWED

Light was coupled into the multi mode fiber in the similar manner as it was done in the 1^{st} experiment to obtain maximum coupling and the pinhole detector was setup in front of the output end of the fiber.

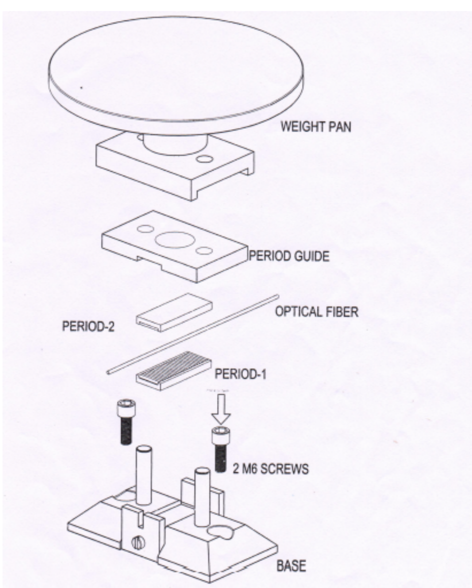

FIG. 3. Microbending apparatus

After that, the microbending apparatus (fig. 3) was setup on the optical breadboard and the fiber was placed in between the deformers. Then weights were put on the weight pan, slowly deforming fiber more and more, and multimeter readings were noted along with it with each step.
The same process of weight increasing was repeated again and 2 set of readings were obtained. Then graph was plotted using those values, and a theoretical curve was also plotted using eq.(3), by using suitable values of C and k. Then all the plots were combined into one plot to see whether they follow the theoretical curve or not. The experimental values and the observation are given in the next section. .

V. EXPERIMENTAL DATA

A. Microbending Loss Set-1

TABLE I. Microbending Loss

Weight put on weight pan (mg)	Voltage of multimeter (V)	Normalized Power
106.124	0.318	1
201.528	0.31	0.950318
298.169	0.296	0.866421
392.4649	0.284	0.797595
490.9039	0.268	0.710257
592.0839	0.109	0.117489
688.75	0.05	0.024722
785.1219	0.037	0.013538
892.1219	0.026	0.006685
990.8099	0.02	0.003956

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B. Microbending Loss Set-2

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TABLE II. Microbending Loss

Weight put on weight pan (mg)	Voltage of multimeter (V)	Normalized Power
101.18	0.316	1
207.303	0.299	0.918403
302.707	0.292	0.875904
399.876	0.285	0.834412
496.247	0.263	0.710653
589.711	0.190	0.37085
688.453	0.120	0.147929
787.141	0.090	0.08321
883.208	0.067	0.046115
990.208	0.036	0.013314

C. Theoretical Transmittance

TABLE III. Microbending Loss

Weight put on weight pan (mg)	Transmittance
101.18	0.962592
207.303	0.85217
302.707	0.710912
399.876	0.550502
496.247	0.396376
589.711	0.26624
688.453	0.157936
787.141	0.082035
883.208	0.03728
990.208	0.016178

VI. GRAPH

From the previous experimental observations, the following graph is plotted:

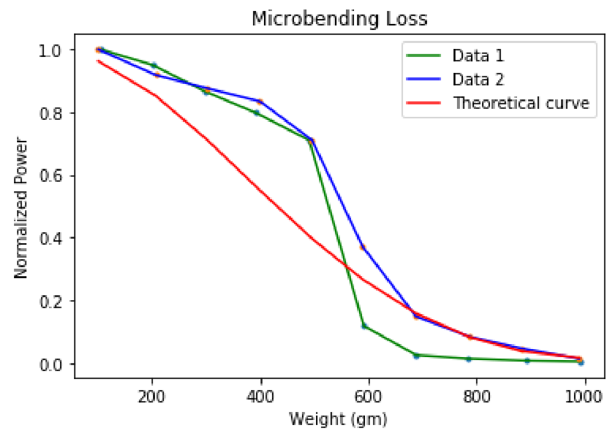

FIG. 4. Normalized Power vs weight

VII. RESULT AND DISCUSSION

As it can be seen from the graph that the experimental curve do not differ much from the theoretical curve, which tells us that the experimentally observed data agrees with the theory. And the pressure sensor is working fine.

[1] YOLUX setup manual,*School of Physical Sciences,NISER*

[2] A.K Ghatak and K. Thyagarajan,*Introduction to Fiber Optics*, Cambridge University Press,Cambridge(1998)