

# **Lab 14 – Fiber Optics Principles and Position Sensor**

## **I. Objective:**

Fiber optics represents a large technology market in many areas of optical science and photonics. Fiber optics can be used for telecommunications, sensors, etc. In this lab, basic principles of fiber optics will be studied. These principles will be applied to build and test a simple fiber optics position sensor.

## **II. Procedure:**

### **A. Optimizing the coupling into a large core fiber optic cable**

1. Using a large area photodetector, measure the power of the He-Ne laser. Before proceeding make sure that the detector is linear. For this lab, the absolute power of the laser is not important. You can use "Photodetector Voltage" as a measure of the detected power.
2. Using a large core (about 1mm) fiber optic cable, couple the light from a He-Ne laser into the fiber as shown in Figure 1. Optimize the position of the fiber optic cable using the 3-D positioner. At this point the laser light should be unfocussed.
3. Record the optical power which emerges from the fiber (when optimized).
4. Use a 50mm lens to focus the laser light onto the fiber optic cable. Optimize the position of the fiber to maximize the optical power emerging from the fiber. Record this optimized power (voltage if using a photodetector).
5. Repeat with a 25mm lens and a 100mm lens

### **B. Bending losses**

1. Using the unfocused laser beam, optimize the light in the fiber.
2. Make a loop in the fiber with a 20cm radius and record the optical power emerging from the fiber.
3. Repeat the measuring with 15cm, 10cm, 5cm, 2cm diameters of fiber. If you do not measure any reduction in the optical power with smaller loops, decrease the diameter until you do. For each loop diameter, record the optical power.

### **C. Optimizing the coupling into a small core fiber-optic cable.**

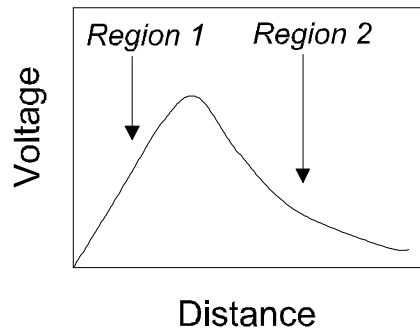
1. Using a small core (6 micron) fiber optic cable, try to couple the light into the fiber using an unfocussed laser beam as shown in Figure 1. Optimize the position of the cable using the fiber optic positioner. At these point the light should be unfocussed.
2. Record the optical power that emerges from the fiber (when optimized).
3. Repeat using a 100mm, 50mm lens and a 25mm lens and record the optimized powers

### **D. Building and Evaluating a fiber-optic position sensor.**

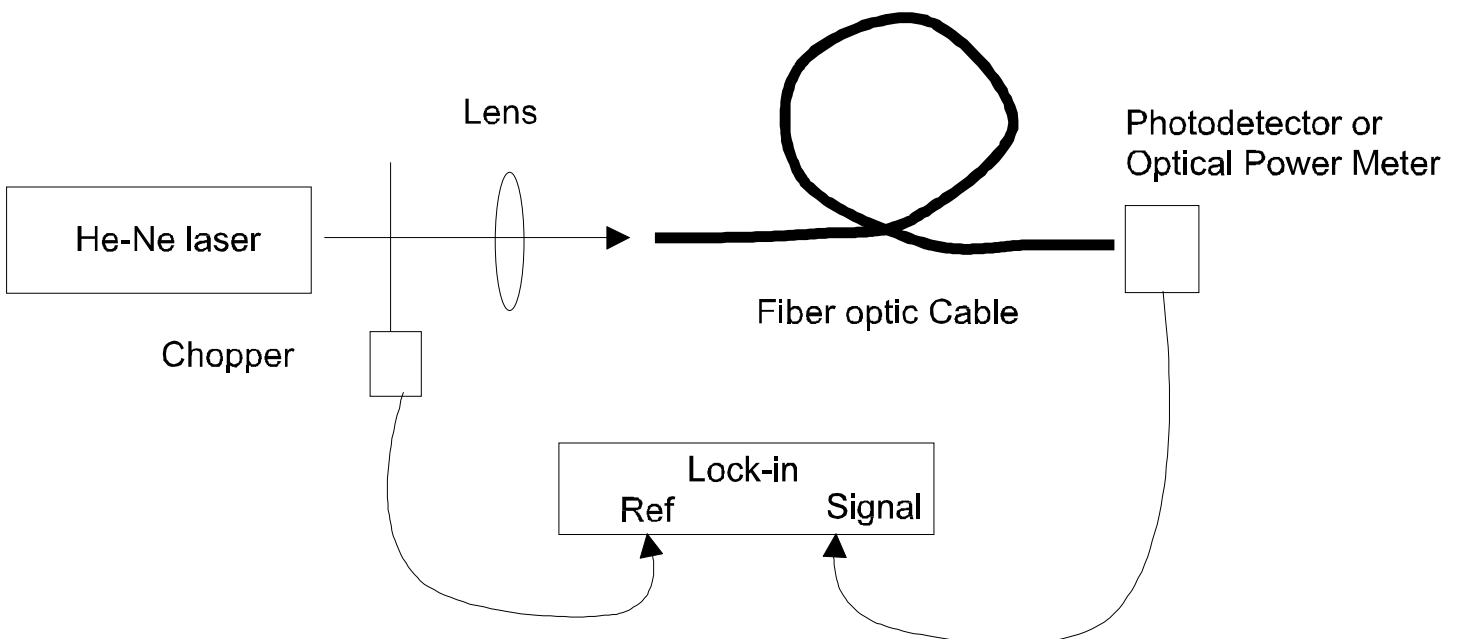
1. Using the large core fiber optic cable, assemble a fiber optic position sensor as shown in Figure 2.
2. Measure the detected power as a function of displacement  $d$  of the mirror. Make sure that the displacement is over a large enough range ( $0 < d < 5\text{cm}$ ) since a part of the lab is determine the displacement range over which the position sensor will work.
3. For a fixed displacement position (about 1cm), estimate the uncertainty in the detected power. You will need this number to estimate the minimum detectable displacement by the sensor. The uncertainty can be estimated by observing the fluctuations which you measure in the detected photodetector voltage. (eg. the measured voltage is  $100 \pm 10\text{mv}$ ).

### III. Discussion:

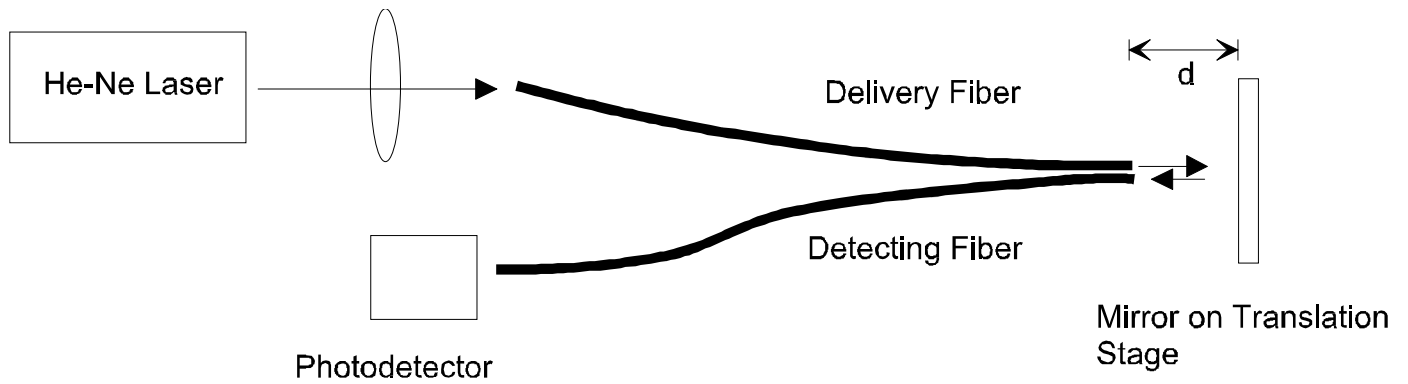
1. For part IIA, plot the detected optical power as a function of  $1/f$  where  $f$  is the focal length of the lens (use  $1/f=0$  for unfocussed light). Which lens couples the most light into the fiber? Is it the lens that focuses the light to the smallest spot size?
2. For part IIB, plot the detected optical power as a function of the bend diameter. What is the smallest diameter of bending before bending losses become noticeable?
3. Briefly explain (use diagrams if necessary) WHY there are bending losses.
4. Repeat Discussion question 1 for part IIC. Why is the optimal focussing lens different for Part IIA and part IIC. HINTS: consider (a) the SIZE of the fiber core and (b) the Numerical Aperature of the fiber.
5. Based on your results for the fiber optic based position sensor (part IID):
  - Plot the detected optical power versus displacement of the mirror. Your plot should look something like the following:



- Starting from zero displacement, why does the detected light intensity first INCREASE from zero (region 1) in above figure and then decrease (region 2)?
- Is there any displacement region where this displacement sensor is linear?
- What the range of detection (not necessarily when the sensor is linear)? Ie. What is the smallest detectable displacement? What is the largest detectable displacement? *Explain how you arrived at these answers.*
- To what accuracy can the displacement be experimentally determined? *Explain how you arrived at this answer.*
- Would you expect the displacement sensor to work on a diffusively reflecting surface (eg. a piece of cardboard)? Why or Why not?



**Figure 1:** Schematic of coupling laser light into a fiber. For the large core fiber, use a photodetector as the detector (make sure it is linear). For the small core fiber (125 micron outer diameter), use the optical power meter.



**Figure 2:** Schematic of Fiber optic position sensor. The intensity of light which is coupled into the detecting fiber after reflection from the mirror should depend on the displacement  $d$  of the mirror. The lock-in amplifier and Chopper (not shown) should be set up as shown in Fig. 1 above.