

EXPERIMENT 6

FIBER MISALIGNMENT LOSS MEASUREMENT

OBJECTIVES:

The objective of this experiment is to measure the dB power loss due to longitudinal and lateral misalignments of two identical multimode GI fibers.

EQUIPMENT REQUIRED

- 1- Optical power meter: INFOS, Model # M100.
- 2- Mells Griot horizontal and vertical translation stages, (0.01 mm resolution) with a fiber holder assembled on a Mells Griot bench base.
- 3- Laboratory jacks for raising the Mells Griot bench base [Two].
- 4- HeNe laser: Coherent, Model # 31-2090-000 on a horizontal and translation stage, all assembled on a ¼ m bench.
- 5- Approximately 2m long, 50 μm core diameter, GI fibers (Orange Color), NA = 0.22 [Two].
- 6- Additional optical fiber holders [Two].
- 7- Horizontal and vertical stages assembled on a (½ m) bench base: Ealing Electro-Optics.
- 8- Translation stage assembled on a (¼ m) optical bench [Two Sets]: Ealing Electro-Optics.
- 9- Bench base: Ealing Electro-Optics.
- 10- General purpose holders [Two].
- 11- Thin lens holder.
- 12- Magnifying lens.
- 13- Thin lens, focal length 5 cm.
- 14- Meter stick.
- 15- Plate (black).
- 16- Black screen.

PRELAB ASSIGNMENT

Read the introduction to this experiment, before you attend the laboratory.

INTRODUCTION:

Examples of optical fiber misalignments include longitudinal, lateral and angular misalignments. Longitudinal and lateral misalignments of two *identical* fibers are illustrated in Figure 1. Longitudinal misalignment (see Figure 1a) refers to the fibers' end separation z . Lateral misalignment refers to the separation x of the fibers' axes (see Figure 1b). Large optical power loss can occur when the two fibers are misaligned. The degree of loss due to fiber misalignment is a function of the core diameter, the refractive index profile and to a lesser degree on the operating wavelength.

Generally, in the case of longitudinal misalignment ($z > 0$), a millimeter and sometimes a *fraction of a millimeter* can cause large optical power loss. However, in the case of lateral misalignment ($x > 0$), the degree of loss depends mostly on the core diameter. When the fiber's core size is small, a few *micrometers* can result in a large power loss. The fibers used in this experiment have small core diameters. Thus, large losses are expected to occur for x in the micrometer range and therefore, one has to be *extremely careful* in aligning the two fibers in the lateral direction and also in measuring fibers' separation in this direction. When x exceeds the *core diameter* of the fiber, almost no optical power is coupled from one fiber into the other.

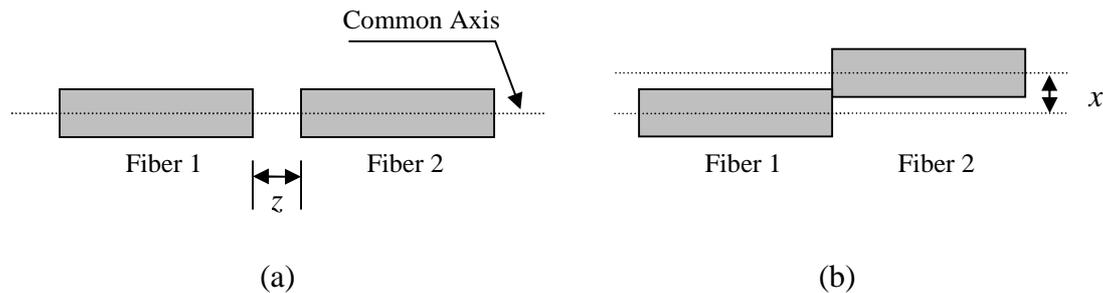


Figure 1: (a) Longitudinal Misalignment ($z > 0$). (b) Lateral Misalignment ($x > 0$).

In this experiment, the longitudinal and lateral misalignment losses of two identical GI fibers will be measured. Light from a HeNe laser will be coupled into the input end of fiber 1 and an optical power meter will be connected to the output end of fiber 2. The misalignment loss can be found from the optical power reading.

The following expression can be used to estimate the longitudinal misalignment loss L_z (in dB) between two identical fibers:

$$L_z \approx 3(NA/a)z, \text{ for } z \gg a \quad (1)$$

Where NA is the numerical aperture of the fiber, a is the *core radius* and z is the longitudinal separation of the two fibers. For multimode GI fibers with a parabolic refractive index profile, the lateral misalignment loss L_x (in dB) can be estimated theoretically using the following simple expression:

$$L_x \approx -10 \log[1 - 0.75(\frac{x}{a})], \text{ for } 0 < x < 0.4a \quad (2)$$

Where a is the core radius and x is the lateral separation. Notice that equation (1) has a limited, but very practical range of applicability.

Determination of the fiber misalignment loss should be straight forward to do experimentally. However, there are two difficulties. First, two fibers with relatively small cores (i.e. $2a = 50\mu\text{m}$) have to be well-aligned, which needs patience and accuracy. The experimental procedure details a possible method for doing this task. The second difficulty arises because the optical power meter has a finite sensitivity. It cannot measure optical power below a certain level. For the HeNe light, the readings of the optical power meter used in this experiment becomes unreliable below about

-62 dBm (using the $\lambda = 0.85\mu\text{m}$ setting). In addition, since the fiber misalignment introduces additional power losses, the optical power reaching the optical power meter can become too small to measure when the HeNe laser light is coupled directly to fiber 1. For this reason, the light from the HeNe laser source is first focused into fiber 1 using a thin lens in order to maximize the input power.

PROCEDURE:

[IMPORTANT: INSURE THAT BOTH ENDS OF THE TWO FIBERS HAVE BEEN CLEANED AND RECENTLY CLEAVED, OTHERWISE LARGE EXPERIMENTAL ERRORS MAY OCCUR].

[**WARNING:** DO NOT LOOK DIRECTLY AT THE FIBER'S END WHEN THE FIBER CARRIES LASER LIGHT. THIS MAY CAUSE SERIOUS EYE DAMAGE].

- 1- Turn the HeNe laser source.
- 2- Connect one end of fiber 1 to the first z stage (Z1), as shown in Figure 2 (main experimental setup).
- 3- Connect one end of fiber 2 to the first $x-y$ (XY1, Mills Griot) and the other end to the optical power meter.
- 4- Align the fibers ends. The two fibers must be first *visually* aligned. Use the following procedure for the visual alignment:

- Use the magnifying glass as an aid, because the fibers' tips may be hard to see and use a *black background* for much improved visibility. Use the black plate and screen to produce a black background.
- Adjust the Z1 translation stage until the fibers' tips are very close to each other ($z \approx 1\text{ mm}$). [*Do not allow the tips to touch each other*].
- Adjust the horizontal stage (x - direction) while *looking from above* to bring the fibers' tips closer until they are aligned in the horizontal direction.
- Adjust the vertical stage (y - direction) while *looking from the side* to bring the fibers' tips closer until they are aligned in the vertical direction.
- Repeat the above two steps as necessary until the fibers axes are aligned.
- Reduce z further until the gap between the two tips is almost invisible and the two fibers appear almost a single continuous fiber, while taking care that the two tips don't touch.

5- Now, refer to the HeNe lens laser/fiber setup shown in Figure 3. Adjust the distance from the laser output end to the thin lens to about $20-40\text{ cm}$. The laser light must pass through the center of the lens (exactly) and should be perpendicular to the lens. [*Refer to the laser/fiber lens coupling procedure done in experiment 5*].

6- Adjust the distance from the tip of fiber 1 to the thin lens initially to about 7 cm .

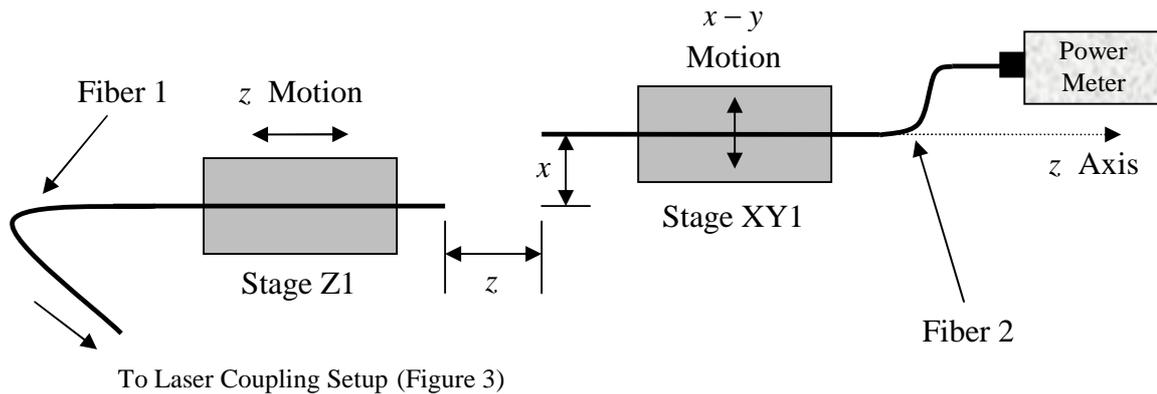


Figure 2: The Main Experimental Setup.

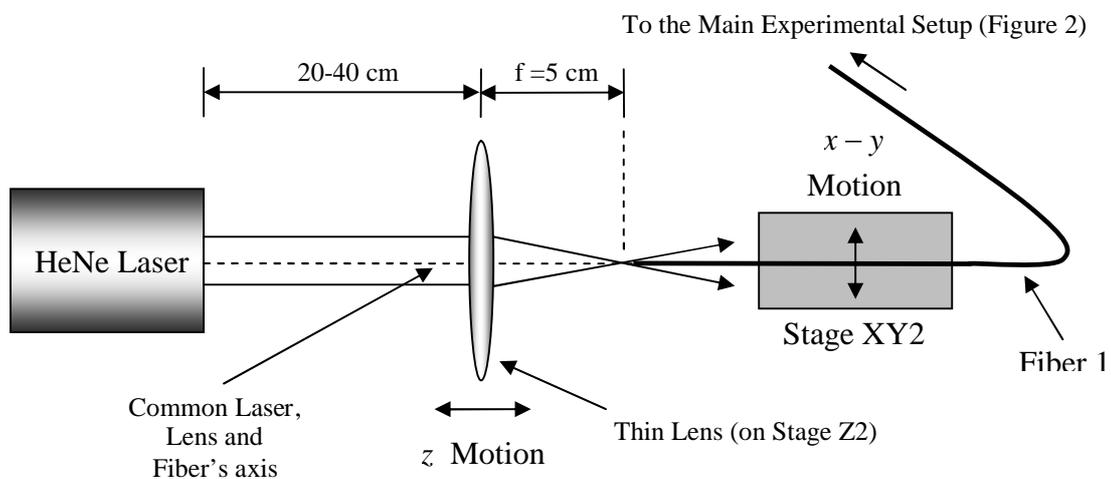


Figure 3: Laser Coupling Setup.

7- Move stage XY2 in the horizontal and vertical directions until the focused laser light hits the tip of fiber 1. [You will see somewhat faint light leaving the other end of fiber 1 when this occurs].

8- Adjust the XY2 stage until maximum amount of light is seen leaving fiber 1.

9- Adjust stage Z2 to bring the fiber's tip closer to the focal point and visually monitor the level of scattered light from the output end of fiber 1 (remember the fiber's tip must be at 5 cm for absolute maximum power coupling).

10- Repeat steps 8 and 9 iteratively until the level of scattered light from the output end of fiber 1 is sufficiently high.

11- Turn the power meter on and set it to the dBm scale and $\lambda = 0.85 \mu\text{m}$.

12- The power meter should show a substantial reading (much more than -60 dBm). If the meter's reading is too low, visually check the fibers' alignment (Figure 2) or the location of fiber 1 tip with respect to the focused laser light (Figure 3). You may also need to check the connection to the power meter.

13- Again move the XY2 stage in the horizontal and vertical directions and this time monitor the power meter until you get maximum meter reading.

14- Move the second z translation stage (Z2) slightly backward and forward to fine tune the laser power coupling to fiber 1 by observing the power meter reading, until

you obtain maximum power coupling. [*Fiber 1 must be exactly at the focal point for maximum power coupling*].

15- Use the power meter's reading to also fine tune the fibers' alignment (Figure 2), until you obtain maximum power reading [*Do not change the value of z while you are doing this step*].

16- Record the maximum power in the *second* row of table 1.

17- Rotate the z stage knob clockwise to increase z and take the meter's reading every 0.2 mm. [*One full rotation of Ealing translation stage equal 1.00 mm*]. Record the results in table 1.

18- Reduce z as much as possible by rotation the stage counterclockwise until the gap is almost invisible again.

19- Adjust the $x - y$ stage again for maximum power reading and record the result in the *bottom* row of table 2.

20- Move the horizontal stage in steps of $\Delta x = \pm 5 \mu m$ and record the optical power meter readings in table 2. [*The separation between the individual marks of the Mills Griot micrometer corresponds to $10 \mu m$ and a full turn = 0.5 mm, use the magnifying lens for a better view of the markings on the micrometer*].

| z (mm) | P (dBm) |
|----------|-----------|
| 0 | |
| 0.2 | |
| 0.4 | |
| 0.6 | |
| 0.8 | |
| 1.0 | |
| 1.2 | |
| 1.4 | |
| 1.6 | |
| 1.8 | |
| 2.0 | |

Table 1: Variation of the Received Optical Power in dBm Versus the Longitudinal Displacement z .

| $x(\mu m)$ | P (dBm) | $x(\mu m)$ | P (dBm) |
|------------|-----------|------------|-----------|
| -65 | | 5 | |
| -60 | | 10 | |
| -55 | | 15 | |
| -50 | | 20 | |
| -45 | | 25 | |
| -40 | | 30 | |
| -35 | | 35 | |
| -30 | | 40 | |
| -25 | | 45 | |
| -20 | | 50 | |
| -15 | | 55 | |
| -10 | | 60 | |
| -5 | | 65 | |
| 0 | | - | |

Table 2: Variation of the Received Optical Power in dBm Versus the Lateral Displacement x .

REPORT REQUIREMENTS:

1- Plot the longitudinal misalignment loss [$L_z \equiv P(z) - P(0)$] versus z in millimeter, where $P(z)$ is the dBm powers recorded in table 1 and L_z is longitudinal alignment loss in dB. [Recall: the difference between dBm powers results in dB power loss. There is no such thing as dBm power loss].

2- On the same figure, plot the theoretical longitudinal loss using equation (1). Compare the theoretical and experimental results.

3- Comment on the experimental longitudinal loss versus longitudinal separation and comment on the linearity of the resulting plot. How critical is the longitudinal separation?

4- Plot the lateral misalignment loss $L_x \equiv P(x) - P(x)|_{\max}$ versus x in micrometer. Where $P(x)$ is the dBm powers recorded in table 2, $P(x)|_{\max}$ is the maximum

measured dBm power that appears in table 2 and L_x is the lateral alignment loss in dB. [Note: if $P(x)|_{\max}$ is not the same as $P(0)$, then reset the x-axis, so that the maximum received dBm power occurs at $x = 0$].

5- On the same graph, plot the theoretical results using equation (2), keeping in mind that equation (2) has a limited range of applicability. Compare the theoretical and experimental results.

6- Comment on the experimental lateral loss versus lateral separation including symmetry. How critical is the lateral separation?

7- Discuss and comment on the experimental results and the experiment in general. Is the experiment easy to do? What precautions do you have to observe for accurate measurements? Write a summary and some conclusions.

QUESTIONS:

1- Based on the experimental data, which displacement is more critical, the lateral or the longitudinal? Explain briefly.

2- Do you think this experiment will be easier or harder to do if the fibers used are single mode? Explain briefly. Give at least two reasons to justify your answer.

3- Briefly explain why it was necessary to use the thin lens?

4- Given two types of multimode GI optical fibers: Fiber 1 has a numerical aperture of 0.22 and a core radius of $50 \mu\text{m}$ and fiber 2 has a numerical aperture of 0.275 and a core radius of $62.5 \mu\text{m}$. Use equations (1) and (2) to answer the following questions:

a) For which fiber is the longitudinal misalignment more critical?

b) For which fiber is the lateral misalignment more critical?