Experiment 2

FIBER ATTENUATION

OBJECTIVES:

In this exercise, you will measure one of the most important fiber parameters; the attenuation per unit length, of a multimode communications-grade optical fiber. The technique demonstrated here is called the "cutback method" and is generally used for this measurement. You will also be introduced to the way that the conditions under which light is launched into the fiber can affect this measurement. You learn about mode scrambling and how to generate a desirable distribution of light in the fiber

MEASUREMENT OF OPTICAL FIBER ATTENUATION:

Attenuation (loss) is a logarithmic relationship between the optical output power and the optical input power in a fiber optical system. It is a measure of the decay of signal strength, or loss of light power, that occurs as light pulses propagate through the length of the fiber. The decay along the fiber is exponential and can be expressed as:

$$I(z) = I(0)10^{-(\Gamma z/10)} \qquad (2\text{-}1)$$

The length of the fiber, z, is given in kilometers, and the attenuation coefficient, Γ, is given in decibels per kilometer (dB/km). Because the designers of fiber optic systems need to know how much light will remain in a fiber after propagating a given distance, one of the most important specifications of an optical fiber is the fiber's attenuation. In principle, the fiber attenuation is the easiest of all fiber measurements to make. The method which is generally used is called the "cutback method." All that is required is to launch power from a source into a long length of fiber, measure the power at the far end of the fiber using a detector with a linear response, and then, after cutting off a length of the fiber, measure the power transmitted by the shorter length. The reason for leaving a short length of fiber at the input end of the system is to make sure that the loss that is measured is due solely to the loss of the fiber and not to loss which occurs when the Light source is coupled to the fiber Fig. 2.l shows a schematic illustration of the measurement system.

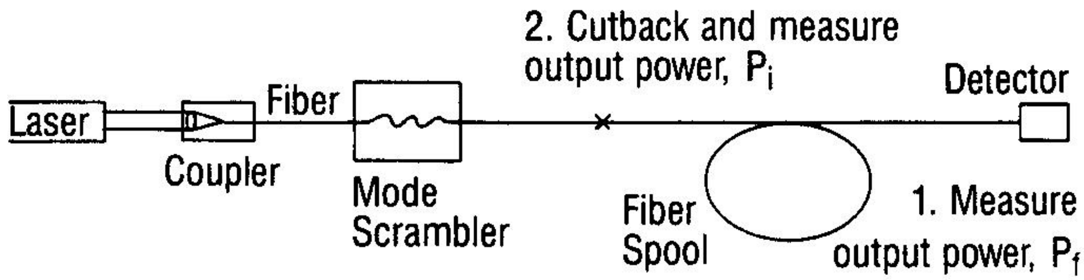


Figure 2.1. *Schematic of laboratory set-up for cutback method of determining fiber attenuation.*

The transmission through the fiber is written as

$$T = P_f \,/\, P_i \qquad (2\text{-}2)$$

where we have substituted P_i (initial power) and P_f (final power) for I(0) and I(z), respectively A logarithmic result for the loss in decibels (dB), is given by

$$L(dB) = -10\log(P_f \,/\, P_i) \qquad (2\text{-}3)$$

The minus sign causes the loss to be expressed as a positive number This allows losses to be summed and thensubtracted from an initial power when it is also expressed logarithmically (In working with fiber optics, you will often find powers expressed in dBm, which means "dB with respect to l mW of optical power." Thus, e.g., 0 dBm = 1 mW 3 dBm = 2 mW and -10 dBm = l00 pW Note that when losses in dB are subtracted from powers in dBm, the result is in dBm. For example, an initial power of +3 dBm minus a loss of 3 dB results in a final power of 0 dBm. This is a shorthand way of saying "An initial power of 2 mW with a 50% loss results in a final power of 1 mW.")

The attenuation coefficient, Γ, in dB/km is found by dividing the loss, L, by the length of the fiber, z. The attenuation coefficient is then given by

$$\Gamma(dB \,/\, km) = (1/z)[-10\log(P_f \,/\, P_i) \qquad (2\text{-}4)$$

The total attenuation can then be found by multiplying the attenuation coefficient by the fiber length, giving a logarithmic result, in decibels (dB), for the fiber loss.

PRACTICAL PROBLEMS:

The cutback method works well for high-loss fibers, with Y on the order of l0 to 100 dB/km. However, meaningful measurements on low-loss fibers are more difficult. The highest-quality fibers will have losses which are on the order of 1 dB/km or less, so that cutting a full 1 km from the fiber will result in a transmitted power decrease of less than 20%, putting greater demands on the measurement system's resolution and accuracy

There is also an uncertainty due to the fact that the measured loss will depend on the characteristics of the way in which light is launched into the fiber. When a fiber is overfilled, many high-order and radiation modes are launched. These modes are more highly attenuated than are low-order modes. When a fiber is under filled, mostly low-order modes are launched and lower losses occur.

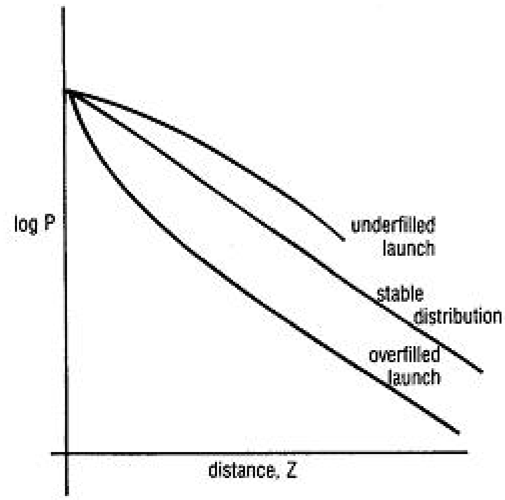


Figure 2.2. *Comparison of attenuation characteristics of various launch conditions.*

The solution to this problem is to attempt to generate what is known as the stable mode distribution as quickly as possible after launching. Fig. 2.2 compares the transmission characteristics of the stable distribution with those of the overfilled and under filled launch conditions. The stable mode distribution may be achieved, even in a short length of fiber, by using mode scrambling to induce coupling between the modes shortly after the light is launched.

Mode scrambling generates an approximation of a stable distribution immediately after launch and allows repeatable measurements, which approximate those that would be found in the field, to be made in the laboratory Fig. 2.2 compares the optical power in a fiber as a function of propagation distance for the three types of launch conditions: over filled, under-filled, and stable distribution. The slope of the curve at large distances is equal to the attenuation coefficient. It is the fact that the mode scrambling generates a stable distribution immediately after the source that allows a short cutback length to be used in the cutback method of measuring attenuation.

PART LIST

Cat#	Description	Qty.
XSN-22	2x2 Breadboard	1
U-1301P	1 mw He-Ne laser	1
807	Laser mount	1
304C	Clamp	1
41	Short rod	1
815	Power meter	1
F-916	Fiber coupler (w/o lens)	1
M-20X	20X objective lens	1
F-CL1	Fiber cleaver	1
FK-BLX	Ball-driver set	1
SK-25	¼ -20 Screw kit	1
VPH-2	Post holder	1
SP-2	Post	1
FP-1	Fiber positioner	1
FM-1	Mode scrambler	1
F-MLD-500	100/140 MM fiber, 500 meter	1

PROCDURE:

1. Prepare both ends of the 500 meter fiber spool which has been provided, as you learned to do in first part. This fiber is the Newport F-MLD-500 fiber with a 100 μm core and a 140 μm OD. You may have to use some care in freeing the end of the fiber which was the start of the winding onto the spool. (This end will be referred to as the far end of the fiber)

2. Place the cleaved far end of the fiber in an FPH-S holder which has been removed from an FP-l Fiber Positioner and insert this into the post-mounted FP-l. Also,

post mount the detector head of the Model 8l5 power meter. Align the detector head with the fiber end so that you will be able to measure the output power.

3. The use of the F916 Fiber Coupler to couple light from a He-Ne laser into a fiber is illustrated in Fig 2.2. Align the coupler and the He-Ne laser so that the laser beam shines along the axis of the F-9l6 Fiber Coupler Mount a 20X microscope objective in the F-9l6. Place the cleaved front end of the fiber into the fiber chuck from the F-9l6 and insert this into the coupler Carefully align the fiber to maximize the light launched into the fiber, using the power meter to monitor the launched power. Use a microscope slide cover glass in the path of the laser beam to look at the Fresnel reflection from the fiber end face. Focus the Fresnel reflected beam by adjusting the z component of the fiber position, as defined in Fig. 2.3; turning the z adjustment knob on the fiber positioner does this. When this reflection is focused, the fiber end face is in the focal plane of the coupler's microscope objective lens.

4. Position the FM-l Mode Scrambler at a convenient place near the launch end of the fiber.

5. Rotate the knob of the FM-l counter-clockwise to fully separate the two corrugated surfaces. The PM-l Mode Scrambler is illustrated in Fig. 2.4. Place the fiber between the two corrugated surfaces of the Mode Scrambler Leave the fiber jacket on to protect the fragile glass fiber Rotate the knob clockwise until the corrugated surfaces just contact the fiber Examine the far-field distribution of the output of the fiber Rotate the knob further clockwise and notice the changes in the distribution as the amount of bending of the fiber is changed. Since a narrow collimated He-Ne beam is being used to launch light into the fiber, the original launched distribution will be under filled. When the distribution of the output just fills the NA of the fiber, an approximation of the stable distribution has been achieved. Do not add any more bending than is necessary to accomplish this, since that will result in excess loss. This launching and mode scrambling set-up should not be changed again during the remainder of the exercise.

6. Measure the power out of the far end of the fiber. Note the exact length of the fiber. It will be part of the information on the label of the spool.

7. Break off the fiber ~2 meters after the mode scrambler (See Fig. 2.1.) from the launching set-up. (Be sure to note on the spool how much fiber you have removed, so that

other people using the same spool in the future will be able to obtain accurate results.) Cleave the broken end of the fiber and measure the output from the cutback segment.

8. Calculate the fiber attenuation, using Eq.2.4, and compare this with the attenuation written in the fiber specification on the spool. Give me the reason, why your value is somewhat higher than the specification.

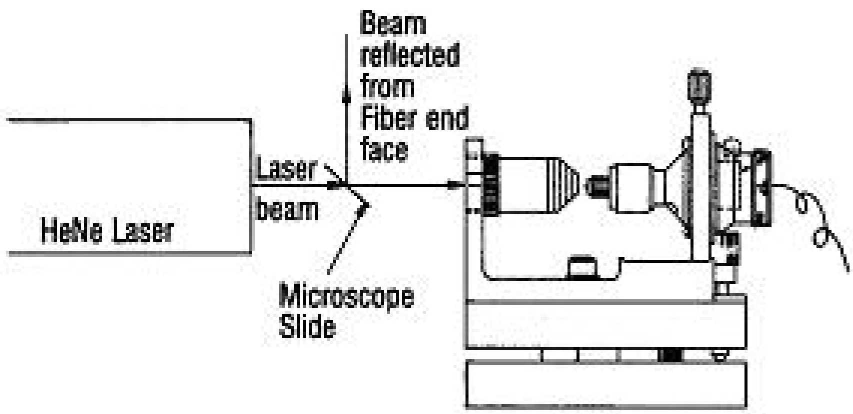


Figure 2.3. *F-916 Fiber Coupler.*

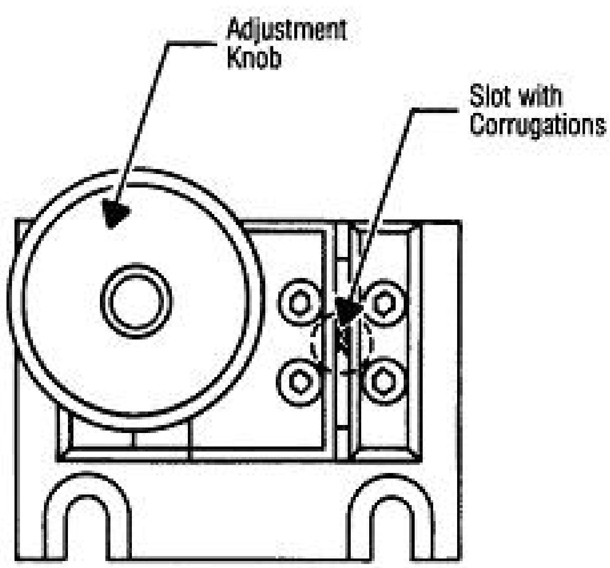
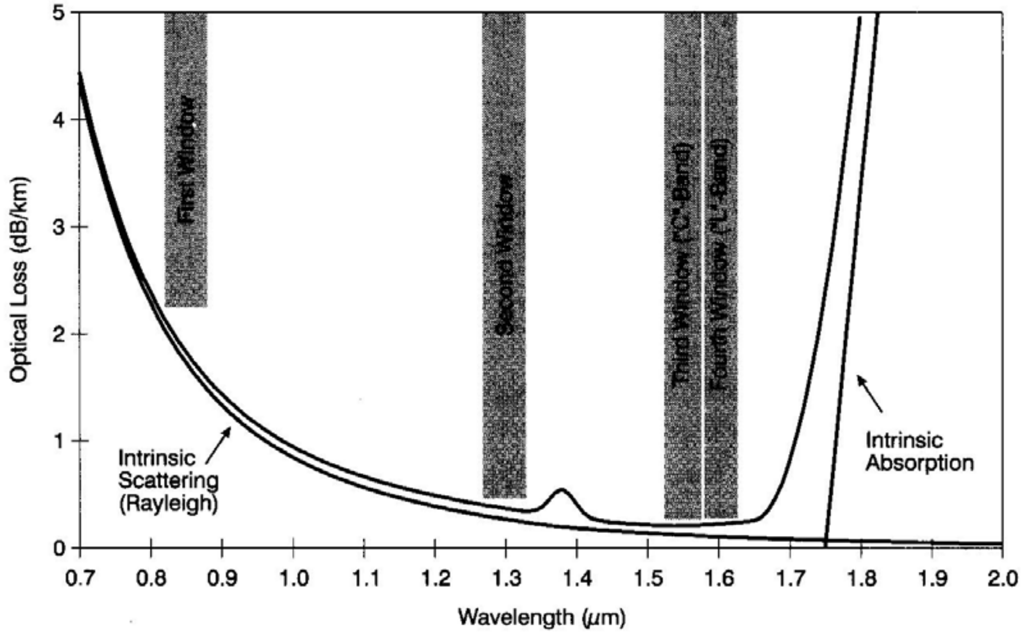


Figure 2.4. *Model FM-1 Mode Scrambler.*

APPENDIX:

OPTICAL LOSS VERSUS WAVELENGTH



TYPICAL FIBER LOSS

Fiber		Optical Loss (dB/km)			
Size	**Type**	**780 nm**	**850 nm**	**1310 nm**	**1550 nm**
9/125 μm	SM	---	---	0.5-0.8	0.2-0.3
50/125 μm	MM	4.0-8.0	3.0-7.0	1.0-3.0	1.0-3.0
62.5/125 μm		4.0-8.0	3.0-7.0	1.0-4.0	1.0-4.0
100/140 μm		4.5-8.0	3.5-7.0	1.5-5.0	1.5-5.0
110/125 μm		---	15.0	---	---
200/230 μm		---	12.0	---	---