Experiment 8:

Fiber Modes and Attenuation

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1 Measurement of Optical Fiber Attenuation

Task:

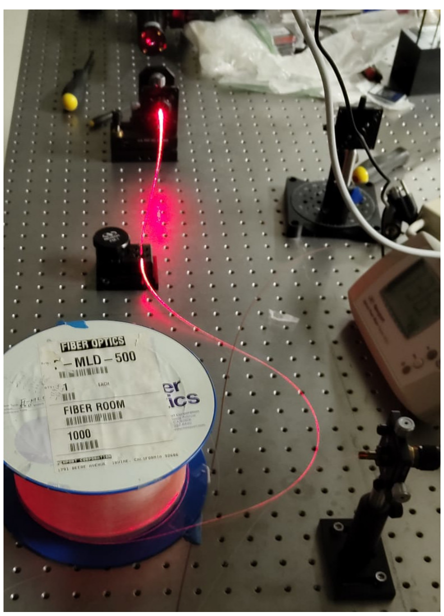
Prepare both ends of the 500 meter fiber spool as you learned to do in lab#1. This fiber has a 100 μm core and a 140 μm outside diameter (OD). You may have to use some care in freeing the end of the fiber which was the start of the winding onto the spool. (this end will be referred to as the far end of the fiber.)

Instead of the spool mentioned on the instructions, we ended up using a fiber without shielding on the whole spool, that was in fact 500 m long. However some chunks of it had already been used so they were subtracted of the total spool to a total of 487.28 m.

Task:

Place the cleaved far end of the fiber in a Fiber Chuck and insert this into the post mounted Fiber Positioner. Also, post mount the detector head of the power meter. Align the detector head with the fiber end so that you will be able to measure the output power. The laboratory set-up for this project is shown in the picture below.

The fiber was cleaved on both ends and treated as expected from previous experiments. It was mounted into a coupler which focused the beam of a *HeNe* laser into the fiber with a 20x microscope objective. Small adjustments were necessary to ensure proper alignment of the optical equipment.



Task:

The use of the Fiber Coupler to couple light from a HeNe laser into a fiber is illustrated in the figure to the right. Align the coupler and the HeNe laser so that the laser beam shines along the axis of the Fiber Coupler. Mount a 20X microscope objective in the Fiber Coupler. Place the cleaved front end of the fiber into the fiber chuck from the Fiber Coupler 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 the figure. This is done by turning the z adjustment knob on the fiber positioner. When this reflection is focused, the fiber end face is in the focal plane of the coupler's microscope objective lens.

The power measured was carefully observed while the fiber was being positioned correctly into place, trying to get the maximum power reading possible. Also, the light exiting off the fiber was projected to a screen to ensure the proper cleavage of said fiber.

Task:

Position the Mode Scrambler at a convenient place near the launch end of the fiber, as shown in the picture of the experimental setup above.

Rotate the knob of the Mode Scrambler counterclockwise to fully separate the two corrugated surfaces. The Mode Scrambler is illustrated below. 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 HeNe beam is being used to launch light into the fiber, the original launched distribution will be underfilled. 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 experiment.

As described on the task title, a mode scrambler was set up close to the beginning of the spool. As the knob on the scrambler was tightened, two pair of metallic teeth were biting on the fiber, causing it to bend in somewhat acute angles. This caused most of the light to leak on this spot, being visible at this point to the human eye for this exact reason. Meanwhile, the power on the screen was visibly reduced, confirming the increase in leakage at the scrambler.

Task:

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.

Break off the fiber 1/2 meter after the mode scrambler 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.

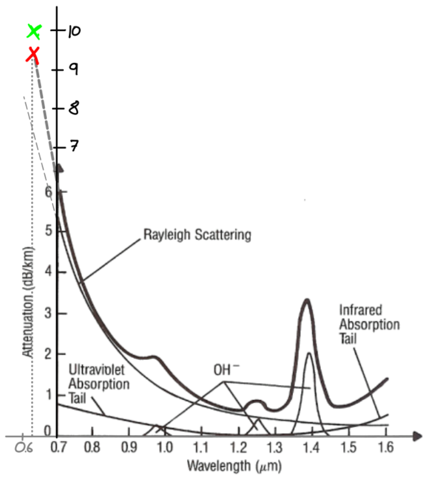
This procedure was made to achieve a measurement of the incident light power at the scrambler's location. The fiber was cleaved at the breaking point, and the laser was again aimed at the start of the fiber. The newly cleaved end was aimed into the power meter so as to make a measurement. The power observed was of $P_{\text{in}} = 480\ \mu W$. The power measured with the whole spool and scrambler in place was of $P_{\text{out}} = 158.5\ \mu W$.

Task:

Calculate the fiber attenuation, using the equation given above, and compare this with the attenuation written in the fiber specification on the spool. Your value is probably somewhat higher than the specification. Why?

The equation used to calculate attenuation is

$$\alpha = -\frac{10}{L}\log_{10}\left(\frac{P_{in}}{P_{out}}\right) = -\frac{10}{487.28}\log_{10}\left(\frac{158.5}{480}\right) = 9.875\cdot 10^{-3}\left[\frac{db}{m}\right] = 9.875\left[\frac{db}{km}\right] \tag{1}$$



As the exercise title suggests, the attenuation per kilometer is is higher than what it is expected, which is about 0.17 $^{dB}/_{km}$ at 1550 nm for a single mode fiber. However the laser we used was in the visible range, not infrared, where by looking at the table we can see how the expected attenuation is more on the range of 9.4 $^{db}/_{km}$, which is within 5% of the expected value.

If it is higher than expected, I would attribute this to the scrambler setup; multimodal fibers have higher attenuation and any mode that the scrambler might have not eliminated would have affected the final result which was, in fact, somewhat higher.

The gray lines are prolongations from the original plot and may not represent accurately real life. The reason for this is that I could not find reliable sources with values of attenuation for our experimental wavelength. The red cross represents the expected value and the green one the 'literature' point.

2 Addenda

LaTeX code that generates this document

PHOTONICS-LabRep8:attenuation.tex