EXPERIMENT 8

OTDR MEASUREMENT OF FIBER LENGTH, ATTENUATION AND SPLICE LOSS

OBJECTIVES:

In this experiment, the fiber's length, fiber's attenuation and splice loss of a relatively short unknown optical fiber link will be measured using the OTDR at two different operating wavelengths.

EQUIPMENT REQUIRED

1- OTDR: Agilent Technologies E6000 Mini OTDR Main Frame with E6005A Module (850/1300 nm High Performance Multimode Module).
2- Unknown length of *two different types* of fibers connected together with *three* splices (two *fusion* splices and one *mechanical* splice). The fiber types are: $50\,\mu m$ multimode GI (orange) and $62.5\,\mu m$ multimode GI (gray).

PRELAB ASSIGNMENT:

Read the introduction to this laboratory and review the previous experiment and the OTDR manual to prepare for this experiment.

INTRODUCTION:

Figure 1 shows an imaginary OTDR trace of an optical fiber link in which three different types of fibers are connected together to form the entire link. This arrangement is not very common in practice, but some existing links use more than one fiber type. The reason we know that three different types of fibers exist in the link (whose OTDR scan is shown in Figure 1) is because there are three distinct straight lines (due to Rayleigh scatter) with *different* slopes. The first line segment has a slightly larger slope than the second straight line segment. This means fiber 1 is slightly lossier than fiber 2. Therefore, they must be different types of fibers.

From the trace, we also know that the lengths of fibers 1, 2 and 3 are L_1, $L_2 - L_1$ and $L_3 - L_2$, respectively. We already know how to find the fiber's attenuation in dB per unit length by finding the slope of each straight line segment, since we did this in the previous experiment. The splice between fibers 1 and 2, located at $z = L_1$, is non-reflective because of the sudden *decrease* in the reflected power without a spike. Non-reflective event can be due to either a good splice, fiber break or fiber bends. We can find the loss of this splice, simply by calculating the difference in the power levels before and after the splice (i.e. $P_1 - P_1^{'}$).

The joint between fibers 2 and 3, located at $z = L_2$, is reflective because of the sudden *increase* (*with a spike*) in the reflected power (if the sudden increase has no spike, then it must be interpreted as a non-reflective event). The joint between fibers 2 and 3 could be due to either a poor splice or a connector. The loss due to this joint can be calculated as before (i.e. $P_2 - P_2^{'}$). The trace also shows a reflective fiber's end at $z = L_3$. This is due to light reflection at the glass/air interface (Fresnel reflection) at the fiber's end. If desired, the fiber's end can be made non-reflected. This can be done by immersing the fiber's end into *an index-matched fluid* (a fluid that has the same refractive index as glass) to minimize Fresnel reflection. Alternatively, it is also possible to wrap the fiber's end several times around a tight bend to produce a non-reflective end. The tight bend causes large power loss, without reflection. In this manner, the light reaching the un-terminated fiber's end becomes too weak to detect.

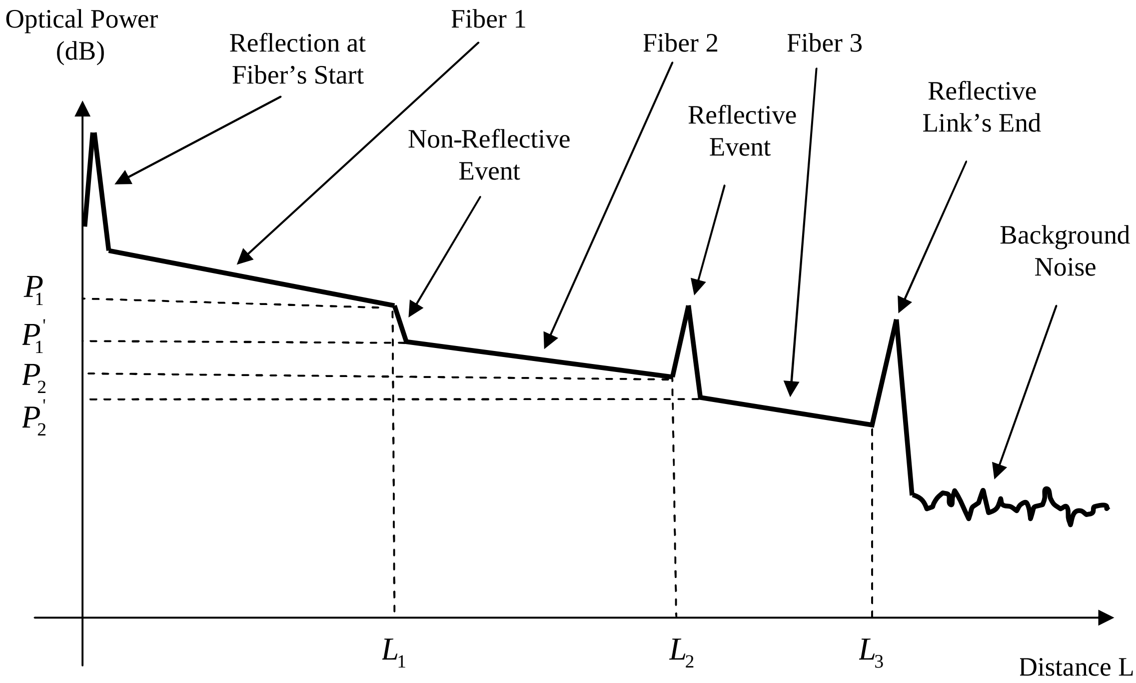

Figure 1: An Imaginary OTDR Trace of an Optical Fiber Link Consisting of Three Different Fiber Types Spliced Together. The OTDR Trace Shows the Locations of the Reflective Events, the Non-Reflective Events and the Link's End.

The OTDR trace shown in Figure 1 assumes that the three fibers used in the link have the same *Rayleigh scattering coefficients*. Rayleigh scattering coefficient is related to the *fraction of power scattered due to Rayleigh* scatter. For instance, suppose fiber 2 has a significantly higher Rayleigh scattering coefficient than fibers 1 and 3, then the OTDR scan of Figure 1 may be modified to the one shown in Figure 2. The OTDR trace due to Rayleigh scatter from fiber 2 appears as *power gain*. In this link, it is impossible to have optical power gain, because the system does not have optical amplifiers. The sudden rise in power is simply due to the higher percentage of power scattered from fiber 2. In reality the optical power in fiber 2 is less than the optical power in fiber 1.

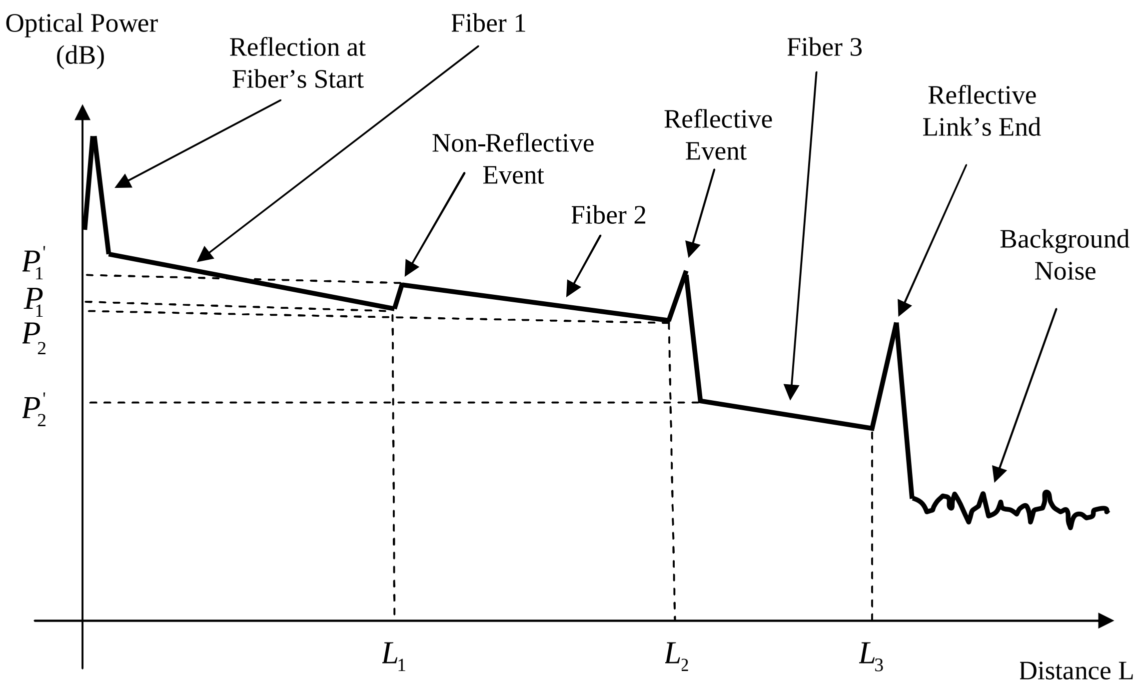

Figure 2: Sudden Rise in the Scattered Power when Fiber 2 has a higher Rayleigh Scattering Coefficient than Fiber 1 and Fiber 3.

When two fibers with different Rayleigh scattering coefficients are joined together, the joint loss *cannot be calculated* using the difference in power $P_1 - P_1'$ and $P_2 - P_2'$. The only way to compute the joint loss in this case is by first knowing the Rayleigh scattering coefficient of the two fibers. Unfortunately, we do not know the values of the Rayleigh scattering coefficients for the fiber types used in the experimental link. To summarize: when two different fiber types are joined together, the joint loss cannot be computed from the OTDR trace, unless the Rayleigh scattering coefficients of the two fibers are known.

The optical fiber link that you are going to examine in this experiment consists of two fiber types joined together using three joints. The first and second joints are fusion splices between two dissimilar fibers. The last joint is a *homemade mechanical splice* between two identical fibers. Thus, only the loss of this third joint can be computed, because it connects two identical fibers. In addition, because this splice is mechanical, its dB loss is expected to be relatively high.

PROCEDURE:

[**The test fiber should be connected by the laboratory instructor or the laboratory technician.** ***Do not remove the fiber from the OTDR. DO NOT LOOK DIRECTLY AT THE OUTPUT END OF THE FIBER***].

INVETIGATING A FIBER OPTIC LINK.

1- Read the fiber reel *letter* (e.g. A, B, C, etc.) and record it in the top row of table 1.
2-Turn the OTDR on and wait for the self test to end.
3- Select $\lambda = 855\,nm$ from the SETTINGS menu.

4- Select AUTO.
5- Press the RUN/STOP to generate an OTDR trace and wait for the averaging to end or the trace to be free of noise.
6- Print the trace. [*The printed trace should be included in your experimental report. The printed trace must show the correct wavelength*].
7- Find the distance from the fiber's start to the first splice (splice 1). Record the distance in table 1.
8- Zoom around splice 1 until you see it clearly and print the magnified OTDR trace. [*Change both the horizontal and vertical scales to see the details. Include the magnified trace in your report*].
9- Determine if the splice is reflective or non-reflective and record the result in table 1.
10- Repeat steps 7 - 9 for the second splice.
11- Repeat steps 7 - 9 for the third splice. In addition, compute the splice loss and record it in table 1.
12- Find the total link length and record it in table 1.
13- Find the total link loss in dB and record it in table 1. The total link loss can be found by finding the difference in dB *just to the right of the fiber's start* and *just to the left of the fiber's end.*
14- Find the loss in dB/Km for the first link segment and record it in table 1 (*Determine the slope of the straight line segment from just to the right of the fiber's start till the very beginning of splice 1, i.e. the left hand side edge*).
15. Repeat step 14 for link segments 2, 3 and 4.
16- Repeat steps 3-15 at $\lambda = 1310\,nm$. Record the result in table 2.
17- Compare the fiber lengths measured at $\lambda = 855\,nm$ and $\lambda = 1310\,nm$. Discuss.
18- Compare the losses (in dB/Km) of the four fiber segments at $\lambda = 855\,nm$ and indicate if the four segments are made of the *same* fiber type or *different* fiber types.
19- Compare the fiber losses (in dB/Km) and at $\lambda = 855\,nm$ and $\lambda = 1310\,nm$. Are those losses expected to be dependent or independent of λ ? Discuss.
20- Compare the measured loss of the third splice at $\lambda = 855\,nm$ and $\lambda = 1310\,nm$.
21- Discuss the over all experimental results and make appropriate comments and conclusions.

FIBER REEL LETTER ( )	
Location of splice 1 (m)	
Type of splice 1 (Reflective/Non Reflective)	
Location of splice 2 (m)	
Type of splice 2 (Reflective/Non Reflective)	
Location of splice 3 (m)	
Loss of splice 3 (dB)	
Type of splice 3 (Reflective/Non Reflective)	
Total link length (m)	
Total Link Loss (dB) [Including splice loss]	
dB Loss/Km of segment 1	
dB Loss/Km of segment 2	
dB Loss/Km of segment 3	
dB Loss/Km of segment 4	

Table 1: Summary of OTDR Measurements at $\lambda = 855\,nm$.

Location of splice 1 (m)	
Type of splice 1 (Reflective/Non Reflective)	
Location of splice 2 (m)	
Type of splice 2 (Reflective/Non Reflective)	
Location of splice 3 (m)	
Loss of splice 3 (dB)	
Type of splice 3 (Reflective/Non Reflective)	
Total link length (m)	
Total Link Loss (dB) [Including splice loss]	
dB Loss/Km of segment 1	
dB Loss/Km of segment 2	
dB Loss/Km of segment 3	
dB Loss/Km of segment 4	

Table 2: Summary of OTDR Measurements at $\lambda = 1310\,nm$.

QUESTIONS:

1- Is the *end* of the link reflective or non-reflective? If it is reflective, what can you do to make it non-reflective?

2- Is the third splice you found good or poor? Explain.

3- Are the types of fibers used in this experiment suitable for *a repeaterless* link 50 Km long and operating at $\lambda = 1310\,nm$? Explain briefly.

4- Using the experimental data for $\lambda = 1310\,nm$. What is transmission efficiency of the third splice? (Hint: $\eta = 10^{-0.1 dB_{loss}}$).

5- Suppose that the input power to the experimental link at $\lambda = 855\,nm$ is $5mW$. Calculate the power remaining in the fiber *just before the fiber's end.*

6- In some cases, it is possible to immediately know if the link has more one type of fiber (without finding the fiber loss in dB/km). Explain.