Simple application of

Optical Time Domain

Reflectometer

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Abstract

From this experiment we could know the basic component of the OTDR, Optical Time Domain Reflectometer. In optics application, OTDR is mainly used for trouble-shooting in optical fiber network, and finding out the distance to the problem.

Here we simulate a simple situation—a broken fiber, using a long fiber and measure the reflected signal from the other side of coupling.

Main idea

Realize the fundamental of Optical Time Domain Reflectometer, make a simple practice and set up.

Experiment equipments

**Item list**

Laser sources
1. 632nm laser beam 1.
   for light path correction
2. 1eV (1240nm) diode laser w/ pulse generator 1.
   major signal source

Light coupling devices
3. fiber coupler 1 set.
4. beam splitter 1.

Specimen
5. a core refractive index=1.46 multimode fiber about 500m.

Detectors
6. photo diode w/ supply 1 set.

Observation tools
7. oscilloscope 1.
8. CCD(IR, visible) w/ monitor 1 set.
9. IR card 1.

Miscellaneous
10. support braces numerous.
11. support table 1.

*OTDR main components: light source and detector include item 2, 3, 4, and 6.

*1. FI=1.46 is borrowed from single mode fiber, and the result is quite close.

Photographs of important equipments
Item 2. diode laser w/ pulse gen.
Item 6. photo diode w/ supply
Item 4. beam splitter
Item 7. oscilloscope
Item 3. fiber coupler

Setup graph
The principle in application

Optical Time Domain Reflectometer—it is a common way to measure if the optical fiber network is well, and to find out where the signal loss and attenuation is.

OTDR uses **backscatter** to indirectly measure the loss of signal. Put it in simple, **backscatter** here means to mete the difference between incidental signal and reflected instead of **cut-back**, directly measure the two ends of fiber. This way makes the measurements easier on already setup networks.

When light pulse incidents into fiber, parts will be reflected at reflection and scattering positions. These effects could be explained by **Rayleigh scattering** and **Fresnel reflection**. Rayleigh scattering is responsible for most attenuations, while Fresnel for interface defects or breaks along the fiber length. For more information, readers could get details in almost all optics books.

Analyze the results, we could know attenuation, insertion loss, and clearly know where the connect points, brakes, and bends are.

Below is the general components setup chart:

The general process is following: (1) laser diode emits a light/laser pulse, (2) through directional coupler and front connector (in this experiment, we use a beam splitter and a coupler instead, this part can redirection returned pulses), (3) to fiber under test, (4) than from photodiode/signal amplifier, reads the data and using other analyzing programs to draw out the info we need.

Below is a general measurement result of OTDR. Vertical axis is reflected signal power
in dB, while horizontal is the range of OTDR to some point in fiber.  

**Basic meaning of measured results in plot**

- **Lines:** Rayleigh backscattering distribution.

- **Slope of Lines:** loss per km in fiber (dB/km).

- **Positive spike:** Fresnel reflection distribution. Mechanical connections, connectors, and broken will have minor reflections, caused positive spikes. At the end of fiber, it will have a enormous reflection and produce positive or negative spikes according to fiber’s physics specification.
**Front connector**: The connection between OTDR and object fiber, usually is a bad connector. A bad connector will make loss of photo-power because of insertion loss, as well as multiple reflections.

**Fusion splice**: Gamoconnection points will make the backscatter level trace in plot suddenly dropped.

**Bend**: The stress from environment bends the fiber, and makes parts of light project from cladding, induce the trace sudden drop in plot, same as Gamoconnection points.

At last, here is the OTDR setup photo of this experiment:

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**Practice steps**

*The signal attenuation part has been ignored since no powermeter provided this time.*

1. Setup OTDR.
2. Correct the coupling kit with 623nm red light He-Ne laser.
   *The beam splitter is a small square cube, you should let the directions of projecting lights as perpendicular as possible.*
3. Instead He-Ne laser of pulsed IR diode laser and make minor corrections.
   Some may have problem at this step. You should have noticed that the beam from IR laser diode is not concentrated. For this reason, we should make the distance between each item is nearest. When you change He-Ne laser to IR laser, the
direction and altitude of IR diode laser should still the same as He-Ne laser, using IR
card or CCD camera to help you check this.

4. Adjust the amplifier of photo diode until see the reflect signal on oscilloscope,
remember to send trigger signal.

5. Record it and analyze what you have seen.

6. For advance users, you may recode the amplitude of signals using computer and
calculate the attenuation in distance.

**THIS STEP MAY NEED VERY MUCH EFFORT.**

**Data analyzing**

From oscilloscope monitor below, we could see the time lag between front connector
reflect and fiber end’s.

![Oscilloscope Monitor](image)

You can see the reflected signal is similar to original.

Delay time is $4.680 \mu s$, from first peak(higher) to second peak(lower).

Light speed in this fiber is: $c_f = c_0 \times 1.46 \times 2.05337300 \times 10^8 (m/s)$, multiply delay
time is the length of light goes through: $l_f = 960.978546 (m)$.

Last step, divide $l_f$ by 2, get the length of fiber:

$$ l_f = 480.489282 (m). $$

As the length NEWPORT wrote on the side of flake of fiber, 500 meters, is close to the
result we got: 481m. In the order of magnitude, it’s correct. For more precise calculation, we
must exactly know the refraction index of IR diode laser. For something you may not advert,
this index is borrow from single mode’s, so may vary on this multi mode fiber. I’ve mailed
technical support of NEWPORT, but they haven’t replied yet before I complete this report.

In most cases in practice, the index is a must know for tests.

*Notice: Here we ignored other minor reflections (by beam splitter, condense len, fiber’s coupling side, etc) because it’s much shorter than fiber’s length, and it’s not the primary information we need.

Notes

This experiment uses IR laser diode as the source, quite similar to normal application in commercial(1310nm). Actually, OTDR can do much more than what we did in this experiment.

We could clearly see fiber end’s reflection even without a mirror/polished metal at the end, also tells the reflection not only happens on full reflect interface. This characteristic is important in fiber communications.

For technical advise, CCD camera w/ monitor helps a lot in set up this IR coupling mission, lots more helpful than IR-card, which turn IR lights into visible lights, if the intension is enough to see.

Reference:

http://fiber.et.ntust.edu.tw/main/newpage112.htm
http://www.2cm.com.tw/docs/serial/12/c01225.htm
http://www.flukenetworks.com/us/Cabling/Copper+Cabling/OptiFiber/Features/Auto+OTDR+Analysis.htm
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