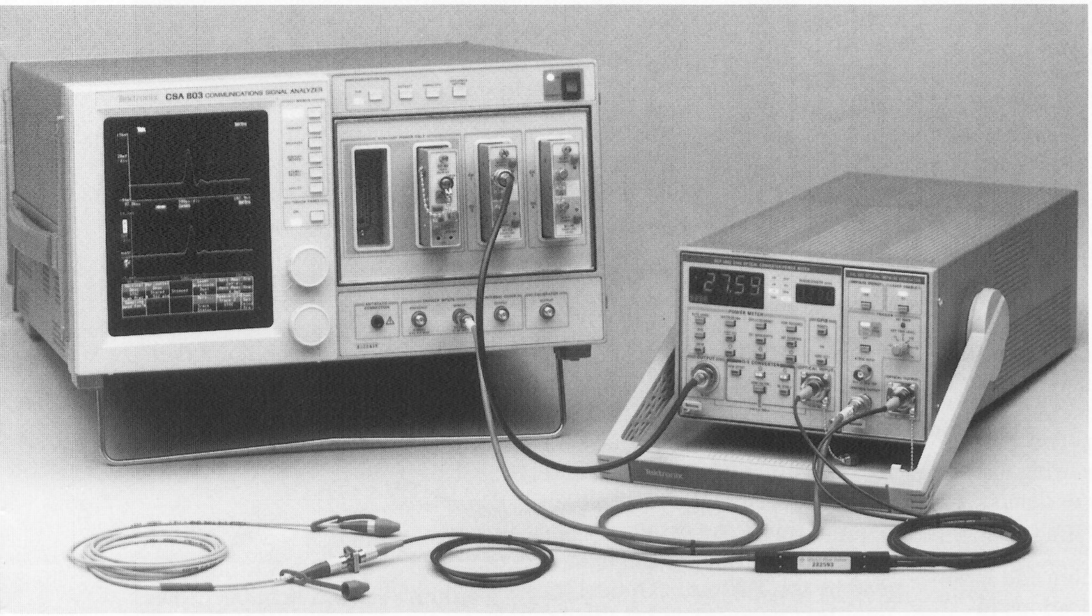
Application Note

Tektronix
Test and Measurement

OIG 500

High-Resolution Optical Reflection Testing with the Tektronix OIG 500 Series Optical Impulse Generators



Optical Reflection test bench

Time domain reflectometry (TDR) has been a well-understood, often-used measurement method for decades. The basic concept is quite simple. A pulse of energy is applied to a transmission path. As this pulse travels the path, some of its energy is absorbed by various loss mechanisms. Some of its energy is reflected by discontinuities in the path. And any remaining energy is absorbed (reflected or transmitted) by the transmission device.

In short, TDR is a means of evaluating certain transmission path characteristics by analyzing the reflected pulse energy. When applied to fiber optic paths, the measurements are typically made with an optical time domain reflectometer (OTDR).

SOME KEY TERMS

Dead Zone – An area where OTDR cannot "see" a reflection or distinguish multiple reflections.

Fresnel Reflection – Optical energy that is reflected by a change in medium, such as the unterminated end of an optical fiber.

Incident Pulse – An optical impulse launched into a fiber or optical subassembly to induce reflections for acquisition and analysis by an OTDR system.

Rayleigh Scattering – Signals that result from the interaction of electromagnetic radiation with inhomogeneities in a fiber.

Return Loss – The level of a returning reflection relative to a reference reflection, usually expressed in dB.

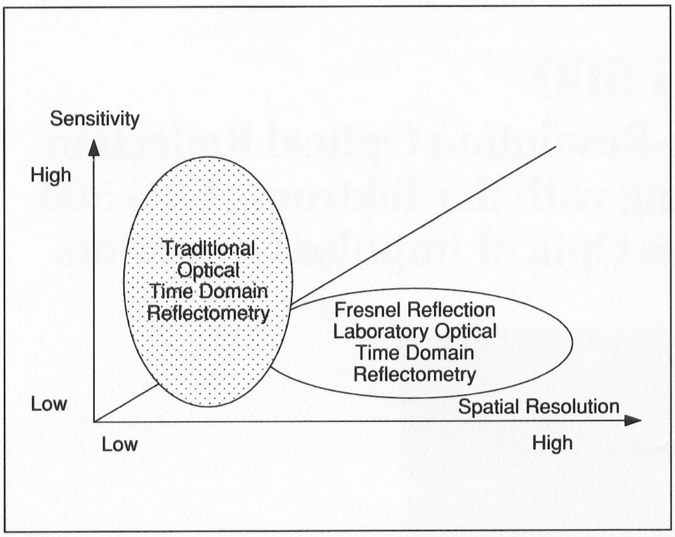


Figure 1. Rayleigh scattering OTDRs differ markedly from Fresnel reflection OTDRs in sensitivity and spatial resolution. These differences result in optimum solutions for different applications.

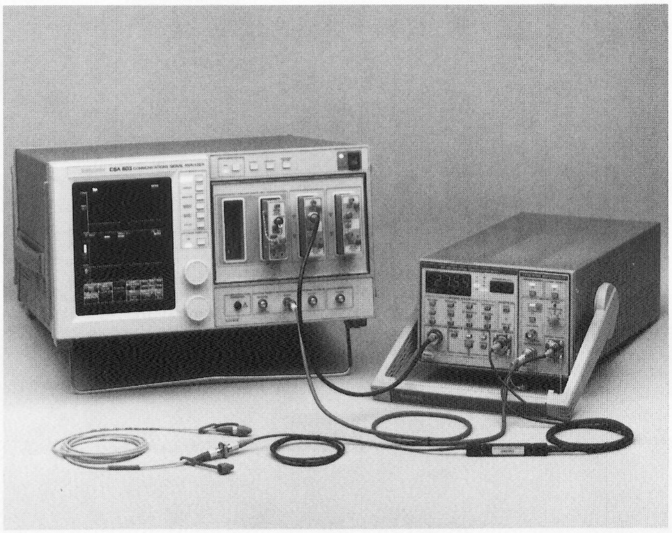


Figure 2. A system for high-resolution measurement of optical component reflection level (return loss) and optical fiber lengths. The system uses a Tektronix OIG 502 to apply optical impulses shorter than 35 ps and a Tektronix CSA 803 to capture and analyze reflections.

Most OTDRs are designed and optimized for measurements based on reflections caused by Rayleigh scattering. This makes them ideal for measuring losses and finding breaks or defects in long-distance fiber optic links.

Today, however, more and more measurement applications involve short fiber lengths. These runs could be several meters or even less than a meter. Often, it's also necessary to evaluate a specific optical component, such as a splice or a connector. This requires extremely precise spatial (distance) resolution, down to a few millimeters or less for example.

Rayleigh scattering OTDRs simply don't provide this kind of resolution, as indicated by Figure 1. Their spatial resolution is limited by their high sensitivity and associated dead zones. In today's OTDRs, these dead zones are short enough that breaks or defects can still be resolved within a meter or so. This is quite adequate for servicing long fiber runs, such as several kilometers. But it's not adequate for observing reflections on short cable runs (a few meters or less) and especially not for evaluating optical connectors.

However, you can obtain the necessary resolution by using extremely narrow optical impulses and measuring Fresnel reflections. Figure 2 shows an instrument system for making such measurements. This application note discusses how this system works and how to use it for precision distance and reflection measurements. A key element in this is the extremely narrow optical impulses generated by the Tektronix Optical Impulse Generator and the wide bandwidth acquisition capabilities of the instrument system.

Some Optical Reflection Theory. To better understand the capabilities and use of the system in Figure 2, it's best to review some OTDR theory first.

All forms of OTDR require a pulsed light source and a detection system. The light source is directed at the object being characterized. For our purposes here, that object is an optical fiber. The detection system is then used to capture and observe the light reflected from the fiber.

One of the simplest mechanisms for reflecting light occurs when the light reaches a change in medium. This could be the end of the fiber for example. When such a change is reached, the light reflects according to equations first proposed by Augustin Fresnel (pronounced "frah-nel"). These reflections are typically referred to as Fresnel reflections.

For properly cleaved fibers, the light beam will be normally incident (perpendicular) to the reflecting surface (end of the fiber). When normal incidence is the case, reflectivity is given by the following Fresnel equation –

$$R = (n-1)^2/(n+1)^2$$

In this equation, $n = n_2/n_1$. This is the ratio of the transmitting medium's refractive index (n_2) to the refractive index of the reflecting medium (n_1).

To get an idea of the reflection levels to expect, let's put some typical values into the above equation. For example, let's look at glass, which is the typical medium in an optical fiber. Glass has a refractive index of 1.5. If a glass fiber is properly cleaved and the end left terminated in air, the air is the reflecting medium. Air has a refractive index of 1.0. Thus, $n = 1.5/1.0 = 1.5$.

Computing R with $n = 1.5$ yields the following result –

$$R = (1.5-1)^2/(1.5+1)^2 = 0.25/6.25 = 0.04$$

This means that the expected back reflection at the end of the fiber should be approximately 4% of the incident light pulse.

Usually reflection levels are expressed in dB as a return loss. This is done as follows –

$$RL\ dB = 10 \bullet \log_{10}(R)$$

So, for the case of $R = 0.04$, the dB reflection level (or return loss) is –14 dB. In other words, an air terminated fiber has a Fresnel reflection return loss of –14 dB.

Another useful example is the case where the fiber is terminated in water. Water has a refractive index of 1.33. So n = 1.5/1.33 = 1.13. This results in a reflection of –

$R = (1.13-1.0)^2/(1.13+1.0)^2 = 0.0169/4.54 = 0.0037$

This tells us that a reflection from water termination is only 0.37% (or –24.3 dB return loss). That's roughly 10 times less than a fiber terminated in air.

In early fiber optics, none of the optical connectors were physically contacting (PC). As a result, when light came to a connector, at least 4% of it would be Fresnel reflected.

Today, many of the better connectors offer a physical contacting version, such as FC/PC. This eliminates much of the Fresnel reflection. In fact, return losses as low as –30 dB (0.1%) are often specified.

However, if a piece of dust or other foreign matter gets on the ends of a PC connector, physical contact may not be made. This, of course, will result in 4% Fresnel reflections due to the air gap. In practice, the dust particle itself may cause even higher reflections. Also, since the end faces of the glass fibers in the PC connectors actually come into contact, they are susceptible to scratching or other work damage if a contaminant is present.

Fresnel reflections are generally visible only when there is a clean, abrupt interface, such as a cleaved fiber. However, in many cases, the reflected optical energy needed for fiber characterization may be several orders of magnitude lower than that possible from Fresnel reflections. For example, fusion splices often have less than –50 dB of back reflection. In other cases, a fiber may be cracked or crushed, resulting in a very irregular termination. Back reflection from such defects will be very low.

Defects that cause very low reflections can be characterized by measuring optical signal loss through the defect. This requires use of an optical signal source at one end of the fiber under test and a detector on the far side the defect. A much more convenient alternative for long fibers is to characterize the defect from one end of the fiber by using Rayleigh scattering.

Rayleigh scattering results from the interaction of electromagnetic radiation with inhomogeneities in the fiber. The scattering signals from this can be as low as –90 dB. As a result, Rayleigh scattering OTDRs must have extremely high sensitivity. But optimizing for sensitivity means putting more energy into each optical pulse so that the backscatter can be measured. This is done by using wider optical pulses (usually on the order of 1 µS) for testing. The end result is that the system's spatial resolution is degraded as pulse width, and hence sensitivity, increases.

Additionally, there are resolution limitations resulting from dead zones in Rayleigh scattering OTDRs. Dead zones are areas where the OTDR is essentially "blinded" for short periods of time during which it's unable to "see" reflected energy. The primary factors affecting dead zone occurrence and duration are OTDR receiver overdrive recovery time and the optical pulse's length.

What happens is that the receiver's high sensitivity allows it to be easily overdriven. This inevitably occurs when the incident optical pulse is launched into the fiber. The incident pulse's high energy over drives the receiver, blinding it for a dead zone at the front panel. The length of this dead zone, which is the time it takes for the receiver to recover from being overdriven, is usually a few meters.

Dead zones also occur beyond the front panel in the reflection trace. These are due to the optical pulse's length. Essentially, an optical pulse of a given length is inherently unable to discriminate ("to see") multiple reflective events spaced closer together than the pulse's length. Thus, only one event is seen where there may be several closely spaced events.

The trick to designing a capable OTDR is to be able to launch sufficient optical power to produce backscatter signals that are still detectable after transiting long fiber runs. At the same time, OTDR sensitivity has to be high enough to detect heavily attenuated backscatter signals, and instrument recovery times have to be minimized for dead-zone reduction. With the right combination of launched power (and waveshape), sensitivity, and instrument recovery, spatial resolutions on the order of a few meters or less can be obtained. This is fine for locating defects in fiber runs of kilometers or even hundreds of kilometers. And that's just the type of application where Rayleigh scattering OTDRs do best.

For example, the Tektronix FiberMaster, which is a Rayleigh scattering OTDR, has dead zones as small as four meters. It can also provide resolutions down to one meter, and it can cover fiber runs as long as 200 kilometers.

But, if you want to examine fiber optic media and subassemblies with closely spaced optical components, spatial resolution must be on the order of a centimeter or less. You may even need resolution into the millimeter range for some applications. For such resolution, the test system must use extremely narrow optical pulses and be optimized for high bandwidth.

The sensitivity of such a system won't be as high as a Rayleigh scattering system. But it needn't be that high for measuring Fresnel reflections. These reflections, as discussed previously, typically run from –14 dB to –30 dB of return loss and can be lower in some cases.

Test Equipment Selection. The exact combination of test equipment used for Fresnel reflection measurements depends on the specific application. Table 1 lists a variety of Tektronix instrument combinations that provide various resolutions and sensitivities.

For highest time resolution, you probably want to use an SD-46 20 GHz O/E Converter and an SD-26 20 GHz Sampling Head with the Tektronix 11800 Series Digital Sampling Oscilloscope or CSA 803 Communications Signal Analyzer. However, for connector return loss (back reflection) evaluation, the recommended combination is a CSA 404 with a high bandwidth amplifier and the Tektronix OCP5002 Optical Converter/Power Meter.

The CSA 404 provides the best time-distance resolution. This is due to the random sampling and trigger method used. Rather than triggering and counting out samples to the event in question, as is the case with sequential sampling, the CSA 404 allows triggering to be moved out to the event in question. This reduces jitter and allows full resolution to be applied at the event. This makes the CSA 404 a better acquisition system for ranges 200 meters and beyond.

For any of these systems, including the one in Figure 2, the amplified 2 GHz O/E converter in the OCP5002 allows the system to measure return losses as low as –50 dB. Also, the OCP5002 has an integral average power reading meter. This allows additional measurements, such as connector insertion-loss, without having to connect a separate power meter.

It's important to note that all of the systems discussed here use a Tektronix OIG 500 Series Optical Impulse Generator. This generator provides a selection of low-energy or high-energy optical impulses for different reflection measurement applications. For example, the low-energy impulse resolves distances as close as 4 mm when used with the appropriate acquisition system. On the other hand, the high-energy impulse allows you to detect return losses as low as –50 dB with certain acquisition systems.

Understanding the OIG 502 Pulse Shapes. Before using the OIG 502, it's important to understand the differences between the low-energy and high-energy impulse waveshapes. It's also important to understand how the measurement system affects these impulses.

Table 1

Reflection Measurement Performance of Selected Tektronix Acquisition Systems

Acquisition System	Single Event Distance Resolution	Typical FWHM Distance Resolution	Typical Reflection Sensitivity*
CSA 803 or 11800 Series Oscilloscope with with SD-22 Sampling Head and OCP 5002 O/E Converter	<0.1 mm***	2.3 cm***	−50 dB***
CSA 803 or 11800 Series Oscilloscope with SD-26 Sampling Head and SD-46 O/E Converter	<0.1 mm**	3.4 mm**	−28 dB**
CSA 803 or 11800 Series Oscilloscope with SD-22 Sampling Head and SD-46 O/E Converter	<0.1 mm**	6.4 mm**	−32 dB**
CSA 803 or 11800 Series Oscilloscope with SD-26 Sampling Head and SD-42 O/E Converter	<0.1 mm**	5.5 mm**	−27 dB**
CSA 803 or 11800 Series Oscilloscope with SD-22 Sampling Head and SD-42 O/E Converter	<0.1 mm**	5.9 mm**	−34 dB**
CSA 803 or 11800 Series Oscilloscope with SD-22 Sampling Head and P6703 O/E Converter	<0.1 mm***	4.5 cm***	−47 dB***
11403 Oscilloscope with 11A71 Amplifier and P6703 O/E Converter	<0.1 mm***	5.5 cm***	−46 dB***
2440 Oscilloscope with P6703 O/E Converter	<4.0 mm***	12 cm***	−43 dB***

* All measurements made after averaging 512 traces.

** Measurements using the OIG 502 low-energy impulse

*** Measurements using the OIG 502 high-energy impulse.

Note that the product combination with the highest resolution has the lowest sensitivity and vice versa.

Figure 3 shows the low-energy impulse waveshape. This was captured and displayed using a Tektronix 11801A digital sampling oscilloscope with an SD-26 Sampling Head and SD-46 O/E Converter. Both the SD-26 and SD-46 have 20-GHz bandwidths.

Notice that the low-energy impulse has an essentially Gaussian shape. Also, as measured with the SD-26 and SD-46, it typically has 5 mW of peak power and is 35 ps full width at half maximum (FWHM).

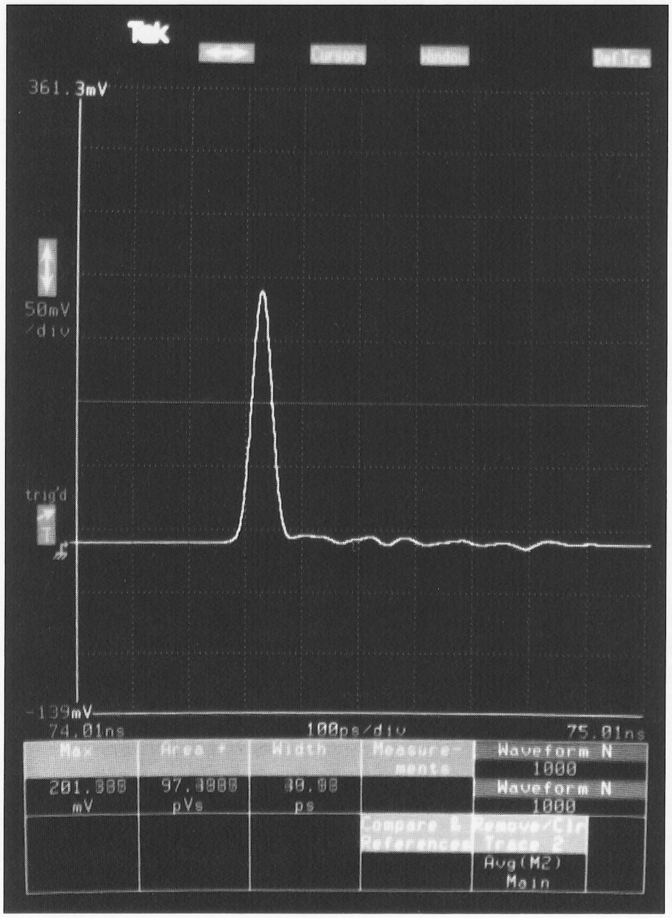
The high-energy pulse, shown in Figure 4, is somewhat different. As measured with the CSA 803/SD-26/SD-46 combination, it typically produces an impulse of 15 mW peak energy and 250 ps FWHM. Notice also that the high-energy pulse has a more complicated structure. This pulse is intended to maximize the optical energy launched into the fiber. It does so at the expense of the near Gaussian shape.

The high-energy impulse is normally used with lower bandwidth equipment. It's also used in applications requiring higher total pulse energy, such as reflection testing.

Both the low- and high-energy impulses will appear somewhat broader than their actual specified values. This broadening is due to the total rise time of the measurement system used. The point is that the impulse broadening and flattening tend to increase with lower bandwidth O/E converters and sampling heads. Thus, it's always important to consider pulse response when selecting a measurement system for use in optical measurements with the OIG 502 General Optical Reflection Test Setup.

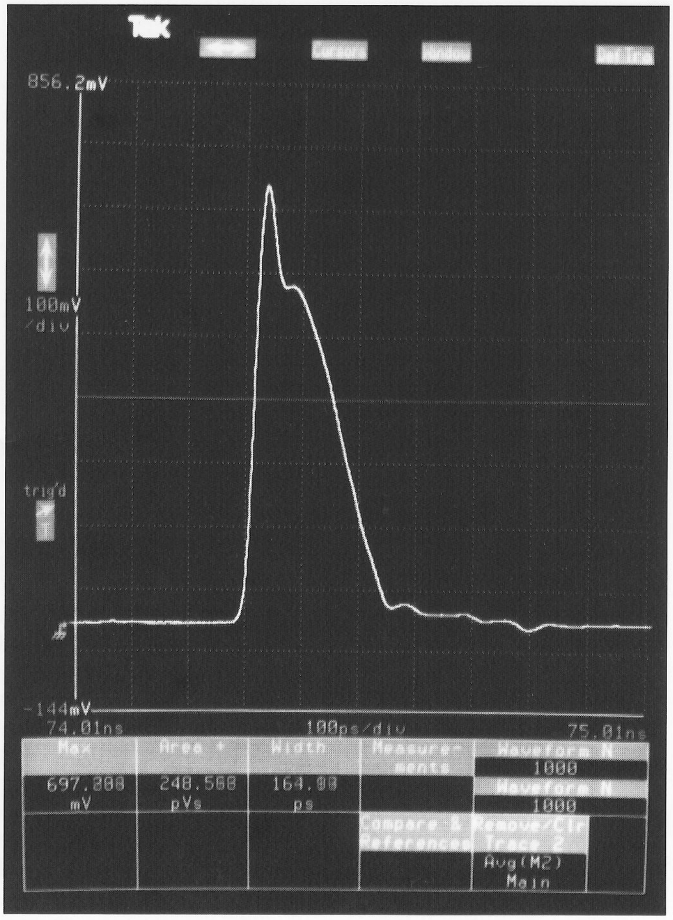
Figures 5 and 6 show the general test configurations for reflection testing. The only difference in these two setups is in the type of O/E converter used (scope plug-in O/E head or standalone OCP5002).

Notice also that the splitter is connected to direct return reflections to the O/E converter. What is typically considered to be one of the splitter's output legs is actually used as the input for the incident pulse, and the splitter's input is used to output the pulse to the fiber or device under test (DUT). This reversed or backward connection of the splitter allows it to be used as a directional coupler. (The splitter used for this should have one input with two 50% output legs and be of the fused biconic type – i.e., a 1x2, 50:50, optical splitter.)



Max 201.000 mV
Area + 97.0000 pVs
Width 40.00 ps

Figure 3. The OIG 502 low-energy impulse as captured by a Tektronix 11810A sampling oscilloscope with an SD-26 Sampling Head and SD-46 Optical to Electrical Converter.



Max 697.000 mV
Area + 248.500 pVs
Width 164.00 ps

Figure 4. The OIG 502 high-energy optical impulse as captured by a Tektronix CSA 803 Communications Signal Analyzer with an SD-26 Sampling Head and SD-46 Optical to Electrical Converter.

The basic system setup and use is as follows:

1. Before connecting the splitter and any fiber jumpers or pigtails, make sure all fiber ends have been cleaned.
2. As indicated in Figures 7 and 8, connect the OIG 502 OPTICAL OUTPUT to one of the "output" legs of a 3 dB optical splitter with an appropriate fiber size. (If the splitter doesn't have pigtails, use short fiber jumpers for the connections.)

The recommended OIG 502 setup is as follows:

Laser Enable:	Active
Impulse Energy:	High
Internal Trigger:	1 MHz

3. Connect the other splitter "output" to the O/E converter and the O/E converter to the oscilloscope's sampling head.
4. Be sure the unconnected end of the pigtail (or jumper) on the splitter input has been cleaned for a good air-glass interface. This interface provides the –14 dB Fresnel reflection reference.
5. Connect the OIG 502 -PRETRIG OUTPUT to a 5X attenuator. Then connect the 5X attenuator to the oscilloscope trigger input. This connection is used to synchronize scope acquisition with OIG 502 impulse generation. For this, the oscilloscope's triggering should be set to EXTernal and –SLOPE.
6. Select the desired OIG 502 pulse energy and the internal trigger rate. (HIGH energy and the 1 MHz INT rate usually work best for reflection applications. However, when looking at long optical fiber runs – e.g., about 200 meters and longer – you may begin to see a second occurrence of the 1 MHz impulse. When this happens, you may want to select a lower repetition rate in order to see just the reflection that you want to measure. Then, once you've identified the reflection to measure, switch back to 1 Mhz to get the best measurement of the reflection amplitude.)
7. Make sure the oscilloscope is properly set up for waveform acquisition and that the channel for the sampling head being used is selected.

With the system set up as above, press the oscilloscope's AUTOSET button to get an initial reflection display. Look at the display closely for the reflection from the air-terminated end of the splitter pigtail (or jumper). You'll probably need to adjust the scope's time window to find this reflection. To do this, set the scope's Vertical Size to 20 mV and Main size to about 90 ns. You should now see the reflection from the unterminated end of the splitter.

In setting up an initial reflection display, it's also best to use the OIG 502's high-energy pulse. This provides a larger, easier-to-see pulse for initial location of the reflection. Once you've found the reflection, you can switch back to the low-energy impulse if that's what your application requires.

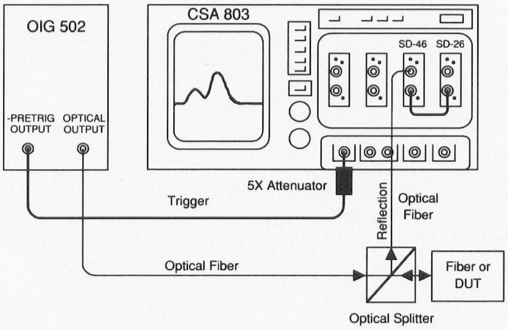


Figure 5. High-resolution OTDR system configuration when an SD Optical to Electrical Converter is used.

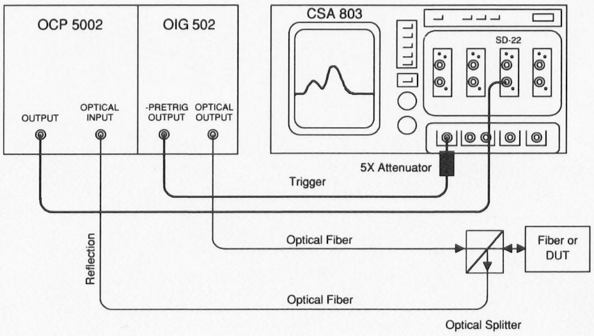


Figure 6. High-resolution OTDR system configuration when an OCP5002 Optical Converter/Power Meter is used.

You should verify that the reflection you've found is actually from the splitter's pigtail end. You can do this by dipping a piece of lens tissue into distilled water or isopropyl alcohol and wiping the tissue across the splitter's unterminated connector end. The liquid will drastically change the Fresnel reflection. If you see this change on the scope display, you're looking at the right reflection. If you don't see such a change, you're looking at a reflection from somewhere else in the system.

After verifying that the display is showing the reflection from the unterminated pigtail, clean the fiber end to regain the glass-air interface. You can do this by simply letting the liquid dry or by using pressurized air from an aerosol can.

The next step is to average the reflection using the scope's average function. Usually 32 trace averages produces a clearly viewable waveform.

When averaging is complete, note the amplitude value of the –14 dB reference reflection. This measured value of the –14 dB reflection (the return loss) will be used to calibrate other reflections. Also note the time location of the reflection if you plan to make distance measurements (e.g., fiber length). For convenience in these latter measurements, it's best to store this Fresnel *reference reflection* waveform in the scope's memory.

Now, using an in-line coupler, connect the fiber or device under test (DUT) to the splitter's pigtail. The reflection you have been observing as the *reference reflection* will decrease.

The decrease seen in the *reference reflection* is due to optical energy continuing on into the test fiber or DUT.

As was done for the reference reflection, you should average this *DUT reflection* display and store it in the scope's memory. Using stored traces simplifies comparison and measurement of the *DUT reflection* relative to the *reference reflection* display.

To measure the reflection level, turn off the live trace. Then call up the stored DUT and reference reflection traces. Now vertically expand the *DUT reflection* trace to overlay it as closed as possible on the *reference reflection* trace. With the traces overlaid, the scale factors of each trace can be ratioed to obtain the relative amplitude of the DUT reflection.

For example, let's say the trace for the glass-air interface reflection has a scale factor of 20 mV/div and the DUT reflection trace has a scale factor of 250 µV/div. The DUT reflection's relative amplitude can be computed as follows:

Relative Return Loss
$= 10 \bullet \log_{10}(250\ \mu V/20\ mV)$

$= -19$ dB (relative to reference reflection amplitude.)

Since the reflections are additive, the Fresnel reference reflection must be added to the above result to obtain the final DUT return loss value:

Net DUT Return Loss
$= (-19\ dB) + (-14\ dB)$

$= -33$ dB (relative to incident pulse.)

(Note that the accuracy of the device's return loss will depend on the surface condition of the fiber end – e.g., cleavage angle, dust particles, etc. Additionally, attenuation and pulse broadening are not accounted for in this procedure, but they are normally negligible in fibers under 200 meters.)

The length of the test fiber (or DUT) can also be computed by measuring the time between the DUT and reference reflections on the DUT reflection trace. This propagation delay is then divided by twice the propagation velocity constant of the test fiber. When comparing this measured optical reflection length to physically measured runs, be sure to take into account the test setup jumper or pigtail lengths.

Figure 7 shows an example set of Fresnel reflection displays. One of the displays is the impulse going into the optical splitter. The other is the DUT reflection. Both of these pulses have been converted from optical signals to electrical signals for display on the oscilloscope. Also, their

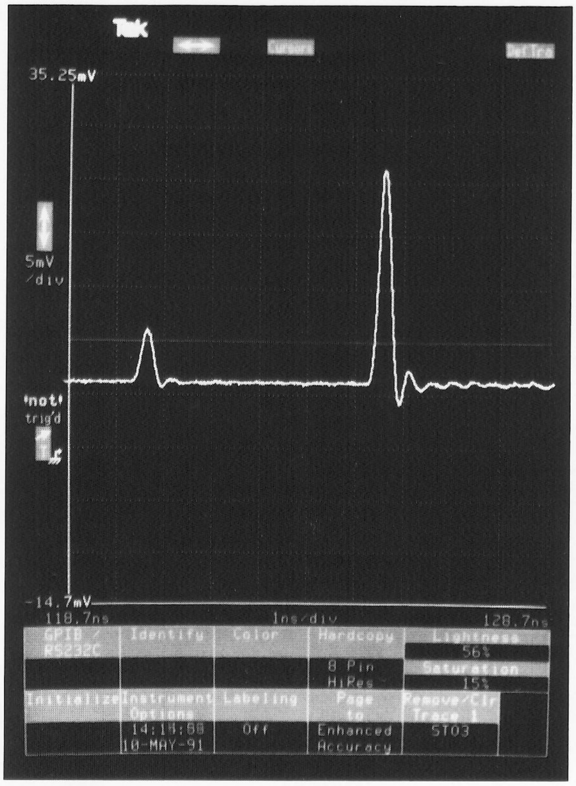


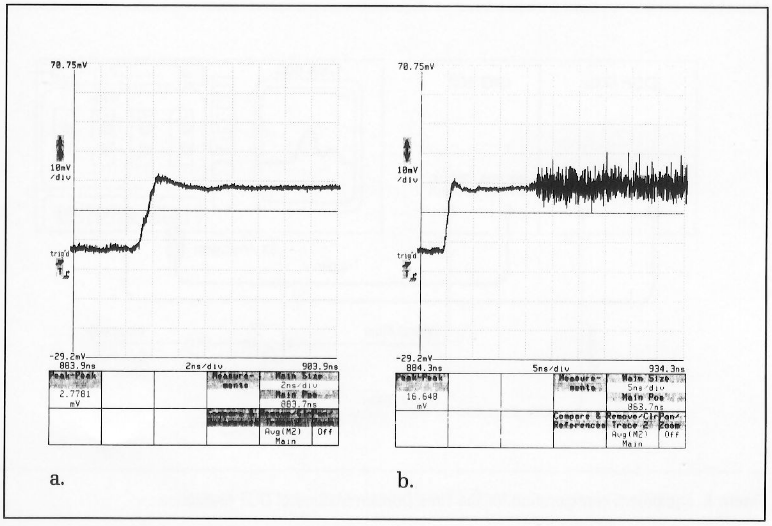
Figure 7. A set of typical optical reflection displays. The pulses displayed on the oscilloscope will be attenuated by losses introduced from two passes through the optical splitter

displayed amplitudes will be attenuated by losses introduced from two passes through the optical splitter.

Analyzing such reflections is a straightforward and effective means of evaluating DUT return loss. In fact, this has considerable advantages over the EIA/TIA Fiber Optic Test Procedure 107 (FOTP-107), as described in the accompanying box entitled "An Alternative Way to do DUT Return-Loss Evaluation."

Connector Reflections. The same basic test setup can also be used to evaluate reflections from optical connectors. This is becoming increasingly important to do since connector reflections can induce unwanted feedback in laser transmitters. Figure 8 illustrates this situation. Figure 8a shows a laser output without feedback effects, and Figure 8b shows a laser output with feedback induced noise.

Connector reflections as low as –30 dB, and even lower in some cases, can induce the level of oscillation shown in Figure 8. Single-mode fiber systems are particularly vulnerable to such induced laser transmitter oscillations.



a.

b.

Figure 8. Typical optical reflection waveforms (a) without and (b) with reflection induced laser oscillation noise.

This ability for high spatial resolution observation and analysis of reflections offers a great deal of flexibility and power for evaluating optical systems, subassemblies, and components. Not only is the Fresnel reflection method more accurate in many instances, but it can also be easier and quicker than traditional light source and power meter methods of return loss evaluation. And it is certainly more revealing in terms of reflection related optical structure and spatial detail.

An Alternative Way to do DUT Return-Loss Evaluation

A standard optical power meter can be used to measure return loss as specified by EIA/TIA Fiber Optic Test Procedure (FOTP) 107. This procedure is described below. Also, fiber lead termination is done by immersing fiber ends in index matching fluid.

FOTP 107 Procedure. As will be seen from the following procedure description, the FOTP-107 method is complicated and requires making fusion splices. Moreover, the method is not always accurate enough – or even appropriate – for some optical component evaluation needs.

The first step in the FOTP-107 procedure is to determine the coupler's insertion loss. This is done by fusion splicing one end of the coupler (Port 3) to an optical power source. An output (Port 2) is then connected to a power meter while all other coupler outputs (Ports 1 and 4) are terminated. The power measured under these conditions at Port 2 is referred to as P2.

Next, cut the fused fiber between the fusion splice and the coupler (Port 3). Then measure the power at this point. This power is referred to as P3.

From these two measurements (P2 and P3), the insertion loss of the coupler is computed as follows – Lc = –10 • log(P2/P3).

Continuing from here, DUT return loss is determined by first connecting the light source to Port 1 of the coupler. The power transmitted to Port 3 is then measured while all other fiber leads are terminated. This power is referred to as PO.

Next, terminate the fiber from Port 3 and measure the power from Port 2. This power is referred to as Pi's.

Now, cut the test jumpers in half and fusion splice one end of the fiber to Port 3. Then couple the DUT to a pigtail and terminate the pigtail end in a nonreflective termination (e.g., index matching fluid). And, finally, measure the power at Port 2. This power is referred to at Pi.

The DUT return loss can now be calculated as –

Lr = –10 • log[(Pi'-Pi)/PO] – Lc

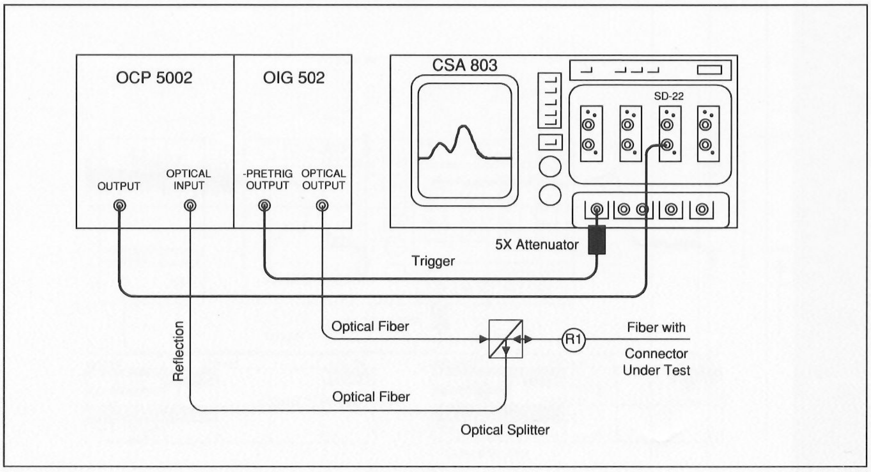


Figure A. Equipment configuration for the Time Domain Method of DUT evaluation.

Comments. The above test procedure has several drawbacks. First of all, you have to perform two fusion splices. Not only is this time consuming, but fusion splicing equipment may not be available.

Secondly, you're required to sever the fiber containing the DUT. This means you'll need to reform the fiber if you plan to use the DUT for anything else. This, of course, is completely unacceptable for production or incoming QA device testing.

And, lastly, the method has inherent inaccuracies. This is because fiber termination in index matching fluid does not totally eliminate reflections that affect the readings, especially at low reflection values.

Alternative Procedures

However, an alternate method has been proposed to the EIA/TIA. Not only is this method much faster to use, but it also eliminates uncertainties about which reflection is actually being measured.

This alternate method is referred to as the Time Domain Method. It requires monitoring Fresnel reflection signals in real time with a system such as illustrated in Figure A.

The first step in the Time Domain Method is to connect a standard reference reflector at Port 2. The resulting Fresnel reflection is then observed on the oscilloscope screen. After taking steps to reduce reflection R1 as much as possible, the reflection amplitude at the reference is measured in volts and stored as R2.

Next, a jumper fiber is connected to Port 2, and the DUT is connected to the jumper. Then the DUT reflection amplitude is recorded as R2'. The return loss of the DUT is then given by –

$RL = 10 \bullet \log(R2'/R2)$ + Std. Reflector (in dB)

This Time Domain Method eliminates any ambiguity about which reflection is responsible for the reflection being measured. In fact, return losses lower than –50 dB have been measured with the instrument configuration shown in Figure A.

Also, the Time Domain Method is not subject to reflection errors arising from terminations in index matching fluid.

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