ν-OTDR - High resolution OTDR

Application note 2: Rayleigh Back Scattering calibration

One of the most useful features in OTDR traces, in addition to the reflection peaks, is the continuous and mostly flat line, given by Rayleigh Back Scattering (RBS) in the fiber. During propagation in the fiber, some light is scattered in all directions. Part of this is coupled into the fiber, in the backward direction. This is the RBS. The intensity of the RBS at each point is proportional to the intensity of the propagating light, the factor being dependent on the fiber characteristics, and on the OTDR itself. The value of the RBS can thus be used to measure distributed loss in a fiber, loss at a connector or at a splice.

One important point to remember though is that RBS depends on the length of the OTDR pulse. The shorter the pulse, the lower the intensity of the RBS. The high resolution OTDR from Luciol has very short pulses (about 500 ps), and consequently very low RBS. For a standard SMF at 1550 nm, the value is about -81 dB. In addition, RBS is a random process: light is scattered by microscopic inhomogeneities in the fiber. It is therefore intrinsically noisy on this scale. The very smooth line, seen on standard OTDRs is due to the large spatial averaging. For higher spatial resolution, the RBS gets noisier. Therefore, there is a trade-off between spatial resolution and reflectivity resolution. This will limit the precision in reflectivity measurements with high resolution OTDRs.

The low RBS value is both an advantage and a limitation. It is an advantage, because it enables seeing very weak reflection peaks, such as the ones created by mated FC/APC connectors, which cannot be observed with standard OTDRs. It is a limitation, because a very high dynamic range would be required to see both the RBS (-81 dB) and high reflections (such as a Fresnel reflection, from a polished end facet at -14.5 dB). Presently, no high resolution OTDR can achieve such a high dynamic range, so that it is not possible to see both the RBS and a Fresnel reflection on the same trace, for a SMF at 1550[i].

In order to calibrate the RBS of a fiber, we recommend using an artefact, made in the following way. You need one fiber patchcord, preferably about 2 m-long, with two connectors. One end is a FC/APC connector, or any other connector, which can be adapted to the OTDR. The other end is a flat connector (any type), such that the reflection from this end is a Fresnel reflection. Alternatively, this second end can be a cleaved fiber, provided it is kept clean (it is much easier to clean a connector than a bare fiber). Cleave the patchcord roughly in the middle (keeping 1 m on each side), and splice the two sides again, with a bad splice. This can be achieved by displacing the two sides laterally, by a few microns. The splice loss has to be measured, and should be between 17 to 30 dB. This type of artefact can also be purchased from Luciol (contact info@luciol.com for details). The trace obtained with one artefact is shown in Figure 1.

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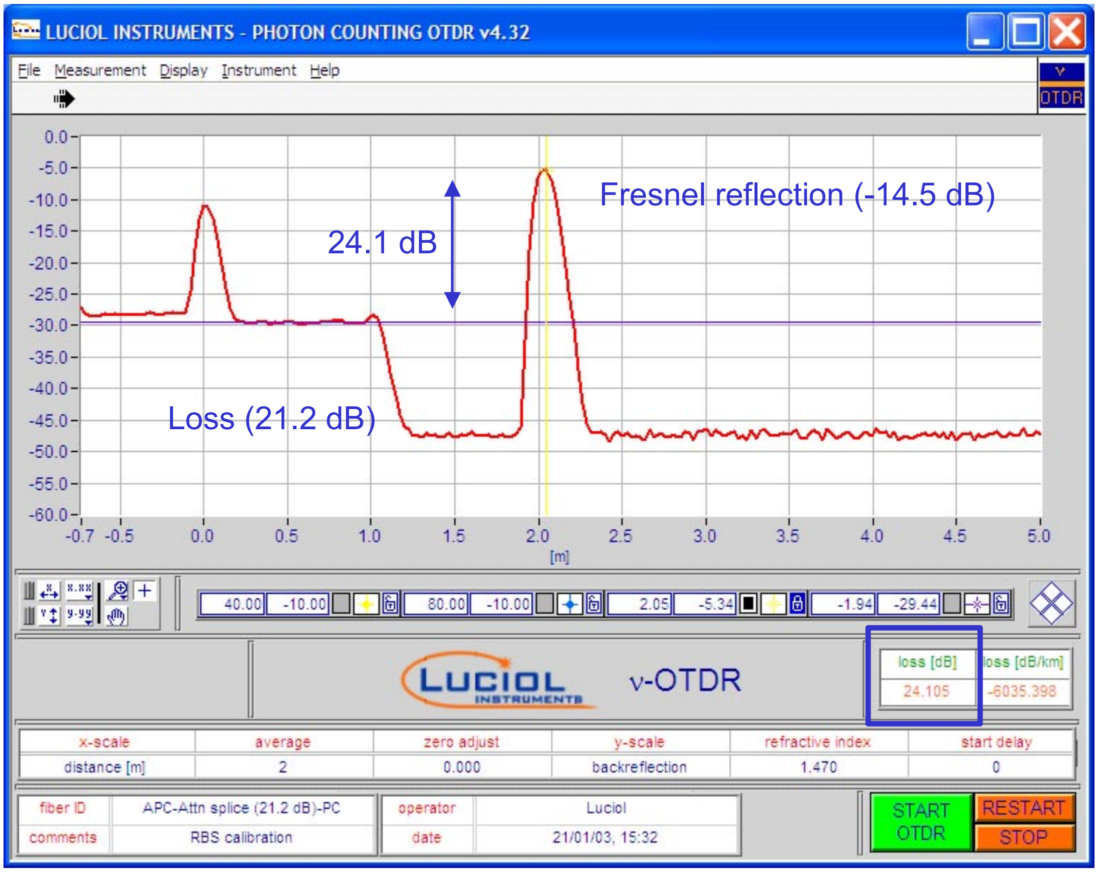

Figure 1: The RBS calibration artefact

The first peak at 0 m is the front panel reflection (FC/APC). The lossy splice at 1m was measured independently to be 21.2 dB. The end reflection at 2.05 m is a Fresnel reflection at -14.5 dB (open, flat connector). We use the cursors (see User's Manual for details) to find the exact height between the reflection peak and the RBS before the lossy splice: 24.1 dB. The RBS after the splice is 42.4 dB below (the loss measured was for one way), or 42.4 + 24.1 = 66.5 dB below the Fresnel reflection (at -14.5 dB).

This means that the RBS is at -81 dB.

We estimate the precision on this measurement to be about ± 1 dB (precision on the Fresnel reflection, splice loss...).

Once we have this RBS calibration, we can measure the reflectance of the FC/APC connector on the front panel. The procedure is explained in more details in Application Note 4: Reflectance measurement. Here the FC/APC reflection is 17 dB above RBS, to give: -64 dB

Note that the horizontal signal after the bad splice is not RBS anymore, due to the limited dynamic range (more than 40 dB between the highest reflection and the noise level). It is only noise, created by the dark counts of the detector. The sure sign of this is the fact that there is no jump in the signal before and after the end of the fiber (2.05 m). Indeed, before the end of the fiber, we have both RBS and noise, while after the end of the fiber only the noise remains. A jump of 3 dB for example, would mean that RBS and noise are similar. Here RBS is much lower than noise, and there is no jump at all. It is possible to correct for this effect, as long as some jump is seen, as explained in Application Note 5: dark counts correction.

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[i] However, in multimode glass fibers (MMF) at 850 nm, or for Plastic Optical Fibers (POF), RBS is much higher, and both RBS and Fresnel reflections can be seen on one trace.