Research on FTTH, Optical Time Domain Reflectometer testing (Joe Botha Nov-2017)

To begin with, the trouble with FTTH PON, OTDR testing is that once a splitter or cascaded splitters are in place, OTDR testing can ONLY be performed from the optical network terminal (ONT) i.e. customer end. This produces a trace showing the losses and reflections becoming to the link under test, all the way to the optical line terminal (OLT). Which of course, includes the high loss event through the splitter.

From the OLT end however, with the splitter/s in place, a conventional looking trace is generated up to the splitter. At the splitter, the downstream pulses are split and with diminished intensity they simultaneously travel down the distribution and last-drop fibres. Meanwhile, backscatter and reflections from these pulses are guided back up the fibres, merging at the splitter and after that, barrelling along back towards the OTDR. At the OTDR, the converged light from each of the splitter legs appear as overlapping backscatter and reflections, taking it well beyond the bounds of possibility to determine which fibre-leg might be responsible for any excessive loss or reflection.

Without the restorative privileges of bidirectional averaging, why can testing a fusion splice unidirectionally only, be a problem? And how problematic can that be? You simply press a few buttons on the OTDR and whoopee, a 0.0-something dB loss is displayed. Piece of cake, right? What could be easier? Okay, yes, all will be fine and dandy when unidirectionally testing a G.652D spliced onto G.652D or, G.657A onto G.657A. However, the problem with this assumption is that on several FTTH installations, the drop cable will be bend-insensitive G.657A and the feeder and/or distribution cables, G.652D. I can immediately confirm that testing G.657A onto G.652D from only one end, will produce a fictitiously large reading.

Unidirectional OTDR results do not reflect the true loss of a splice. In fact, you could be lured into thinking the splice is acceptable, or not acceptable, when in fact the opposite is true. So, without the benefit of a bi-directional average, how are we to know what "fictitiously large reading" is acceptable? The answer to this question, is the intended purpose of this research. The sample size was 10 fusion splices, which in my opinion, is a defensible number in terms of comparable validity. This is endorsed by the fact that the results from this research, revealed that variations were all within a tight range.

λ	G.652D to G.657A1		G.657A1 to G.652D	AVE
1310nm	-0.098		0.152	0.027
1310nm	-0.106		0.138	0.016
1310nm	-0.105		0.156	0.025
1310nm	-0.065		**0.184**	0.059
1310nm	-0.107		0.145	0.019
1310nm	-0.093		0.157	0.032
1310nm	-0.101		0.148	0.023
1310nm	-0.112		0.151	0.019
1310nm	-0.104		0.159	0.027
1310nm	-0.106		0.150	0.022
AVE	**-0.099**		**0.154**	**0.027**

The worst fusion splice, G.657A1 onto G.652D (ONT to OLT) at 1310 nm, is a punchy 0.184 dB loss. Which of course, is a misleadingly large reading. But bi-directionally, a not too shabby 0.059 dB splice loss is chalked up.

A reasonable observer, will of course, agree that this clearly implies that 0.184 dB is a perfectly acceptable unidirectional splice loss, when testing at 1310 nm.

λ	G.652D to G.657A1		G.657A1 to G.652D	AVE
1550nm	-0.125		0.196	0.027
1550nm	-0.140		0.181	0.016
1550nm	-0.139		0.191	0.025
1550nm	-0.105		**0.215**	0.059
1550nm	-0.143		0.180	0.019
1550nm	-0.131		0.193	0.032
1550nm	-0.135		0.189	0.023
1550nm	-0.140		0.178	0.019
1550nm	-0.126		0.193	0.027
1550nm	-0.138		0.184	0.022
AVE	**-0.132**		**0.190**	**0.029**

The worst fusion splice, G.657A1 onto G.652D at 1550 nm, delivers a sizeable 0.215 dB loss. This is cushioned by an ultra-low -0.105 dB negative contribution from the other end. As was the case when testing at 1310 nm, 1550 nm also gives us a 0.059 dB average splice loss.

Again, this implies that 0.215 dB cannot be challenged as not being an acceptable unidirectional splice loss, when testing at 1550 nm.

λ	G.652D to G.657A2	G.657A2 to G.652D	AVE
1310nm	-0.303	0.370	0.033
1310nm	-0.270	0.403	0.066
1310nm	-0.281	0.406	0.062
1310nm	-0.295	0.388	0.046
1310nm	-0.278	0.400	0.061
1310nm	-0.288	0.390	0.051
1310nm	-0.263	0.419	0.078
1310nm	-0.296	0.388	0.046
1310nm	-0.310	0.372	0.031
1310nm	-0.310	0.371	0.030
AVE	**-0.289**	**0.369**	**0.040**

It is evident that G.657A2 is not as backward compatible with G.652D, as is the case with G.657A1.

The worst fusion splice, G.657A2 onto G.652D at 1310 nm, limps in at a 0.419 dB loss. But bi-directionally, a not too displeasing 0.078 dB splice loss was racked up.

In my view, it will be a dereliction of duty, not to accept 0.419 dB as a perfectly acceptable unidirectional splice loss, testing at 1310.

λ	G.652D to G.657A2	G.657A2 to G.652D	AVE
1550nm	-0.291	0.374	0.041
1550nm	-0.271	0.400	0.064
1550nm	-0.278	0.390	0.056
1550nm	-0.279	0.384	0.052
1550nm	-0.283	0.384	0.050
1550nm	-0.292	0.370	0.039
1550nm	-0.280	0.386	0.053
1550nm	-0.297	0.386	0.044
1550nm	-0.303	0.363	0.030
1550nm	-0.300	0.360	0.030
AVE	**-0.287**	**0.380**	**0.046**

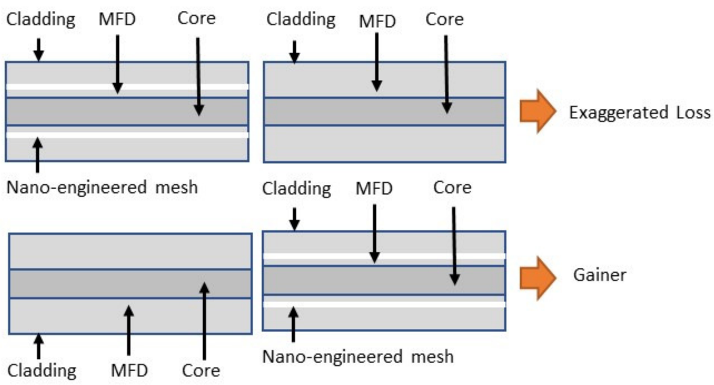
The worst fusion splice, G.657A2 onto G.652D at 1550 nm, has a mammoth 0.400 dB loss. But bi-directionally, a respectable 0.064 dB splice loss is obtained.

Again, as unappealing as it might seem, 0.400 dB can hardly be dismissed as an unacceptable unidirectional splice loss, when testing at 1550 nm.

The OTDR optical receiver records only a tiny proportion of light, typically <0.000001% is backscattered in response to an injected light pulse. So, how do we explain why changes in mode field diameters (MFDs), cause a shift in backscatter intensity, when splicing G.652D onto G.657A? A MFD is the diameter of the light-carrying region of the fibre (core + cladding). Ideally and presumably, you would want the commentary of a leading scientist, working at the cutting edge of the design and manufacturing of optical fibre. I must agree, but nevertheless, in what follows, is my view.

To improve the bend performance of fibre, the refractive index on the outskirts of the core (the cladding), needs to be lowered. And this is accomplished by introducing a nano-engineered mesh barrier in the cladding to keep the light trapped in the core, when the fibre is bent.

Changes in MFDs, will cause a measurable shift in backscatter intensity of the injected light pulse from an OTDR, when going from G.652D to G.657A and G.657A to G.652D, at the splice.



My take on reconciling this is that the presence of the nano-engineered ring in the cladding, marginally increases the size of a bend-insensitive fibre's MFD. So, the forward propagating pulse from the OTDR will spend marginally more time in this larger MFD - with the light bending more and therefore, increasing the backscatter intensity.

So, when light passes from a larger MFD (bend-insensitive fibre) into a smaller MFD (G.652D), less light is reflected, making it seem like the loss is greater than it really is i.e. an exaggerated loss. Conversely, if light goes from a smaller MFD into a larger MFD, more light is reflected at this point and the OTDR will think that power was gained at the splice, popularly referred to as a "gainer". Finally, this does, of course, raise the question if small intensity changes in backscatter will have a functional impact on system performance. The answer is no, forward propagating light is not put off their stride by small intensity changes in backscatter. We are very, very, very lucky.