MONITORING PORTS IN FIBER OPTIC NETWORKS

Key to Fast Installation and Low Maintenance Costs

Monitoring Ports in Fiber-Optic Networks – Key to Fast Installation and Low Maintenance Costs

Currently, there are no more telecom or cable operators who do not have at least a piece of optical fiber in their network. Outstanding capacities, faultlessness, and low maintenance costs have long ago caused the competing transmission media to be left abandoned. The enormous fiber-optic network bitrate is made accessible mostly by the use of the WDM (*Wavelength Division Multiplexing*) technology. It allows the transmission of a few, a dozen, or tens of optical channels differing in wavelength in one fiber. This way, the gigantic total bandwidth of the fiber-optic medium is divided among smaller spectrum blocks, which are easier to process by the much slower electronics.

The WDM technology is available in a few flavors:

- From the classical 1310/1550 nm WDM,
- To 18-channel **CWDM** (*Coarse Wavelength Division Multiplexing)*, in which along the pure CWDM channels, special ones such as the grey 1310 nm channel or the wide channel dedicated for the whole DWDM multiplex often propagate – more on this subject can be found in our whitepaper ***The Whole Truth about CWDM Transmission,***
- To **DWDM** systems (*Dense Wavelength Division Multiplexing*) that can have more than 100 optical channels (described e.g. in our whitepaper ***Passive DWDM Systems***),
- Or more and more frequently encountered PON and NG PON, where along with the GPON 1490/1310 nm wavelengths, other channels appear, for example the so-called **RF 1550 nm overlay**, which is used to broadcast the "analog" television, or new spectral blocks defined for various versions of 10G PON, TDM PON, and WDM PON.

The common denominator for all types of WDM networks is the necessity to use **optical multiplexers and demultiplexers**, which combine optical channels emitted by separate transmitters into one common fiber at the link input (multiplexers) and separate these channels at the link output (demultiplexers). In many cases, on day one the multiplexers installed have higher number of ports than initially populated to ensure the possibility of future seamless expansion. Of course, every operator hopes that adding more channels in the future will not affect the already existing channels. In an ideal case, this just means connecting a new transmitter by a patchcord to the dedicated client port on the multiplexer and demultiplexer. In practice, the new channel might not "get up" straight away, for example because the transceiver is not supported by the active device, because the connector on the patchcord is dirty and the power level is too small, because the installer confused the client ports, etc. Moreover, it could also happen that the new channel has little chance of operating since the link attenuation exceeds its power budget. This is possible for example in CWDM networks, where each channel can see a very different attenuation depending on fiber quality and type, as shown in **Fig. 1**

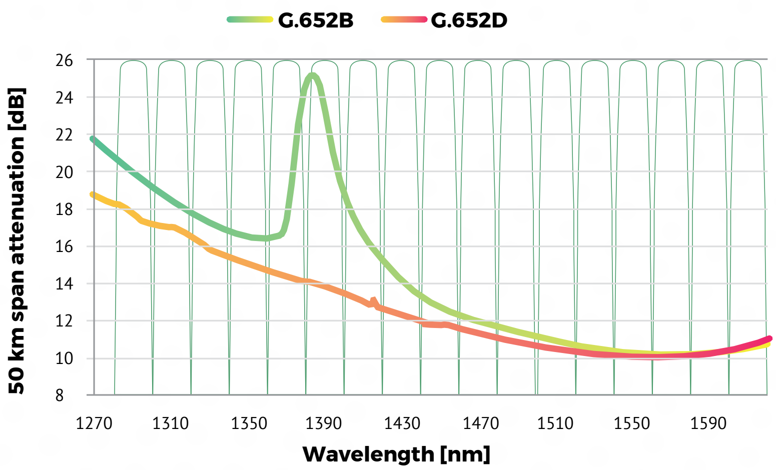

Figure 1. Spectral attenuation characteristics of 50 km G652B and G.652D fibers with schematically shown CWDM channel positions

In such situation, it is essential to be able to diagnose the root cause of the problem, of course preferably without turning the already operating channels off. Also, during link operation, something can happen and some channels may stop functioning, or errors may start to appear, and their cause has to be diagnosed. **Only the capability to effectively diagnose guarantees fast installation and low installation and maintenance cost of fiber-optic links.**

The best tools for such noninvasive diagnostics are monitoring ports built into the network, mostly at the end points, so in the multiplexers and demultiplexers. They can be OTDR monitoring ports (which enable reflectometer measurements of live network in order to detect e.g. a broken cable or fiber bend) or power monitoring ports. We will focus on the second type in this article.

Power monitoring port is an additional port which decouples a small ratio of the total optical power from the main line so that it can be analyzed without disconnecting the main line cable. In the case of multiplexers, it is usually an additional port that is the output line port's "younger brother", and it typically decouples 1% or 5% of the total power launched into the line cable. In the case of demultiplexers, it is a similar port, which carries a small ratio of the total incoming power to the demultiplexer from the link before further demultiplexing. The spectrum available at the demultiplexer's power monitoring port gives information about what happens between the terminals. In the case of bidirectional transmission in one fiber, the same terminal functions as both the multiplexer and demultiplexer, so in this case it is worth to install a bidirectional power monitoring port in it, which would allow simultaneous analysis of what is launched into the link and what comes out of it. **Fig. 2** schematically shows such a bidirectional link with bidirectional monitoring ports on both sides.

What can the power available at the monitoring port tell us? It depends on the link and installer's equipment. In the simplest case, it gives information about the total optical power and whether it changed since e.g. last year – a simple power meter (such as the **FIBRAIN FOPM-250**) would be enough for this. This way, we can monitor link ageing (and unfortunately DDMI readings on the transceivers do not guarantee any stability or accuracy). If we are installing a new channel, on the power monitoring port on the multiplexer we should see an increase of the total power corresponding to the power of the channel. Immediately we can see if e.g. the installer did not confuse the client ports or if the CWDM transceiver is indeed a 1430 nm tranceiver as supposed and if the channel is "getting up." If we have a more intelligent power meter or spectrum analyzer, the available power brings much more useful information. In a CWDM link we can have up to 18 channels, and let us assume that for some reasons only one of them does not operate. If we have an inexpensive, but very useful **FIBRAIN FCPM-18/1310** CWDM meter (shown in Fig. 3), it measures individual power of each channel in this link simultaneously and we can clearly see which ones are present and what is their relative power. Thanks to this, the technician knows where to look for the cause of the problem (maybe the optical fiber started recovering the water peak or one of the transceiver wavelengths fluctuates, or else the installer has bent the fiber too strongly, or otherwise everything is fine optically, but the active device is misconfigured). In DWDM links, monitoring is even more critical. In long, optically regenerated links, the signal power levels need to be uniform, otherwise one channel may e.g. saturate optical amplifiers or nonlinearly distort other signals. It is also possible that optical noise in the case of a few channels starts to degrade the transmission, which can be easily, quickly, and painlessly checked by connecting optical spectrum analyzer to the power monitoring port.

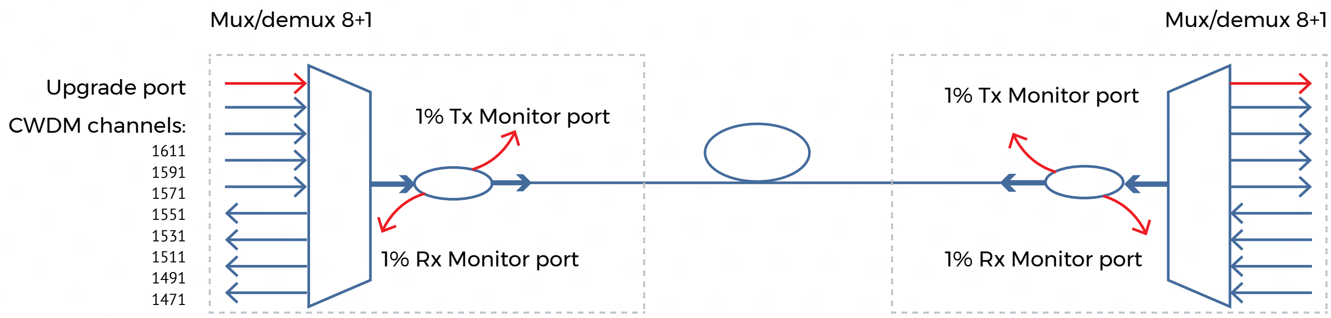

Figure 2. Bidirectional CWDM link with monitoring

Figure 3. FCPM-18/1310

As we can see, power monitoring ports are extremely useful and indispensable help for every technician at the stage of installation and maintenance of every fiber-optic link in which more than one wavelength propagates. Moreover, **the cost of power monitoring port is a small fraction of the cost of the whole multiplexer,** so it is a functionality that is really cost-effective and worth having even if currently it may not be directly used in the link, because in three years such an application will most likely be found.

As mentioned, power monitoring port typically carries 1% or 5% of the total power – it is meant not to add large excess losses in the link, and at the same time the available power has to be higher than the optical meter sensitivity. To obtain such functionality, a low-percentage FBT (*Fused Biconical Tapering*) coupler is most often added. The FBT coupler technology has the advantage of allowing to manufacture 1x2 couplers with any split ratio, so also 1/99% and 5/95%. Unfortunately, it also has disadvantages. The crucial one is the fact that the split ratio is strongly dependent on wavelength. This means that coupler with a nominal split ratio of 1/99% for 1310 and 1550 nm can have attenuation higher on the 1% port (so on the power monitoring port) even by 2 dB for other wavelengths. Moreover, the way the FBT couplers are manufactured causes the water peak at about 1383 nm to re-appear during the manufacturing process. This results not only in false power measurement results for this spectral region on the monitoring port, but also increases the attenuation of the "production" part of the power that propagates in the 99% port of the coupler (on the line port of the multiplexer).

Fig. 4 shows **spectral characteristics of the low-percentage ports for typical 1/99% and 5/95% FBT couplers** (the third, much more flat one is for monitoring port manufactured in an alternative technology, which we shall get to in a moment). As we can see, the 1% port, which would be nominally described as the 20 dB monitoring port, in practice **has losses very nonlinearly changing by almost 2 dB** in the whole CWDM range. The 5% port (nominally described as 13 dB) has about 1 dB of loss variation. It means that to be able to accurately approximate the actual power in the line cable for a given monitored optical channel , the technician would need to know the "calibration curve" of the port. This is impossible in practice. It is even more upsetting as many CWDM and DWDM meters (including the FCPM-18/1310) have user-settable offset functionality (a method of referencing the power monitoring port attenuation so that the power displayed corresponds to the power in the line cable so power of the actual interest). It also needs to be remembered that for example 2 dB of false power reading for any channel in a DWDM or CWDM link can mean a BER difference between 1e-7 (unacceptable) to 1e-15 (ideal) or shows presence of dirt on one of the connectors. Such dirt might not cause problems just yet, but with time it can migrate towards the core of the fiber if our terminal is placed e.g. in a cabinet next to railway tracks.

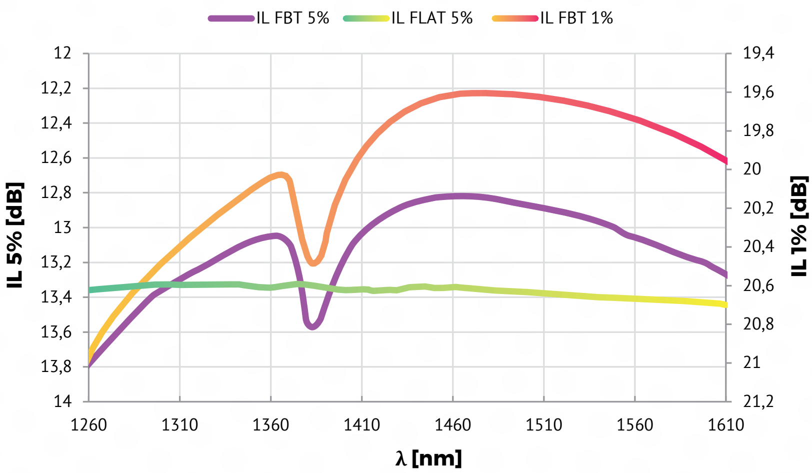

Figure 4. Characteristics of monitoring ports manufactured in the FBT and flattened technologies

Fig. 5 shows **spectral characteristics of the high-percentage 95% and 99% FBT coupler ports (so multiplexer line ports).** The additional, flat curve represents a coupler manufactured in an alternative technology, which will be discussed later. Again, for FBT couplers not only the poor flatness of the curve, but most importantly the recovered water peak can be seen. The peak in extreme cases can add even 1.5 dB of additional losses – in the case of CWDM and NG PON networks with tight power budget these losses may mean the difference between an operating and a non-operating link (and of course the second identical port on the demultiplexer may add as much loss again).

strongly dependent on wavelength (especially for the monitoring ports). This is why **FIBRAIN has developed a unique technology of manufacturing flattened monitoring ports.** They are available as nominally 5% ports and, as can be seen in Figure 4, indeed the attenuation of such a port does not change by more than 0.1 dB over the whole CWDM wavelength range (1260-1620 nm, the same spectral range is also required i.e. by NG PON, WDM1r, CEx or CEMx type multiplexers). This allows accurately determining the actual powers of all channels, thus significantly more accurate diagnostics. Moreover, the multiplexer or demultiplexer line port in which such a power monitoring port is built into has low losses and independent of wavelength attenuation characteri-

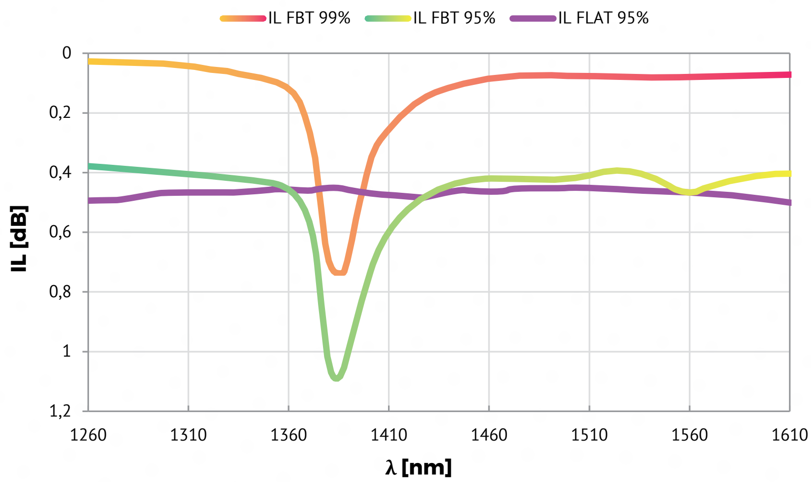

Figure 5. Characteristics of line ports manufactured in the FBT and flattened technologies

As we can see, using the FBT technology to achieve the power monitoring functionality, despite having many advantages (it is certainly better to have such a port than none at all), has its drawbacks which are simply impossible to eliminate because they result from the very way the FBT couplers are produced – there will always be some water peak and attenuation fairly

stics (which facilitates power budget calculations), which can be seen in Figure 5. The best part of it is **the cost of the flattened power monitoring port, which is the same as the cost of traditional ports manufactured in FBT technology.**