White Paper

Sterlite Tech

Optical Fiber extended environmental aging studies

Authors
Sudipta Bhaumik and Andrew McGrath

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Abstract
Hundreds of millions of kilometers of optical fiber is installed throughout the world with an impressive history of mechanical reliability and optical performance. This paper summarizes some of the results of extended environmental aging studies of single mode silica glass optical fibers.

Keywords
Optical fiber, Fiber aging, Damp Heat, Water immersion, Extended Lifetime Testing

1. Background

Optical fibers deployments starting in the 1980s has enabled the transmission of multi Gbps transmission bandwidths over thousands of kilometers. It can be argued that historically optical fiber has had a useful technical life where its optical performance limits transmission upgrade options, but importantly it also has a physical lifetime due to the degradation of the cable and fiber components and in the limit catastrophic failure of the fiber by stress corrosion.

There are therefore two definitions of fiber lifetime:

1. Limit of useful technical life when the fiber performance limits the upgrade options

2. Limit of useful physical life .. when the network downtime increases through fiber failure by stress corrosion, poor handling and splicing, increased loss and Polarization Mode Dispersion (PMD)

Modern fiber has excellent performance with low well-controlled loss, PMD and chromatic dispersion. Early fiber had considerably higher transmission loss, PMD, and splice losses and thus in older mature networks, where fiber may be up to 30 years old, fiber transmission properties such as loss and PMD may vary widely.

The upgrade requirement for the core and access optical networks is likely to be different. Therefore, it is necessary to understand how many upgrades in transmission technology can be made before the fiber needs to be replaced. While the fiber deployed in the access network is at the start of its technology lifetime, the fiber in the core network may be much older and reaching its transmission limits as bandwidths increase substantially. The physical lifetime of the optical fiber and cable also needs to be considered.

During the design stage prior to any fiber deployment optical power budgets are set for each link to determine the maximum link distance to meet the optical performance requirements on day 1 and the end of life (EOL). One of the components of the power budget is the ageing margin, which is likely to vary between operators and networks. The estimate of ageing is complicated by the probability of cable damage, repair, and replacement during the lifetime of the system. Each cable repair adds more splice points and sometimes an extra section of cable increasing the loss of the link. Furthermore the rate of ageing and the risk of cable damage by third parties will be affected by the cable deployment and installation technique, e.g. whether the cable is an aerial cable, blown into sub-ducts, or simply ploughed into the ground.

Fiber lifetimes have been extensively studied and the time to failure estimated for different applied stresses culminating in widely used rules for the maximum constant applied stress to give lifetimes of 25 years or so. This research has supported the deployment of the millions of fiber kilometres we see today. To ensure the on-going performance and reliability of optical fiber systems requires the study of the materials; design; installation and operational environment of the optical fiber cables. However, relatively little work has been done on understanding cable and fiber ageing under different deployment conditions for extended lifetimes, possibly because of the considerable effort and extensive testing required. Sterlite has recognized this and has embarked on a program of research to better understand possible degradation and so inform the design and use of optical fiber cable systems in the future. This paper summarizes some of the results.

2. Extended lifetime testing

The likelihood of the cable performance degradation and ultimate failure requires an understanding of the different deployment techniques and environments, the ageing characteristics of the cable and the interaction between its constituent materials. Thus accelerated ageing or conditioning of the fiber or cable prior to any optical or mechanical testing needs to take into account the ageing mechanisms of the different materials used.

Standards organizations such as the IEC provide guidance and norms for the performance of optical fibers, for example IEC 60796-2-50 product specification for optical fibers, where a number of environmental testing requirements are described, such as damp heat and water immersion. The period of fiber conditioning or ageing suggested in the standards to meet the minimum fiber performance requirements is typically 30 days.

These types of tests are commonly referred to as 'accelerated ageing'. Failures are not expected within the test period and the time to failure is not typically measured: no comparative test between designs is made other than pass/fail within 30 days. A first step in designing extended lifetime cables is to determine a benchmark for the actual time to failure of products using current ageing environments.

As part of a program of fiber and cable ageing studies, Sterlite has measured the change in attenuation of fiber conditioned in damp heat and room-temperature water for over 1000 days: over 33 times the minimum laid down in standards. Fiber with coating from different suppliers is used for this extended aging study.

3. Samples & Measurements

Damp heat

Two lengths of loosely coiled fiber (≈ 2km) with different coatings (A & B) were conditioned in damp heat at 85°C and 85% RH[1] . The attenuation was measured with an OTDR at 1310 nm and 1550 nm every two days. The repeatability of the OTDR for all the measurements was 0.005 dB/km.

Figures 1 & 2 show the change in attenuation with damp heat ageing for the G.652.D fiber with coating (A) and coating (B) respectively. The horizontal line is the IEC limit for the maximum change in attenuation at both 1310 nm and 1550 nm. The maximum increase in attenuation after 1034 days for both the fiber samples were less than 0.025 dB/km, which is less than by 50% of the IEC requirement of 0.05 dB/km. The loss trends measured during exposure are larger than the measurement repeatability of the OTDR but the variation is much less than the specification and is typical of that random variation seen during long-term exposure measurements.

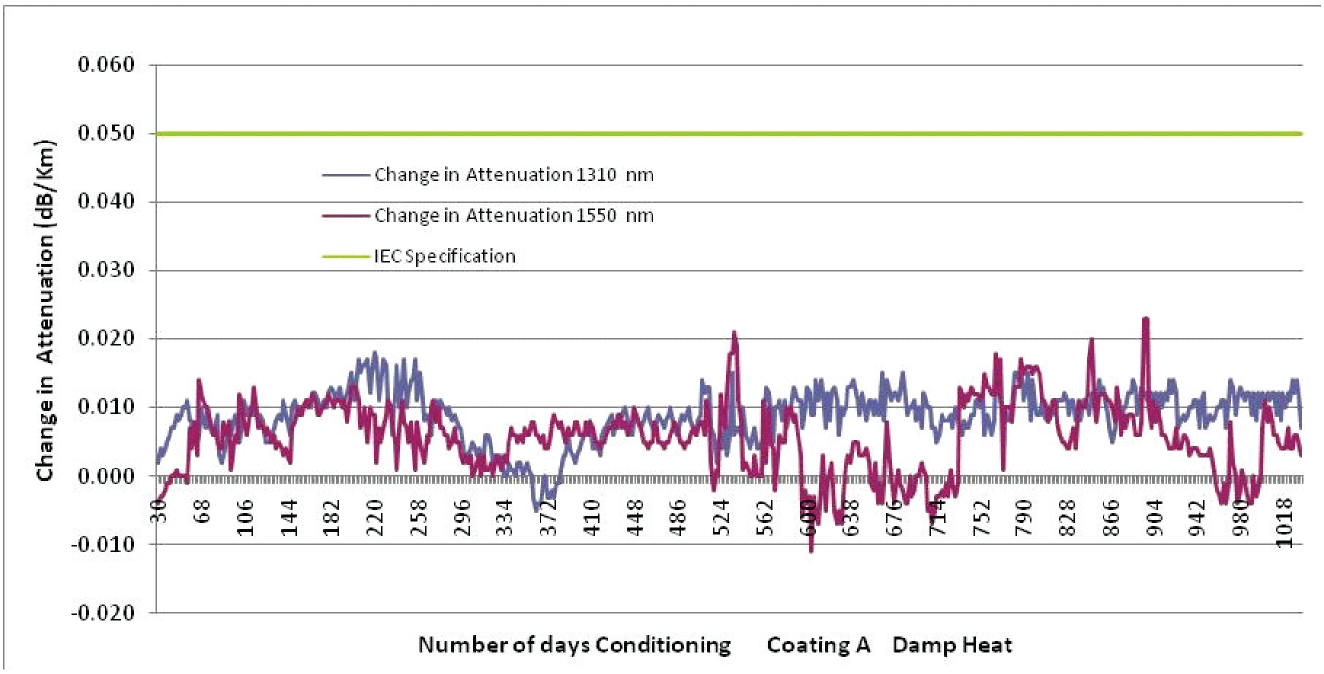

Figure 1: Change in attenuation with damp heat conditioning, coating (A)

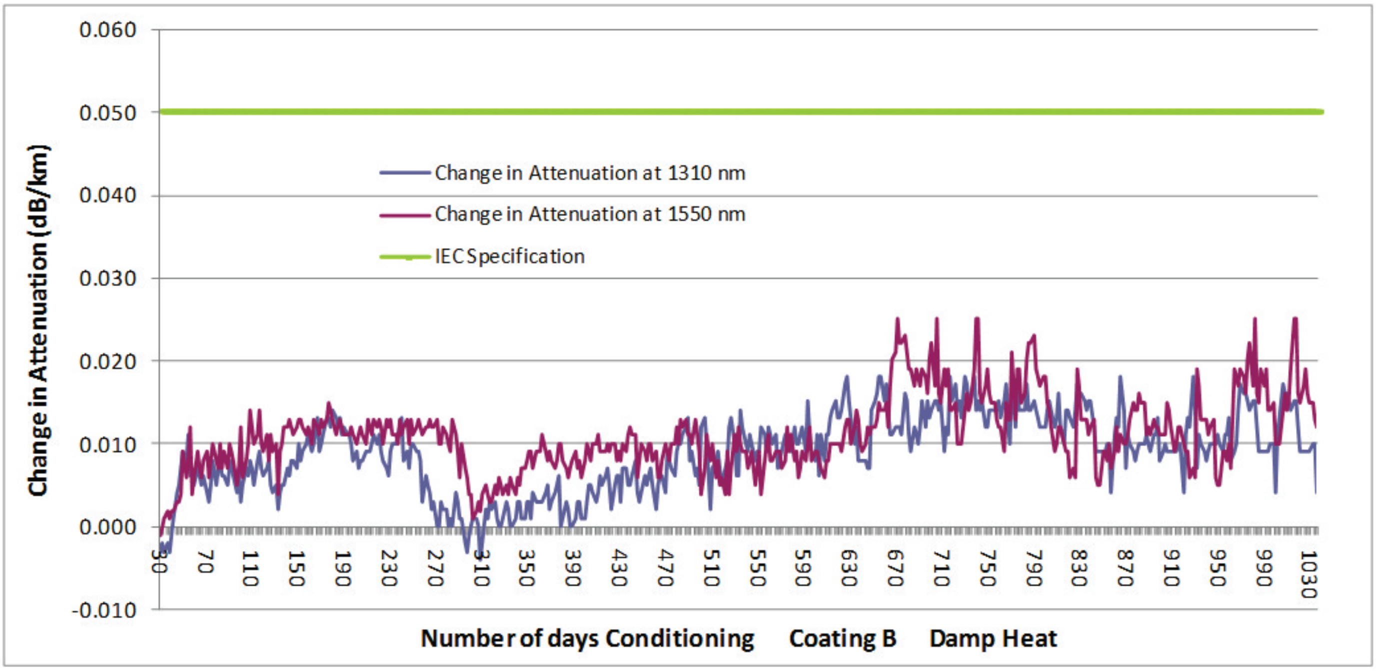

Figure 2: Change in attenuation with damp heat conditioning, coating (B)

Water immersion

Three samples of G.652.D fiber, one sample each with coating (A), (B) and (C) were conditioned by immersing them in de-ionized water at ambient temperature 23 ± 2°C. The attenuation was measured every two days after 30 days at 1310 nm and 1550 nm with an OTDR. The samples are conditioned for at least 1400 days to a maximum 1850 days. Changes in attenuation with conditioning time are shown in figures 3 to 5. The maximum increase in attenuation after extended aging over 1400 days for the fiber samples with coating from three different suppliers were less than 0.035 dB/km, which is well within the IEC requirement of less than 0.05 dB/km.

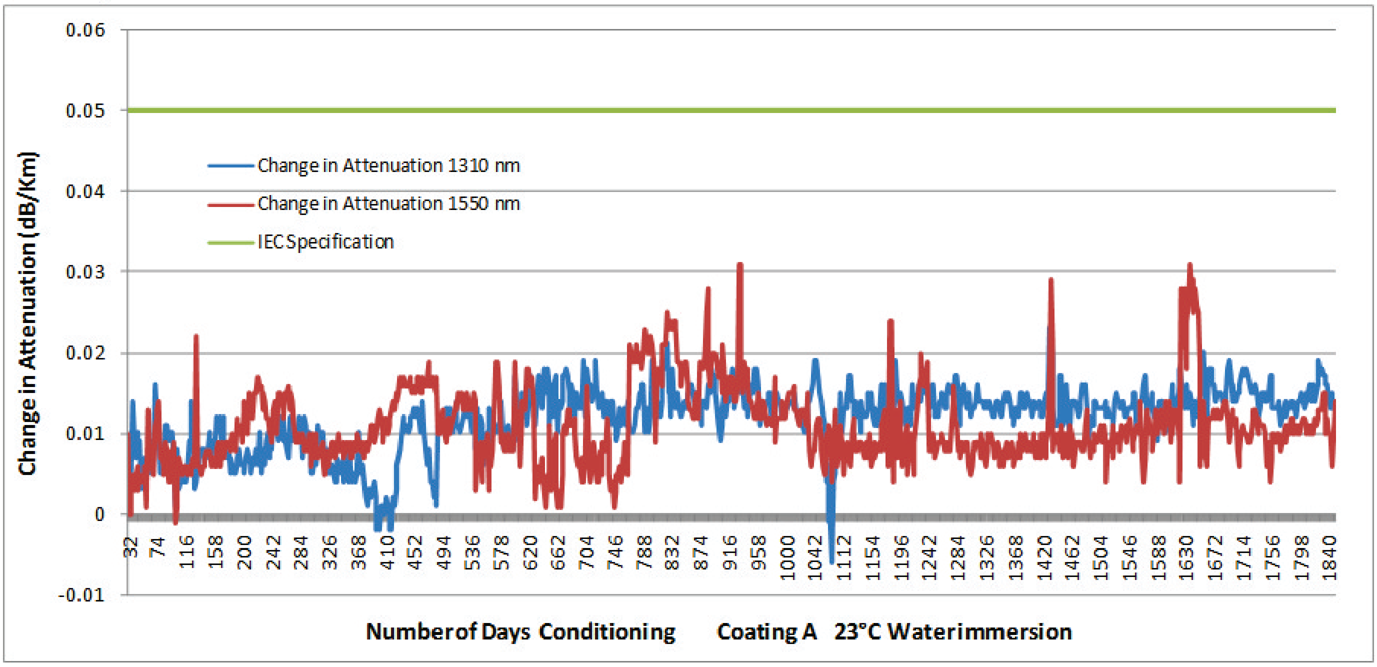

Figure 3: Change in attenuation with water immersion, coating (A)

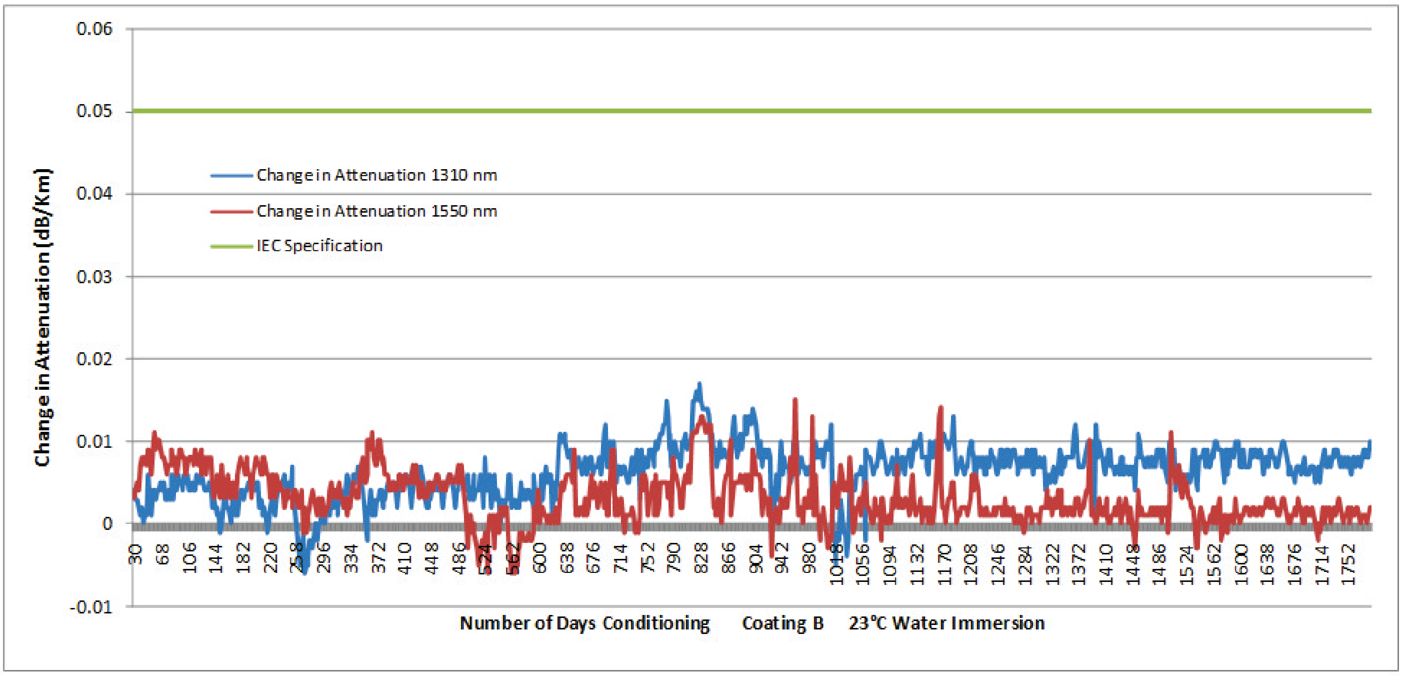

Figure 4: Change in attenuation with water immersion, coating (B)

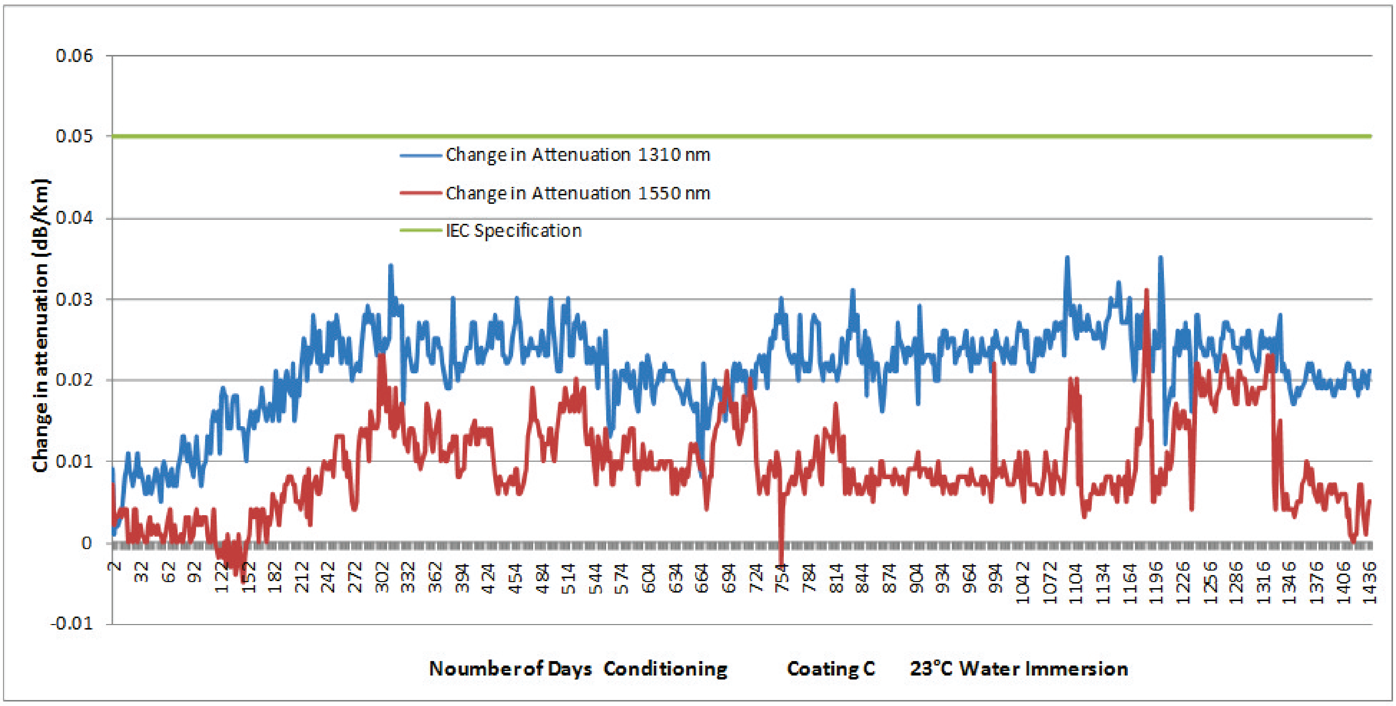

Figure 5: Change in attenuation with water immersion, coating (C)

4. Conclusion

The above results are a snapshot of some early findings from a new initiative: an extensive program to explore the long-term changes in the performance of optical fiber and cable to establish the likely degradation mechanisms and possible risk of failure over extended lifetimes. The timely development and test of extended lifetime products requires short-term ageing tests that give valid lifetime comparisons between designs. As part of this work, samples of optical fiber have been exposed to current damp heat and room temperature water immersion tests for over 1000 and 1400 days respectively: over 33 times the standard conditioning time. No failures or significant changes in attenuation have been seen. These extended environmental aging test results provide increased confidence in the performance of the current product in these environments.

5. References

1. IEC standard 60793-1-50, “Measurement methods and test procedures – Damp heat (steady state)”, First Edition.

2. IEC standard 60793-1-53, “Measurement methods and test procedures – water immersion”, First Edition.