

Solving The Issues Associated with High Power Raman Amplification

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To lower pump powers and help alleviate concerns for eye safety, fiber coating damage, and connector damage, a system-wide combination of technologies of OFS (including OFS' TrueWave® fibers, BlueTiger™ Jumpers and LC Connectors or Expanded Beam Connectors) can be used. TrueWave fibers increase Raman gain efficiency and LC Connectors lower coupling loss to significantly lower Raman amplification pump power levels in transmission systems. BlueTiger Jumpers lower bend loss to avoid coating damage from leaked optical power. And Expanded Beam Connectors increase the optical spot size at the connector to lower power density to below connector damage thresholds

The use of Raman optical amplification offers the great benefits of lower noise, uniform gain over a wide band of optical channels, and the flexibility to amplify any band of channels desired by appropriately locating the Raman pump lasers approximately 100 nm below the desired signals. As with any new technology, closer evaluation of this new amplification solution raises concerns over its practical application in real-world optical networks. As we shall see, while the concerns are valid, the selection of appropriate technologies across the network system can help alleviate these deployment fears and open networks to the significant advantages of Raman amplification

Raman optical amplification requires high power pump lasers. There are, therefore, three primary questions regarding the practical use of Raman optical amplification. These questions and concerns have most recently been raised by Sprint at NFOEC 2003 regarding the use of Raman amplification with conventional single mode fiber.¹ First, is whether there is a way to ensure sufficient eye safety for craft personnel who will be installing and maintaining these networks. Phillippe A. Perrier, the director of photonic subsystems engineering at Xtera Communications Inc. warns that the powerful lasers used in Raman amplification could injure the engineers working on patch panels. He notes that "It's not only a technical issue. It's a safety issue as well."² Second, can the more powerful lasers used in Raman amplification lead to damage to optical connector end faces? David Chen, advisory engineer in the optical and data network division of WorldCom Inc., advises that "if the connector has some dirt on it, you can damage it. If you're not careful, the tip can melt."³ Finally, can the more powerful lasers lead to burnt fiber coatings resulting from jumper cordage bent at very small diameters in the fiber management part of the network?⁴ Ed Sikora and his colleagues at British Telecom have noted that powers as low as 500 mW can induce permanent damage in singlemode fiber that is bent at a bend diameter of 13mm or less.⁵

The physical network locations of these concerns are shown in Figure 1, which is a schematic of typical network elements located in the terminal offices or network operation centers as well as the outside plant. Most of these concerns arise in the locations of the network associated with fiber management and fiber optic transmission equipment. As a result, the industry's only integrated fiber, cable, and connectivity provider, OFS, is the perfect entity to provide a solution.



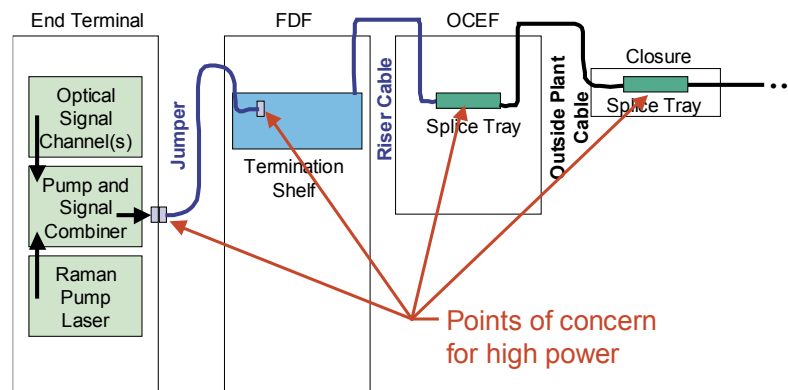


Figure 1. Schematic of a typical network showing the areas where damage from high power is a concern to fiber, connectors, and fiber coatings and where eye safety is a concern for installation and maintenance personnel. FDF=fiber distribution frame, OCEF=optical cable entrance facility

While these power level issues are quite real at the component level, taking a broader systems-level approach to these concerns can lead to solutions that can more than adequately address them all. By combining technologies designed for transmission fiber, jumper cordage and optical connectors, OFS has developed the best possible system-wide solution that helps alleviate concerns about connector damage, jumper damage, and safety issues associated with higher-power Raman pump lasers in optical networks.

Perhaps most importantly, the right choice of a transmission fiber with high Raman gain efficiency can help avoid higher Raman pump powers from the very beginning. Distributed Raman amplifiers work by sending high power (typically > 200 mW) laser light into the transmission fiber carrying the optical signals in a fiber network. The light from these high power pump lasers is then translated into the signal wavelengths through the Raman scattering process. The more efficient this process is, the lower the pump power required for a set amount of optical amplification.

OFS' unique TrueWave fibers (such as, TrueWave *REACH* fiber) have been intentionally designed to have the characteristics needed to provide optimally efficient Raman gain while avoiding unwanted effects such as non-linear crosstalk resulting from high signal power in the transmission process. In fact, TrueWave REACH fiber is the first and only commercially available fiber explicitly designed with Raman amplification requirements in mind. Raman gain efficiency is related to the slope of the Raman on-off gain versus the pump-laser power. A high Raman gain efficiency means that one can achieve higher Raman on-off gain at lower optical pump-laser powers. Thus, higher Raman efficiency means lower power pump-lasers. The higher Raman efficiency of TrueWave fibers compared to other transmission fibers is shown in Figure 2.

As a result of its significantly superior Raman efficiency, TrueWave fibers provide the ability to use lower power pump-lasers and avoid both eye safety and connector damage limits from the very start. Furthermore, the lower power pump-lasers made possible by TrueWave fibers are also much less expensive than those required by other transmission fibers. Thus, TrueWave fibers not only help alleviate the eye safety and connector damage concerns, but also help lower both deployment and operational costs for service providers.

In addition to the transmission fiber characteristics, the high power of the Raman pump laser must be delivered to the outside plant transmission fiber through a series of optical connectors and jumpers shown in Figure 1. These components must be low in optical loss, so as not to further increase the power requirements and costs of the Raman pump lasers, but must also be tolerant of the hazards of Raman amplification. OFS LC connectors can achieve lower insertion loss than many other commercially available connectors. Since connector loss is a factor in the amount of Raman pump laser power, a lower loss connector can help reduce the required pump power, further concerns about eye safety and damage

It has been shown that clean LC connectors can readily handle high optical power without reliability or damage concerns,⁶ however, it is also known that high optical powers can cause substantial damage in optical connectors that are not rigorously cleaned and very carefully handled.⁷ A more tolerant design for a connector would increase the effective area or spot size of the mode at the connector interface, thus lowering the intensity of the light at the connector face.⁸ Once the intensity is below the damage threshold, the connector will be more tolerant to high optical power. As such, OFS can supply expanded beam connectors that dramatically alleviate the concerns regarding substantial damage at connector interfaces.

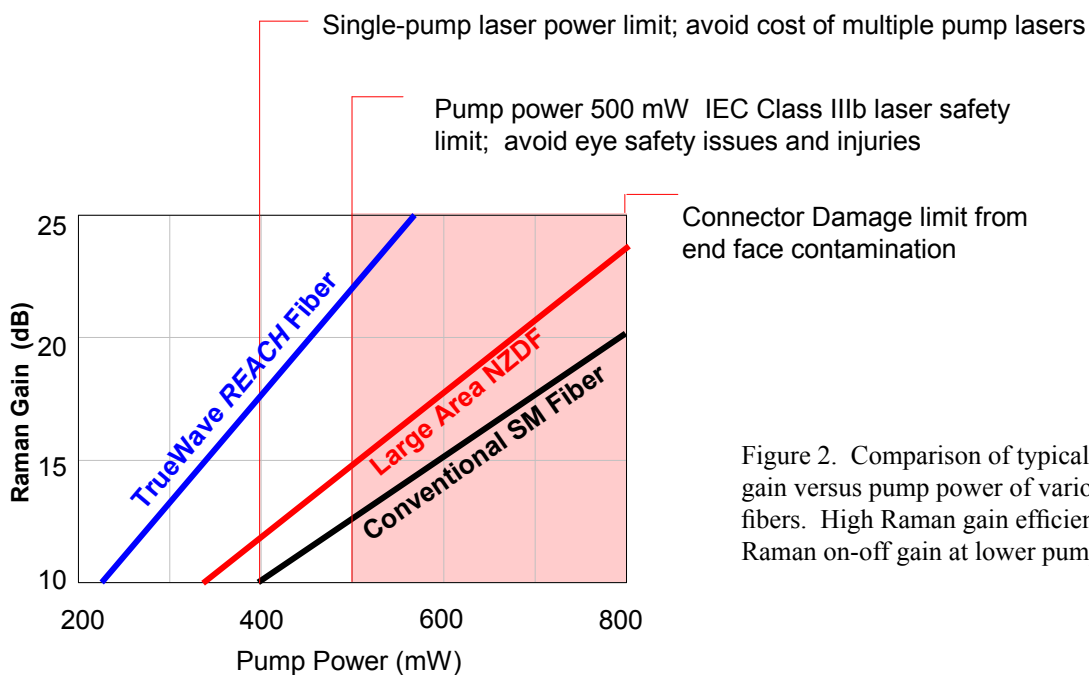


Figure 2. Comparison of typical Raman on-off gain versus pump power of various transmission fibers. High Raman gain efficiency helps increase Raman on-off gain at lower pump powers.

Movement of jumper cordage during installation, maintenance or removal creates the opportunity to bend or crimp the fiber at very small radii, even if for short time periods, caused by tugging or pulling on the jumper or inadvertently bumping or moving neighboring jumpers. Such small bend radii can cause large amounts of optical power to leak out of the guided mode only to be dumped into the fiber coating and buffering materials. As such, either the materials need to be made resistant to damage caused by high optical power or the fiber itself made to resist leakage of power to unguided modes at small bend radii. Fiber bend loss limit recommendations from standards bodies are insufficient to eradicate this problem. OFS' Blue Tiger jumpers have been specifically designed to keep power in the guided mode even at small bend radii and well below the standards recommendations. The low induced bend loss of Blue Tiger high performance jumpers at very small bend radii (<15 mm) is shown in Figure 3.

As shown here, the Blue Tiger jumper will keep optical power in the guided mode better than other jumper products, thus helping avoid coating damage. Also, with its 200 kpsi proof test level, 40 year failure rates below 1 ppm are expected.

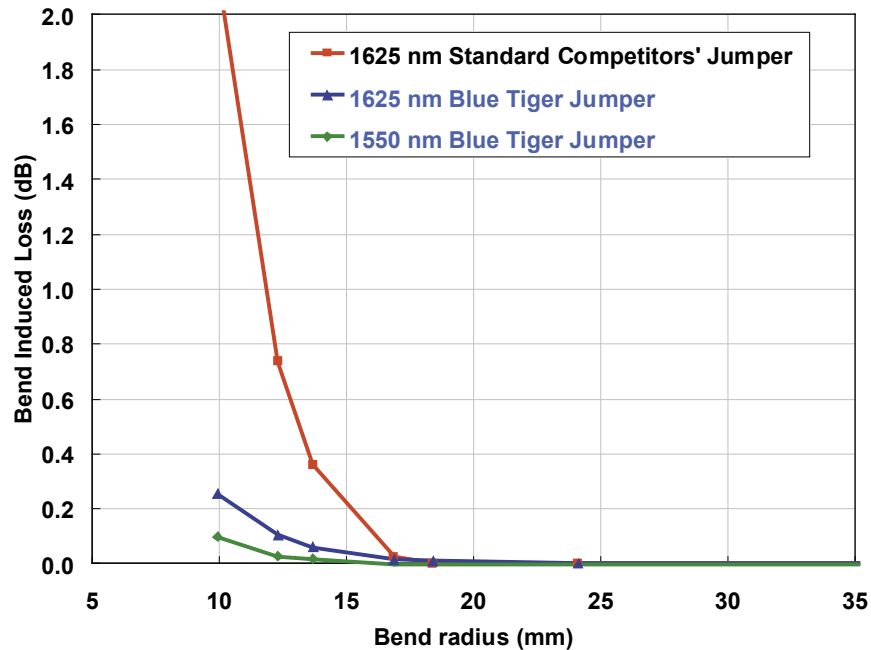


Figure 3. Comparison of induced bend loss of OFS Blue Tiger high performance jumper with standard competitors' jumper product.

Working as an integrated fiber and fiber management system, OFS has developed a set of technologies that manage the issues associated with the higher power transmissions needed to realize the tremendous benefits of Raman amplification. OFS transmission fiber cable and integrated fiber management systems can help alleviate the eye safety, connector and coating damage issues typically associated with high power Raman amplification – and can also significantly reduce the costs of realizing the significant benefits of Raman amplification.

¹ Y. Akasaka, et al., “Practical Challenges for Deploying Distributed Raman Amplifiers on a Traditional Fiber Network and Their Mitigation,” NFOEC 2003.

² P. Heywood, “Raman Risks Emerge”, Light Reading, News Analysis, March, 2001.

³ *ibid.*

⁴ R.M. Percival, E.S.R. Sikora and R. Wyatt, “Catastrophic damage and accelerated ageing in bent fibers caused by high optical powers,” *Elec. Lett.*, 36(5), (2000).

⁵ O. Graydon, “Bent fibers put networks at risk,” www.optics.org August, 2003.

⁶ D. N. Ridgway, “Effects of higher power levels on optical connectors, splices and related components,” NFOEC 2001, p. 561.

⁷ M. E. De Rosa, V. A. Bhagavatula, Q. Wu., K. Matusick, “High optical power testing of physical contact connectors at 1550nm,” OFC’01, Technical Digest, TuI7-1.

⁸ A.D. Yablon, et al., “Novel Beam Expanders and High-Power Connectors,” NFOEC 2003, p.1287.

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