TrueWave® *REACH* Fiber
Low Water Peak

ofs
Leading Optical Innovations

Optimized for Long Distance and High Capacity and Now with New Metro Application Capabilities

US Patent 5,418,881 and 5,298,047

Product Description

With TrueWave® *REACH* Low Water Peak (LWP) fiber, OFS continues the wave of optical innovation that began with the award-winning TrueWave fiber introduced in 1993. Now, TrueWave *REACH* LWP fiber provides lower losses in the 1400 nm region further optimizing performance for today's optically amplified systems over longer distances and with higher capacity. Specifically, TrueWave *REACH* LWP fiber currently offers:

- Fully compliant to both ITU-T G.655 and G.656 recommendations for Non-Zero Dispersion fiber (NZDF)
- Optimum dispersion slope over the standard C-, L- bands, and S band (for future use) of any other NZDF, thereby providing optimum performance in all three wavelength bands
- Fully matched, commercially available dispersion compensating fiber module solutions
- Optimized characteristics for Raman amplification performance are further enhanced by LWP performance
- Excellent Polarization Mode Dispersion (PMD) performance
- The ability to increase regenerator spacing well beyond 1000 km, for 10 and 40 Gb/s transmission systems, enabling the highest performance at the minimal system cost
- Low and stable atternuation at the water peak helps ensure Coarse Wave Division Multiplexing (CWDM) use in the wavelength range from 1310 to 1625 nm (16 channels).

These characteristics translate into greater information capacity, while minimizing the need for complex dispersion and dispersion slope compensators and additional optical amplification. When designing today's long haul networks, you need assurance that the fiber you choose will optimally operate with transmission systems available today and in future systems under demonstration today in research laboratories. Using TrueWave *REACH* LWP fiber, OFS has demonstrated:

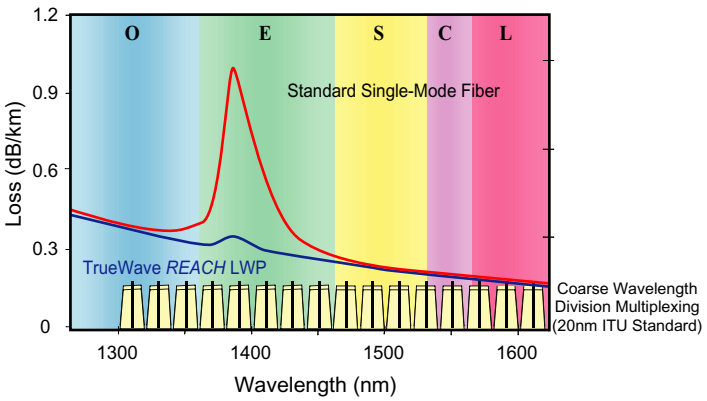
- 3200 km transmission of 80 wavelength channels operating in the C-band alone, at 10 Gb/s each
- Greater than 3 Tb/s per second transmission over 1200 km of TrueWave *REACH* fiber, with 77 wavelength channels operating in both the C- and L-bands, each at 40 Gb/s
- S-band transmission of 40 wavelength channels at 10 Gb/s each, over 1200 km, with a Raman amplified system
- 2000 km transmission of 80 wavelength channels, each at 40 Gb/s, with wideband Raman amplification and RightWave DCMs that simultaneously compensate both the C- and L-bands

All of these demonstrations have been done with 100 km spans, consistent with actual terrestrial application distances.

Low and Stable Attentuation at Water Peak

TrueWave *REACH* LWP fiber has benchmark low attenuation at the waterpeak region. The typical value is ≤ 0.35 dB/km at 1383 nm, and the value is maintained after exposure to hydrogen according to test defined in IEC 60793-2-50. TrueWave *REACH* LWP fiber with low waterpeak attenuation enables use of CWDM channels over the entire wavelength range from 1310 to 1625 nm; 16 channels in total.

Finally, the low waterpeak attenuation results in low attenuation at wavelengths close to the waterpeak. These critical wavelengths are used for Raman pumping, and the optimized use of distributed Raman Amplification requires low attenuation at these pump wavelengths.

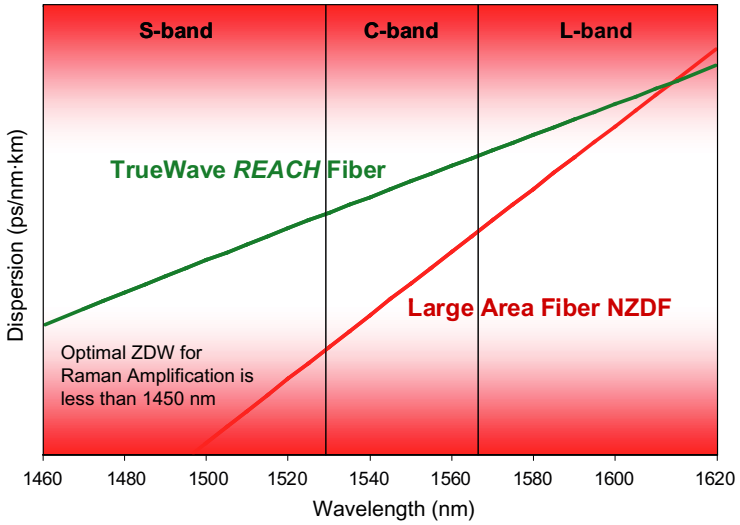


Relative Water Peak Performance

Wide Operating Band with TrueWave *REACH* LWP Fiber

Ideally, the chromatic dispersion of an optical fiber should have a constant, moderate value over the entire operating wavelength region. However, the dispersion of all fibers changes with wavelength, as determined by the dispersion slope. The smaller the slope, the less the dispersion changes with wavelength. For optimum performance over the C-, L- and S-bands, dispersion slope should be minimized. The TrueWave *REACH* LWP fiber is one of the few NZDF products on the market fullfilling the G.656 requirement based on its low dispersion slope.

Another advantage of TrueWave *REACH* LWP fiber is that its small dispersion slope allows its minimum dispersion to be increased to better suppress the four wave mixing (FWM) nonlinearity, while still keeping the fiber's maximum dispersion small enough for signals to travel over long distances with minimum need for dispersion and dispersion slope compensation over the C-, L- and S-bands.



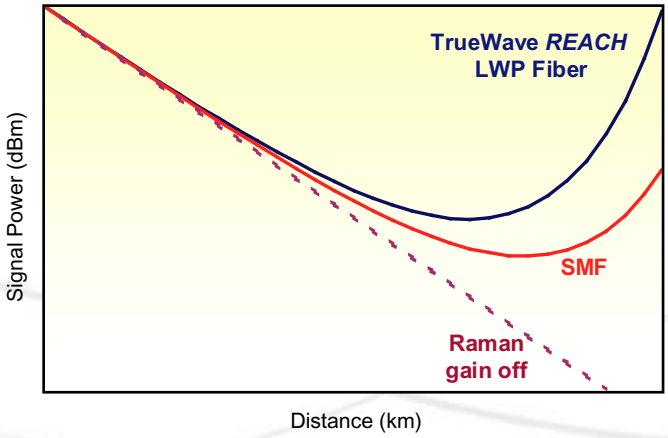
TrueWave REACH LWP Has Optimal Dispersion Across All Three Bands

Finally, for optimum distributed Raman Amplification, the Zero Dispersion Wavelength (ZDW) should be below 1450 nm in order to avoid FWM between Raman Pump source and transmission signal. This is fulfilled on TrueWave *REACH* LWP fiber as one of the few NZDF's on the market.

Flexible Amplifications Choices

TrueWave *REACH* LWP fiber allows DWDM transmission channels to be used over the full S, C and L-bands (1460 to 1625 nm). Amplifier technologies used may be both Erbium Doped Fiber Amplifiers (EDFA's), and the fast emerging distributed Raman Amplification technology.

Distributed Raman Amplification technology shows advantages in reducing system noise and enabling wideband amplification as compared to today's EDFA's. How well the transmission fiber can utilize this new amplifier technology is defined by the Raman Gain Efficiency.



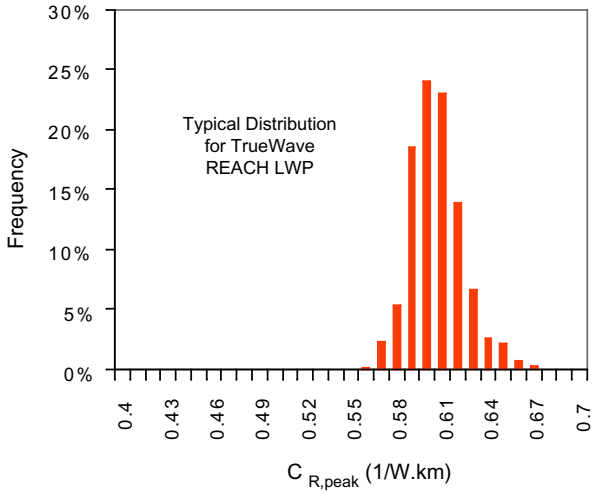
Raman Amplification Performance

Lower & Stable PMD

OFS was the first to adopt specifications for Polarization Mode Dispersion (PMD) in single-mode fibers. Manufactured using both a patented fiber drawing process and extensive process control, TrueWave *REACH* LWP is specified at levels much lower than the minimum requirements defined by ITU-T G.655 and G.656. OFS PMD performance, assured by the patented drawing process also greatly improves stability from fiber to cable to field application including time and temperature variations.

OFS understands that PMD is a statistical value that is dependent on the properties of the fiber as well as the mechanical condition of the fiber in cable. OFS uses a low mode coupled (LMC) measurement to help ensure fiber performance since spooled fiber PMD measurements are not indicative of final cabled performance. OFS fiber PMD is specified in fiber form with a best in class Link Design Value (LDV) and a Maximum Individual Fiber Value to support customer validation of system performance as well as individual product performance.

Optimal Raman Gain Efficiency



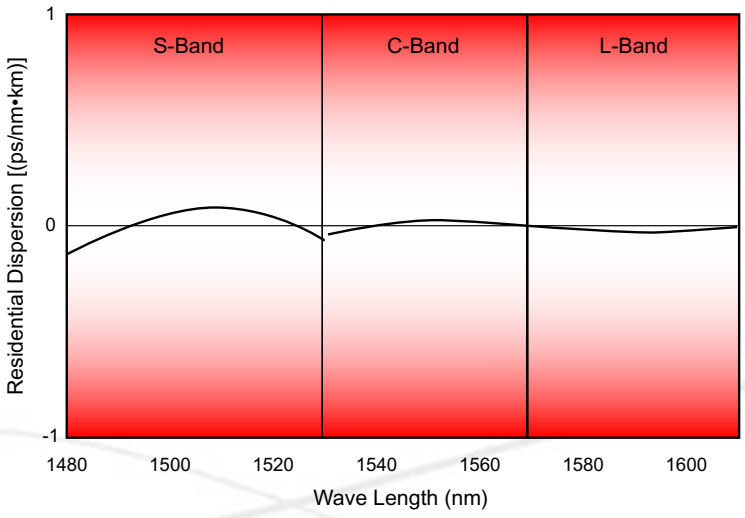
Raman Gain Efficiency ($C_{R,Peak}$)

TrueWave *REACH* LWP fiber has been optimized to have one of the best Raman Gain efficiencies compared to other transmission fibers due to the optimized effective area of the fiber. A typical value for TrueWave *REACH* LWP fiber is 0.60 W-1 km-1 compared to 0.40 - 0.45 for Standard Single Mode fiber and Large Effective Area NZDF respectively.

Precise Dispersion Compensation With TrueWave *REACH* LWP Fiber

The highest capacity systems today attribute their success to the use of the wide spectral bands available in optical fibers. To achieve long distance transmission for these 10 and 40 Gbit/s systems, precise dispersion compensation over the full extent of these bands is required.

TrueWave *REACH* LWP fiber is optimized to achieve precise wideband dispersion over the C-, L- and S-bands. TrueWave *REACH* LWP fiber's dispersion properties result in a low relative dispersion slope across all three bands. This low relative dispersion slope makes it easier to create the precise wideband compensating modules needed for high capacity systems. Coupled with OFS' RightWave™ Dispersion Compensating Modules (DCM), TrueWave *REACH* LWP fiber provides unsurpassed system performance compared with other NZDF products.



RightWave DCM with TrueWave REACH LWP delivers Unsurpassed Residual Dispersion

For long DWDM systems, the low relative dispersion slope of TrueWave *REACH* LWP fiber helps eliminate the need for complex dispersion compensation schemes such as splitting the wavelength band into several sub-bands, each of which are individually compensated with different amounts of dispersion compensation, or using special slope compensators. TrueWave *REACH* LWP fiber helps eliminate the need for this complexity and added cost.

Geometrical Characteristics:

Glass Geometry:	
Cladding Diameter	125.0 ± 0.7 µm
Core/Clad Concentricity Error	≤ 0.5 µm
Cladding Non-circularity	≤ 0.7%
Coating Geometry:	
Coating Diameter (uncolored)	245 ± 5 µm
Coating/Cladding Concentricity Error	≤ 10 µm
Length:	
Standard as well as customer specific lengths are available up to 50.4 km	

Transmission Characteristics:

Attenuation:	
Maximum noncabled fiber attenuation coefficient (loss):	
@ 1310 nm ≤ 0.4 dB/km	typically ≤ 0.35 dB/km
Water Peak Attenuation after aging[1]:	
@ 1383 nm ≤ 0.4 dB/km	typically ≤ 0.35 dB/km
@ 1450 nm < 0.26 dB/km	typically ≤ 0.25 dB/km
@ 1550 nm ≤ 0.22 dB/km	typically ≤ 0.20 dB/km
@ 1625 nm ≤ 0.24 dB/km	typically ≤ 0.21 dB/km
Attenuation vs. Wavelength:	
The maximum attenuation in the range from 1525 to 1625 nm is no more than 0.05dB/km greater than the attentuation at 1550 nm	
Macrobending Attenuation:	
The maximum attenuation with bending does not exceed the specified values under the following deployment conditions:	

Deployment Condition	Wavelength	Induced Attenuation
1 turn, 32 mm (1.2 inch)	1550 nm	≤ 0.50 dB
mandrel diameter	1625 nm	≤ 0.50 dB
100 turns, 60 mm (24 inch)	1550 nm	≤ 0.05 dB
mandrel diameter	1625 nm	≤ 0.05 dB

Point Discontinuities:	
There are no point attenuation discontinuities greater than 0.05 dB at 1550 nm.	
Chromatic Dispersion:	
C-Band 1530-1565 nm	5.5 - 8.9 ps/nm-km
L-Band 1565-1625 nm	6.9 - 11.4 ps/nm-km
Dispersion Slope at 1550 nm:	≤ 0.045 ps/nm² -km
S - L bands 1460 - 1625 nm	2.0 - 11.4 ps/nm² -km
Zero Dispersion Wavelength:	≤ 1405 nm
Mode Field Diameter:	8.6 ± 0.4 µm @ 1550 nm
Effective Area:	55 µm² (typical) @ 1550 nm
Fiber Polarization Mode Dispersion @ 1550 nm²:	
PMD Link Design Value (LDV)[3]	≤ 0.04 ps/√km
Maxium Individual Fiber	≤ 0.1 ps/√km

Other Performance Characteristics:

Chromatic Dispersion at 1310 nm:	-5 ps/nm-km (typical)
Cable Cutoff Wavelength:	≤ 1310 nm
Raman Gain Efficiency[4]:	≥ 0.6 (typical)
Effective Group Index of Refraction	
1310 nm	1.471
1550 nm	1.470
1625 nm	1.470
Typical Dispersion Slope at 1550 nm:	0.040 (ps/nm² -km)
Rayleigh Backscattering Coefficient (for 1 µs pulse width)	
1310 nm	-45.4 dB
1550 nm	-49.8 dB
1625 nm	-51.1 dB
Dynamic Fatigue Parameter (N_d):	≥ 20
Weight per unit length:	64 grams/km
Typical Cabled Polarization Mode Dispersion @ 1550 nm²:	≤0.02 ps/√km

Notes:

1 H2 aging according to IEC 60793-2-50

2 PMD value may change when cabled. Check with your cable manufacturer for specific PMD limits in cable form.

3 The PMD Link Design Value complies with IEC 60794-3 Ed.3.0, Method 1, March 31, 2000, March 31, 2000 (N=24, Q=0.1%). Details are described in IEC 61282-3 TR Ed.1.0, October 27, 2000."

4 Using 1450 nm pump source.

Environmental Characteristics:

Operating Temperature	-60° C to +85° C
Temperature Dependence of Attenuation:	
Induced attenuation at 1550 & 1625 nm at -60° C to +85° C	≤ 0.05 dB/km
Temperature — Humidity Cycling:	
Induced attenuation at 1550 & 1625 nm at -10° C to +85° C and 95% relative humidity	≤ 0.05 dB/km
Water Immersion, 23° C:	
Induced attenuation at 1550 & 1625 nm due to water immersion at 23 ± 2° C	≤ 0.05 dB/km
Accelerated Aging (Temperature), 85° C:	
Induced attenuation at 1550 & 1625 nm due to temperature aging at 85 ± 2° C	≤ 0.05 dB/km
Retention of Coating Color:	

D-LUX® coated fiber shows no discernible change in color when aged for:

- 30 days at 95° C and 95% relative humidity
- 20 days in dry 125° C heat

Mechanical Characteristics:

Proof Test Level:	0.7 GPa (100 kpsi)
Dynamic Tensile Strength:	
The median tensile strength of unaged samples with a 0.5 meter gauge length is:	≥ 3.8 GPa (550 kpsi)
Fiber Curl Radius:	≥ 4 m
Coating Strip Force:	
The force to mechanically strip the dual coating is:	≥ 1.3 N (0.3 lbf.) and ≤ 8.9 N (2.0 lbf.)

For additional information please contact your sales representative. You can also visit our website at http://www.ofsoptics.com or call 1-888-fiberhelp.

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