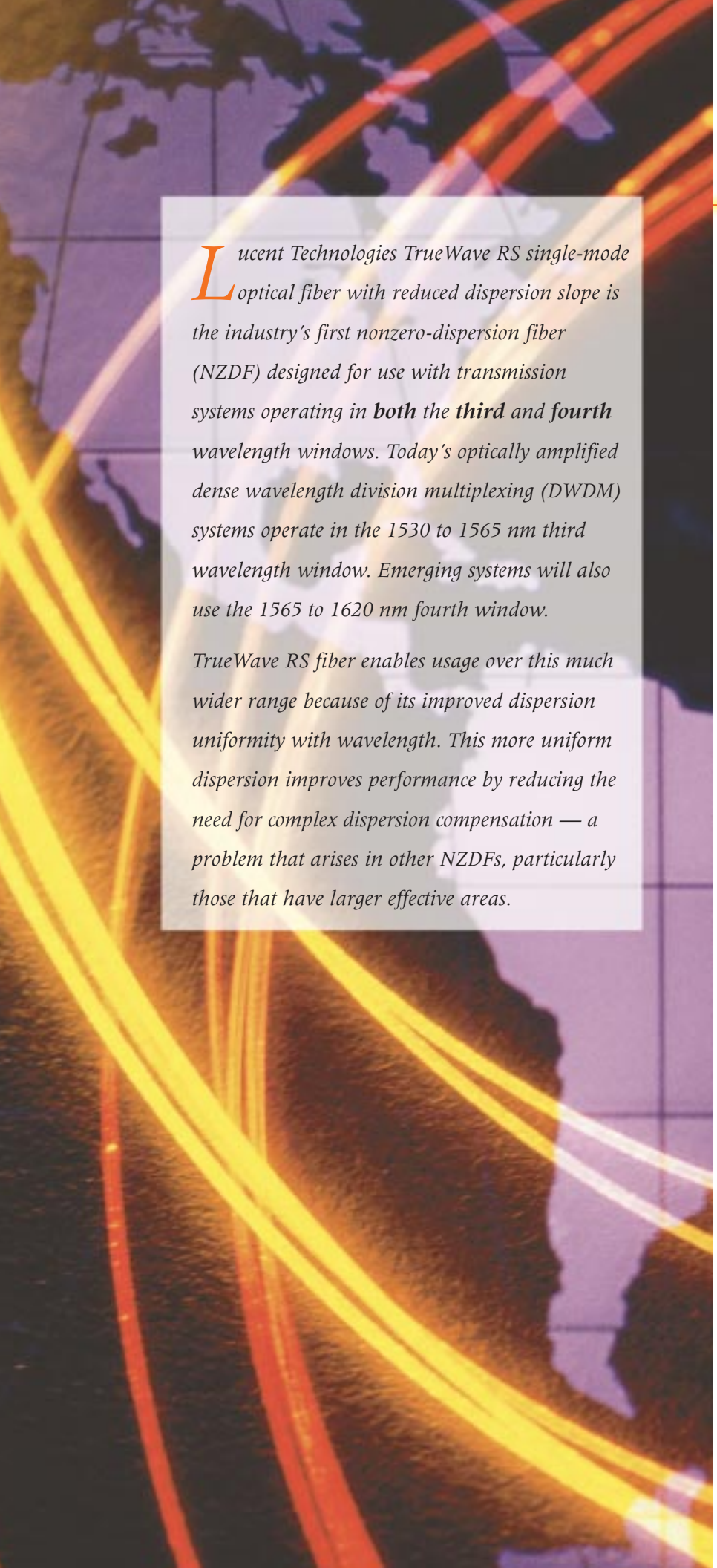
Lucent Technologies
Bell Labs Innovations

TrueWave® RS
Nonzero-Dispersion Optical Fiber

Optimized for the Third and Ready
for the Fourth Wavelength Window!



Lucent Technologies TrueWave RS single-mode optical fiber with reduced dispersion slope is the industry's first nonzero-dispersion fiber (NZDF) designed for use with transmission systems operating in ***both*** *the* ***third*** *and* ***fourth*** *wavelength windows. Today's optically amplified dense wavelength division multiplexing (DWDM) systems operate in the 1530 to 1565 nm third wavelength window. Emerging systems will also use the 1565 to 1620 nm fourth window.*

TrueWave RS fiber enables usage over this much wider range because of its improved dispersion uniformity with wavelength. This more uniform dispersion improves performance by reducing the need for complex dispersion compensation — a problem that arises in other NZDFs, particularly those that have larger effective areas.

With TrueWave RS fiber, Lucent Technologies continues the technology innovation Wave that began with the patented and award-winning TrueWave fiber introduced in 1993. Now, TrueWave RS improves upon this performance and extends it to longer wavelengths, becoming the only NZDF with both third and fourth window specified performance. Specifically, TrueWave RS is unique from other NZDFs by having:

- a more uniform chromatic dispersion over the third and fourth windows
- low bending induced loss at 1550 nm and at the more critical 1600 nm wavelength
- attenuation and dispersion specifications in the fourth window.

These characteristics translate into greater information capacity while minimizing the need for complex dispersion slope compensators.

When designing today's network, you need assurance that the fiber you choose will optimally operate with transmission systems available today and those that have already been demonstrated in research laboratories. Lucent Technologies has demonstrated 1200 Gb/s transmission on TrueWave fiber using wavelengths as high as 1620 nm!

More Uniform Dispersion

Ideally, the chromatic dispersion of an optical fiber should have a constant value over the entire wavelength operating region. However, the dispersion of all fibers varies with wavelength, and this variability is quantified by their dispersion slope (S_O). The smaller the slope, the less the dispersion varies with wavelength.

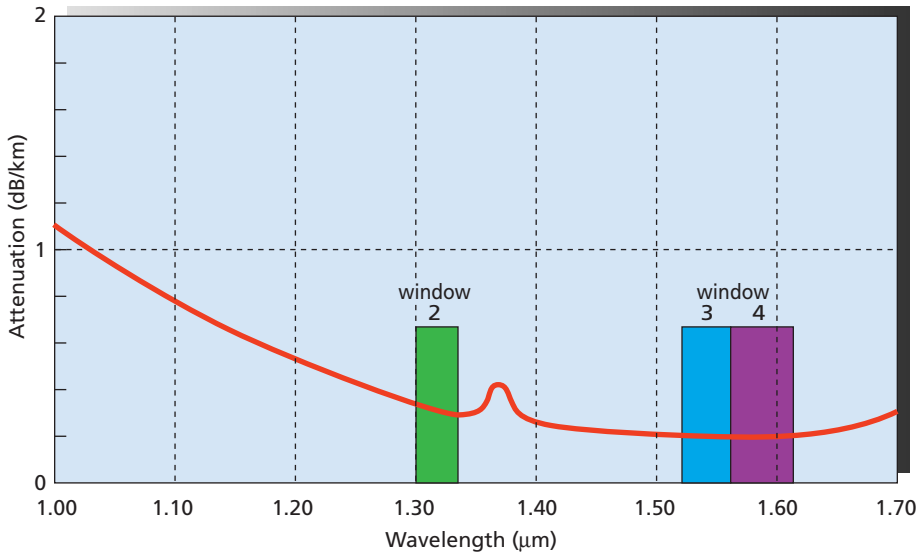
For optimum performance in the third and fourth wavelength windows, dispersion variability should be minimized. TrueWave RS fiber has at least 36% less dispersion variability with wavelength than other NZDFs and 55% less variability than larger mode area NZDFs.

Another advantage of TrueWave RS 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.

Flexible Optoelectronic Choices

TrueWave RS fiber supports wavelengths over the full 1530 to 1565 nm wavelength range (the C band third window) defined by standards bodies for NZDF. Additionally, the fiber supports wavelengths up to 1620 nm in the long wavelength L band — the fourth operating window. This flexibility enables the fiber to be used with a wide variety of transmission equipment.

TrueWave RS fiber is compatible with other NZDFs and with conventional single-mode fiber, using the same installation and splicing techniques. This is possible because of TrueWave RS fiber's excellent micro- and macrobending performance in both the 1550 and 1600 nm operating windows.



Reduce Signal Interference With TrueWave RS Fiber

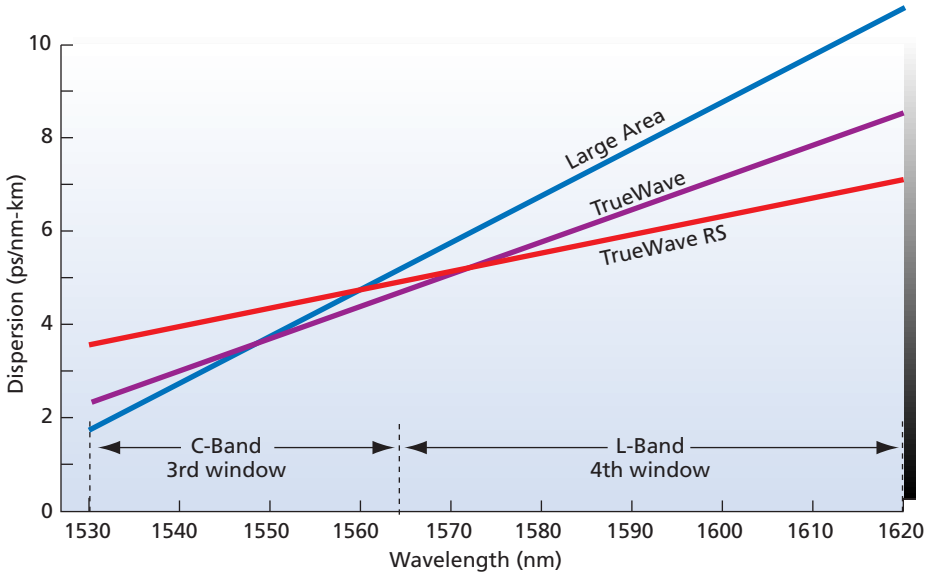
The uniform dispersion of TrueWave RS fiber overcomes four wave mixing nonlinearities by providing a controlled amount of chromatic dispersion throughout the third and fourth wavelength operating windows. This dispersion prevents phase matching between the various signal wavelengths, thereby virtually eliminating wavelength mixing interference. The dispersion value is small enough to allow 10 Gb/s transmission rates at each of multiple wavelengths over long distances without dispersion compensation.

Reduce System Cost With TrueWave RS Fiber

Dispersion unshifted (conventional) fiber was designed to minimize loss and maximize bandwidth for 1310 nm systems. The fiber's high chromatic dispersion at 1550 nm (approximately 17 ps/nm-km) may require the additional cost of dispersion compensation and/or more transmission equipment when used in high capacity amplified systems.

TrueWave RS fiber keeps the cost of dispersion compensation to a minimum compared with unshifted and other NZDFs. For example, NZDFs having larger effective areas tend to have large dispersion variability with wavelength. For long DWDM systems, this large variability necessitates the use of complex dispersion compensation schemes. The wavelength band must be split into several sub-bands each of which are individually compensated with different amounts of dispersion compensation. TrueWave RS fiber reduces the need for this complexity and added cost.

TrueWave RS fiber uses a special refractive index profile in the core, surrounded by synthetic silica cladding layers having different refractive indices, to achieve low attenuation and nonzero-dispersion in the third and fourth operating wavelength windows. This reduces and can even eliminate the cost of dispersion compensation.



Lower PMD

Manufactured using a patented fiber drawing process, TrueWave RS fibers have low Polarization Mode Dispersion (PMD).

Because the PMD of a fiber can depend on its geometrical and mechanical condition, the best indicator of true PMD is the PMD of the fiber in the finished cable — before it is shipped from the factory. This arises because the fiber's bend diameter and back tension on a spool can mask its true PMD. Low values of PMD measured when the fiber is wound on a spool do not guarantee consistently low PMD in finished cable.

With TrueWave RS fiber, Lucent Technologies is the first manufacturer to specify a new product parameter — the PMD Link Design Value in finished cable. This parameter complies with the U.S. contribution to the IEC standards body, and gives network designers a useful tool for computing the PMD of concatenated cables. For example, the 0.1 ps/$\sqrt{\text{km}}$ PMD LDV for TrueWave RS cabled fiber produces a 2 ps value for a 400 km long route. This excellent PMD performance is sufficiently small to enable 40 Gb/s transmission at each of multiple wavelengths!

Improved Core/Cladding Eccentricity

Accurate centering of the core in its cladding makes it easier to achieve low loss fusion splices using standard techniques and equipment. At ≤ 0.6 µm, the core/cladding concentricity error of TrueWave RS fiber is the industry's best for NZDF.

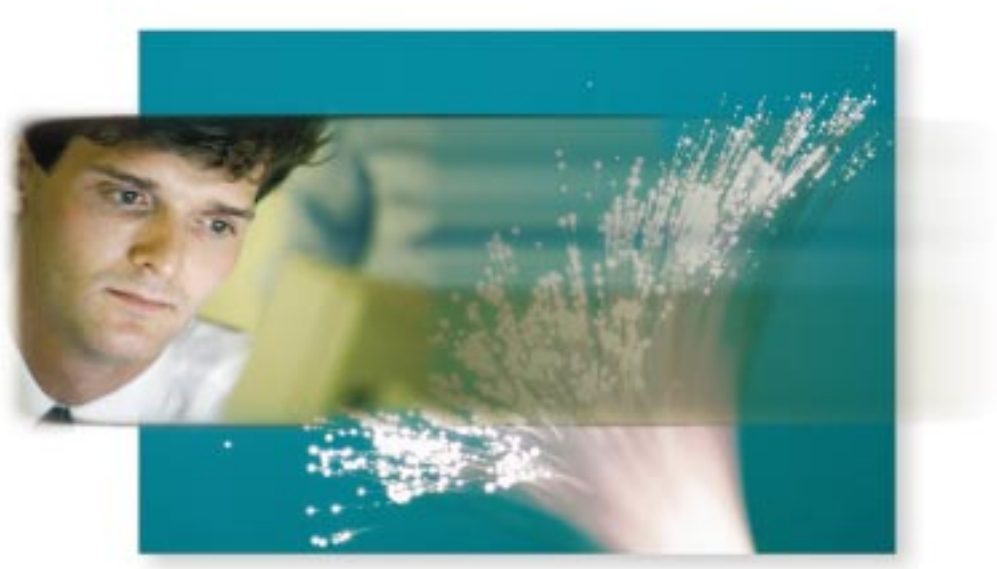
Choose TrueWave RS Fiber For Long-term Reliability

TrueWave RS optical fiber features D-LUX® Coating for world class environmental performance and long-term reliability. This dual coating system is applied over the cladding to protect the fiber. Each fiber is proof tested to at least 100 kpsi to ensure that it will survive installation loads and associated long-term stresses, even under extreme environmental conditions.

Cutting Edge Technology Wins Top Awards

Lucent Technologies has received five awards for its patented TrueWave single-mode optical fiber products. Separate panels of technical experts selected TrueWave fiber products from many nominees for the following awards:

- "Commercial Technology Achievement Award for Fiber Optics" from Laser Focus World Magazine, 1995.
- "Circle of Excellence Award" from Photonics Spectra Magazine,1995.
- "R&D 100 Award" in telecommunications technology from R&D Magazine, 1995.
- "Technology Award for Fiber and Cable" from FIBEROPTIC Product News Magazine, 1995.
- "Circle of Excellence Award" from Photonics Spectra Magazine, 1998.



Stay in the Vanguard with Lucent Technologies

Lucent's family of TrueWave single-mode optical fibers and cables represent the most complete product line in the industry for building high capacity transport systems. Lucent received the first NZDF (G.655) patent in 1994 and its TrueWave NZDF product family has been recognized with unprecedented awards for excellence in commercial technology and technological significance. And now, TrueWave RS fiber is the latest Wave from Bell Laboratories in this evolution of product innovation .

Why invest in obsolescence? TrueWave RS Fiber and Cables offer unparalleled growth potential — now and for years to come. Choose TrueWave RS single-mode optical fiber and cables from Lucent Technologies. You'll know you've seen the future.

Transmission Characteristics

Attenuation

The maximum attenuation coefficient (loss) may be specified between 0.22 and 0.25 dB/km and the value will pertain at 1550 and 1600 nm.

Attenuation vs. Wavelength

The maximum attenuation in the range from 1525 to 1620 nm is no more than 0.05 dB/km greater than the attenuation at 1550 nm.

Attenuation at Water Peak

The attenuation coefficient at the OH^- absorption peak (1385 ± 3 nm) is less than or equal to 1.0 dB/km.

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) diameter	1550 nm	≤ 0.5 dB
	1600 nm	≤ 0.6 dB
100 turns, 75 mm (3 inch) diameter	1550 nm	≤ 0.05 dB
	1600 nm	≤ 0.05 dB

Point Discontinuities

There are no attenuation discontinuities greater than 0.10 dB at 1550 nm and at 1600 nm.

Chromatic Dispersion

3 rd window: 1530 to 1565 nm	2.6 to 6.0 ps/nm-km
4 th window: 1565 to 1620 nm	4.0 to 8.6 ps/nm-km
Dispersion Slope	≤ 0.05 ps/nm^2-km

Mode Field Diameter

at 1550 nm	8.4 ± 0.6 µm
at 1600 nm	8.7 ± 0.6 µm

Cutoff Wavelength

Cable Cutoff Wavelength (λ_{cc})	≤ 1260 nm

Cabled Fiber Polarization Mode Dispersion at 1550 nm[1]

link design value[2]	≤ 0.1 ps/$\sqrt{km}$

[1] In Lucent Technologies cables. Check with your cable manufacturer for specific PMD limits in cable form.

[2] The PMD Link Design Value complies with the U.S. contribution to IEC SC 86A/WG1, Method 1, September 1997.

Geometrical Characteristics

Glass Geometry	
Cladding Diameter	125.0 ± 1.0 µm
Core/Clad Concentricity Error	≤ 0.6 µm
Cladding Non-circularity	≤ 1.0%
Coating Geometry	
Coating Diameter (uncolored)	245 ± 10 µm
Coating/Cladding Concentricity Error	< 12 µm
Length	
Lengths can be cut to specific customer specifications	
Standard spool lengths	4.4, 6.4, 12.6, 19.2, 25 km

Environmental Characteristics

Operating Temperature	-60° C to +85° C
Temperature Dependence of Attenuation	
Induced Attenuation at 1550 nm at -60° C to +85° C	≤ 0.05 dB/km
Temperature — Humidity Cycling	
Induced Attenuation at 1550 nm at -10° C to +85° C and 95% relative humidity	≤ 0.05 dB/km
Water Immersion, 23° C	
Induced Attenuation at 1550 nm due to Water Immersion at 23 ± 2° C	≤ 0.05 dB/km
Accelerated Aging (Temperature), 85° C	
Induced Attenuation at 1550 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	100 kpsi (0.7 Gpa)*
Dynamic Tensile Strength	
The median tensile strength of unaged samples with a 0.5 meter gauge length:	≥ 550 kpsi (38 Gpa)
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.)
Coating Appearance	
The dual coating layers are free of voids or entrapped bubbles.	
Pullout Force (Adhesion of Coating to Glass Surface)	
The pullout force is	> 6.2 N (1.4 lbf.) and < 22.2 N (4.9 lbf.)
Fiber Curl	≥ 2m

Fiber Shipping Spool Mechanical Specifications

	A (for lengths < 15 km)	B (for lengths > 15 km)
Flange diameter	9.25 in (23.50 cm)	9.25 in (23.50 cm)
Barrel Diameter	6.00 in (15.24 cm)	6.00 in (15.24 cm)
Traverse Width	3.39 in (8.61 cm)	4.70 in (11.94 cm)
Weight	1.22 lbs (0.46 kg)	1.36 lbs (0.51 kg)

* Higher proof test levels are available upon request.

Other Performance Characteristics (Typical Values)

Attenuation Coefficient at 1310 nm	< 0.4 dB/km
Chromatic Dispersion at 1310 nm	-9 ps/nm-km
Dispersion Slope (ps/nm^2-km)	0.045
Effective Group Index of Refraction	
1310 nm	1.471
1550 nm	1.470
Rayleigh Backscattering Coefficient (for 1 µs pulse width)	
1310 nm	-46.2 dB
1550 nm	-49.8 dB
Dynamic Fatigue Parameter (N_d)	> 20
Static Fatigue Parameter (N_s)	> 20
Weight per unit length	64 grams/km
Cabled Polarization Mode Dispersion at 1550 nm[1]	≤ 0.05 ps/$\sqrt{km}$

[1] In Lucent Technologies cables. Check with your cable manufacturer for specific PMD limits in cable form.

For more information about this and other Lucent Technologies products and services, please contact your Lucent Technologies Sales Representative.

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