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White Paper

Introduction to Single-Mode Fiber: Addressing Common Perceptions

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In recent years, more enterprise and data center networks have adopted single-mode fiber optics. Traditionally, single-mode has been limited to applications such as long haul, service provider networks, metropolitan area networks, and backbone distribution for large campuses. However, single-mode is now finding its way into shorter reach applications.

In early 2018, Leviton surveyed network professionals about the type of fiber they would install today to plan for future growth, and found a significant jump in OS2 compared to surveys from previous years. This change is likely a result of decreasing cost and recent standards committee activities that continue to promote more single-mode options for higher speeds such as 200 and 400 Gb/s. As this trend continues, the market in general will find single-mode to be a more enticing option.

If you are new to single-mode networks and installations, this paper will address some prevailing preconceived notions about single-mode fiber — whether true or false — and provide guidance for single-mode testing, cleaning, and inspecting.

Common Beliefs About Single-Mode

SINGLE-MODE HAS FEWER GENERATIONS OF FIBER TYPES TO DEAL WITH.

True. It certainly is the case that more multimode generations have been introduced over the years, all supporting different distances. With single-mode, there has only been two fiber cable types in the past 20 years: OS1a and OS2. This makes single-mode much more predictable for supporting distances and future upgrades.

FIGURE 1: Single-mode has fewer generations of fiber than multimode

Multimode Cable Type	100GBASE-SR4
OM1	Not supported
OM2	Not supported
OM3	70 m
OM4	100 m
OM5	100 m

Single-Mode Cable Type	100GBASE-DR
OS1a	500 m
OS2	500 m

For example, consider the cable types and distance limits for handling new 100 Gb/s short reach standards in **Figure 1**. Older multimode standards like OM1 and OM2 can't support the 100GBASE-SR4 standard, while OM3 can support it up to 70 meters, and OM4 or OM5 can support it up to 100 meters. On the flipside, the distance is the same for single-mode, whether you installed OS1 15 years ago or OS2 last year. Connectors will likely need replacing over the years, but there is no need to pull new cable with single-mode. The 500 meter example below for single-mode is for 100GBASE-DR, a duplex 2-fiber solution introduced in 2018.

SINGLE-MODE TRANSCEIVERS ARE MORE EXPENSIVE.

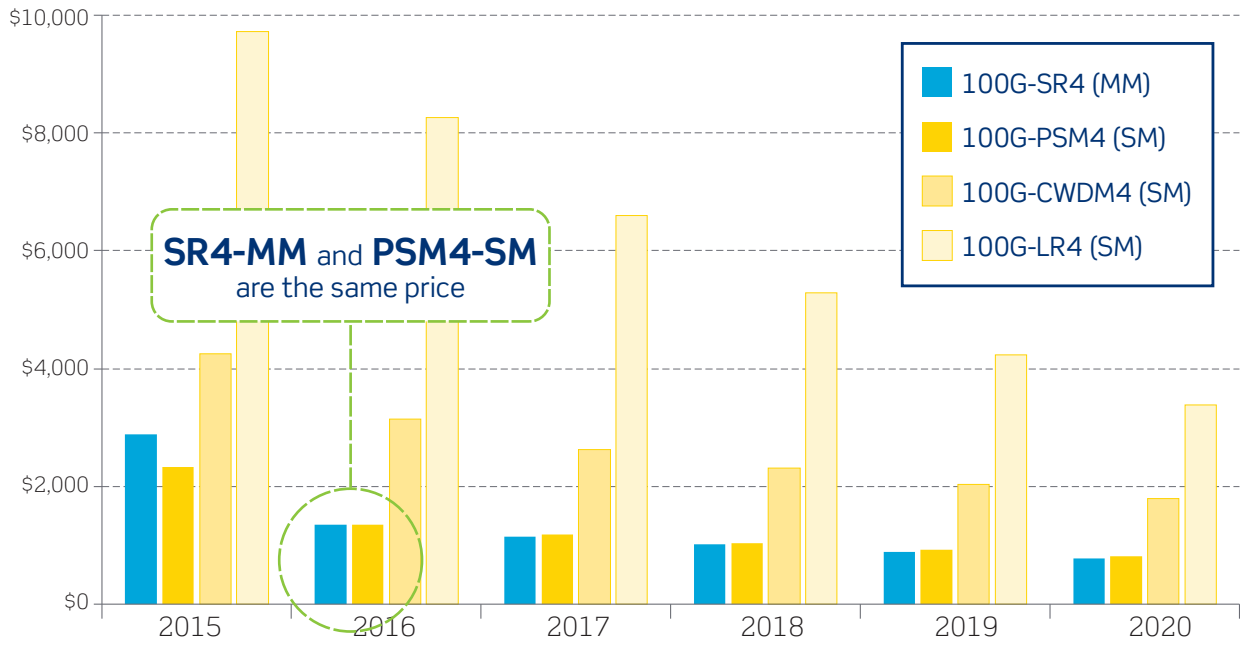
True and False. If single-mode cable offers a much longer life, as pointed out above, why hasn't more of it been installed? The primary decision to use multimode instead of single-mode over the years comes down to transceiver cost. In fact, there was a point in time when a single-mode transceiver was 7.5 times the cost of a multimode transceiver.

However, times have changed, and single-mode transceivers have come down in cost. This is largely the

result of large hyperscale data centers installing more lower cost single-mode transceivers, and as a result, reshaping the enterprise and data center markets. Adoption by these companies has reduced the cost of single-mode optics to the point where the cost for 100 Gb/s single-mode dropped tenfold over the past two years, bringing it in line with multimode fiber.

For example, 100GBASE-PSM4 single-mode technology, created in 2014 by a multi-source agreement group, is currently the same price as 100GBASE-SR4 multimode transceivers. PSM4 transceivers were specifically designed as a low-cost option for 500 meters or less, using an 8-fiber MPO/MTP connection. As large hyperscale data centers buy single-mode options like PSM4 in large quantities for short reach, the prices drop. Similarly, the price for long-reach single-mode solutions such as 100G-LR4 and 100G-CWDM4 have dropped and will continue to drop, as shown in **Figure 2** below.

FIGURE 2: Estimated prices for 100 Gb/s transceivers



Source: LightCounting, 2016

SINGLE-MODE ONLY WORKS WITH DUPLEX CONNECTIONS, NOT MPO/MTP® CONNECTIONS.

False. While formerly true, transceiver vendors are now making single-mode versions that run on parallel optics — as shown in **Figure 3** — in order to reduce costs for shorter data center links. These parallel options also allow for cabling breakouts, which have already become a very popular approach in multimode networks. With breakouts, you can split a 100 Gb/s transceiver out to four 25 gigabit channels. This helps create more efficiency and greater port density in network designs.

FIGURE 3: Single-mode options to 400 Gb/s over parallel optics

Bandwidth	Standard/MSA	Distance
100 Gb/s	100GBASE-PSM4	500 m
200 Gb/s	200GBASE-DR4	500 m
400 Gb/s	400GBASE-DR4	500 m

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A GREATER INSERTION LOSS IS ALLOWED FOR SINGLE-MODE COMPARED TO MULTIMODE.

False. This is no longer a true statement. With cheaper transceivers comes a reduced allowance for insertion loss. Designers especially need to be aware of reduced loss budgets for newer transceivers targeted at data centers. And if your design has multiple connections, you can run into trouble. Be sure to ask specific questions, particularly if you are using MPO/MTP connections.

As an example of stricter insertion loss allowances for 100 Gb/s, consider the channel loss limits listed below in **Figure 4**. When you move to new single-mode options like CWDM4 (Coarse Wave Division Multiplexing), 100GBASE-PSM4, and 100GBASE-DR, you are no longer designing for 6 or 7 dB loss but down to 3 dB.

FIGURE 4: Channel Loss Limits

100 Gb/s Ethernet	Channel Loss
100GBASE-ER4	15.0 dB
100GBASE-LR4	6.3 dB
100GBASE-CWDM4	5.0 dB
100GBASE-PSM4	3.3 dB
100GBASE-DR	3.0 dB

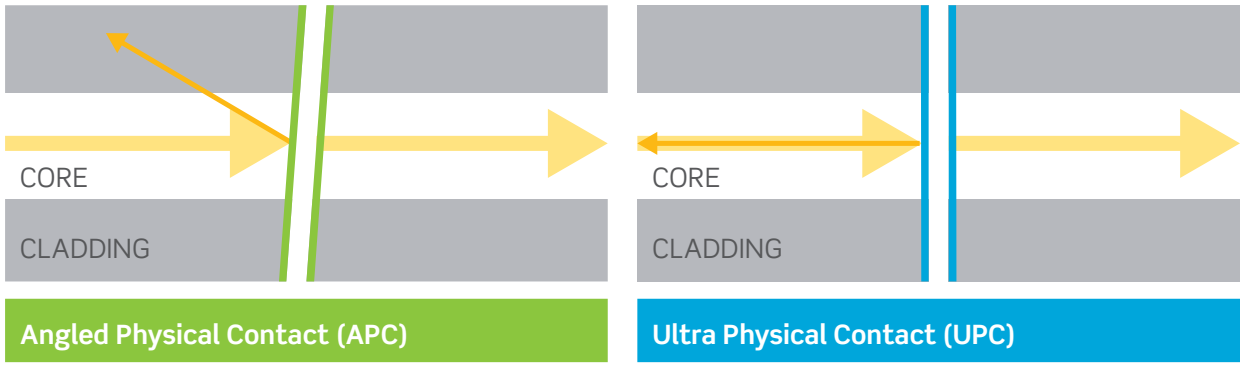
SINGLE-MODE BRINGS ADDITIONAL RETURN LOSS (REFLECTANCE) CONCERNS.

True. Return loss is a real concern with single-mode. Multimode is very tolerant of light being reflected back into the transceiver, but single-mode is not. At higher data rates, errors are generated if too much light is received back. In fact, with higher powered lasers, too much reflectance can actually damage the laser.

Reflectance is a result of small air gaps that can occur at the physical contact (PC) where two connections are joined together, as shown by the yellow arrow in **Figure 5**. Return loss is measured as a ratio (in decibels) of the power of the outgoing signal to the power of the signal reflected back.

Due to reflectance concerns, the majority of single-mode connections use an angled physical contact (APC). In fact, all single-mode MPO/MTP connections use APC, as it is nearly impossible to achieve a good reflectance with a UPC MPO over single-mode. With APC, an eight-degree angle results in any reflection being absorbed into the cladding rather than the transceiver, resulting in better return loss.

FIGURE 5: Reflectance in PC and APC connections



A note on terminology: Return loss and reflectance are essentially the same thing, and both terms can be found in standards language. For example, ANSI/TIA-568.3-D standard uses connector return loss, while IEEE 802.3 calls out reflectance. However, the two terms do differ in how they are calculated, as return loss is shown as a positive number (e.g., 45 dB) while reflectance is shown as a negative number (-45 dB).

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SINGLE-MODE TRANSCEIVERS USE HIGH POWER LASERS, AND AS A RESULT THERE ARE ADDITIONAL SAFETY CONCERNS.

True and False. This notion is true for long haul single-mode versions, but not for the lasers used in the enterprise and data centers. These lasers — known as Class 1M lasers — are considered safe for viewing, except when passed through magnifying devices such as microscopes and telescopes.

That said, if you are viewing an end face, make sure your fiber scope has a built-in filter. Eyeglasses or reading glasses are not considered a filter.

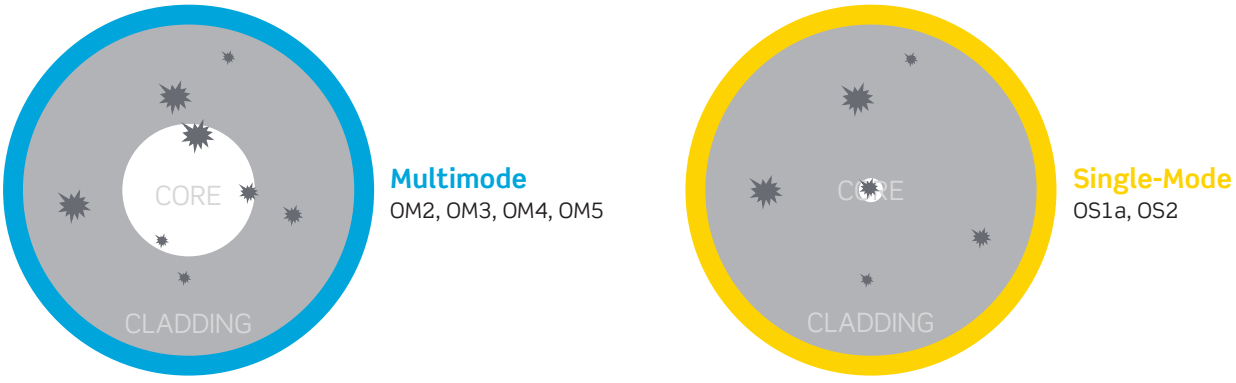
IF A SINGLE-MODE LINK IS TOO SHORT, THE TRANSMITTED LIGHT COULD SATURATE THE RECEIVER AND REQUIRE AN ATTENUATOR TO REDUCE THE POWER OF THE SIGNAL.

True and False. This issue only arises with high powered lasers used in outside plant installations. Data centers typically use low power Fabry-Perot (FP) lasers, with a nominal output of -3 dBm. CWDM4 transceivers use a slightly higher powered laser known as Distributed Feedback (DFB) Laser, with a nominal output of 2.5 dBm, but this is still a relatively low power. For Class 1M lasers, saturation of the receiver
is not an issue, as long as the link is 2 meters (6.6 feet) or longer.

SINGLE-MODE FIBER IS MORE CHALLENGING TO CLEAN THAN MULTIMODE.

True. This is a real concern. While more dirt can collect on the multimode core, light can still pass through multimode's larger 50 µm core size. With single-mode, one speck of dust can block all light. The size of a speck of dust in an office is 2.5 to 10 µm. A multimode fiber core is 50 µm, whereas a single-mode core is 8.2-8.6 µm, as shown in **Figure 6**. To put these into perspective, a single human hair is 100 µm. That means that, in single mode fiber, data is transmitted through an area that is one-tenth the thickness of a human hair.

FIGURE 6: Dust in Multimode and Single-Mode Fiber



If you are a technician who is new to working with fiber, a video microscope is a great way to accustom yourself with what a clean or dirty fiber looks like.

Be sure to inspect all connectors before installing and clean them if necessary. Then be sure to inspect

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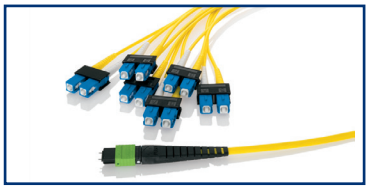
them one more time after cleaning.

If you are working with angled physical contact (APC) connectors — whether duplex or MPO/MTP® — you will need to use different camera tips than those used for physical contact (PC) connectors. The angle at the end of the APC connector changes the focal depth, and in turn requires an angled camera tip. Note that all single-mode MPO/MTP connectors are APC. The cleaning supplies will be the same between PC and APC – only the camera tips need to change with APC inspection.

Forward-looking Fiber Systems

Regardless of the type of fiber network, IT managers are looking for cabling systems that can weather multiple generations of tech upgrades with minimal disruption, dark fibers, or changes. Leviton's single-mode cabling systems not only meet current bandwidth requirements, but alsod provide the flexibility needed to meet future network demands.

The Leviton Opt-X® Unity Fiber Migration System is a single, simple connectivity solution that reduces cost and saves time by reusing the fiber backbone. This makes it easy to migrate from 10 to 40, 100, 200 and 400 Gb/s networks to speed tech refreshes, reduce labor and minimize network downtime. The system of trunks, harnesses, array cords, and cassettes features industry-leading 24-fiber MTP® connectors.



For enterprise backbones and small data center applications, our Opt-X Enterprise cabling system pairs high-quality, guaranteed performance with user-friendly designs to support fast and easy installation and maintenance. The system features 8- and 12-fiber low loss MTP cabling assemblies and cassettes with LC or SC patch cords.

Learn about our full range of single-mode and multimode fiber solutions at Leviton.com/Fiber.

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Today's networks must be fast and reliable, with the flexibility to handle ever-increasing data demands. Leviton can help expand your network possibilities and prepare you for the future. Our end-to-end cabling systems feature robust construction that reduces downtime, and performance that exceeds standards. We offer quick-ship make-to-order solutions from our US and UK factories. We even invent new products for customers when the product they need is not available. All of this adds up to the **highest return** on **infrastructure investment**.

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