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Expanded beam optical solutions can lead to lower costs

Executive summary

This white paper explores the economic advantages of 3M-developed expanded beam optical solutions in data centers and tactical applications. Using 3M testing and customers' case studies, we highlight the impact of the latest EBO solutions on deployment, maintenance and operational efficiencies, and demonstrate their long-term value.

Introduction

Since the introduction of the first low-loss optical fibers in the 1970s, the industry has worked consistently to improve data transmission. Besides the fiber material itself – the first fibers were made of glass and data loss was a major headwind – connection methods between fibers have been a particular focus. Traditional MPO (multi-fiber push-on) fiber optic connectors join the fiber end faces using direct physical contact. To achieve acceptable signal clarity, MPO requires precise alignment using mechanical hole-and-pin functionality. It also requires rigorous processes and procedures to help keep fibers clean where even small particles of dust and debris can interfere with signal integrity.

Expanded beam technology has emerged as a viable solution. Here, the 3M™ Expanded Beam Optical Ferrule 12F/ 16F expands and collimates light into a larger beam that is less sensitive to small particles. The light then travels to the receiving ferrule that refocuses the signal into the receiving fiber. Issues related to precise alignment are greatly reduced, as well as the issue of dirt or damage due to physical contact.

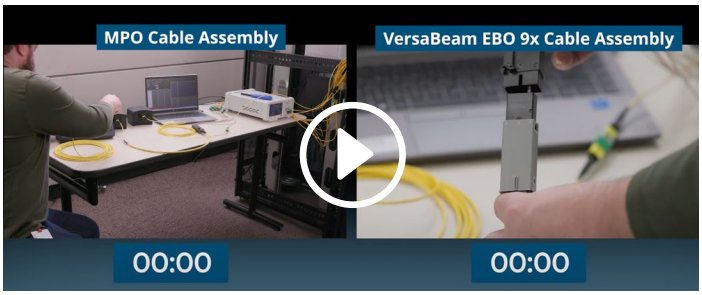
The growth of data centers

Advancements in artificial intelligence have rapidly evolved. Because of this, we continue to see rapid-scale growth in data centers. Time to revenue is a major challenge. Many designers and developers have responded by supplying pre-configured, pre-wired racks shipped assembled to data center locations. The need for fast, seamless connectivity is crucial to staying competitive and to keeping cost of ownership low for data centers – during initial setup, and for ongoing maintenance. Efficient connectivity is also vital for scalability, now and in the future.

The latest development in expanded beam connectivity addresses these challenges. This example shows the process for inspection and cleaning of a traditional MPO connector vs. that of a connector using 3M Expanded Beam Optical Ferrule technology. The result shows an 81% decrease in time per connector 2:32 per connector for traditional MPO; :29 for a connector that utilizes 3M EBO ferrules.

Testing and cleaning comparison: VersaBeam EBO vs. MPO Connectors

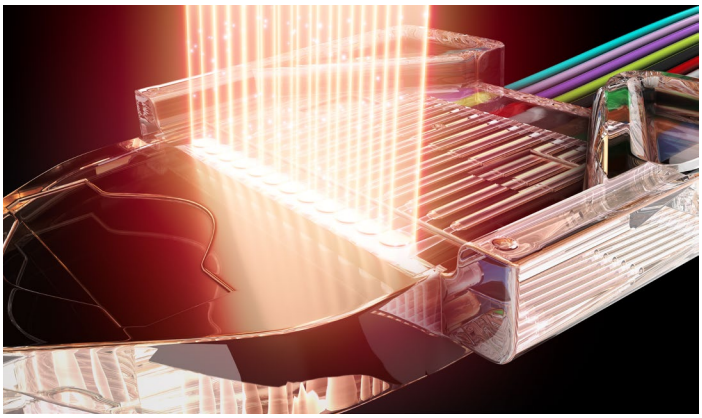
Click to watch video.



Additionally, 3M™ Expanded Beam Optical solutions allow for better flexibility and scalability – multiple 3M EBO ferrules can be stacked in a single connector, allowing for connectors with fiber counts of 192 fibers or more, that can be connected with very low mating force.

3M EBO technology

Manufacturers have responded with ferrule designs that vary from the traditional "straight out/straight in" design of current MPO and expanded beam technologies. A particularly interesting development from 3M EBO features flat ferrules that slide smoothly into parallel alignment, and utilizes mirrors to turn the light, resulting in beams perpendicular to the fiber axis. With proper installation, the beam does not leave the connector. And the expanded beam makes the connector extremely insensitive to dust and other particles.



Significant advantages in time to revenue and scalability

This design requires virtually no inspection and greatly reduces or eliminates time related to cleaning. The 3M EBO ferrule design has been shown to reduce cleaning time up to 85%* vs. conventional MPO connectors.

Additionally, the ferrules are supported by the fibers themselves without the need for anchors. Ferrules can be mated with extremely low insertion force (<1N), so the ferrules can be stacked in multiple configurations into a single connector. This provides high-density connectivity and flexibility to quickly scale up as data center requirements grow.

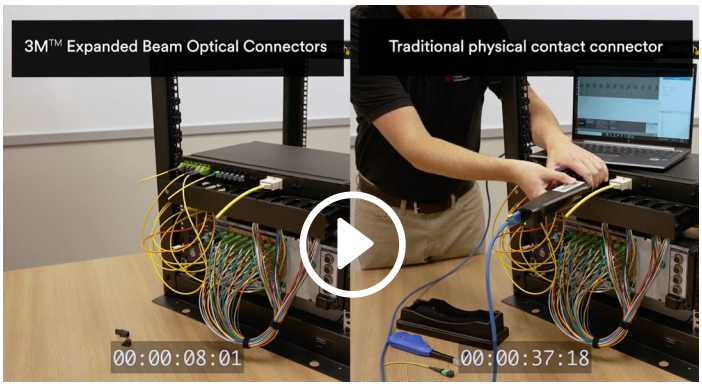
Faster time to revenue.

- Can reduce installation time from ~3 minutes per physical contact connector to ~30 seconds.**
- Full installation and deployment time can be reduced from 6 months to as little as 3 days.**

Installation

Following initial setup, installation is the next area where connectors can deliver significant time savings. In this video, we summarize a side-by-side comparison of the installation time of 3M EBO connectors vs. traditional MPO. This study shows an approximate 2:18 minutes for inspecting, testing and installing a traditional MPO connector. The 3M EBO solution requires minimal inspection and testing and can be installed in ~8 seconds.

Click to watch video.



Installation time for MPO and 3M EBO connectors

This breakdown from a US large scale deployment using 3M EBO connectors shows how time savings between MPO and 3M EBO can be realized as the installation scales.

	MPO (Sec)	MPO (Min)	MPO (Hr)	3M EBO (Sec)	3M EBO (Min)	3M EBO (Hr)	Time savings
1 - 12f connector							
Clean	25.0			8.0			
Inspect	156.0			0.0			
Clean	25.0			0.0			
Test	42.0			29.0			
TOTAL	248.0			37.0			**85%**
32 - 12f Connectors							
Clean	800.0	13.3	0.2	256.0	4.3	0.1	
Inspect	4,992.0	83.2	1.4	0.0	0.0	0.0	
Clean	800.0	13.3	0.2	0.0	0.0	0.0	
Test	1,344.0	22.4	0.4	928.0	15.5	0.3	
TOTAL	7,936.0	132.3	2.2	1,184.0	19.7	0.3	**85%**
512 - 12f Connectors							
Clean	12,800.0	213.3	3.6	4,096.0	68.3	1.1	
Inspect	79,872.0	1,331.2	22.2	0.0	0.0	0.0	
Clean	12,800.0	213.3	3.6	0.0	0.0	0.0	
Test	21,504.0	358.4	6.0	14,848.0	247.5	4.1	
TOTAL	126,976.0	2,116.3	35.3	18,944.0	315.7	5.3	**85%**
1024 - 12f Connectors							
Clean	25,600.0	426.7	7.1	8,192.0	136.5	2.3	
Inspect	159,744.0	2,662.4	44.4	0.0	0.0	0.0	
Clean	25,600.0	426.7	7.1	0.0	0.0	0.0	
Test	43,008.0	716.8	11.9	29,696.0	494.9	8.2	
TOTAL	253,952.0	4,232.5	70.5	37,888.0	631.5	10.5	**85%**

Maintenance costs

Standard procedures for inspecting fiber end faces in "Basic Test and Measurement Procedures Standard for Fiber Optic Interconnecting Devices and Passive Components", IEC 61300-3-35 certifies the cleanliness of a fiber end face based on the number and size of scratches and defects found in each region of the end face, including the core, cladding, adhesive layer, and contact zones. Each face needs to be inspected and, if necessary, cleaned before connection. MPO connectors generally have larger surface areas, making it easier for contaminants to move from one fiber to another. With 16- or 24-fiber MPO connectors, the fiber height differential is also more difficult to control. Even slight height variances across the fibers can increase the risk of contamination, as fibers can protrude slightly from the end of the connector and attract dirt and debris. As well, fiber variances can reduce the probability of proper and equal cleaning. Additionally, pins and holes on MPO ferrules can become contaminated and prevent proper mating. This makes careful and repeated inspection and cleaning procedures crucial.

According to the True Cable podcast, a test equipment manufacturer reported that in a typical installation about 4%-6% of initial MPO connections fail due to contamination in the first year. About 80% of network issues are cleaning related, and 95% of the manufacturer's truck rolls (maintenance requests) were for connector cleaning, at a cost of $390 per request.

Conducted with a global connector manufacturer, the study below analyzes the costs associated with ongoing maintenance at a typical tactical application. It compares a standard market solution (MPO) with a 3M EBO connector solution.

While the initial investment for assembled connectors is equal or slightly higher, costs for ongoing maintenance, cleaning and inventory are significantly lower. Specifically, connectors using 3M EBO ferrules require little to no cleaning or inspection over time. There is also virtually no need for replacement or reassembly.

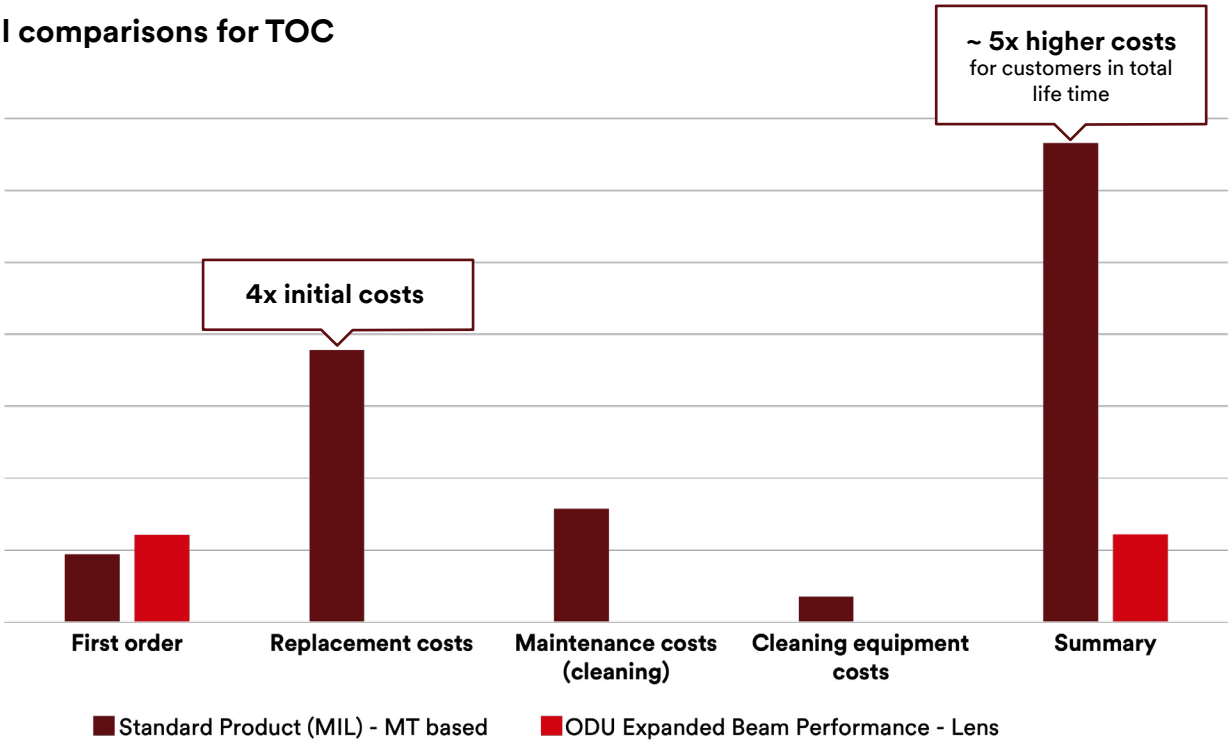
Total cost of ownership

This table compares the TOC of a standard connection solution using MT ferrules with an ODU solution using 3M EBO ferrules. It accounts for harsh environments such as those in defense and medical applications requiring at least 2500 mating cycles.

> "3M EBO ferrules are ideal for our highly robust fiber optic connections. Low contamination means lower overall costs and system downtime and adds real value to our customers' systems, especially in defense and medical applications."

	Standard market solution (mated pair) 3 × 24 MT APC	**ODU Solution (mated pair)** 6 × 12 Expanded Beam Performance
Number of needed assemblies Per lifetime (estimated number of mating cycles for a customer device with I/O connectors ~ 2500)	5 pcs.	1 pcs.
Cleaning equipment	MTP Click Cleaner 500 cleaning cycles*** ~ $118.26	Emergency cleaning set ~ $59.13
Number of cleaning tools needed Per lifetime	30 pcs.	1 pcs.
Maintenance effort Per cycle / per system	4 Minutes (cleaning per mated connection)	-

Overall comparisons for TOC

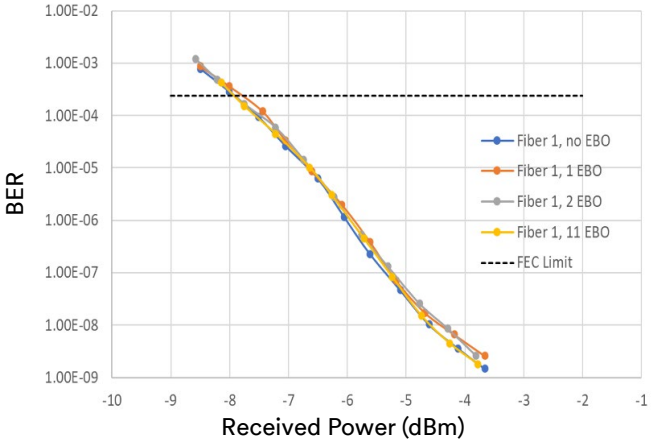


High-speed transmission tests

EBO connectors are not impacting high-speed transmission.

Multimode

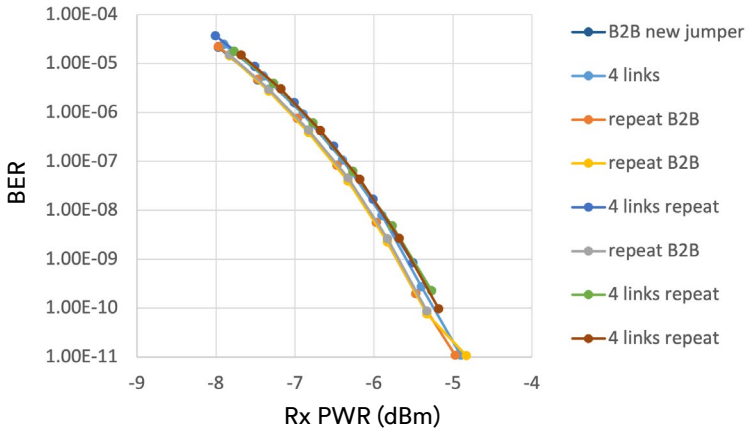
Fiber 1 Back-to-Back



- 850 nm, 50 Gbit/s, PAM4 signal, PRBSQ31, 3 min
- BER vs received power is same for 0, 1, 2, 11 connections

Single mode

Short Ribbon Length Test at PRBS9 and 25Gbps



- 1310 nm, 25 Gbit/s, NRZ signal, PRBS9, 30 sec
- BER vs received power is same for 0, 4 connections

Performance

While MPO connectors can afford excellent signal performance when properly installed, 3M EBO has been shown to deliver similar performance. These internal 3M tests show no concern for bit error rate with multiple 3M EBO connectors.

In addition, the 3M EBO ferrule delivers typical insertion loss comparable to that of physical-contact (PC) connectors and return loss performance exceeding that of PC connectors (reflectance ≥55 dB single mode and ≥35 dB multimode).

Conclusion

As optical fiber technology continues to advance, fiber connection methods have become more critical for high-density data centers facing demands for faster time to revenue and greater scalability. Assembly time and maintenance are growing obstacles to efficiency. Traditional connectors deliver good signal clarity when properly aligned, inspected and cleaned, but are susceptible to dust and debris as well as increased assembly and maintenance costs. Traditional expanded beam solutions help solve the issue of alignment and signal interference from small particles, but do not always resolve the need for cleaning and maintenance downtime.

The latest 3M Expanded Beam Optical solutions feature a ferrule design that in which the beam never leaves the connector when property installed. This virtually eliminates the need for inspection and cleaning, which can drastically reduce installation time and ongoing maintenance. Comparisons between traditional MPO and 3M EBO solutions show tremendous benefits in Total Ownership Cost (TOC). They include:

- Reduced steps during setup for lower cost outlay
- Reduced installation time from minutes to seconds per connector
- Faster deployment, from months or weeks to days
- Greatly reduced need for maintenance, with simpler processes and equipment
- Greater flexibility and scalability virtually without replacement
- Similar signal performance

About 3M

As a global supplier of cable and fiber optic connectors and related equipment, 3M can deliver interface solutions to help maximize data center capabilities. Our solutions for expanded beam fiber optic connectivity help reduce inspection and cleaning for shorter plug-up times, reduced maintenance and lower total cost of ownership.

Future outlook: Potential advancements and continued cost benefits.

- As more companies adopt 3M EBO, supply chain partners will meet demand for termination
- More connector companies will develop connectors utilizing 3M EBO ferrules
- 3M EBO solutions could be a good option for blind mate connectors that are in development and for mid plane and dense back plane applications
- Transceiver manufacturers are developing products using 3M EBO solutions

References

Testing and cleaning comparison video, 3M EBO solutions to MPO: Testing and Cleaning Comparison: VersaBeam EBO vs. MPO Connectors

Internal 3M study, US large scale deployment

Time savings comparison video, 3M EBO vs. MPO: 3M™ Expanded Beam Optical Connector EBO Time Savings Video

"Basic Test and Measurement Procedures Standard for Fiber Optic Interconnecting Devices and Passive Components", IEC 61300-3-35

Quick tips for MPO cleaning, Viavi Solutions

Cost of truck-rolls for data center maintenance, MPOs

Joint study, 3M and ODU

Internal 3M lab testing, signal performance

* Time reduction for ferrule inspection and cleaning is based on testing performed during actual 3M customer deployment with a hyperscale data center in the US. Your results may vary.

** Time savings is based on testing performed during actual 3M customer deployment with a hyperscale data center in the U.S.

*** A cleaning cycle includes cleaning 6 ferrules per plug/socket. 42 cleaning cycles = 504 cleanings.

**** Costs based on $94.61 personnel costs per working hour.

The ODU Group is an international manufacturer of connector systems, specialized in defense, medical and test- & measurement applications.

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3M Display and Electronics
3M Center, Building 223-3S-32
St. Paul, MN 55144-1000 USA

Web 3M.com/opticalinterconnect
Phone 1-800-810-8513

60-5005-0554-4