Amphenol
NETWORK SOLUTIONS™

AI-Driven Demand for High-Density Optical Interconnections in Data Centers

White Paper

Written by: Charles Su (PhD), *Senior Optical Engineer*

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1. Introduction

The rapid advancements in network switching and artificial intelligence (AI) technologies are pushing data center applications beyond the bandwidth capabilities of traditional optical transceivers. This has led to an increasing demand for higher fiber density in networks. Emerging hyperscale data center architectures require cabling solutions that legacy connectors cannot efficiently support.

Very Small Form Factor (VSFF) duplex and multi-fiber connector systems have emerged as a solution, offering significantly improved fiber density compared to traditional LC and MPO connectors. VSFF technology enables unmatched fiber density for cabling, patch panels, card-edge, and on-card applications. For instance, a standard 1RU (rack unit) space spanning 19 inches, which typically supports 72 LC duplex ports (144 fibers), can now accommodate up to 6,336 fibers with 24 fibers per connector.

With the growing adoption of 400 Gb/s, 800 Gb/s, and 1.6 Tb/s networks, two pluggable transceiver types are widely deployed in data centers:

- QSFP-DD (Quad Small Form Factor Pluggable - Double Density)
- OSFP (Octal Small Form Factor Pluggable)

Emerging transceiver formats are now evolving with dual multi-fiber connector interfaces. For example, 800 Gb/s transceivers for AI data center clusters utilize a 2 × 400 Gb/s configuration with two base-8 MPO connectors. Additionally, the OSFP-XD specification now includes 2-port MPO and 2-port VSFF transceiver formats.

While dual MPOs can fit vertically within transceiver footprints, their size increases the vertical module interface, impeding airflow and complicating internal fiber routing. Conversely, VSFF connectors can be arranged vertically or horizontally, reducing footprint size, enhancing airflow, and optimizing fiber routing for future transceiver formats.

800G OSFP Optics Modules

Name	Modulation	Reach	Connector
800G-ZR	16-QAM	100km	LC
800G-LR	16-QAM	1-10km	LC
800G-FR4	200G-PAM4	1-2km	LC
800G-DR4	200G-PAM4	1-2km	Quad SN/MDC
800G-FR8/LR8	100G-PAM4	2km/10km	LC
800G-2FR4/2LR4	100G-PAM4	2km/10km	Dual LC
800G-DR8	100G-PAM4	2km/10km	MPO/8xSN/MDC
800G-SR8	100G-PAM4	50m	MPO/8xSN/MDC

Fig. 1 800G OSFP transceiver modules. Courtesy of Arista

Dual LC, Mini-LC, MPO, 8xSN/MDC

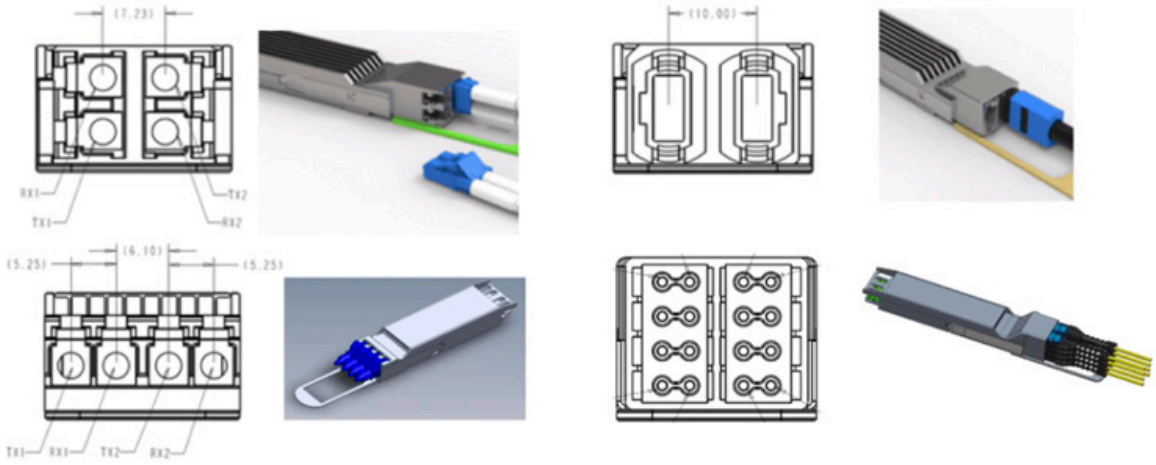


Fig. 2 800G transceiver with SFF and VSFF connector. Courtesy of Arista

Looking ahead to 1.6 Tb/s and 3.2 Tb/s applications, VSFF connectors with multi-row fiber arrangements will be essential.

1.6T OSFP-XD Optics Modules

Name	Modulation	Reach	Connector	Power
1.6T-ZR	16-QAM	100km	Dual LC	30W
1.6T-LR	16-QAM	1-10km	Dual LC	28W
1.6T-CWDM8	200G-PAM4	1-2km	LC	22W
1.6T-2FR4	200G-PAM4	1-2km	Dual LC	22W
1.6T-DR8	200G-PAM4	1-2km	Octal SN/MDC	21W

Fig. 3 1.6Tb/s transceiver. Courtesy of Arista

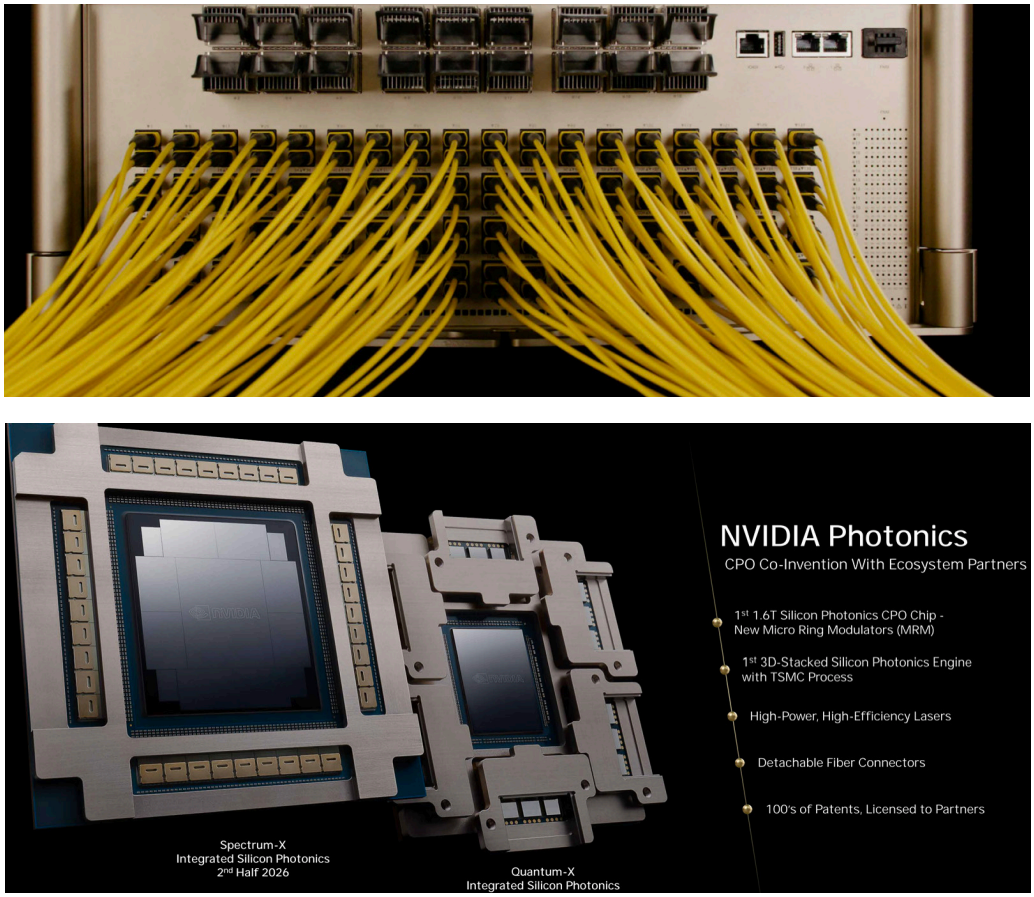


Fig. 4 Nvidia GTC 2025 newly released Spectrum-X with CPO. Courtesy of Nvidia

2. The Evolution of Fiber Optic Connectors

Fiber optic networks have continuously evolved to accommodate increasing data transmission demands. VSFF connectors represent the latest innovation in high-density data center cabling, offering increased density, enhanced performance, and simplified management.

The Early Days: GBIC and SFP

In the early data center era, transceiver interfaces evolved slowly. The Gigabit Interface Converter (GBIC) with its Duplex SC Interface enabled 1 Gb/s data transmission. This was followed by the more compact Small Form Factor Pluggable (SFP), also known as the "Mini GBIC," which standardized the LC Duplex Interface, offering more efficiency in networking.

The Rise of MPO Interfaces

Around 2012, the Quad Small Form Factor Pluggable Plus (QSFP+) revolutionized data centers by introducing MPO interfaces. These enabled higher data rates and greater flexibility, with MPO-based transceivers like SR4 and PSM4 supporting structured cabling with breakout options.

VSFF Connectors: The Next Leap Forward

VSFF connectors are the next step in fiber optics, especially for high-density data center networks. They offer a compact footprint, improved performance, and better fiber management. Their advantages include:

- **Triple Density:** VSFF connectors provide 3× the density of traditional LC duplex connectors.
- **Vertical Alignment:** Utilizing the same 1.25mm ferrules as LC, VSFF connectors maintain compatibility while maximizing density.
- **Performance Consistency:** Despite their compact size, VSFF connectors offer performance on par with LC duplex interfaces.

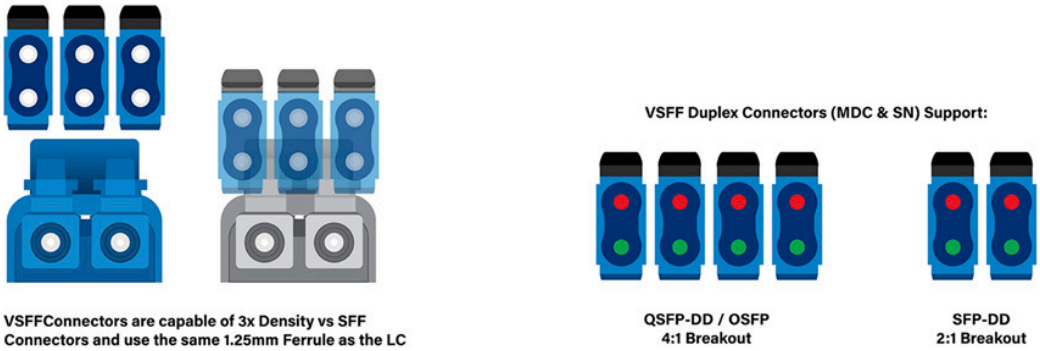


Fig. 5 VSFF vs SFF connector

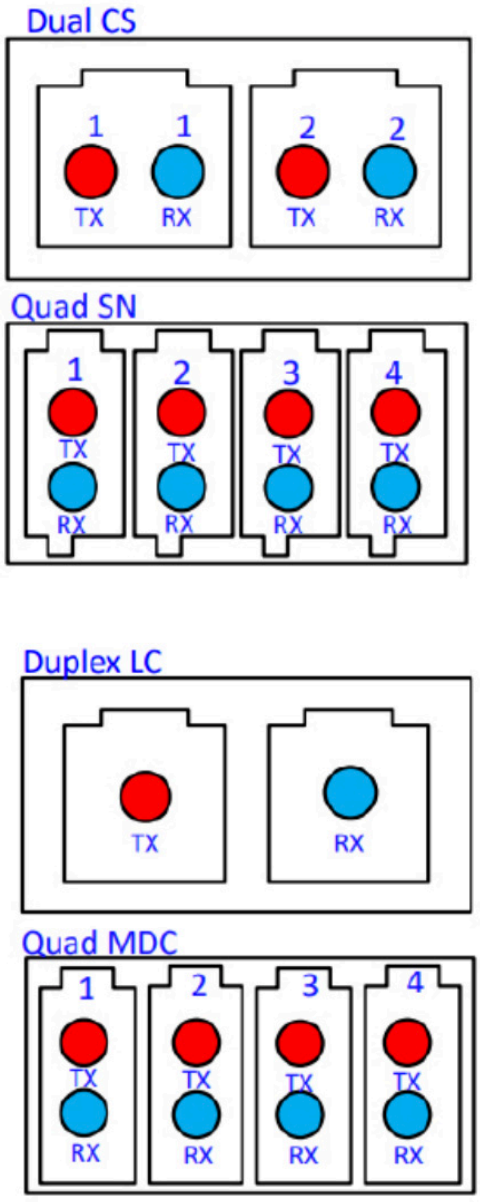
3. VSFF Connector Variants: SN vs. MDC

There are two main VSFF connector types gaining traction:

- **SN Connector (Senko):** Senko Nano (mini LC version). SN-MT (mini MPO version) supports up to 16 fibers per row (24 fibers in two rows), with a flexible boot for easy handling. However, it is not compatible with MDC connectors.
- **MDC Connector (USCONEC)**: Mini Duplex Connector (mini LC version). MMC (mini MTP version) supports up to 16 fibers per row (24 in two rows), providing similar density and vertical alignment but is incompatible with SN connectors.

Why Choose SN or MDC?

- **Direct Breakout Access:** Both SN and MDC connectors enable direct breakout at the transceiver, eliminating the need for additional cables or cassettes.
- **Space Efficiency:** VSFF connectors reduce rack space required for fiber cabling, freeing up space for active equipment.



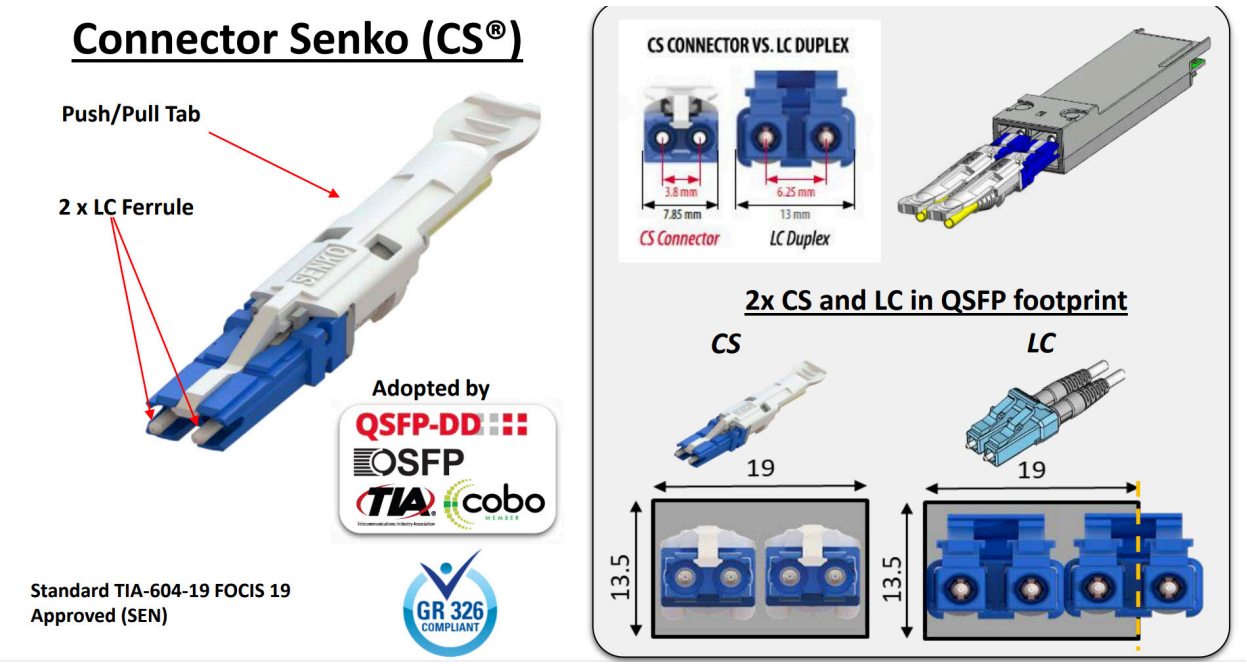


Fig. 6 An example of CS type VSFF optical interface in QSFP transceiver. Courtesy of Senko.

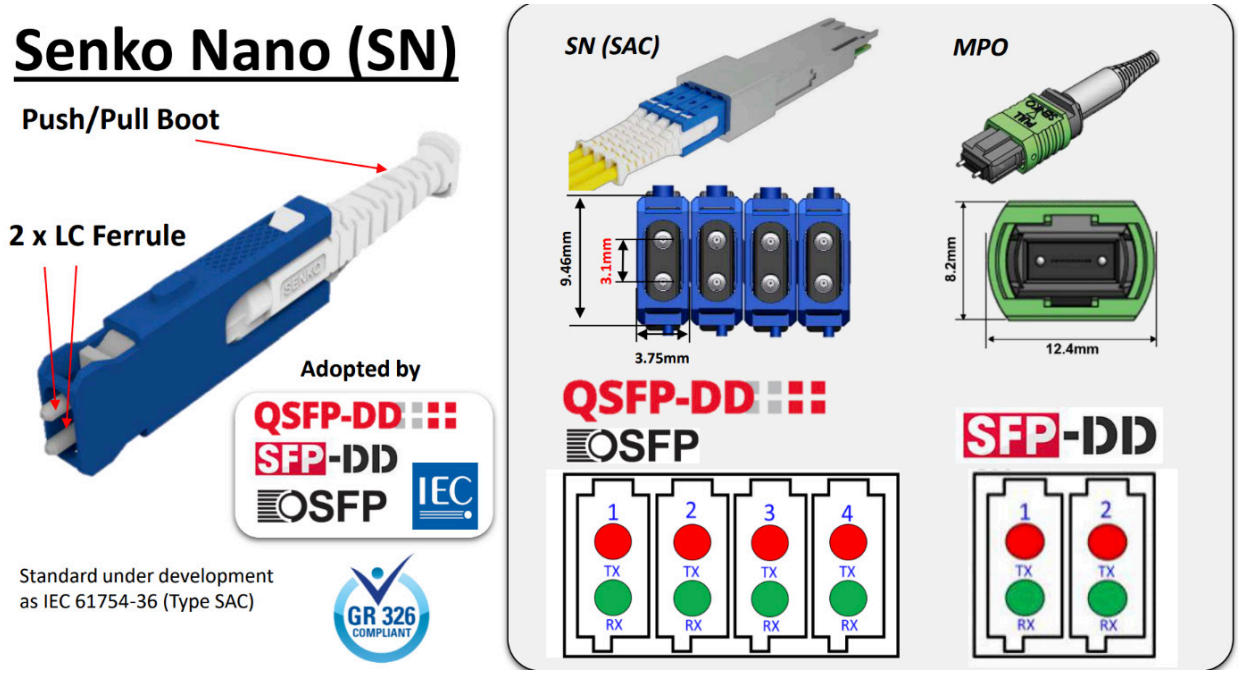


Fig. 7 SN type VSFF connector QSFP-DD and OSFP transceiver. Courtesy of Senko

4. Uses Cases for VSFF Connectors

VSFF connectors are gaining industry attention due to their practical advantages. Key use cases include:

1. **Transceiver Interfaces:** Direct access to SerDes (lane) speed at the transceiver interface without requiring breakout cables or conversion modules.
2. **High-Density Patch Panels:** VSFF connectors enable at least double the density per RU compared to LC duplex connectors, optimizing both new and existing installations.
3. **Structured Cabling:** VSFF-based cabling systems reduce the number of RUs dedicated to cabling, maximizing space for active equipment.

Connector Standardization and Market Adoption

While VSFF connectors present significant benefits, industry adoption depends on standardization. Key considerations include:

- Will cabling standards officially recognize VSFF connectors?
- Which specific VSFF connectors will be standardized?
- What are the risks if a chosen connector type is not widely adopted?

Standardized connectors tend to be produced in higher volumes, reducing costs. Customers opting for non-standardized connectors may face higher expenses for cable assemblies and reduced compatibility.

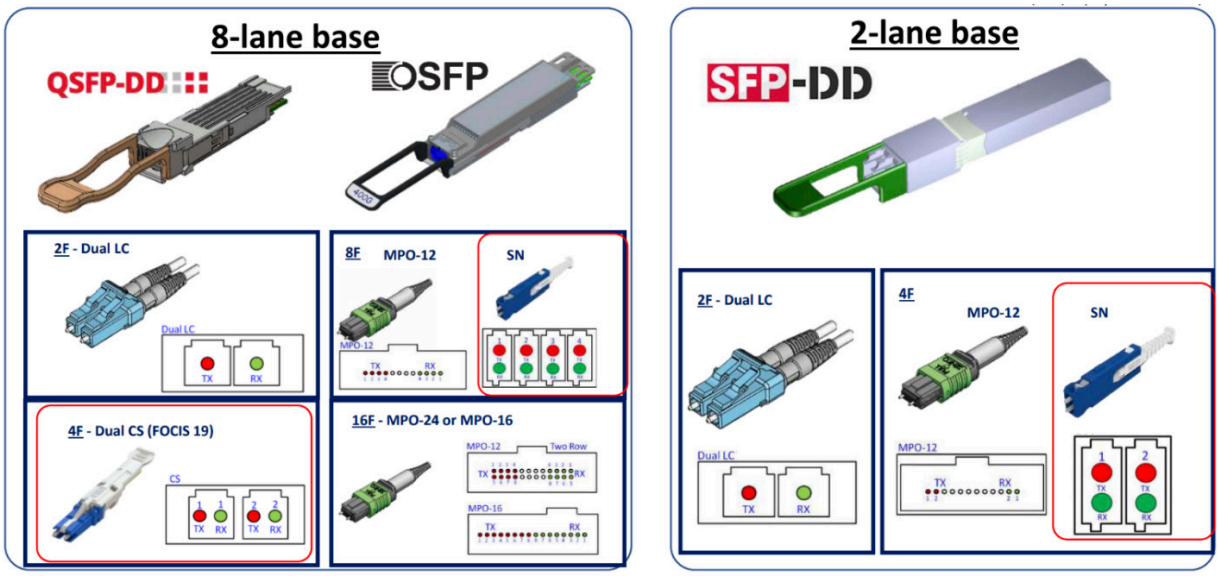


Fig. 8 Use cases of pluggable optical transceiver's optical interface with Senko Connectors

5. High-Density Fiber Connectivity Solutions: Amphenol's Cascade Panel

Amphenol Network Solutions has introduced the **Cascade Panel**, designed for scalability and high-density fiber connectivity using VSFF connectors.

Key Features:

- 1RU panel supporting 96 LC connections
- VSFF connector options (SN and MDC families)
- Sliding tray for easy access and maintenance
- Enhanced cable management with four fiber routing clips
- Optimized for data centers and telecom environments

> "The Cascade Panel was built to address high-density fiber networks while prioritizing accessibility. With its sliding tray design, VSFF options, and flexible routing, it simplifies fiber management for technicians working in tight spaces."
>
> *- Harley McAllister, Senior Product Manager at Amphenol Network Solutions.*

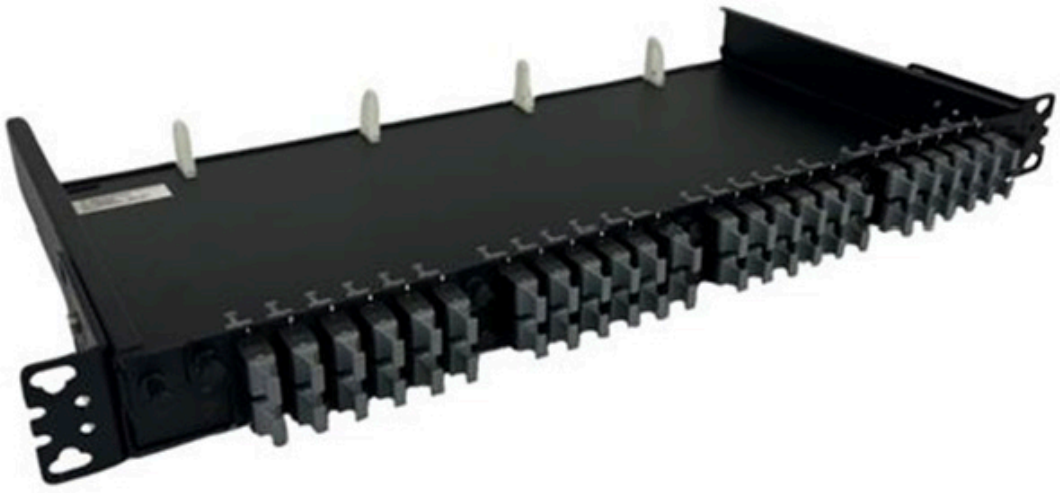
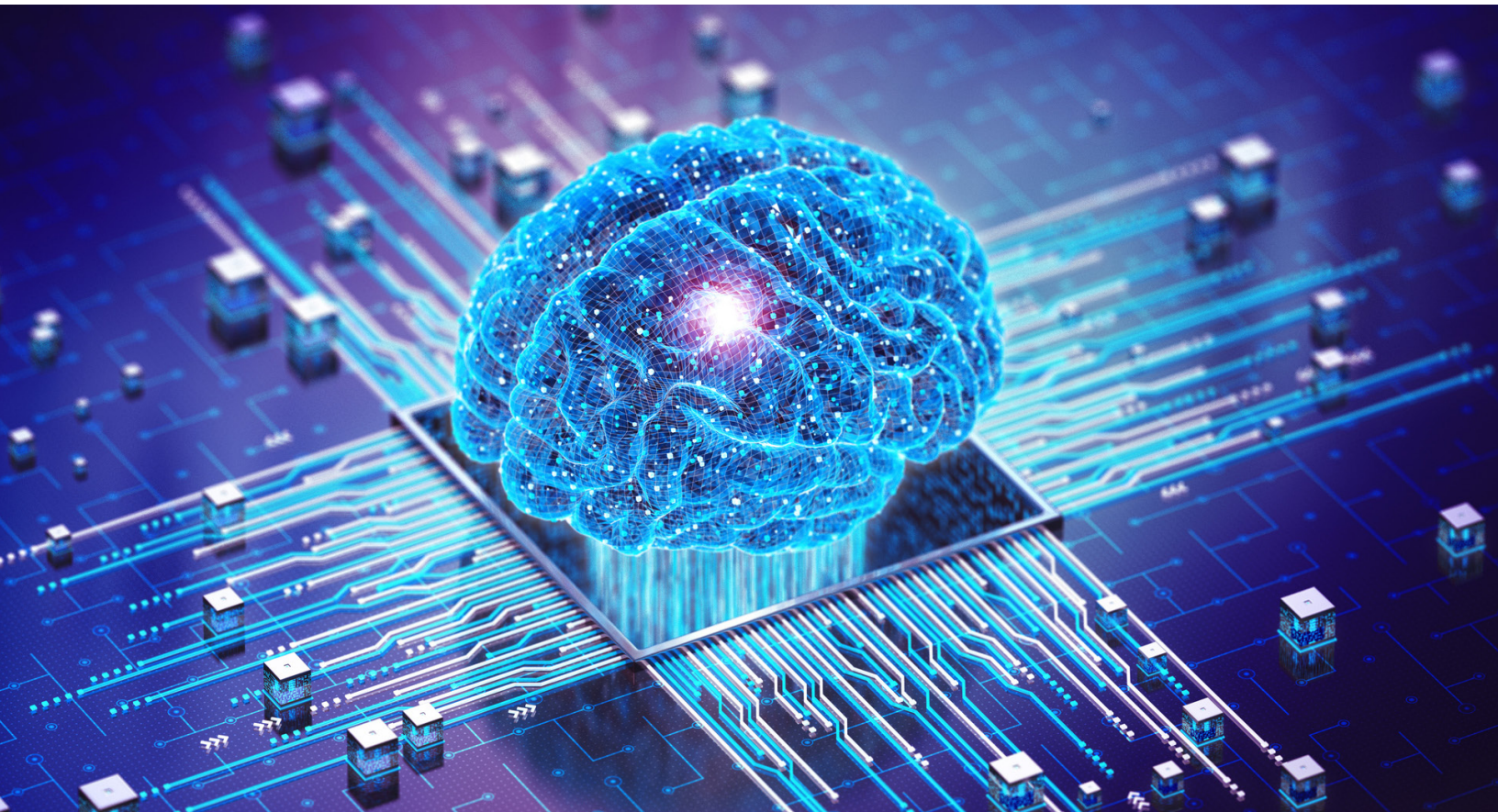


Fig. 9 Amphenol Network Solutions Cascade Panel

6. Conclusion

As AI workloads drive unprecedented data demands, high-density optical interconnections have become critical. VSFF connectors, with their compact size, high fiber density, and improved airflow, are poised to reshape data center fiber infrastructure. By enabling more efficient transceiver interfaces and structured cabling, VSFF technology supports the scalability required for next-generation data center networks. As standardization efforts continue, VSFF adoption will accelerate, providing cost-effective and future-proof solutions for hyperscale environments.



About the Author

Charles Su (PhD)

Senior Optical Engineer, Amphenol Network Solutions

Charles Su, PhD, is a seasoned Senior Optical Engineer with over 20 years of experience in the telecom industry. Specializing in optical fiber components and systems, he has demonstrated strong leadership capabilities, successfully leading teams and delivering impactful solutions to address complex challenges. With a deep understanding of fiber optics technologies, Charles Su is renowned for his forward-thinking approach to next-generation product development. He has a passion for understanding and meeting customer needs, consistently developing innovative solutions that exceed expectations. Committed to driving customer success, Charles Su leverages his extensive industry knowledge and dedication to continuous improvement to deliver exceptional results.

About Amphenol Network Solutions

At Amphenol Network Solutions, we are driven by a passion for innovation and a relentless commitment to creating customized solutions that seamlessly integrate with your unique requirements. With our deep understanding of fiber optic technology, we specialize in creating tailored solutions that anticipate and adapt to the rapidly evolving demands of your network. Through our responsive support, unwavering commitment, and ongoing collaboration, we ensure that our solutions are ready to deliver superior performance and reliability.

509.926.6000

getinfo@amphenol-ns.com

www. amphenol-ns.com