Pass-Through ELSFP with Optional Integrated Optical Mux and Demux for Colorless CPO Systems

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Abstract: We demonstrate a novel type of Pass-Through ELSFP module configuration with (or without) integrated optical Mux and Demux, potentially enabling a WDM “colored” (or “colorless”) system through a Colorless DR-type optical engine. © 2024 The Author(s)

1. Introduction

Emerging technologies such as Big Data, Cloud Computing, and Artificial Intelligence (AI) are driving explosive growth in data center (DC) traffic, leading to a surge in demand for optical-based interconnection. Confronted with this phenomenon, the deployment strategies of DCs are undergoing gradual adjustments. Traditional DC deployment involves Ethernet switches and pluggable optical modules. Within this deployment model, Ethernet switches, once deployed on-site, can be reconfigured with diverse optical interface types, such as DR4 and FR4, dictated by the optical module types. This deployment approach is flexible but accompanied by power consumption and cost challenges. The adoption of Co-Packaged Optics (CPO), a groundbreaking technology that integrates optical and electronic chips onto the same substrate, is expected to break this impasse enabling expanded bandwidth, saving power, and reducing costs [1]. As we all know, architectures utilizing external laser small form factor pluggable (ELSFP) and optical engines (OEs) are widely acknowledged and extensively adopted by the industry in CPO system deployment due to their superior heat dissipation, maintainability, and reliability [2]. The exiting CPO OEs are divided into DR (without Mux and Demux, called Colorless DR-type OE) and FR (with Mux and Demux, called Colored FR-type OE). In the current CPO-based Ethernet switch deployment model, the optical interface types are pre-configured by the types of OE before the system is deployed. The OEs and ELSFP modules must be pre-configured in pairs and cannot be reconfigured in the field. However, with the evolution of DC network architecture, CPO system deployment faces scenarios of mixed application of DR4 and FR4. Therefore, there exists a need to improve the existing ELSFP modules drafted by OIF [3] to render them not subject to the optical interface configurations and endowed with plug-and-play functionality.

In this paper, we propose a novel configuration of Pass-Through ELSFP module, which incorporates an integrated optical Mux and Demux, deserving attention for future prospects. The innovative Pass-Through ELSFP variant holds the potential to facilitate the deployment of DR4, FR4, or other multi-channel WDM “colored” systems with a Colorless DR-type OE, offering versatility in system choices. This configuration is determined by the Pass-Through ELSFP module type and can be reconfigured in the field. The module has an optical output power of up to 20 dBm (100 mW) over the commercial temperature range, a total power consumption of less than 4 W, and a power conversion efficiency (PCE) of up to 13.9%. This emerging ELSFP variant significantly bolsters the flexibility and adaptability of the CPO-based Ethernet switch.

2. Structure and characteristics of the Pass-Through ELSFP variant

Fig. 1 shows a schematic illustration of the Pass-Through ELSFP variant structure. The Pass-Through ELSFP variant ingeniously segregates the polarization-maintaining fiber (PMF) responsible for laser transmission and the single-mode fiber (SMF) designated for signal transmission, situating them within distinct optical connectors instead of the integrated placement specified by the OIF. This design difference frees up valuable space within the module, which enables the integration of optical Mux/Demux devices, typically housed in the OE, directly within the ELSFP module. This integration can move the determination of DR4 and FR4 optical interfaces away from the OE, effectively reducing the complexity associated with the design and manufacturing of OEs. As a result, the Pass-Through ELSFP variant has the potential to enable FR4 or other multi-channel WDM “colored” system deployment (e.g., LWDM) through a Colorless DR-type OE. In other words, only one Colorless DR-type OE suffices to meet the mixed application of DR4 and FR4. Specifically, for FR4 or multi-channel WDM configuration, Mux/Demux and pairing “colored” continuous wave (CW) lasers are integrated inside the Pass-Through ELSFP; for DR4 configuration, the Pass-Through ELSFP comprises solely of "colorless" CW lasers. The configuration is determined by the Pass-Through ELSFP module type and can be reconfigured in the field. The novel ELSFP variant enhances the flexibility of the CPO-based Ethernet switch.

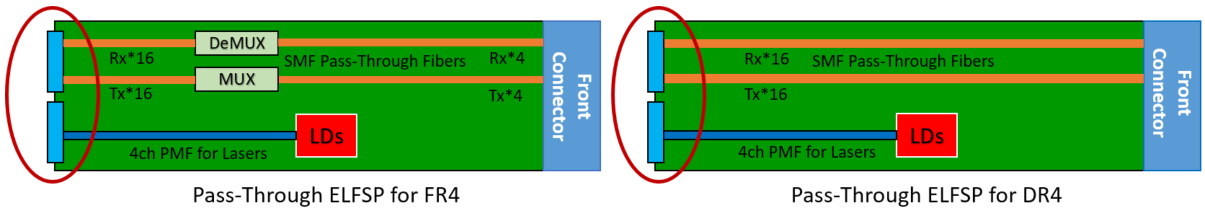

Fig. 1 Schematic illustration of the Pass-Through ELSFP variant structure for FR4 and DR4 application.

The Pass-Through ELSFP variant comes in an OSFP package with a mechanical size that conforms to OIF conventional ELSFP standard [3] but with an extension height on the front panel side. Fig. 2 illustrates the Pass-Through ELSFP variant inner layout. The mechanical size of the entire ELSFP module is 152.75 mm (length) × 22.58 mm (width) × 13.8 mm (height). Within the ELSFP variant, there is a TOSA responsible for supplying a CW laser source to the CPO OE. The TOSA comprises 4 CW lasers, with 4 parallel channels operating at 1311 nm for the DR-type ELSFP variant and 4 channels operating at CWDM wavelengths for the FR-type ELSFP variant. These lasers are connected to an MT connector via 4 parallel PMFs. Another MT connector is utilized to establish a fiber channel between OE and the front panel, to connect the Tx and Rx signals from the OE to the panel through SMFs. In the case of the DR-type ELSFP variant, there is a 32-SMF array (16 channels Tx and 16 channels Rx) arranged to enable direct connections between the host connector and the front panel connector. For the FR-type ELSFP variant, the module integrates Mux and Demux to aggregate the Tx and Rx signals from the host connector side, transmitting the WDM signals to the front panel connector side, or vice versa. The Mux chip consists of 4 groups of 4-channel CWDM Mux arrays, which aggregate 4 groups of CWDM signals (a total of 16 channels Tx from the host connector side) to 4 channels WDM signals (a total of 4 channels Tx on the front connector side). Similarly, the Demux chip contains 4 groups of 4-channel CWDM Demux arrays, which disaggregate 4 channels of WDM signals (a total of 4 channels Rx from the front connector side) to 4 groups of CWDM signals (a total of 16 channels Rx on the host connector side).

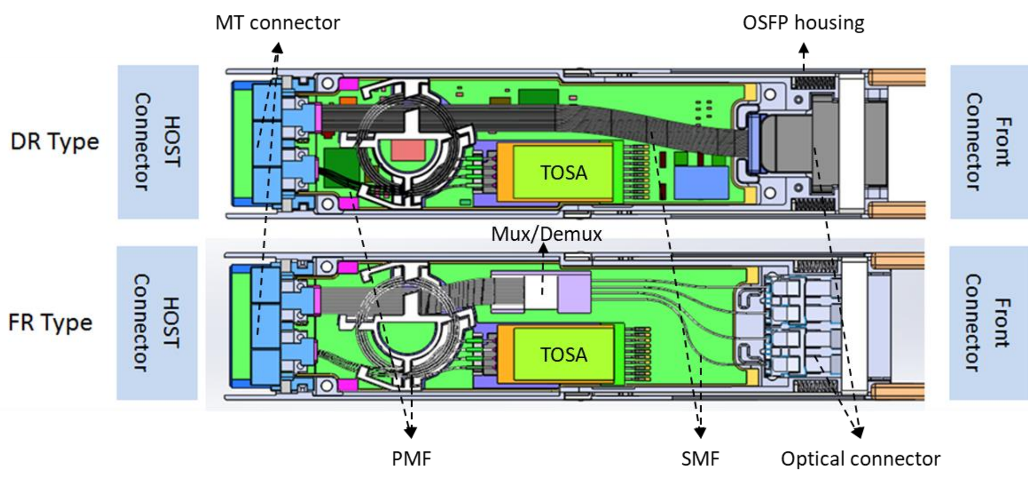

Fig. 2 Illustration of the DR and FR type Pass-Through ELSFP variant inner layout.

Fig.3 demonstrates the Pass-Through ELSFP variant model and optical interface. On the host connector side, both DR-type and FR-type ELSFP variants possess identical optical interfaces. This side includes two MT connectors. The first MT connector houses 12 fibers, of which 4 fibers are active (8 fibers in idle) and utilized to connect the 4 CW lasers to CPO OE. The second MT connector features 36 fibers, arranged in 3 rows of 12 fibers each, and it is employed to establish connections for 16 channels Tx and 16 channels Rx from OE, with 4 fibers remaining in idle state. On the front panel connector side, the DR-type ELSFP variant is equipped with a 36-fiber MT receptacle to accommodate 16 channels Tx and 16 channels Rx (4 fibers in idle). In contrast, the FR-type ELSFP variant is designed for 4 channels Tx and 4 channels Rx. Meanwhile, users have the option to select between different connector types, including but not limited to SN, MDC, CS, and Dual LC.

Fig. 4 (a) depicts the typical optical output power of 4 channels ELSFP variant at 0 ℃, 45 ℃, and 70 ℃ with an LD bias current of ~ 350 mA. The optical output power of all channels is capable of achieving the OIF-defined very high power (VHP) [3] class level of 20 dBm (100 mW) within the commercial temperature range. Fig. 4 (b) shows the total power consumption and power covert efficiency (PCE, PCE = total output power/total power consumption) of 4 channels ELSFP variant at 0 ℃, 45 ℃, and 70 ℃ with an LD bias current of ~ 350 mA. Even under the worst conditions at 70 ℃, the total power consumption remains below 4 W (power consumption as low as 3 W at 45 ℃), while achieving a PCE of over 10% (PCE as high as 13.9% at 45 ℃). The high PCE observed in challenging environmental conditions primarily stems from the remarkable coupling efficiency engendered by the superior optical pathway design and the excellent heat dissipation facilitated by structural optimization.

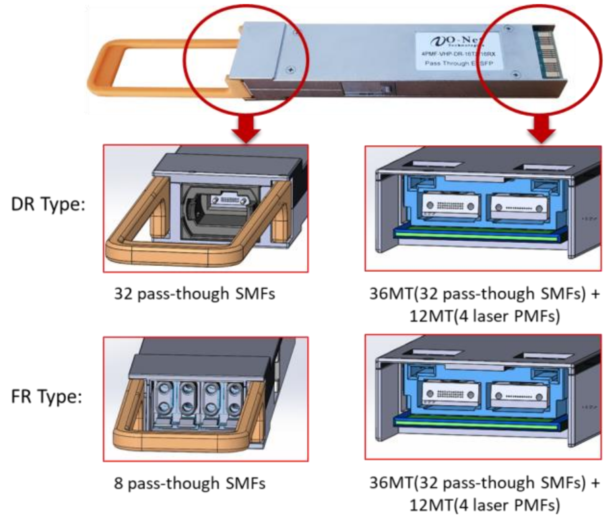

Fig. 3 Illustration of the DR and FR type Pass-Through ELSFP variant model and optical interface.

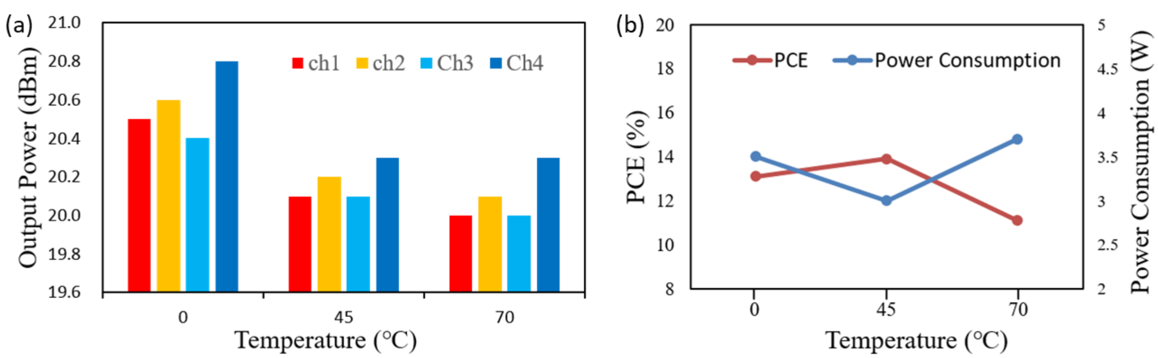

Fig. 4 Typical 4 ch VPH Pass-Through ELSFP variant Performance. (a) The optical output power of 4 ch ELSFP variant at 0, 45, and 70 ℃. (b) The total power consumption and PCE of 4 ch ELSFP variant at 0, 45 and 70 ℃.

3. Conclusions

We present a novel Pass-Through ELSFP module, optionally featuring integrated optical Mux/Demux for CPO application. This ELSFP can be categorized into DR and FR types, enabling DR4 and FR4 applications through Colorless DR-type OE in CPO-based switch deployments, thereby augmenting deployment flexibility. CPO switches necessitate no prior pre-configuration. Their optical interfaces are deployment-based and can be conveniently reconfigured in the field. At commercial temperatures, all channels of the ELSFP module achieve an optical output power of more than 20 dBm (100 mW) with an LD bias current of ~ 350 mA. The total power consumption can be less than 4 W (3.7 W) at the worst case of 70 ℃, more than 10% (11.1%) PCE can be achieved.

4. References

[1] C. Minkenberg, R. Krishnaswamy, A. Zilkie, and D. Nelson, "Co-packaged datacenter optics: Opportunities and challenges," IET Optoelectronics, **15**, no. 2, 77–91, (2021).
[2] M. Tan et al., "Co-packaged optics (CPO): status, challenges, and solutions," Front. Optoelectron., **16**, no. 1, 1, (2023).
[3] B. Jock, "ELSFP implementation agreement," OIF, Revision 09, (2023)