

Pluggable Optics for Coherent Systems: The CFP2-ACO Interface



Figure 1. CFP2-ACO Optical Module

Standardization of Coherent Optics

The OIF has played a pivotal role in the standardization of optics for coherent transmission. Over the last eight years, the OIF has helped the industry develop Dual Polarization Quadrature Phase Shift Keying (DP-QPSK) as an important modulation format for 100Gbps and above transmission, clearing the way for more advanced formats.

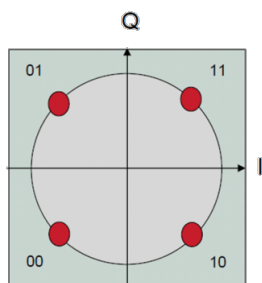


Figure 2. QPSK Symbol Constellation

The OIF has published Interoperability Agreements (IAs) that defined the physical and performance attributes of the optical components and modules that can be used for 100 Gbps DP-QPSK transmission including a dual polarization intradyne coherent receiver² (ICR) and an

optical modulator³ capable of generating the appropriate dual polarization Cartesian modulation constellations.

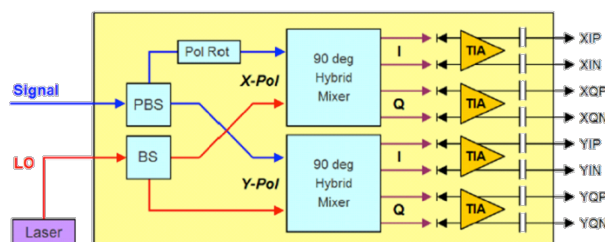


Figure 3. Coherent Receiver (ICR) Schematic

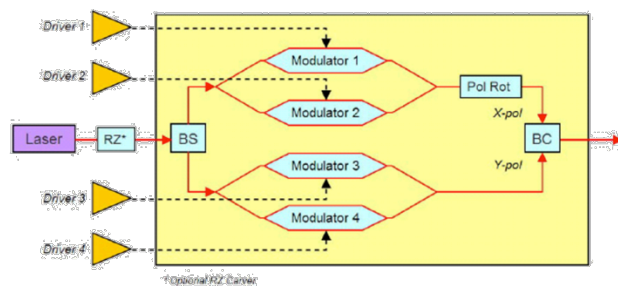


Figure 4. Polarisation Multiplexed IQ Tx Schematic

The Implementation Agreements (IA) for the ICR and modulator were first published in spring of 2010. These were quickly followed by documents covering a 100Gbps long haul module⁴, a smaller footprint ICR⁵ and modulator⁶ variants for small form factor module applications, and the micro-Integrable Tunable Laser Assembly⁷ (micro-ITLA).

The CFP2-Coherent Optics Interface

The OIF has published IAs for a 100Gbps coherent optics transceiver module housed in the CFP-MSA⁸ organization's CFP⁹ form factor. The interface maximizes faceplate density and minimizes first install costs for Metro/Regional line-side transport equipment. By specifying a pluggable coherent optical module, the

dominant materials costs and reliability contributors of the optics could be readily separated from the power intensive electrical signal processing functions and their cooling requirements on the host card.

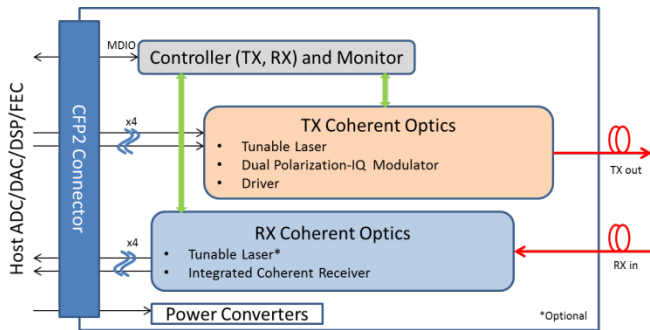


Figure 5. Pluggable Coherent Optics Schematic

It was envisioned that coherent optics in a CFP2 form factor would be compatible across several generations of digital signal processing (DSP) ASICs. In addition, it would be capable of supporting data rates from 50Gbps through 200Gbps and support modulation formats from BPSK through to higher level signalling such as 16-QAM.

Technology Challenges

Development of the interface was challenging in terms of miniaturization of component form factor and operation of a wide bandwidth RF channel over a hot-pluggable connector interface. Significant technical hurdles were envisioned across a number of technical disciplines. The project drew focus from a diverse range of OIF Members. The widely differing technical specializations of OIF Members made the OIF a suitable body to take on an interface such as CFP2-ACO. The OIF has attendees at face-to-face quarterly meetings who can address subject matter which varies from wide bandwidth integrated circuits for signal path applications such as modulator drivers and trans-impedance amplifiers (TIAs) through to the pluggable connector or equally importantly control interface firmware implementation for normalized system operation.

Differentiated Variants

A number of optical system vendors as well as optical component and module vendors are OIF members, and each bring a different viewpoint and enhance the comprehensiveness of OIF IAs. The result of this

interaction helped to define three broad product classes for the CFP2-ACO.

- Type 1 offering a limiting amplifier in the transmit chain and supporting the DP-QPSK or simpler modulation formats. All module control functions are internal in this variant.
- Type 2 having a linear driver amplifier allowing multi-level – multi-phase modulation formats such as 16-QAM as well as Nyquist filtered DP-QPSK. Like Type 1 all module control functions are internal to the module in this variant.
- Type 3 added an analogue control interface allowing numerous optical component bias and balance control functions to be host addressable. The aim of this was to enable the possibility of customized module operation finesse in certain high end system applications.

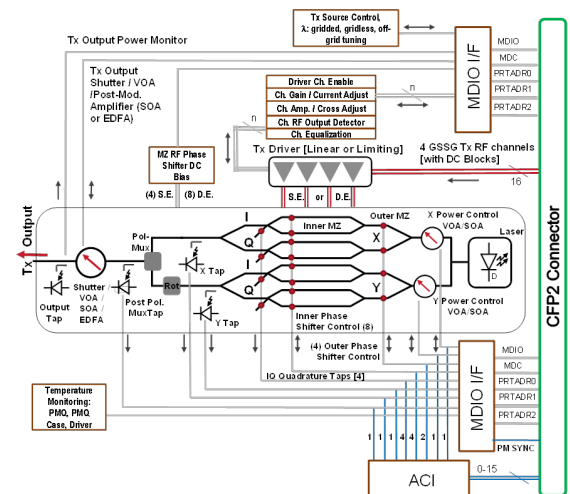


Figure 6. CFP2-ACO Type 3 Tx Schematic

Signal Path Engineering

For all three of these types, the receiver chain is a linear optical to electrical signal path and low harmonic distortion is essential. In the case of Type 2 and 3 the transmit path is also a linear path allowing n-QAM modulation. This aspect increases the flexibility and enlarges the application space for the CFP2-ACO module. The linear transmit path allows a wider range of transmit side DSP signal filtering to be applied at the coherent ASIC and will increase the number of DSP ASIC iterations that remain compatible with the same electro-optic modules.



Figure 7. 32Gbps Quad Driver Module

Connector Signal Integrity

A major contributor to the response of the RF path in the CFP2-ACO module is the pluggable interface connector which is defined by the CFP-MSA Organization CFP2 Mechanical Specification. Connector manufacturers are represented within the OIF and contribute regularly to Common Electrical Interface (CEI) Implementation Agreements¹⁰. These IAs define connectorized interfaces for digital signals from a chip to a module or across back plane situations.

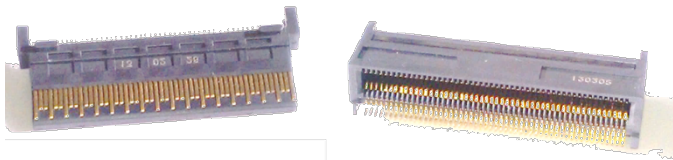


Figure 8. CFP2 Host and Plug Connector Halves

The CFP2-ACO team was able to draw on this reserve of specialist knowledge to understand how to define and also test the linear RF channels into and out of the module.

Transmitter and Receiver Optical Components

In parallel with the development of the IA for the CFP2-ACO Module, a smaller form factor Intradyme Coherent Receiver (“Micro-ICR”) component IA was developed. The aim of that IA was to enable multi-sourcing of the coherent receiver function within the module. With a generation 1 and 1.2 ICR function successfully completed within the OIF this further foot print shrink was seen as a helpful way to reduce supply risk of the CFP2 ACO Module.

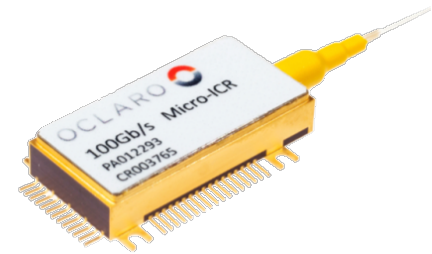


Figure 9. Micro-ICR for CFP2-ACO

In contrast the wide variability in the technology base for the transmitter modulator component potentially integrating the narrow line width laser necessary as the photonic source made it impossible to agree on an IA to represent the transmitter component function although there was a determined effort to explore the possibility to its fullest extent.

Management Interface and Registers

The Management Interface Specification (MIS) of CFP2-ACO draws on the CFP-MSA Organizations’ MIS document¹¹ originally issued by the CFP-MSA group and later augmented with additional registers to enable the OIF 100G Long-Haul DWDM Coherent Transmission Module IA. The CFP2-ACO team determined that additional registers were needed to enable best use of the various internal functions and maximize the longevity of the CFP2-ACO with DSP ASIC iterations.

Hex Addr	Hex (NN)	Access Type	Bit	Register Name Bit Field Name	Description	Bit Value
Tx Subsystem General						
BB80	(24)	RO		Tx RF Channel Mapping		
			15	XY mapping	0 = XY 1 = YX As defined in CFP2-ACO IA Section 8.3 and Table 3.	0b
			14:13	I,Q mapping	00 = I,Q 01 = Q,I 10 = I,Q 11 = Q,I As defined in CFP2-ACO IA Section 8.3 and Table 3.	00b
			12:10	PN mapping	000 = pin pin pin 001 = pin pin pin 010 = pin pin pin 011 = pin pin pin 100 = pin pin pin 101 = pin pin pin 110 = pin pin pin 111 = pin pin pin As defined in CFP2-ACO IA Section 8.3 and Table 3.	000b
			9:0	Reserved		
BB81	(24)	RO		Tx Optical Features	Summary of available PMO features in the CFP-ACO	
			15	PSM Tx Power Control In-Line Power Monitor	1 = Available, 0 = Not Available	
			14	PSM Pwr. Mnz (and Pwr Tx Power Control) In-Line Power Monitor	1 = Available, 0 = Not Available	
			13:12	X-Pol Power Monitor Options	00 = None, 01 = In-Line, 10 = Complementary, 11 = Reserved	
			11:10	Y-Pol Power Monitor Options	00 = None, 01 = In-Line, 10 = Complementary, 11 = Reserved	
			9:8	PSM Pwr. Mnz (and Pwr Tx Power Control) Options	00 = None, 01 = SOA or EDFA, 10 = VOA, 11 = SOA or EDFA	
			5:4	Y-Pol Power Control Options	00 = None, 01 = VOA, 10 = SOA, 11 = Reserved	
			3	I,Q, X,Q, Y, Y,Q Complementary Power Monitor	1 = Available, 0 = Not Available	
			2:0	Reserved		
BB82	(24)	RO		Tx Analog Control Interface (ACI) Availability		
			15	I,Q, X,Q, Y, Y,Q Complementary Power Monitor	1 = Available, 0 = Not Available	0b
			14	X-Pol and/or Y-Pol Power Monitor	1 = Available, 0 = Not Available	0b

Figure 10. Example of Register Definitions Table

The OIF works with numerous other industry organizations and standards bodies through formal liaison letters, informal relationships and personal networking. In

the case of the MIS the CFP2-ACO team turned to the CFP-MSA Organization to seek their assistance in providing new register addresses and further updates to the CFP MIS document.

Summary

The CFP2-ACO IA delivers a high-performance analog interface to pluggable optics. This interface allows the separation of high-power and large DSP components from the optical components. It also allows the generally lower reliability optical components to be in a pluggable form factor. Lastly, the IA enables these components to evolve on their own paths.

References

1. OIF-FD-100G-DWDM-01.0-100G Ultra Long Haul DWDM Framework Document (June 2009)
2. OIF-DPC-RX-01.0 Implementation Agreement for Integrated Dual Polarization Intradyne Coherent Receivers (April 2010)
3. OIF-PMQ-TX-01.0 Implementation Agreement for Integrated Polarization Multiplexed Quadrature Modulated Transmitters (March 2010)
4. OIF-MSA-100GLH-EM-02.0 – Multisource Agreement for Generation 2.0 100G Long-Haul DWDM Transmission Module – Electromechanical (August 2013)
5. OIF-DPC-RX-01.2 – Implementation Agreement for Integrated Dual Polarization Intradyne Coherent Receivers (November 2013)
6. OIF-PMQ-TX-01.1 – Implementation Agreement for Integrated Polarization Multiplexed Quadrature Modulated Transmitters (August 2013)
7. OIF-microTLA-01.0 – Micro Integrable Tunable Laser Assembly (September 2011)
8. www.cfp-msa.org/Documents
9. www.cfp-msa.org/Documents/CFP2-BASELINE-REV-1L-20130806.pdf
10. OIF-CEI-03.1 – Common Electrical I/O (CEI) – Electrical and Jitter Interoperability agreements for 6G+ bps, 11G+ bps, 25G+ bps I/O (February 2014)
11. CFP MSA Management Interface Specification Version 2.2 (R06a)

Editor and Contributors

Original Editor:
Stephen Gardner, Oclaro, Inc.
Contributors:
John Johnson, AVAGO Technologies
Revision Editor
Brian Holden, Kandou Bus SA