Implementation Agreement for High Bandwidth Integrated Polarization Multiplexed Quadrature Modulators

IA # OIF-HBPMQ-TX-01.0

January 19th, 2017

Implementation Agreement created and approved
by the Optical Internetworking Forum
www.oiforum.com

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For additional information contact:
The Optical Internetworking Forum
5177 Brandin Ct, Fremont, CA 94538
510-492-4040, info@oiforum.com

www.oiforum.com

Working Group: Physical and Link Layer (PLL) Working Group

TITLE: **Implementation Agreement for High Bandwidth Integrated Polarization Multiplexed Quadrature Modulators**

SOURCE:

TECHNICAL EDITOR

Roberto Galeotti
Oclaro, Inc.
Via Federico Fellini 4
20097 San Donato M.se, Italy
Phone: +39 02 51884 216
Email: roberto.galeotti@oclaro.com

PPL WORKING GROUP CHAIR

David R. Stauffer, Ph.D.
Kandou Bus, SA
QI-I
1015 Lausanne, Switzerland
Phone: +1.802.316.0808
Email: david@kandou.com

PLL WORKING GROUP - OPTICAL VICE CHAIR

Karl Gass
Qorvo, Inc.
Phone: +1.505.301.1511
Email: iamthedonutking@mac.com

ABSTRACT: This Implementation Agreement specifies key aspects of integrated polarization multiplexed quadrature modulators operating at rates up to 64GBd.

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1 Document Revision History

Table 1 provides the document revision history.

Document	Date	Revisions/Comments
OIF-HBPMQ-TX-01.0	Jan 19th 2017	Release created from OIF2016.012.05

Table 1: Document revision history

2 Introduction

This document details an Implementation Agreement (IA) of an optical integrated Polarization Multiplexed (PM) quadrature modulator for coherent applications with nominal symbol rates up to 64GBaud. This Implementation Agreement strives to remain modulation format and data rate agnostic whenever practical to maximize applicability across applications.

3 Functionality

This Implementation Agreement specifies in detail a single opto-electronic module with the functionality contained in the yellow area enclosed by the bold line in Figure 1. This module will be referred to as Polarization Multiplexed-Quadrature Modulator or PM-Q Modulator.

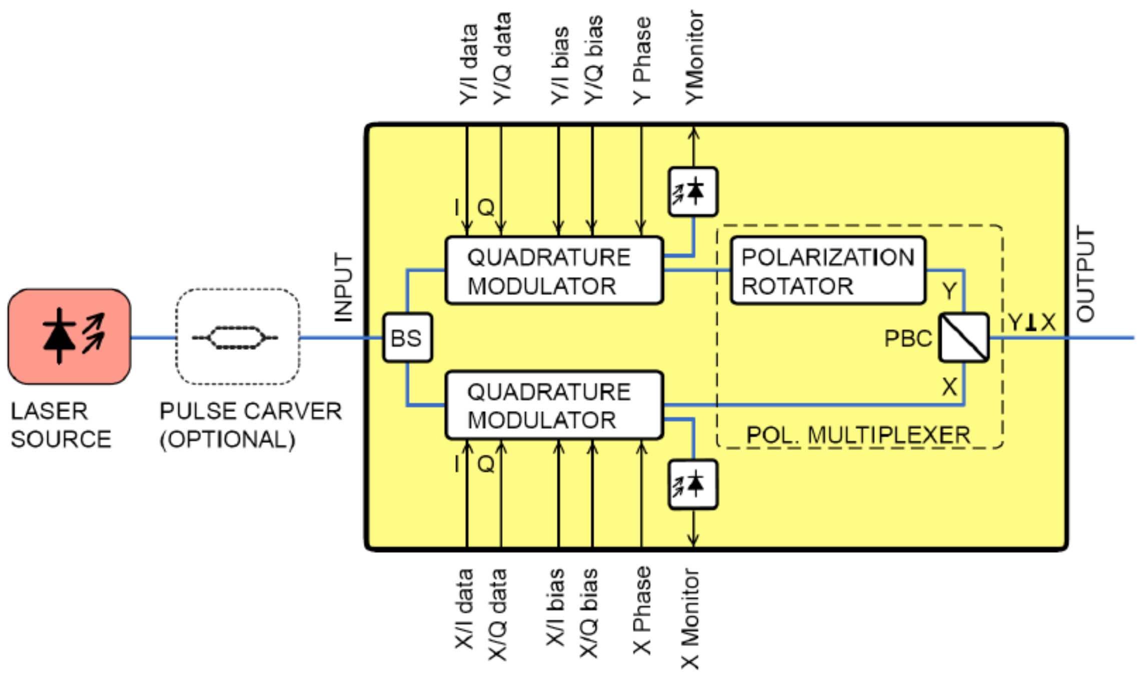

Figure 1: Functional diagram of a polarization multiplexed quadrature modulated integrated transmitter with a detailed functional diagram of the data modulator.

The optical power from an input fiber is divided into two parts and each part is independently modulated by a quadrature modulator. The resulting two modulated signals are combined with their polarizations orthogonal to each other, and output through an optical output fiber. The power in each of the two polarizations is independently monitored with photodiodes.

Each quadrature modulator typically comprises of two inner nested Mach-Zehnder modulators with bias control, a 90º phase shifter in the outer modulator with phase control, and an output power monitoring output. Any implementation or technology choices may be used to realize this basic functionality.

As indicated in Figure 1, the PM-Q Modulator includes the following basic functional components:

- One optical input
- One optical power splitter
- Two independent quadrature modulators
- Two independent monitoring photodiodes
- One polarization multiplexer
- One optical output

The PM-Q Modulator module specified in this Implementation Agreement does not include drivers or any control electronics.

The following independent interfaces are specified for the PM-Q modulator:

- One optical input fiber
- One optical output fiber
- Four high-speed data interfaces
- Four modulator bias control interfaces
- Two phase control interfaces
- Two power monitoring interfaces

The two polarized signal components in the output are referred to as "X" and "Y", and the quadrature modulators that encode information onto the polarization components are correspondingly referred to as X and Y modulators. Each quadrature modulator is driven by an "I" and a "Q" data signal. The four high-speed data interfaces are referred to as XI, XQ, YI and YQ.

Each of the four data modulators needs to be biased with a suitable DC voltage. This IA specifies biasing pins supporting both single-ended as well as push-pull biasing. The naming of the bias pins is consistent with the naming of the high-speed data interfaces. The I and Q phase offset is controlled via phase control pins also supporting both single-ended as well as push-pull control. The phase offset between I and Q in X and Y arms is controlled by phase control interfaces *X Phase* and *Y Phase* respectively.

I and Q are established by the heterodyne technique, with the frequency of the Signal input to the receiver greater than the frequency of the LO input. The I and Q channel outputs are measured in the time domain.

Under these conditions the Signal Q channel phase lags by nominally +90 degrees the Signal I channel phase, as shown in Figure 2.

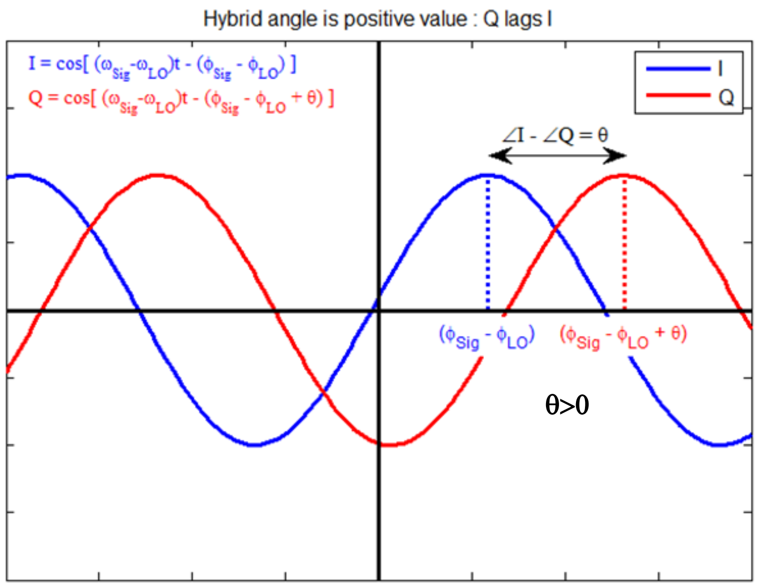

Figure 2: I and Q phase definitions

4 Mechanical Properties

Dimensions of the mechanical layout are defined in Figure 3; high speed interface position details are defined in Figure 4 and Figure 5 (dimensions are in mm and are intended as nominal values if not otherwise specified). A reference point or datum (D) is used to reference the extent of the module, the location of all electrical interfaces, mounting holes and fiber bending radius.

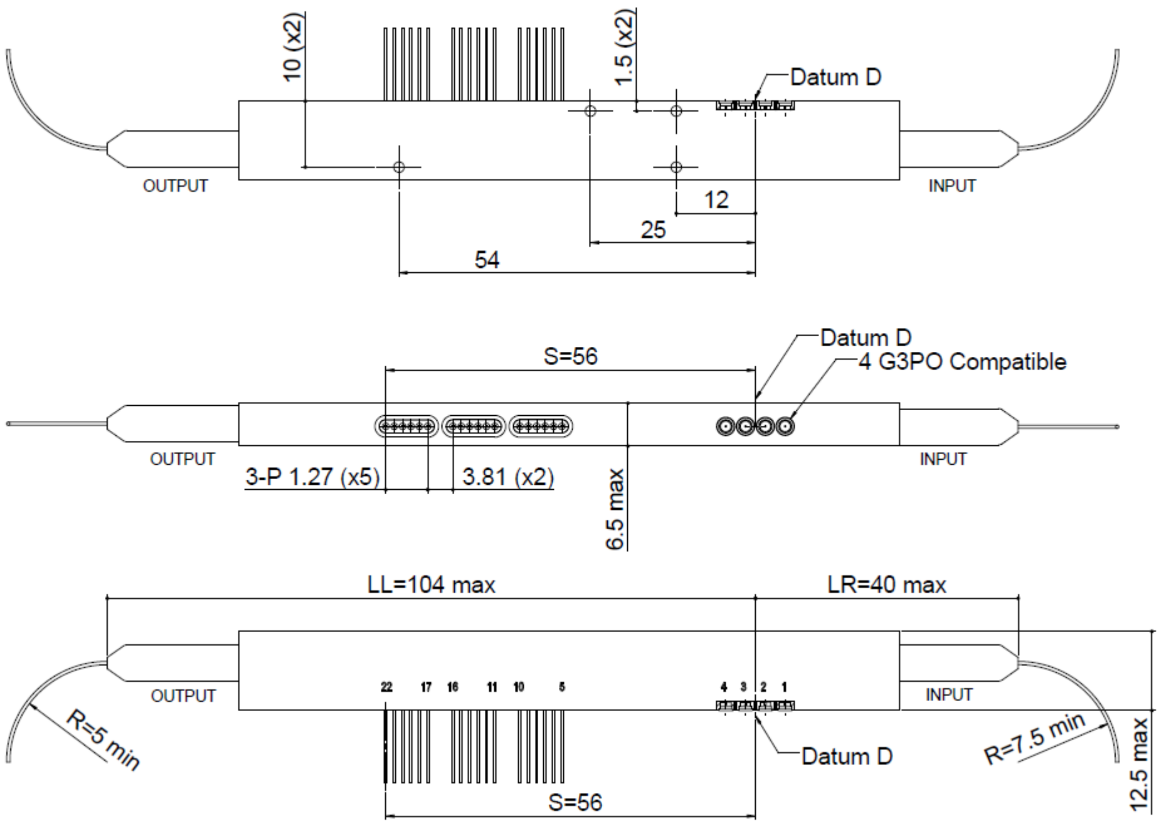

Figure 3: Mechanical layout, electrical interfaces and mounting holes location.

LL and LR specify maximum dimensions. Lower values than these are allowed.

Boot lengths are not explicitly specified to avoid restricting the choice of implementation or technology.

Mounting holes shall be M2 type threaded.

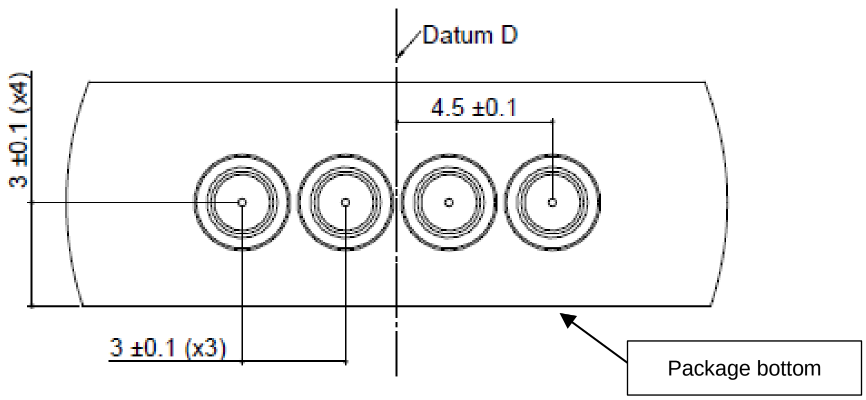

Figure 4: G3PO compatible connectors position details

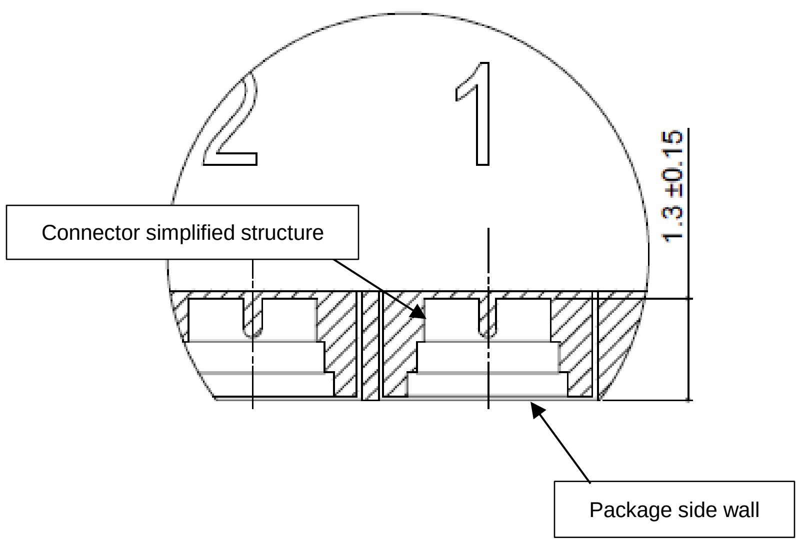

Figure 5: Position detail of G3PO compatible connectors internal reference plane

5 Electrical Interfaces

5.1 Mechanical Specification and Location of Electrical Interfaces

The high-speed data interfaces of the PM-Q Modulator module shall be coaxial G3PO compatible connectors.

The position of four in-wall male G3PO compatible connectors is shown in Figure 3, Figure 4 and Figure 5; the position of 18 low-speed pins is shown in Figure 3. The distance S between low-speed pins and the high-speed interfaces is referenced to the datum shown in the figure, centered between the center lines of the high-speed connectors. The low-speed pins are grouped in groups of 6 pins. The type of the low-speed pins and their distance from the bottom plane of the modulator package are not specified.

Low speed pins shape shall be one of the two following options (option shall be the same for all 18 pins; dimensions are in mm and are intended as nominal values if not otherwise specified):

a) Straight pins as shown in Figure 6
b) Bent pins to be suitable for the PCB landing pads design shown in Figure 7 and with the flat bottom part height specified in Figure 8

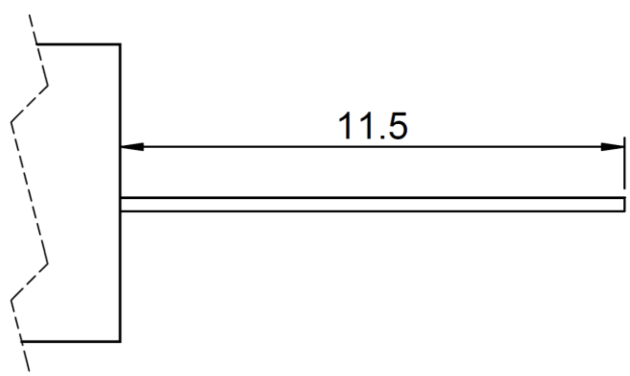

Figure 6: Straight low speed pins specification

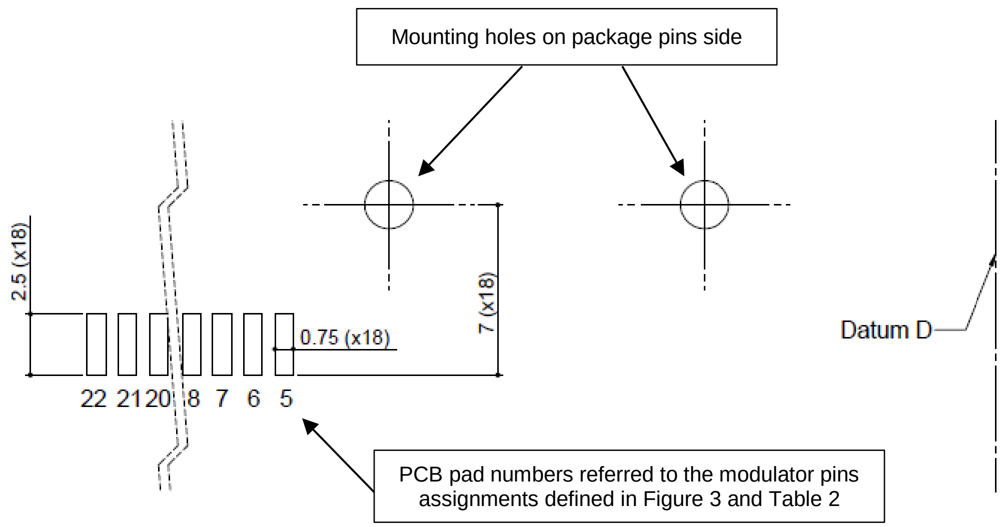

Figure 7: PCB landing pads specification for bent low speed pins

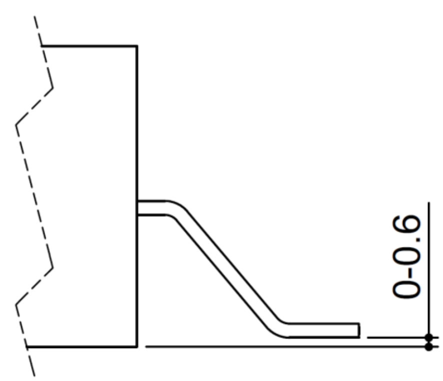

Figure 8: Flat bottom part height specification for bent low speed pins

5.2 Electrical Interface Pin Assignments

The pin numbering starts with the first high-speed data interface connector furthest from the low-speed pins and the pin number increases towards the opposite side. Electrical interface grouping, ordering and function are listed in Table 2.

Pin	Symbol		Description
1	Data_XI		X-polarization in-phase data input
2	Data_XQ		X-polarization quadrature data input
3	Data_YI		Y-polarization in-phase data input
4	Data_YQ		Y-polarization quadrature data input
5	Bias_YQ(p)	Bias_YQ	YQ modulator (positive) bias
6	Bias_YQ(n)	GND or NC	YQ modulator neg. bias (push-pull) or GND or NC (single-ended)
7	Bias_YI(p)	Bias_YI	YI modulator (positive) bias
8	Bias_YI(n)	GND or NC	YI modulator neg. bias (push-pull) or GND or NC (single-ended)
9	Bias_XQ(p)	Bias_XQ	XQ modulator (positive) bias
10	Bias_XQ(n)	GND or NC	XQ modulator neg. bias (push-pull) or GND or NC (single-ended)
11	Bias_XI(p)	Bias_XI	XI modulator (positive) bias
12	Bias_XI(n)	GND or NC	XI modulator neg. bias (push-pull) or GND or NC (single-ended)
13	Phase_Y(p)	Phase_Y	Y pol. phase (positive)
14	Phase_Y(n)	GND or NC	Y pol. phase negative (push-pull) or GND or NC (single-ended)
15	Phase_X(p)	Phase_X	X pol. phase (positive)
16	Phase_X(n)	GND or NC	X pol. phase negative (push-pull) or GND or NC (single-ended)
17	NC		Not Connected
18	Y_A		Y-polarization photodiode Anode
19	Y_C		Y-polarization photodiode Cathode
20	GND		Ground
21	X_C		X-polarization photodiode Cathode
22	X_A		X-polarization photodiode Anode

Table 2: Electrical interface pin-out and function with multiple options for biasing and phase control

5.3 Power Monitor Interface Electrical Properties

The electrical properties related to the power monitor diodes are specified in Table 3. The opto-electronic properties of the optical modulator including the high-speed data interfaces are specified in Section 6.

Parameter	Unit	Min.	Typ.	Max.	Remarks
Monitor PD Responsivity	mA/W	50		800	Referred to output power complementary taps
Monitoring PD E/O Bandwidth	GHz	1			

Table 3: Power monitor interface electrical properties

6 Opto-Electronic Properties

Electrical specification of the high-speed interface and opto-electronic properties are given in Table 4 at the end of life over the operating temperature and frequency ranges.

Parameter	Unit	Min.	Typ.	Max.	Remarks
S21 E/O bandwidth @-3dB @-6dB	GHz	35 45			3% smoothed, reference frequency at 2GHz
S11 Electrical Return loss f < 30GHz 30 < f < 45GHz	dB			-10 -8	
RF Impedance	Ohm		50		
Vpi_RF	V			3.5	Measured at 2GHz
Vpi_Phase	V		(*1)		
I/Q skew (*2)	ps			50	For each polarization component
Total skew (*3)	ps			100	
I/Q skew variation (*4)	ps			1.5	
Total skew variation	ps			4	

*1 - Application specific – covering a range of applications for this component.
*2 - I/Q skew is the skew between channel pairs XI and XQ, and YI and YQ.
*3 - Total skew is the maximum skew between any of the four physical channels XI, XQ, YI and YQ.
*4 - The objective of this specification is to minimize skew variation between I and Q. I/Q skew variation is a key parameter for system operation in some DSPs

Table 4: Electrical and opto-electronic properties

Skew is defined as the maximum signal propagation time difference between physical signal channels, between electrical input and optical output interfaces. Skew includes any skew variation due to aging, temperature and any other effects.

7 Optical properties

Optical properties of the optical modulator are listed in Table 5 at the end of life over the operating temperature and frequency ranges.

Parameter	Unit	Min.	Typ.	Max.	Remarks
Operating Frequency C-Band L-Band	THz	191.35 186.0		196.2 191.5	At least one range shall be supported in one device
Input power	dBm			18	Peak power
Insertion loss	dB	(*1)		14	All modulators at peak transmission, for each polarization
Insertion loss difference between X and Y				(*1)	
Optical return loss	dB	30			Input and output
Parent MZI ER	dB	22			
Child MZI ER Basic Performance Extended Performance	dB	22 25			
Polarization ER	dB	20			
*1 - Application specific – covering a range of applications for this component.					

Table 5: Optical properties

The input fiber shall be polarization maintaining (PMF) with a 125µm cladding diameter and a 250µm coating diameter. The PMF shall have a maximum "Minimum Bending Radius" of 7.5mm (as shown in Figure 3).

The output fiber shall be single mode (SMF) with a 125µm cladding diameter and a 250µm coating diameter. The SMF shall be compliant to ITU-T recommendations G.657.B3 and G.652.D, and therefore shall have a maximum "Minimum Bending Radius" of 5mm (as shown in Figure 3).

The PMF color shall be natural (transparent) and the SMF color shall be white.

The optical connector key shall be aligned to the slow axis of the polarization maintaining fiber. Optical and opto-electronic specifications assume that a polarized input signal is launched into the slow axis of the input fiber.

8 Environmental

The typically expected operating temperature range is -5ºC to +75ºC. For the purpose of uniform calculation of the Failures In Time (FIT) rate, a fielded temperature of 55ºC shall be used.

9 Glossary

Table 6 presents definitions for acronyms used in this IA.

Term	Definition
BS	Beam Splitter
DC	Direct Current
E/O	Electro-Optical
ER	Extinction Ratio
FIT	Failures In Time
GND	Ground
I	In Phase
IA	Implementation Agreement
LO	Local Oscillator
MZI	Mach-Zehnder Interferometer
NC	Not Connected
PBC	Polarization Beam Combiner
PCB	Printed Circuit Board
PD	Photodiode
PM	Polarization Multiplexed
PMF	Polarization Maintaining Fiber
PM-Q	Polarization Multiplexed Quadrature
Q	Quadrature
RF	Radio Frequency
SMF	Single Mode Fiber

Table 6: Glossary

10 List of companies belonging to OIF at document approval date

Acacia Communications	GigPeak	O-Net Communications (HK) Limited
ADVA Optical Networking	Global Foundries	Oclaro
Alcatel-Lucent	Google	Orange
Alibaba (China) Co., Ltd	Hitachi	PETRA
AMCC	Huawei Technologies Co., Ltd.	QLogic Corporation
Amphenol Corp.	Infinera	Qorvo
Anritsu	Inphi	Rockley Photonics
Broadcom Limited	Intel	Samsung Electronics Co. Ltd.
Brocade	Ixia	Samtec Inc.
BRPhotonics	Juniper Networks	Semtech
China Telecom	Kandou Bus	Socionext Inc.
Ciena Corporation	KDDI R&D Laboratories	Spirent Communications
Cisco Systems	Keysight Technologies, Inc.	Sumitomo Electric Industries
ClariPhy Communications	Lumentum	Sumitomo Osaka Cement
Coriant	MACOM Technology Solutions	TE Connectivity
CPqD	Marvell Technology	Tektronix
Credo Semiconductor (HK) LTD	Mellanox Technologies	Teledyne LeCroy
Dell, Inc.	Microsemi Inc.	TELUS Communications, Inc.
ETRI	Microsoft Corporation	Time Warner Cable
Fiberhome Technologies Group	Mitsubishi Electric Corporation	UNH InterOperability Laboratory (UNH-IOL)
Finisar Corporation	Molex	Verizon
Foxconn Interconnect Technology, Ltd.	MoSys, Inc.	Viavi Solutions Deutschland GmbH
Fujikura	MRV	Xilinx
Fujitsu	NEC Corporation	Yamaichi Electronics Ltd.
Furukawa Electric Japan	NeoPhotonics	ZTE Corporation
Gigamon Inc.	NTT Corporation	