OIF OPTICAL INTERNETWORKING FORUM

Implementation Agreement
for
Integrated Polarization Multiplexed
Quadrature Modulated Transmitters

IA # OIF-PMQ-TX-01.1

August 27, 2013

Implementation Agreement created and approved
by the Optical Internetworking Forum
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Working Group: Physical and Link Layer (PLL) Working Group

TITLE: **Implementation Agreement for Integrated Polarization Multiplexed Quadrature Modulated Transmitters.**

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ABSTRACT: This Implementation Agreement specifies key aspects of integrated polarization multiplexed quadrature modulated optical transmitters operating at rates up to 32 GBd for applications such as 100G PM-QPSK DWDM transmission. This is not a multi-source agreement (MSA) but it is expected that it will serve as a foundation for future MSAs.

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DATE: **August 27th, 2013**

Revision	Date	Changes	Editor
OIF-PMQ-TX-01.0	March 12, 2010	Created from oif2009.186.05	M. Bouda
OIF-PMQ-TX-01.1	August 27, 2013	Based on oif2013.046.05 Changes to Sections 7, 11 and 16 - Updates to Type 3 Envelope - Addition of Type 4 Envelope - Addition of 4-GPPO interface Changes to Appendix B (Informative) - Potential locations of mounting holes Addition of Appendix C (Informative) - SMT landing pad dimension	M. Bouda

5 Introduction

This document details an Implementation Agreement (IA) for an optical integrated Polarization Multiplexed (PM) quadrature modulated transmitter for applications with nominal symbol rates of up 32 GBaud. While specifically addressing 100G PM-QPSK applications with FEC, this Implementation Agreement strives to remain modulation format and data rate agnostic whenever practical to maximize applicability to other future applications. This IA is expected to serve as a foundation for future MSAs.

6 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.
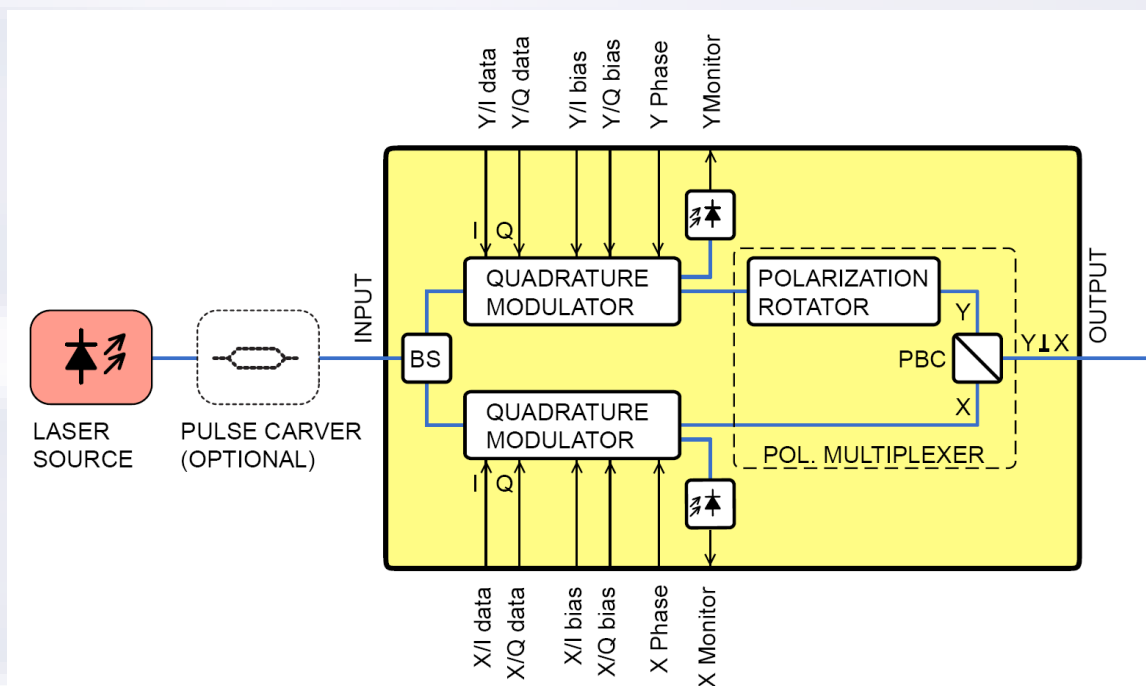
Figure 1 **Functional diagram of a polarization multiplexed quadrature modulated integrated transmitter with a detailed functional diagram of the data modulator.**

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.

The quadrature modulators typically comprise two nested Mach-Zehnder modulators with bias control, a 90º phase shifter in the outer modulators with phase control, and an output power monitoring output. Any implementation or technology choices may be used to realize the same 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 components at the output are referred to as "X" and "Y", and the arms in which information is modulated onto the polarization component are correspondingly referred to as X and Y arms. Each quadrature modulator is driven by an "I" and a "Q" data signal. The four high-speed data interfaces are referred to as X/I, X/Q, Y/I and Y/Q data interfaces. Nominal phase shifts in the quadrature modulators between I and Q shall be the same in X and Y arms.

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.

7   Electrical Interfaces

7.1   Mechanical Specification of Low-Speed Interface and Interface Locations

The mechanical specification of an 18-pin low-speed interface is shown in Figure 2. The low-speed pins are grouped in groups of 6 pins. The type of the low-speed pins, their length and their distance from the bottom plane of the modulator package are not specified.
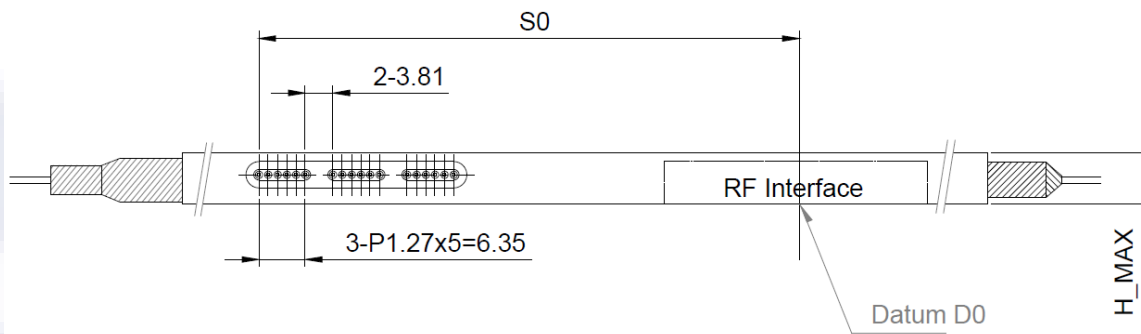
Figure 2   Specification of low-speed interface, and location of low- and high-speed interfaces relative to a Datum.

Figure 2 further defines the positions of both low-speed and high-speed interfaces relative to a Datum D0. Datum D0 is centered between the center lines of the high-speed connectors. The spacing between DC and RF interfaces is defined by parameter S0.

The applicable high-speed interface configuration and the values of H_MAX and S0 are specified in Table 6.

7.2   Mechanical Specification of High-Speed Interface Options

The high-speed data interfaces of the PM-Q Modulator module shall be coaxial GPPO-compatible interfaces. Figures 3 and 4 define high-speed interface configurations.
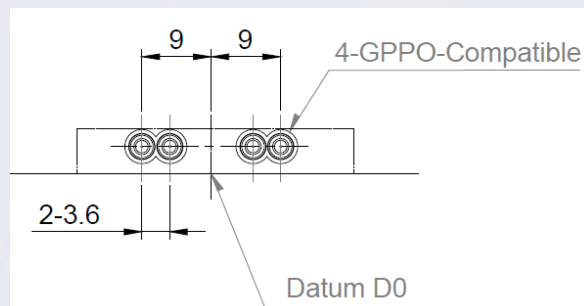
Figure 3   Mechanical specification of a "2+2 GPPO" high-speed interface.
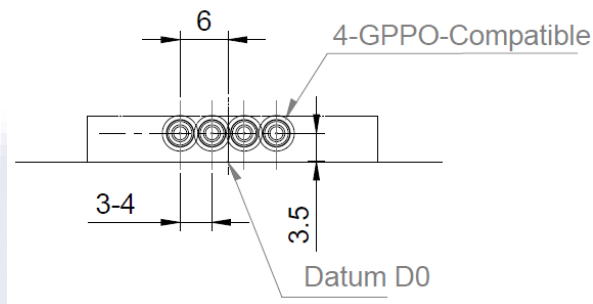
Figure 4   Mechanical specification of a "4 GPPO" high-speed interface.

7.3   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.

A first electrical interface grouping, ordering and function are listed in Table 1. An alternative allowed electrical interface ordering is provided in Table 2. The alternative ordering in Table 2 interleaves corresponding X and Y polarization quadrature bias pins to minimize the electrical crosstalk between the I and Q modulator biases. The separation between the monitor photodiode cathodes is also maximized with this alternative ordering for crosstalk reasons.

Table 1 Electrical interface pin-out and function with multiple options for biasing and phase control.

Pin	Symbol		Description
1	Data_X/I		X-polarization in-phase data input
2	Data_X/Q		X-polarization quadrature data input
3	Data_Y/I		Y-polarization in-phase data input
4	Data_Y/Q		Y-polarization quadrature data input
5	Bias_Y/Q(p)	Bias_Y/Q	Y/Q modulator (positive) bias
6	Bias_Y/Q(n)	GND or NC	Y/Q modulator neg. bias (push-pull) or GND or NC (single-ended)
7	Bias_Y/I(p)	Bias_Y/I	Y/I modulator (positive) bias
8	Bias_Y/I(n)	GND or NC	Y/I modulator neg. bias (push-pull) or GND or NC (single-ended)
9	Bias_X/Q(p)	Bias_X/Q	X/Q modulator (positive) bias
10	Bias_X/Q(n)	GND or NC	X/Q modulator neg. bias (push-pull) or GND or NC (single-ended)
11	Bias_X/I(p)	Bias_X/I	X/I modulator (positive) bias
12	Bias_X/I(n)	GND or NC	X/I 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 or Bias_Subst [1]		Not Connected or substrate bias [1]
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
1) Pin 17 may be used for substrate bias if needed. Otherwise the pin shall be Not Connected.			

Table 2   Alternative electrical interface pin-out and function with multiple options for biasing and phase control.

Pin	Symbol		Description
1	Data_X/I		X-polarization in-phase data input
2	Data_X/Q		X-polarization quadrature data input
3	Data_Y/I		Y-polarization in-phase data input
4	Data_Y/Q		Y-polarization quadrature data input
5	Bias_Y/Q(p)	Bias_Y/Q	Y/Q modulator (positive) bias
6	Bias_Y/Q(n)	GND or NC	Y/Q modulator neg. bias (push-pull) or GND or NC (single-ended)
7	Bias_X/Q(p)	Bias_X/Q	X/Q modulator (positive) bias
8	Bias_X/Q(n)	GND or NC	X/Q modulator neg. bias (push-pull) or GND or NC (single-ended)
9	Bias_Y/I(p)	Bias_Y/I	Y/I modulator (positive) bias
10	Bias_Y/I(n)	GND or NC	Y/I modulator neg. bias (push-pull) or GND or NC (single-ended)
11	Bias_X/I(p)	Bias_X/I	X/I modulator (positive) bias
12	Bias_X/I(n)	GND or NC	X/I 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 or Bias_Subst [1]		Not Connected or substrate bias [1]
18	Y_C		Y-polarization photodiode Cathode
19	Y_A		Y-polarization photodiode Anode
20	GND		Ground
21	X_A		X-polarization photodiode Anode
22	X_C		X-polarization photodiode Cathode

1) Pin 17 may be used for substrate bias if needed. Otherwise the pin shall be Not Connected.

7.4   Electrical Properties of Low-Speed Electrical Interface

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 8.

Table 3   Low-speed interface electrical properties.

Parameter	Unit	Min.	Typ.	Max.	Remarks
Monitor PD Responsivity	mA/W	ffs		ffs	
Monitoring PD O/E Bandwidth	GHz	1			

8 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.

Table 4   Electrical and opto-electronic properties.

Parameter	Unit	Min.	Typ.	Max.	Remarks
S21 E/O Bandwidth (3dB)	GHz	23			3% smoothed, reference frequency at 1.5 GHz or 2 GHz

S11 Electrical Return Loss
  f ≤ 25 GHz
  25 < f ≤ 32 GHz
	dB	10
		8			

Vpi_PRBS	V			3.5	Specified at PRBS31 at 32 GBd
Vpi_LF (*1)	V			3.4	Measured at 1.5 GHz or 2 GHz
RF Impedance	Ohm		50		
I/Q skew (*2)	ps			4	For each polarization component
Total skew (*3)	ps			10	
I/Q skew variation	ps			2	
Total skew variation	ps			5	

1) A module vendor shall provide data showing correlation between Vpi_LF and Vpi_PRBS, and specify a Vpi_LF that guarantees a Vpi_PRBS satisfying the requirements in this table.
2) I/Q Skew is the skew between channel pairs X/I and X/Q, and Y/I and Y/Q.
3) Total skew is the maximum skew between any of the four physical channels X/I, X/Q, Y/I and Y/Q.

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.

9 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.

Table 5 Optical properties.

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	ffs		14	All modulators at peak transmission, for each polarization
Insertion loss difference between X and Y				ffs	
Optical return loss	dB	30			Input and output
Parent MZI ER	dB	20			
Child MZI ER	dB	20			
Polarization ER	dB	20			

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

The output fiber shall be either SMF or PMF.

10 Environmental Conditions

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

11 Mechanical Properties

The dimensions of mechanical envelopes depend on the application. Envelope parameters are defined in Figure 3. A reference point or datum is used to reference the extent of the envelopes, as well as the location of all electrical interfaces.
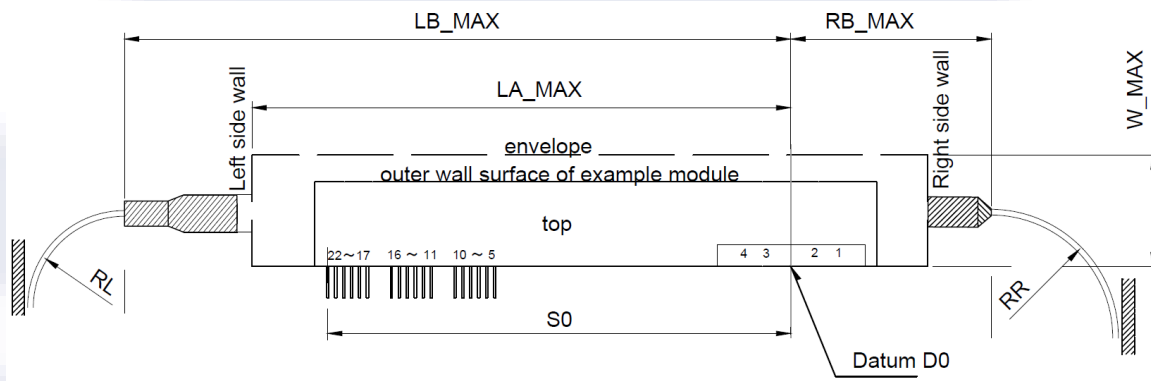

Figure 5 **Location of Datum and dimensions related to Envelope Types 1, 2, and 3 (top view).**
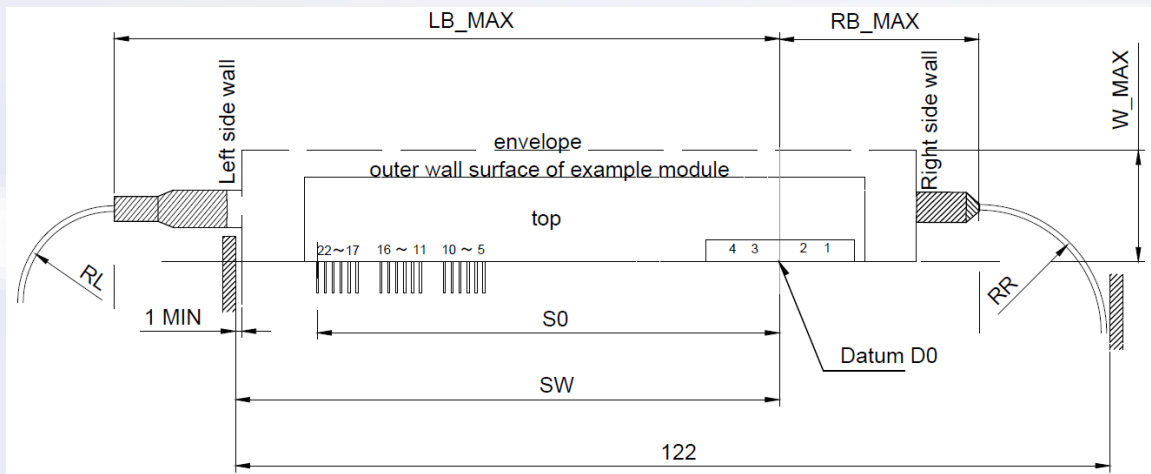
Figure 6 **Location of Datum and dimensions related to Envelope Type 4 (top view).**

Bend radii and boot lengths are not explicitly specified to avoid restricting the choice of implementation or technology.

Table 6 specifies four Envelope Types. Features and dimensions of Envelope Types 1 and 2 are derived from mechanical constraints of a 5"x7" transponder module application. Features and dimensions of Envelope Types 3 and 4 are derived from mechanical constraints of a 4"x5" transponder module application.

Table 6   Envelope Type features and dimensional parameters in mm.

Parameter	Type 1	Type 2	Type 3	Type 4
High-speed interface	2+2 GPPO		4 GPPO or SMT [1]	
Input fiber side wall	right		right	
Output fiber side wall	left	right or left	right or left	right or left
Mounting hole side	bottom		bottom	
S0	74.06		48.83	61.2
SW	-	-	-	67.2
RB_MAX	36.0	51.1	36.0	39.8
LA_MAX		88.5	57.0	-
LB_MAX	-	-	-	85.2
for RR=20mm	98.8	-	89.3	-
for RR=15mm	103.8	-	94.3	-
W_MAX	13.5	20.0	20.0	13.5
H_MAX	7		7	
1) SMT is a single-ended high-speed interface option as described in informative Appendix C.				

Mounting holes shall be of type M2.

12   Test Methods and Definitions

13   Compliance

14   References

Appendix A: Glossary

AC	Alternating Current
BS	Beam Splitter
BW	Band Width
DC	Direct Current
E/O	Electro-Optical
ER	Extinction Ratio
FEC	Forward Error Correction
FIT	Failures In Time
ffs	for further study
GNC	Ground
IA	Implementation Agreement
PBC	Polarization Beam Combiner
PD	Photo Diode
PMF	Polarization Maintaining Fiber
PM-Q	Polarization Multiplexed Quadrature
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SMF	Single Mode Fiber
MSA	Multi-Source Agreement
MZI	Mach-Zehnder Interferometer
NC	Not Connected

Appendix B: Examples of Additional Mechanical Details

This Appendix is informational and intended to avoid incompatible placement of alternate mounting holes and to provide other informative information that may be useful.

Mounting hole placement options are suggested in the area between the low-speed and high-speed electrical interfaces, along the side wall with the electrical interfaces. Other holes will exist. At least one additional mounting hole shall be located at the side opposite the electrical interfaces.
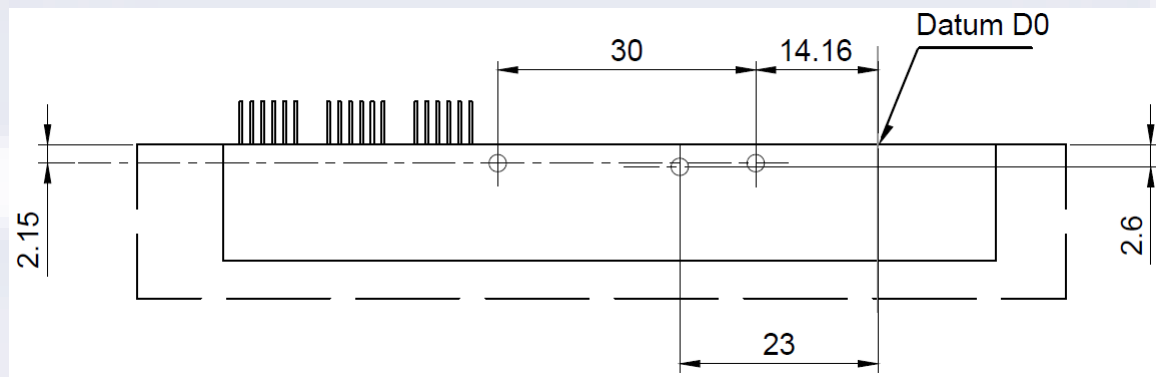

Figure 7   **A subset of locations of potentially existing mounting holes for Types 1 and 2 (bottom view).**
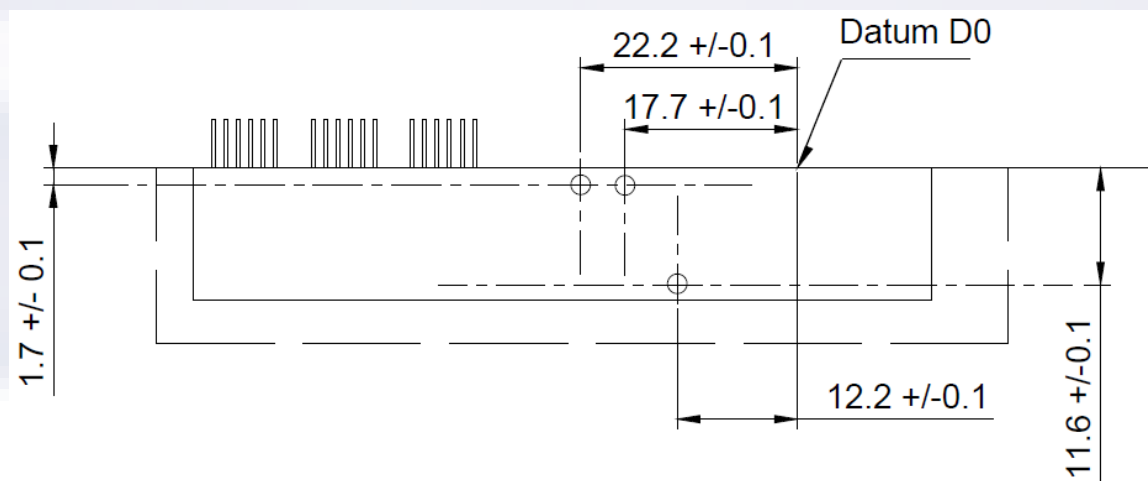

Figure 8   **Potentially existing mounting holes for Types 3 and 4 (bottom view).**

Boot lengths may vary from 21.2mm to 10.3mm depending on implementation.

Appendix C: SMT High-Speed Interface Options

This informative Appendix describes SMT-type interface options. SMT-type interfaces include Flex and CPW.
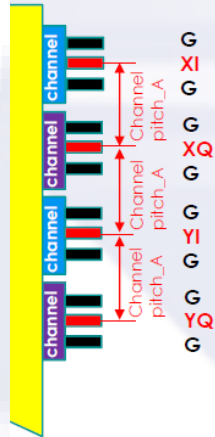

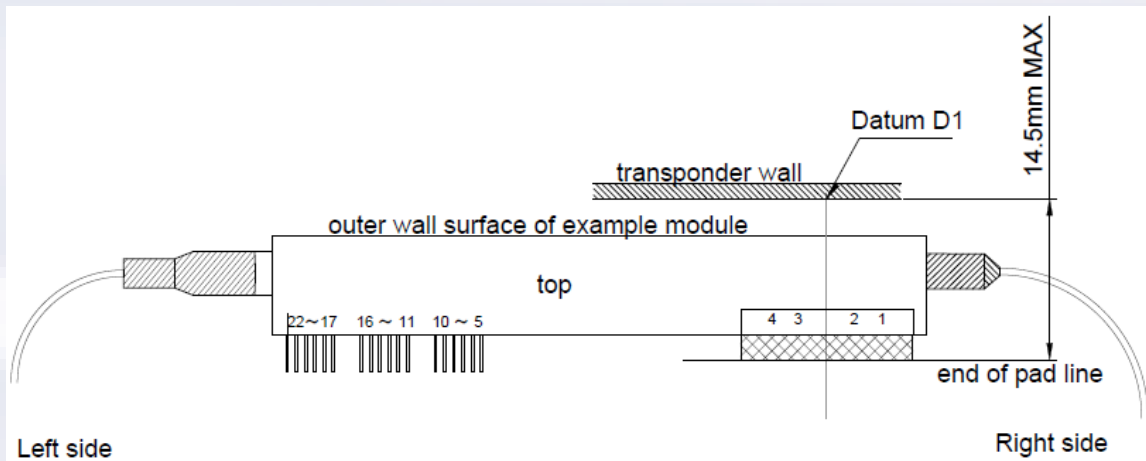**Figure 9   Example of SMT-type interface with GSG configuration.**

Figure 10   Landing pad extent on PCB in case of SMT-type high-speed interface.

Appendix D: Open Issues

The following items may require more study and could be included in future revisions of this IA.

- Insertion loss wavelength dependency
- X/Y orthogonality
- Responsivity of power monitors
- Bias voltage ranges
- Phase control range
- DC pin lead dimensions
- Output and input fiber position (plane or point)
- Heatsink mounting considerations
- Actual practical operating temperature range
- Measurement methods
- Common mounting holes
- Small form factor modulators
- Other RF interface options
- Crosstalk between RF data and the monitoring PD

Appendix E: Companies belonging to OIF when document was approved

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