Thoughts on PMD baseline proposal for automobile based on Si-Photonics

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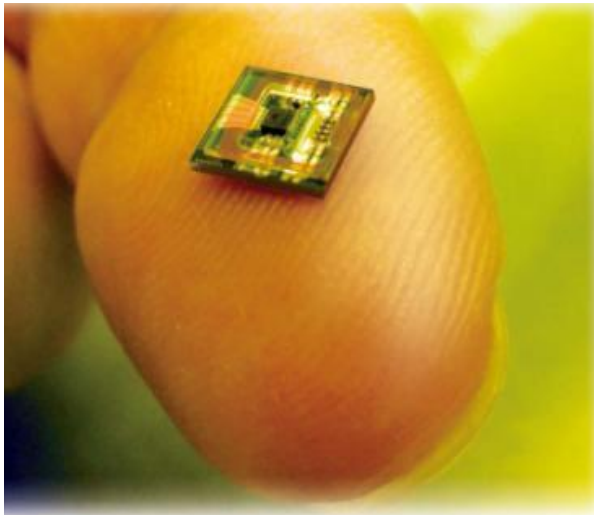
IEEE P802.3cz Multi-Gigabit Optical Automotive Ethernet Task Force

Introduction

Nov. 2019 Hawaii "Introduction of Si Photonics transceiver technology with High temperature operation capability and MMF transmission" by I. Ogura and K. Kurata
Jan. 2020 Geneva "A study for highly-reliable optical transceiver based on Si Photonics technology" by I. Ogura and K. Kurata



Si Photonics for Automobile applications

- High speed: 25Gbps and higher
- 40m reach through OM3@25G

- High temperature:
  Quantum Dot (QD) Laser Source operates over 105℃

- Reliability:
  QD-LD lifetime expected over 20 years @105℃
  Redundancy of light sources is possible for higher reliability

This Presentation

Thoughts on baseline proposal based on Si-photonics
for possible implementation to meet the OMEGA objectives.

Contents

Si-photonics to meet OMEGA objectives

1. 40m reach at 25Gbps
   - For a reference to develop OMEGA specifications
     25Gbps/ch Si-photonics transceiver sub-assembly with MMF
     standardized in IEC SC86C (Optical systems and active devices)
   - Results with conventional OM2,OM3 MMF and 1310nm-optimized MMF

2. 15m reach at 50Gbps
   50Gbps operation by 25Gbaud-PAM4 and 50Gbps-NRZ

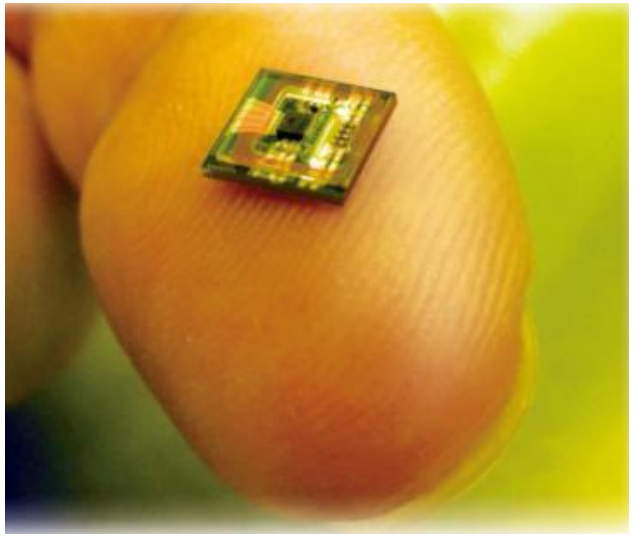
3. Reliability assessment

4. Eye-safety

Si photonics technology commercially available for short reach interconnect

Chip-scale package of silicon photonics transceiver

Item	Specification
Throughput	100G: 25Gx4ch Tx + Rx 300G: 25G × 12ch Tx/Rx
Footprint	5mm × 5mm
Power consumption	5mW/Gbps
Wavelength	1.3μm（O-band）
Media	MMF up to 300m*

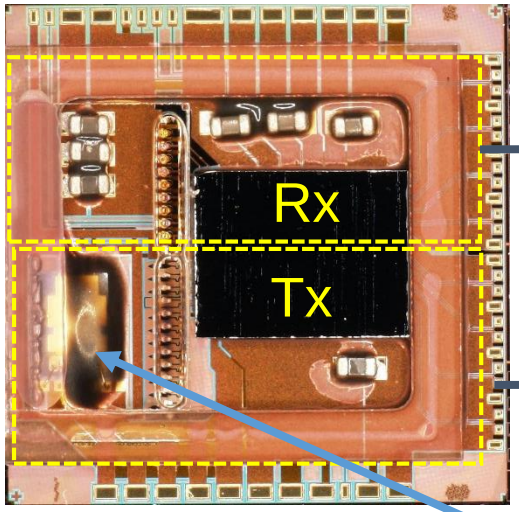


* 1310nm-optimized MMF

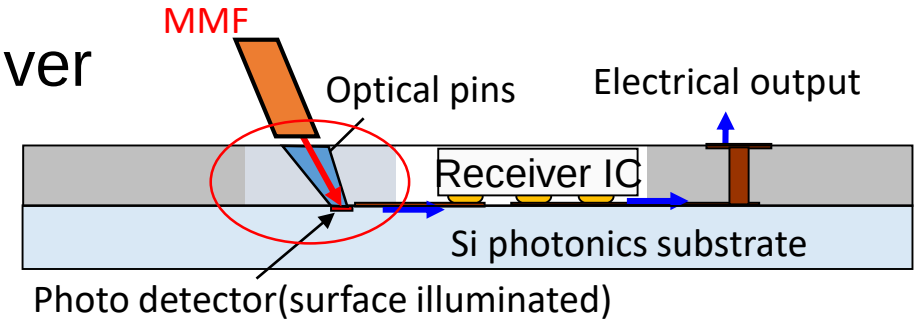
- High density
- Low power consumption
- Low cost solution through the combination of
  Si-Photonics and multimode optics with wide alignment margin

Si photonics with QD-laser and MMF optics for short reach interconnects incl. automobile

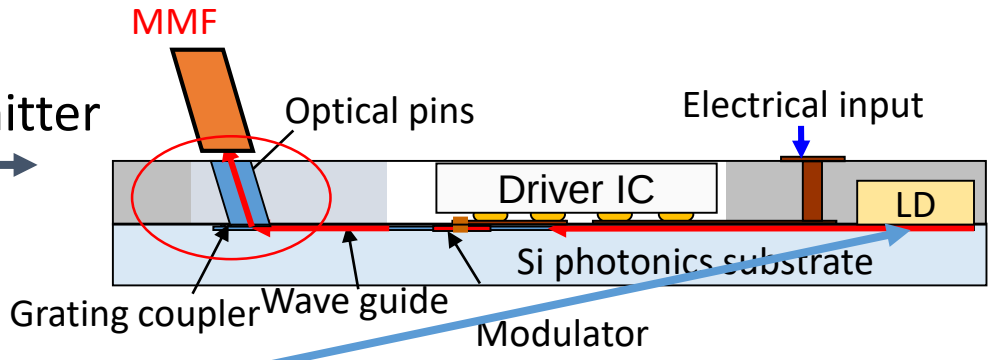
Si photonics one-chip transceiver



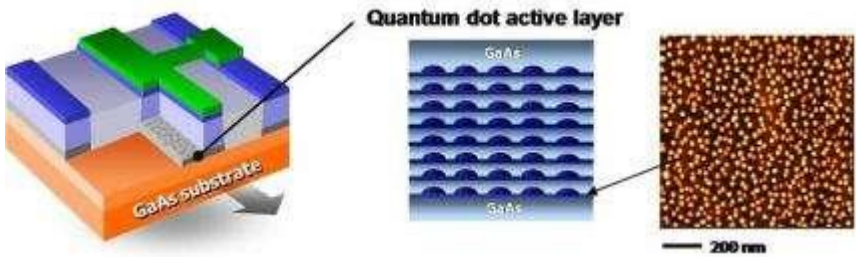
Receiver



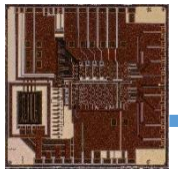
Transmitter



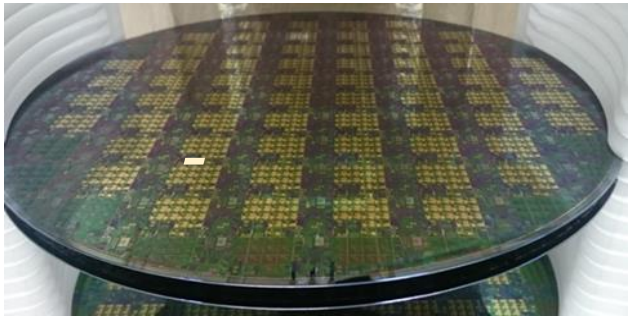
Quantum dot laser light source: wide temperature range



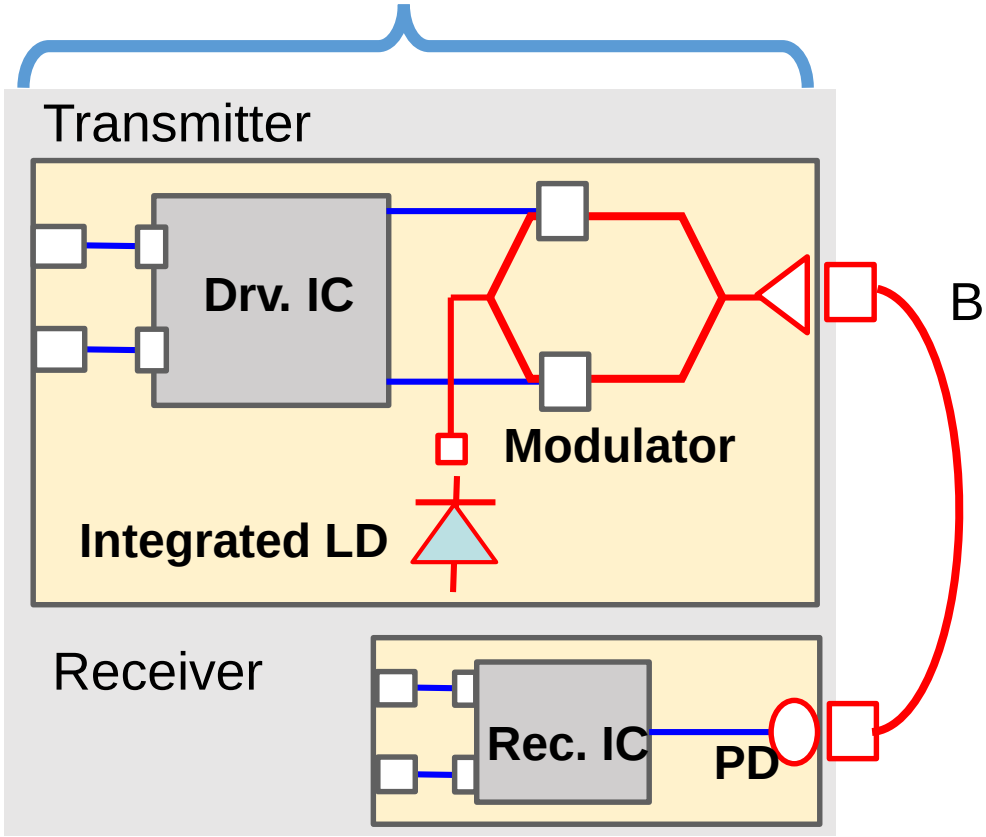
Integrated Si photonics transceiver



Si wafer



One chip integration
Mass-producible



Butt coupling to MMF

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   50Gbps operation by 25Gbaud-PAM4 and 50Gbps-NRZ

3. Reliability assessment

4. Eye-safety

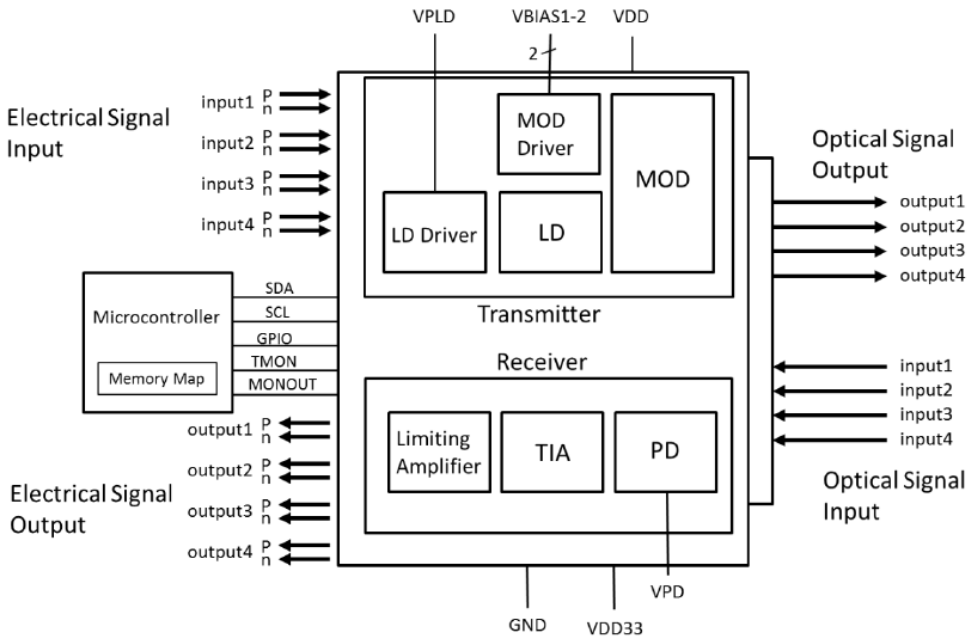
FIBRE OPTIC ACTIVE COMPONENTS AND DEVICES –PERFORMANCE STANDARDS –

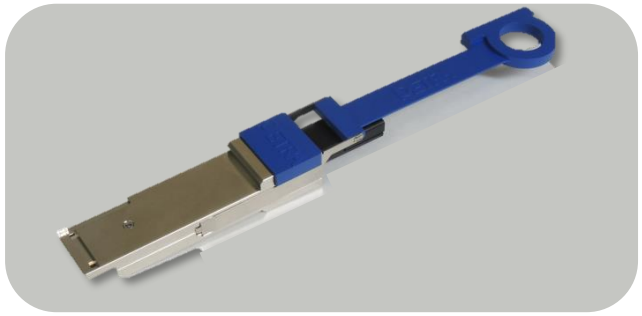
Part 11: Multiple channel transmitter/receiver chip scale package with multimode fibre interface

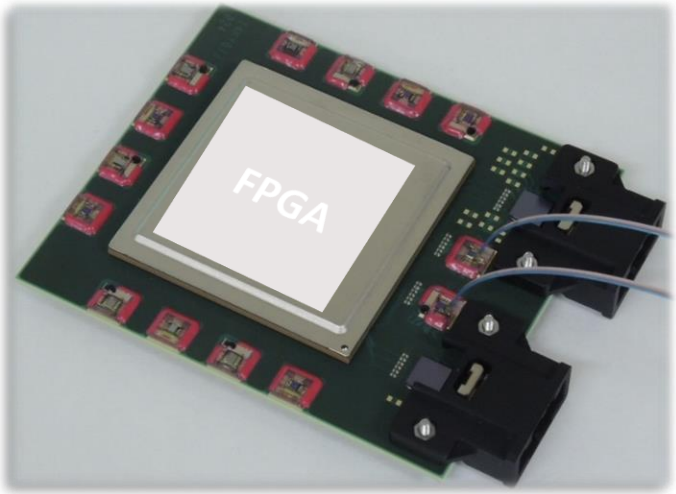
Published May,2020

Raw characteristics of Si-photonics transceiver sub-assembly
- operating at 25Gbps/ch with 1310nm MMF
- without CDR and FEC

Building block for short reach pluggable or embedded optics







FIBRE OPTIC ACTIVE COMPONENTS AND DEVICES
–PERFORMANCE STANDARDS –
Part 11: Multiple channel transmitter/receiver chip scale package with multimode fibre interface
Published May,2020

Operating conditions

Parameter	Symbol	Min	Typ	Max	Units	Reference
Case temperature	Tc	0		70	°C	
1,0 V power supply voltage	VDD	1,0	1,02	1,1	V	
3,3 V power supply voltage	VDD33	3,135	3,3	3,465	V	
Signal rate per channel		1,0		28	Gbit/s	
MMF fibre length (2 000 MHz·km)		0,5		300	m	Maximum length is for the signal rate of 28 Gbit/s

Up to 300m at 28Gbps with 1310nm-optimized MMF (2000MHz・km)

Reference for OMEGA specifications at 25Gbps;
Single channel configuration,
Target BER with FEC, Reach, Power budget with 4 inline connectors

Part 11: Multiple channel transmitter/receiver chip scale package with multimode fibre interface

Raw characteristics of Si-photonics transceiver sub-assembly
- operating at 25Gbps/ch with 1310nm MMF
- without CDR and FEC

Transmitter optical characteristics

Parameter	Symbol	Min	Typ	Max	Units	Reference
Average output optical power (each channel)	P_o		−3	2,0	dBm	
Average output optical power -disabled (each channel)				−15	dBm	
Extinction ratio	E_x	2,0	3,5		dB	
Centre wavelength	λ_c	1 280		1 320	nm	
Spectral width - rms	$\Delta\lambda$		3	5	nm	

Receiver optical characteristics

Parameter	Symbol	Min	Typ	Max	Units	Reference
Input optical power sensitivity [a] (each channel)	S			−9,0	dBm	
Overload optical power(OMA) [a] (each channel)		−2,0			dBm	
Operating centre wavelength	λ_c	1 280		1 320	nm	
Return loss		10			dB	
[a] Bit-error ratio=10^{-12}						

Reference for OMEGA specifications at 25Gbps;
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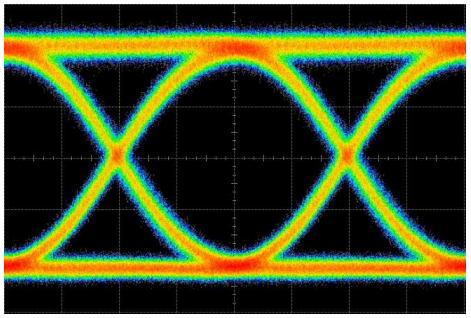
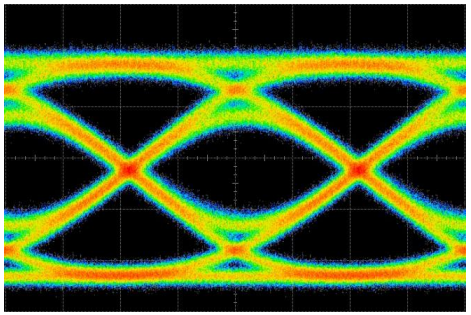
MMF transmission results at 25Gbps

OM2 (500MHz・km@1310nm) and OM3

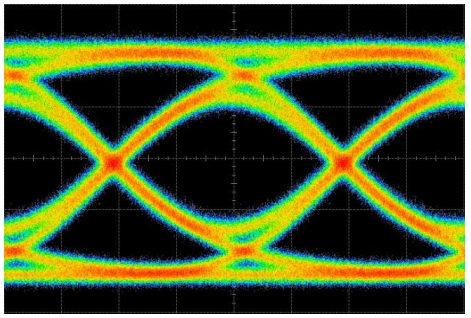
BtoB



OM2 40m

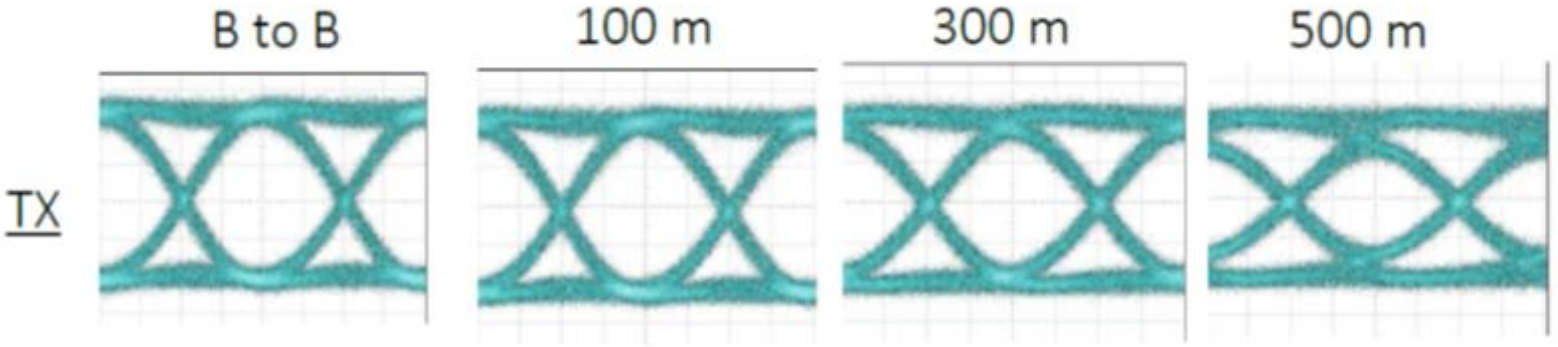


OM3 40m



If 40m is enough, OM2 can be a low cost solution

1310nm-optimized (2000MHz・km) :300m-500m



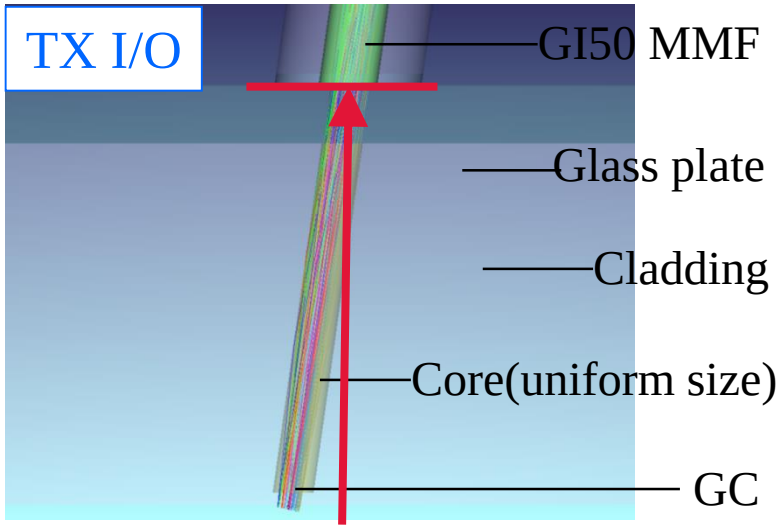
Longer reach is feasible

4 inline connectors

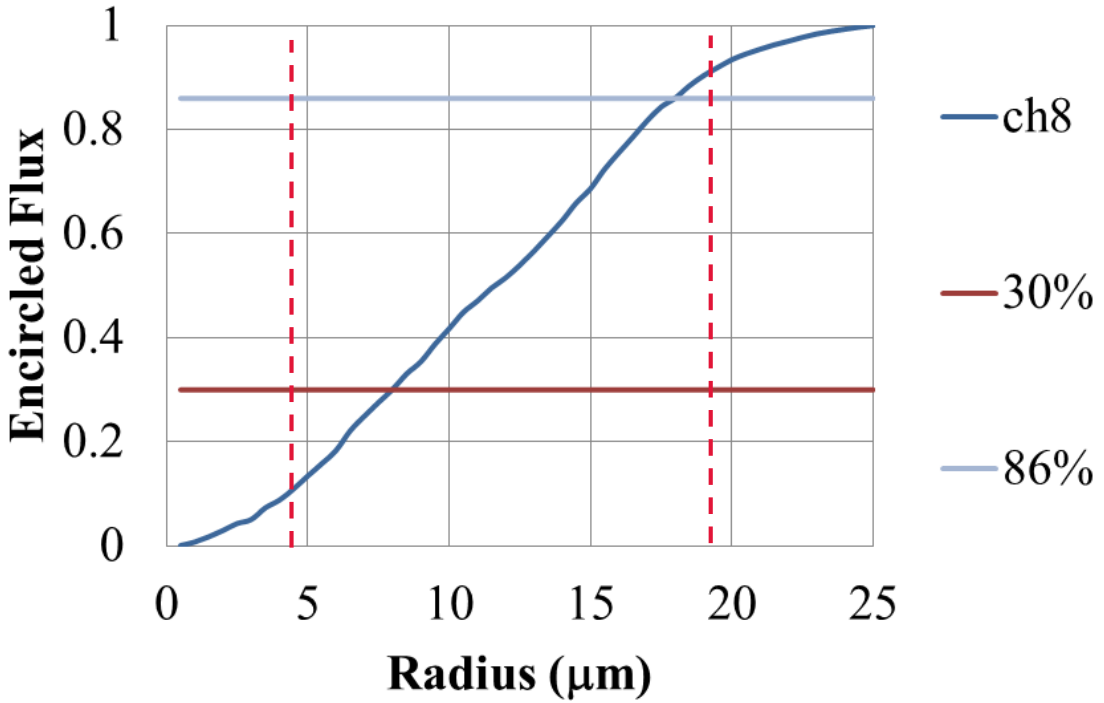
Comply Encircled flux launch for stable connection

- EF evaluated by using near field pattern at output plane
- The light from TX optical pin met the standard TIA/EIA-455-203 (FOTP-203)

(less than 30% at R = 4.5 μm and larger than 86 % at R = 19 μm)



EF based on measured NFP



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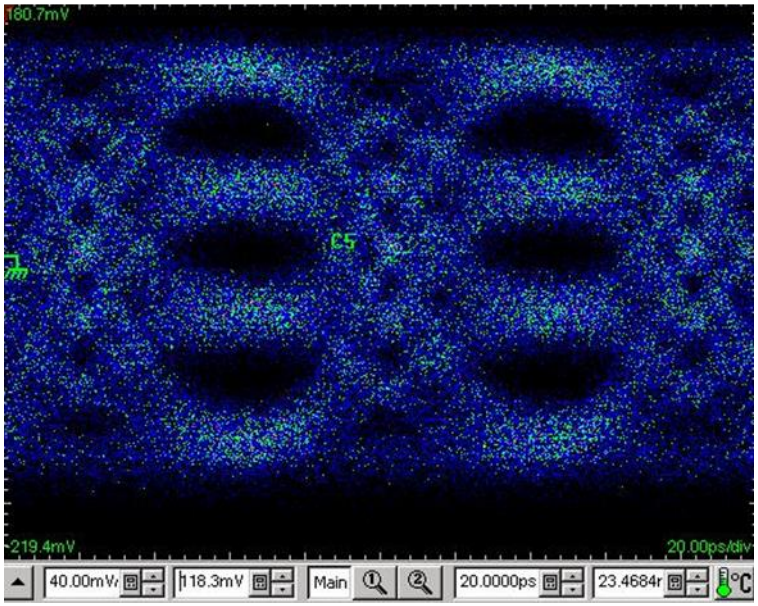
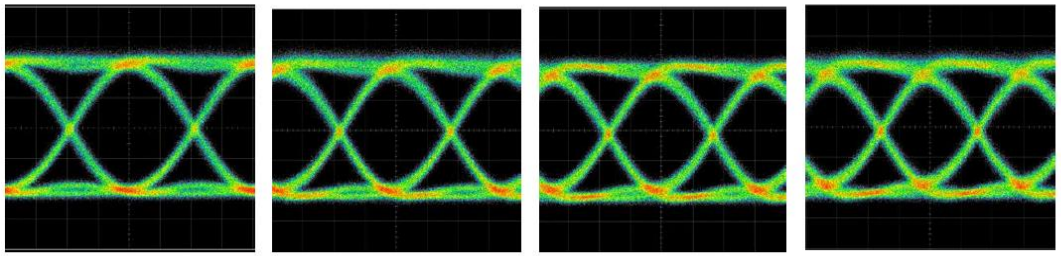
50Gbps (25Gbaud-PAM4) operation demonstrated
Same Si-photonics chip is used

25Gband PAM4 optical
output
for 0.87V_{pp} modulation



50Gbps-NRZ operation under development (future 100G-PAM4)

Tx waveform in each operation speed

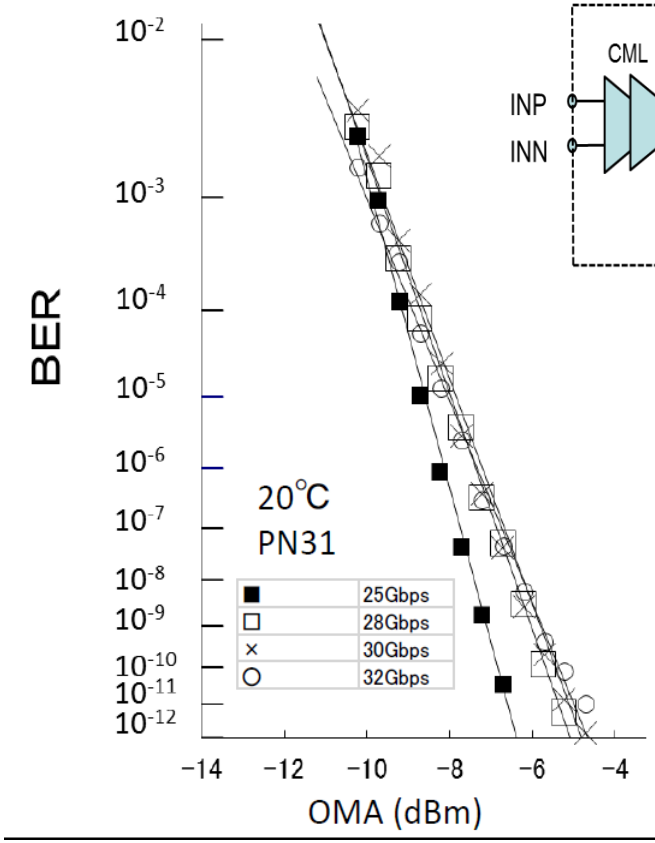


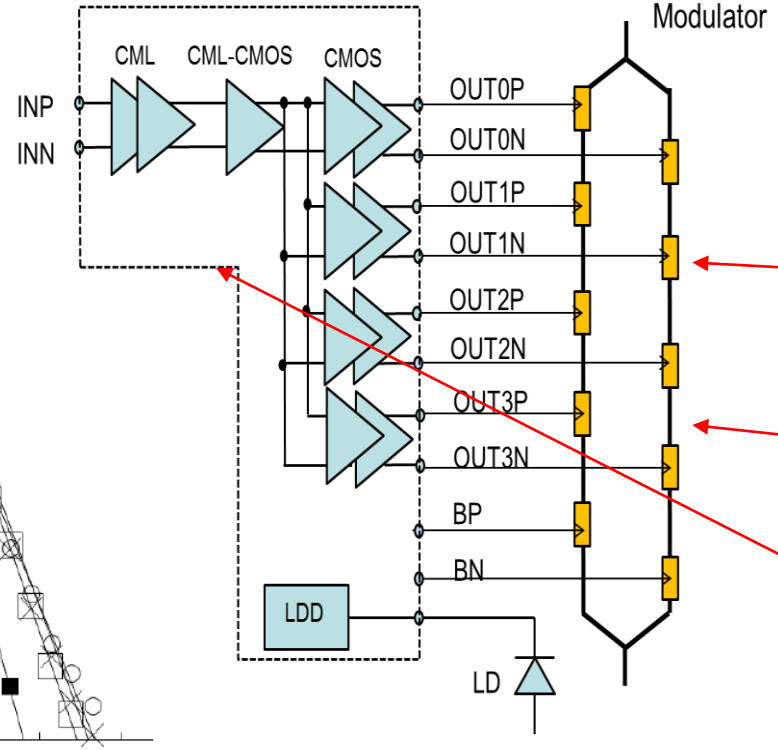
25Gbps 28Gbps 30Gbps 32Gbps

Clear eye opening was observed up to 32Gbps

(32Gbps:PPG limitation)

Next 56G(NRZ)





Optimization of segment number

Improvement of Modulation efficiency

Higher operation of CMOS

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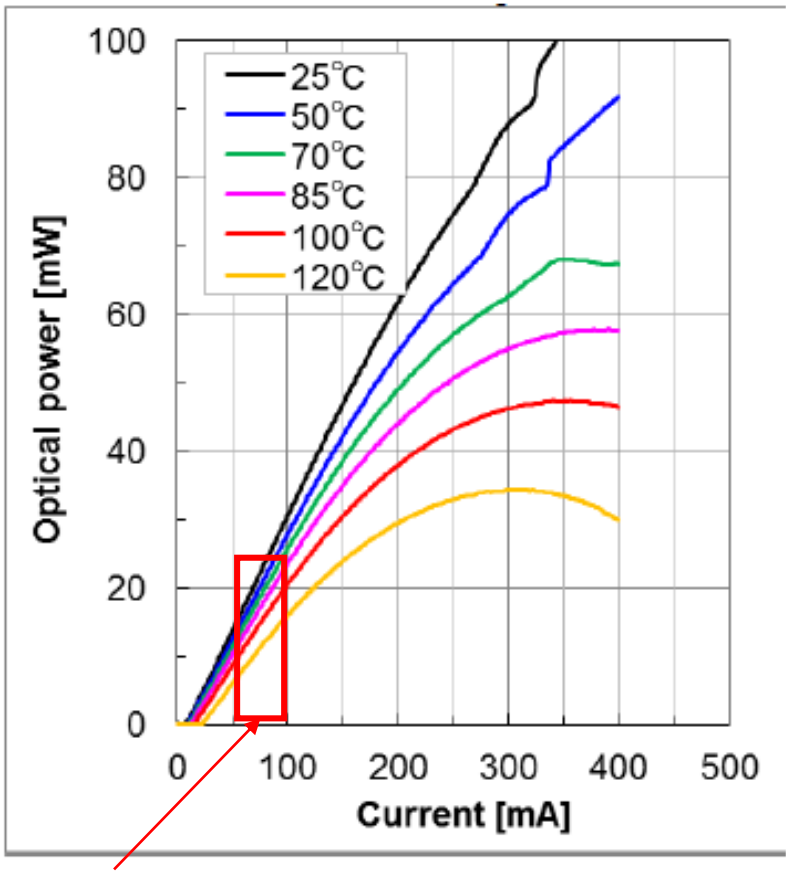
High temperature operation of Quantum Dot LD light source

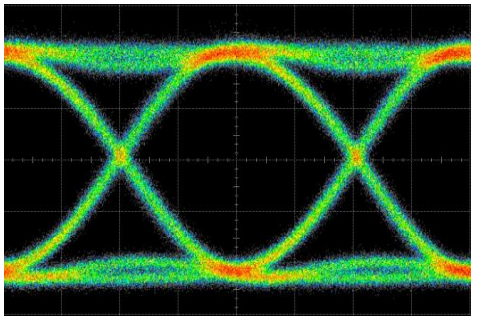
(Temp. range limited by equipment)



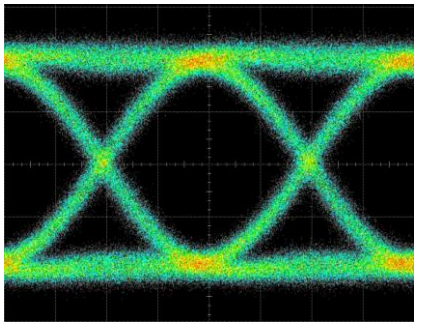
General Operation current

25Gbs Tx waveform

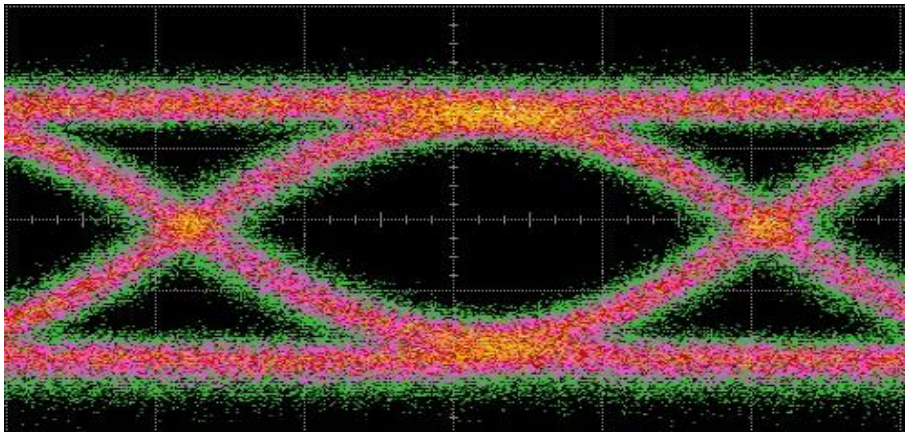
-5ºC



85ºC



105℃ (W/O LD bias control)



LD lifetime test results (tentative up to 105℃)

Acceleration test (Po=31mW) for QD laser Results in Ea=0.746eV

Arrhenius equation

κ= A* EXP(-Ea/(kB*T))

where κ : rate constant

Ea: Activation energy 0.746eV

kB: Boltzmann Constant(=8.617*E-5 eV/K)

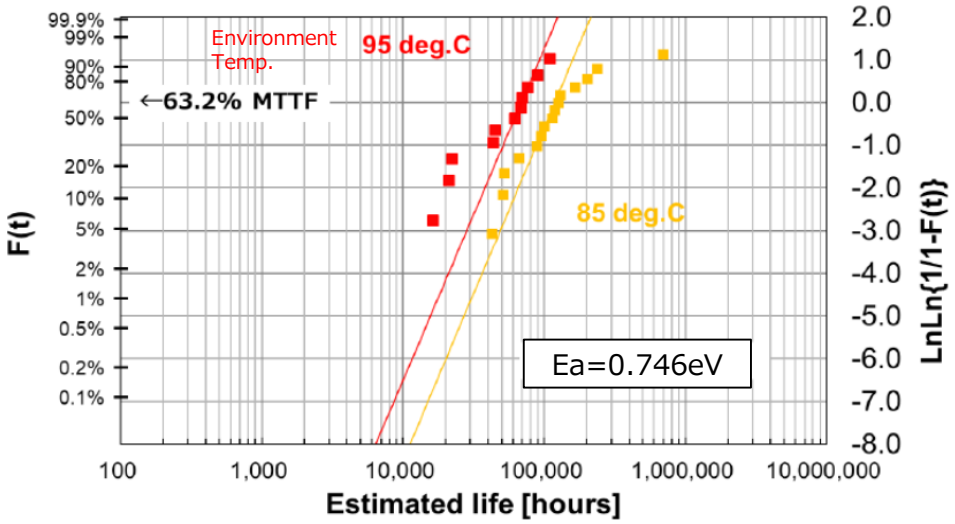
T : Absolute temperature(in kelvins)

MTTF in actual use at Po=20mW for Ea=0.746eV Expexted to be 20 years at 105℃

$k = ko * \exp\{Ea/kB * (1/T - 1/To)\} * (\frac{I}{Io})^{-n} * (\frac{P}{Po})^{-m}$

assumed n=2 & m=1

	85°C	95°C
MTTF (Cumulative failure rate, F(t)=63.2%)	134,470 [hours]	63,682 [hours]
Median life (Cumulative failure rate, F(t)=50%)	112,450 [hours]	50,470 [hours]



Actual use condition(20mW@100mA、TO CAN)

Environment Temp.	Junction Temp. Tj(℃)	MTTF of 4 Channels (years)
60℃	68.1	642
85℃	95.0	87.5
105℃	116.8	20.9

Mission profile study (after Ruben)

Service time =15 years

Operation total time = 32000 hours

	Temperature,℃	Percentage, %	Operating hours, H
T0	-40	6	1920
T1	23	20	6400
T2	50	65	20800
T3	100	8	2560
T4	105	1	320
total		100	32000

Estimated lifetime of QD light source

20years at 105℃ (vs. 320H)

- Si-photonics may commit to reliable automobile network
- CW light source has no constraint for higher speed operation of 100Gbps or over

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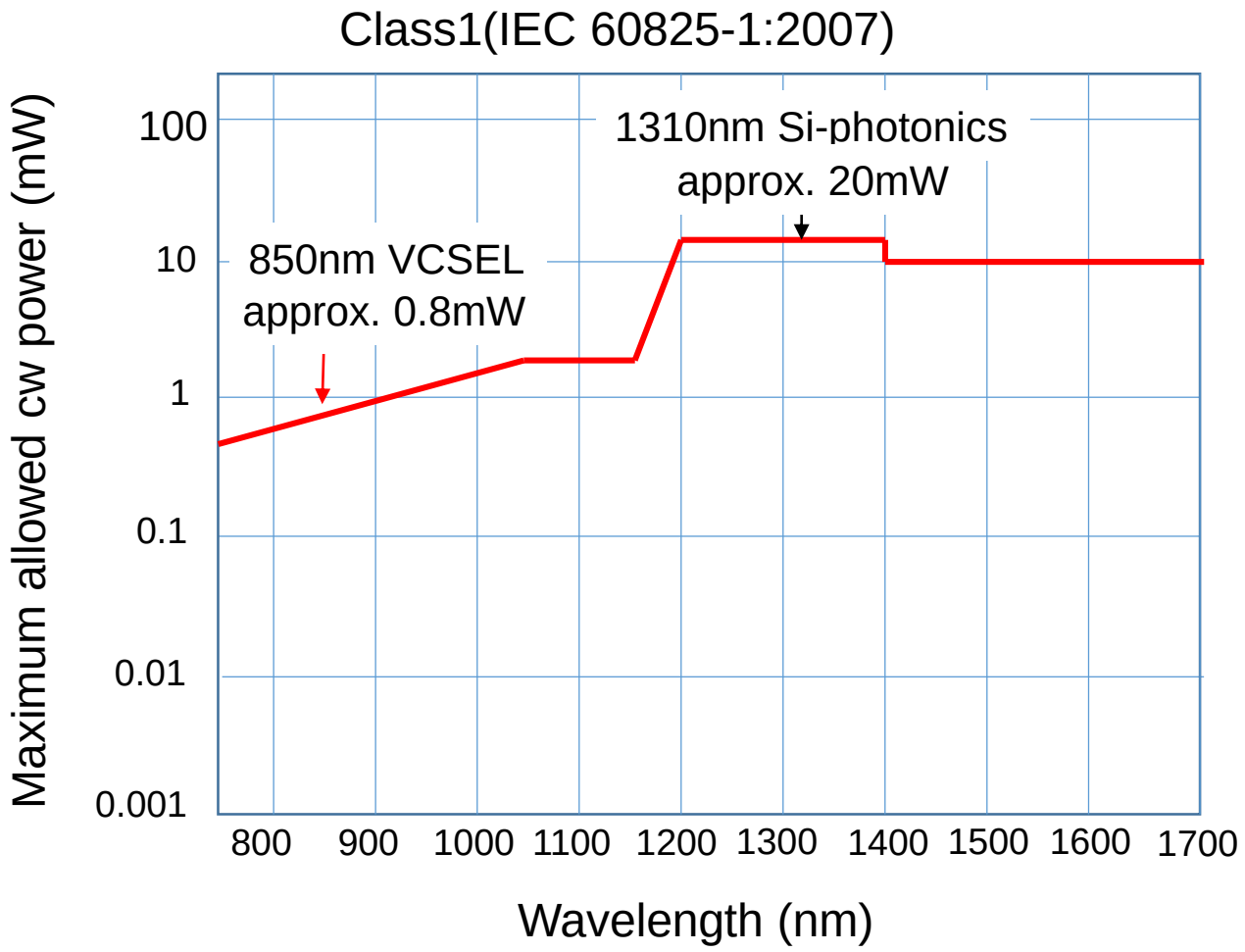
Class1 eye safety level for 850nm(VCSEL) and 1310nm(Si-photonics)

Eye-safety constraints (power, handling) are relaxed at 1310 nm



Summary

Si-photonics to meet OMEGA objectives

1. 25Gbps transmission
   IEC standard of 25Gbps/ch Si-photonics transceiver sub-assembly with MMF as a reference, working on OMEGA specifications for single channel configuration, target BER with FEC, reach, power budget with 4 inline connectors

   40m with OM2,OM3 MMF and 300m with1310nm-optimized MMF are feasible

2. 15m reach at 50Gbps
   25Gbaud-PAM4 is feasible and
   50Gbps-NRZ is under development (for future 100G-PAM4)

3. Reliability assessment
   Estimated lifetime of QD laser light source (20years at 105℃)
   may commit to reliable automobile network
   Si-photonics using CW laser light source

4. Approx. 20 times higher eye-safety power level for Si-photonics at 1310nm than 850nm-VCSEL may relax constraints of power and handling

Appreciate your feedback for baseline proposal