A study for highly-reliable optical transceiver based on Si Photonics technology

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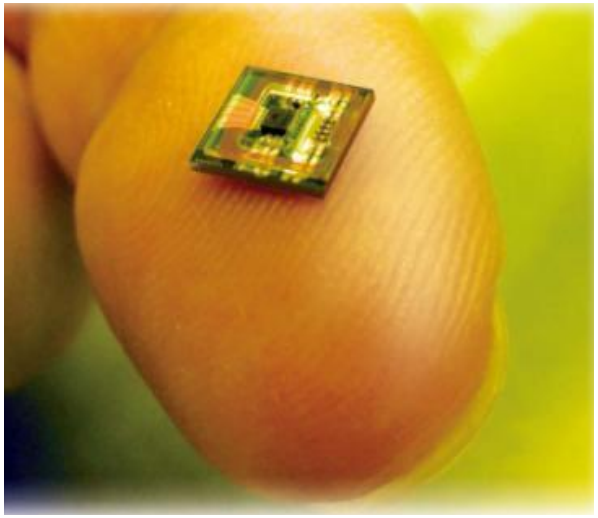
Optical PHY Study Group

Introduction

Last Hawaii Meeting

I. Ogura and K. Kurata “Introduction of Si Photonics transceiver technology with High temperature operation capability and MMF transmission”

Data-based approach of Si Photonics for Automobile applications for High speed, High temperature and High reliability



- High speed: 25Gbps and higher

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

- Reliability:
  QD-LD lifetime expected over 20 years @105℃

This Presentation

A study for highly-reliable optical transceiver based on Si Photonics
- Redundant laser light sources integrated in a transceiver chip employing a design for mission-critical HPC applications

Discussion on reliability assessment for automobile applications

- September 2019 Indianapolis, IN;
  - "Open discussion on objectives"
  - "Technical and economic feasibilities Requirements and methodology for assessment"
- November 2019 Waikoloa, HI;
  - "VCSEL reliability analysis for technical feasibility assessment"

→ 1-10 FIT for 15 years @temperature 105℃ (125 ℃)

Challenging in Quality Control of optical modules

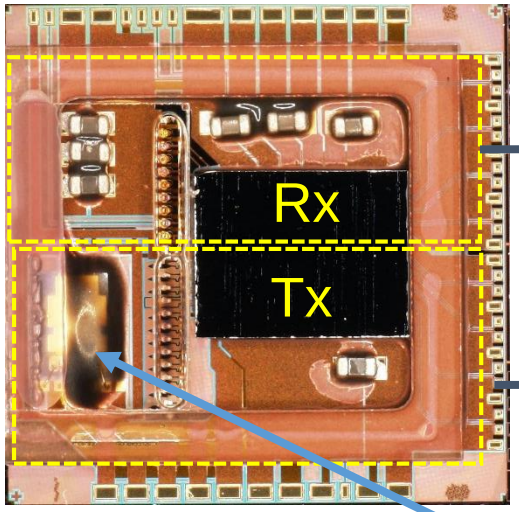
Compare to Repeater in Submarine cable systems

22 FIT for 25 years @0-35 ℃ (<1 ship repair of 200 repeaters/system)
employing redundancy of active components: 4 LDs (Fujitsu.58 (07, 2007))

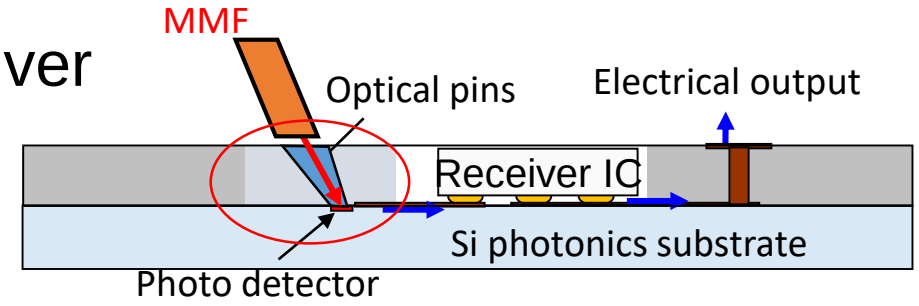
This talk: our package strategy for
Mission-critical server and HPC:RAS(Reliability, Availability, Serviceability)
Example of Si Photonics transceiver with Quantum-Dot laser + Redundancy for feasibility and specification assessment

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

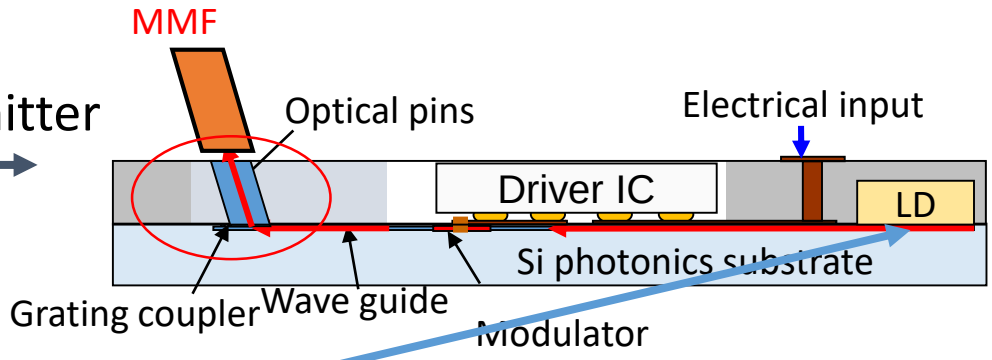
Si photonics one-chip transceiver



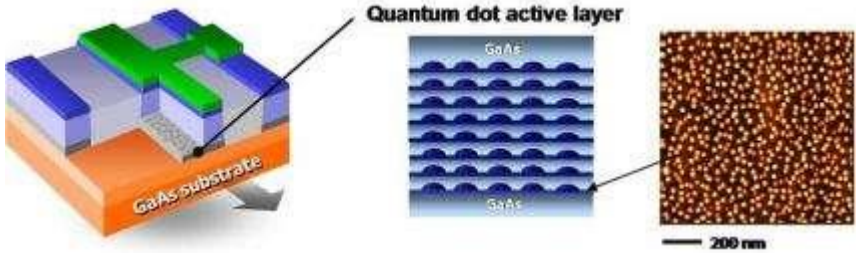
Receiver



Transmitter



Quantum dot laser light source



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))

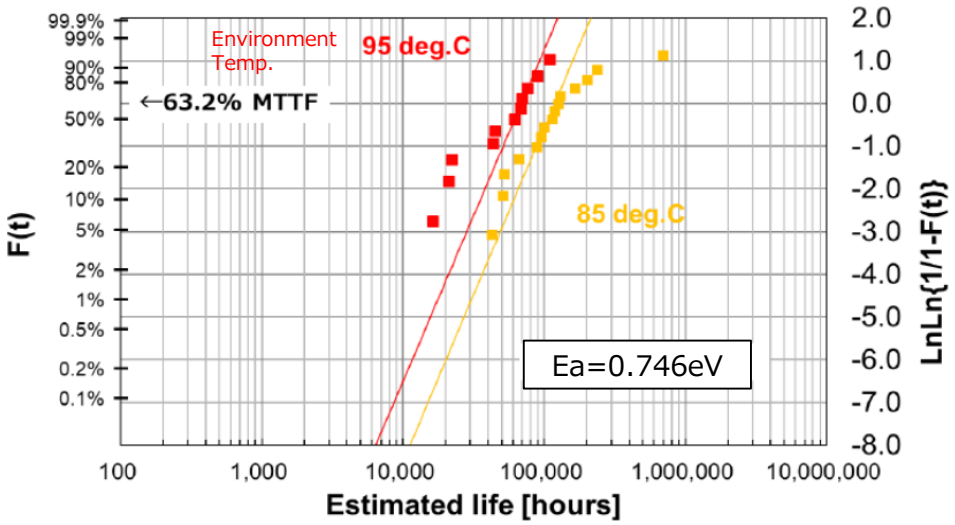
where κ : rate constant

Ea: Activation energy 0.746eV

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

T : Absolute temperature(in kelvins)

	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]



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

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

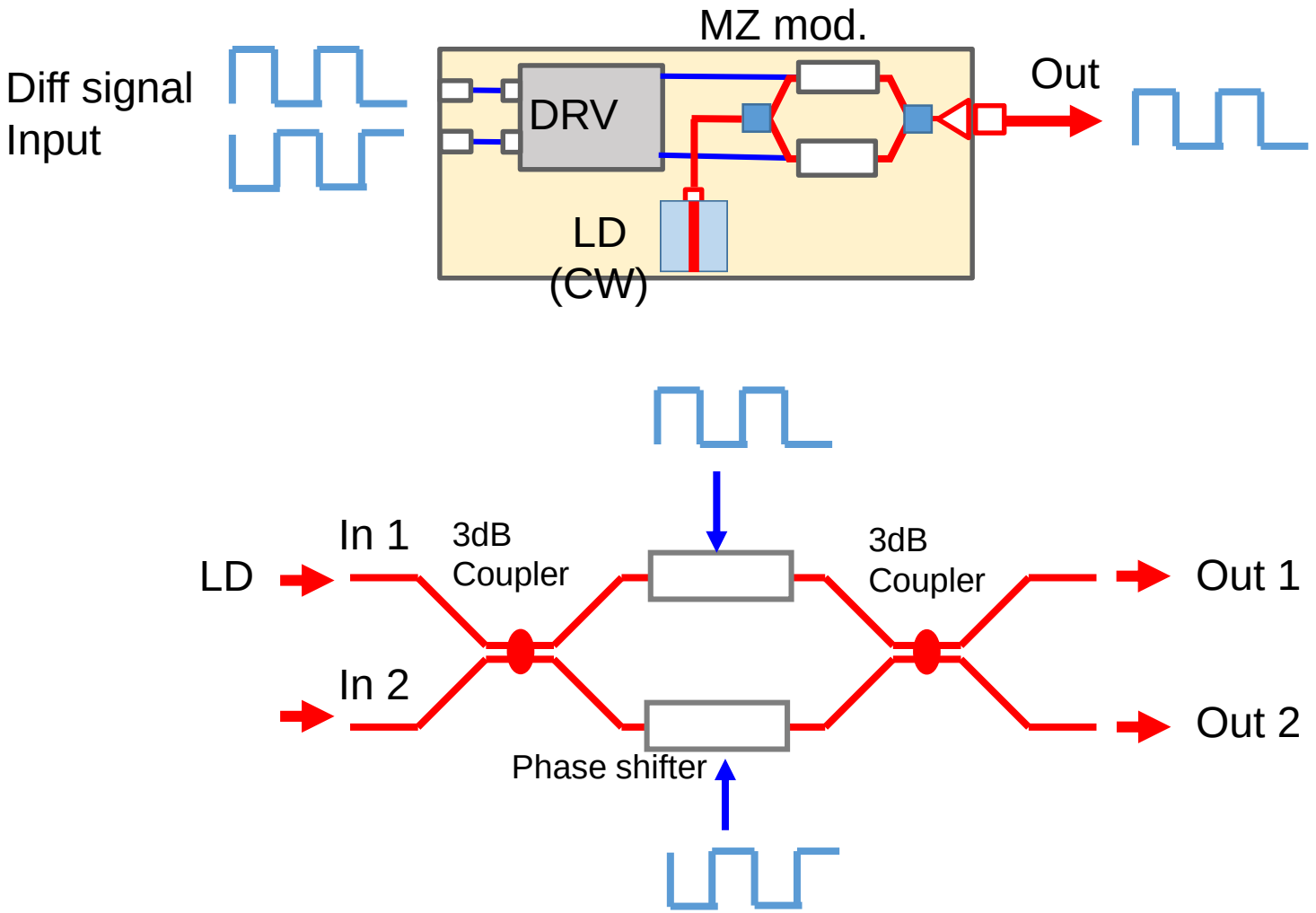
assumed n=2 & m=1

Redundancy will give higher reliability and availability (continuous operation)

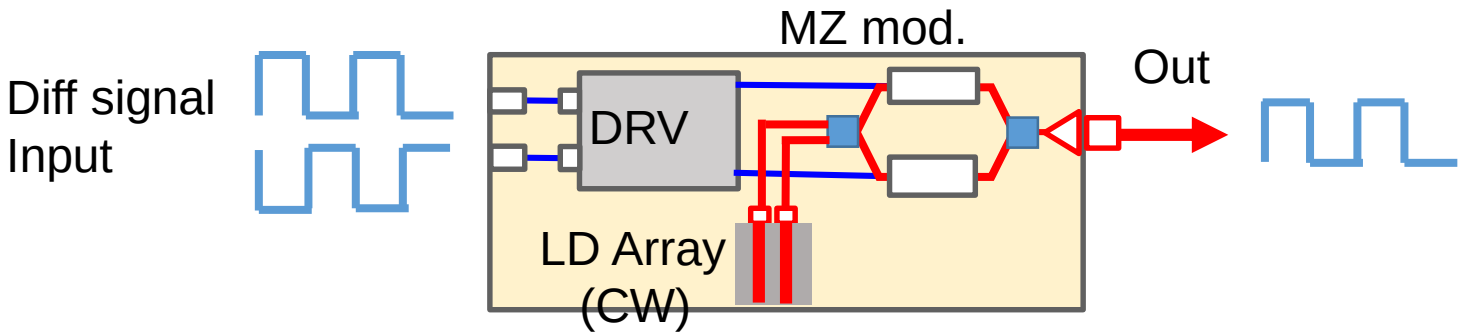
Actual use condition(20mW@100mA、TO CAN)

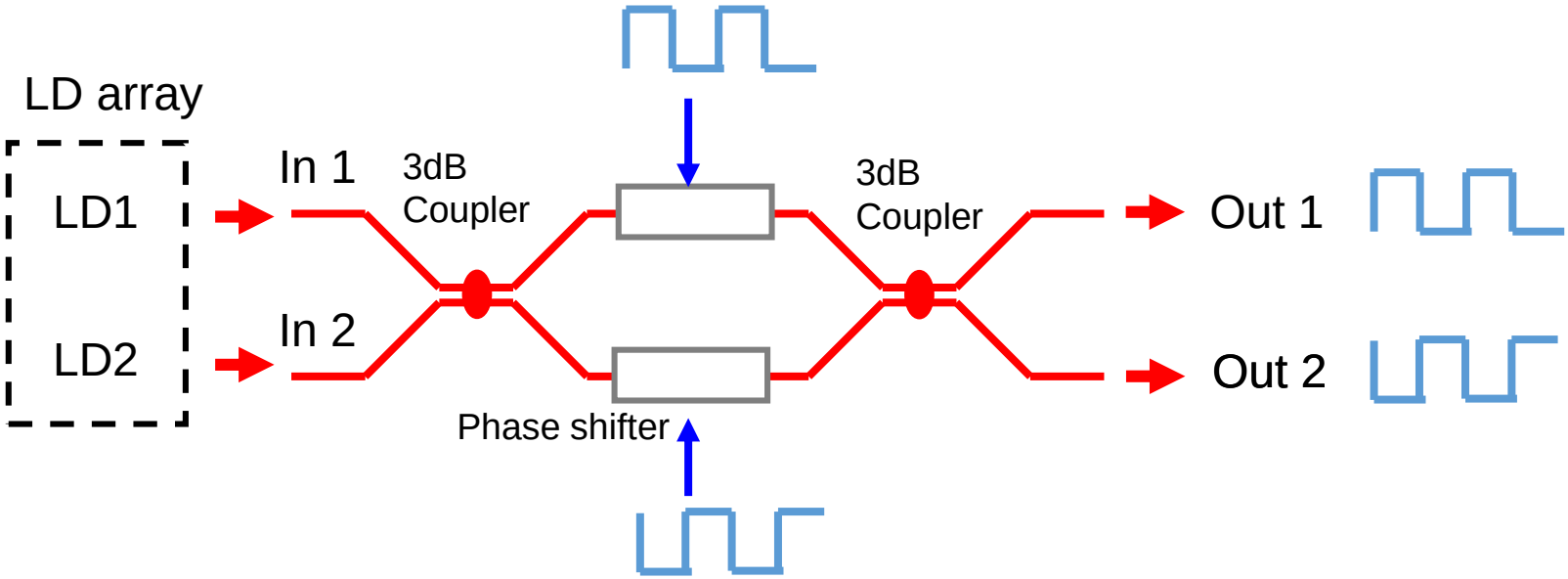
Environment Temp.	Junction Temp. Tj(℃)	MTTF of 4 Channels (years)
60℃	68.1	642
85℃	95.0	87.5
105℃	116.8	20.9

Mach-Zehnder modulator integrated in Si Photonics chip

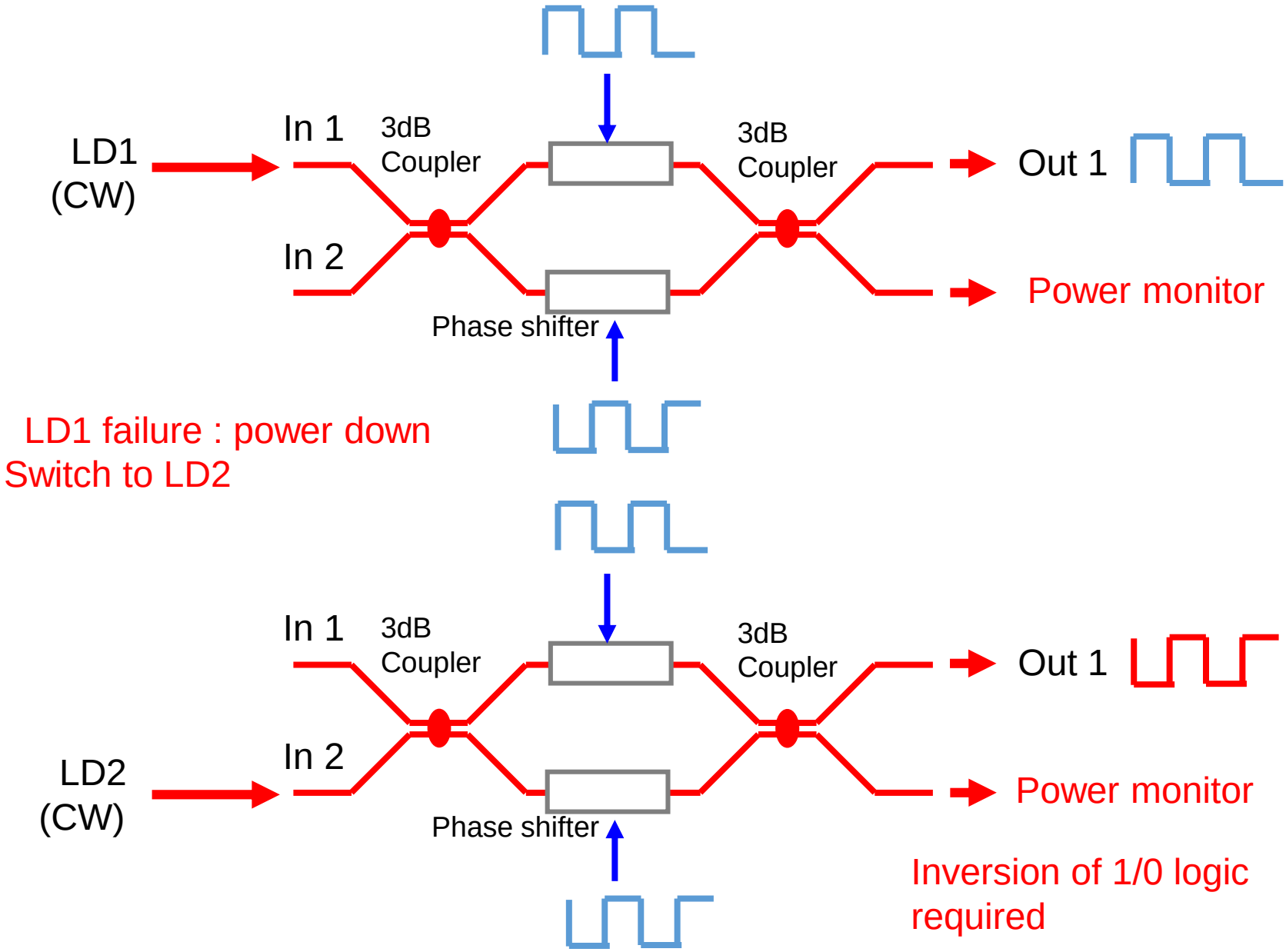


Redundant light sources integrated in Si Photonics chip



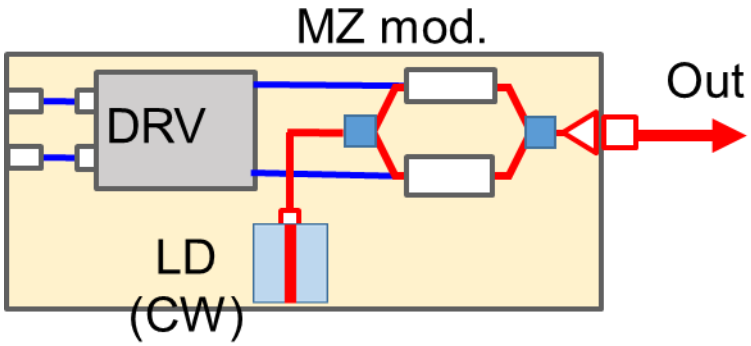


Scenario of redundant operation

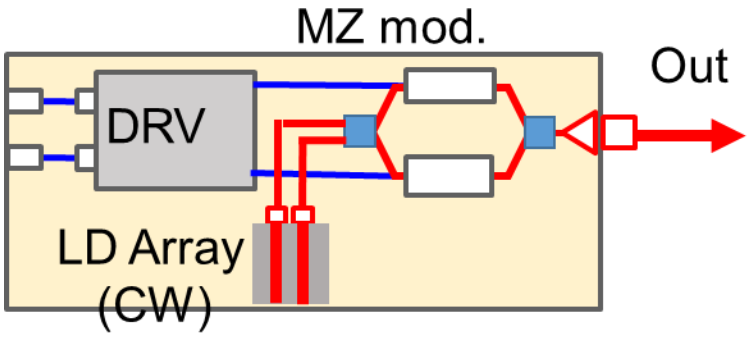


Dual redundant for higher reliability and availability is feasible without major change in Si Photonics transceiver structure

Single LD



Dual redundant LD source



- Footprint of transceiver chip: same
- Size of LD chip: same
- MZ modulator structure: same except using MMI 2x2 couplers instead of 2x1
- Optical structure: same output coupling
- LD control: switch function added in LD driver,
  same power monitor used in the transmitter
- Logic : output logic is inverted by DC biasing to phase shifters

Summary

A study for highly-reliable optical transceiver based on Si Photonics employing a design for mission-critical HPC applications

Dual redundant LD light source is feasible without major change in chip structure

- High speed: 25Gbps and higher

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

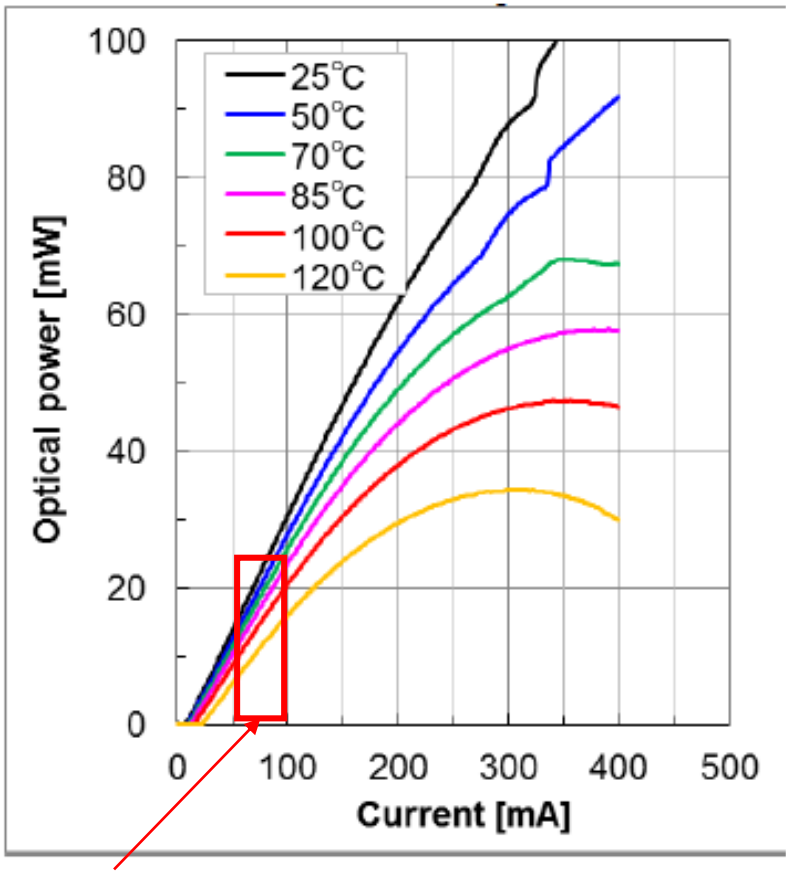
- Reliability:
  QD-LD MTTF expected over 20 years @105℃
  Dual redundancy is feasible for higher reliability and availability

We would like to contribute to the specification assessment and appreciate your feedback

Back up

High temperature operation of Quantum Dot LD light source

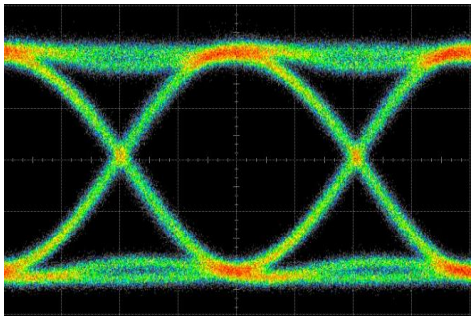
(Temp. range limited by equipment)



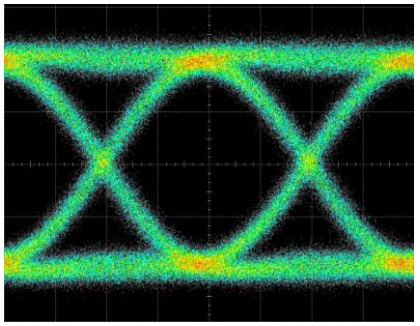
General Operation current

25Gbs Tx waveform

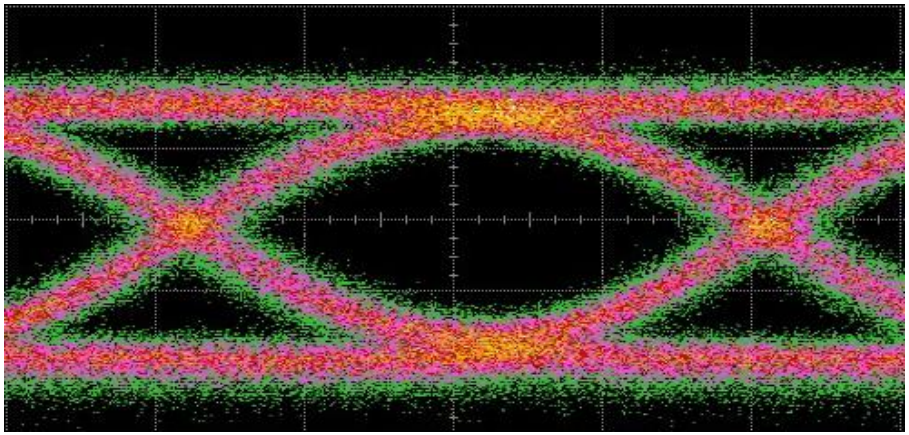
-5ºC



85ºC

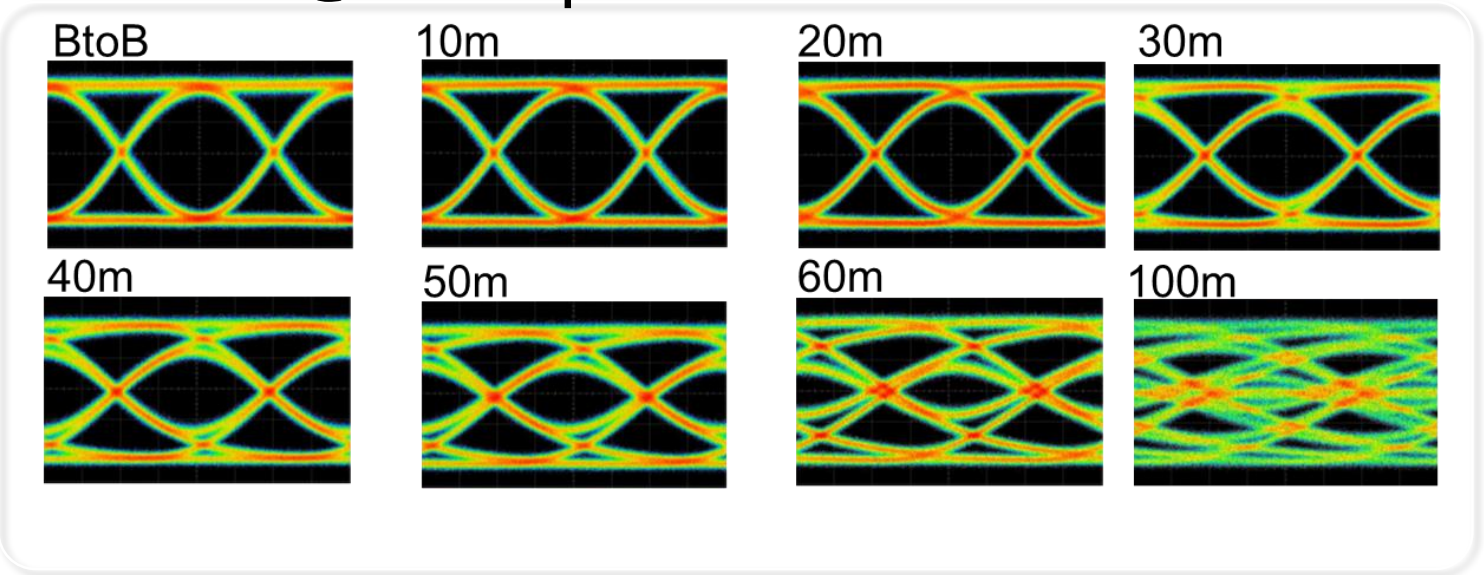


105℃ (W/O LD bias control)



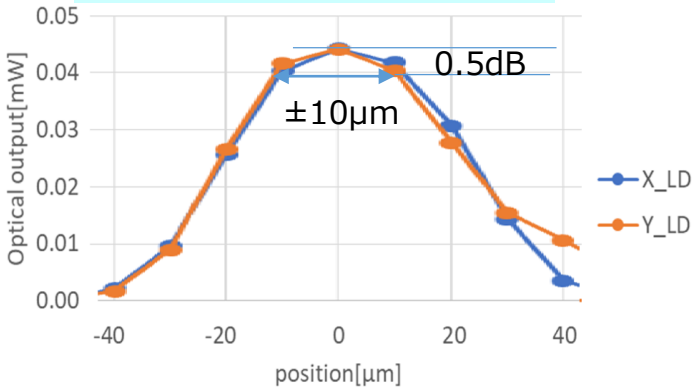
MMF Transmission data for OM3

OM3 >40m@25Gbps

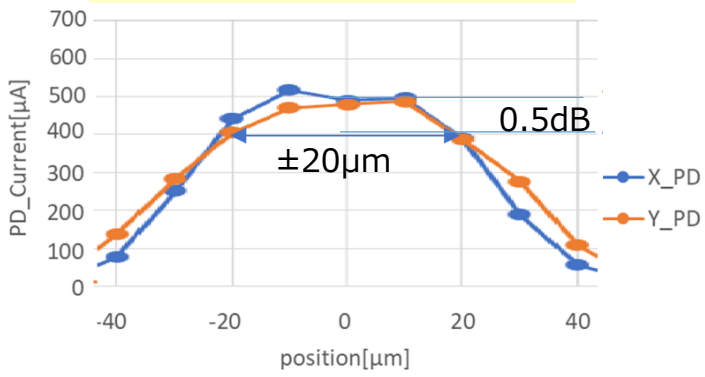


Optical coupling tolerance >10μm for MMF

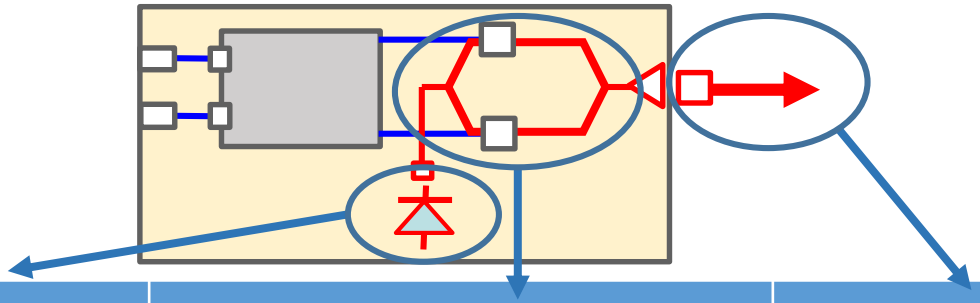
Tx interface tolerance



Rx interface tolerance



Features for automobile applications



Quantum dot laser	Si photonics platform	MMF transmission
High temperature operation	Temperature independent modulator High speed operation High productivity (Low cost/High volume)	Large optical coupling tolerance (>10um) MMF (OM3) for automobile reach (40m)

- Operation temperature up to 105 ℃
- Operation up to 25Gbps (50G-NRZ in future)
- Commercial MMF(OM3) available for 40m reach