

A wireframe model of a car, rendered in a light blue and yellow color scheme, is the background of the slide. The car is shown from a front-three-quarter perspective, with its headlights and front wheel visible. The wireframe consists of a grid of lines that define the car's shape.

# Silicon photonics economic feasibility and relative cost analysis for automotive applications

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# Contributions on silicon photonics in 802.3cz TF

Ref #	Date	Title
[1]	<b>November 2019</b>	Introduction of SI Photonics transceiver technology with high temperature operation capability and MMF transmission
[2]	<b>January 2020</b>	A study for highly-reliable optical transceiver based on Si Photonics technology
[3]	<b>January 2021</b>	Thoughts on PMD baseline proposal for automobile based on Si-Photonics
[4]	<b>March 2021</b>	A proposal of Si-photonics for automobile
[5]	<b>March 2021</b>	Photonics for Automotive - Response to Proposal Assumptions
[6]	<b>April 2021</b>	Thoughts on interoperable PMD
[7]	<b>June 2021</b>	Status of silicon photonics reliability test
[8]	<b>July 2021</b>	Status of silicon photonics link budget

# Relevant publications

## Scientific papers

- i. Kurata, K. et al., "Short reach, low-cost silicon photonic micro-transceivers for embedded and co-packaged system integration," Proc. SPIE 11286, Optical Interconnects XX, 112860R (28 February 2020); <https://doi.org/10.1117/12.2546626>
- ii. Pitwon, R. et al., "Hyperscale Integrated Optical and Photonic Interconnect Platform," 2020 IEEE Photonics Conference (IPC), Vancouver, BC, Canada, 2020, pp. 1-2, doi: 10.1109/IPC47351.2020.9252246.
- iii. Nakamura, T. et al., "Fingertip-Size Optical Module, "Optical I/O Core", and Its Application in FPGA" IEICE TRANSACTIONS on Electronics, Vol.E102-C, No.4, pp.333-339
- iv. Mogami, T. et al., "1.2 Tbps/cm<sup>2</sup> Enabling Silicon Photonics IC Technology Based on 40-nm Generation Platform," J. Lightwave Technol. 36, 4701-4712 (2018)
- v. K. Kurata, I. Ogura, K. Yashiki and Y. Suzuki, "Chip-scale si-photonics optical transceiver for a photonics-electronics convergence system (invited paper)," 2016 Tenth IEEE/ACM International Symposium on Networks-on-Chip (NOCS), Nara, Japan, 2016, pp. 1-6, doi: 10.1109/NOCS.2016.7579338.

## Market Research Reports

- vi. Yole Developpement report Silicon Photonics 2021
- vii. LightCounting Integrated Optical Devices Report (May 2021)

# Suitability of silicon photonics for target environment

## Market availability

By 2026 silicon photonics will be the dominant optical transceiver type by revenue ([LightCounting Integrated Optical Devices Report \(May 2021\)](#))

## Reliability in target environment

Silicon photonics transceivers, which are based on CMOS modulation of separate, more stable continuous wave lasers, are inherently more reliable than transceivers based on directly modulated VCSELs

## Evidence

Contributions [1] – [8] demonstrate complete multimode silicon photonics transceiver assemblies' suitability to operate in the target environment including link budget, high temperature operation over long period, stable laser operation and low FIT

# Economic viability

- Over the past 5 years silicon photonics transceivers have become mainstream datacom commodities deployed in all hyperscale data centres.
- They benefit from economies of scale cost reduction associated with widescale deployment
- Global support from major international foundries with established PDKs to achieve high volume
- The main cost challenge is singlemode fibre-to-chip coupling and a robust package that will maintain the requisite high-precision coupling under vibration and temperature extremes
- Multimode SiPh transceivers enable a strong reduction in assembly, package and test cost

# Relative cost overview

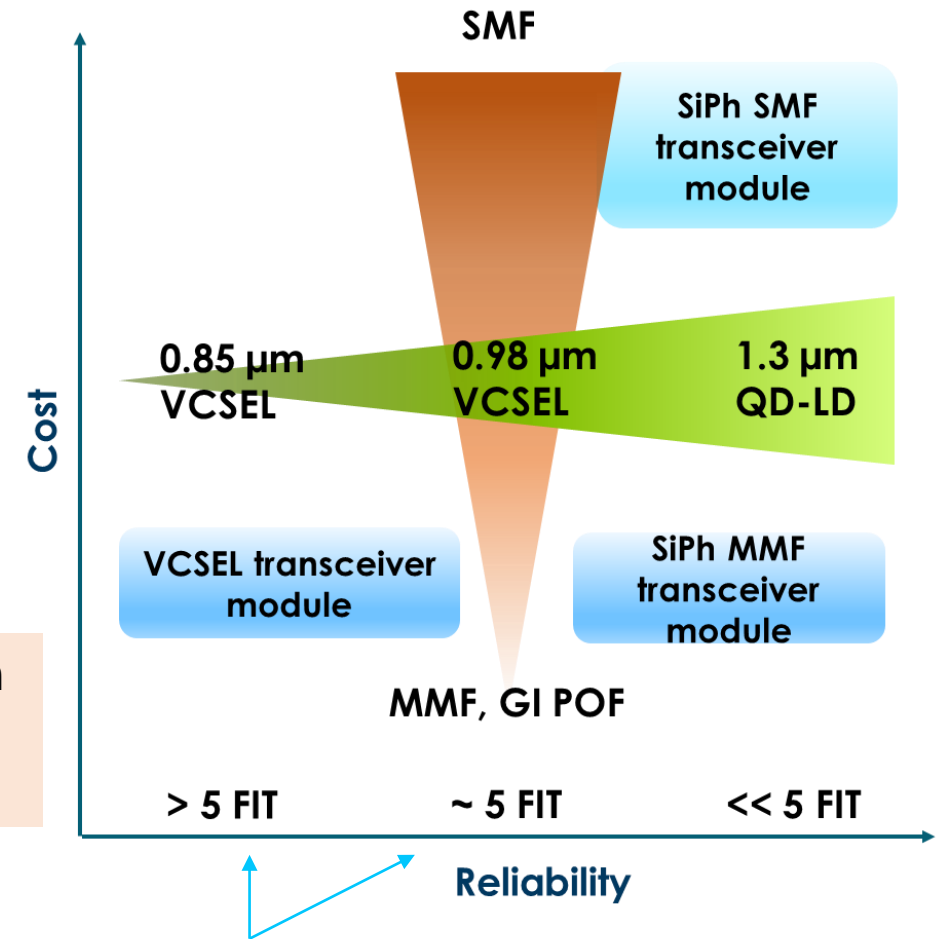
- Optical transceiver cost is strongly influenced by the fiber type \*1
- The cost of the light source is typically less than 1/10 of the cost of the transceiver module.
- Existing VCSEL modules are low-cost, partly because they use MMF and thus have lower assembly, packaging and test costs compared to singlemode.
- The combination of Si-Ph and MMF provides a reliable and low-cost solution.

Commonly discussed reports include differences in transmission distances as well as speeds  
Comparison of fiber, speed, and distance on the next page

The reliability has already been reported \*2 [7]  
In this article, we report on relative cost and availability.

\*1) [https://www.photonics.com/Articles/The\\_Merits\\_of\\_Single-Mode\\_vs\\_Multimode\\_Fiber/a63723](https://www.photonics.com/Articles/The_Merits_of_Single-Mode_vs_Multimode_Fiber/a63723)

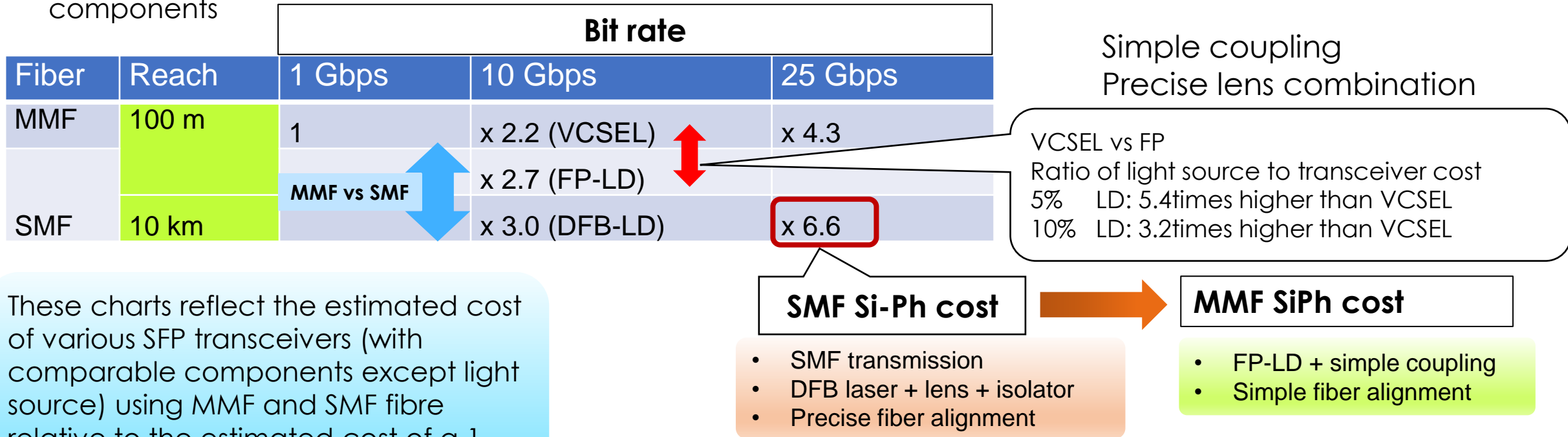
\*2) [https://www.ieee802.org/3/cz/public/29\\_jun\\_2021/ogura\\_3cz\\_01\\_290621\\_Status\\_SiPhotonicsReliabilityTest\\_v13.pdf](https://www.ieee802.org/3/cz/public/29_jun_2021/ogura_3cz_01_290621_Status_SiPhotonicsReliabilityTest_v13.pdf)



The FIT estimates for the VCSELs are an assumption by the authors.

# Transceiver relative cost analysis

- Relative cost comparison of commercial SFP modules was carried out
- Cost increases with bit rate, regardless of light source
- Cost is dominated by the structure of the packaging (especially the optics) rather than the cost of the components



These charts reflect the estimated cost of various SFP transceivers (with comparable components except light source) using MMF and SMF fibre relative to the estimated cost of a 1 Gbps SFP transceiver using MMF fibre. Readers should make their own comparison based on their estimated relative costs.

Existing SiPh optical transceivers have higher packaging costs due to SMF mounting, but when MMF is applied, packaging cost of the optical coupling part is equivalent to MMF module.

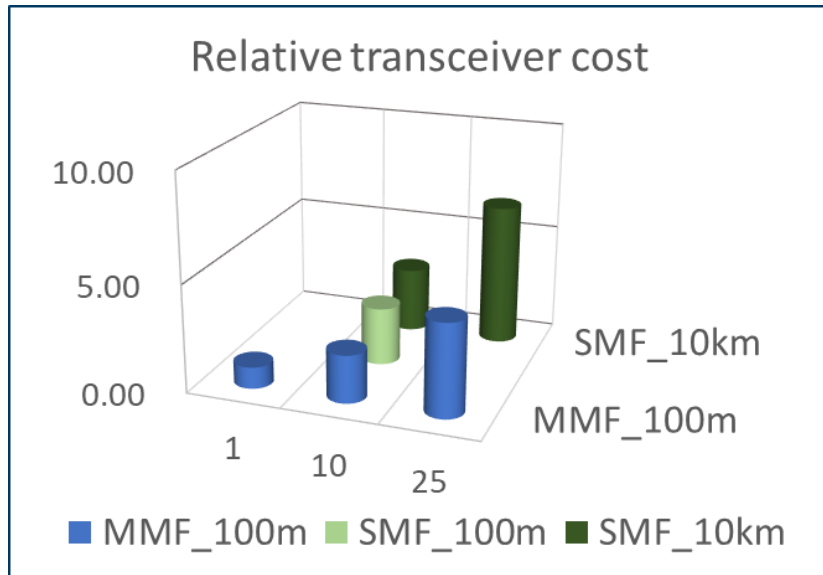
# Transceiver relative cost analysis

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		Bit rate		
Fiber	Reach	1 Gbps	10 Gbps	25 Gbps
MMF	100 m	1	x 2.2 (VCSEL)	x 4.3
			x 2.7 (FP-LD)	
SMF	10 km		x 3.0 (DFB-LD)	x 6.6

Simple coupling  
Precise lens combination

VCSEL vs FP  
Ratio of light source to transceiver cost  
5% LD: 5.4times higher than VCSEL  
10% LD: 3.2times higher than VCSEL



**SMF Si-Ph cost**

- SMF transmission
- DFB laser + lens + isolator
- Precise fiber alignment

**MMF SiPh cost**

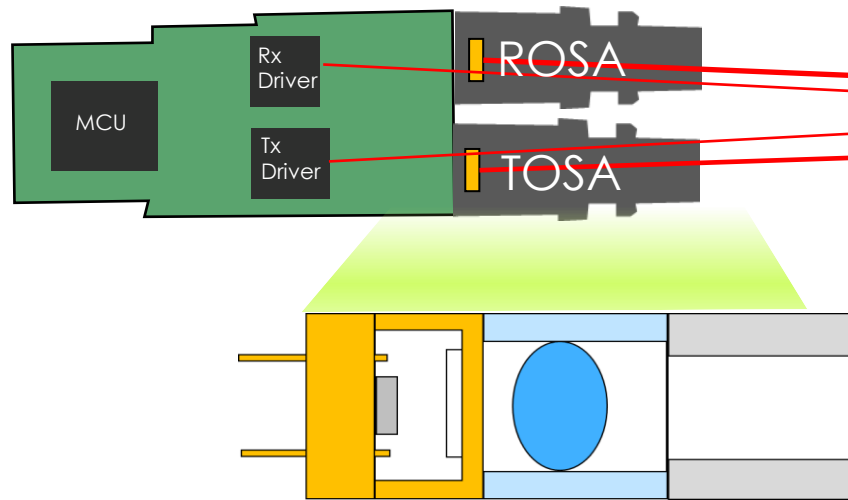
- FP-LD + simple coupling
- Simple fiber alignment

Existing SiPh optical transceivers have higher packaging costs due to SMF mounting, but when MMF is applied, packaging cost of the optical coupling part is equivalent to MMF module.

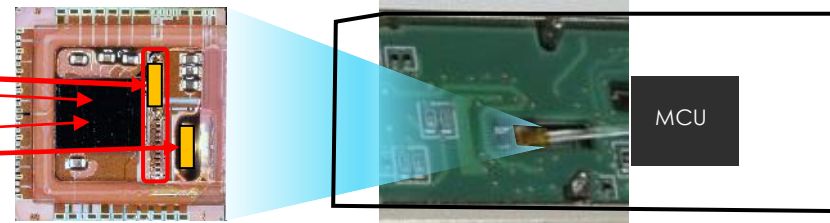


# Relative cost reduction through integration

## VCSEL based transceiver module



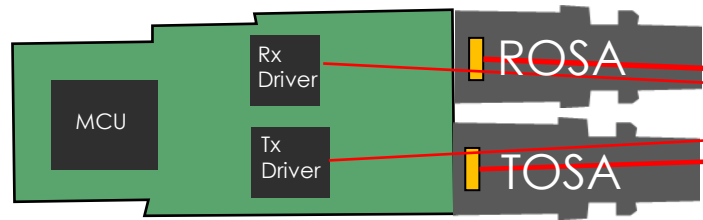
## MM SiPh based transceiver module



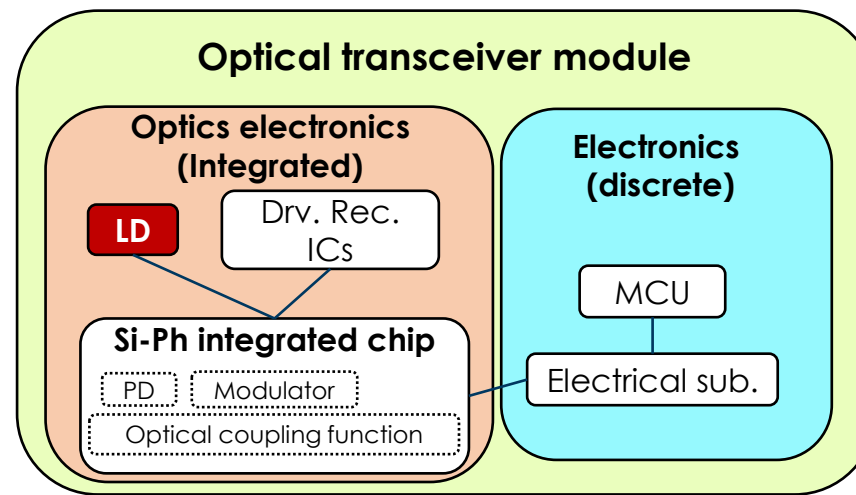
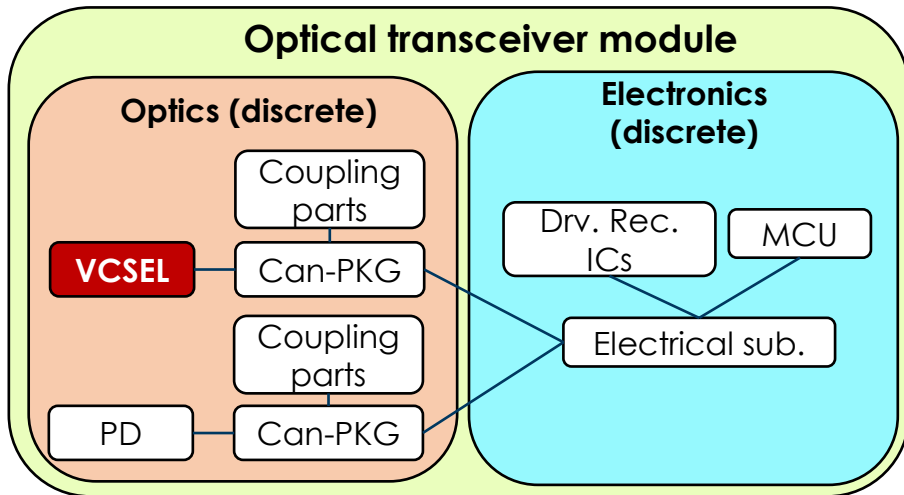
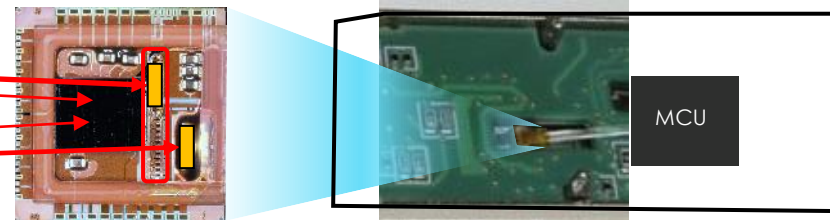
- The cost of an optical transceiver depends on components such as transmission, reception devices, and ICs, as well as the cost of mounting and testing.
- The cost of the light source is  $< 1/10$  of the cost of the optical transceiver.
- In SiPh transceivers, many optical functions are integrated on the Si-Ph die.
- A significant portion of the manufacturing is converted from assembly to process.
- The number of parts is reduced, and the mounting cost is reduced.
- SiPh die cost depends on the chip size: A few  $\text{mm}^2/\text{ch}$  can achieve very low cost

# Relative cost reduction through integration

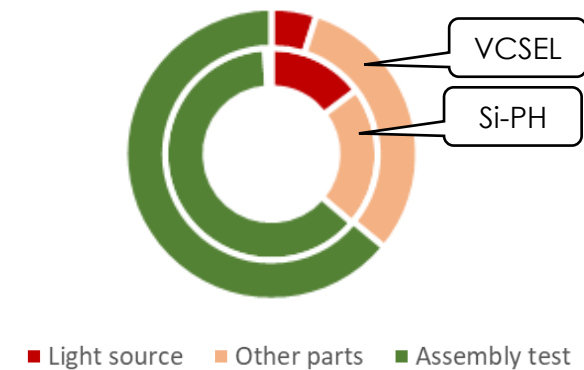
VCSEL based transceiver module



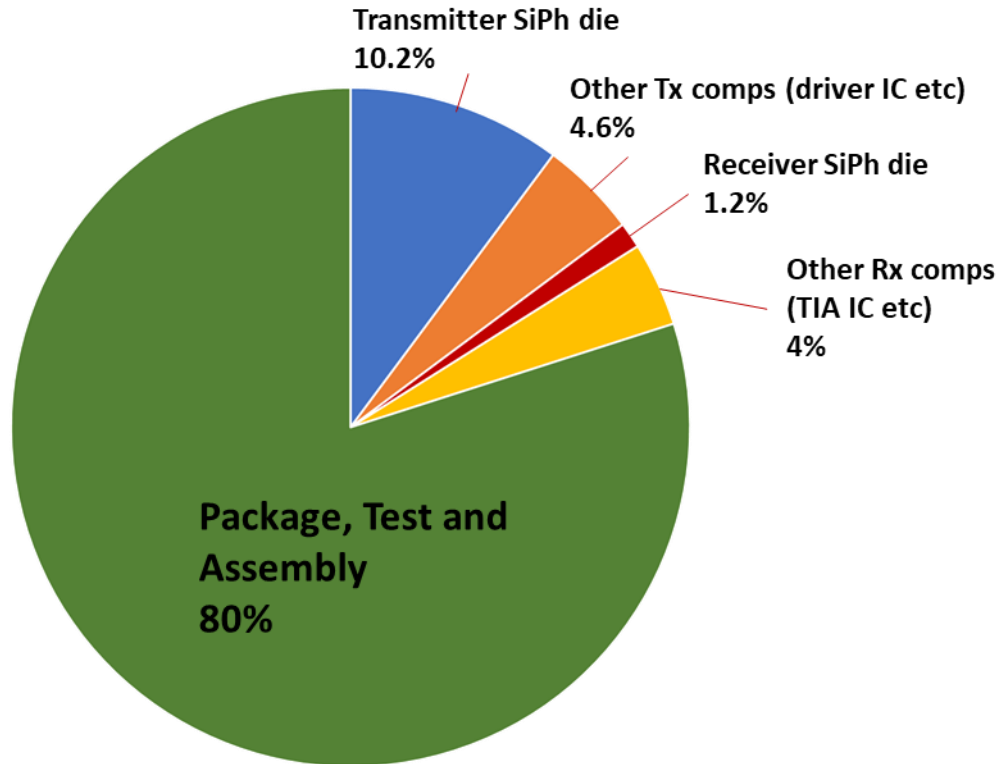
MM SiPh based transceiver module



Transceiver breakdown estimate



# Cost breakdown for singlemode SiPh transceivers



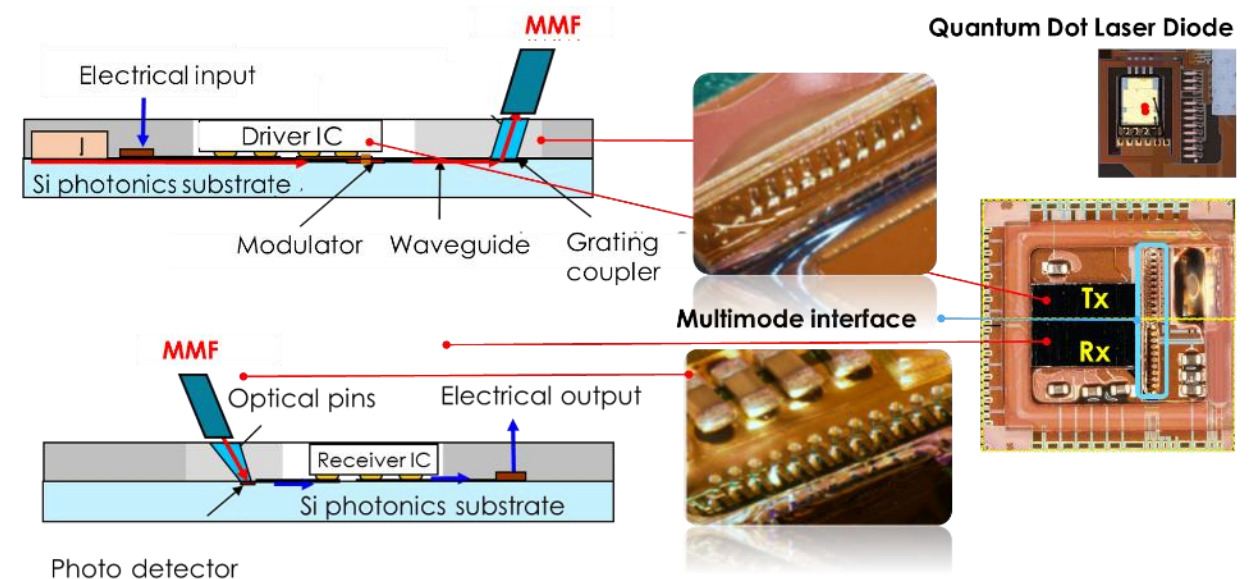
Item	Breakdown
Transmitter SiPh die	10.19%
Transmitter components	4.63%
Receiver SiPh die	1.23%
Receiver other components	4.01%
Package, test and assembly	79.94%
<b>Total</b>	<b>100.00%</b>

- Breakdown is derived from information in Yole Developpement Silicon Photonics Report 2021.
- 80% of the cost of a full datacom transceiver module is package, test and assembly, which includes the relatively high cost of high precision singlemode fibre alignment, fixture and testing.

# Relative cost of multimode SiPh transceivers

- **Multimode SiPh transceivers estimated to achieve a relative reduction in package, test and assembly of over 50% - 75% compared to singlemode SiPh transceivers due to:**
  - Faster assembly
  - X10 lower precision alignment tolerance
  - Passive and/or automated assembly
  - Robust fixture to withstand vibration and temperature
  - Higher yield
  - Lower cost test and measurement

Therefore **Cost per Gbps** for multimode SiPh transceivers  $\ll$  benchmark



**THANK YOU**

