Silicon Photonics Launch Condition Consensus Definition at 1310 nm

Ichiro Ogura, PETRA
Kazuhiko Kurata, AIO Core
Richard Pitwon, Resolute Photonics

IEEE 802.3cz Multigigabit Optical Automotive Ethernet Interim Task Force
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Contributions on silicon photonics in 802.3cz TF

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

References relevant to silicon photonics transceiver under test

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/cm2 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 transceiverfor 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.

References relevant to launch condition

IEEE802

1) John S. Abbott, “Transceiver Requirements for 802.3cz: SiP,” IEEE 802.3 cz, September 2021
2) John S. Abbott, “Estimated minEMB for OM3 at 1300nm,” IEEE802.3 cz, July 2021
3) D. Vernooy et al., “Spiral Launch Method for Enhanced MMF Bandwidth,” IEEE 802.2 10Gb/s on FDDI-grade MM Fiber Study Group

Scientific papers

4) C. P. Tsekrekos et al., “Near-field intensity pattern at the output of silica-based graded-index multimode fibers under selective excitation with a single-mode fiber,” OPTICS EXPRESS, Vol. 15, No. 7, 2 April 2007
5) Sim, D. H.et al., “Robustness Evaluation of MMF Transmission Link using Mode-Filled Matched Center-Launching Technique,” Proc. OFC/NFOEC 2008, OWR3 (24–28 February 2008)
6) Sim, D. H et al., “High-Speed Multimode Fiber Transmission by Using Mode-Field Matched Center-Launching Technique,” J. Lightwave Technol. 27, 1018-1026 (2009)

Overview

- This contribution is a launch condition consensus definition of silicon photonic PMD with [1] – [9]

- Measurements confirm a restricted EF launch profile from SiPh transceivers, which satisfies specifications: EF <0.3 at R=4.5µm and EF > 0.86 at R=19 µm for full range of temperatures measured (10 °C – 110 °C)

Motivation

Transceiver Requirements for 802.3cz: SiP

John S. Abbott
Corning Incorporated
abbottjs@corning.com

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SUMMARY

SiP/Single-mode is used in 802.3 400GBASE-DR4 standard and the proposed use in 802.3cz simplifies from 100Gb/s (50Gb/s PAM4) to 10Gb/s and 25Gb/s NRZ, and simplifies the connection from single-mode to multi-mode fiber.

The estimated BW of 800MHz.km is higher than the worst case OFL BW of 500MHz.km at 1310nm, and is achieved with a launch which is more restricted than the general VCSEL launch assumed for OM3. A different launch specification analogous to EF is needed and must be developed for this SiP application

SiP is **technically feasible** on experimental links but requires a clear specification of a robust launch condition enabling broad manufacturing support, including round robins with multiple sources and multiple fiber suppliers, similar to the development of OM3/VCSEL systems

The SiP-MM option is attractive long-term but we need to address timing/rigor/robust specification as well as clarity on the 802.3 desire for "distinct identity"

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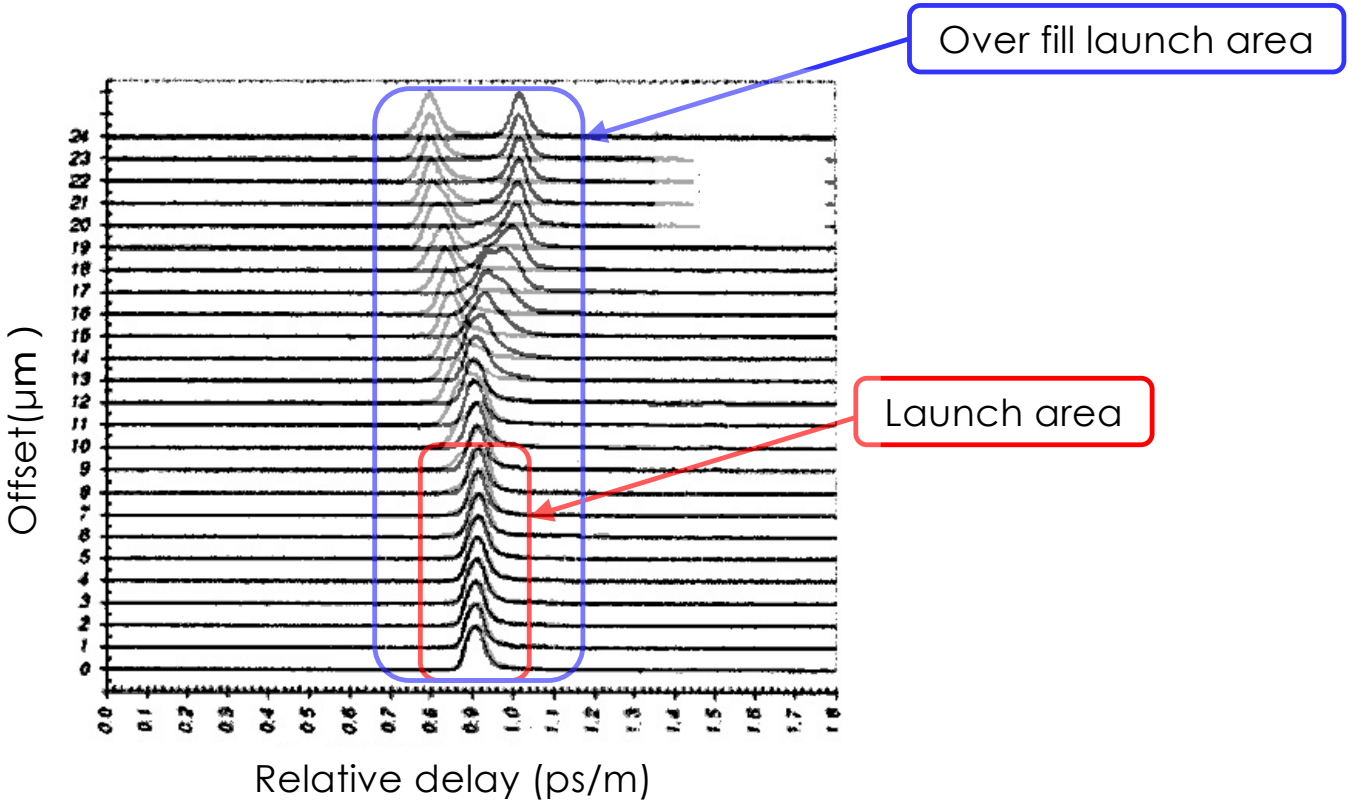
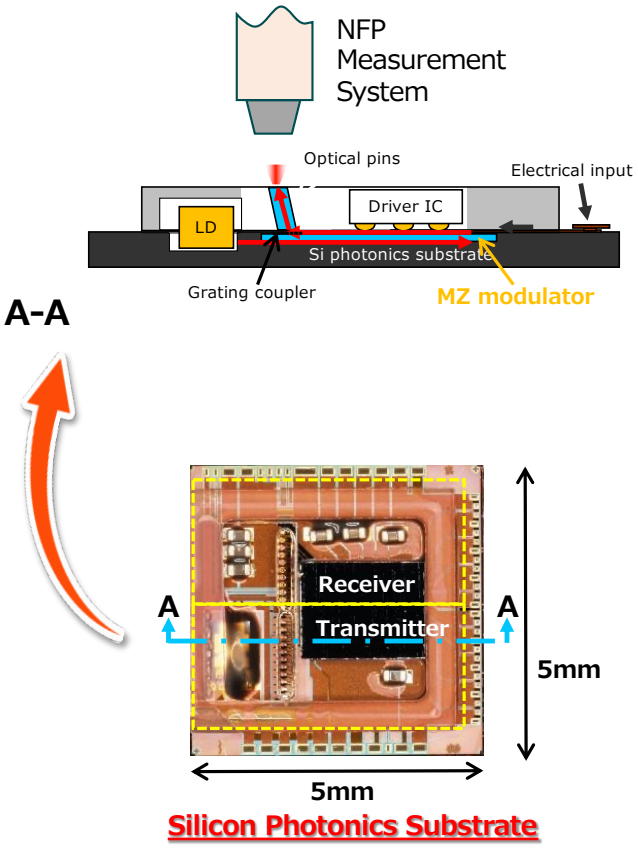
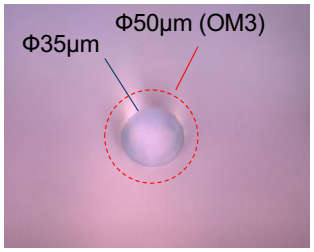
Common MMF DMD Images



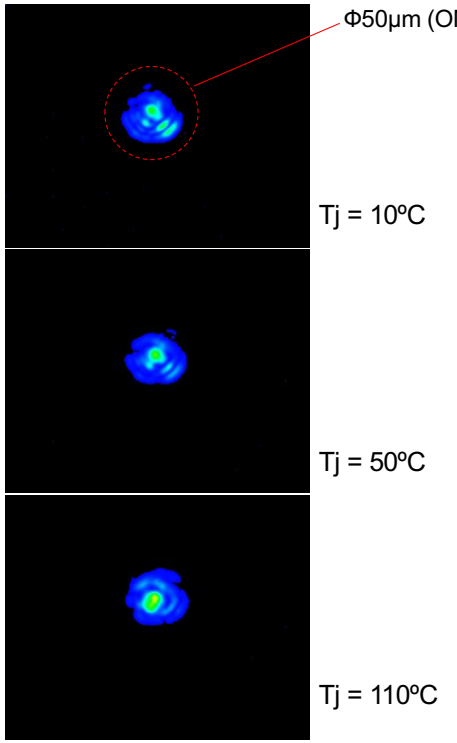
NFP, Launch Condition of Silicon Photonic Transceiver



Visual Image

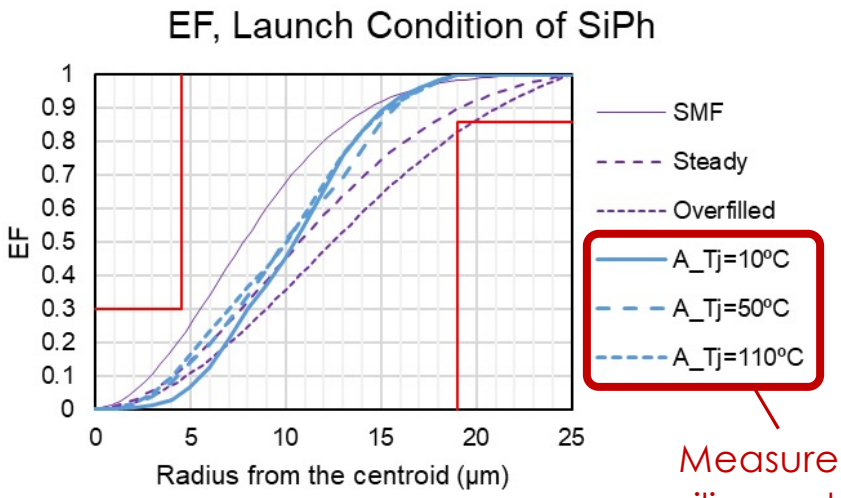


NFP



Optical pin
(Tx vertical waveguide)

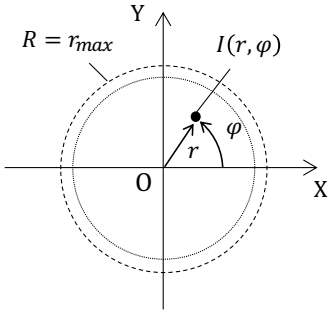
EF, Launch Condition of Silicon Photonic Transceiver



Measured EF from silicon photonics transceiver

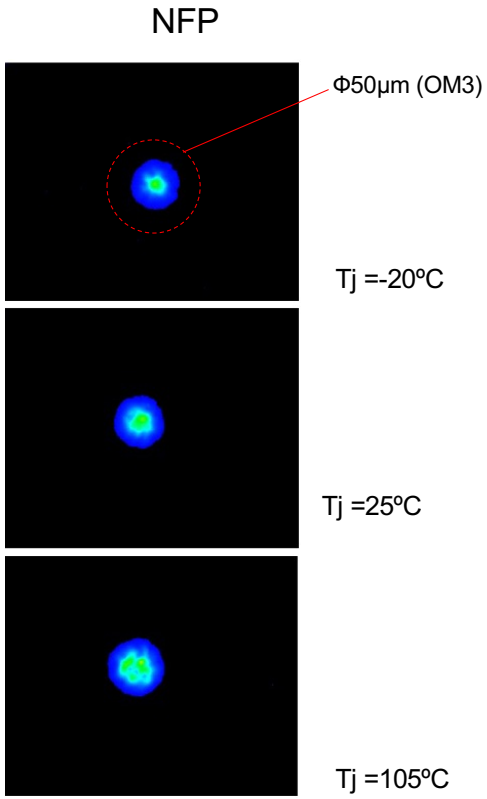
2D Encircled Flux

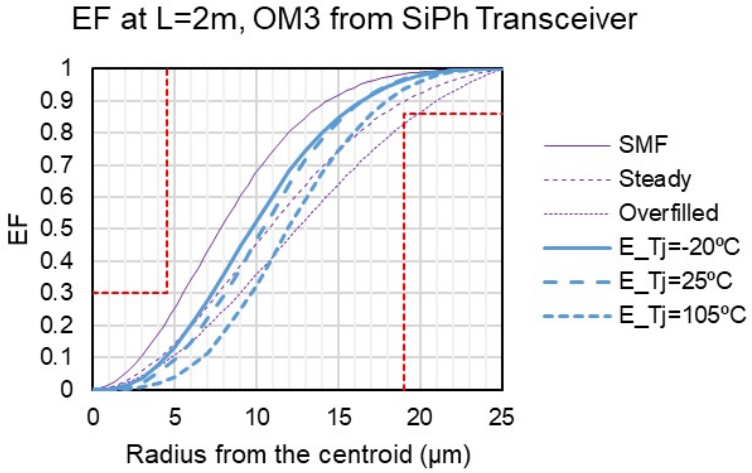
$$EF = \frac{\int_0^{2\pi}\int_0^{r} I(r,\varphi)\cdot r\cdot dr\cdot d\varphi}{\int_0^{2\pi}\int_0^{R} I(r,\varphi)\cdot r\cdot dr\cdot d\varphi}$$



- **Satisfied the existing EF specifications: EF<0.3 at R=4.5μm, EF at R=19 μm EF>0.86**
- **Generated lower mode launch condition designed by silicon photonic transceiver regardless of junction temperatures.**

Modal Condition at L = 2 m from SiPh Transceiver





- **After propagating through 2 m of OM3 fiber, modal conditions are maintained lower modes.**
- **NFPs are not dramatically changed as far as properly placed optical fibers by 1 km shown in 4).**
- **Completely reached the automotive optical cabling of 40 m has been presented with the contribution of [8].**

Summary

- Restricted mode launch condition is confirmed by the measurement of optical output from SiPh transceiver multimode interface
- Automotive optical cabling of 40 m has been presented with contribution [8].
- We need a collaborator (hopefully fiber manufacturer) to measure bandwidth measurement with the combination of SiPh transceiver and OM3 fiber.