COBO Webinar ‘Introduction to Multimode Waveguide (MMWG) Interconnect Systems for Photonic Integrated Circuits

Advanced PCBs with Optical Waveguide Interconnects

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February 23rd, 2022

Outline

- TTM Technologies Introduction
- Electro-Optical PCBs with Waveguides for Next Gen Data Centers
  - Waveguide Dimensions and Structural Definition
  - Optical Passive Components for On-Board Waveguide Routings
  - Channel Termination and Needed Optical Connectors
- Examples of Collaborative Industry Programs
- Summary

TTM's Business Units

End Market Leadership & Expertise

Aerospace & Defense/Specialty

(A&D) Business Unit

Automotive & Medical, Industrial & Instrumentation

(AMI&I) Business Unit

RF & Specialty Components

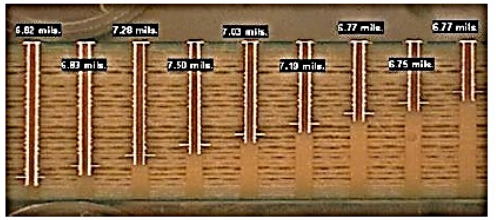
(RF&S) Business Unit

Communications & Computing

(C&C) Business Unit

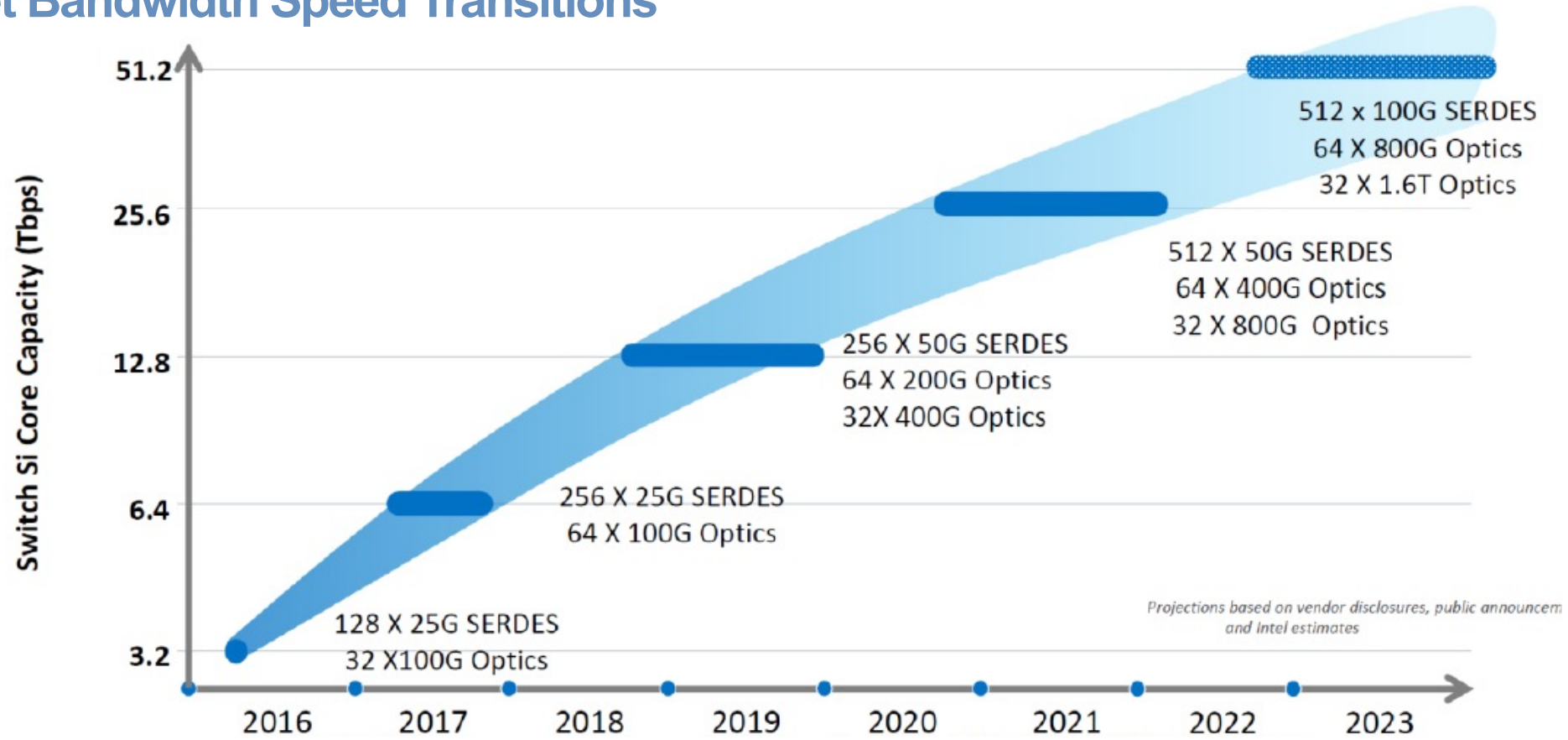
TTM – Global Leader in Advanced PCB Solutions

- Up to 64 layers
- Oversized large format PCB
- Flex and Rigid-Flex PCBs
- RF/mmWave PCBs for wide range of frequency bands, 110GHz+
  - Amplifier, Filter, Patch Antenna, Power Dividers, Balun, etc.
- Advanced high density interconnect (HDI) solutions
  - Sequential lamination blind and buried via technology
  - Via in pad technology
  - Copper filled and epoxy filled microvias
  - Advanced pattern plating & etching process
- High aspect ratio plating, >24:1
- Signal Integrity modeling, characterization and testing
  - Impedance, Insertion Loss, Back drilling, Via Structures, 3D EM Modelling
- Back drilling and via structures to minimize signal noise
- Advanced Materials expertise and testing services
- Buried Capacitance and Buried Resistance
- Engineered Thermal Management Solutions
- Heavy copper up to 12 ounces
- Defense/Aerospace certifications; ITAR, CGP, MIL-PRF-31032, MIL-PRF-50884, MIL-PRF 55110 and 55110G, AS9100D, NADCAP
- Commercial certifications: ISO9001, ISO14001, ISO/IEC 17025, ISO27001, ISO45001, IATF16949, TL9000, QC080000

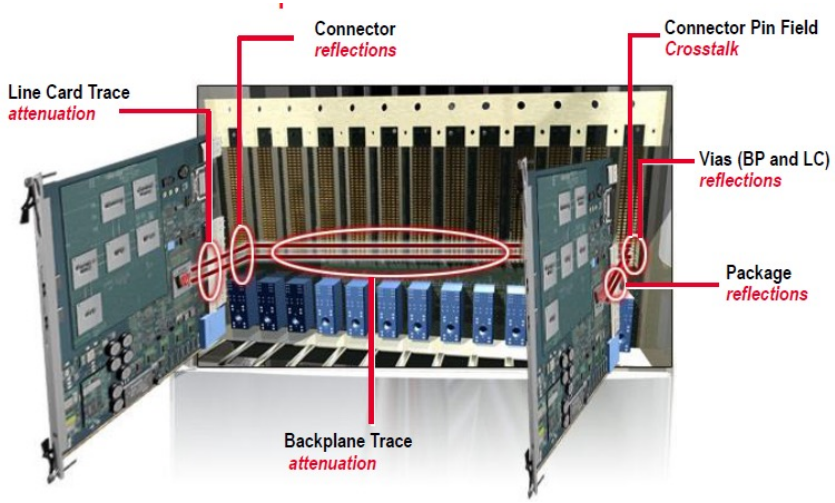


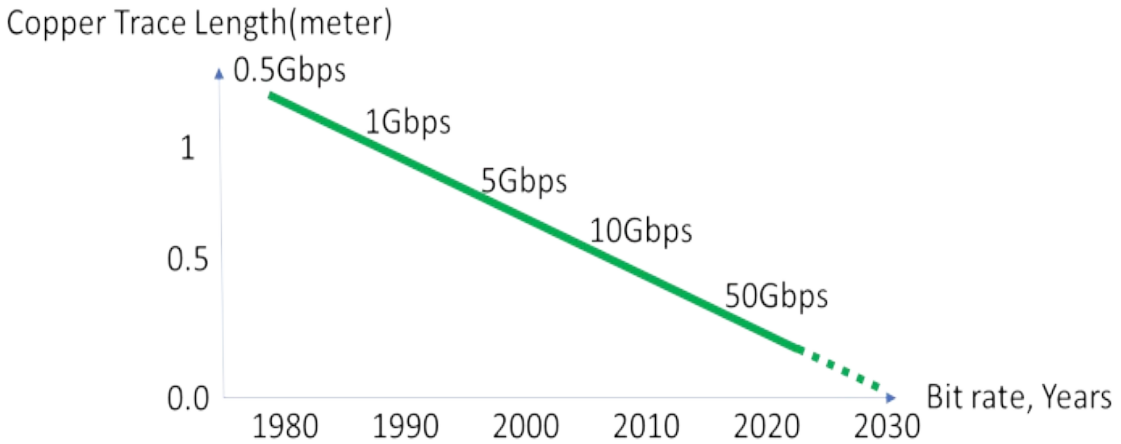
Industry Roadmap

Ethernet Bandwidth Speed Transitions



Challenges for Electrical Interconnects on PCBs – Fabricator's View

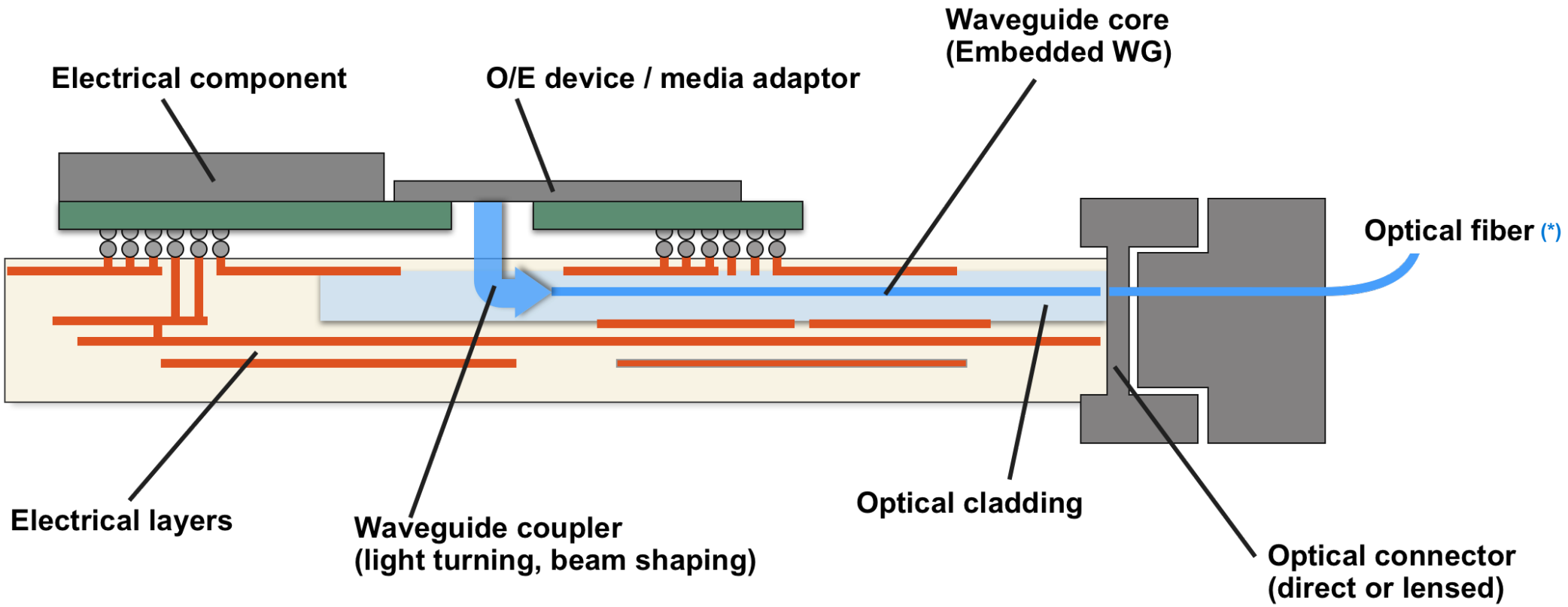




- RF Dk/Df electrical performance, but closer to FR4 cost
- No skew inducing material and structures
- Better CAF performance for more 0.4/0.65mm and less BGA pitch
- Cost/performance optimized materials are required
  - Not one size fits all materials

Dielectric	Structure	Conductors	Vias
Dk	Registration	Foil Roughness	Stub Length
Df	Size & Thickness	Oxide Roughness	Outer Diameter
Core Thickness	Via Structure	Width Tolerance	Material
Prepreg Thickness	HDI PCB Strength	Registration	Aspect Ratio

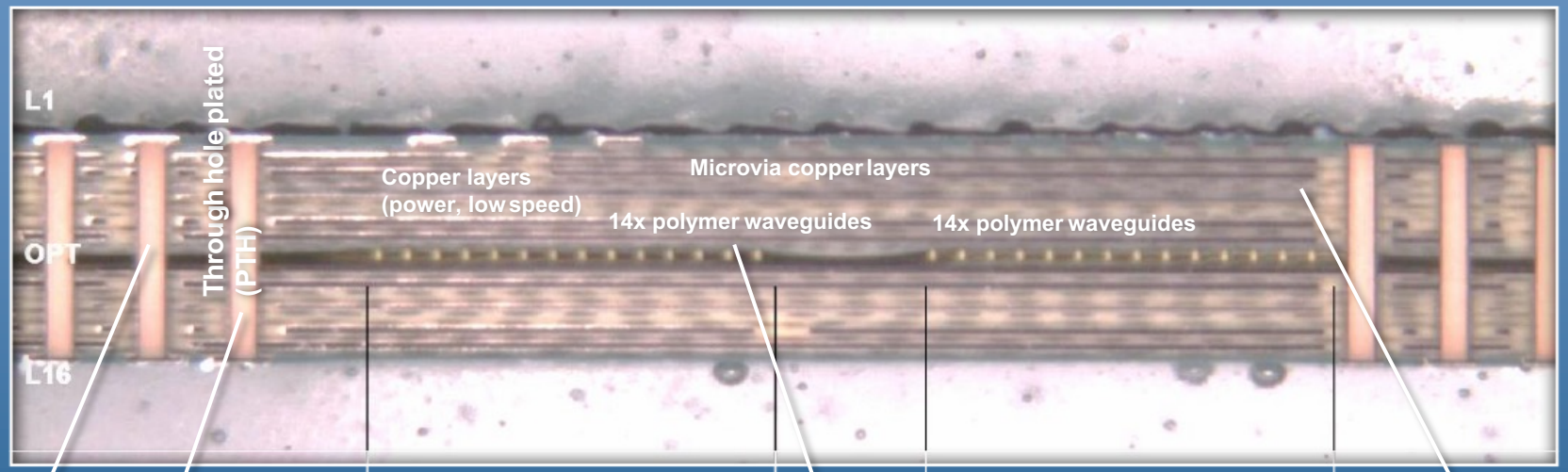
Electro-Optical PCB with Waveguides



(*) Optical fiber link within rack

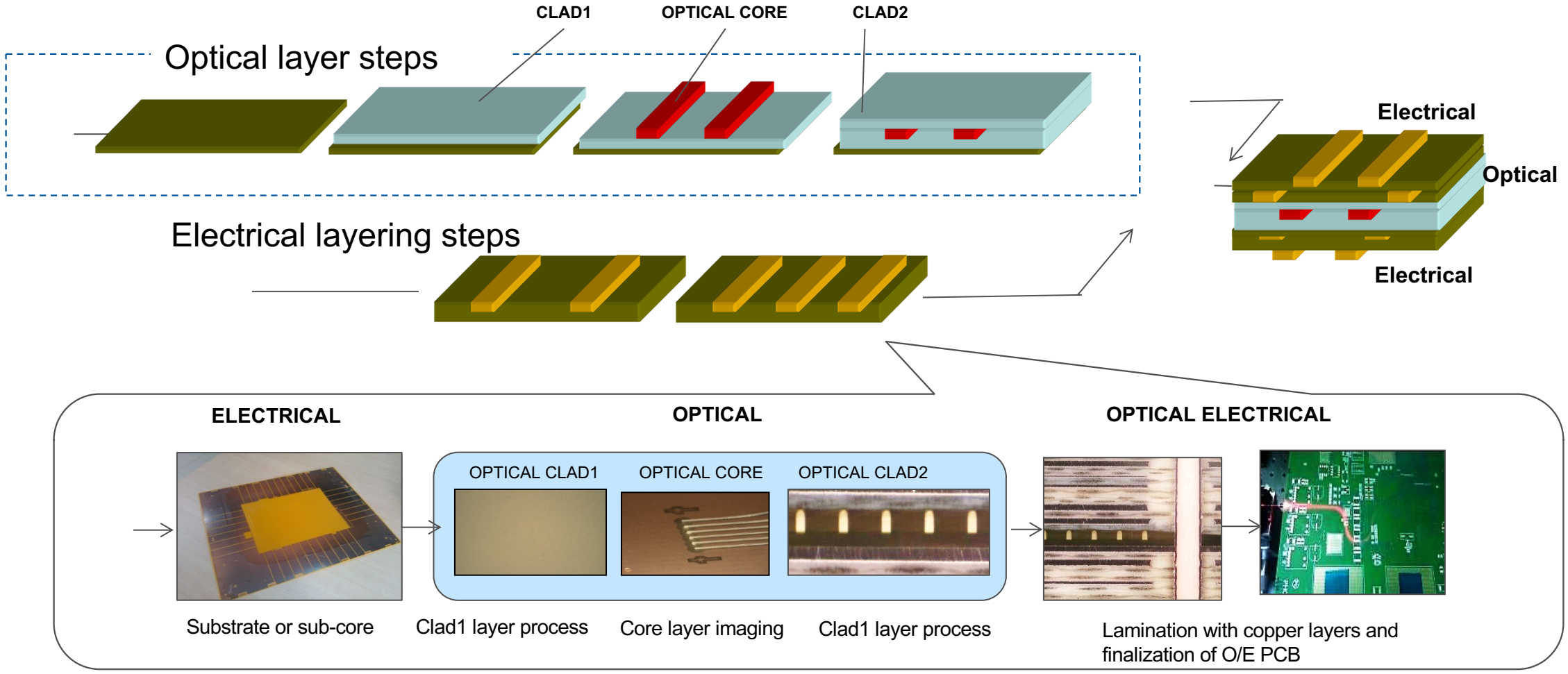
Example of O/E PCB Product : 16 Copper + 1 Optical Layer

Cross-section across 16L + 1Opt stack showing 14 + 14 optical signal waveguides



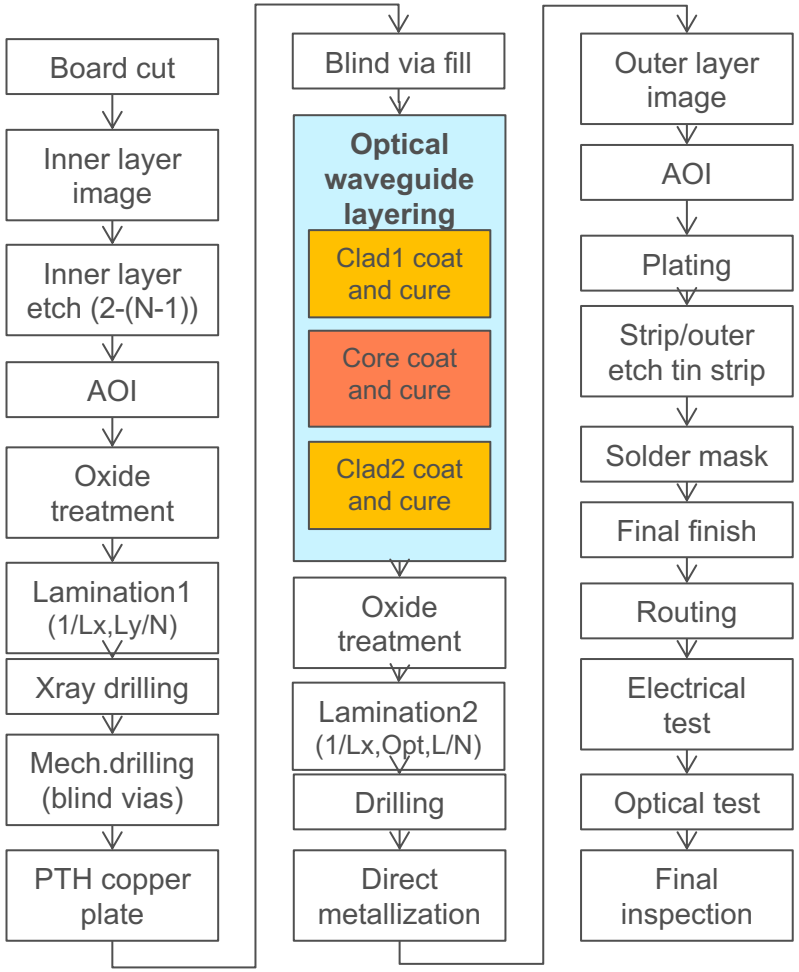
P. Maniotis, N. Terzenidis, A. Siokis, K. Christodoulopoulos, E. Varvarigos, M. Immonen, H. J. Yan, L. X. Zhu, K. Hasharoni, R. Pitwon, K. Wang, N. Pleros, "Application-oriented On-board Optical Technologies for HPCs" J.of. Lightwave Technology, Vol. 35, Iss. 15, pp. 3197-3213 (2017) DOI: 10.1109/JLT.2017.2681972

Polymer Waveguide Fabrication Processes and Integration to OE PCB

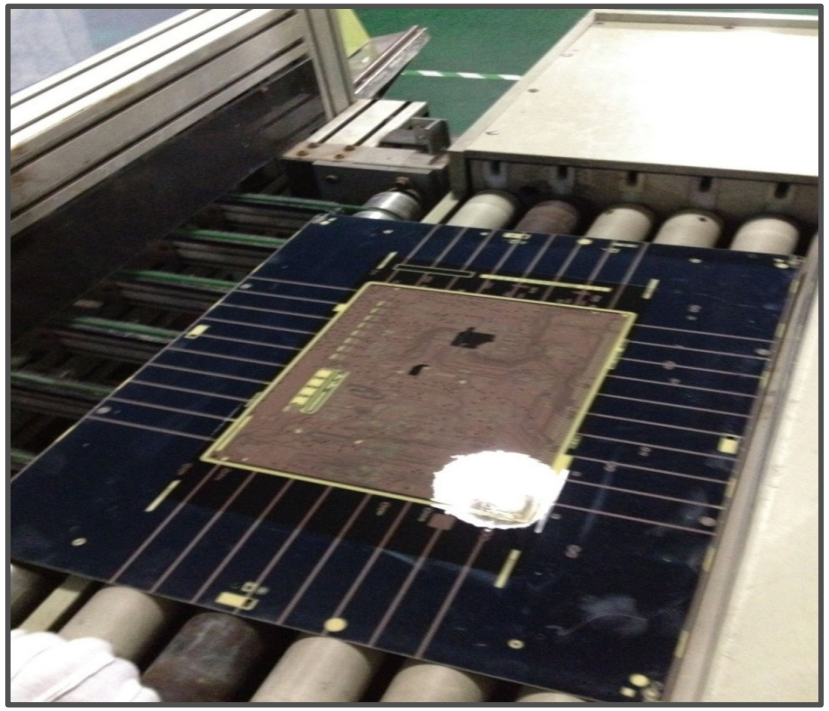


Optical PCB Fabrication Flow [Example Process]

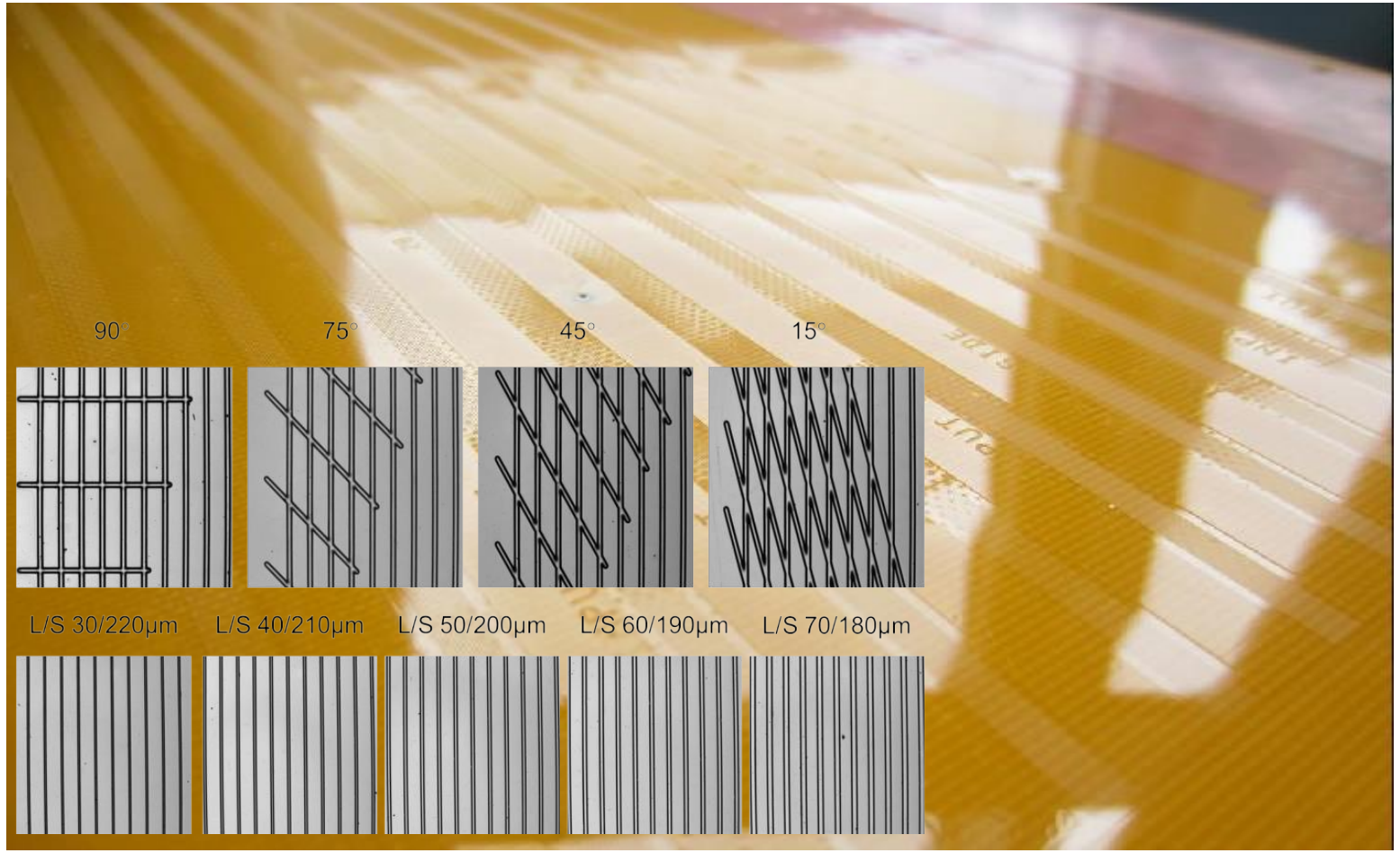
Example Flow: (N)L+1Opt

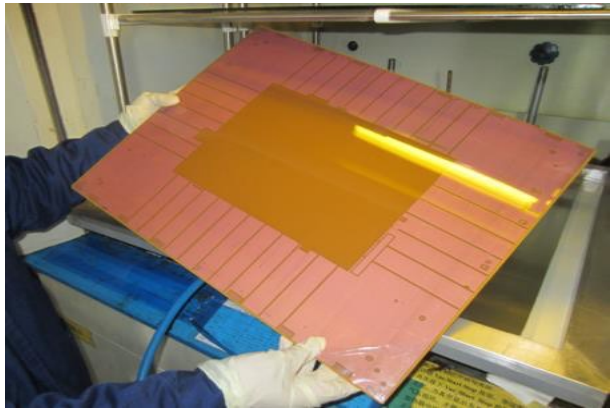


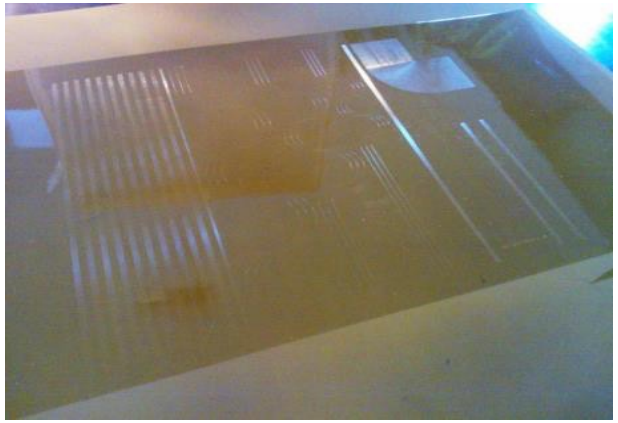
Process utilizes standard fabrication procedures in key steps of fabrication of O/E PCBs -> Robust & repeatable production



Multimode Waveguide Technology – Fabrication in PCB Shop using Hi-Vol Panel Scale Processes and Infrastructure



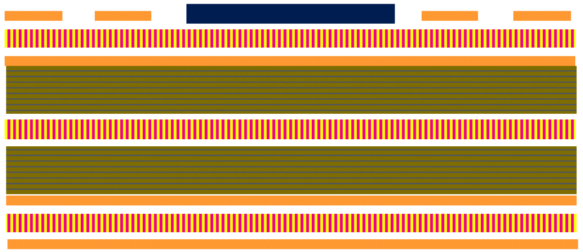




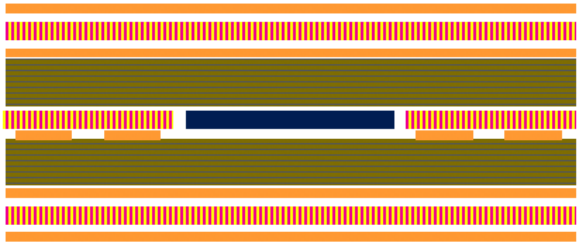
Optical Waveguides Can be Built in Various Layer/s in PCB Stackup

N+1Opt+N

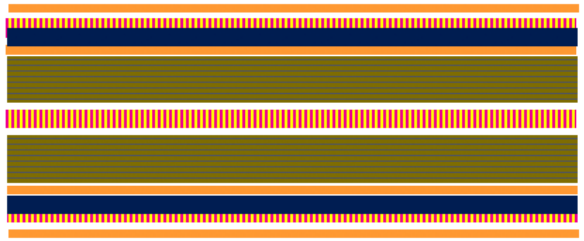
N+1Opt



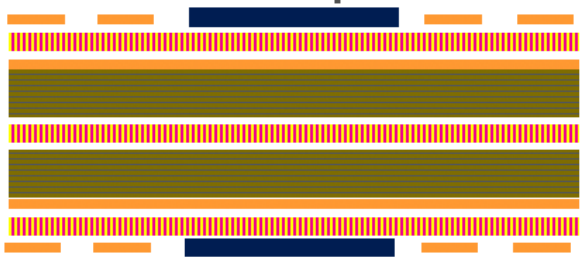
N+1Opt+N



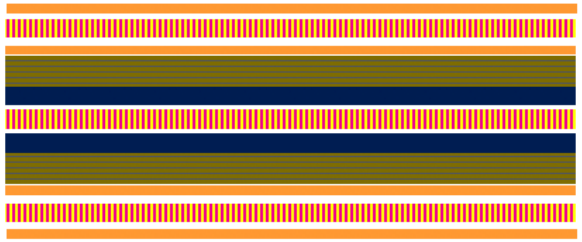
N+2Opt+N



N+2Opt

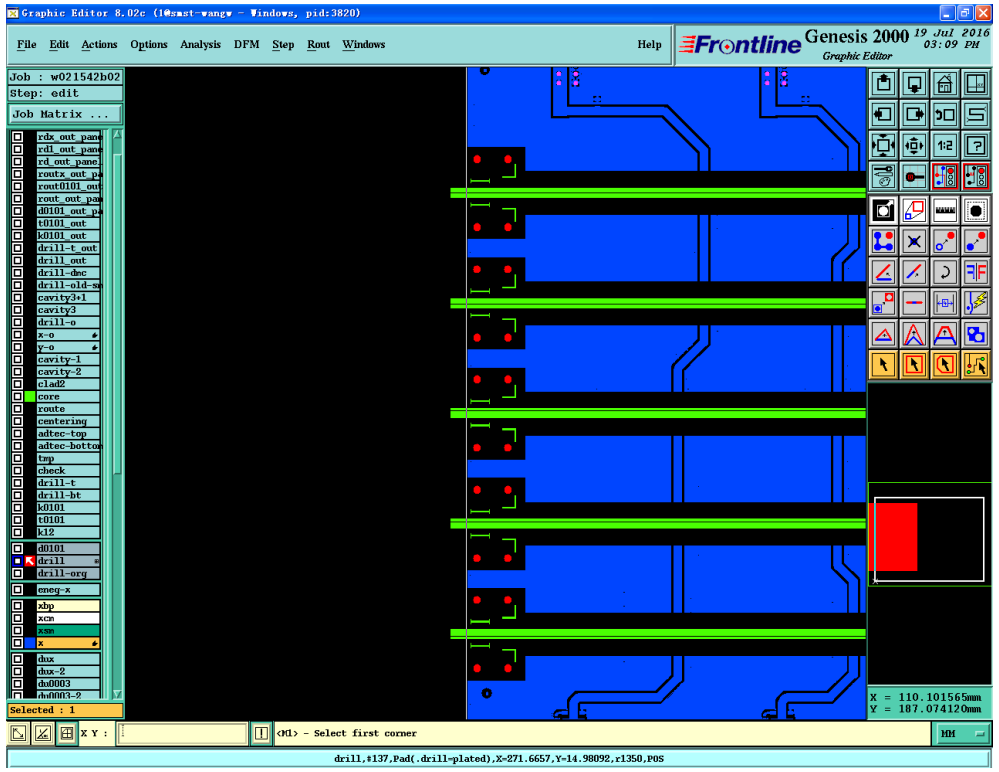


N+2Opt+N



Optical PCB Design : Electrical and Optical Co-Design within EDA Tool

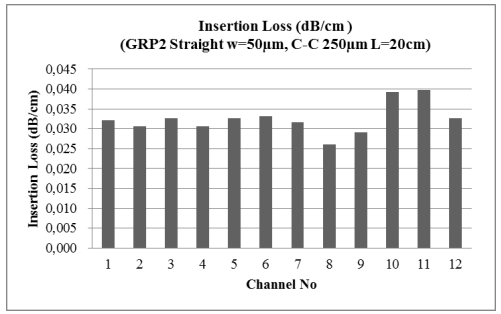
Optical and electrical design using EDA tools



- Commercial tools available in market
- Electronic & Photonic layout within EDA/ EPDA: Waveguide + electrical routing layout
  - Lumerical-Cadence (Cadence)
  - Lightsuite (MentorGraphics)
- Simulation of photonic components via additional suite (e.g. Lumerical System Suite) or ext. domain (e.g. RSOFT, Comsol, Fimmwave)
- Each vendor has database with experimentally validated design rules for photonic components per material

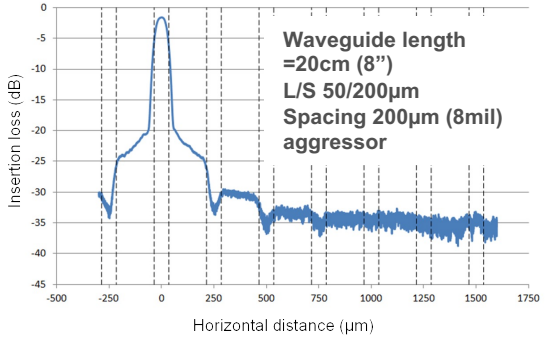
Functional Test Results - MM PWGs (λ= 850nm)

INSERTION LOSS



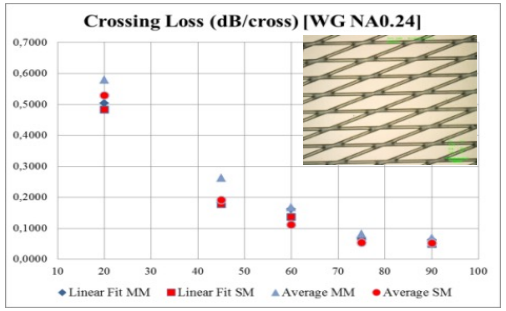
IL: < 0.05 dB/cm at 850nm (MMF)
TL: 0.03-0.05 dB/cm at 850nm (MMF)
TL: 0.4 dB/cm at 1310nm (MMF)

CROSSTALK



Crosstalk isolation: -32 dB

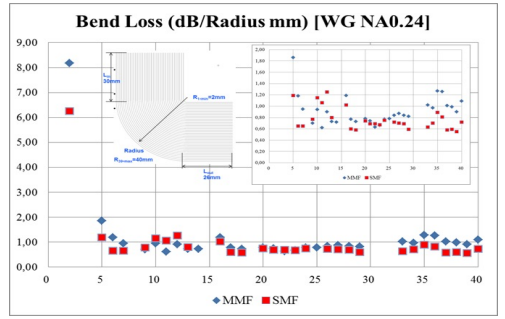
CROSSING LOSS



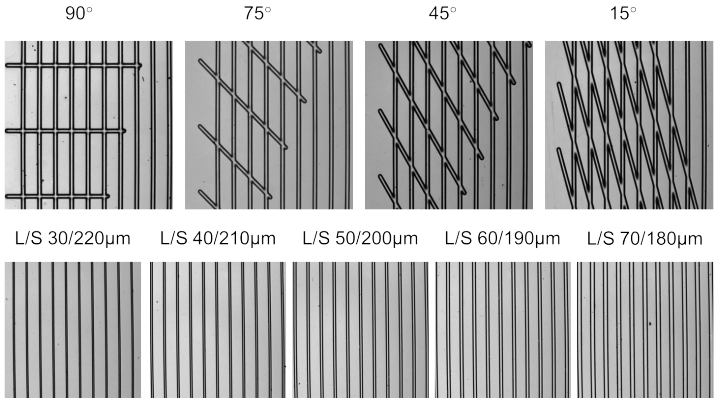
< 0.057 dB/X (MMF) 90°
< 0.046 dB/X (SMF) 90°

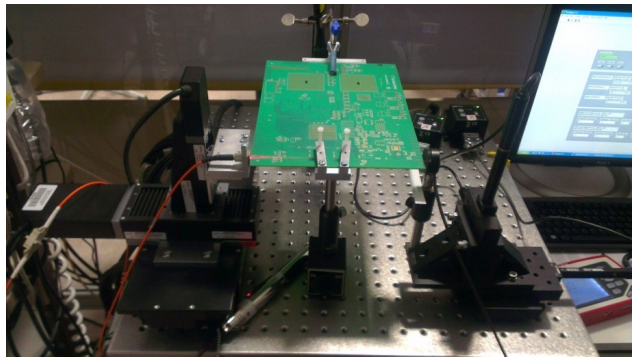
< 0.17 dB/X (MMF) 45°
< 0.17 dB/X (SMF) 45°

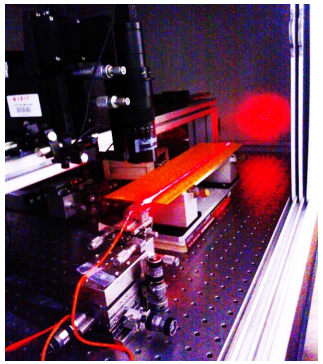
BEND LOSS



RoC 5mm < 1.9 dB (MMF) < 1.2dB (SMF)
RoC 10mm < 1 dB (MMF) < 1.2 dB (SMF)







M. Immonen, J.Wu, H. J. Yan, L. X. Zhu, P.Chen, T.Rapala-Virtanen, "Development of electro-optical PCBs with embedded waveguides for data center and high performance computing applications", Proc. of SPIE 8991, Optical Interconnects XIV, 899113. 8 Mar, 2014.

Transmission Results Over Long Multimode Waveguide Channel

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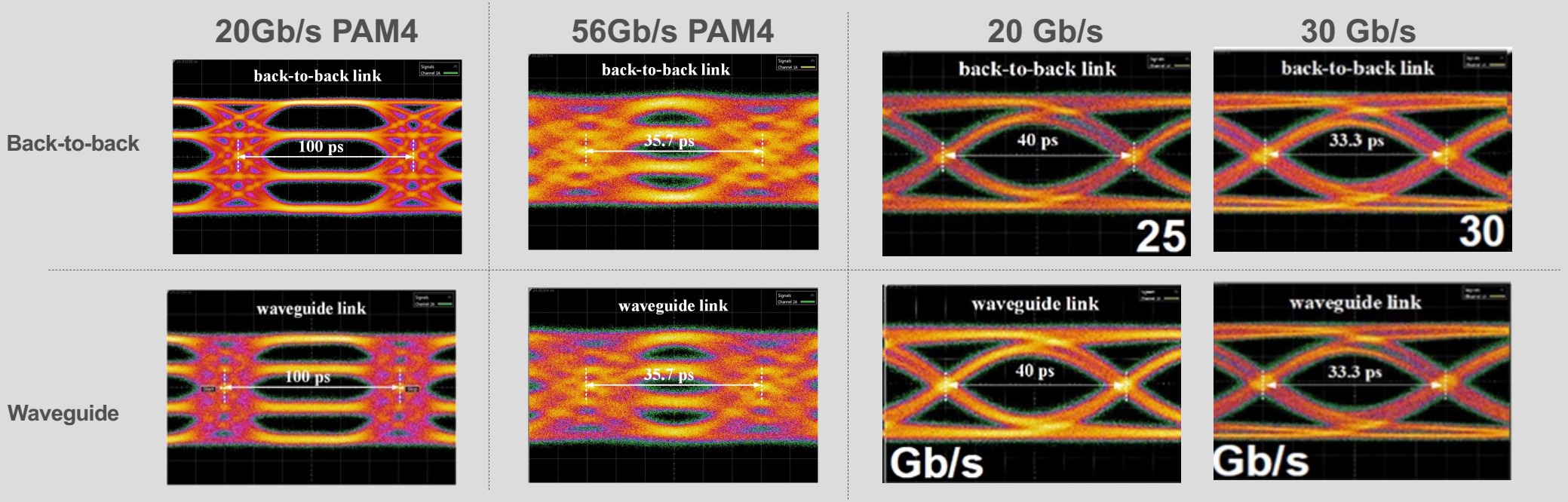
Test channel: 94-cm long WG, bend channel design, no termination

Poly_WG (Δ=0.24, SI/semi-GI), core (□ 50μm, nom.), λ1 (850nm)



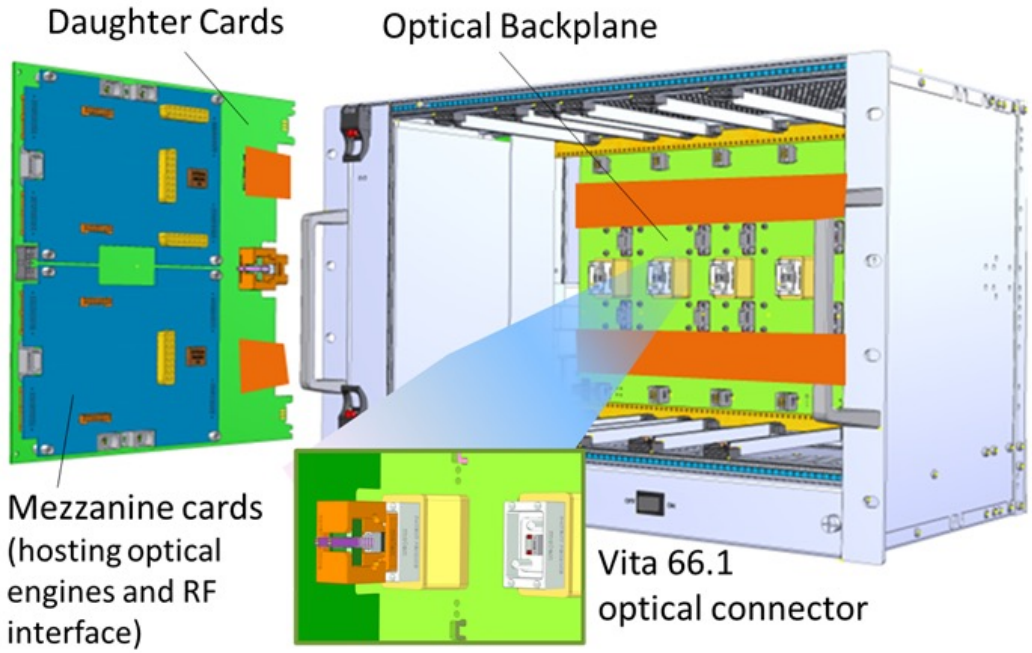
Eye diagrams of waveguide link at (a) 10 Gbaud (20 Gb/s) for average received optical power of -5 dBm and (b) 28 Gbaud (56 Gb/s) for average received optical power of -2 dBm.

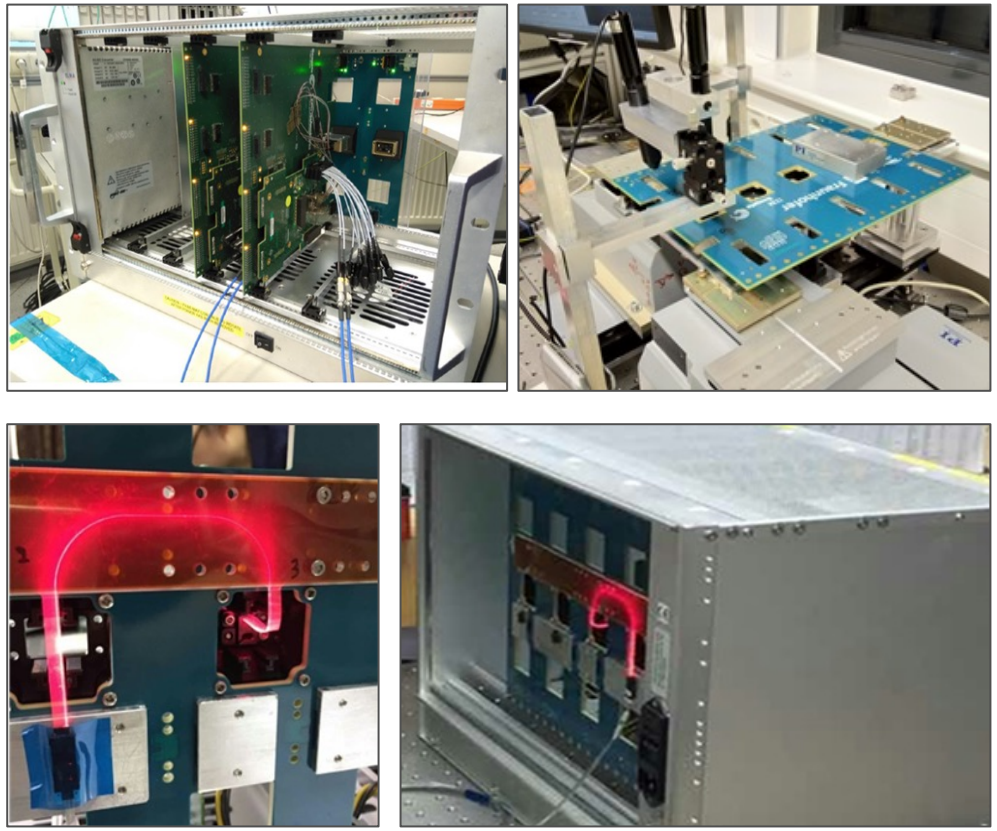
X. Xu, L. Ma, M. Immonen, X. Shi, B. Swatowski, J. V. DeGroot, Z. He, "Practical Evaluation of Polymer Waveguides for High-Speed and Meter-Scale On-Board Optical Interconnects", IEEE JLT Vol: 36 Iss. 16, pp. 3486 – 3493 (2018)
DOI: 10.1109/JLT.2018.2847461

Collaborative Industry Effort OPCB Technology Demonstrator

TTM Technologies

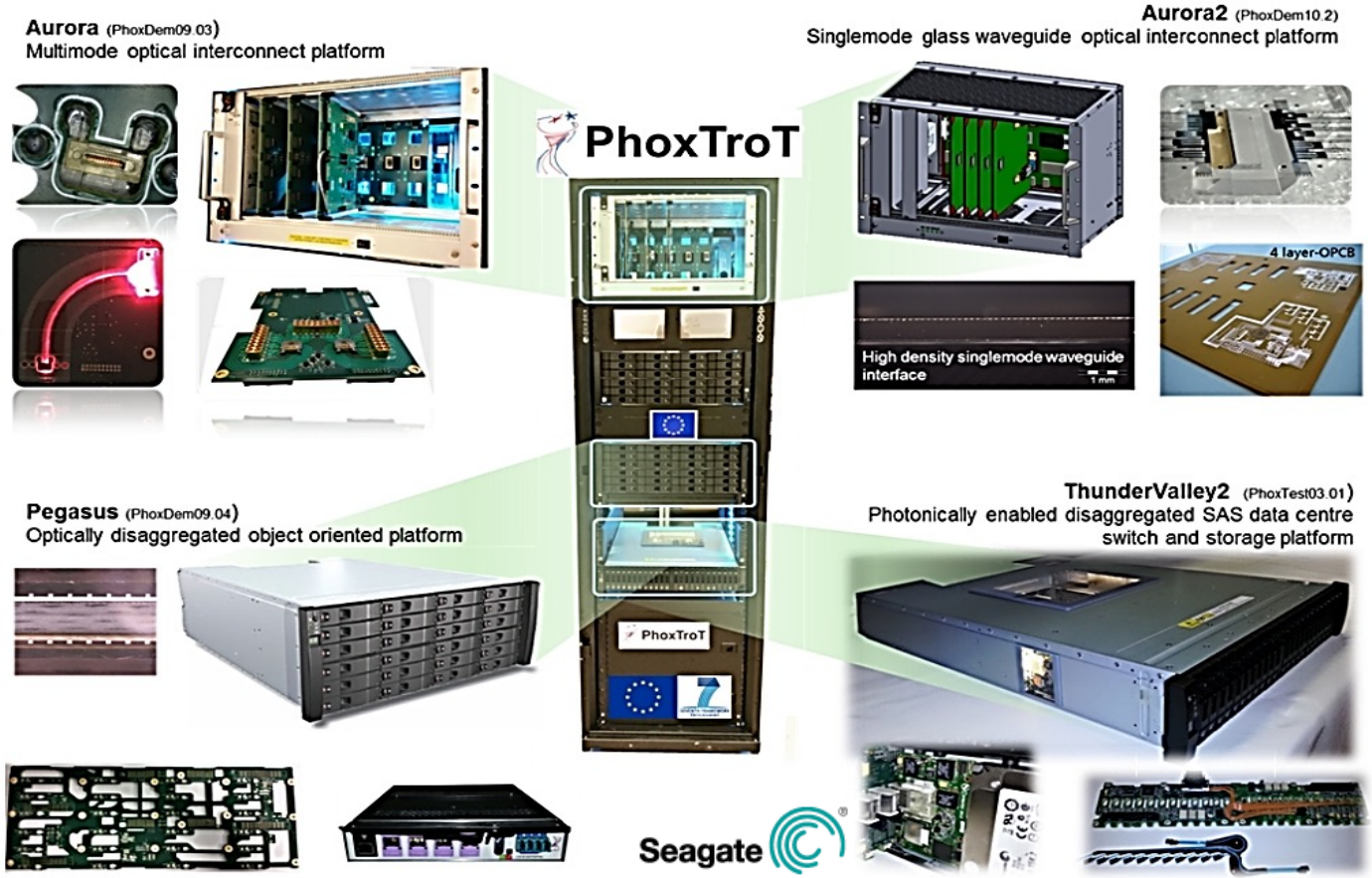
HDPUG (High Density Packaging User Group) Optoelectronics Phase 2





https://hdpusergroup.org/project/optoelectronics-ii/

Technologies Developed during PhoxTrot for Next Gen. Applications



https://phoxtrot.eu/

PhoxTroT

Photonics for High-Performance, Low-Cost & Low-Energy Data Centers, High Performance Computing Systems: Terabit/s Optical Interconnect Technologies for On-Board, Board-to-Board, Rack-to-Rack data links

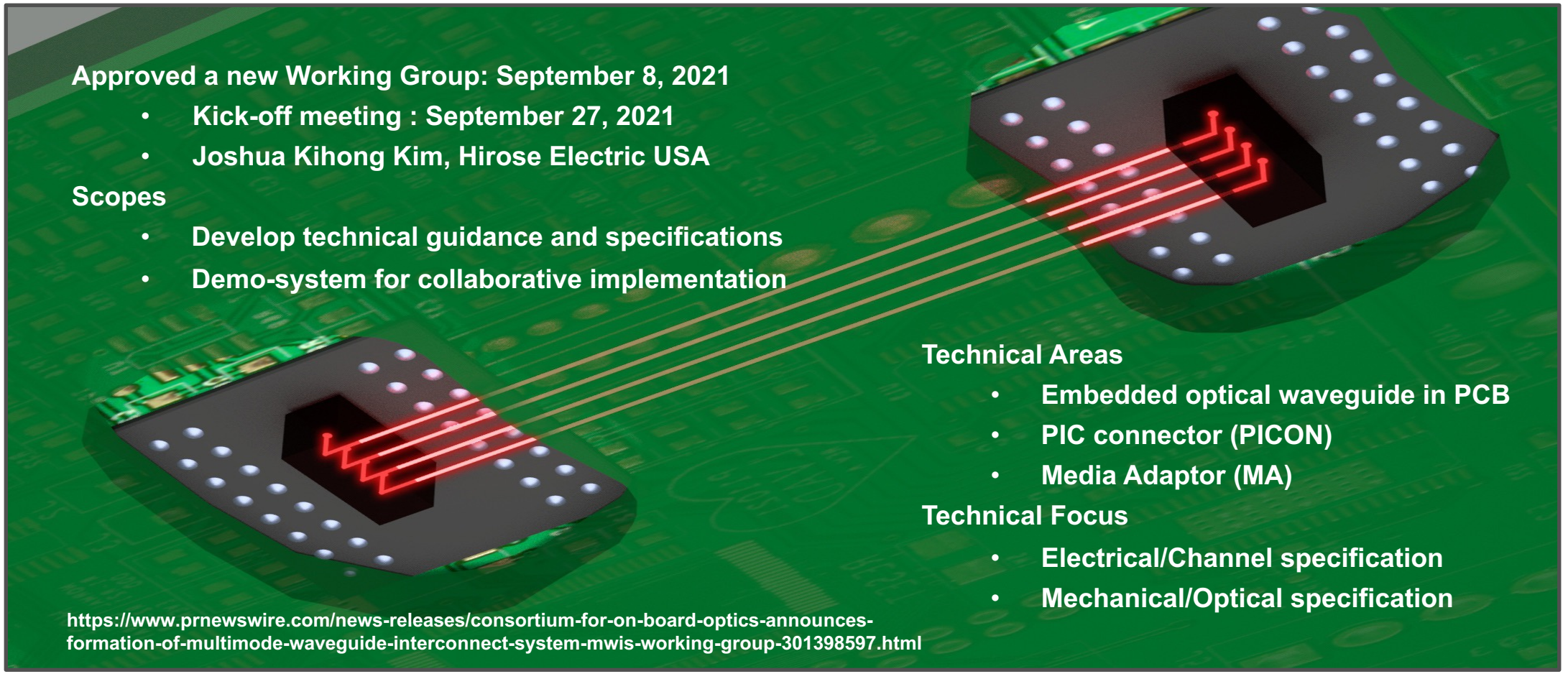
Photonics for High-Performance, Low-Cost & Low-Energy Data Centers, High Performance Computing Systems: Terabit/s Optical Interconnect Technologies for On-Board, Board-to-Board, Rack-to-Rack data links

- ★Fraunhofer IZM (DE)
- ★Fraunhofer HHI (DE)
- ★Vertilas GmbH (DE)
- ★Xyratex Technology Ltd (UK)
- ★ams AG (AT)
- ★TTM Technologies (HK)
- ★AMO GmbH (DE)
- ★ICCS/NTUA (EL)
- ★DAS Photonics SL (ES)
- ★Phoenix BV (NL)
- ★CERTH (EL)
- ★Compass EOS Ltd (IL)
- ★Bright Photonics BV (NL)
- ★CTI (EL)
- ★CNRS-UB (FR)
- ★CNRS-LPN (FR)
- ★KIT (DE)
- ★SDU (DK)
- ★UPVLC (ES)
- ★IMEC (BE)

Complete rack-level demonstrator platform including application specific optical demonstrator designs

COBO's new Working Group: MWIS (Multimode Waveguide Interconnect System)

TTM Technologies



Approved a new Working Group: September 8, 2021

- Kick-off meeting : September 27, 2021
- Joshua Kihong Kim, Hirose Electric USA

Scopes

- Develop technical guidance and specifications
- Demo-system for collaborative implementation

Technical Areas

- Embedded optical waveguide in PCB
- PIC connector (PICON)
- Media Adaptor (MA)

Technical Focus

- Electrical/Channel specification
- Mechanical/Optical specification

https://www.prnewswire.com/news-releases/consortium-for-on-board-optics-announces-formation-of-multimode-waveguide-interconnect-system-mwis-working-group-301398597.html

Summary and Conclusions

- Power has become first order issue and drive new solutions for development
- Hybrid PCB with copper and optical offer a viable 112/ 224Gbps solution - no re-timers, no cables, exploits best of both worlds
- TTM has capability to build optical PCBs using standard high volume scalable processes. Multimode solution is mature, lower cost, robust vs. single mode
- Need to start to defining target channel specification and opto/ mechanical specification early on for MMIS vendor compliance
- Eco-system partnering with material, connector, EMS/ test developer to align customer roadmaps, readiness and multi-sourcing

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Inspiring Innovation

Thank You!

cobo