On-Board Optical Interconnection
A Joint Development Project Consortium

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• Executive Summary
• Issues in Board-Level Optical Interconnect
• Origin of the Project Proposal
• Project SOW and Deliverables
• Project Participation & Anticipated Benefits
Generic Board-Level Interconnection System
A proposal is now being written for a project to build and characterize a board-level interconnect system based on silicon photonic (SiPh) modules & single-mode (SM) expanded-beam connectors. The goal is to identify gaps in technologies needed for cost-effective volume deployment of SiPh board-level interconnect. Potential participants are being recruited to contribute to the detailed proposal, which is due by December 1st. This project is intended to first Phase of a longer, more comprehensive project that will ultimately build demonstration vehicles for optical coupling to SiPh chips and PCB-embedded waveguides in later Phases.
Issues in Board-Level Optical Interconnect
Board-level optical interconnections are those where light is transported within the “geographical bounds” of a Printed Circuit Board/Blade (= inside board perimeter).

This includes Optical:
• Module-to-module connections on a single PCB
• Module-to-board-edge connections on the PCB (for frontplane/backplane connections), ultimately connecting optically to other boards in the same or other chassis.

We will exclude optical connections inside the optical module/package, which are part of the (related) packaging technology.

We will exclude electrical connections at the board edge to an off-board transceiver (e.g. Active Optical Cables), since the connector requirements may differ.
Why Transition to Optical Interconnect On-Board?

• Bandwidth density— especially important on high-port-count switch boards
  
  Board edge space is limited
  
  Air circulation must be maintained for cooling
  
  Fiber connector pitch is one advantage…WDM is a huge advantage.

• Potential for lower power dissipation than copper
  
  Copper power loss increases rapidly with BW
  
  Power is key to cost component of operating of large data centers

• Lower crosstalk than copper

• Avoid length-dependent signal impairments characteristic of copper
  
  Optical link impairments are “distance agnostic” at these short lengths
Why NOT Transition to Optical Interconnect On-Board?

- Cost of components (TRX, optical connectors...)
- Chicken-and-Egg” cost/volume scenario for components.
- Cost/benefit ratio when viewed as complete “ecosystem”
- Precision required in optical connector components
- Labor-intensive PCB assembly process (plug-in modules; route & connect cables)
- Increased level of labor skill for installation and maintenance
- Reliability and maintenance concerns
- Potential disruption of PCB supply chain (especially PCB-embedded waveguides)
- SiPh operates at 1300 or 1550nm; polymer waveguide loss is high.
- Inertia, fear of unknown consequences, risk-value tradeoff.....
Limitation of Scope: Exclude Multi-Mode Systems

Vertical-Cavity Surface-Emitting-Laser (VCSEL) Based MM Systems

- TRX packaging is simpler.
  - Relaxed alignment tolerances
  - VCSEL emission region easily located
  - Better match to fiber than are high $\Delta n$ SiPh waveguides.
- Connectors are easier (at least mechanical tolerances)

**Do we really need SM on board?**  YES, if we assume:

- SiPh will deliver the lowest-cost transceivers per functionality.
- SiPh will scale in bandwidth & density more readily than VCSELs (WDM)
- We need high-bandwidth optical connections to distant chassis.
Electrically-Pluggable Module, with Fly-Over Optical Fiber Cables
There are more on-board interconnects inside the package.
**Advantages**

- Can use existing cables and connectors.
- Can use either optically connectorized or pigtailed (cheaper) modules.
- Use electrically connectorized modules, so modules don’t need reflow compatibility.
- Replacement of connectorized modules is simplified.
- Separates electrical from optical alignments.

**Disadvantages**

- Adds manual process of electrically plugging modules to PCB assembly.
- Adds manual process of mating optical cable connectors to mid-board modules.
- Adds manual process of routing cables to board-edge connector.
- Adds manual process of installing optical board-edge connector.
- Complex inventory of cable lengths expected.
- Cable management may result in reliability issues (mechanical snag)

**What’s Missing?**

- Low-enough-cost components & processes.
Silicon Photonics Device Package Reflowed on PCB with Embedded Waveguides

SiPh Waveguide Grating Coupler
SiPh Chip
SiPh Chip Carrier
Module Package (also has electronic chips)
Expanded Beam
Package Window
SM Waveguide Core
Electrical Vias
Optical Connector Receptacle
Optical Fiber Cable
Embedded Waveguide PCB

This would be the best future solution.
Advantages

- Final PCB assembly process flow can be similar to today’s standard process.
- Minimizes board assembly labor.

Disadvantages

- Module failures = blade failures
- PCB fab process maximally disrupted.

What’s Missing?

- Requires new waveguide materials with low absorption loss at ~1310 and ~1550 nm
- Requires new PCB fabrication processes to integrate waveguides into PCBs
- Requires PCB optical backplane/frontplane connectors, and termination processes.
- Requires new, reflow-compatible optical modules.
- Requires new, reflow-compatible optical interface from package to PCB-embedded waveguides; must accept PCB assembly tolerances.
- Requires improvements in optical module reliability?
Origin of the Project Proposal
How to Take the First Step?

- AIM MIT Meeting, June 2016
  - TL Smith Board Level Interconnect Overview
  - J. MacWilliams Connector TWG
    - “Low-Hanging Fruit” Challenge
    - Meaningful project for 18 month timeframe
    - Proposed SiPh, expanded-beam connector demo

- AIM Academy Webinar, October 2016
  - TL Smith & J. MacWilliams program overview

- IPSR Weekly Project Planning Webmeetings
  - Scope of Phase I narrowed: no chip connection
  - Phase II and Phase III objectives drafted.
    - Phase II = chip connection technology demo
    - Phase III = PCB embedded waveguide technology demo
Phase I Project:
Statement of Work & Deliverables
Phase I Statement of Work (1)

- Build demonstration system:
  - 25 Gbps/channel SiPh optical transceivers
  - SM expanded-beam connectors
  - Backplane and Frontplane hardware
Proposed Phase I Demo System

- Frontplane
- Backplane
- Module
- Right Angle Optical Plug
- TRX
- TRX Socket
- Optical Medium
- Connector for Box-Box
- "Frontplane-like"
- Board-Edge Interface
- Connector for Box-Box

PCB / Blade
Chip connection is “out of scope” for initial project.
Phase I Statement of Work (2)

• Characterize Components & System
  – Connector loss
  – Wavelength dependent connector loss
  – Polarization-dependent connector loss
  – Connector return loss
  – Connector re-mating loss variations
  – Temperature & Humidity effects (Telcordia GR-1435 U.E.)
  – Dust contamination connector loss variation
  – Bit Error Rate vs connector number & loss.
  – System cost estimates.
Phase I Deliverables

• Document Findings
  – System performance issues identified.
  – Component readiness assessed.
  – Gaps identified.
  – Product needs identified.
  – Timing of SiPh expanded beam system anticipated.

• Publish results.
  – Details TBD by participants

• Formulate and Initiate Phases II and III
Detailed Phase I Statement of Work

- The detailed statement of work will be refined by potential project participants by the proposal due date, December 1.
- The SOW will be dependent on the interests and capabilities of the participants.
- Participants are expected to contribute components and services *free of charge* to the Project, for the mutual benefit of all.
Anticipated Benefits of the IPSR Project

• **Quantify performance of SiPh-based on-board interconnect.**
  Understand BER vs data rate with n-connector daisy chains.
  Understand power dissipation trade-offs
  Understand compatibility with Telcordia GR-1435, IEC-60529, IP5X/IP6X
  Understand relative issues in SiPh vs VCSEL implementations

• **Understanding design tradeoff in SiPh-based on-board interconnect system.**
  Understand impact of EB connectors on power budget.
  Understand impact of molded plastic optics at ~ 1550 nm WDM wavelengths
  Understand impact of EB connectors on temp, humidity, vibration stability
  Understand impact of EB connectors on dust tolerance.
  Understand cost benefit of relaxed mechanical tolerances of EB connectors
  Improve understanding of pigtailed vs connectorized module trade-offs.
  Improve understanding of fly-over vs PCB-embedded optical media trade-offs.
More Anticipated Benefits of the IPSR Project

• Identification of component developments needed to fill gaps.
  Are connectors currently under development adequate?
  Are existing cable routing techniques adequate for dense board implementation?
  Do SiPh transceivers have adequate power for use with multiple connectors?

• Improve industry & public understanding of SiPh benefits, issues, and timing.
  Publish data on the first interconnect system test with SM EB connectors.

• Potential acceleration of market for associated SiPh transceivers, connector components, and fiber cables.
  Overcome implementation hesitancy due to reliability concerns.
  Identify missing parts of the SiPh commercialization “ecosystem”
  Motivate industrial development of missing infrastructure.
Contributions Needed from Participants

- SiPh TRx modules, with SM fiber interfaces
- Developmental SM expanded beam connectors.
- Developmental connector bodies for backplane and frontplane.
- PCB and backplane assembly
- Connector termination services
- System test capabilities
- Environmental test capabilities.
Types of Organizations to Participate

- Connector & cable suppliers
- SiPh transceiver suppliers
- System integrators, including:
  - Server manufacturers
  - Telecom switch manufacturers
  - Supercomputer manufacturers
- PCB suppliers
- Electronic assembly houses.
Current Project Proposal Participants

• 3M-Terry Smith (Proposal Co-Leader)
• 3MTS- Bill Bottoms
• Corning- Alan Evans
• Celestica-Tatiana Berdinskikh
• Macom-Rich Grzybowski
• Molex-Tom Marrapode
• Promex Industries-Dick Otte
• US Conec- Darrell Childers
• US Competitors-John MacWilliams (Proposal Co-Leader)
Schedule for SOW

– October 20: AIM Webinar Presentation on Project

– Oct 31 & Nov.1: This Presentation, and Connector TWG

– November 1 to December 1: Proposal Preparation

– December 1: Full Proposal (SOW) Submission
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Thank You!