iNEMI – AIM Photonics / IPSR

Board-Level Optical Interconnect Demonstration Program-- Overview

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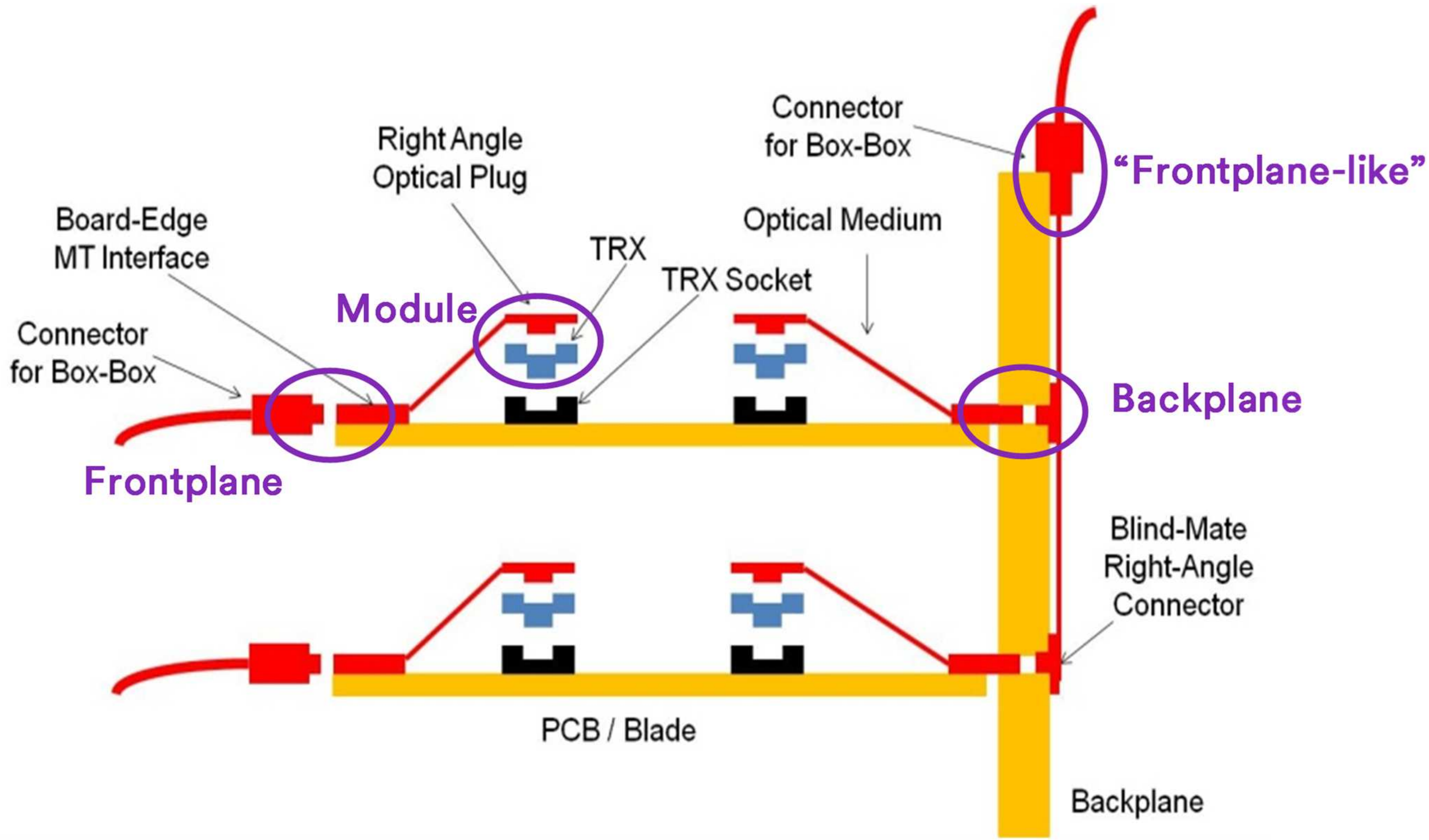
Board-Level Optical Interconnect



Intra-Chassis Distance < 3 meters

Why Switch to Optical?

- Bandwidth density– important on high-port-count switch boards

    Board edge space is limited

    Air circulation must be maintained for cooling

    Fiber 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 data centers

- Lower crosstalk than copper
- Avoid length-dependent signal impairments of copper

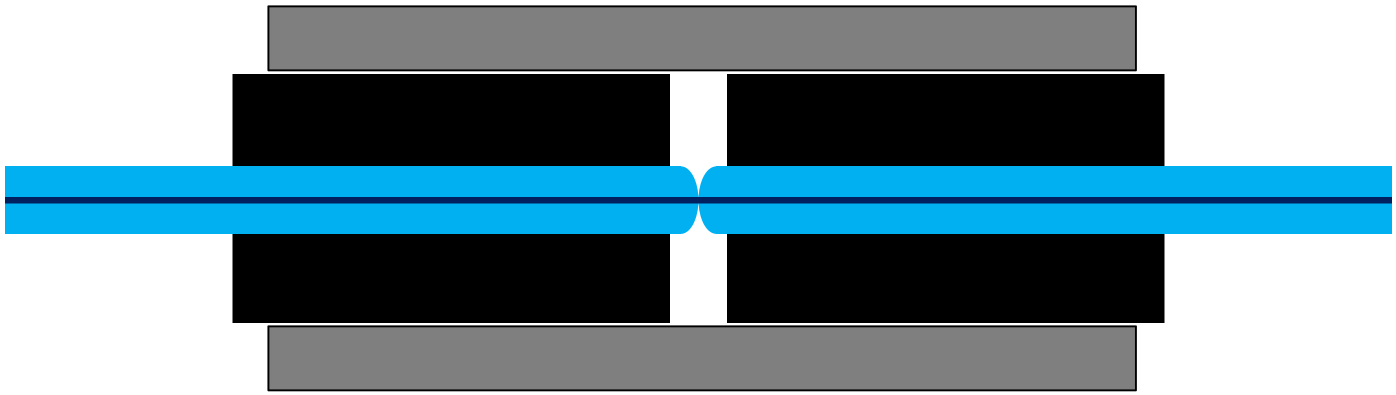
    Optical link impairments are ~ “distance independent”

Why NOT Switch to Optical?

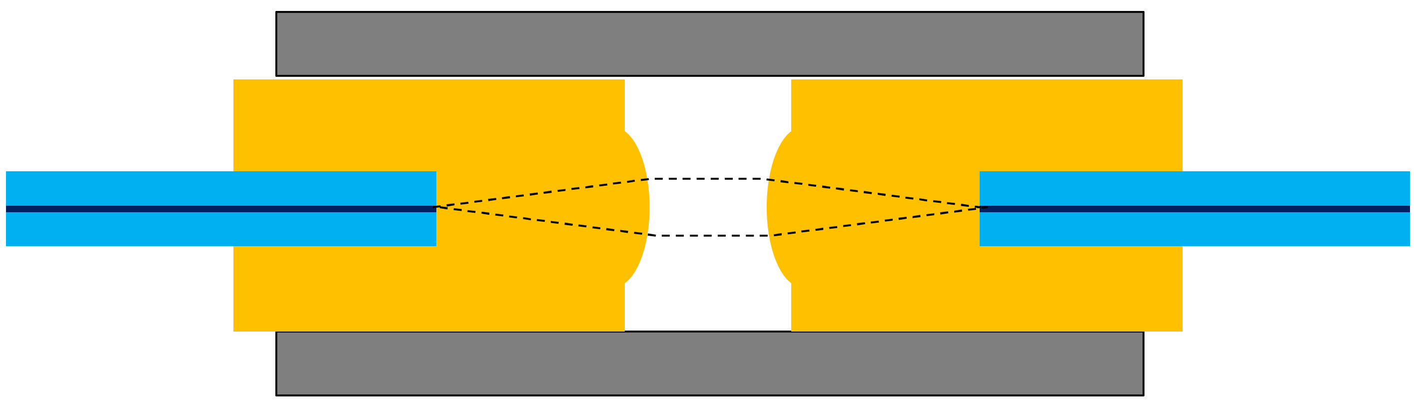
- Cost of components (TRX, optical connectors…)
- Precision required in optical connector components
- Labor-intensive PCB assembly process (plug-in modules; route & connect cables)
- Increased level of labor skill for installation and maintenance
- Reliability and maintenance concerns
- Cost/benefit ratio when viewed as complete "ecosystem"
- "Chicken-and-Egg" cost/volume scenario.
- 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…..**

Blue font = direct or indirect cost impact

What is an Expanded-Beam Connector?



Physical Contact Connector: 9 micron cores in optical contact



Expanded-Beam Connector: beam expanded to 80 microns; no contact.
Now need to address reflections at surfaces.

Benefits of Expanded-Beam Connectors

- Relaxed connector-to-connector requirements for precision in lateral mechanical alignment.
  - Beam size ~ 80μ instead of 9μ => 9x improvement
- Greater tolerance to debris; less cleaning.
  - Non-contact optical surfaces.
  - Smaller fraction of beam obscured by a particle.
- Lower mating force
  - No need for "physical contact" of optical cores.
  - Looser fit of alignment features
- Potential for lower-cost systems.

Note: Expanded-beam connector products are already commercially available for use with multimode fiber, but not single mode fiber.

Issues with Expanded-Beam Connectors

- **Expanded beam results in tighter <u>angular</u> alignment tolerances (wavelengths across beam area).**
  - **Typically easier to obtain than lateral alignment.**
- **Alignment of the fiber to the expanding optical element is NOT relaxed, so tight tolerances must still be held within each connector.**
  - **This can be difficult, if optics and fiber holder are made by parts of the mold that move relative to each other shot-to-shot.**
- **Additional optical elements/surfaces may add to loss.**
  - **Anti-reflection coatings may be required.**

What About MultiMode & VCSELs?

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 Δn SiPh waveguides.**
- **Connectors are easier (at least mechanical tolerances)**

Do we really need SM on board? YES, if we <u>assume</u>:

- **SiPh will deliver the lowest-cost transceivers per functionality.**
- **SiPh will scale better in bandwidth & density (WDM)**
- **We need our mid-board modules to connect to <u>distant</u> chassis.**

Project Introduction

- The iNEMI-IPSR-AIM Board Level Interconnect program originated in MIT MicroPhotonics Consortium Technology Working Group Discussions (T. Smith, J. MacWilliams).
- The high-level goal is to assess the technology benefits and issues of using **SM expanded-beam connector** interfaces in board-level optical interconnect, by building and testing systems using developmental parts.
- The program is divided into 3 major phases:
  - Phase I: SM Expanded-Beam Connectors for fiber-fiber connections.
  - Phases IIa and IIb: SM Expanded-Beam Connectors for fiber-module connections.
  - Phase III: SM Expanded-Beam Connectors for module-waveguide connections, for PCB-embedded waveguide technology.

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Background

- Project is aligned with AIM (American Institute for Manufacturing Integrated Photonics), iNEMI, MIT MicroPhotonics Consortium, and industrial roadmaps
- These roadmaps predict that silicon-photonics-based transceiver modules will provide the most cost-effective solutions for on-board interconnections in the future
- This is based on the expected reduction of optoelectronic chip cost to be achieved via leveraging of the CMOS silicon foundry infrastructure
- Before the anticipated cost benefits of silicon photonics can be realized, new high-performance and cost-effective solutions to optical packaging and connectorization must be developed
- Optimum performance and functionality from silicon photonics devices requires single mode (SM) fiber/waveguide interconnect media

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Background

- **Single mode operation requires precision (sub-micron) alignment in optical connections, both inside the package and in optical connectors; the tight mechanical tolerances needed in connector parts result in high-cost components with automated assembly and environmental reliability issues**

- **To address the need for improved SM connections, manufacturers have begun developing expanded-beam optical connectors, in which optical mode of the SM fiber (~ 10 microns diameter) is expanded to a larger collimated beam (e.g. 80 microns in diameter) thus relaxing mechanical alignment tolerances, and reducing the effects of physical mating and dust, etc.**

- **However, to date, expanded-beam versions of SM connectors have higher losses than desired by system designers, and thus have not yet been commercialized**

- **The overall goal of this project is to make early-phase expanded-beam connector "library elements" available to system developers, so they can assess the benefits of such connections in systems**

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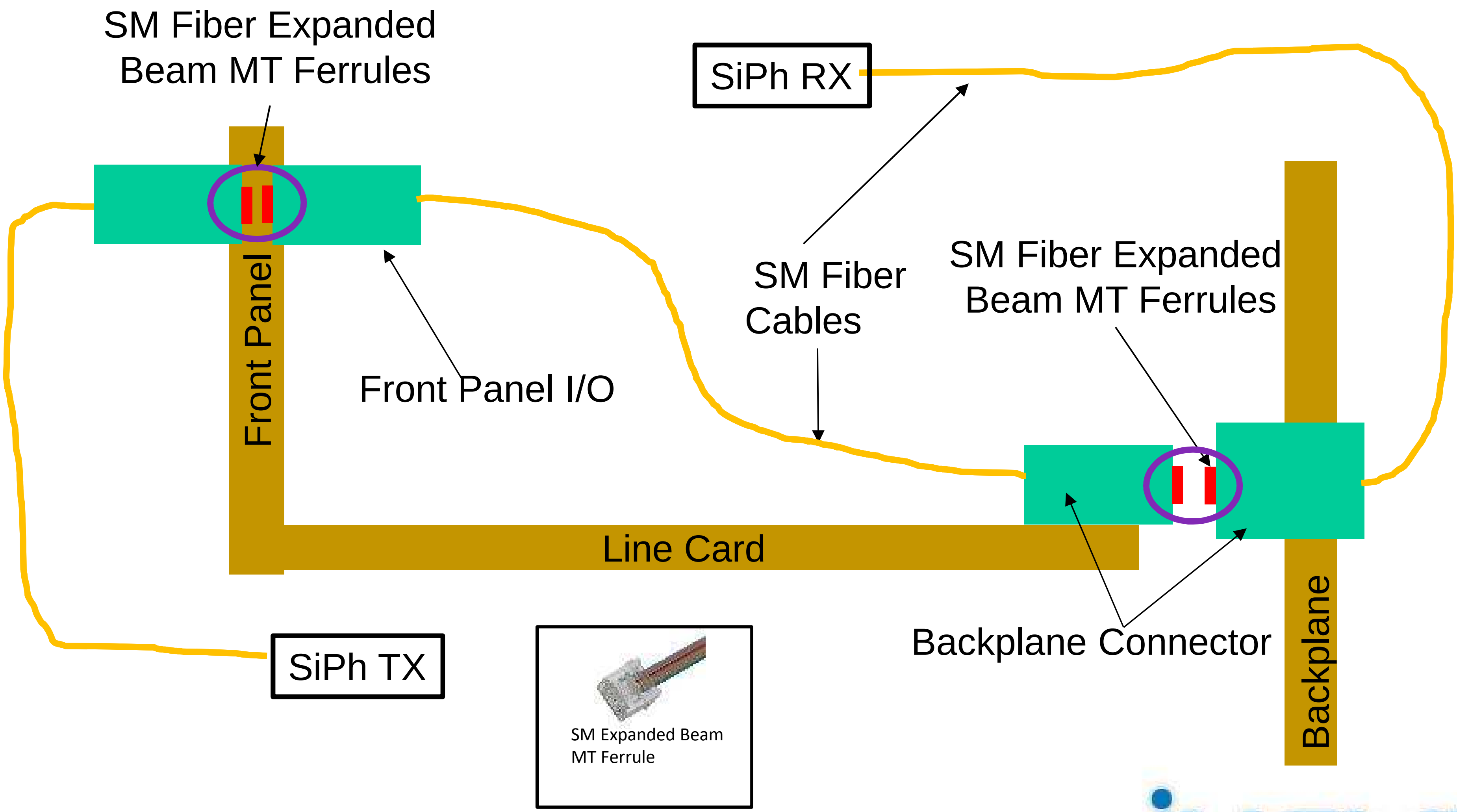
Phase I Demonstrator: High Level



IPSR Phase II: Expanded-beam Module Interface Project Purpose

- **Phase II of the AIM Photonics / iNEMI Board-Level Interconnect Demonstrator project will consist of specifying, designing, modeling, building and demonstrating a board-level optical interconnect system in which an expanded-beam optical connector interface will be developed for the chip module.**

- **Given the complexity of the challenge, and the time and cost associated with fabrication of specialized tooling for optical coupling parts, the Phase II effort is subdivided into 2 Sub-phases, IIa and IIb, each lasting approximately one year**

Each Sub-phase will be a separate iNEMI QuickTurn Project

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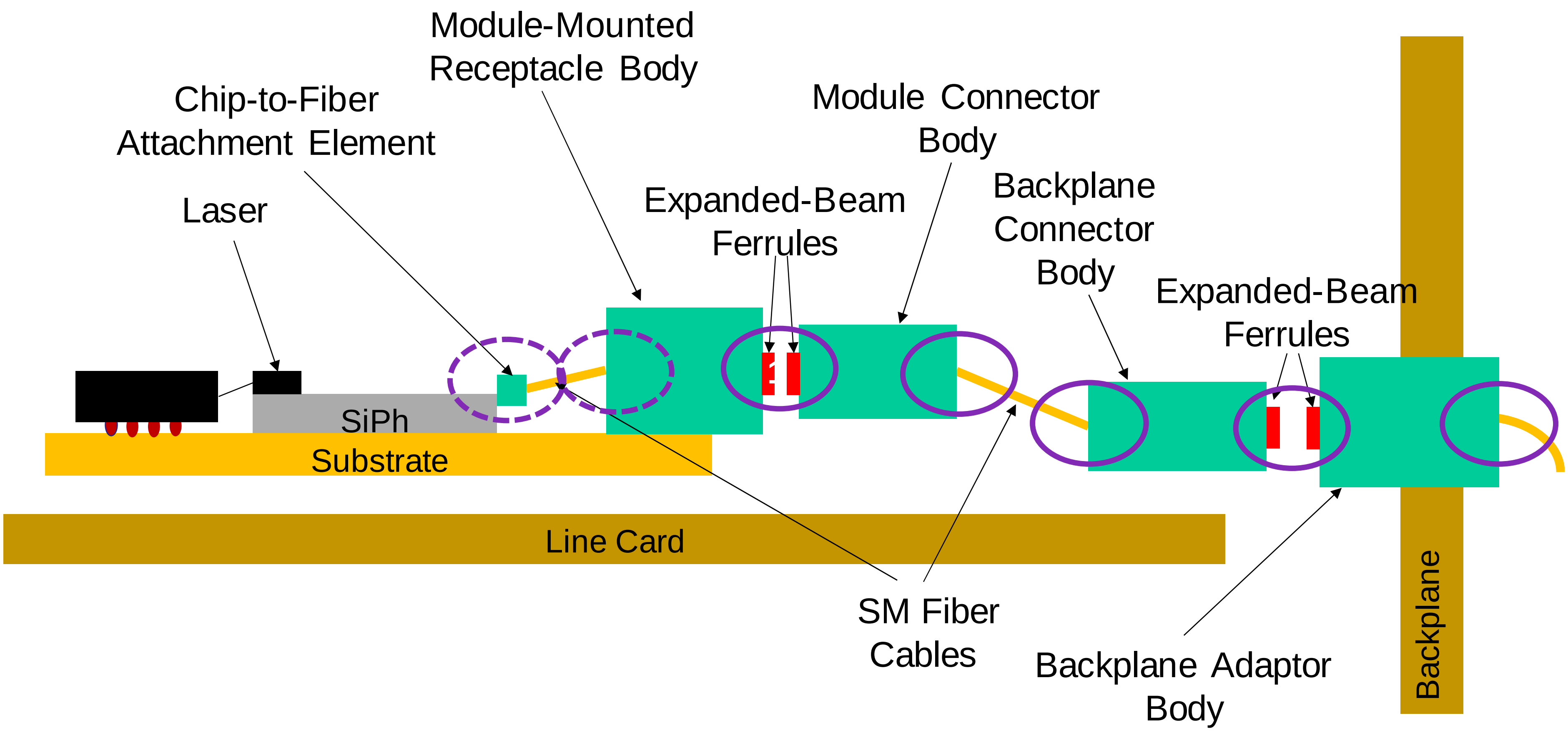
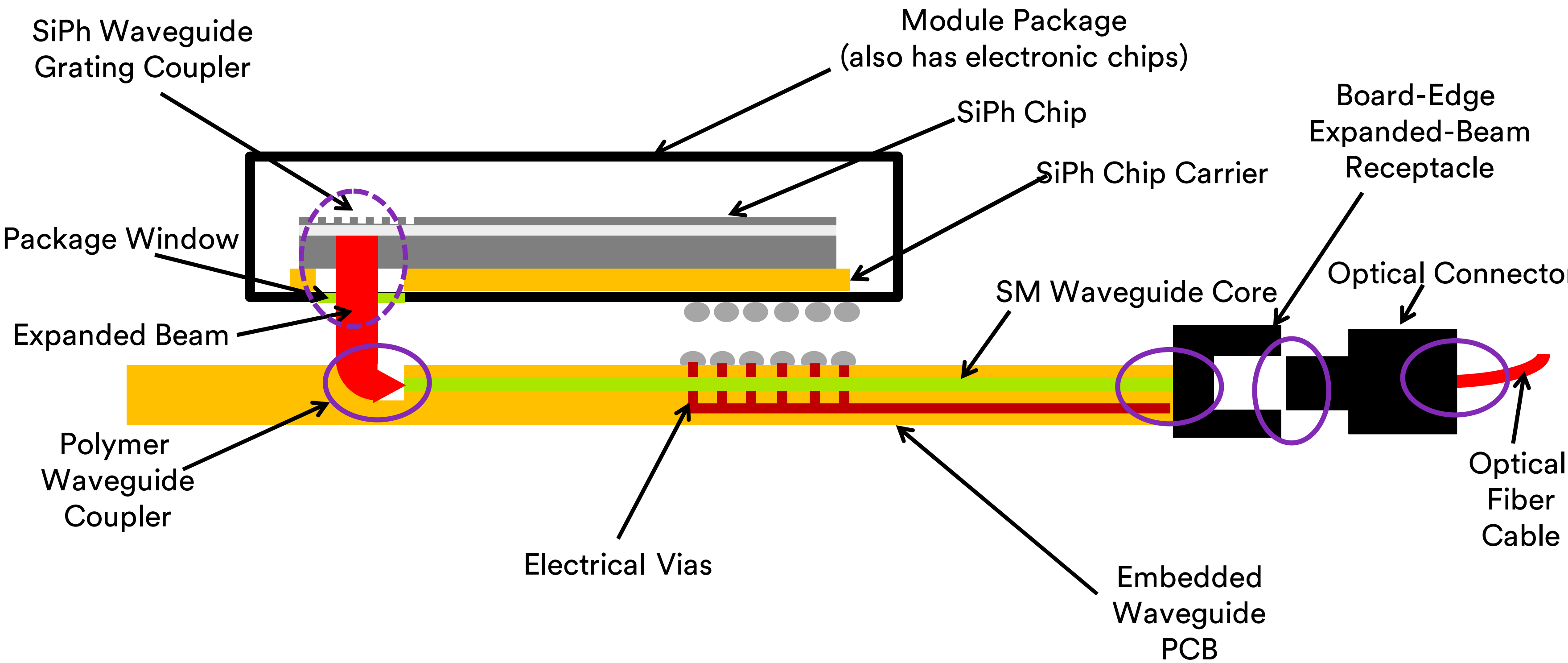
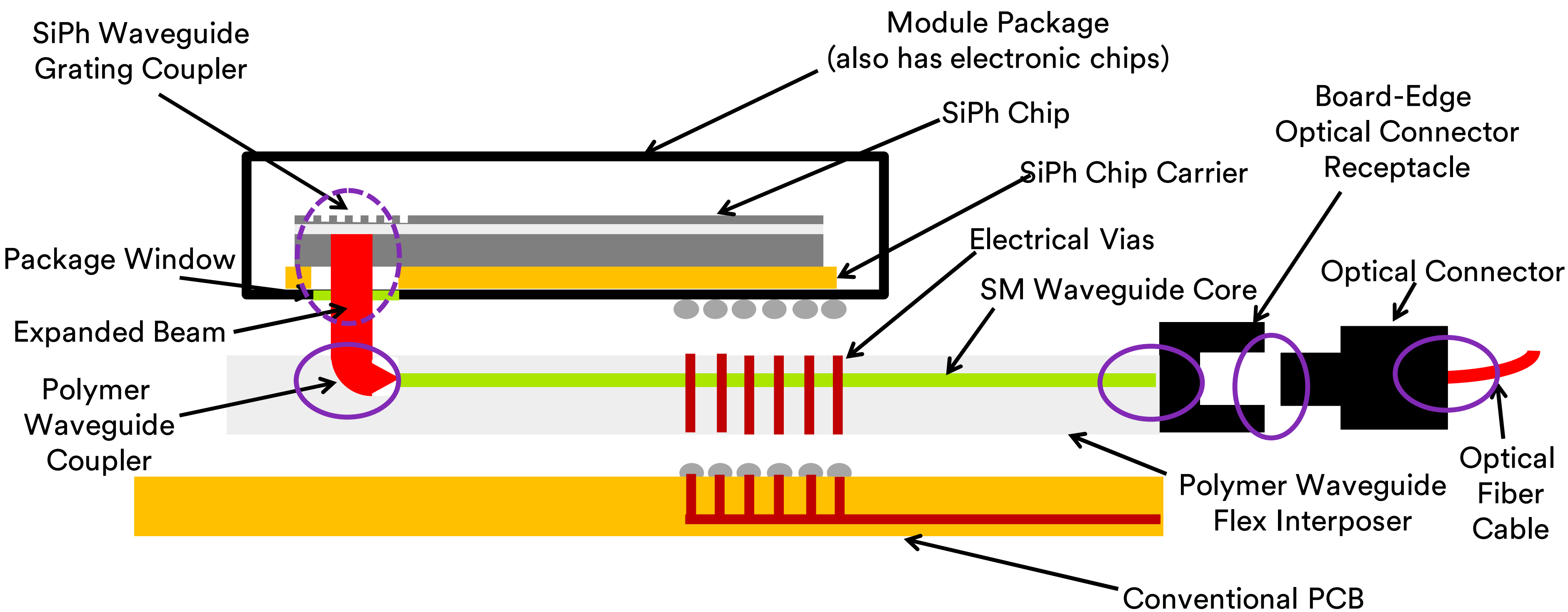
Phases II and IIa: Expanded-beam Module Demo



Phase III: Module & Optical PCB Demo



Phase III: Module & Optical Interposer



IS / IS NOT Analysis

This Project IS:	This Project IS NOT:
Board-Level Optical Interconnect Demonstration Program	
Meant to assess the technical feasibility of embryonic expanded-beam board-level interconnect technology in general, prior to any attempt at standardization.	Development of a specific standard(s)
The first attempt to determine the performance and economic viability of expanded-beam SM optical interconnect systems.	Repeat of prior or existing work
Mean to identify key barriers to board-level optical interconnect, to provide guidance to all interested component developers.	Biased towards specific suppliers, geographies, or market segments
Resourced primarily from in-kind contributions from committed participants who wish to become component suppliers.	Resourced predominantly by government funding.

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Additional Slides

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Project Purpose

- The purpose of the Phase II Project is to continue the assessment of technical and economic viability of expanded-beam connector interfaces for single-mode board-level optical interconnect, by building demonstration systems.
- Phase II will focus on the development and demonstration of expanded-beam pluggable connector interfaces for silicon photonics modules.
- At the end of Phase II, SM optical interconnection at 25 Gpbs/channel will be demonstrated between modules with expanded beam interfaces, through various numbers of expanded beam connectors.

Scope of Work

The exact scope of the work will depend on the participants willing to contribute components and labor, but will include procurement and/or development of the following technologies for a system demo:

1. Silicon photonic transmitter and receiver chips.

   Ideally, both vertical- and end-fire-coupling chips would be employed.

2. A module-mounted expanded-beam connector receptacle.
3. Components and processes for optically coupling the receptacle to the SiPh chip with low loss and minimal labor.
4. A connector and cable assembly for mating to the connector receptacle.
5. Expanded-beam single-mode frontplane/backplane connectors and mid-span connectors for use in system tests.

Phase I Deliverables

- Quantification of the performance achievable with singlemode expanded beam MT ferrules and silicon-photonics on-board interconnect
- Understanding of system tradeoffs in designing a silicon-photonics based on-board interconnect system
- Identification of component developments needed to fill gaps in the ecosystem of silicon-photonics-based on-board interconnect
- Build confidence for acceleration of the markets for associated silicon photonics transceivers, connector components, and fiber cables
- White Paper
- End of Project Webinar
- Phase 2 SOW Development

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