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Statement of Work (SOW)
iNEMI Optoelectronics TIG
IPSR Roadmapping Group
Quick-Turn
iNEMI-IPSR Board-Level Optical Interconnect Project

Version #1.1

Date: February 22, 2017

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Co-Project Leader:
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Basic Project Information

Scope of Work

Description of Work

The proposed work will consist of designing, assembling and testing a prototype on-board fiber optic interconnection system based on silicon photonic transceiver modules, single-mode fiber cables, and expanded-beam optical connectors for the package, backplane, and front-plane interfaces. The prototype will be based on 12-fiber ribbon fiber cables and 12-channel optical connectors, and will operate at 25 Gbps channel rate. Existing technologies will be leveraged wherever possible to allow a system demonstration to be performed in the shortest possible timeframe.

The work proposed here will comprise the First Phase of the On-Board Optical Interconnect Technology Demonstration Project. The Second Phase, to be undertaken after completion of the First Phase, will investigate the use of PCB-embedded waveguides to replace fly-over fiber cables.

Major Goals

Major goals of the project include:

- Demonstration of a connectorized silicon photonics transceiver package with an expanded-beam interface.

- Demonstration of expanded beam connectors for mating ribbon cables to the transceiver module, and for backplane and front-plane connections.
- Integrating the system components into a demonstration system transmitting data at 25 Gbps per channel between two blades mounted on a backplane.
- Characterization of the performance of the prototype system, including assessments of signal integrity, loss budget, connector loss, connector mating force, etc.
- Characterization of environmental degradation effects on the system performance, including temperature, humidity, and dust testing.
- Identification and documentation of key challenges in performance, manufacturing and cost of product systems based on the technology, as revealed via the prototype.

Timeframe

The work plan is designed to deliver a functional and tested on-board interconnect system, along with documentation regarding performance and major findings within 12 months from the start of the project.

Purpose of Project

Alignment with Roadmap

This project is well aligned with AIM, 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.

However, 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. This is because obtaining optimum performance and functionality from silicon photonics devices requires single mode (SM) operation. 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. Costs associated with packaging and connectorization currently dominate the manufacturing cost of short-distance interconnects, and are inhibiting commercial implementation of such systems.

To address the need for lower-cost SM connections, manufacturers have begun developing expanded-beam optical connectors. In these connectors, the optical mode of the SM fiber (~ 10 microns diameter) is expanded to a larger collimated beam (e.g. 80 microns in diameter) thus relaxing the alignment tolerance between connector elements from submicron to a few microns...tolerances that can be held in injection molded parts. Furthermore, the use of expanded-beam connectors offers the added benefit of improved tolerance to contamination of the optical interface with dust. However, to date, expanded-beam versions of SM connectors have higher losses than desired by system designers, and thus have not been commercialized.

The project being proposed here will assess the system-level benefits and issues associated with SM expanded beam coupling for on-board interconnect, allowing the industry to properly prioritize component development required to accelerate the silicon-photonics-implementation inherent in the roadmaps.

Anticipated Benefits to Participants, IPSR and Photonics Industry

Key benefits of the successful completion of the proposed project will include:

- Quantification of the performance achievable with silicon-photonics based 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.
- Improvement of public understanding of the benefits, issues and timing of silicon photonics implementation.
- Acceleration of the markets for associated silicon photonics transceivers, connector components, and fiber cables.

Previous Related Work

Industrial Development

Expanded beam connectors for applications in multi-mode (MM) fiber interconnect systems have been developed by several companies in recent years. Key developers have included US Conec, Molex, and TE Connectivity [references]. Expanded beam MM connector products such as the PRIZM MT ferrule offered by US Conec are commercially available.

To date, SM versions of expanded beam connectors suitable for multi-fiber connectors have not been commercialized, although they are being aggressively pursued by connector suppliers such as US Conec and Molex. This is largely due to the difficulty of molding low-cost plastic elements to the tolerances required for SM operation. Specifically, maintaining adequately-precise alignment between the SM optical fiber and the beam expanding element in a low-cost, high-volume injection-molded connector ferrule to achieve low loss has been elusive. [Note that for premium-priced components meant for single-channel connections, e.g. in military or avionics applications, SM expanded beam connectors based on metal or ceramic mechanics and glass micro-optics are available...but these are not suitable for the cost-sensitive multi-fiber applications being discussed herein.]

Academic Research

There has been very little recent academic research devoted to optical connector design. The primary focus of academics in this general field is in the area of the silicon photonics devices and chips. Overlap with the connectorization issue is primarily associated with the development of waveguide coupling features on the chips to make coupling the chip to a waveguide of fiber interface inside the package simpler or lower loss.

Prospective Participants

Affiliation	*Participant*	*Title*	*Proposed Contributions*
Molex	Tom Marrapode, IPSR Project Leader	Director of Advanced Technology Development	- Interconnects; backplane, front panel, I/O and cables - Prototype single mode expanded beam MT ferrules
Celestica	Tatiana Berdinskikh	Principal Optical Engineer	Rack Hardware
Juniper Networks	Bo Zhang Valery Kugel	Distinguished Engineer	Link test procedures and performance evaluation
Macom	Richard Grzybowski	Director of Research & Development	- SiPh CWDM TX with pigtailed fiber on evaluation board - HS photodetector - In-house testing
US Conec	Darrel Childers Sharon Lutz	Director of Development	Prototype single mode expanded beam MT ferrules. Interconnects; backplane, front panel, I/O
MRSI Systems	Yi Qian	VP Product Management	Develop proper tool requirements and prototypes in the future phases. Assess process design for manufacturing, manufacturing costs, and high volume automation tool needs.
Rochester Institute of Technology	Drew Maywar	Associate Professor	Test Process
University of Rochester	Tom Brown	Professor	Observer
3M Company	Terry Smith	Senior Staff Scientist	Organizer-Planning for next phases
US Competitors	John Mac Williams	Principle	Advisor-Planning for next phases
MIT	Kazumi Wada	Professor	Advisor-Planning for next phases
IPSR	Robert Pfahl	Director of Roadmapping	Facilitator-Planning for next phases

Project Plan

Phase 1 – Detailed Information

Schedule with Milestones

Project Work Plan

Timeline	*Milestones*	*Deliverables*	*Success Criteria*
1Q	Mechanical design	Overall design completed Testing plan completed	Detailed schematic published
1Q	Hardware collection	All required hardware identified	BOM set.
1Q	Chassis build	Cards and chassis completed	Ready for mechanical assembly
2Q	Passive interconnect assembly	All interconnect assembled	Ready for passive link test
2Q	Link integration	Delivery to link test facility	Ready for preliminary testing
2Q	Link debug	Full link debugged	Link ready for testing
3Q	Link testing	Data collection	Data collection
3Q	Link testing	Data collection	Data collection
3Q	Link testing	Data collection	Data collection
4Q	Reporting	Reporting	Reporting
4Q	Reporting	Reporting	Reporting
4Q	Project completion	Data analyzed and reported	Publishable report

Specific component and system characterizations to be performed include:

- Connector loss
- Wavelength dependence of connector loss
- Connector return loss
- Connector polarization-dependent loss
- Connector re-mating loss variation
- Dust contamination induced connector loss (Test TBD)
- Telcordia GR-1435 Uncontrolled Environment Thermal Aging, Humidity Aging, Thermal Cycling, and Humidity/Condensation Cycling testing
- Signal Bit Error Rate vs. connector number and loss (25 Gbps/channel)
- Estimated system implementation cost

Testing Procedures:

- State anticipated number of parts to be tested. Use discrimination in choosing samples for failure analysis to maximize ROI.
- Use IPC 9701 0-100C as baseline ATC unless justification can be given for alternate test parameters

- For test vehicle design and fabrication, it is recommended that reference components that have been ATC tested on previous projects be used to provide a baseline and facilitate comparison of results between projects.
- Explain design protocol. Use standard design practices and commonly used software to reduce costs and widen applicability of results.
- At what stages testing will be done and time needed

Schedule with Milestones

		Q1			Q2			Q3			Q4			Q5			Q6
Phase 1																	
Task 1 - Confirm Contributors and plan																	
Task 2 - Manufacture and Assemble																	
Task 3 - Assemble and Pre test - Debug																	
Task 4 – Test – Data Collection																	
Juniper Site																	
Macom Site																	
Task 5 - Data Analysis																	
Task 6 - Develop Report																	
Task 7 - Phase II SOW Development End of Project Webinar																	
Phase 2							TENTATIVE (18 months)										
Phase 3							TENTATIVE (18 months)										
…							TENTATIVE (18 months)										

Project monitoring plans

- Planned teleconference schedule
- Request progress reports as tasks are completed
- Dates of technical reviews (2 per year) and progress reports and what they will contain
- Practice risk analysis by anticipating problems and having alternate solutions ready

- Use opportunity analysis to identify new areas or topics that might be addressed in additional projects. This will prevent the scope of the current project from expanding and keep the project focused on original goals
- Review project requirements with suppliers before the project begins

Outcome of the project

Definition of Project Success
Specific benefits of the successful completion of the proposed project will include:

- Quantification of the performance achievable with silicon-photonics based 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;
- Acceleration of the markets for associated silicon photonics transceivers, connector components, and fiber cables; and
- Improvement of public understanding of the benefits, issues, and timing of silicon photonics implementation.
- Success of the program is defined as identification of key technology elements required for commercialization of a system operating at 25 Gbps. Successful completion of this Phase I project requires participation by organizations that can provide the needed parts and processes. Define project success, including what gaps will be closed

Deliverables:

- Quantification of the performance achievable with silicon-photonics based 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;
- Acceleration of the markets for associated silicon photonics transceivers, connector components, and fiber cables; and
- White Paper
- End of Project Webinar
- Phase 2 SOW Development