What is an Application Interest Group (AIG)?

Link to webinar recording (available for up to six months after webinar): http://bit.ly/2pZKasf

Dr. Robert C. Pfahl
Director of Roadmapping

March 22, 2018
AIM Photonics Webinar

Sponsors & Participants

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AIM photonics

Lead Participants

the MicrophotonicsCenter @MIT

iNEMI International Electronics Manufacturing Initiative

Webinar: What is an Application Interest Group?

AIM Photonics is creating Application Interest Groups (AIGs) to develop pragmatic, chip-based solutions for leading-edge applications. This webinar will explain the role of AIGs in developing a consensus and a plan for technology implementation, including a statement of work (SOW) for project development. It will also discuss the links among the Integrated Photonic Systems Roadmap (IPSR), technical plans, and AIGs that can be formed to address the gaps that the roadmap identifies.

2018 IPSR AIG Goals

– Document and Implement a technical planning process to develop additional AIG projects that address strategic gaps that AIM members see as critical

– Launch application interest groups (AIGs) to execute these critical projects

IPSR Roadmap

Participation as of November 2017

- 17 Countries,
- 926 Individuals,
- 308 Organizations

2016 Roadmap is available at
www.photonicsmanufacturing.org

2017 Update will be available shortly

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Steps in IPSR Roadmapping Process

1. Scope and Analyze the Situation
   1. **Market (Applications)**
   2. Technology
2. Identify the Needs and Grand Challenges
   1. Design Tools
   2. Training of Designers
   3. Manufacturing Technologies
   4. Materials
   5. Component Technology
   6. Standards Development
   7. Intellectual Property Protection
   8. Security and Information Management
3. Identify Paradigm Shifts and Strategic Concerns
4. Develop Strategic Recommendations for all Stakeholders
   1. Design Tools
   2. Manufacturing Technology
   3. Materials Development
   4. Supply Chain Development through "Industry Standards"
5. Provide these recommendations to AIM Photonics and other organizations to aid in focusing and prioritizing their Technical Plans for Research and Development

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The Technology Needs Differ by Market Segment and Application

Data Center Product

- Data center servers require heterogeneous integration of memory, logic, power controllers and photonics in 3D-SiP package architecture to meet applications requirements in a controlled environment.
- The solution selected must provide for packaging of replacements for existing "top of rack" components.
- These solutions must include SiP based traffic analysis supporting data path switching decisions, selecting between photonic and electronic data paths and between packet switching and circuit switching.

Photonics for the Internet of Things

- The internet of things (IoT) will require a package for heterogeneous integration of sensors, RF components, memory and photonics in 3D-SiP architectures.
- The package must enable a general purpose SiP IoT hub packaging for environments that may not be well controlled.
- This capability will include energy scavenging to power the IoT hub in many cases and redundancy to ensure long term service free reliability.

Product "Emulators" are Used To Drive Technology Requirements

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Benefits of Roadmapping

- Anticipate technology trends and paradigm shifts
- Collaborate with key players, industry experts, suppliers and customers, globally – in all major markets
- Obtain access to learning and knowledge experts
- Develop consensus for next steps

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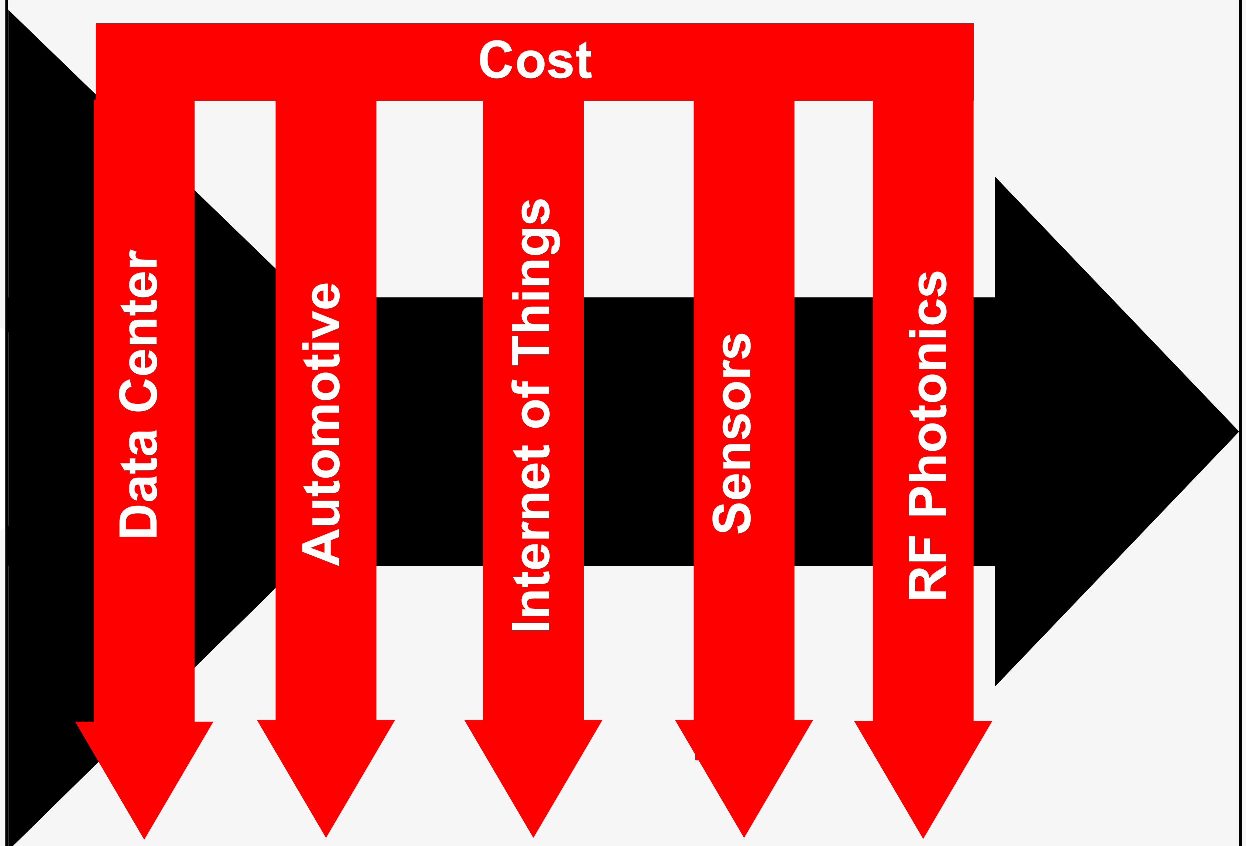
2018 IPSR Roadmap-TWGs and PEGs

TWGs

1. Monolithic Integration
2. Packaging of Integrated Silicon Photonics
3. Connectors
4. Substrates
5. Assembly
6. Test
7. Electronic-Photonic Design Automation
8. Photonic Sensors

Product Emulator Groups



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Strategic Recommendations from the 2017 IPSR Roadmap

Driving Photonics Manufacturing

Strategic Recommendation 2015-2020

- **Focus Projects on Addressing the Grand Challenges**
  - Reduction in Power per function
  - Reduction in Cost
  - Decrease Latency
  - Increased physical bandwidth density
- **Address challenges that the supply chain will not achieve in time to address the quantified industrial needs in the IPSR Roadmap**
  - Design Tools
  - Manufacturing Technology
  - Materials Development
  - Supply Chain Consolidation through "Industry Standards"

Difference Between a Roadmap & a Technical Plan

Roadmaps

- Open to Industry
- Cover Entire Infrastructure
- Developed by TWGs

Gap Analysis-The Bridge Between Roadmaps and Action

Technical Plans

- Open to Members or Potential Participants
- Focus on High Priority Application Interests that will benefit from consortial efforts
- Application Interest Groups develop Technical Plans

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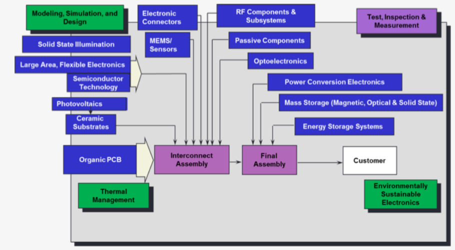
IPSR Roadmapping and Technical Planning Methodology



Roadmapping

IPSR System Plan

⬇

Product Sector Needs (PEGs)
Technology Roadmaps (TWGs)

⬇

Integrated Photonic Systems Roadmap

⬇

IPSR Gap Analysis

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Technical Plan

⬇

Projects

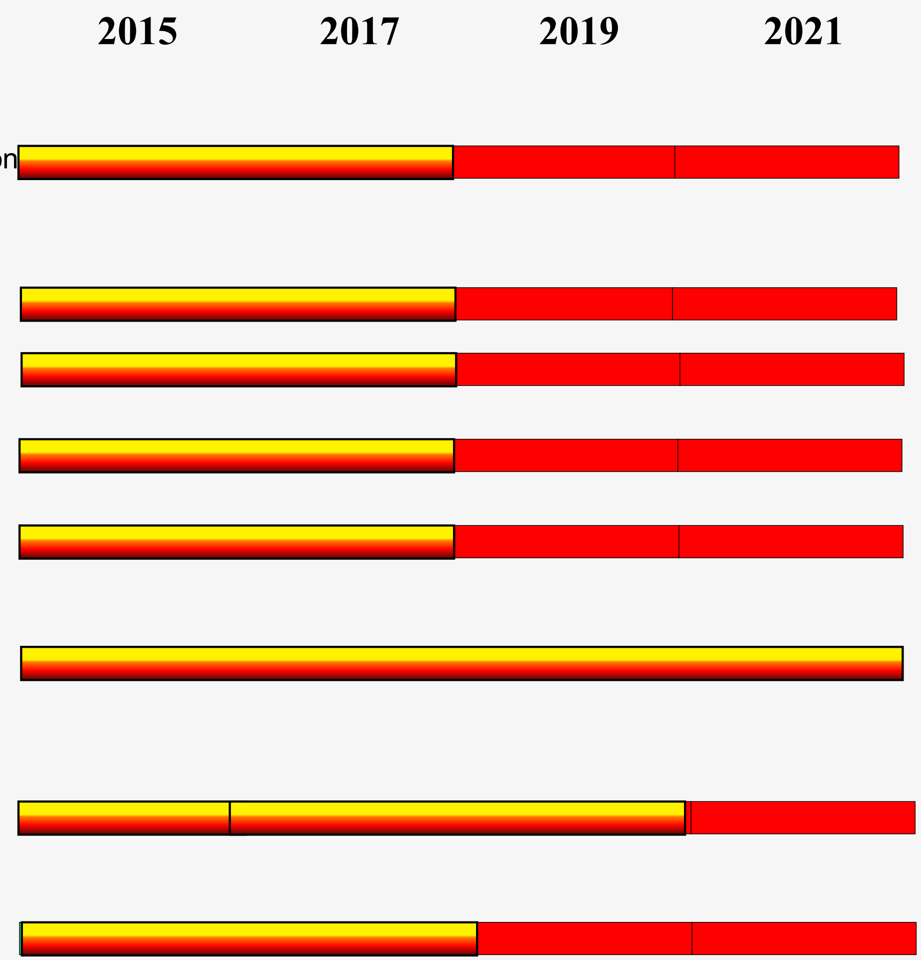
Technical Planning

Developing a Technical Plan

Driving Photonics Manufacturing

Step 1: Prioritized Gap List

Optoelectronics Technology Gaps



Tactical Gaps

Low cost technology to passively align SM components to sub micron accuracy and retain that accuracy through the manufacturing process, test regime and commercial life cycle of the product.

Low cost multiplexing methods.

Higher speed (100Gb/s and up) transceivers.

Cost effective technical solution to replace copper with optical in backplanes.

Methods to transmit more data through fiber.

Development of cleanliness specification for expanded beam connector.

A major need to implement Backplane, On-Card, In-to and Out of package, and On-Chip optical data transmission is a source of photons that can be modulated at the 10's of Gb/s rates required.

High performance, low cost, low/high density flexibility, loose initial - but tight final tolerance, dust tolerant blind mate connector with similar mechanical performance of electrical interface connectors.

White = Manufacturable solutions exist, and are being optimized
Yellow = Manufacturable solutions are known
Yellow/Red = Interim solutions are known
Red = Manufacturable solutions are NOT known

Step 2: Gap Analysis

Required to close gap	Suggested Action
Supply Chain Addressing anticipated gaps	

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Champion a Solution for gap	Establish Consortium or Standards Body

Step 2: Gap Analysis

Required to close gap	Suggested Action
Supply Chain Addressing anticipated gaps	
Investment from Supply Chain	Need publicized in IPSR-Roadmap
Champion a Solution for gap	Establish Consortium or Standards Body
Key gap to establish market	Initiate R&D consortium Project-iNEMI, HDPUG

Step 2: Gap Analysis

Required to close gap	Suggested Action
Supply Chain Addressing anticipated gaps	
Investment from Supply Chain	Gap publicized in IPSR-Roadmap
Champion a Solution for gap	Establish Consortium or Standards Body
Key gap to establish market	Initiate R&D consortium Project-iNEMI, HDPUG
Significant resources and Investment	Initiate AIM Photonics Project
	Vertical Integration

Step 3: Develop Phased Implementation Plan

The Implementation Plan outlines a portfolio of activities to address the identified gaps:

- Research & Development
- Technology Deployment
- Required Attributes
- Drivers

Drivers - Cost reductions - Bandwidth increase- High speed applications (40G/100G) - Rack-to-Rack Applications (Active Cables) - Component Integration - Power reduction - Standardization - Tunability - FTTX - – Faster Manufacturing - Circuit Density -

2015

Attributes

Reduced power

Tunability – 32 wavelengths in single module (C & L Bands)

Data rate – 100G/s / 400G/s

Spectral efficiency

Modulation formats (100G/s /400G/s

Deployed Technology

100G Data speed (CFP2/CFP4)

Tunable (XFP, SFP+, CFP)

100G Test & Meas.

Active Cables (40G)

Optical Backplane / Waveguides-limited

Research /Development

Active Cables (>40G)

Optics – On Chip/Off Chip

Optical Backplane / Waveguides

400G Data speed (parallel)

Lens cleanliness standards

Multi-core, Multi-mode fiber

Integrated photonics

2017

Attributes

Reduced power

Tunability > 32 wavelengths in single module (C & L Bands)

Single Mode fiber use in backplanes

Data rate - 400G/s / 1Tb/s

Spectral efficiency

Modulation format (400G/s / 1Tb/s)

Deployed Technology

400G Data speed

Tunable (XFP, SFP+, CFP)

400G Test & Meas.

Active Cables (>40G)

Optical Backplane / Waveguides

Optics – On Chip/Off

Research /Development

Active Cables (100G)

>100G Data speed (serial)

Terabit Ethernet (Multi Chan.)

Lens Cleanliness Standards

Multi-core fiber & Multi-mode transmission)

Single Mode fiber use in backplanes throughout data center

Integrated photonics, Si Photonics

2019

Attributes

Reduced power

Data rate – 10Tb/s

System capacity- 1 Pb/s

Spectral efficiency – 20 (bit/s)/Hz

Modulation format (10 Tb/s)

Deployed Technology

1Tb/s Data speed- limited

Multi-core fiber and Multi-mode transmission limited

Single Mode fiber from backplane throughout data center

Optical Backplane / Waveguides

Integrated photonics

Silicon photonics

Research /Development

TBD

On-chip server photonics and electronics converged

2021

Attributes

Reduced power

Data rate – 10Tb/s and beyond

System capacity- beyond 1 Pb/s

Spectral efficiency – 20 (bit/s)/Hz

Modulation format (10 Tb/s)

Deployed Technology

1Tb/s Data speed

Multi-core fiber and Multi-mode transmission limited

Optical Backplane / Waveguides

Integrated photonics

Silicon Photonics

Research /Development

TBD

On-chip server photonics and electronics converged

Optoelectronics Technology Gaps

Step 4: Funding of Consortial Projects for Closing Gaps

- Participants must be members of a Consortial Organization
  - Public-Private Partnership with Government Funding, Membership Fees and in kind contributions from Members: **AIM Photonics**
  - Industrial Consortia with membership fees to manage the organization and projects. Projects are funded by members through in kind or cash contributions: **iNEMI and HDPUG**

Management of Consortial Projects for Closing Gaps

- Management Organization
  - Executes precompetitive research registration
  - Manages Intellectual Property Agreements
  - Facilitates development of Project Statements of Work (SOW)
  - Manages Project Execution Agreements
  - Manages Publication Agreements
  - Manages Project Meetings and Project Schedule

Motivation to Participate in Collaborative Projects

- **Reduce Technology Risk During Product Development & Introduction**
  - Reliability – Avoid the negative impact of poor reliability
  - Source of supply – Avoid being late to being late to market

- **Reduce Cost by leveraging resources**
  - Reduce resource demands and investments for each company.
  - Ensure technology readiness when required.
  - Obtain cost reduction through collaboration, can be 8X to 20X on key projects

IPSR Technical Plan and AIGs

- Create five-year plans for the major interest areas that define the projects and activities deemed necessary to close the identified gaps. These plans become the strategic basis for the formation of projects.

- Application Implementation Groups (AIGs) Create the plans
  - A subset of the Roadmap TWGs and PEGs
  - The IPSR TWG Leadership Group and AIM Photonics Technical Committee suggest areas for AIGs.
  - IPSR Facilitates the Development of AIGs and Guides their Development of their Statements of Work.
  - Participants in the process must be evaluating project membership

The Project Roles of IPSR

- Ensure selected projects are aligned to the IPSR roadmap
- Select topics that generate significant interest
  - IPSR Project Formation Process http://photonicsmanufacturing.org/news/how-projects-are-formed
- Organizes and facilitate development of projects

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The First AIG
Board Level Optical Interconnect

Driving Photonics Manufacturing

Technical Plan for Board-Level Optical Interconnect

- **A Three Phase Technical Plan was the result of looking for "low-hanging fruit" at the 2016 IPSR Spring Meeting.**
  - The discussions started with the Interconnection TWG lead by John MacWilliams
  - A small group met weekly to develop a Statement of Work (SOW) for an industry led project.
  - As discussions progressed, more short terms needs have been identified that must be addressed if single mode expanded beam connectors are to be implemented in high volume.
  - High volume is necessary to achieve cost objectives.

AIM photonics Academy

Application Interest Group (AIG)

Board-Level Optical Interconnect

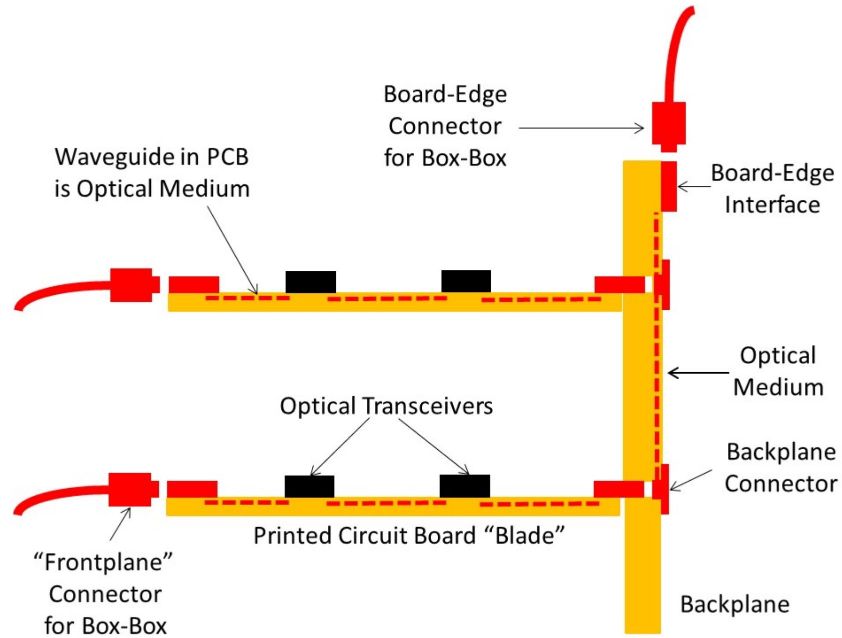
IPSR Integrated Photonic Systems Roadmap | iNEMI International Electronics Manufacturing Initiative | MIT

AIG Vision: Build a diverse team (industry, academia, government) to assess technical and economic issues associated with expanded-beam interconnects for SM board-level optical interconnect, compatible with silicon photonics and other PICs. Build and characterize prototype interconnect systems to identify key technology gaps.

Show stoppers:

- **Understanding of the benefits of expanded-beam connectors in SM fiber communication systems.**
- **Understanding of system trade-offs between loss and relaxed alignment or improved dust resistance.**
- **Understanding of trade-offs between connector loss and overall system cost and reliability.**
- **Lack of technology for low-loss PCB-embedded waveguides operating at ~ 1300 and 1550nm.**
- **Lack of technology for coupling SM optics from PIC modules to embedded waveguides.**

Ultimate Goal: SM Interconnect at Board Level, using waveguides embedded in the PCB.



Approach (within a team):

Phase I (12 months)

- **Demonstrate and characterize SM backplane and front-plane expanded-beam connectors.**

Phase IIa (12 months):

- **Model & design expanded beam interface for modules**
- **Specify and acquire resources for building demonstration modules with expanded-beam interfaces.**

Phase IIb (12 months):

- **Build and test prototype modules with expanded-beam interfaces in a demonstration system.**
- **Develop Phase III Statement of Work**

Phase III (12 months, est.):

- **Demonstrate board-level interconnect with expanded-beam interface to PCB- embedded waveguides.**

Advantages to joining an AIG:

1) **Leverage IPSR roadmapping activities for pre-competitive research**
2) **Build horizontal and vertical integration partnerships**
3) **Work towards industry standard solutions**
4) **Builds competitive advantage to early products**

Contact:

Dr. Terry Smith (tlsmith@mmm.com),
Tom Marrapode (Tom.Marrapode@molex.com

Phase 1 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	Valery Kugel	Distinguished Engineer	Link test parameters and performance evaluation In house testing
US Conec	Darrel Childers Sharon Lutz	Director of Development Product Manager	Prototype single mode expanded beam MT ferrules. Interconnects; backplane, front panel, I/O
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
Senko	Tiger Ninomiya	Business Development	Observer
IPSR	Robert Pfahl	Director of Roadmapping	Facilitator-Planning for next phases

IPSR Application Interest Groups

AIM Photonics is creating Application Interest Groups (AIGs) to develop pragmatic, chip-based solutions for leading-edge applications.

Application Interest Group (AIG)

Multi-Terabit Transceiver for Datacom

AIG Vision: Build a diverse team (industry, academia, government) to

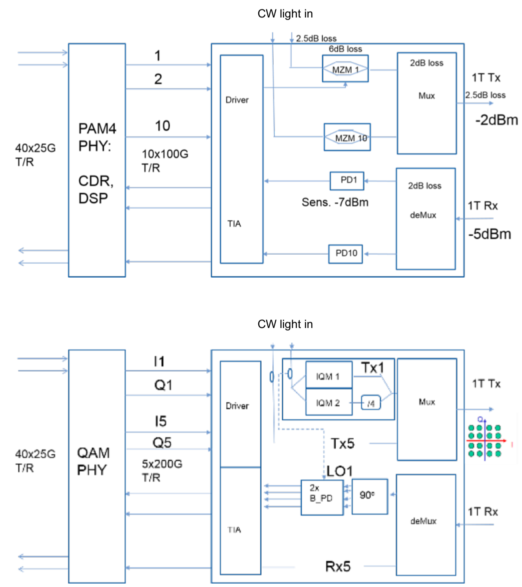
(a) identify technology gaps limiting commercialization of ultra-high bandwidth photonic integrated receivers
(b) propose and prototype solutions

Show stoppers:

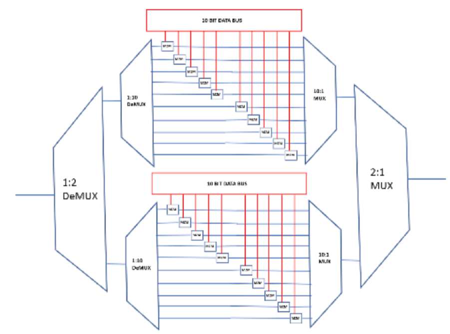
- Quantitative analysis of trade-offs:
  - Power
  - Cost
  - Dimensions
  - Scalability
- Device trade-offs:
  - Modulators
  - Light sources
- Subsystem trade-offs:
  - Devices with modulation formats
- Packaging issues:
  - Fiber coupling
  - CMOS integration

Multi-Terabit transceiver options: trade-offs in cost, energy, risk

PAM4/QAM solutions:



Dense photonics integration (NRZ solution)



Approach (within a team):

Phase I (6 months):

- Assess state of the art
- Define required specs and metrics
- Identify show stopping technology gaps

Phase II (6 months):

- Device and system design

Phase III (6 months):

- Prototyping (MPW, etc)

Identify role for each participant (each participant adds unique value)

Advantages to joining an AIG:

1) Leverage IPSR roadmapping activities for pre-competitive research
2) Build horizontal and vertical integration partnerships
3) Work towards industry standard solutions
4) Builds competitive advantage to early products

Contact: Dr. Madeleine Glick, 617 253 3227, mglick@mit.edu

AIM photonics Academy

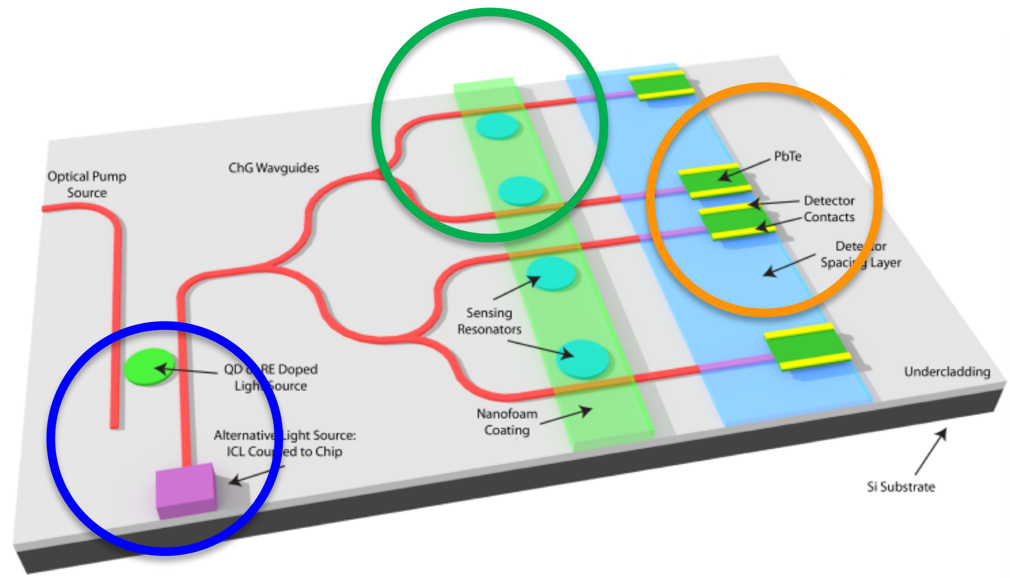
Application Interest Group (AIG)
Mid-range IR Photonic Sensors

IPSR Integrated Photonic Systems Roadmap

AIG Vision: **Build a diverse team (industries, academia, government etc.) to**
(a) identify important show-stoppers in CMOS-integrated mid-infrared chemical sensing technology; and (b) find appropriate solutions

Show stoppers:
1) **On-chip MIR components:**
   1) **Low-loss waveguides**
   2) **Light source**
   3) **Spectrometer**
   4) **Detector**
2) **Packaging**
   1) **Analyte delivery to sensing element**
   2) **Fiber-chip pigtailing**
   3) **On-chip and chip-chip coupling**

Integrated mid-infrared chemical sensor chip



Approach (within a team):
1) **Select a single show-stopper**
2) **Come up with several possible solutions**
3) **Downselect to a final solution**
4) **Identify role for each participant** (participating company should add value)
5) **Design, Fabricate and Test**
6) **Iterate till functional prototype is obtained**
7) **Optimize if necessary**

Advantages to joining an AIG:

1) **Be the trend-setter – first to market with products**
2) **Find an industry standardized solution**
3) **Horizontal and vertical integration already exists due to collaboration with diverse partners**

Contact: Dr. Anu Agarwal, 617 253 5302, anu@mit.edu

Application Interest Group (AIG)
CMOS-3D Integrated Imager

AIG Vision: Build a diverse team (industries, academia, government etc.) to; (a) Identify show-stoppers in CMOS-integrated LiDAR technology, and (b) find appropriate solutions.

Show stoppers of 3D imager:

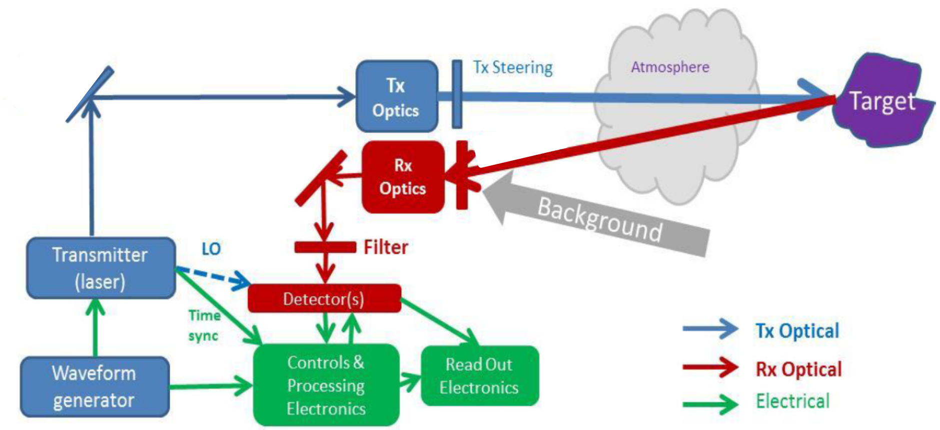
1) Specification:
- **x-y, z, t, and resolution**

2) Device:
- **Light source (Wavelength and modulation mechanism)**
- **Imager (scanner/telescope)**
- **Detector (FPD array,)**

3) System design for integration

Integrated 3D imager function chip

- Define 3D imaging application target,
- Design of device and chip layout via PDK,
- MPW,
- Performance test.



Approach (within a team):

Phase I (6 months):
- **Identify application (volume and spec)**
- **Define critical show-stopper and goal**

Phase II (6 months):
- **Device and system design**

Phase III (6 months):
- **Prototyping (MPW, etc)**

By bringing each participant's expertise.

Advantages to joining an AIG:

1) Be the trend-setter – first to market with products

2) Find an industry standardized solution to assist IPSR

3) Horizontal and vertical integration already exists due to collaboration with diverse partners

Contact: Kazumi Wada, +1-617-452-4063, kwada@mit.edu

Application Interest Group (AIG)

Millimeter wave Signal Processing (millimeter wave to sub-THz)

<u>AIG Vision</u>: **Build a diverse team (industries, academia, government etc.) to**

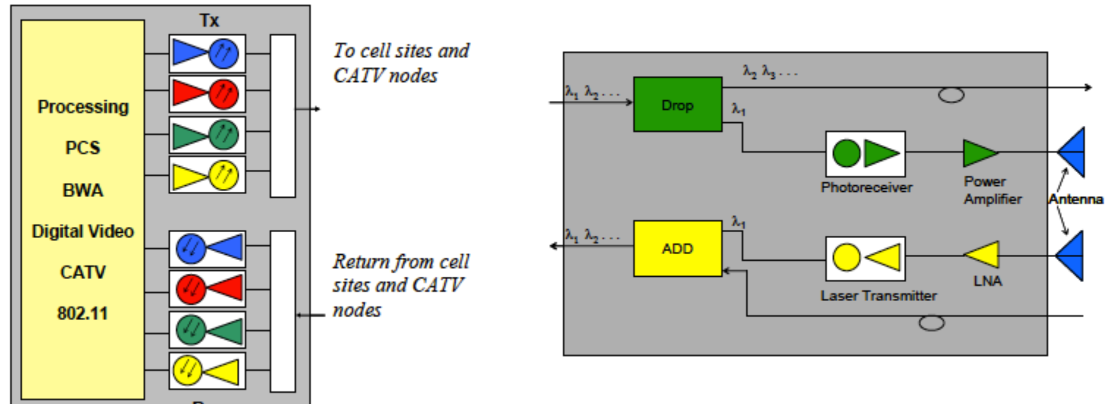
(a) identify technology developments based in CMOS-PIC technology for next generation communications (5G) operating from millimeter wave to sub-THz

(b) find appropriate solutions including materials, components and packaging

<u>Potential show stoppers</u>:

1) **On-chip components**
    1) **Modulators with 100 GHz operating frequency**
    2) **High SFDR amplifiers / frequency translation systems**
    3) **High efficiency power amplifiers**
2) **Modulation schemes**
    1) **64 QAM to 128 QAM**
    2) **AM / FM / Phase**
3) **Packaging**
    1) **Integrated high gain antenna**
    2) **Phased array antenna**
    3) **Fiber optic interconnection**

PIC transceiver for wireless to PIC communications



(a) DWDM Headend

(b) Cell site for wireless services

Source: *A. Paolella et al. Active and Passive Optical Components for WDM Communications IV (Proc. SPIE v.5595), p. 185 (2004). doi: 10.1117/12.579840*

Ref: Directions in radio frequency photonic systems, A. C. Paolella, et. al., 2015 IEEE 16th Annual Wireless and Microwave Technology Conference

<u>Approach (within a team)</u>:

Phase I (6 months):

- **Assess state of the art**
- **Define required specs and metrics**
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Phase II (6 months):

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Phase III (6 months):

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Identify role for each participant (each participant adds unique value)

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3) **Work towards industry standard solutions**
4) **Builds competitive advantage to early products**

<u>Contact</u>: Dr. Arthur C Paolella
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Next Steps

IPSR International Spring Meeting

Monday-Tuesday, March 26-27, 2018 at MIT Media Lab in Cambridge, MA

Register at: http://aimphotonics.academy/roadmap/aim-photonics-spring-2018-meeting

AIM Photonics is creating Application Interest Groups (AIGs) to develop pragmatic, chip-based solutions for leading-edge applications. At the Spring Meeting we will be initiating new AIGs on Data Center, Analog RF, Sensing, and 3D-Integrated Imager to define system requirements, technology gaps, and prototype solutions.

Break out session will be Monday March 26 at 3 PM

Next IPSR International Roadmapping Workshops

- Spring 2018 IPSR Meeting: March 26-27, MIT Media Lab
- 2018 World Technology Mapping Forum 2: June 20-22, University of Twente, NL
- Fall 2018 IPSR Meeting: November 29-30, MIT Samberg Meeting Center

Additional Information on IPSR and AIGs

- IPSR Home Page http://photonicsmanufacturing.org
- How IPSR Projects are formed http://photonicsmanufacturing.org/news/how-projects-are-formed
  - Presentation: How Projects are Formed
  - IPSR SOW template
  - Sample Completed SOW: iNEMI-IPSR Board Level Optical Interconnect Project Phase 1
  - IPSR Project Statement (PS) template
- This Presentation: http://photonicsmanufacturing.org/reports-resources

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For additional information:

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