



# SYSTEM EMBEDDED PHOTONIC INTERCONNECT FOR MEGA-DATA CENTRE ENVIRONMENTS

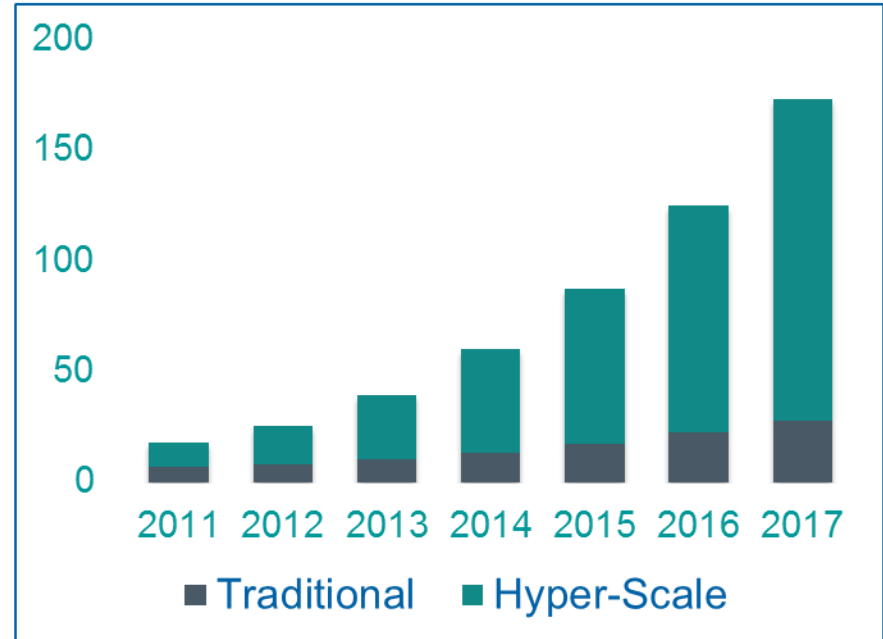
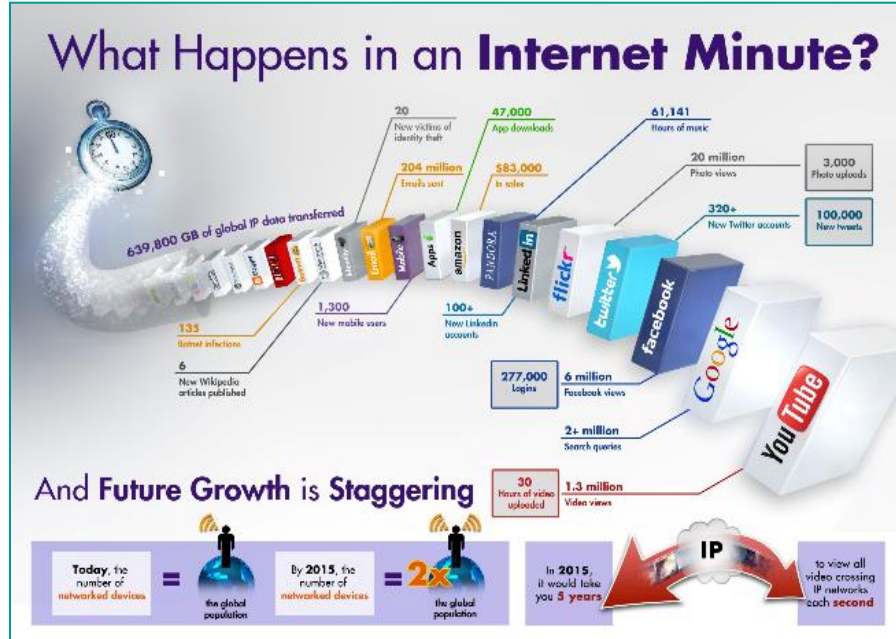
**Richard Pitwon**  
Seagate Systems UK

**ICSJ 2016**  
Kyoto, Japan  
8<sup>th</sup> November 2016



# The “New Data” is Different

Unstructured data is fundamentally changing IT



# Digital Universe: 2020

**44ZB**

Amount of data  
that will be created

**15.4ZB**

Amount of data  
that will be useful if stored

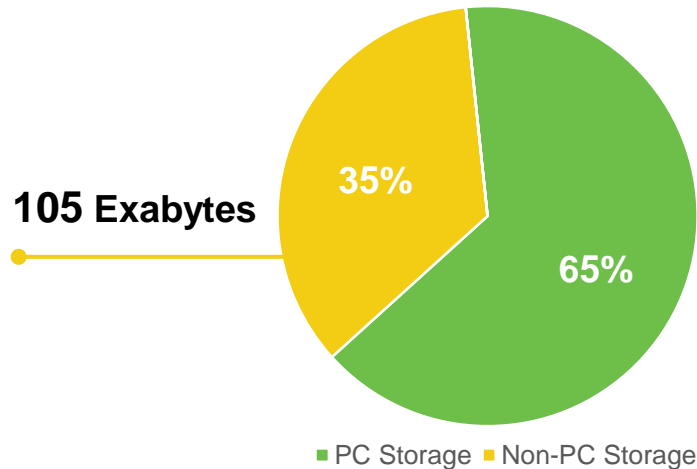
**9.9ZB\***

Amount of data that  
installed capacity will be  
able to hold

Demand **EXCEEDS** all providers – **COMBINED**

# The Move Toward Mobility Is Shifting the Location of Data

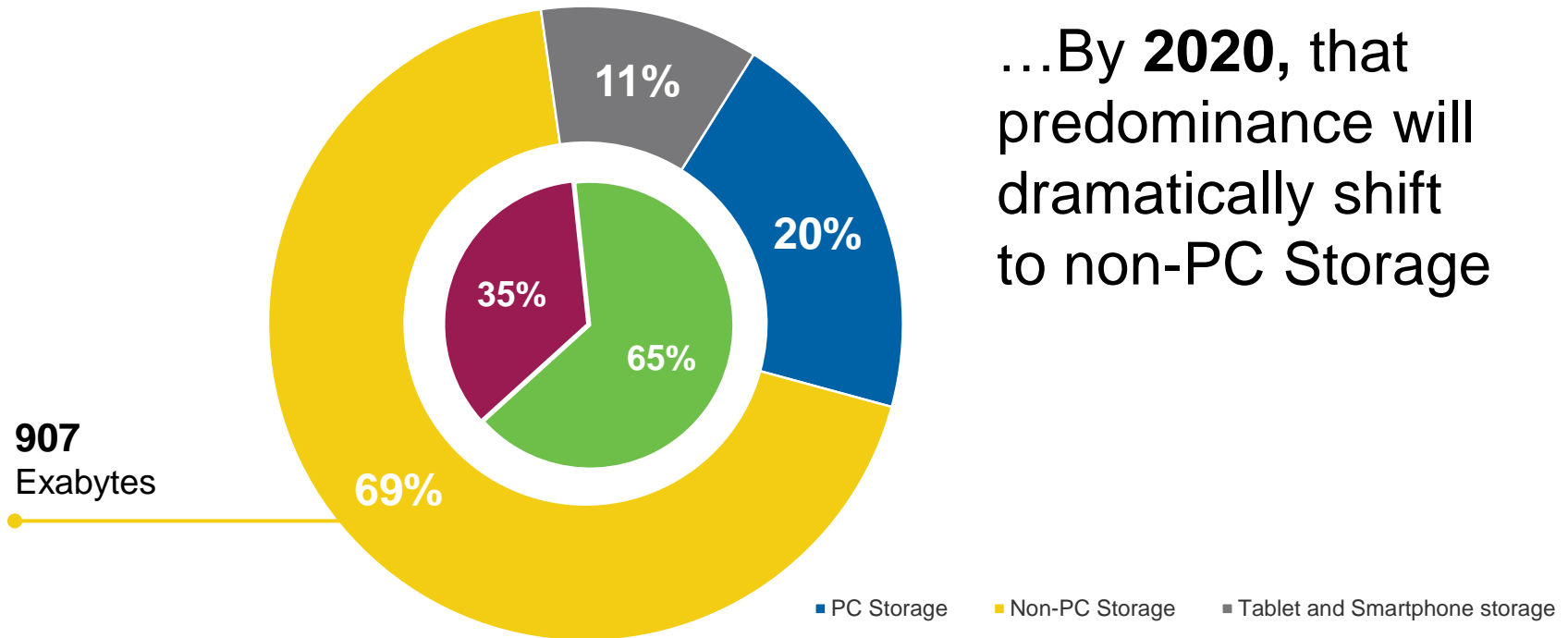
Location of exabytes shipped



In 2010, more than half of the storage was shipped into the PC market...

# The Move Toward Mobility Is Shifting the Location of Data

Location of exabytes shipped

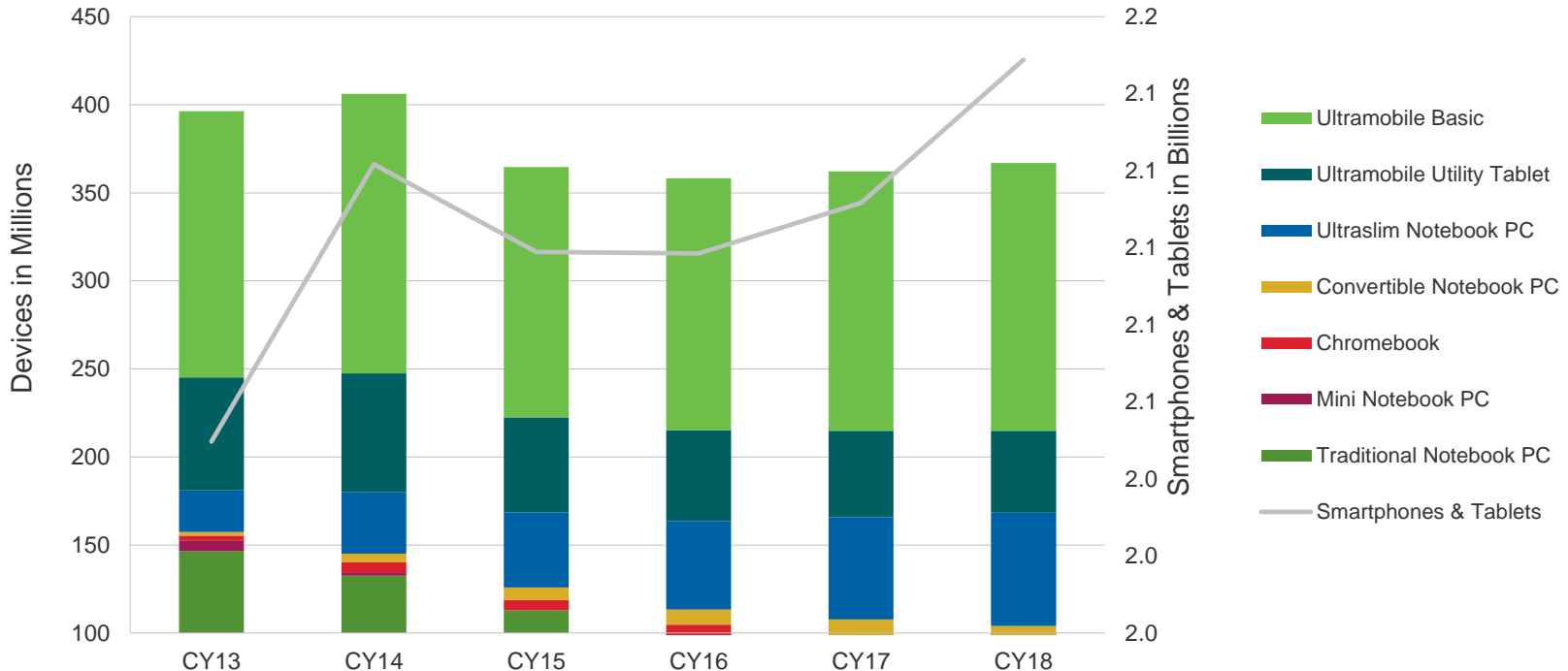


...By **2020**, that predominance will dramatically shift to non-PC Storage

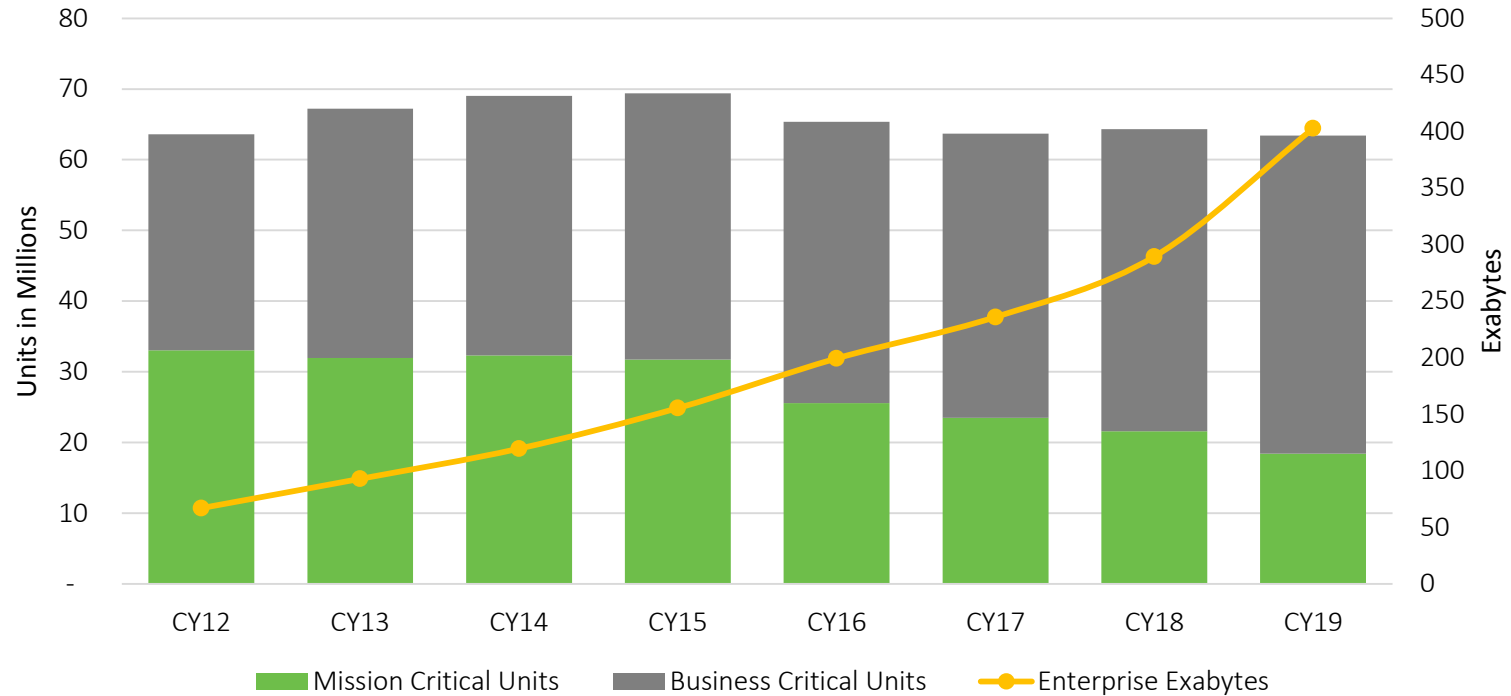
**907**  
Exabytes

# Where Compute Takes Place Now

Today, **EIGHT OF TEN** compute devices are **TABLETS** and **SMARTPHONES** and **SEVEN OF TEN** Notebooks have slimmer form factors for increased mobility



# Data Center Exabytes Continue To Grow



# Emergence of Mega Data Centres



Source: Google



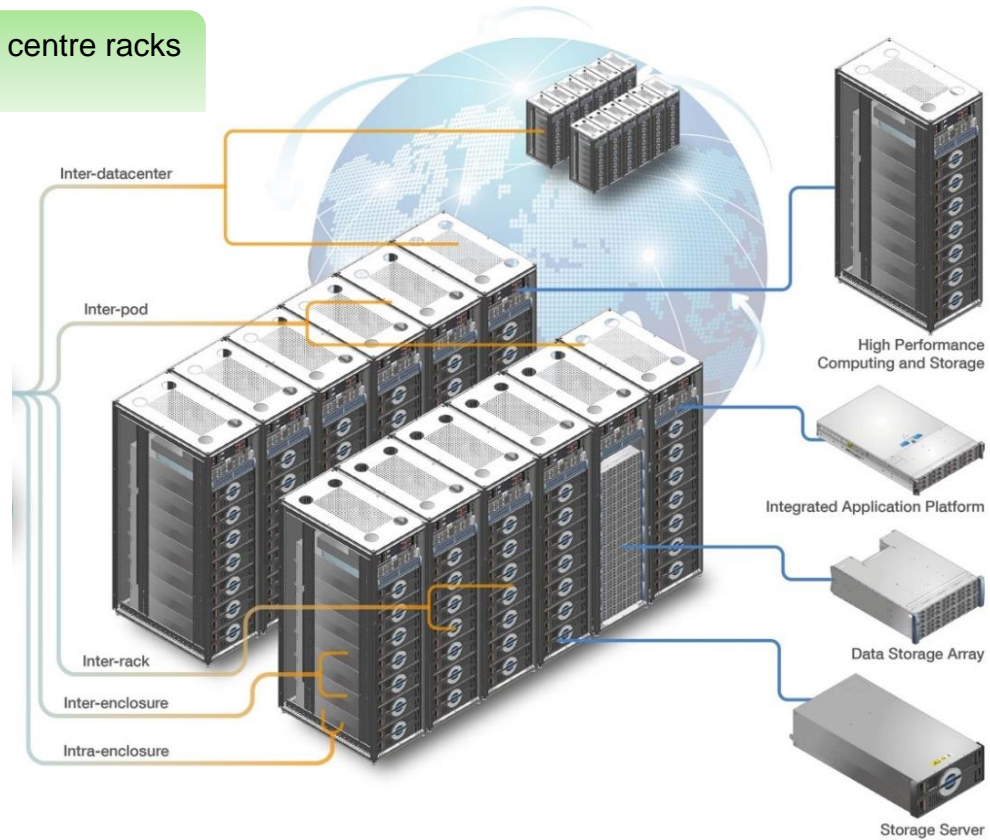
Source: Facebook



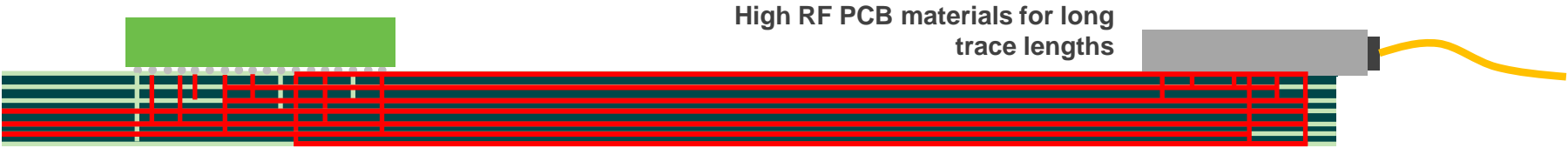


# Optical Interconnect Migration

Optically enabled data centre racks and enclosures



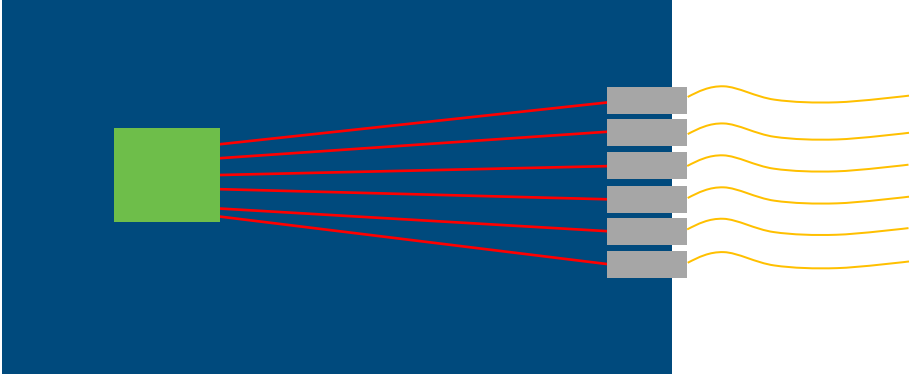
# Optical Interconnect Migration



High speed electrical PCB trace length range = **10 cm – 30 cm**



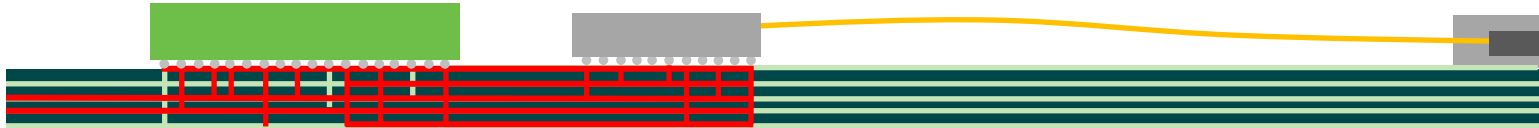
SFP transceivers



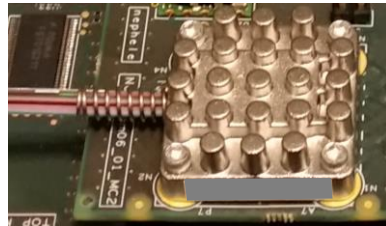
# Optical Interconnect Migration

## Board-level interconnect regime

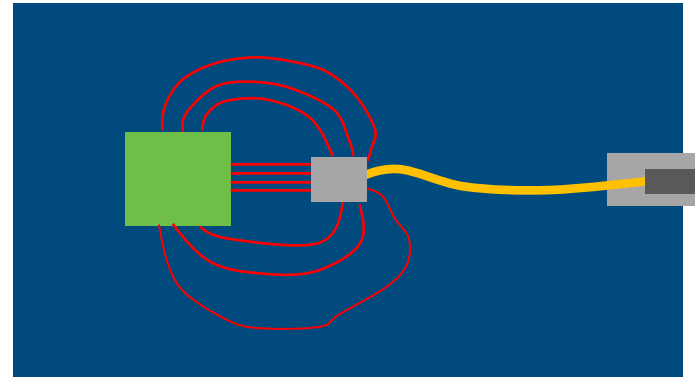
Standard optical fibre ribbon over PCB



High speed electrical PCB trace length range = **5 cm - 20 cm**



Midboard optical modules  
(high port count)



# Optical Interconnect Migration

## Board-level interconnect regime

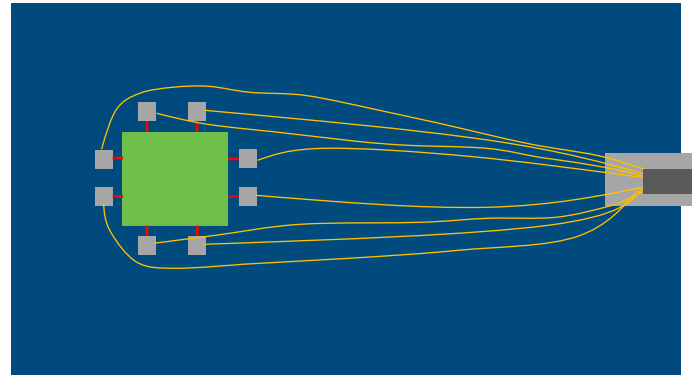
Standard optical fibre ribbon over PCB



High speed electrical PCB trace length range = **1 cm - 3 cm**



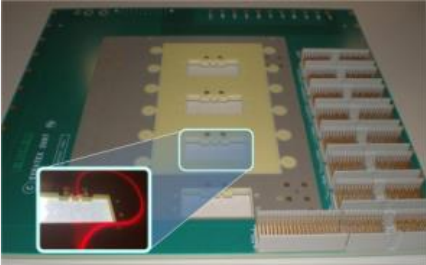
Midboard optical modules  
(commodity, low port count)



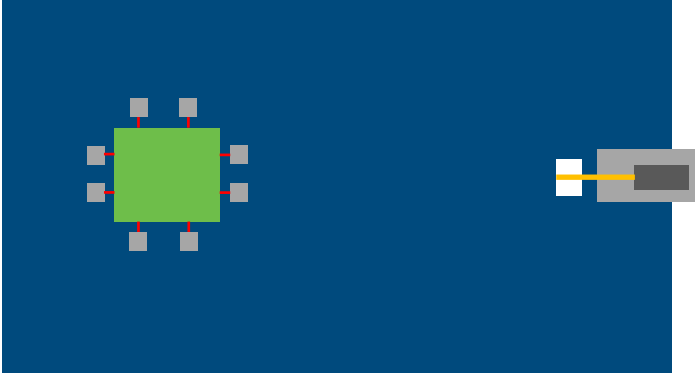
# Optical Interconnect Migration



High speed electrical PCB trace length range = **1 cm - 3 cm**



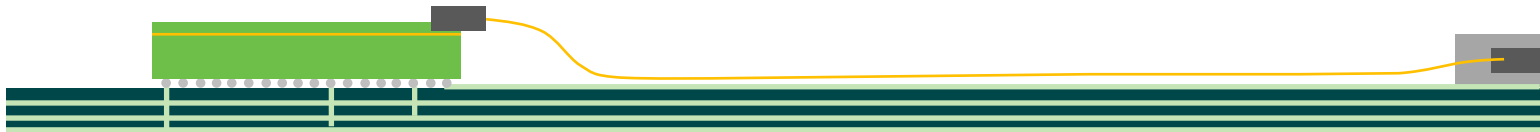
Midboard optical modules (commodity, low port count)



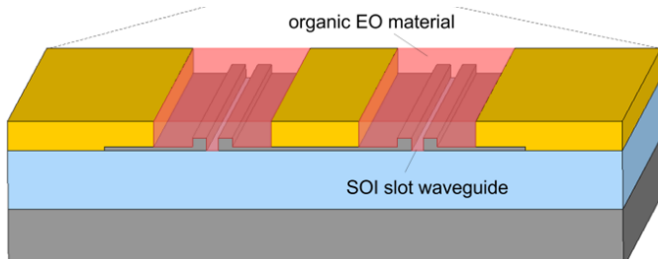
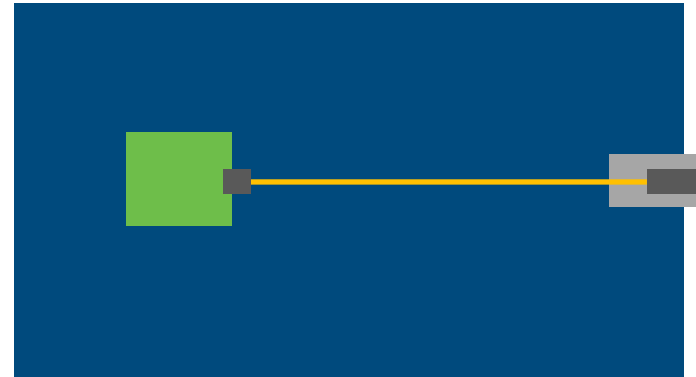
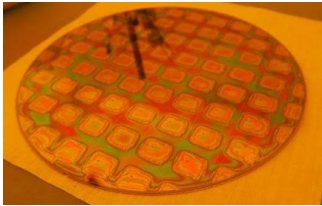
# Optical Interconnect Migration

## Chip-level interconnect regime

Standard optical fibre ribbon over PCB



High speed electrical PCB trace length range  $< 1$  cm



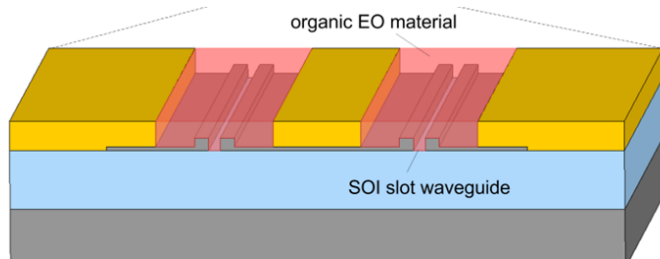
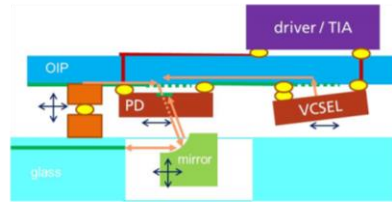
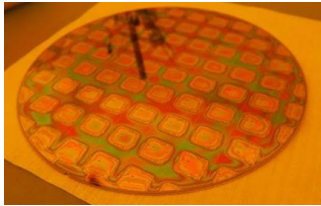
Photonic integrated circuit technologies

# Optical Interconnect Migration



PCB embedded optical channels e.g. polymer or glass

High speed electrical PCB trace length range **< 1 cm**



Photonic integrated circuit technologies

# Photonicallly enabled data centre systems





# Global Investment in Integrated Photonics



## European Union

FP7 and H2020 Photonics R&D programmes

>\$500 million spent over last 10 years in PIC technologies

>\$200 million more by 2020



## United States of America

Integrated Photonics Manufacturing Institute

The US government has set up its latest manufacturing initiative, the sixth of nine, to address **integrated photonics**. The **\$610 million venture** is a combination of public and private funding: \$110 million from the Department of Defense, \$250 million from the state of New York and the rest private contributions.



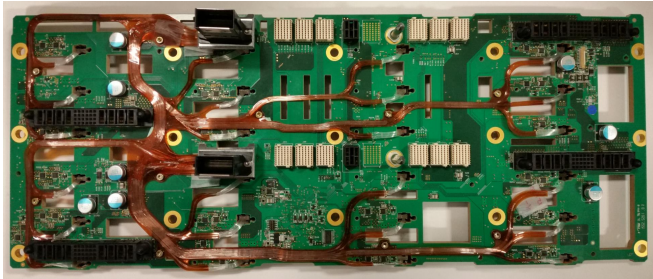
## Japan

PETRA - Photonics Electronic Technology Research Association

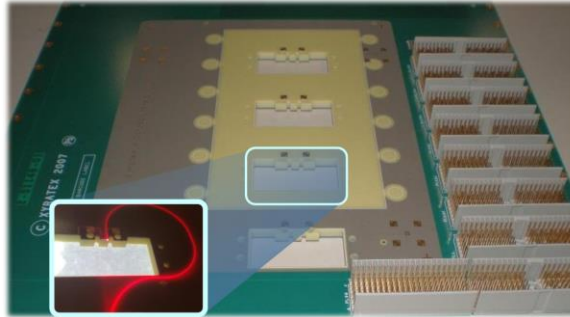
Substantial funding over 10 years (2010 - 2020)

# Electro-optical Midplane Technologies

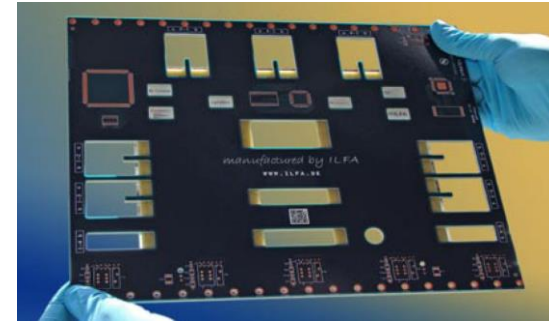
Fibre-optic flexplane



Polymer waveguides



Planar glass waveguides



Pegasus



FirstLight

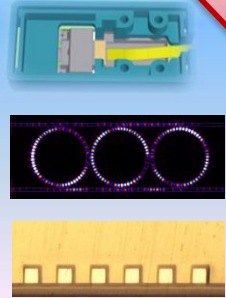
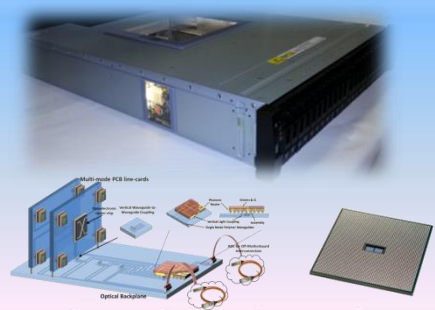


SEPIANet

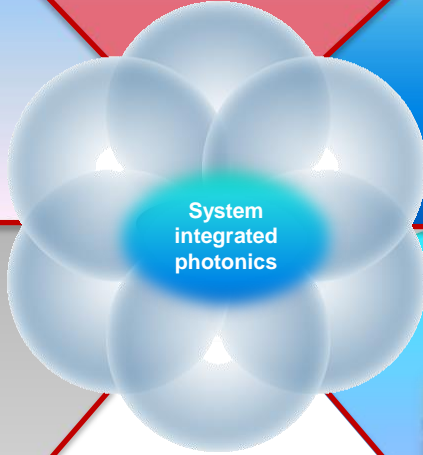


# Research and Development - Integrated Photonics in Data Centres

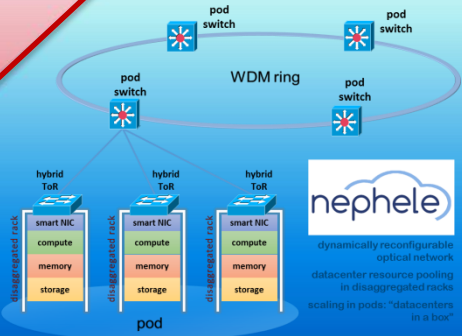
**PhoxTroT**  
 Photonics for High-Performance, Low-Cost & Low-Energy Data Centers, High Performance Computing Systems: Terabit/s Optical Interconnect Technologies for On-Board, Board-to-Board, Rack-to-Rack data links



SEVENTH FRAMEWORK PROGRAMME  
 Technology Strategy Board Driving Innovation  
 HORIZON 2020  
 EPSRC

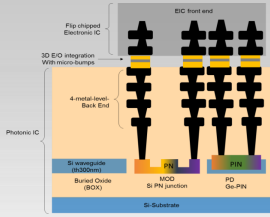


nephele



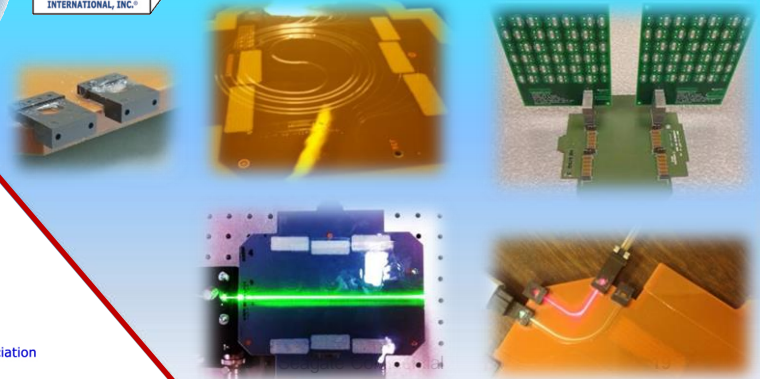
nephele  
 dynamically reconfigurable optical network  
 data-center resource pooling in disaggregated racks  
 scaling in pods: "datacenters in a box"

**COSMIC**  
 CoSi Solutions for Mid-board Integrated transceivers with breakthrough Connectivity & ultra low Cost (COSMIC)



Photonic research and development

HDP  
 USER GROUP INTERNATIONAL, INC.®



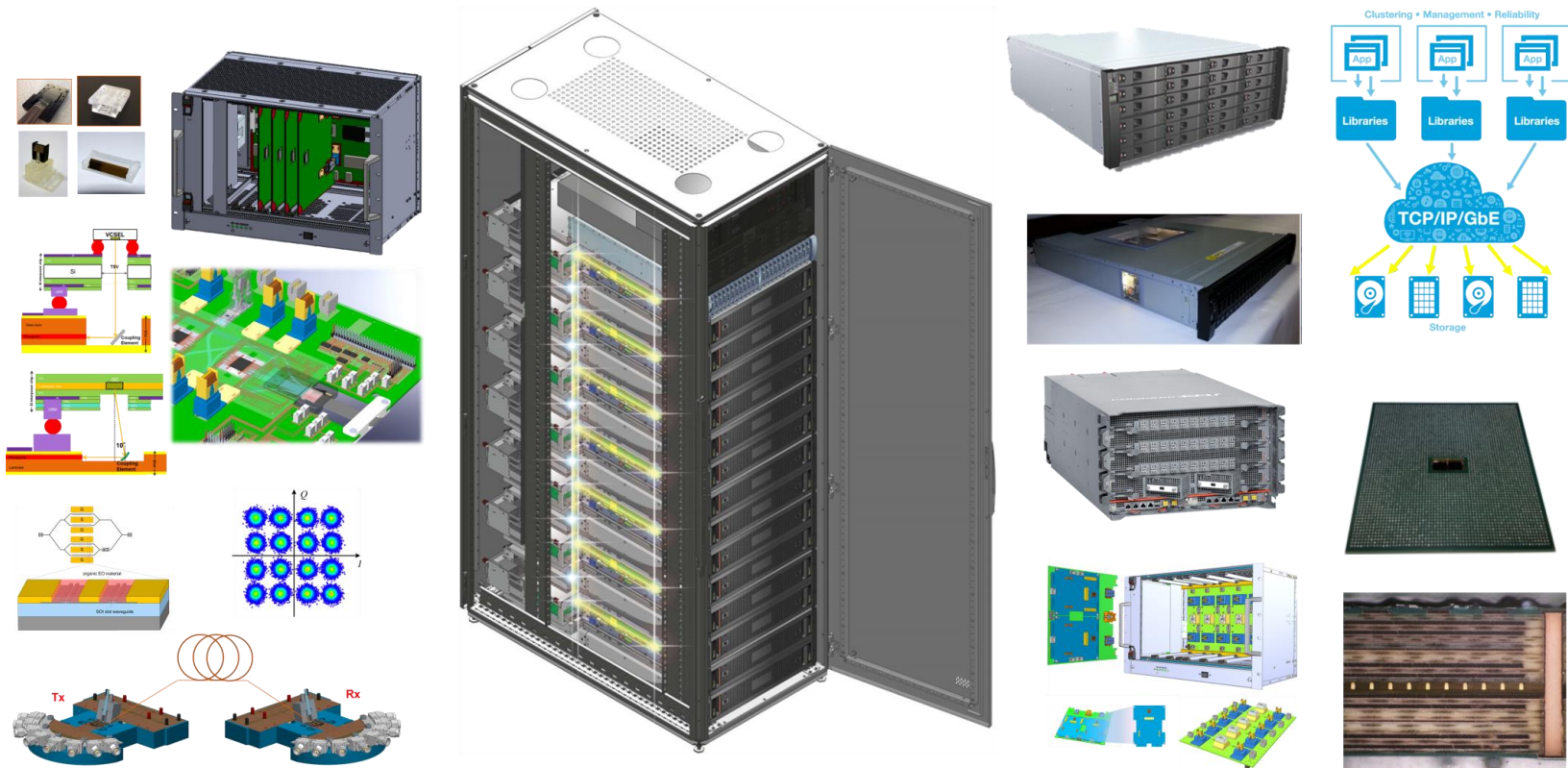
**AIM**  
 photonics  
 AMERICAN INSTITUTE OF MANUFACTURING RESEARCH PARTNERSHIP

**PETRA**  
 Photonics Electronics Technology Research Association

# PhoxTroT project (Oct 2012 – Oct 2016)



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



# PhoxTroT project

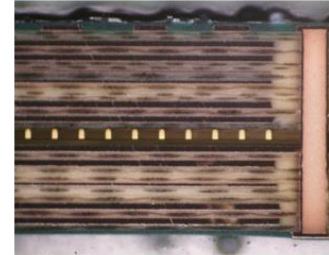
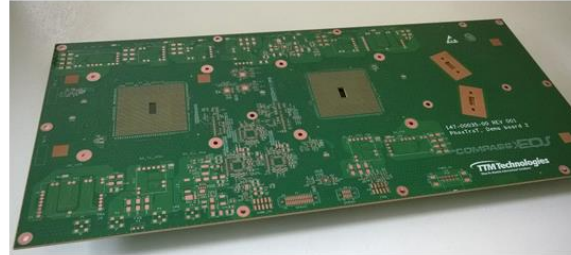
(Oct 2012 – Oct 2016)



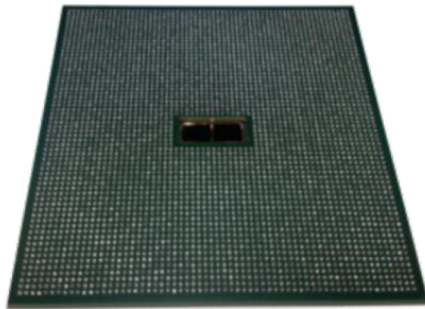
Optically enabled data storage platforms



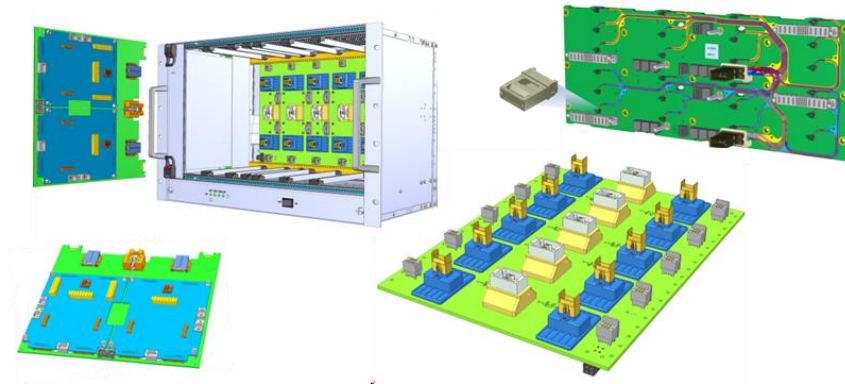
High volume EOPCB manufacture and assembly



Ultra high density electro-optical router chip



State of the art in polymer, glass and fibre EOPCB



# PhoxTroT project (Oct 2012 – Oct 2016)

Photonically enabled disaggregated SAS data centre switch and storage platform

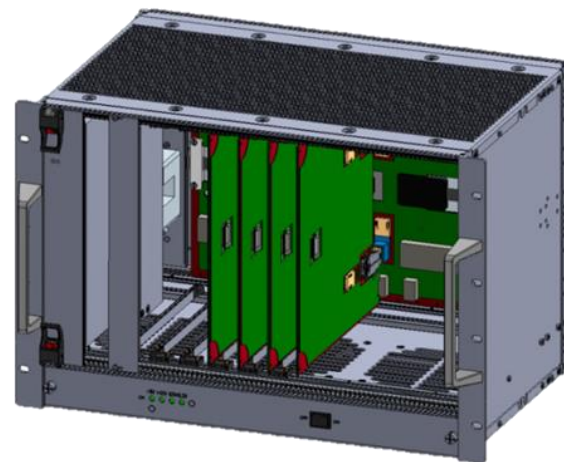
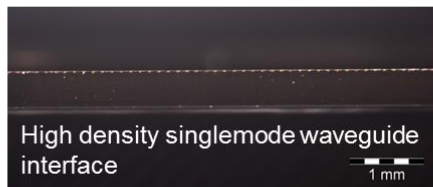
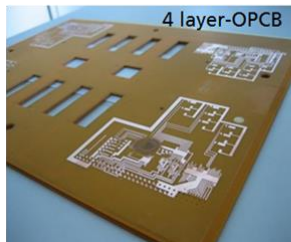


# PhoxTroT project (Oct 2012 – Oct 2016)

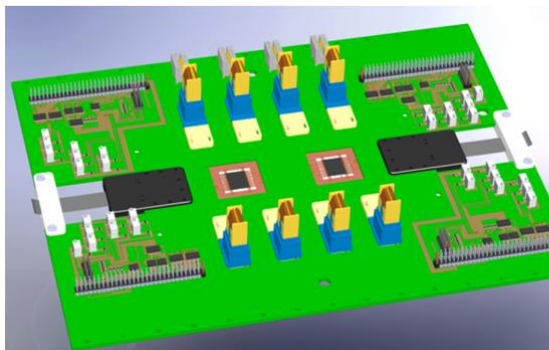
Singlemode embedded optical interconnect



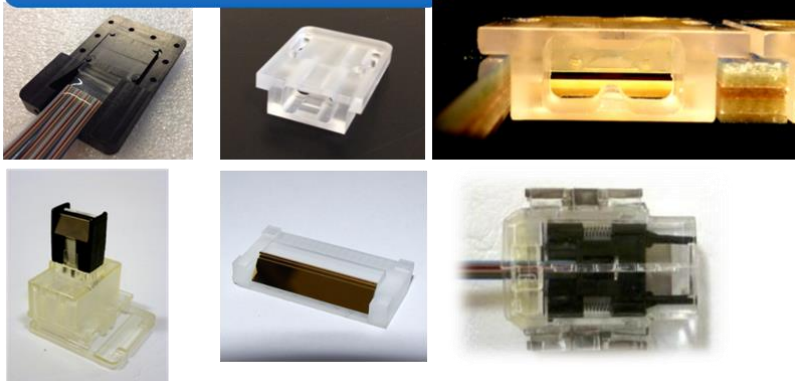
## Glass EOPCB manufacture and assembly



## Singlemode glass waveguide EOPCB fabrication and assembly



## Singlemode and multimode couplers and connectors

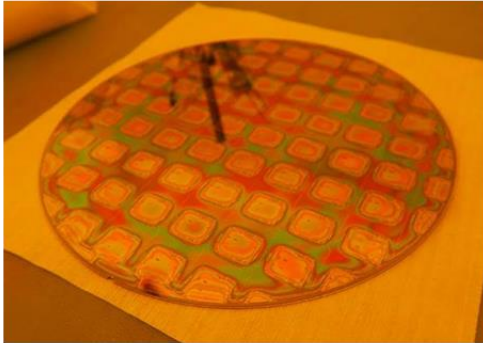


# PhoxTroT project (Oct 2012 – Oct 2016)

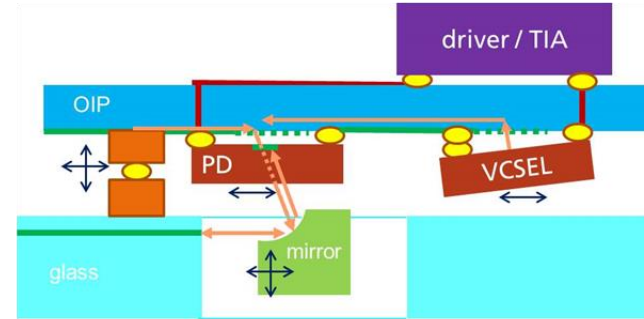
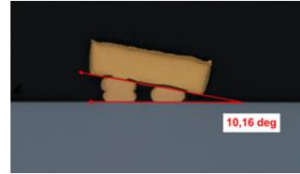


Photonic integrated circuit and 3D assembly

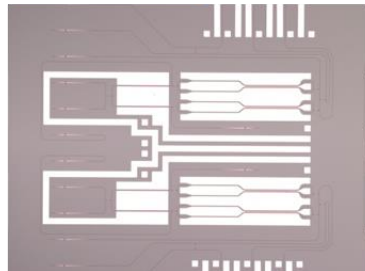
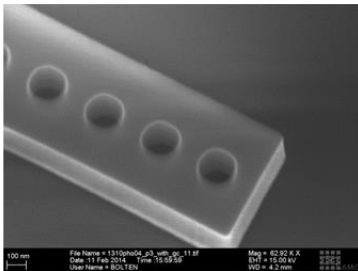
## New EU Silicon Photonics foundry



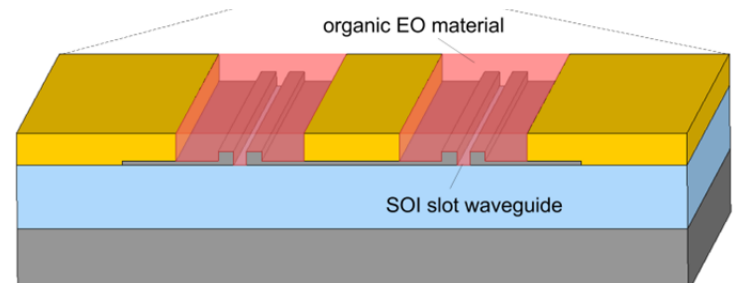
## 3D silicon photonics transceiver and router and coupling



## Nano-photonics



## Silicon organic hybrid technology



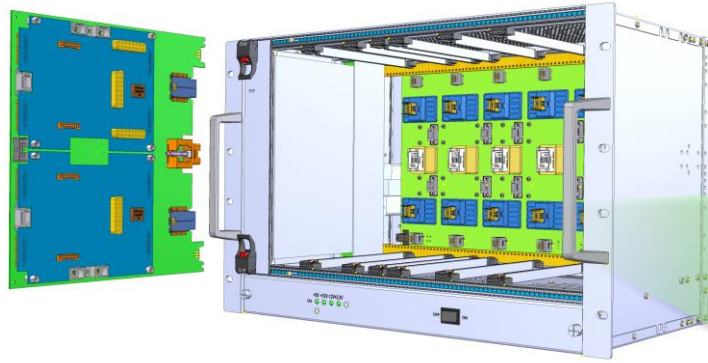


# PhoxTroT project (Oct 2012 – Oct 2016)

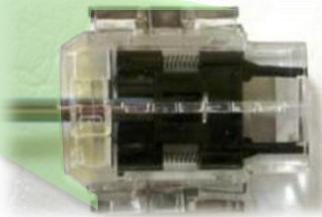
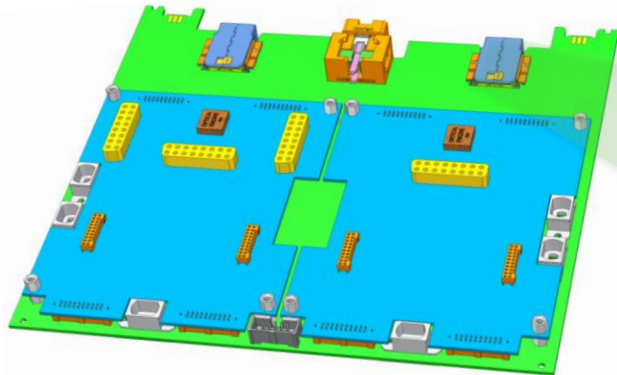
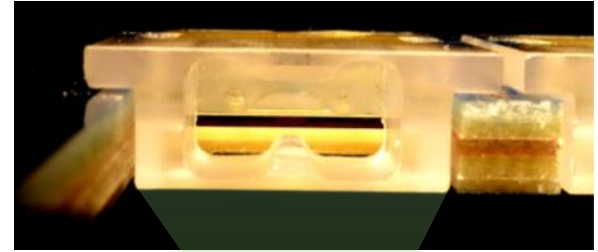


Multimode optical interconnect – interchangeable test daughtercard and mezzanine card form factor

**Board-to-board**



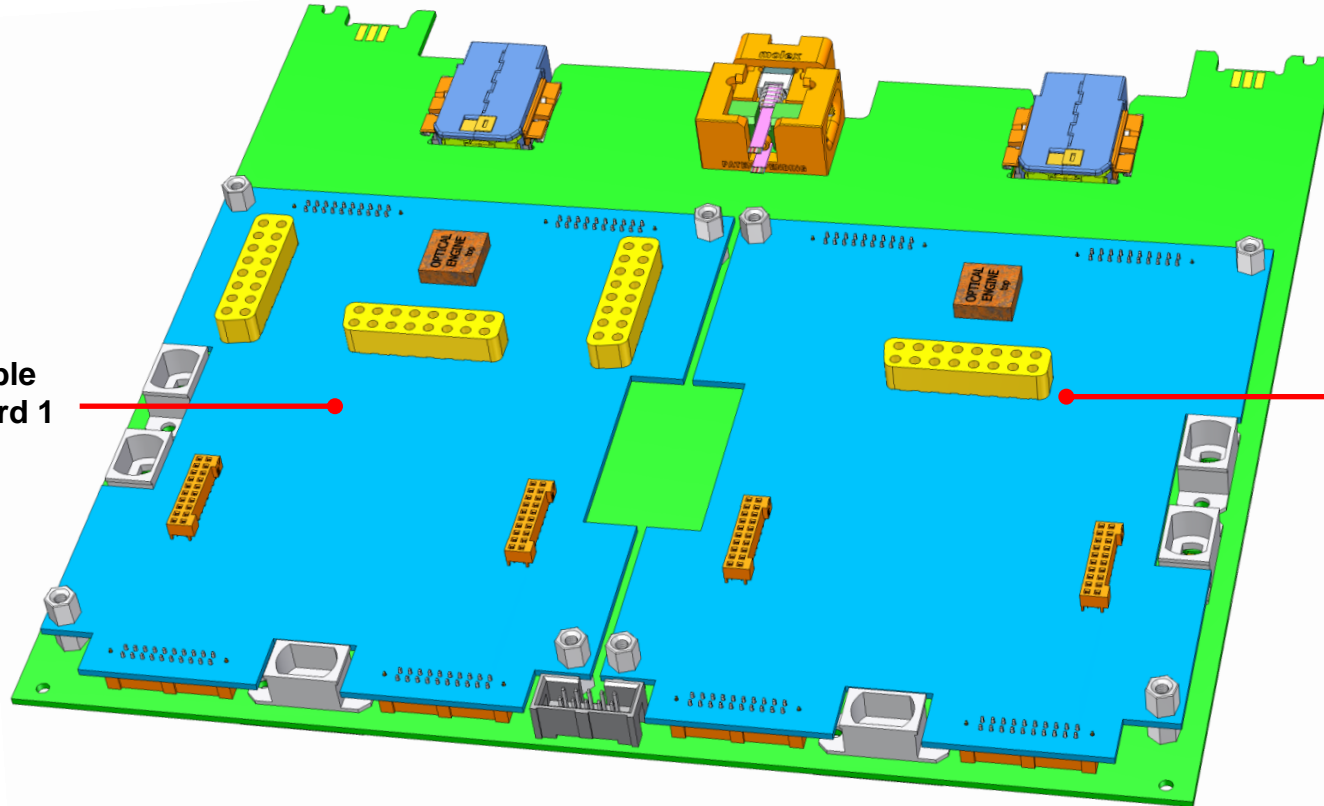
**Fibre-to-board**



# PhoxTroT project (Oct 2012 – Oct 2016)



Multimode optical interconnect – interchangeable test daughtercard and mezzanine card form factor



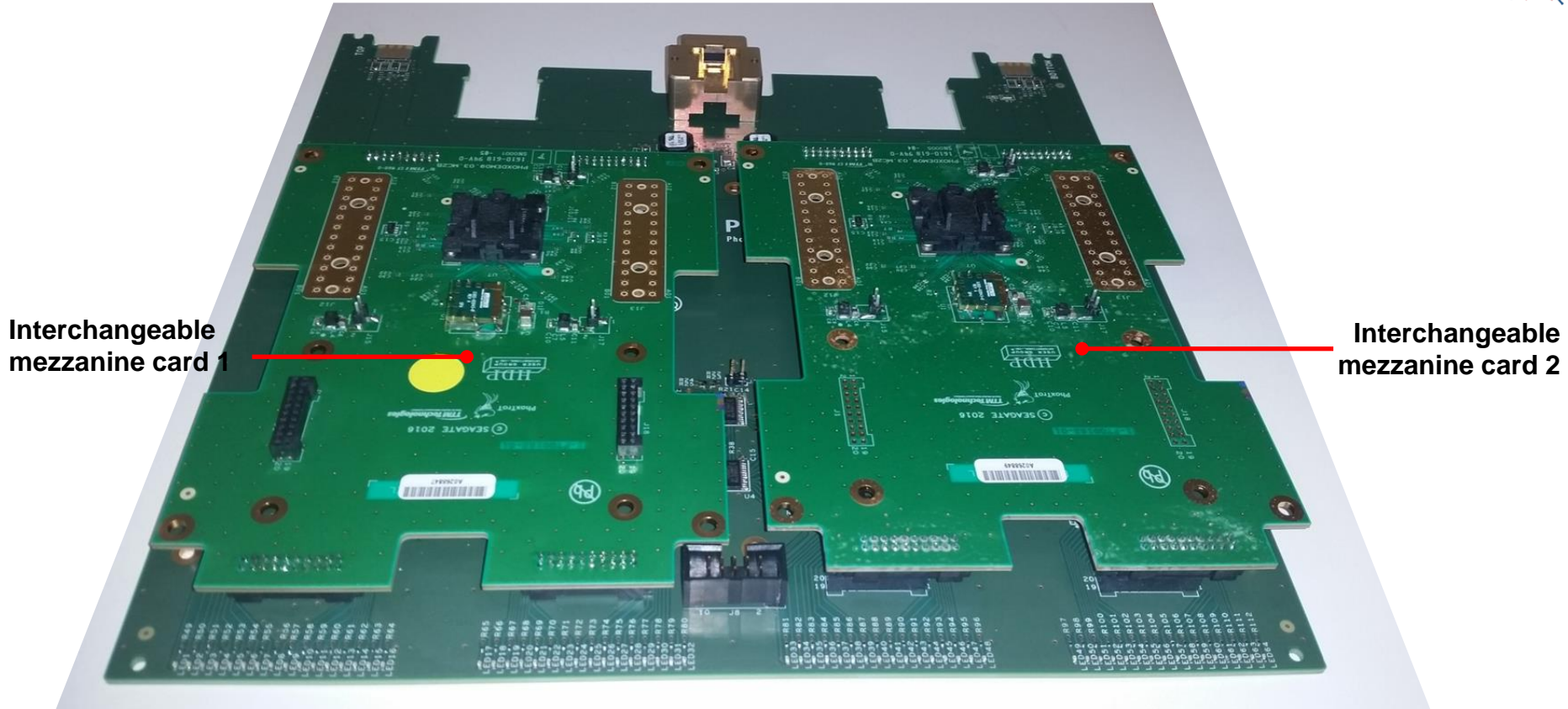
Interchangeable mezzanine card 1

Interchangeable mezzanine card 2

# PhoxTroT project (Oct 2012 – Oct 2016)



Multimode optical interconnect – interchangeable test daughtercard and mezzanine card form factor

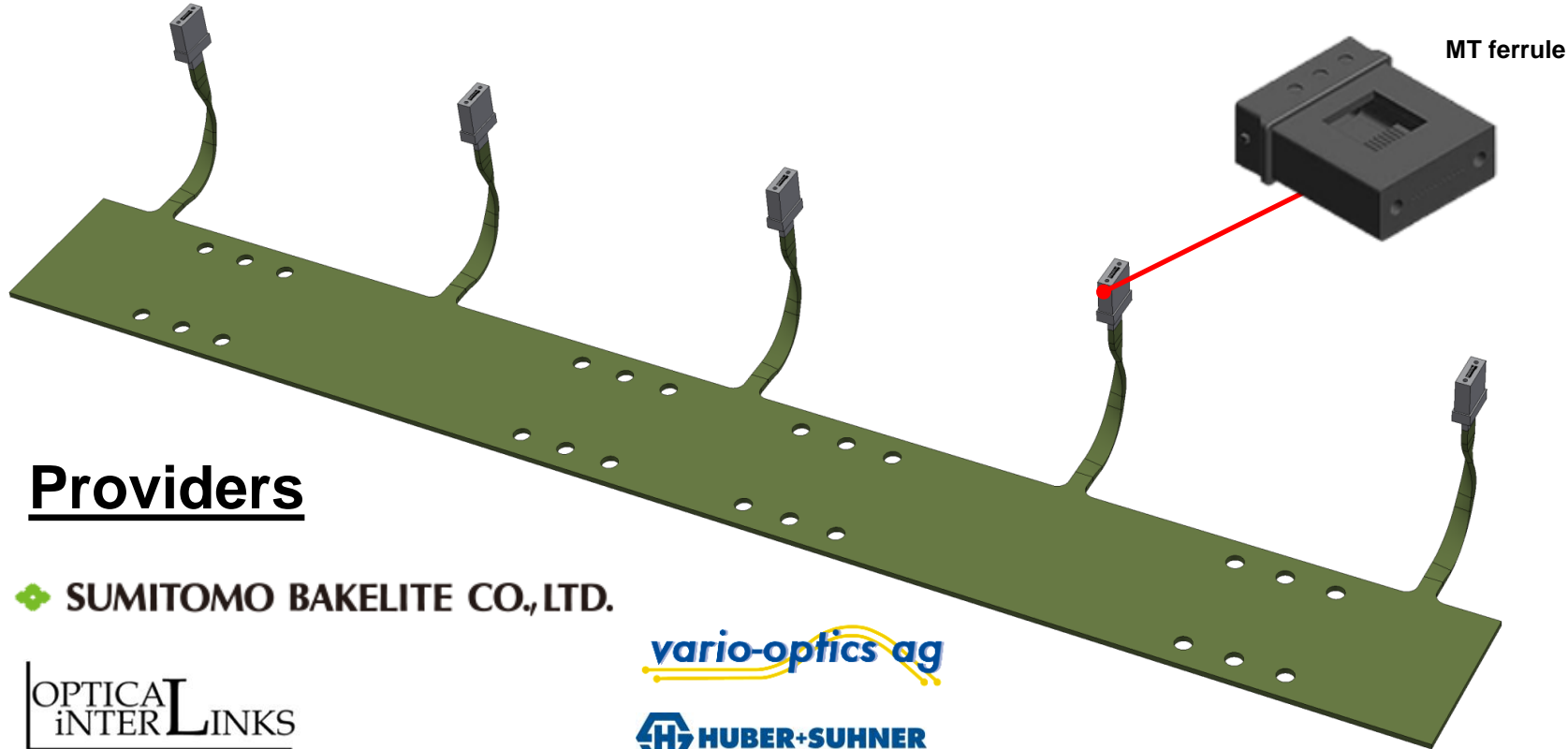


Interchangeable mezzanine card 1

Interchangeable mezzanine card 2

# PhoxTroT project (Oct 2012 – Oct 2016)

Multimode optical interconnect – interchangeable optical waveguide flexplane



## Providers

◆ SUMITOMO BAKELITE CO., LTD.

OPTICAL  
iNTERLINKS

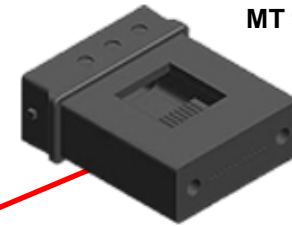
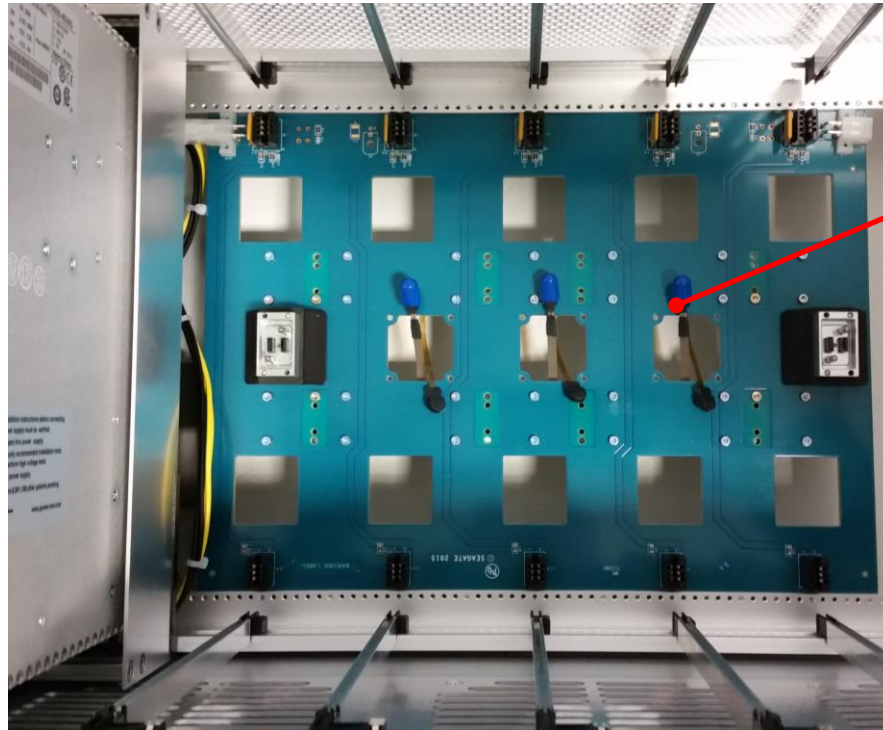
vario-optics ag

HUBER+SUHNER  
Excellence in Connectivity Solutions

# PhoxTroT project (Oct 2012 – Oct 2016)



**Aurora** (PhoxDem09.03) - Multimode universal optical interconnect platform



MT ferrule

# PhoxTroT project (Oct 2012 – Oct 2016)

**Aurora** (PhoxDem09.03) - Multimode universal optical interconnect platform



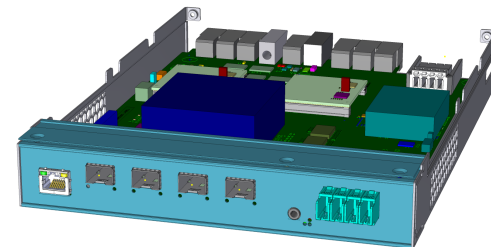
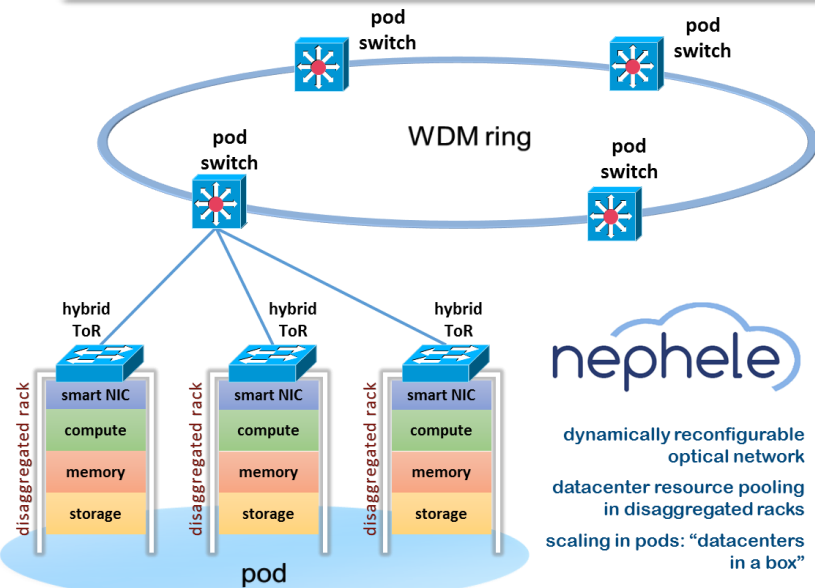
# Nephele project (Feb 2015 – Feb 2018)



End to end scalable and dynamically reconfigurable optical architecture for application aware SDN Cloud datacenters

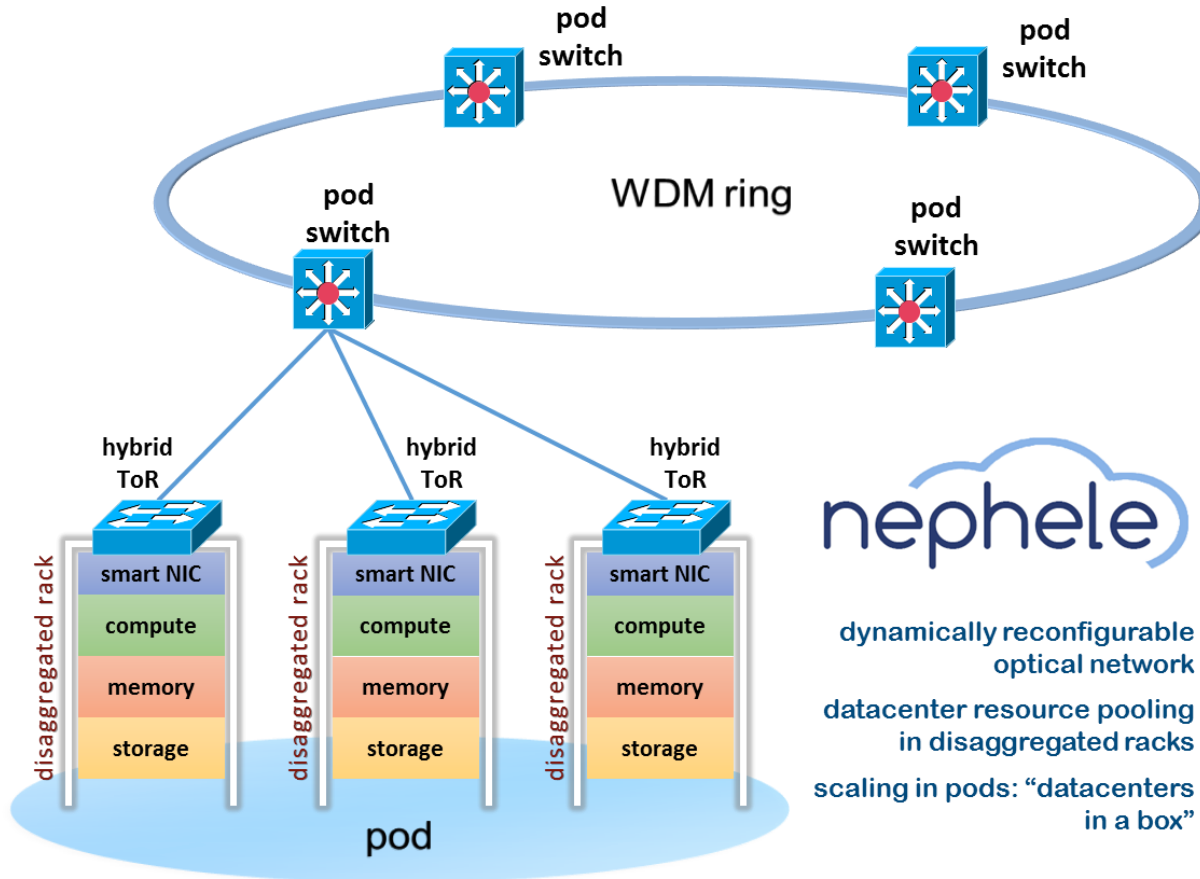
Hybrid electro-optical data centre architecture

Converged data storage and compute platform



dynamically reconfigurable  
optical network  
datacenter resource pooling  
in disaggregated racks  
scaling in pods: "datacenters  
in a box"

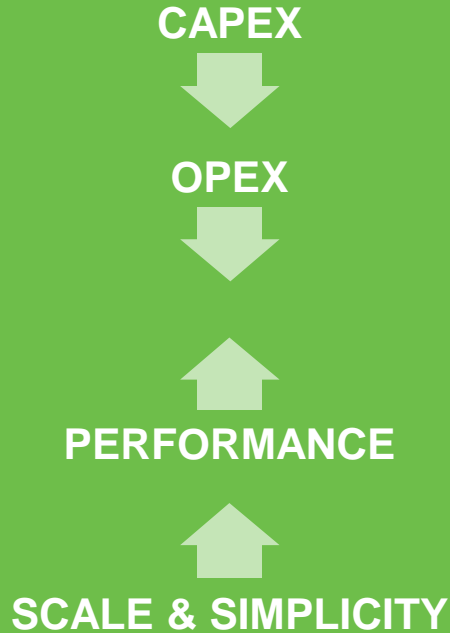
# Nephele project (Feb 2015 – Feb 2018)



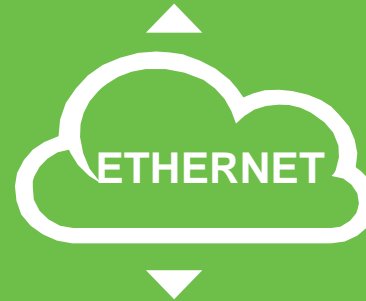
dynamically reconfigurable  
optical network  
datacenter resource pooling  
in disaggregated racks  
scaling in pods: “datacenters  
in a box”



# Kinetic Value Proposition



**APPLICATION**  
Kinetic Library

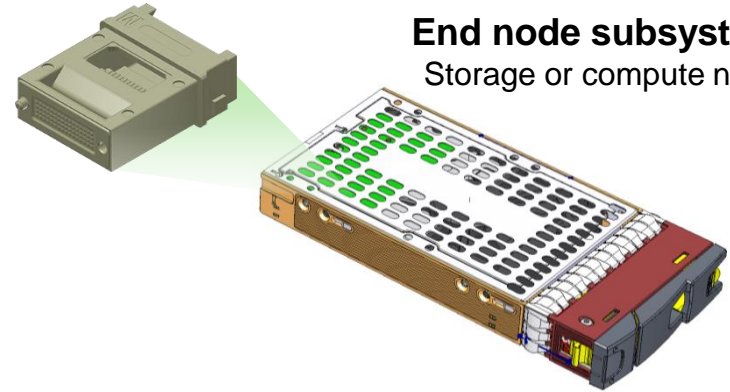


**DEVICES**

- Ethernet Interface
- Key Value Store
- Cylinder, Head, Sector
- Drive HDA

# Pegasus

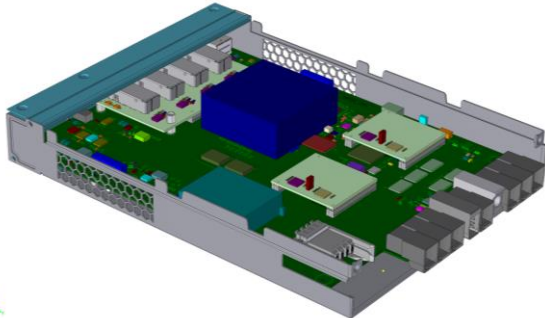
Optically enabled object-oriented disaggregated data centre platform



**End node subsystem**  
Storage or compute node

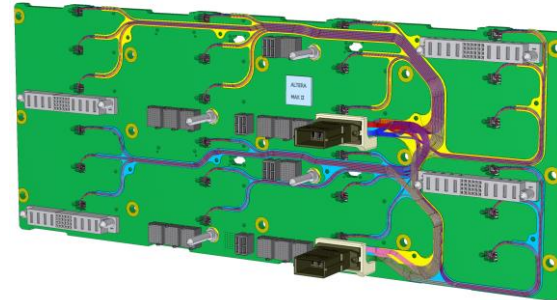
## FireBird

Ethernet switch controller module



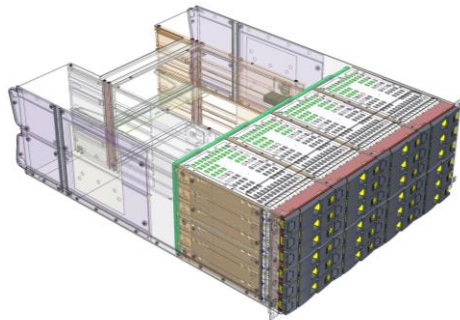
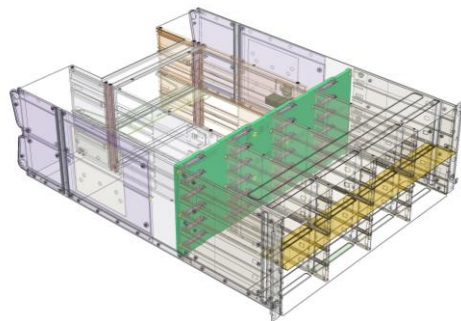
## Electro-optical midplane

Fibre flexplane



# Pegasus

Optically enabled object-oriented disaggregated data centre platform



**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



# Pegasus

Optically enabled Ethernet controller with mezzanine optical engine slots



## Host side optical mezzanine

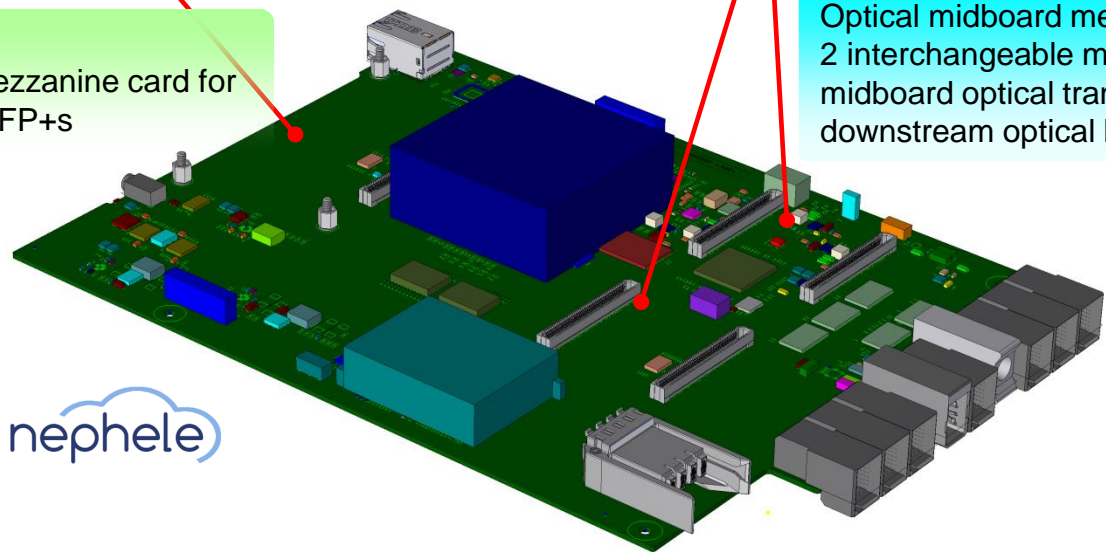


Optical front end mezzanine  
1 interchangeable front end mezzanine card for upstream optical links with 4 SFP+  
s

## Midboard optical mezzanine

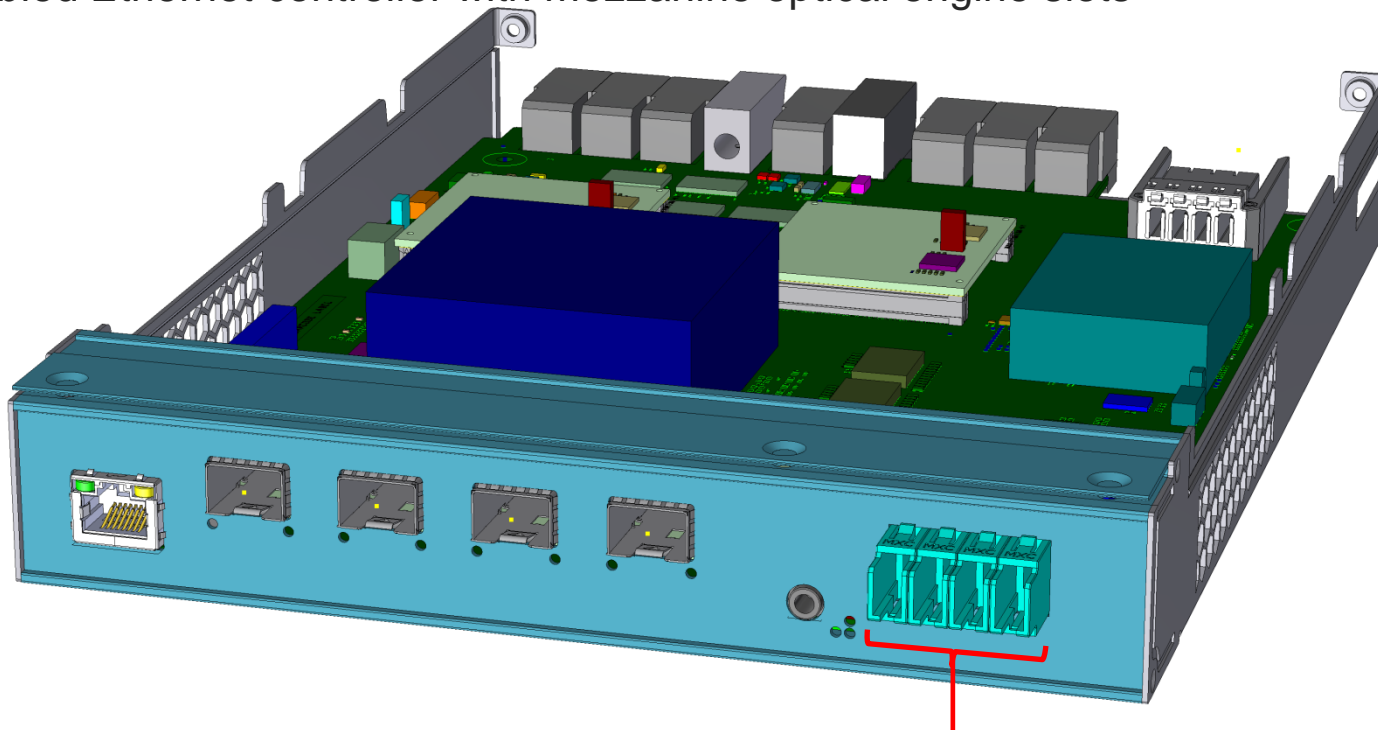


Optical midboard mezzanine modules  
2 interchangeable mezzanine cards with midboard optical transceivers for downstream optical links



# Pegasus

Optically enabled Ethernet controller with mezzanine optical engine slots



**MXC optical interface allowing direct optical access to all back-end drives / micro-servers**



**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



# Pegasus

Optically enabled Ethernet controller with mezzanine optical engine slots



nephele



**MXC optical interface allowing direct optical access to all back-end drives / micro-servers**



**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

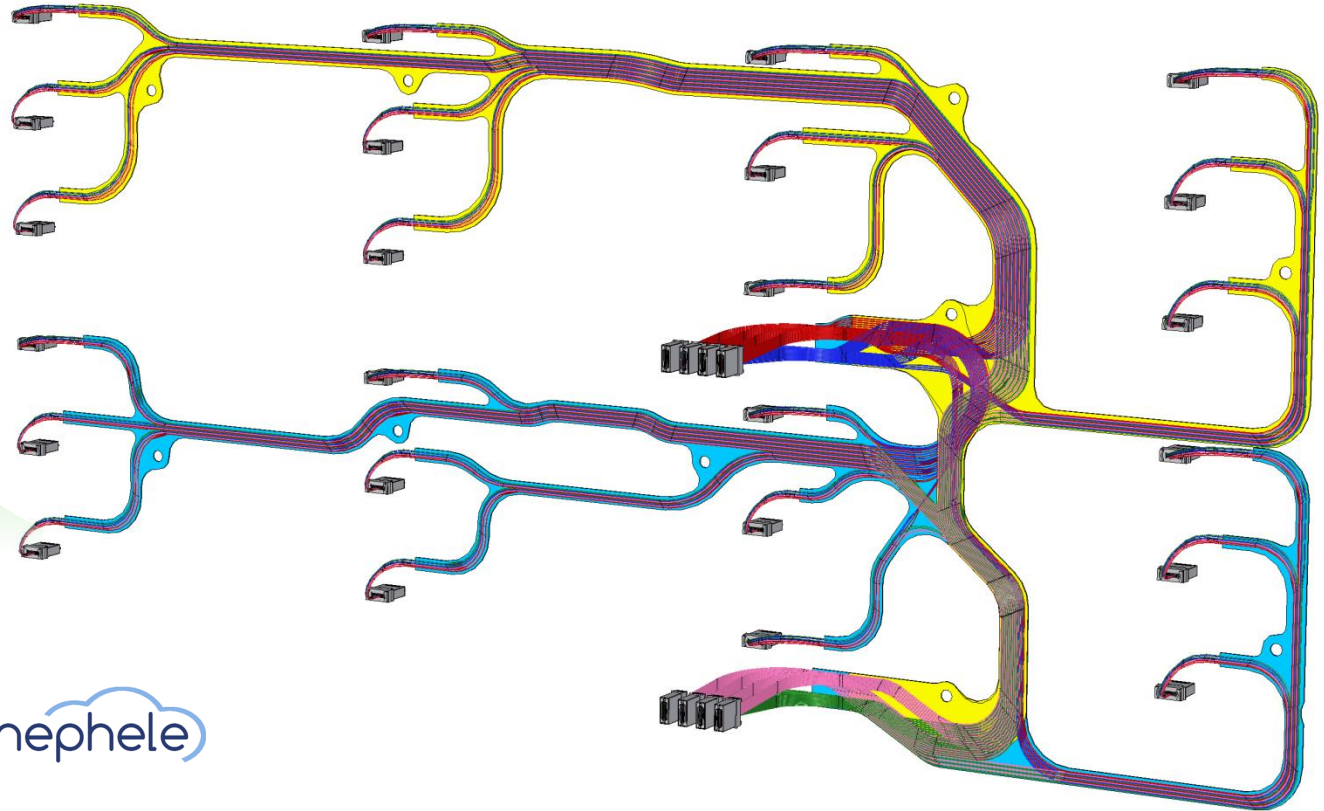
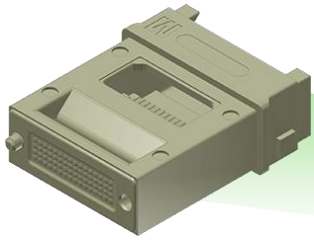
nephele

# Electro-optical midplane

192 fibre flexplane with PRIZM® MT ferrule terminations



nephele



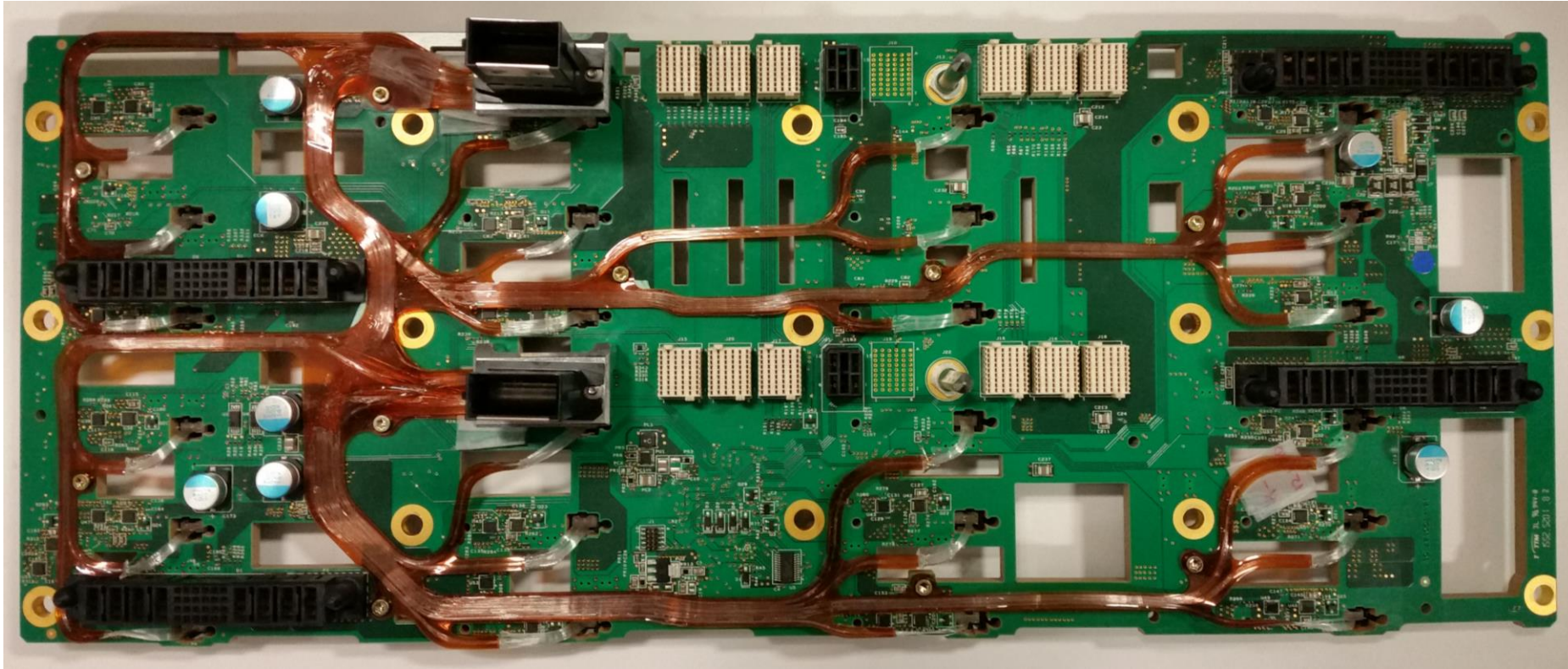
**PhoxTroT**

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

nephele

# Electro-optical midplane

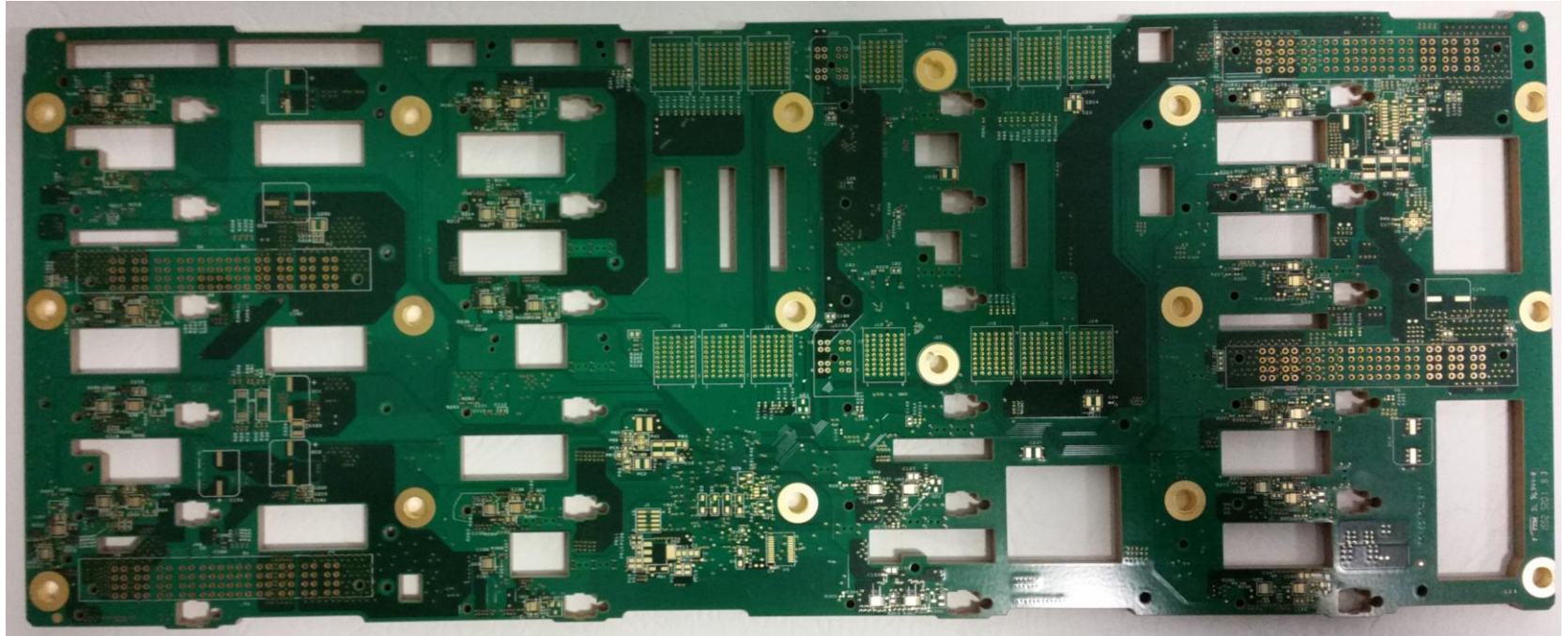
192 fibre flexplane with PRIZM® MT ferrule terminations





# Electro-optical midplane

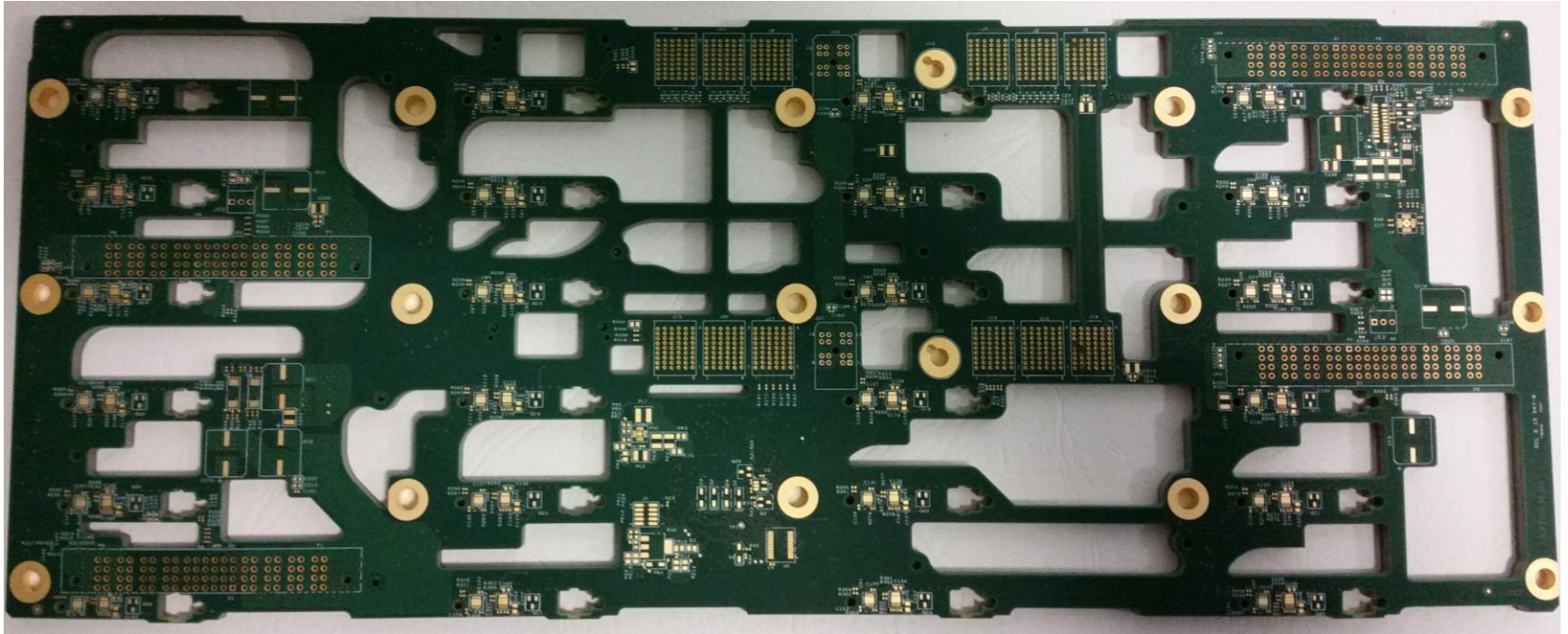
Electrical midplane with high speed electrical channels included



# Electro-optical midplane

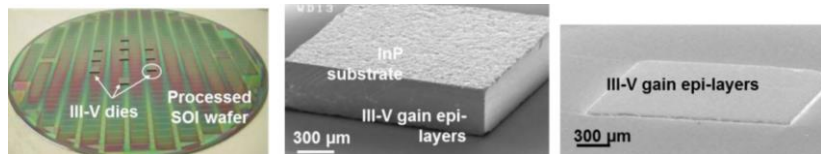
Electrical midplane with high speed electrical channels removed

**Over 30% increase in open board area achieved**

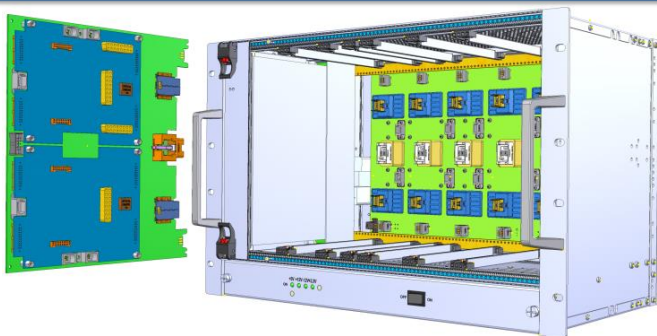


## CMOS Solutions for Mid-board Integrated transceivers with breakthrough Connectivity at ultra-low Cost

### High volume silicon photonics manufacture

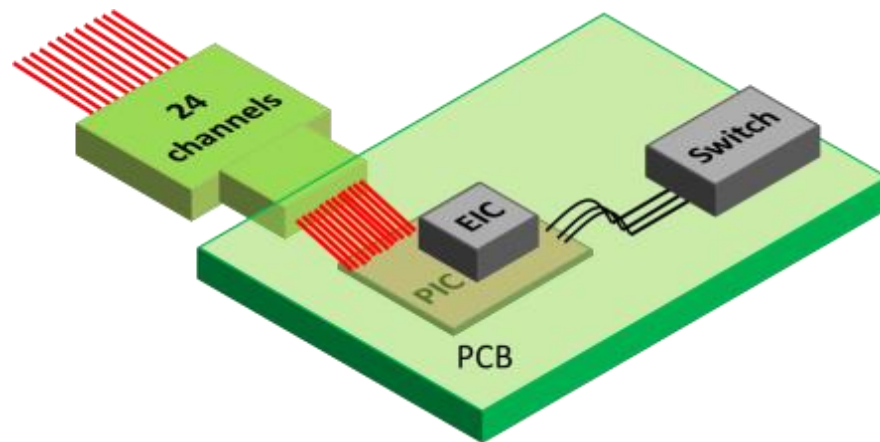


### Standardised test platform



Photonic research and development

### Optical coupling schemes

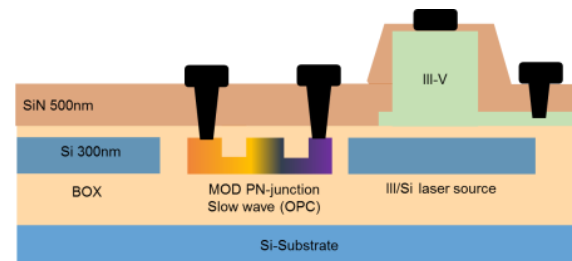
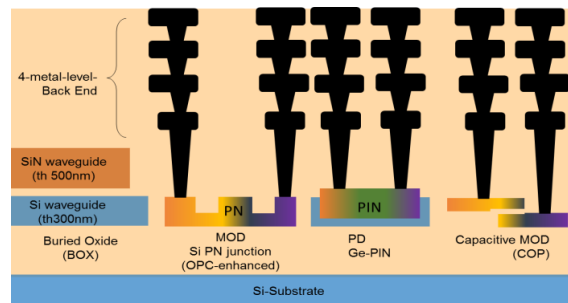
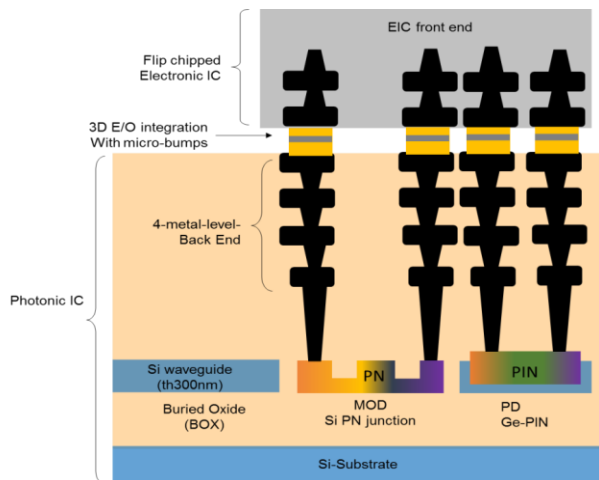


## CMOS Solutions for Mid-board Integrated transceivers with breakthrough Connectivity at ultra-low Cost

Current hybrid photonic-electronic  
fabrication platform

SiN-enhanced platform +  
Compact Si mod.

III-V laser integration in the SiN-  
enhanced platform



# COSMICC project (Dec 2015 – Dec 2018)



## CosDem05.01.MC01

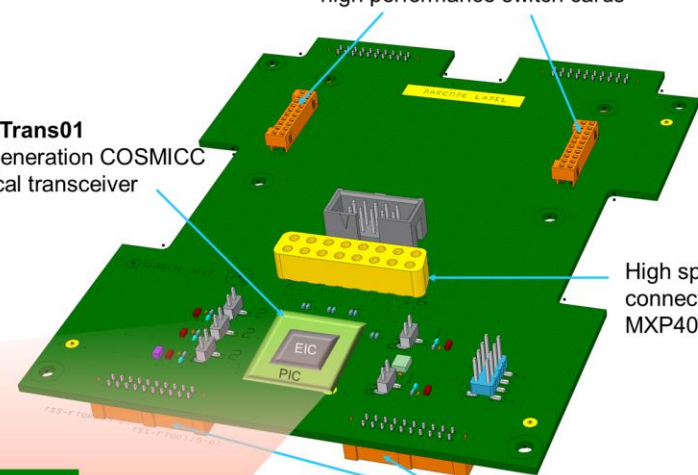
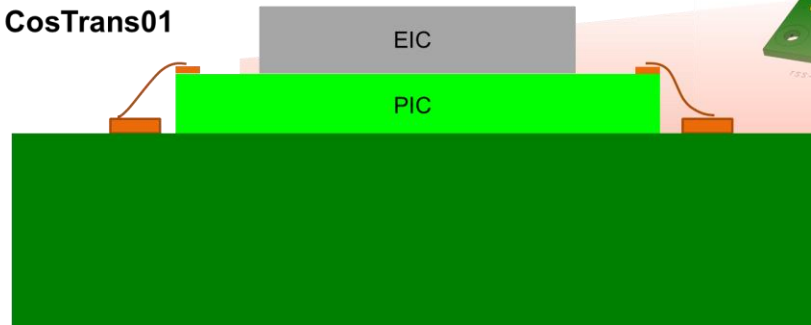
### CosTrans01 1<sup>st</sup> generation COSMICC optical transceiver

Auxiliary power connectors for future  
high performance switch cards

High speed array  
connector  
MXP40

Power connectors to PhoxTrot  
standardised test daughtercard

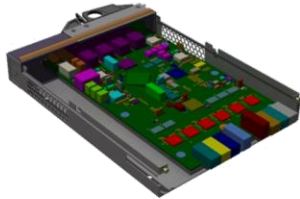
### CosTrans01



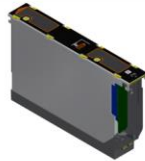
# PhoxLab - Converged data centre test environment



Embedded switch  
and controller in SBB  
form factor



Generic compute,  
storage memory  
subsystems in disk  
drive form factor



Converged flexible  
data centre platform



Fully optically  
disaggregated rack scale  
hyper-demonstrator



# PhoxLab - Converged data centre test environment



**Aurora** (PhoxDem09.03)  
Multimode optical  
interconnect platform

**Aurora2** (PhoxDem10.2)  
Singlemode glass waveguide  
optical interconnect platform

**Pegasus 1** (NephDem06.01)  
Optically disaggregated object  
oriented platform

**System interface**  
Dual display system diagnostic  
interface

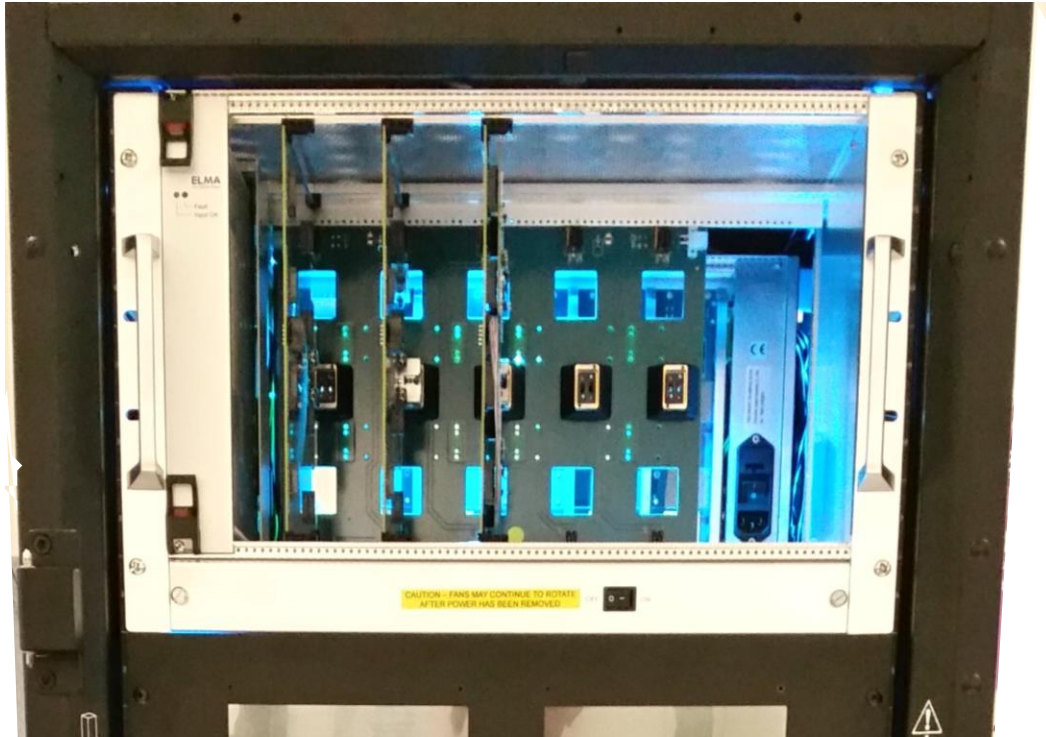
**ThunderValley2** (PhoxTest03.01)  
Photonically enabled disaggregated  
SAS data centre switch and storage  
platform

**Pegasus 2** (PhoxDem09.04)  
Enhanced object oriented  
platform with system embedded  
waveguides

**Computer bay**  
Local computer bay to drive  
converged test regimes



# PhoxLab - Converged data centre test environment





# Thank you

**Richard Pitwon**

Photonics group leader

[richard.pitwon@seagate.com](mailto:richard.pitwon@seagate.com)

