

# Photonic Integrated Circuits at Infinera

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# Who is Infinera?

- ▶ Silicon Valley success story
  - Startup → NASDAQ IPO in 2007
  - 2015: \$886M Revenue, 47.8% GM, 13.1% Profit
- ▶ Industry's First Commercial Large-Scale Photonic Integrated Circuit (PIC)
- ▶ Industry's First Transport Platform to Integrate OTN Switching with WDM
  - Enabled by advantages of PIC Size, Power, Cost, and Reliability
- ▶ Industry's First Transport Platform >20 Tbps in Single Rack for DC Interconnect
  - Shipped at 50% less power than competitive (less integrated) solutions, enabled by PIC Size, Power, Cost and Reliability
- ▶ Transformed & Driving the **Optical Transport** Market



# Why Use Photonic Integration?

- ▶ \$ / Gbps
- ▶ Watts / Gbps
- ▶  $\text{mm}^3$  / Gbps and  $\text{mm}^2$  / Gbps

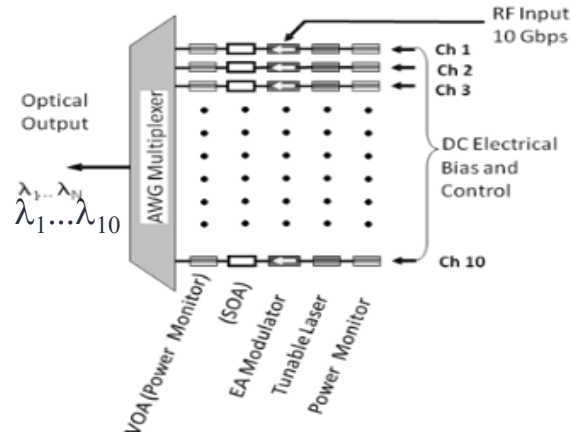
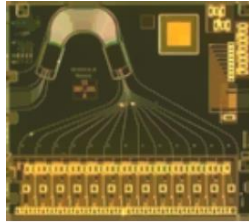
At both component **and** system/network level

Use unique **system-level** advantages:

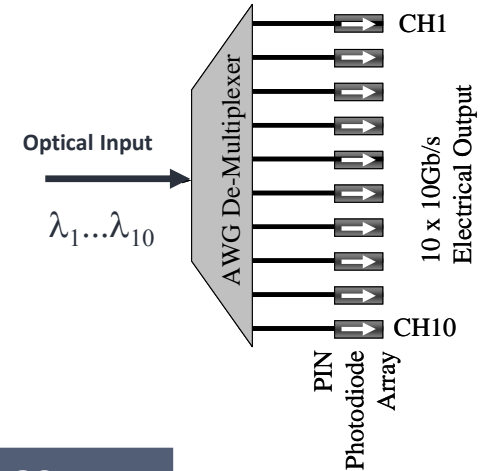
- ▶ Super-channels with sliceability
- ▶ Instant Bandwidth
- ▶ Integrated OTN/WDM Switching

# Infinera Multi-Channel DWDM 100Gb/s Transmitter and Receiver Photonic ICs (2004)

## Infinera 100 Gb/s Transmitter



## Infinera 100 Gb/s Receiver

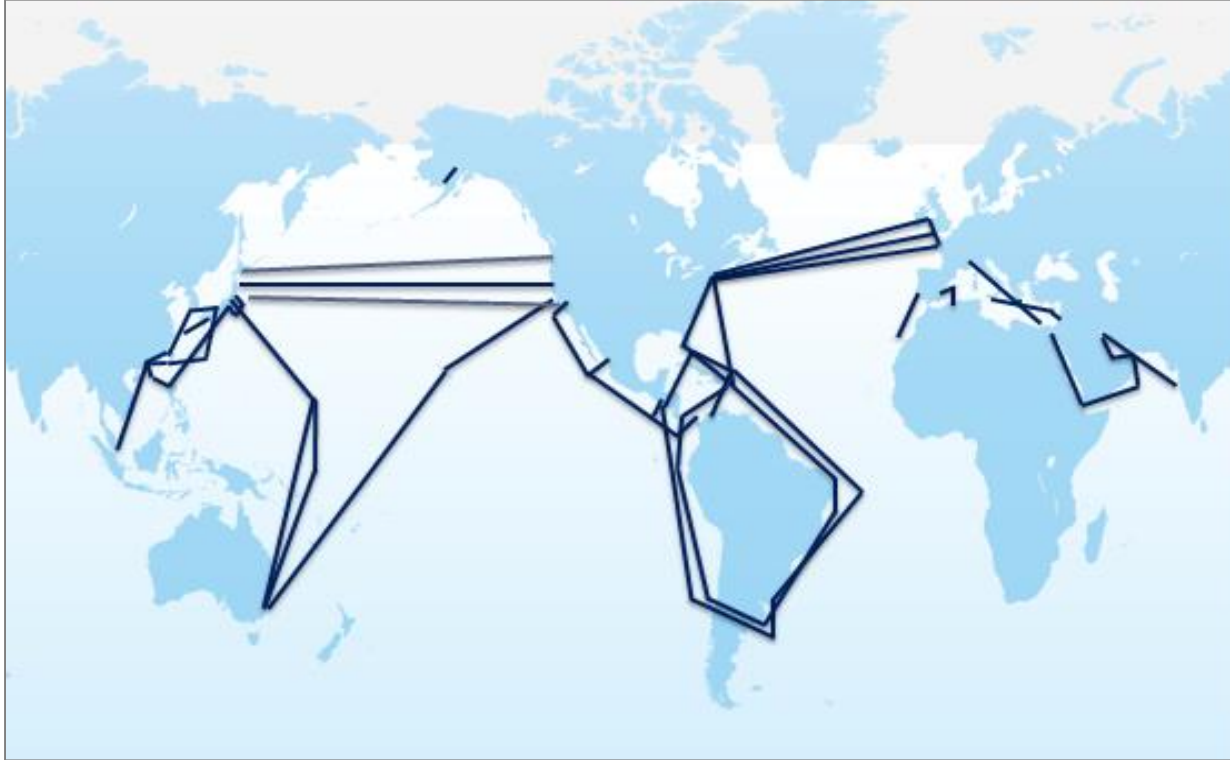


Integrated Optical Functions	>60
Unique Integrated Functions	8
“Gold box” replacements	~20-40
Fiber coupling reduction	>100

# Why Use InP for Photonic Integration?

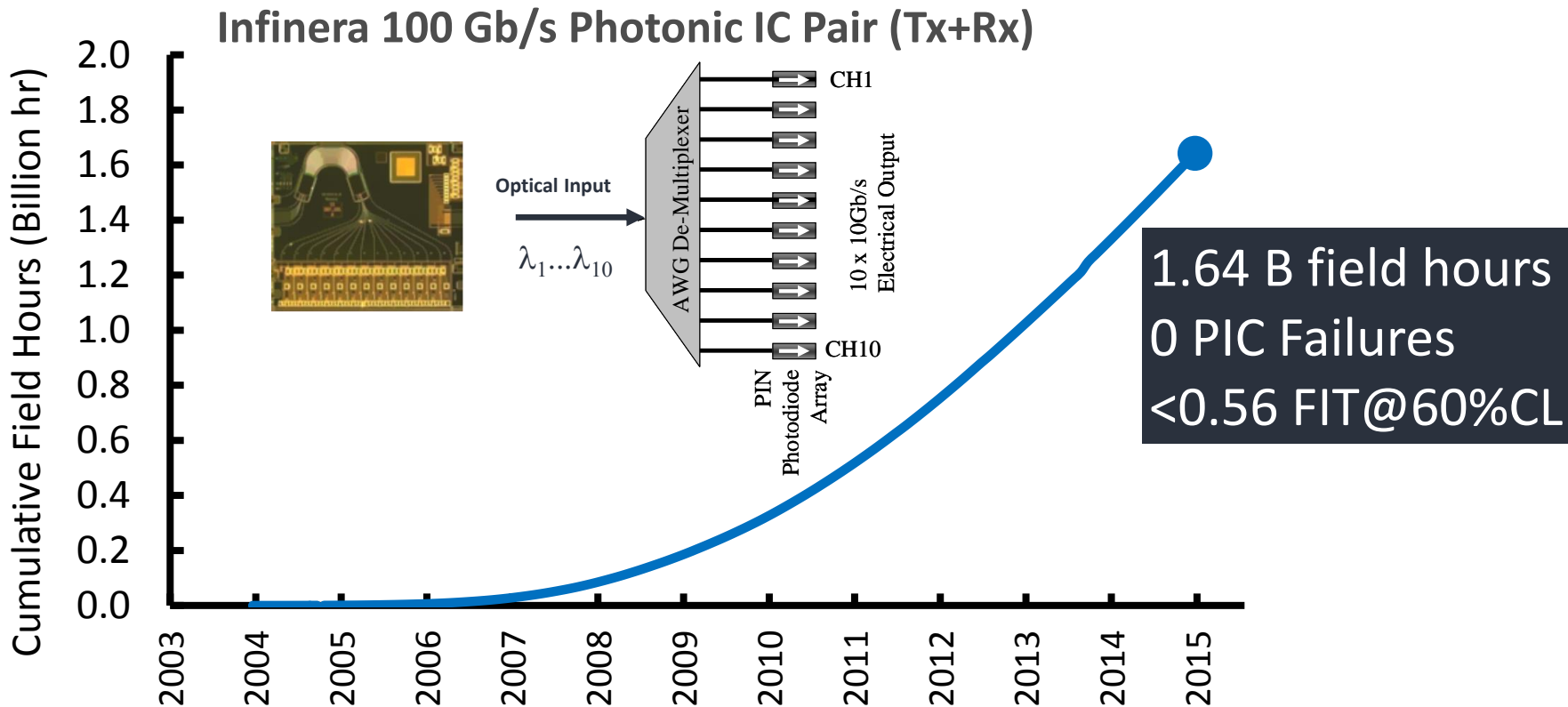
- ▶ Platform capable of highest performance → no compromises vs. discrete for ULH, LH, Metro Regional/Core Markets
- ▶ Platform capable of integration of lasers and gain anywhere in circuit
- ▶ Converge multiple devices onto single manufacturing platform  
Leverage semiconductor learning curve
- ▶ Platform scalable (build generation upon generation)

# Infinera PIC-based Subsea Deployments



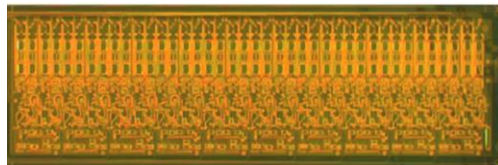
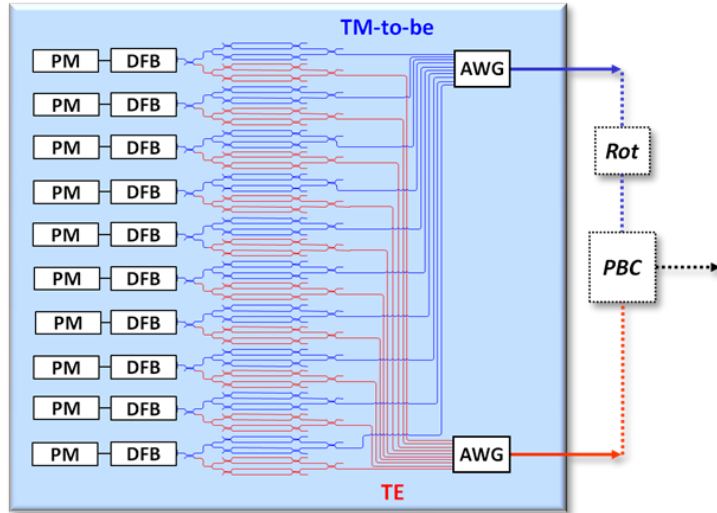
- Over 250,000 route km of deployed subsea systems
- Longest deployed lengths:
  - 9,800 km (BPSK)
  - 4600 km (QPSK)

# Commercial Photonic IC Imperatives: Reliability

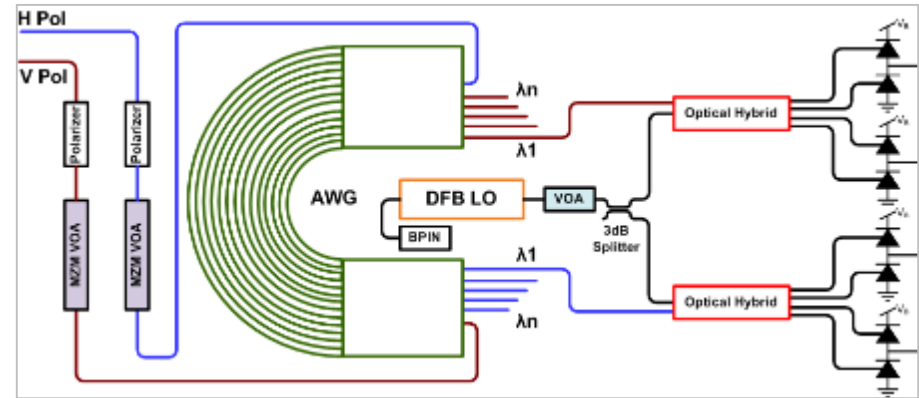


# Infinera Multi-Channel DWDM 500Gb/s Coherent Transmitter and Receiver Photonic ICs (2012)

## Infinera 500 Gb/s Coherent Transmitter PIC



## Infinera 500 Gb/s Coherent Receiver PIC

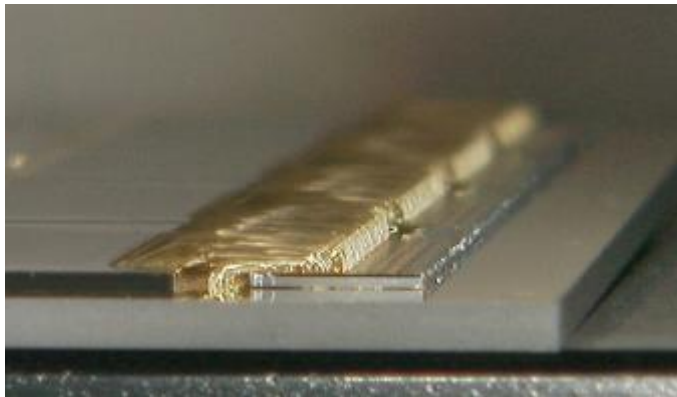


Integrated Optical Functions	>600
Unique Integrated Functions	10
“Gold box” replacements	>100
Fiber coupling reduction	>400



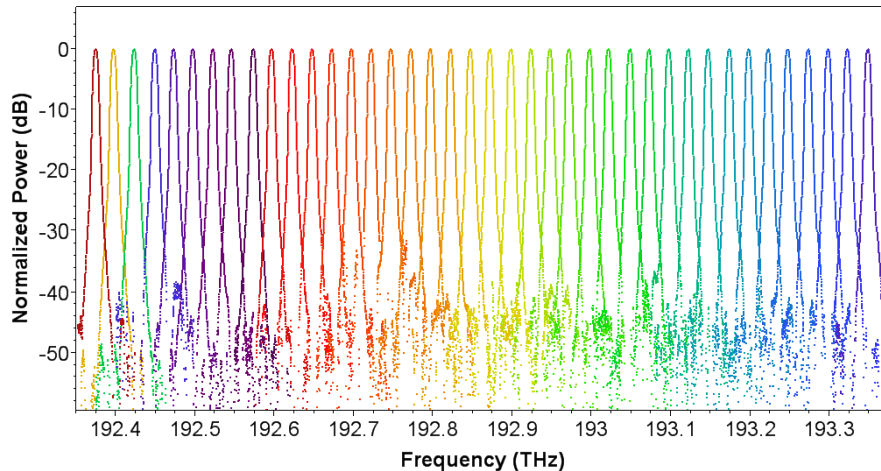
# Infinera InP PIC Scalability (2014)

## Infinera 2.25 Tb/s Transmitter PIC

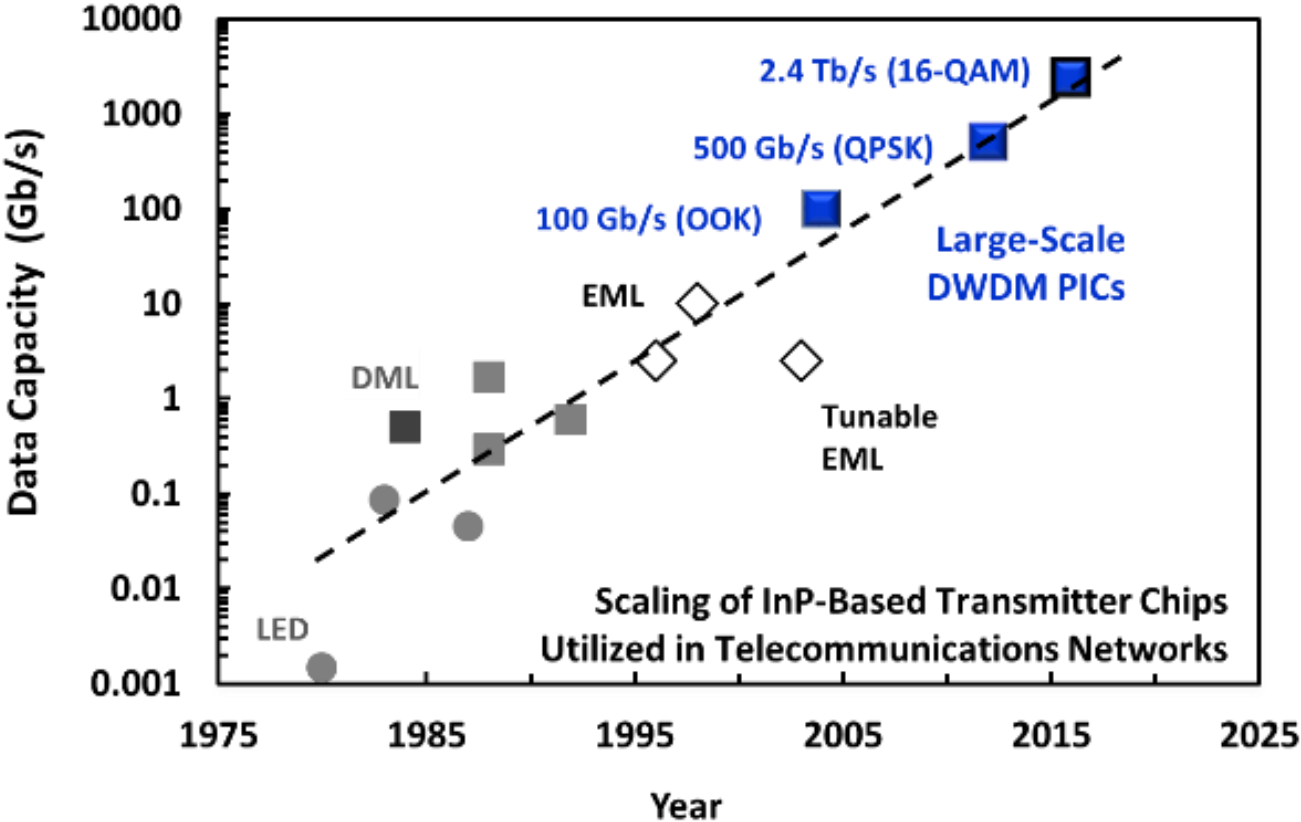


**>1700 functions InP-Based PIC**

## 2.25 Tb/s in 1 THz-wide Super-Channel



# Infinera's World Leading Bandwidth Scaling (Per Module Pair)



# Infinera Photonic Modules (To Scale)

## 100 Gb/s PIC Modules



### 2004 Release

**11 Gbaud OOK**

10 channels x 10G

Flexible Grid

## 500 Gb/s PIC Modules



### 2012 Release

**16 Gbaud QPSK**

5 channels x 100G (dual-carrier)

Flexible Grid

Super Channel

## 2.4 Tb/s PIC Modules



### 2016

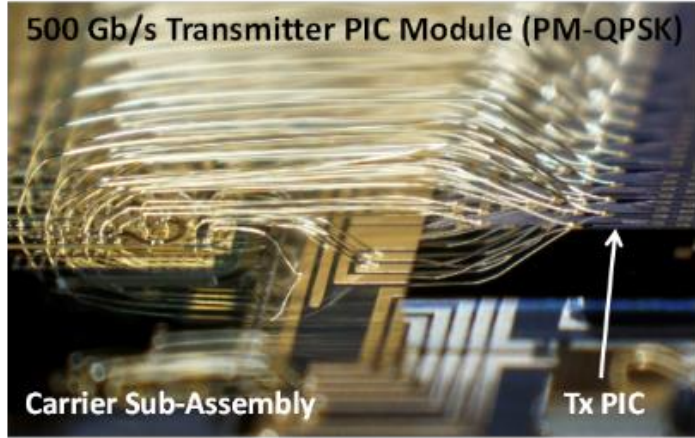
**32 Gbaud QPSK, 16QAM**

12 channels x 200G (single-carrier)

Fully C-band tunable per channel,

Sliceable Super Channel

# Key Considerations For the Future of Photonic Integration



- Co-design of PICs, drivers, package controls, test, and system
- Lack of co-design more than likely does not solve and sufficient problem
- **Cross-terms** are often the keys to ensuring sufficient cost, performance, reliability

- **Key cross terms** include:

- DC & RF Electrical Interconnect → PIC on Carrier, Package and Board
- Optical Interconnect
- DC & RF Testing → PIC, Package, System
- Mechanical & Thermal Interfaces and Interconnects
- Controls → Algorithms, Firmware, Hardware



 **infinera**<sup>®</sup>

what **THE NETWORK** will be