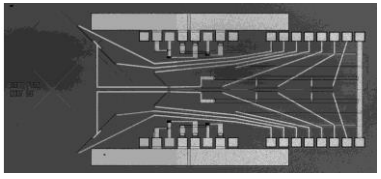
Chris Doerr
Market Watch OFC 2014

Metro Silicon Photonics

Market Watch: PIC vs. Silicon Photonics: Hype or Reality?

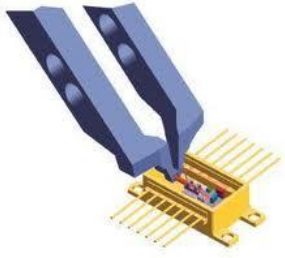
Photonic integrated circuit (PIC) pros/cons

- Small footprint
  - No lenses
  - Strongly confining waveguides



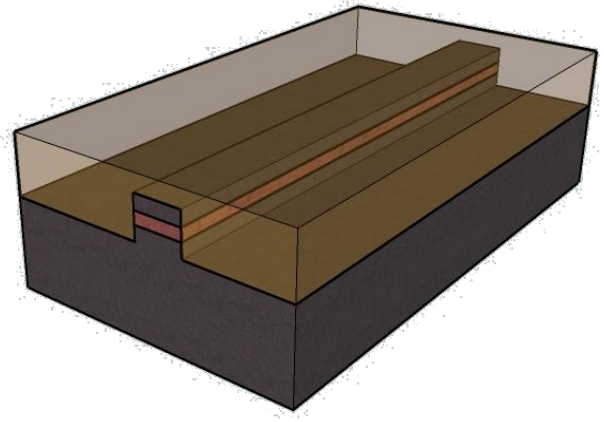
- Low power
  - Avoid 50-ohm lines
- Performance challenge
  - Higher insertion loss
  - Cannot optimize components separately

- Low price
  - Fewer touch points
  - No mechanical adjustments
  - Less test equipment
  - Less material

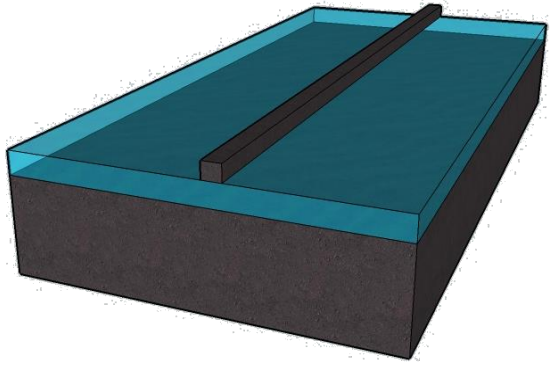


PIC material systems

Indium phosphide (InP) PIC



Silicon (Si) PIC

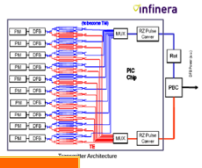


100G+ PICs

Metro challenge: deliver full integration with good price, power, footprint, *and* performance in volume

= InP

= Si



Infinera 100G/500G

Full-integration gap

DWDM Long Haul

Reach

Partial integration (U2T, Oclaro, etc.)

DWDM Metro

Cisco/Lightwire CPAK

Intel/Corning MPX

Telecom Clients

Luxtera AOCs

Data Center Clients

Active Cables

Chip-to-Chip

Priorities
1. Performance
2. Footprint
3. Power
4. Price

Priorities
All very important

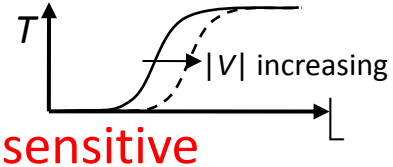
Priorities
1. Price
2. Power
3. Footprint
4. Performance

InP – Si comparison

InP

- Expensive material
  - In is scarce
- Medium yield
  - W.g. material from epitaxy
- Small footprint
  - High index contrast in 1D

- Efficient laser
- No good native oxide
- Low dark current
- Small wafers
  - Brittle material



- Modulator temp. sensitive

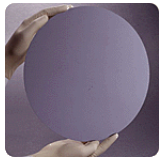
Si

- Cheap material
  - 27% Earth's crust is Si

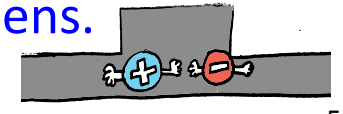
- High yield
  - W.g. material from original boule

- Extremely small footprint
  - High index contrast in 2D

- No native laser
- Excellent native oxide
- Medium dark current
- Large wafers
  - Strong material



- Modulator temp. insens.



SiPh strengths and weaknesses wrt short reach

Pros

- Low-cost material
- High yield
- Extremely small footprint
- Excellent polarization handling
- Excellent native oxide
- Low modulator t
- Large wafers

Opportunities in short reach for SiPh but also challenges with current state of the art

Cons

- No native laser
- Higher dark current
- Strong polarization sensitivity
- Insertion loss challenges
- Modulator nonlinearity

Challenging, tough competition from VCSELs & DMLs

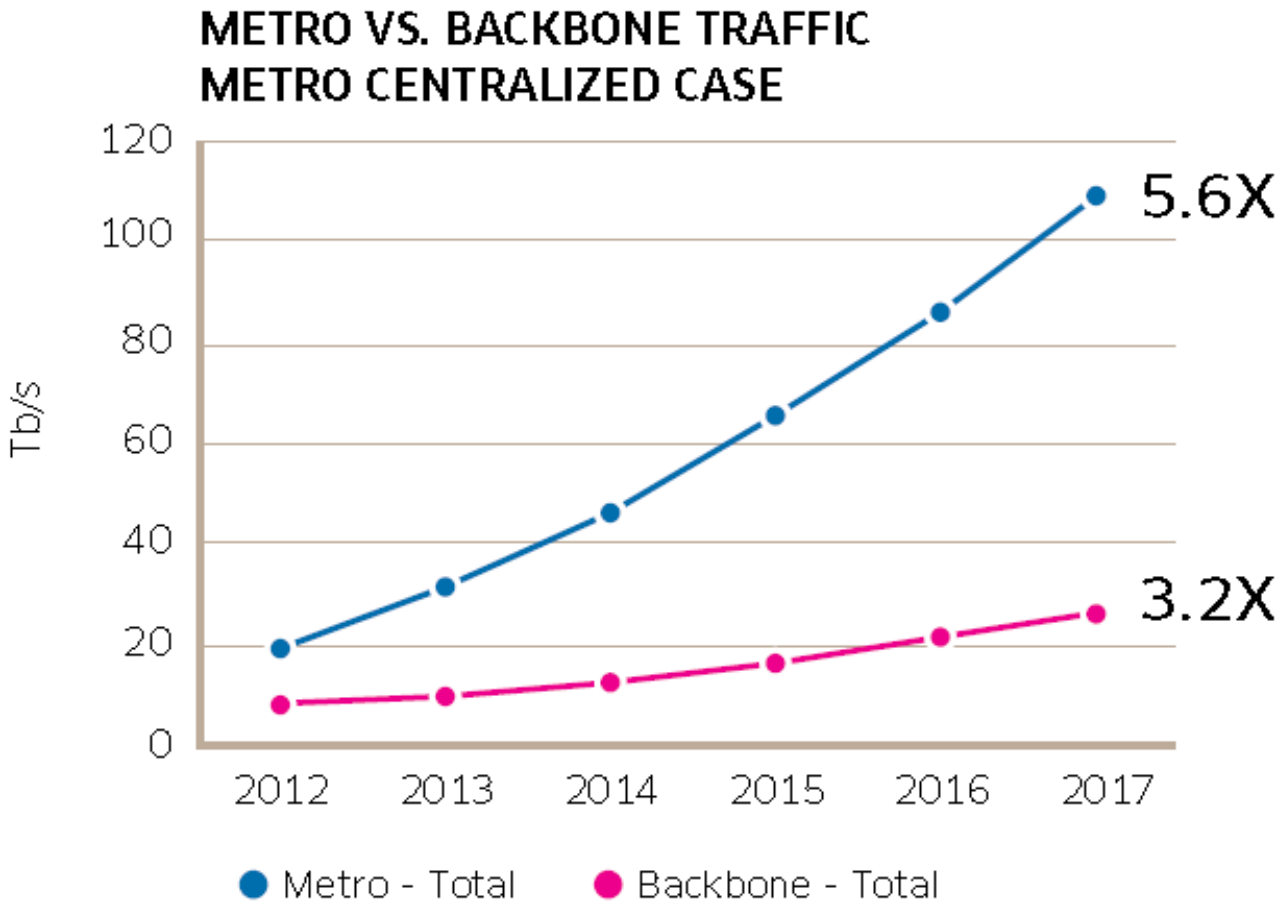
Challenging for direct detection

Challenging, because usually detecting on-off keying with random received polarization

Challenging, because links are very optical power constrained

Challenging for PAM, DMT

Metro traffic expected to grow 560% in next 5 years



560% INCREASE IN TOTAL METRO TRAFFIC

METRO TRAFFIC GROWS ALMOST 2X FASTER

Source – ALU Bell Labs Architecture Study Dec 2013

SiPh strengths and weaknesses wrt metro assuming coherent transceiver

Pros

- Low-cost material
- High yield
- Extremely small footprint
- Excellent polarization handling
- Excellent native oxide
- Low modulator t
- Large wafers

Cons

- No native laser
- Higher dark current
- Strong polarization sensitivity
- Insertion loss challenges
- Modulator nonlinearity

OK, laser shared between Tx & Rx. To minimize electrical connection length eventually want PIC integrated with ASIC and laser far away

Greater opportunities in metro where current limitations do not come into play

In long-haul these current limitations do not really come into play either

Laser

OK, photocurrent is very high from LO in coherent systems

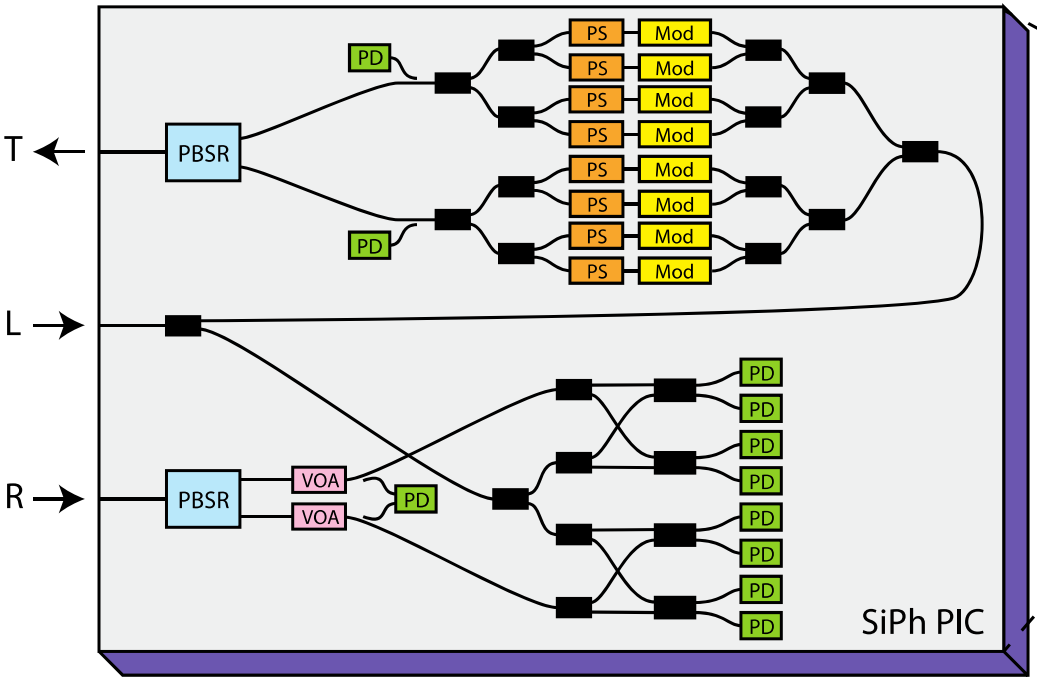
OK, polarization diversity is needed anyway in coherent systems, and actually made easier

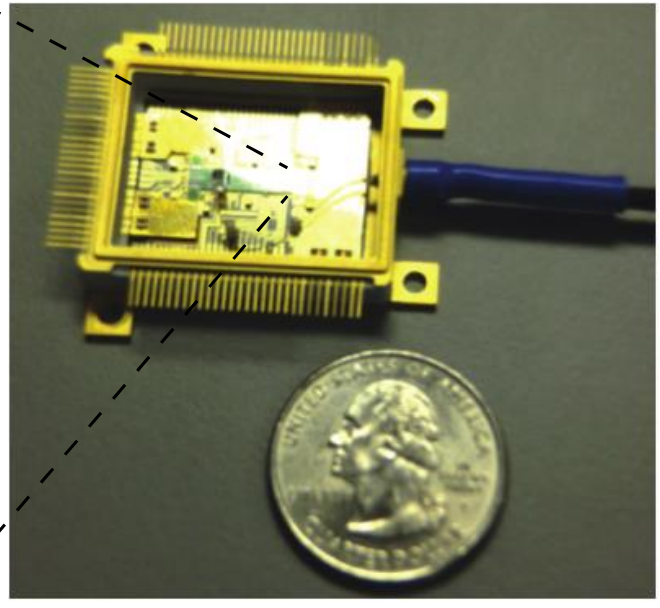
Challenging, but mitigated through design and LO gives gain

OK, can be compensated in coherent DSPs

Single-chip 100G SiPh transceiver

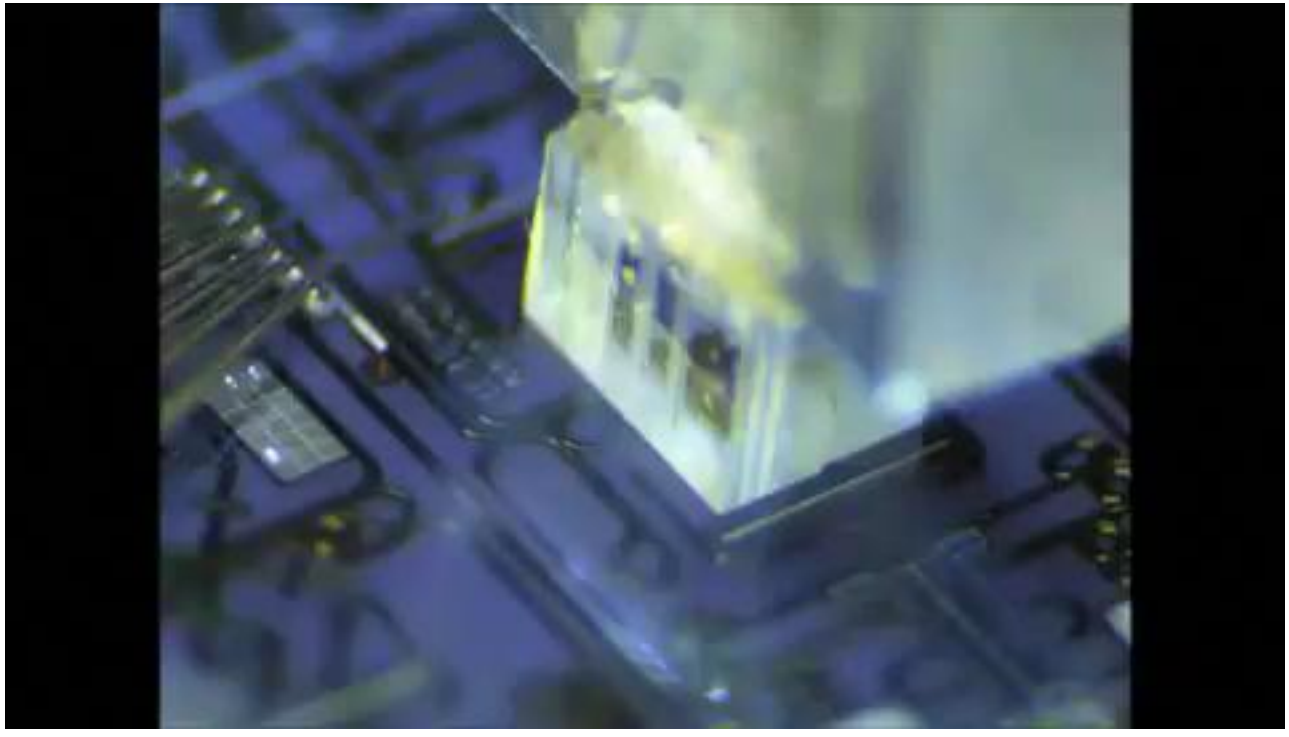
Transmitter and receiver integrated together to save significant packaging cost and size





Package includes linear drivers and TIAs
Total power < 4.5W

On-wafer testable with wafer prober



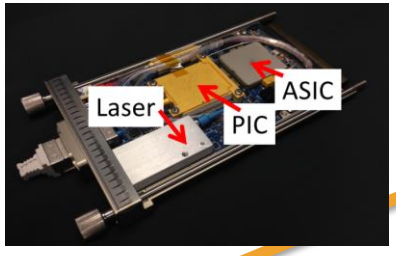
Cost, size, and power erosion of 100G coherent

SiPh is already enabling significant cost, size, and power reduction of coherent transceivers

SiPh allows coherent to enter short reaches coming from the high end

2012
MSA, 70W, discrete optics

2014
CFP, 28W, silicon photonics



D-CFP2

10 Mm

1 Mm

100 km

10 km

1km

Summary

- Terminology should be InP PICs and SiPh PICs
- Price, footprint, power, and performance are key for metro applications and these are well addressed by PICs in general
- Coherent transceivers for metro applications is a particular sweet spot for SiPh PICs
  - Weaknesses of current SiPh not relevant
  - Many advantages including low cost, high yield, small footprint, low temperature dependence
  - SiPh has enabled the first coherent CFP
- SiPh is a reality, *not* hype, in metro