

# **Are Silicon Photonics and DSP Approaches to Optics Delivering on The Promise of Nearly Free Cost?**

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Market Focus Datacenters Panel

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# SiP and DSP Promise for Optics

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- SiP and DSP are CMOS
- CMOS (i.e. mainstream high volume silicon) is free
- Optical components are expensive
- Replace optical components with CMOS
- Optical interfaces will become free
- How to judge SiP and DSP delivery on this promise?

# If you're asking, you are not a believer!

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SiP Worship



DSP Worship



The Ancient Circle of CMOS

# Heretics Examine Past SiP & DSP Use Cases

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- 10G LRM
- 100G Coherent Transport
- 100G LR4
- 40G & 100G AOC
- 40G & 100G PSM4
- 100G Single  $\lambda$  Ethernet

Caution: there are consequences for non-believers



# 10G LRM DSP

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X2 LRM Module



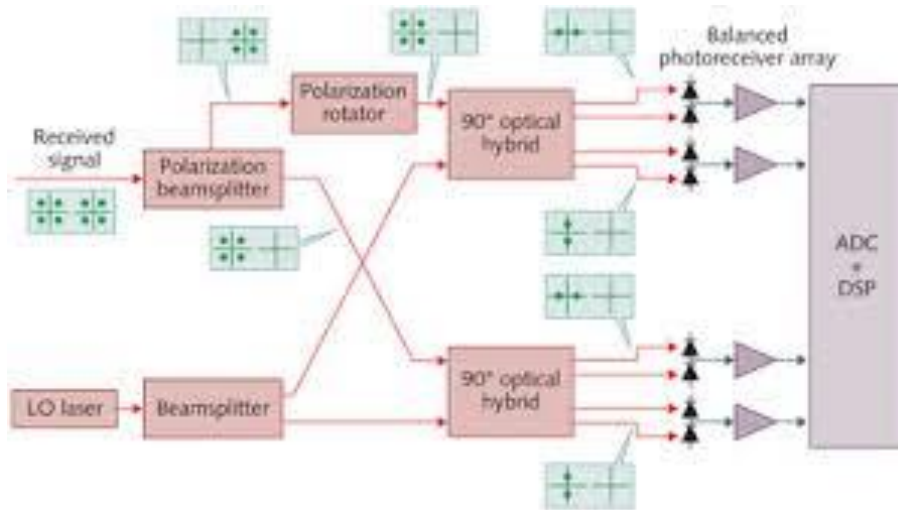
SFP+ LRM Module (linear I/O)



- 10G Serial over 220m to 300m of OM1 & OM2 (old MMF)
- Promise of low cost alternative to 10G LX4 (4x 2.5G WDM)
- >\$100M in V.C. funded start-ups and Corp. investment
- IEEE standard started in 2003, completed in 2006
- Linear interface SFP+ took ~3 additional years
- By then old MMF was replaced with OM3; no more problem

# 100G Coherent DP-QPSK DSP

## 100G Coherent Receiver



## 100G Coherent OIF Module



- Solved the problem of 100Gb/s transmission in 50GHz channel, i.e. spectral efficiency of 2bits/sec/Hz
- Initial optics expensive
- Great cost savings in network deployment and operation
- Rapid cost drop due to volume and innovation like upcoming CFP2 ACO (linear interface, similar concept to LRM)



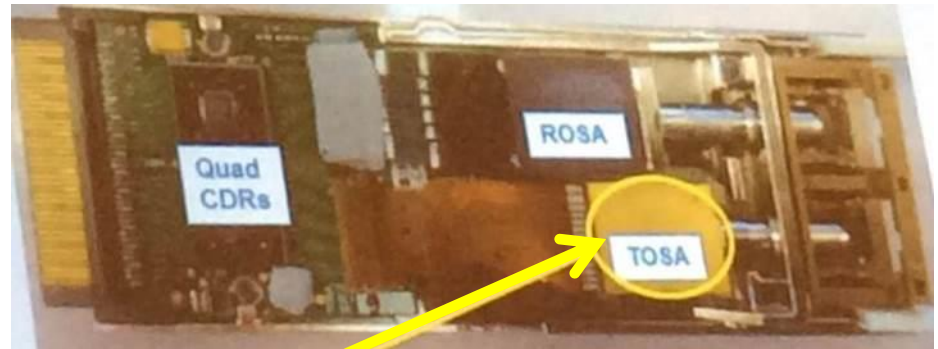
# 100G LR4 SiP

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100G LR4 CPAK Module



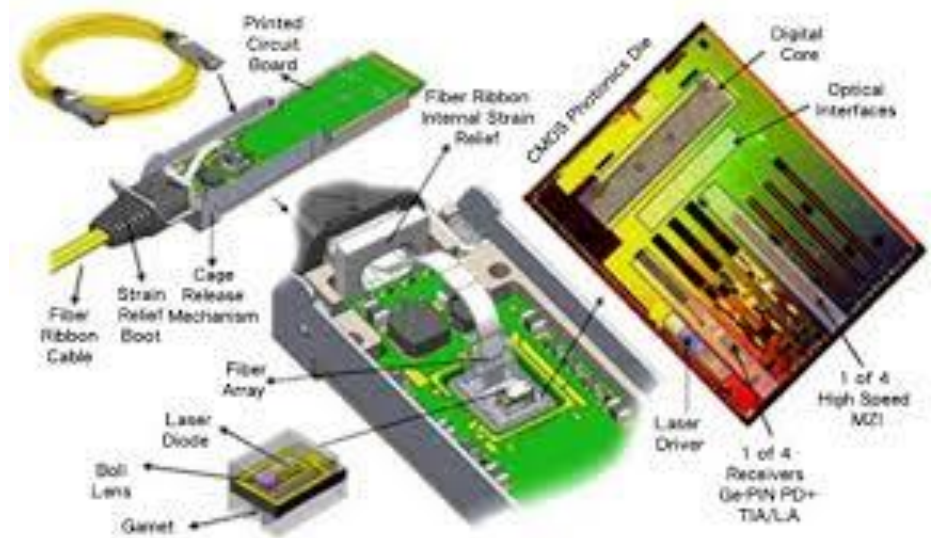
Inside 100G LR4 Module



- LR4 TOSA using SiP WDM technology
- “Gold box” OSA packaging
- Comparable metrics to conventional DFB laser and EML based CFP2 modules
- Suggests optics cost is driven by packaging

# 40G & 100G AOC SiP

- Luxtera/Molex 4x10G AOC (QSFP+ connectors) example

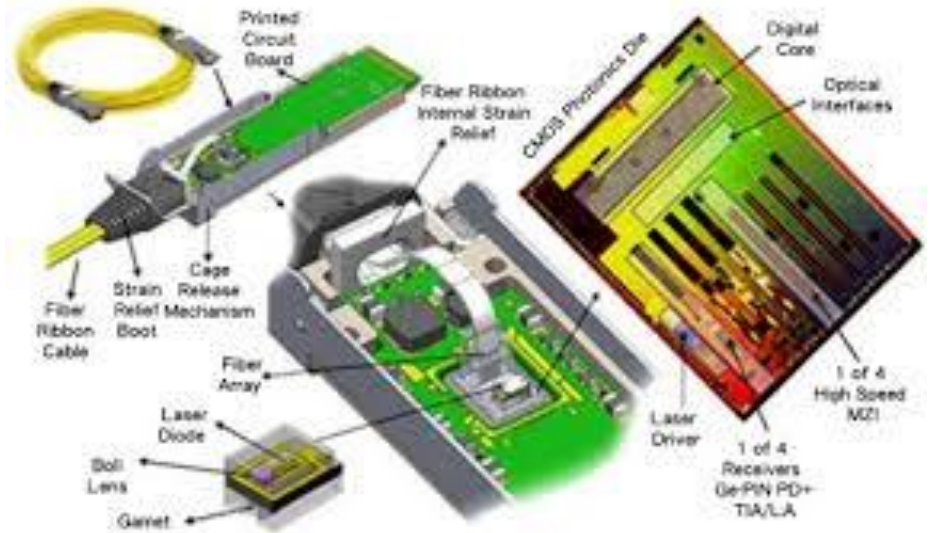


- Competitive AOC vs. VCSEL based AOCs for <100m
- Lower cost AOC for >100m (SMF is cheaper than MMF)
- Unfortunately AOC is not of interest in most >100m apps.



# 40G & 100G PSM4

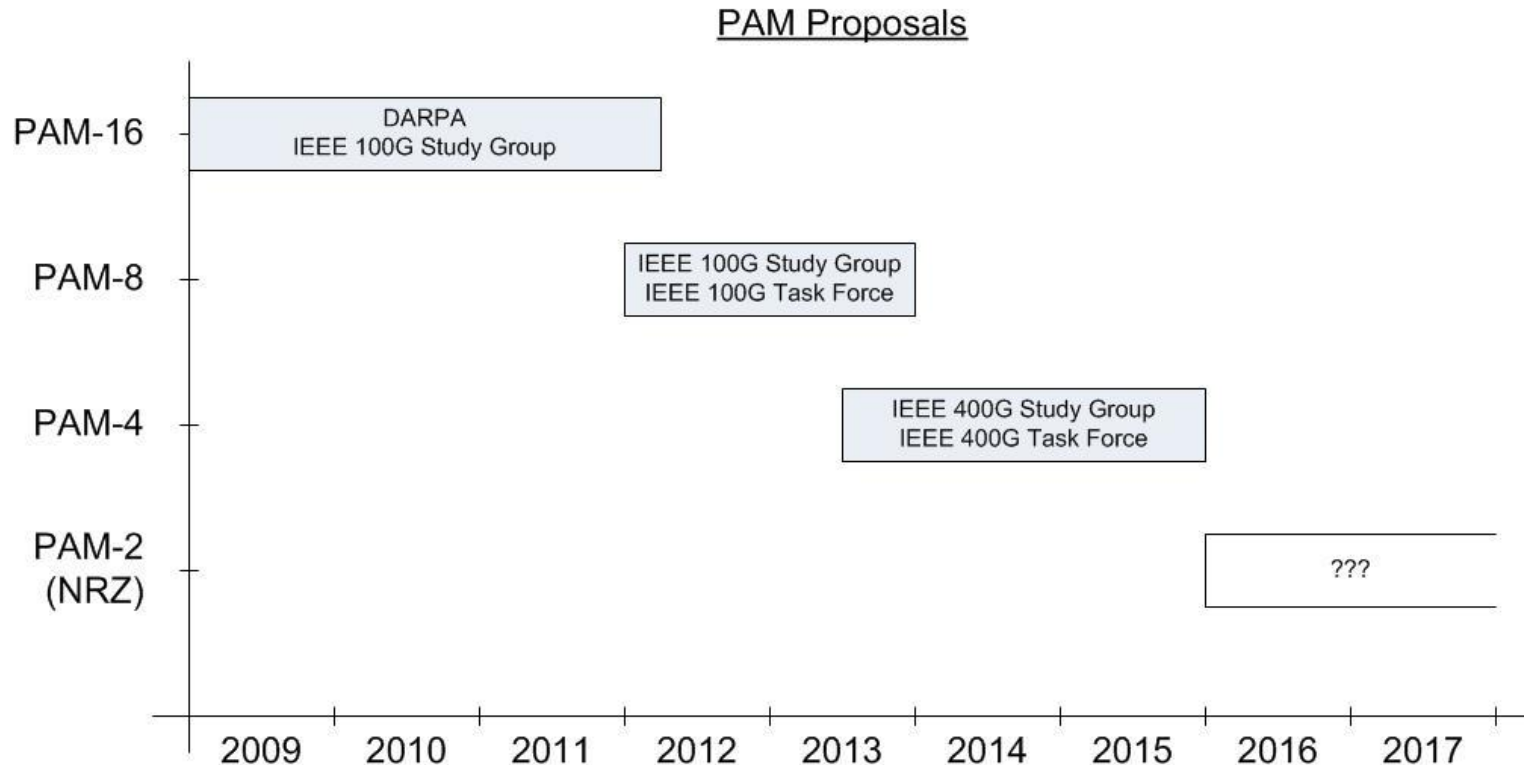
- Luxtera/Molex fiber-tail 4x10G QSFP+ module example



- Fiber-tail because of grating coupler geometry
- Conventional approach is separate module and patch cord
- Low cost in some datacenter apps. that are pre-designed
- When SMF cost is a factor WDM is preferred

# 100G Single $\lambda$ Ethernet SiP & DSP

- Promise of replacing 4x25G WDM (LR4, CWDM4) optics by single laser with no optical WDM Mux/DeMux optics
- 100G  $\lambda$  PAM-N: SiP/DSP architecture keeps changing



# 100G Single $\lambda$ Ethernet DSP

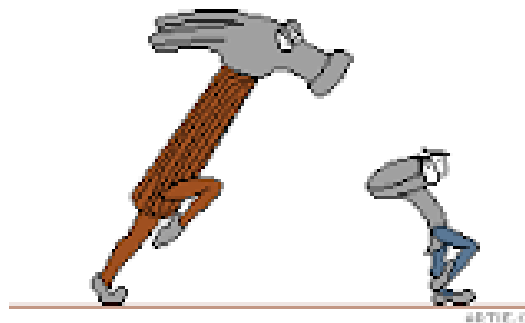
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- Active debate in IEEE: 100G  $\lambda$  vs. 2x 50G  $\lambda$  WDM optics
- 100G  $\lambda$  PAM-4 & DMT proposals: high-power TX, ADC/DSP with high-coding gain FEC (like BCH) RX
- 28nm CMOS DSP ASIC is 3 to 6W
- 14nm CMOS DSP ASIC is projected 2 to 3W
- 100G  $\lambda$  High-power TX & Linear RX is projected 1 to 2W
- LR4 & CWDM QSFP28 modules next year will be 3 to 3.5W
- 2x50G  $\lambda$  WDM modules projected 2 to 2.5W
- 100G  $\lambda$  optics have at least 5dB higher optical spec. requirements than CWDM4
- What DSP get us: holy grail of 1  $\lambda$ , huge R&D investment, higher module power, much more difficult optical specs.

# SiP & DSP in Existing Applications

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- SiP & DSP are just technologies that solve problems
- Not every problem is a nail that needs SiP or DSP hammer



- New technologies do best when they solve problems that can not be solved in other ways; ex. 100G Coherent
- Me-too solutions to solved problems do not conquer markets
- To date SiP & DSP in Datacom optics have not delivered on the promise of nearly free cost

# Unsolved Problem Example

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- Moving beyond WDM “Gold Box” packaging for Datacom
- Will dramatically reduce optics cost
- Multiple companies have announced, shown, or stated they are working on SiP 100G WDM non-gold box modules:
  - Aurrion
  - Finisar
  - IBM
  - Intel
  - Luxtera
  - Mellanox/Kotura
  - Scorpios
  - others
- Excellent market opportunity for a compelling solution

# SiP and DSP Approaches to Optics

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Thank you