Roadmap to 100 GbE, a CWDM Solution
IEEE 802.3 Higher Speed Study Group

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Xavier Clairardin, Kotura
xclairardin@kotura.com

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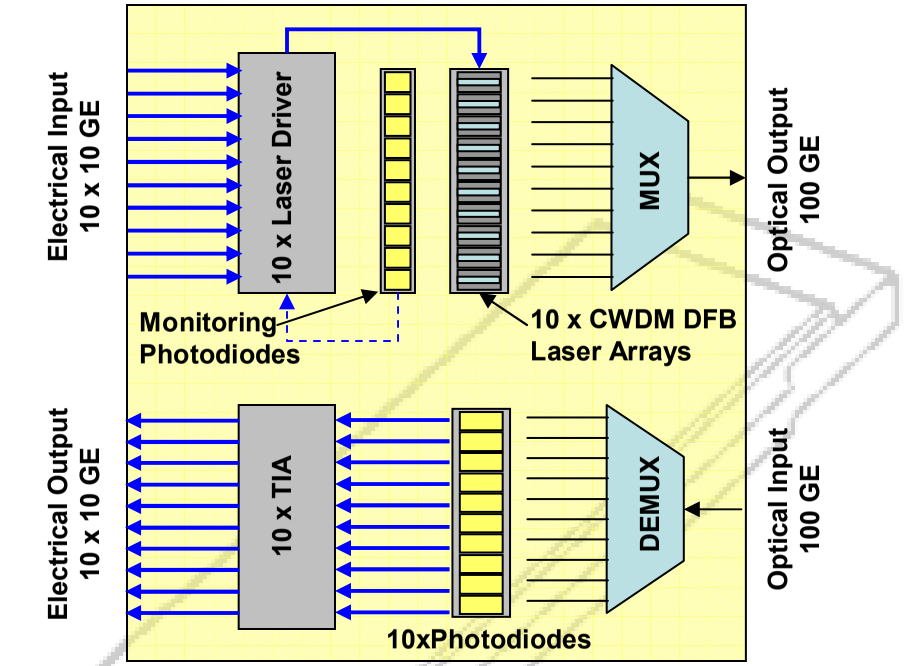
Proposed SMF Study Alternative

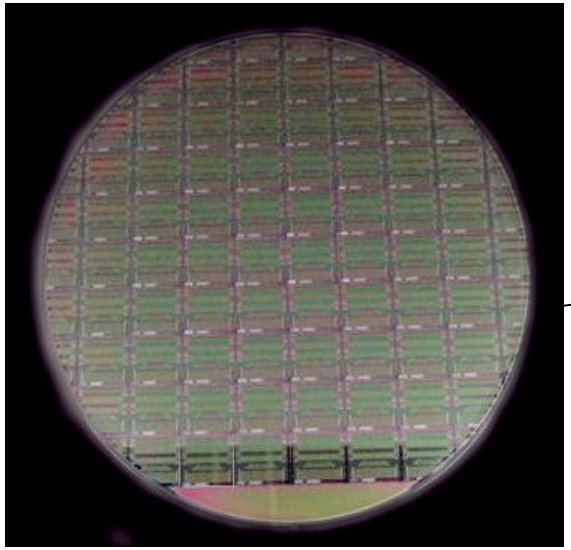
1550nm 10x10 G un-cooled DML CWDM array

- CWDM laser array
  - Un-cooled CWDM DML array
  - 1430 – 1610nm, 20nm spacing
  - ITU G.694.2 Grid
- 10 Gbs PINs array
- Existing 10 Gbs Electronics
- SOI Integration platform
  - Mux / Demux integrated Gratings
  - Automated Flip Chip bonding
  - Passive Alignment
  - Non hermetic package
  - Small Photonic Chip fits in Small Form Factor MSA such as XENPAK
- 100m – 10km Reach over SMF

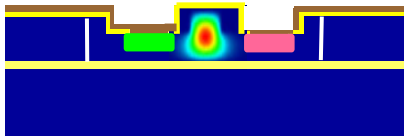


Leveraging Silicon Photonics

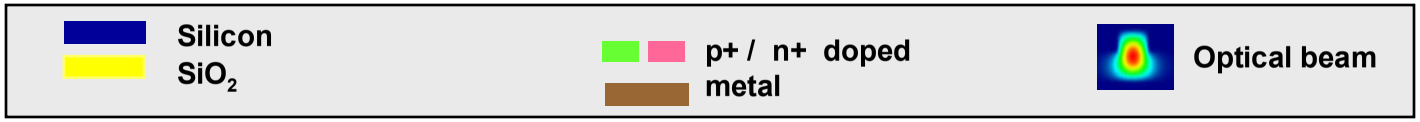
A platform that integrates optics & electronics on the same silicon chip using standard CMOS manufacturing techniques.



Array of CMOS Photonics Chips



Electrons & Photons in Silicon



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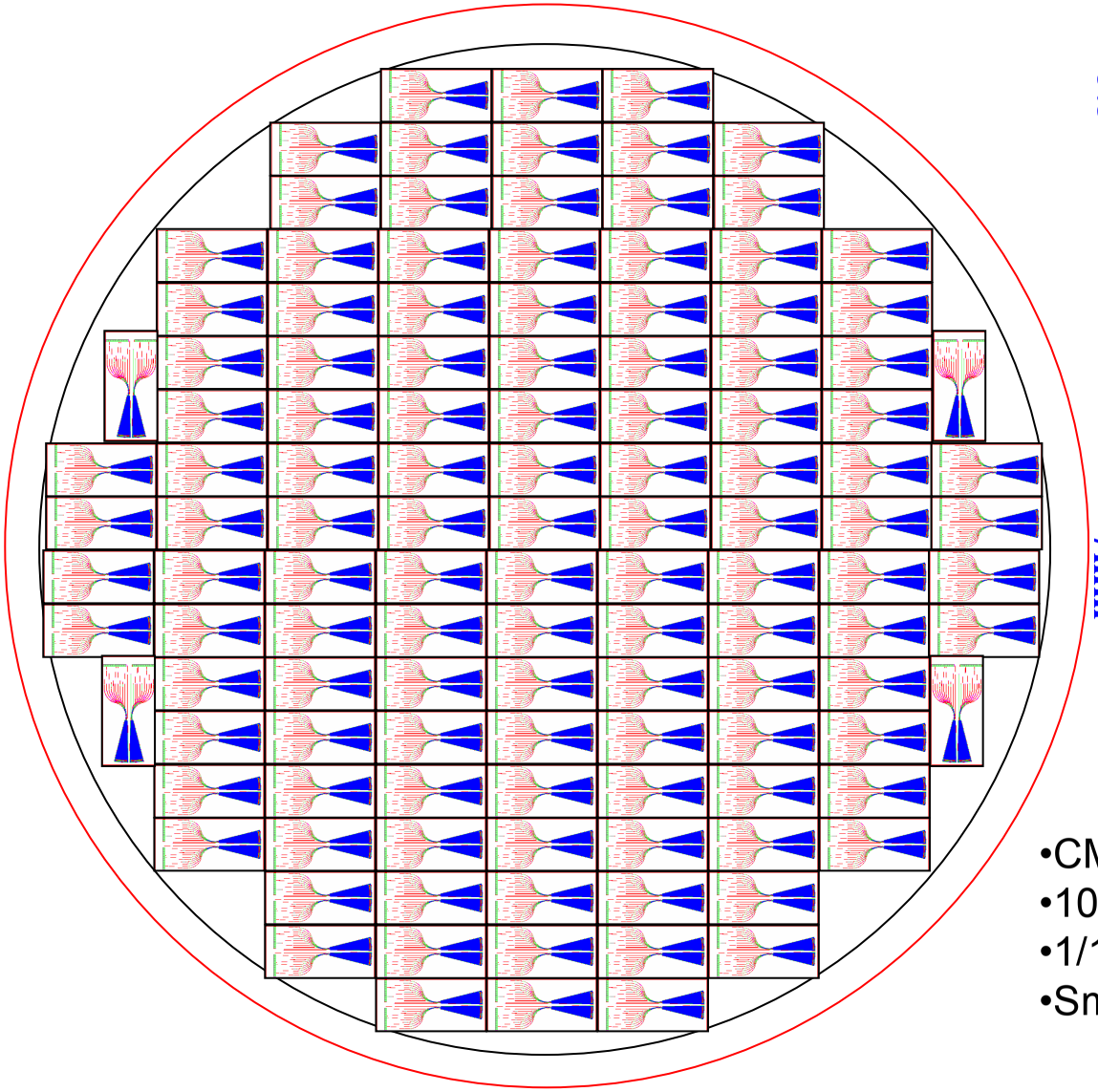
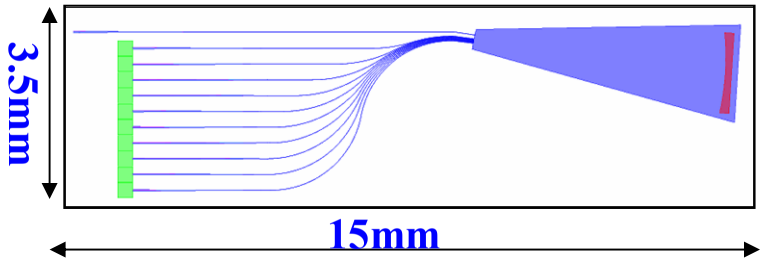
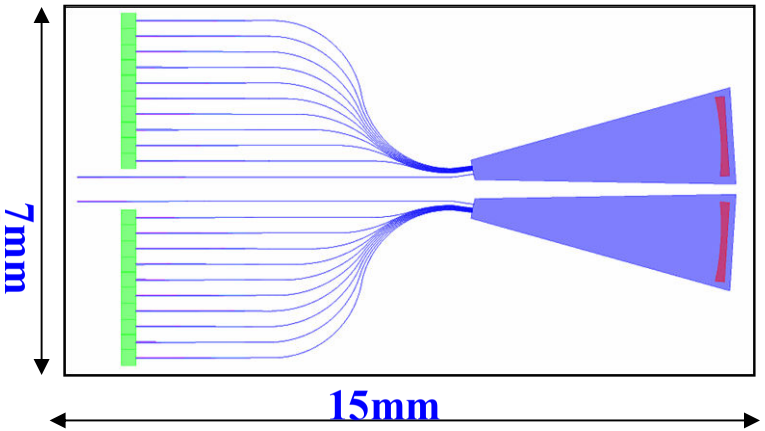
Silicon Allows Very Small Mux /Demux







- CMOS Si process
- 100's of chips per wafer
- 1/10 size of a standard AWG
- Small chip fit SFF MSA such XENPAK

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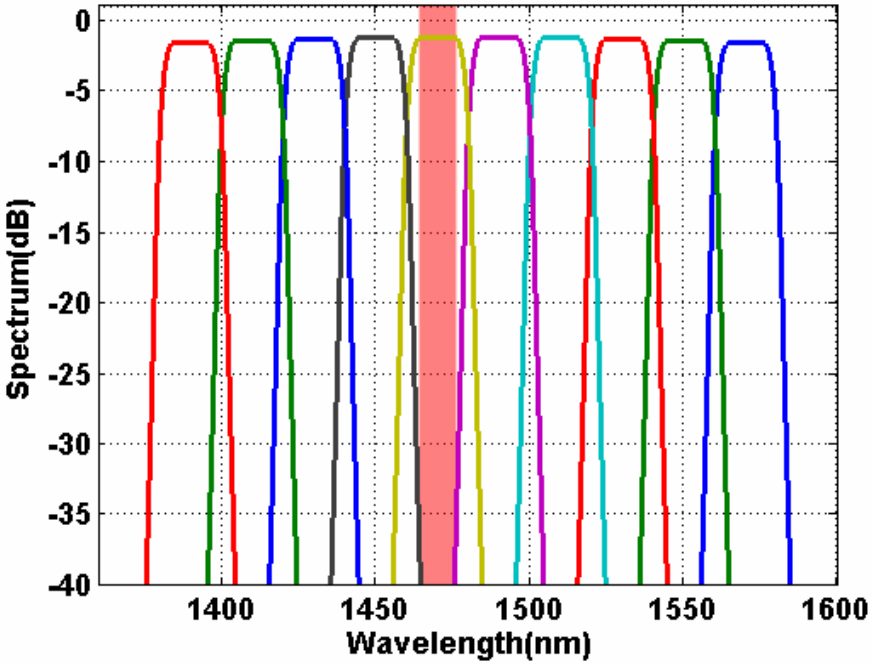
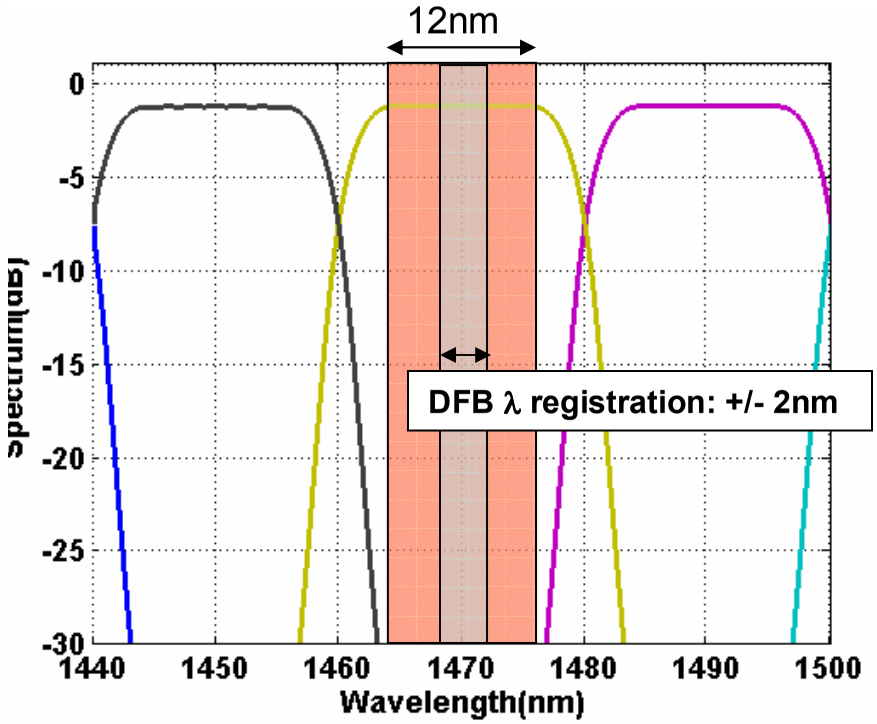
Silicon DeMux response over 10 CWDM channels





RX Demux designed with 12nm Flat passband

- **Allows 4nm for DFB registration**
- **Allows 8nm for variation of Demux over 100°C**
- **Provides <-30dB adjacent channel x-talk.**

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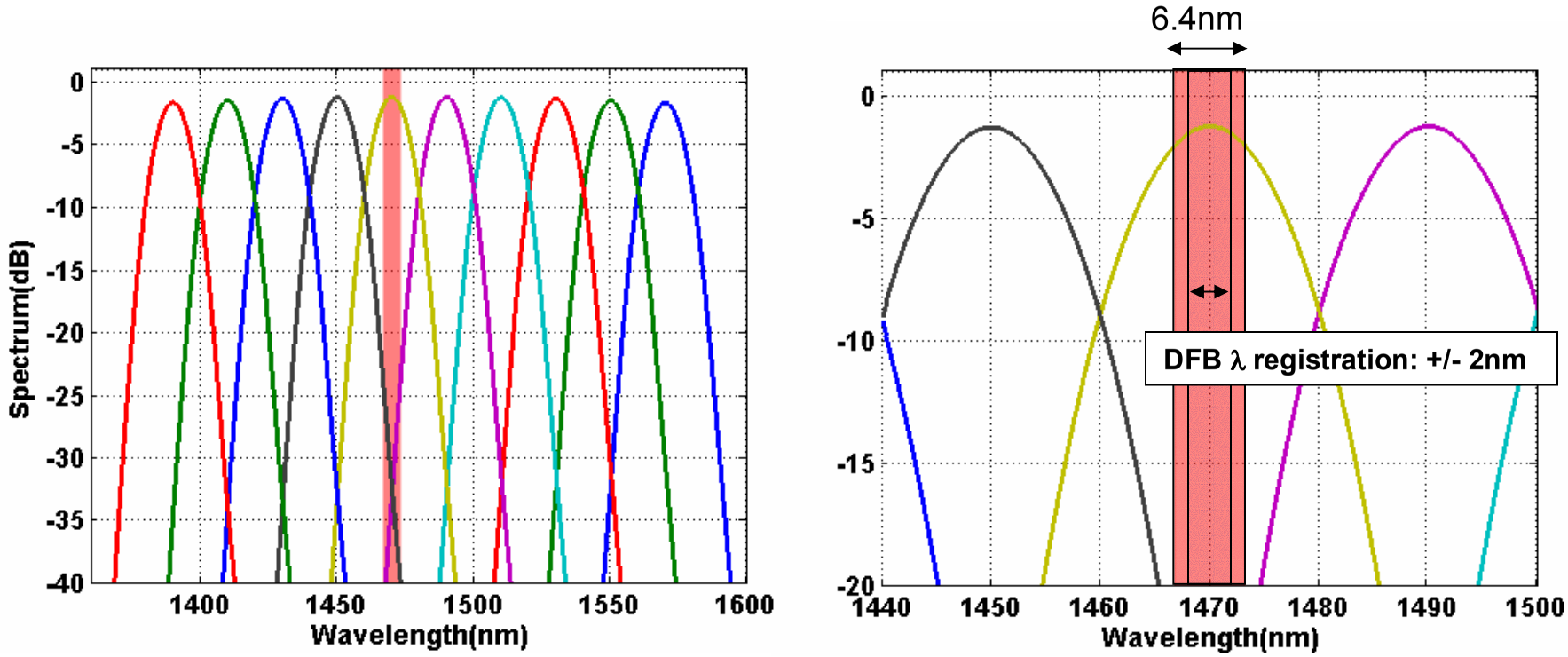
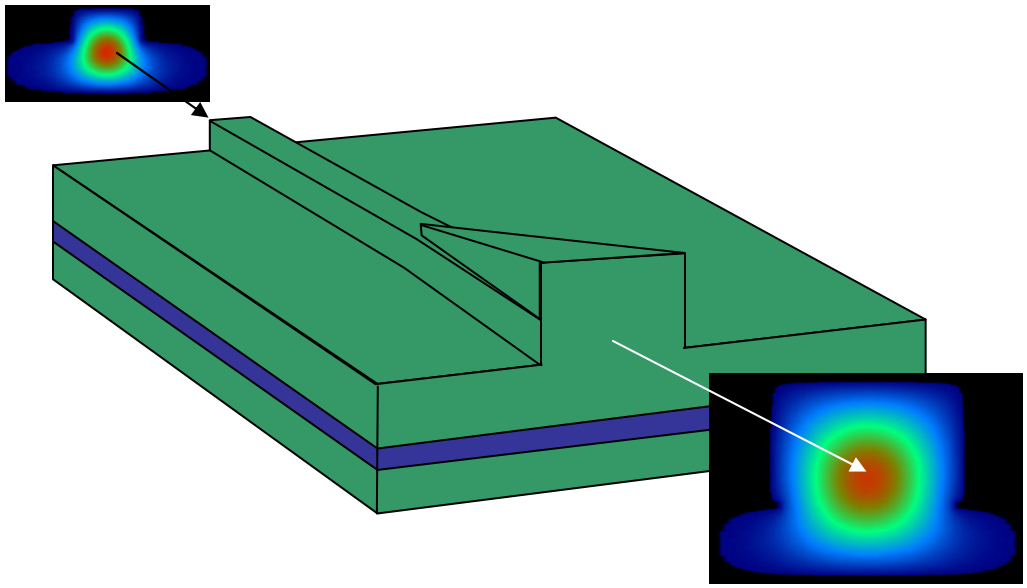
Mux Response over 10 CWDM channels



TX Mux designed with broad Gaussian 6.4nm Passband
allowing 4nm for DFB registration.
5pm/^{o}C $\Delta\lambda/\Delta T$ difference between Si and InP over Temp Range
provides for 20^{o}C for temperature differential across chip.
High thermal conductivity of Si provides good thermal management

Waveguide Optical Coupling



- **Three dimensional mode expander reduces waveguide coupling loss to < 0.5 dB**
- **Total insertion loss of <1dB fiber-to-fiber demonstrated**
- **Reduced Back facet reflection (<-50dB)**
- **Improved PDL (<0.05dB)**

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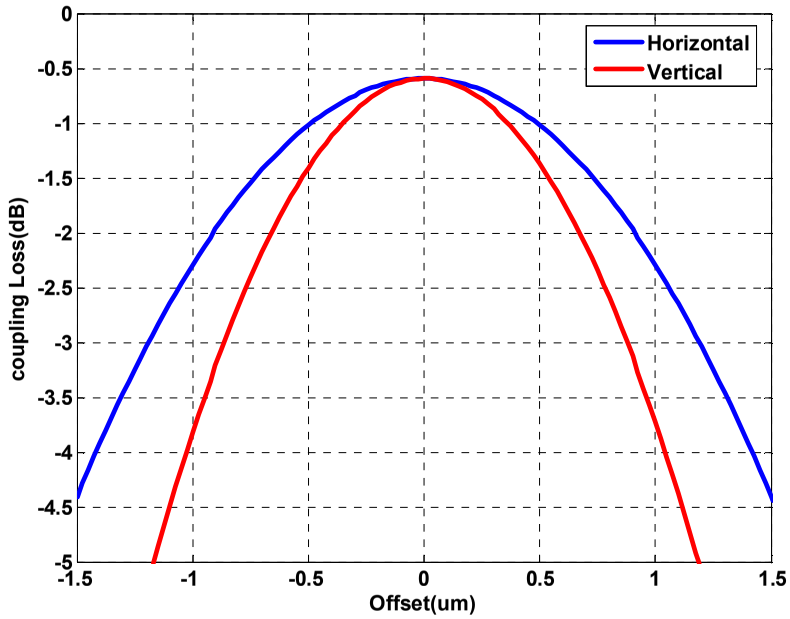
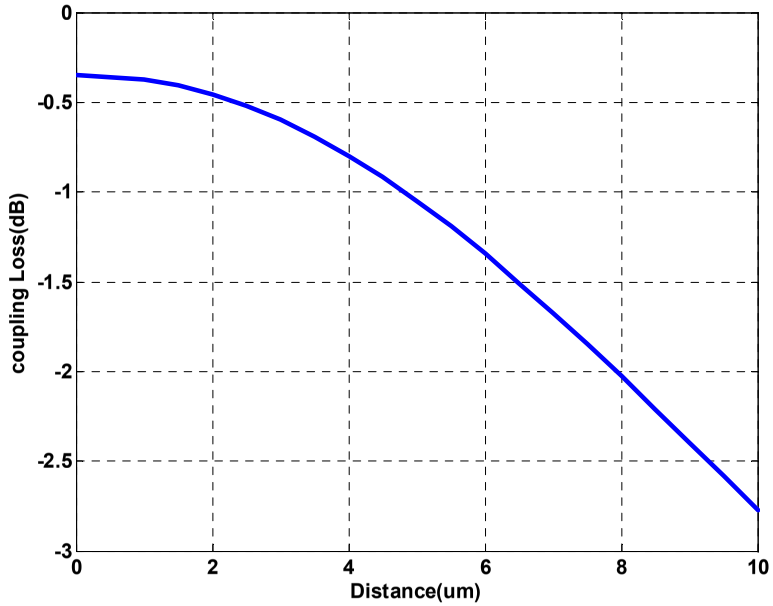
DFB Laser Coupling to a Waveguide





Coupling Loss ~ -1.2dB with passive alignment tolerance:
X±0.5um, Y ±0.3um, Z = 3um±1um

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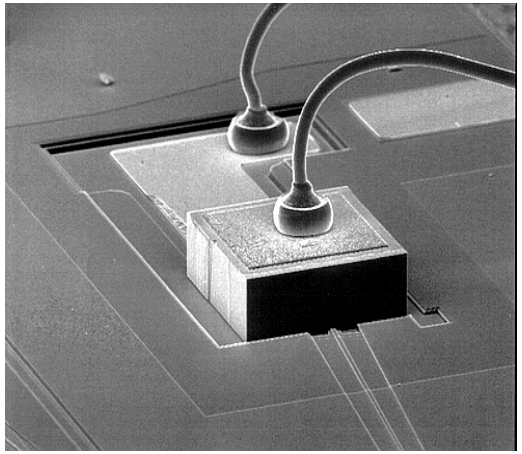
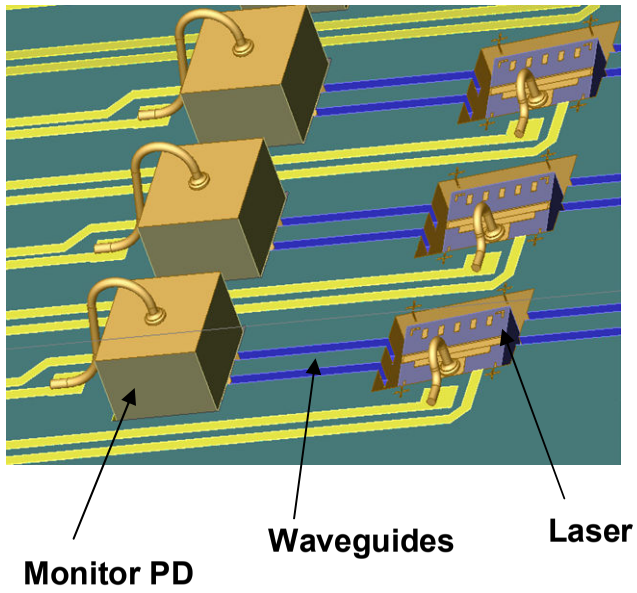
Laser Hybridization – Automated passive alignment

Key Components

- Lasers
- Detectors
- SOAs & LOAs
- SLDs





Key Strengths

- Tuning capability is Key for DWDM applications
- Silicon has similar $\Delta n/\Delta T$ as III/V
- High thermal conductivity enables high power dissipation and good temp control
- No compromise in performance
- Low cost process
- Very high yield

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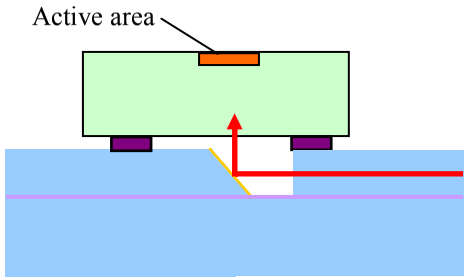
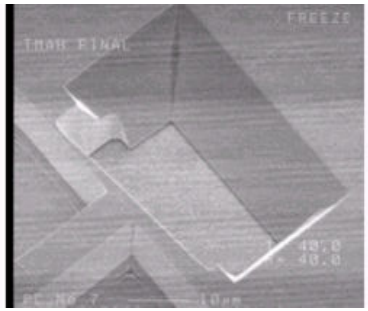
Photodiode Hybridization

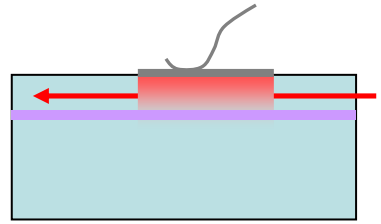


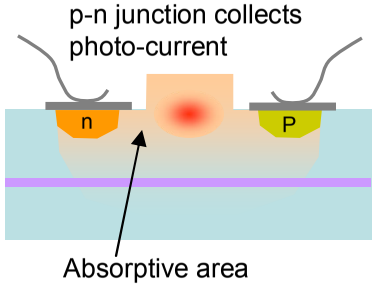


Phase 1: Integrated Mirror with Surface Mount Photodiode

Future Photodiode Integration

Si Ge





Phase 2: Integrated Power Monitor

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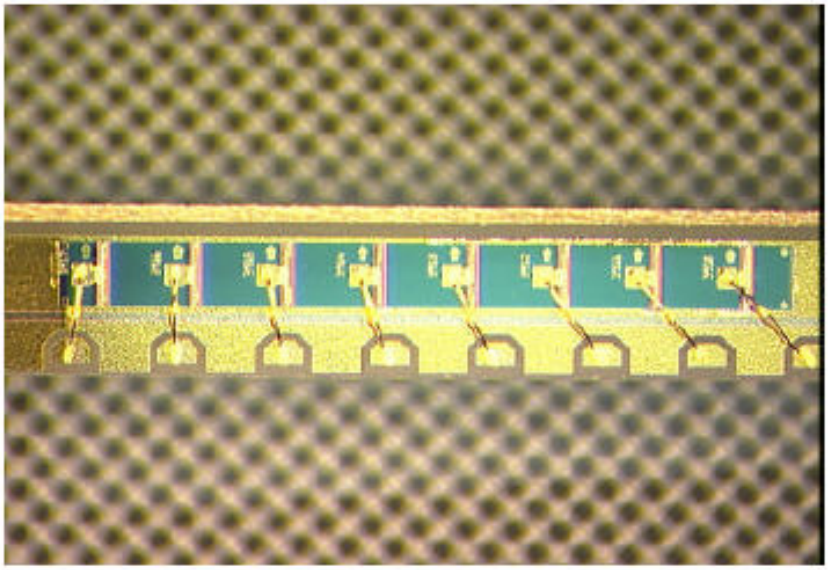
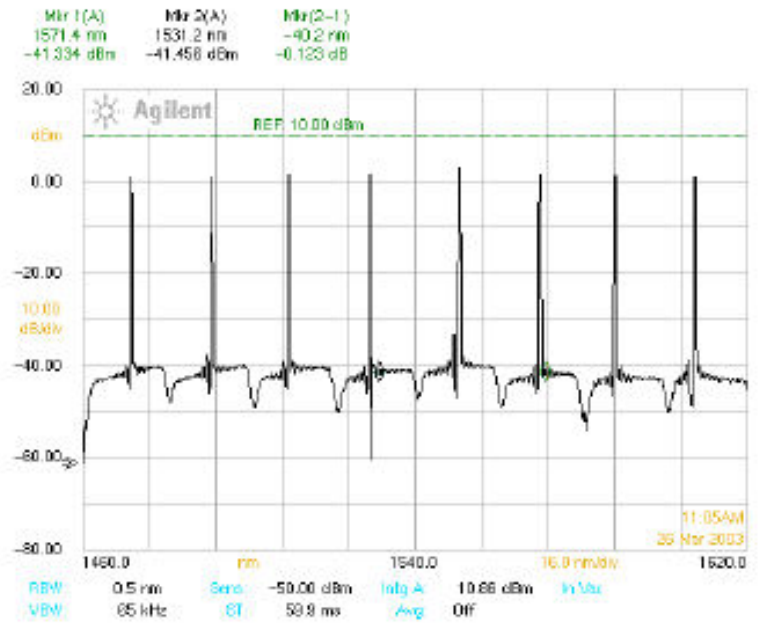
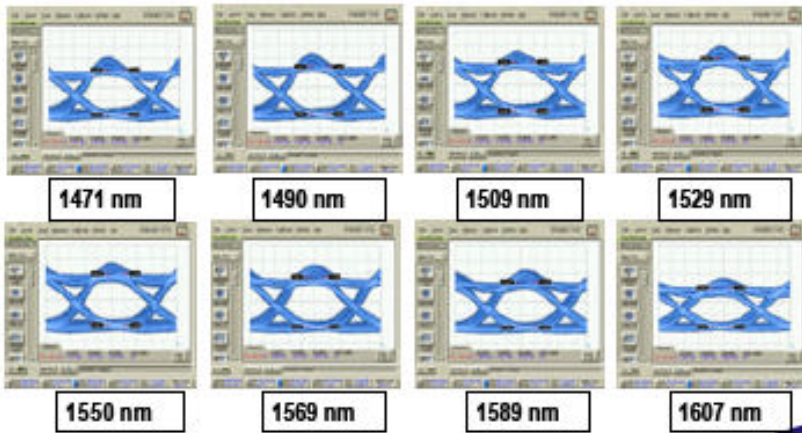
CYOPTICS CWDM Laser Array





- *8 x 10Gb/s CWDM DFB array*
- *1470 – 1610nm, 20nm spacing*
- *Open, clean 10G back-to-back eyes*



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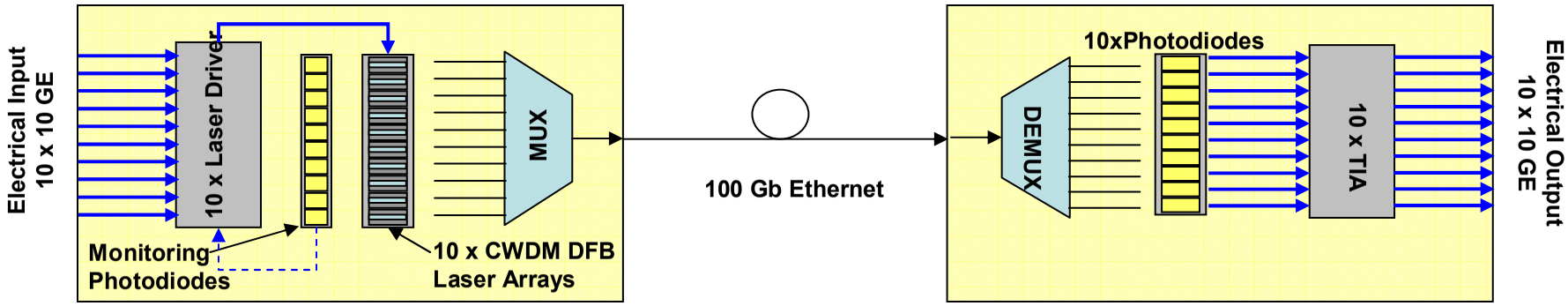
10X10 GE Link Budget Considerations



Link	TX Launch Power		RX Performance		Available Link Budget	Link Power Budget (802.3ae)
	Source (Avg. P_{out}, λ)	Mux & Coupling Losses	Demux & Coupling Losses	Sensitivity (@ 10BG/s, BER 10^{-12})		
2Km SMF	+3dBm/Channel (CWDM, un-cooled DFB 1430 - 1610nm , 20nm spacing)	6.5 dB (Grating, Waveguide, laser coupling, output coupling, margin)	5.0 dB (Grating, Waveguide, PD coupling, input coupling, margin)	-17dBm/channel (PIN-PD)	8.5dB	
10km SMF	+4dBm/Channel (CWDM, un-cooled DFB 1430 - 1610nm , 20nm spacing)			-18dBm/channel (PIN-PD)	10.5dB	9.4dB

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Economic Feasibility

	Silicon Photonics CWDM 10X10GE	Mux Traditional DWDM 10x10GE	Parrallel Fiber - VCSEL
Lanes Port	10 Lanes 1 port (SC / LC)	10 Lanes 1 port (SC / LC) or 10 ports+ MUX	10 lanes 1 port (MT)
PMD	1 Fiber , SMF	1 Fiber, SMF	10 Fiber Ribbon, MMF
Reach	10km	10km	100m
Media Economics	100m	100m	100m 10X
	10km	10km	
Module Economics	low cost	moderate cost	low cost
Overall	Best Solution 100m - 10km	Good Solution for LR but expensive	Bulky but acceptable for SR (<100m)

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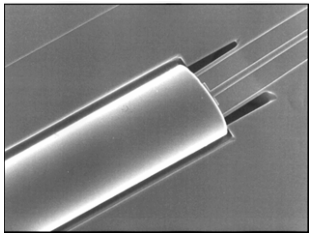
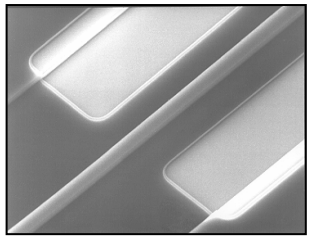
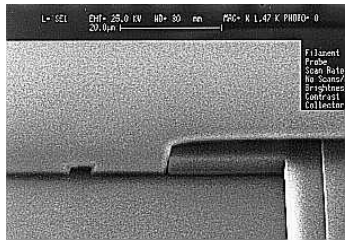
Example of Photonic integration : Next Gen FTTH Triplexer



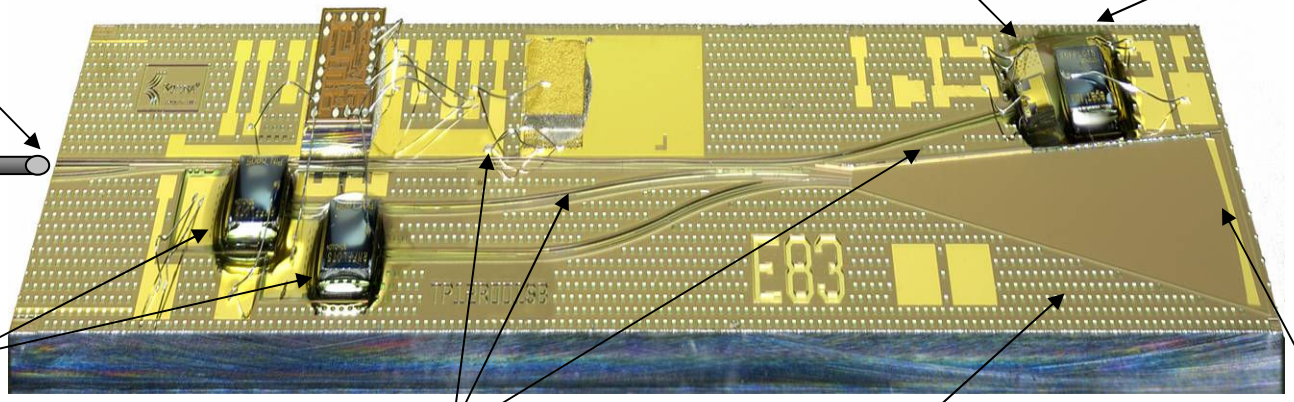


Monolithically Integrated Front Facet Monitor

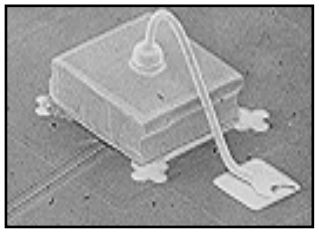


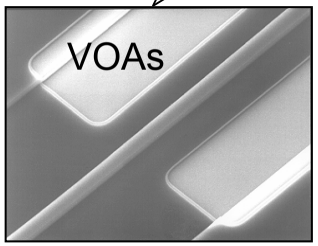
Laser: Passive Auto-aligned

Passive Fiber Attach

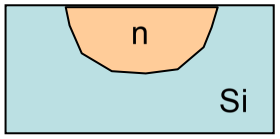


Surface Mount PD



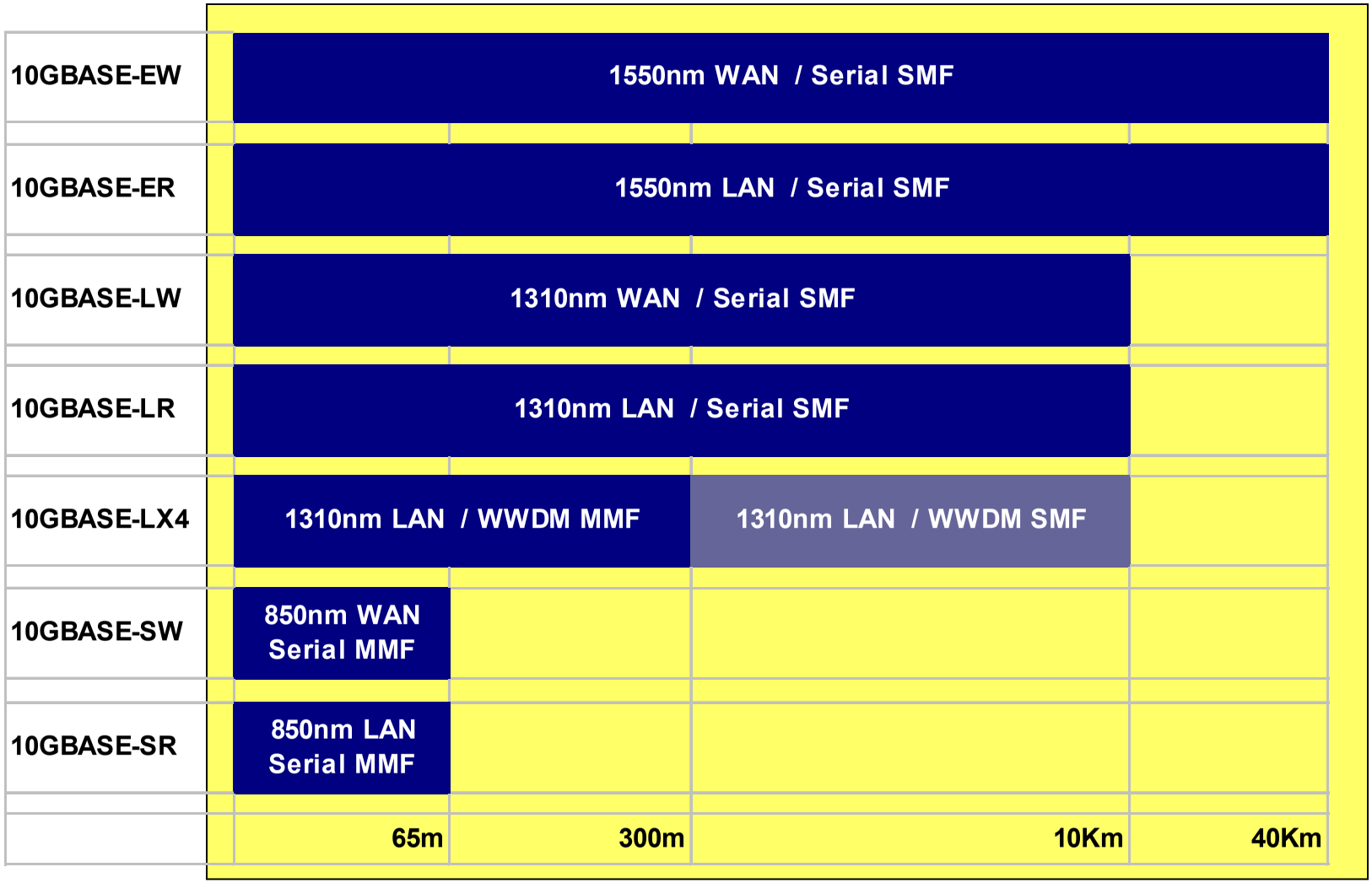


Absorbers

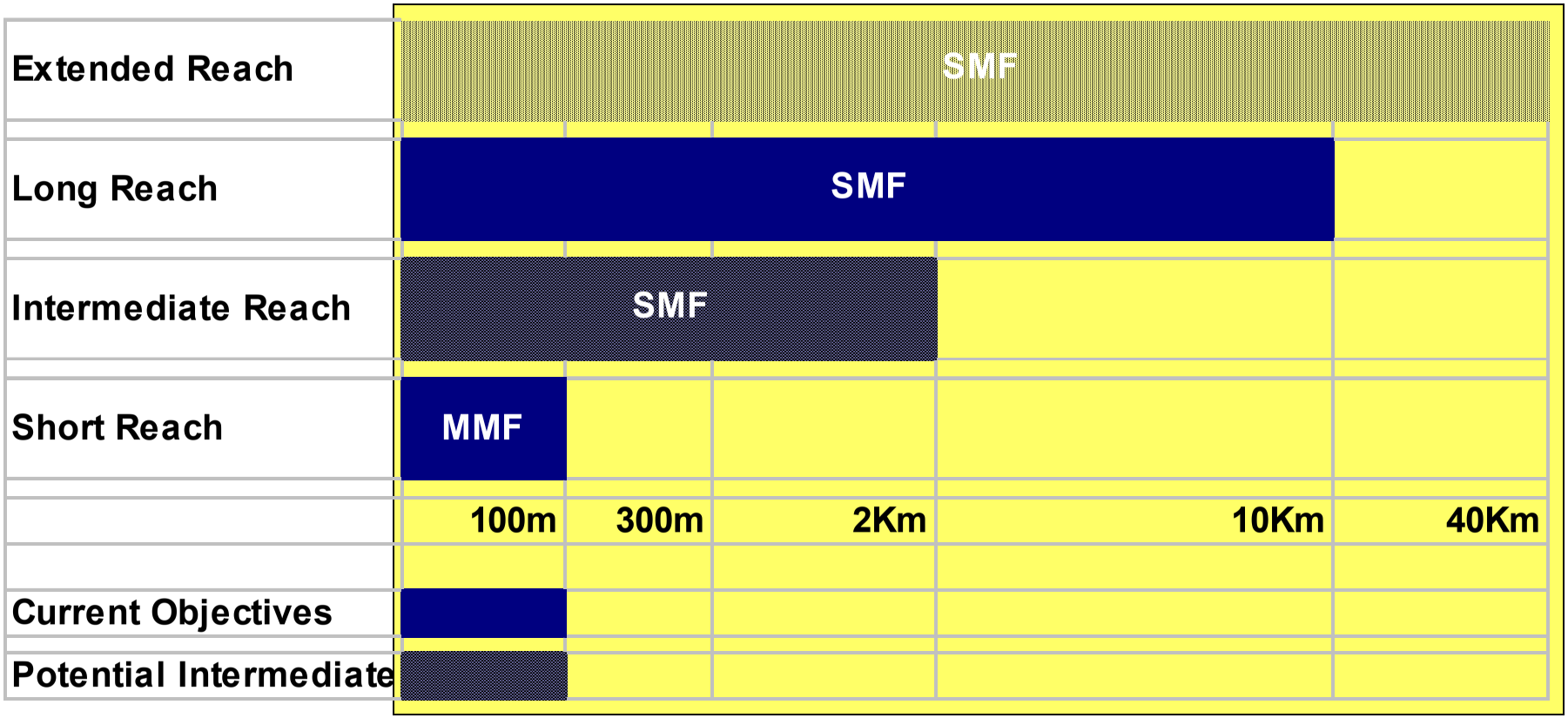


Mux/ Demux Grating Element

10 GE Landscape



100 GE Current Reach/PMD Objectives



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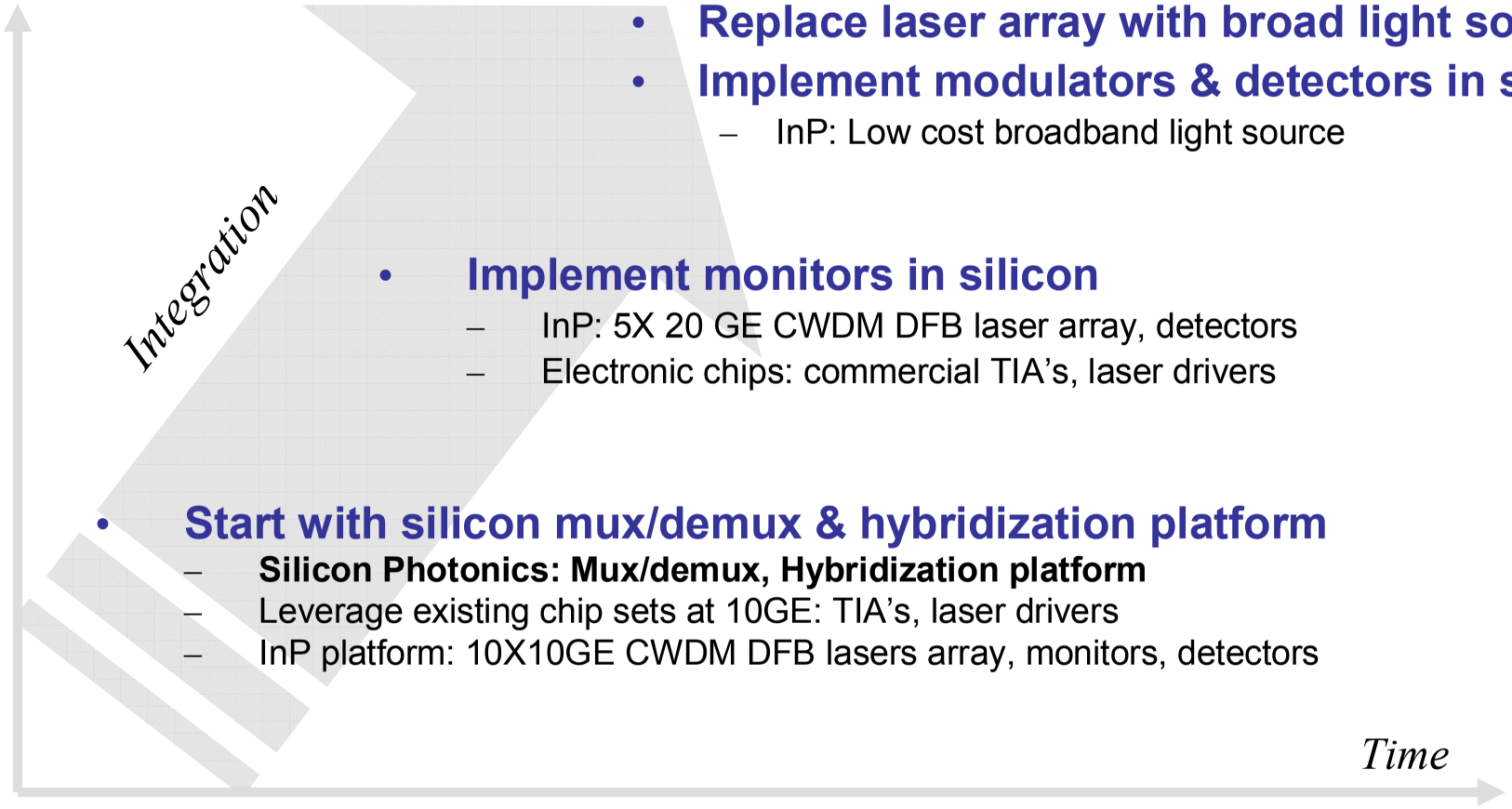
Roadmap to Lower Cost & Higher Performance

"Do whatever you can in CMOS and the rest in InP," (Infinera)



- **Replace laser array with broad light source**
- **Implement modulators & detectors in silicon**
  - InP: Low cost broadband light source

- **Implement monitors in silicon**
  - InP: 5X 20 GE CWDM DFB laser array, detectors
  - Electronic chips: commercial TIA's, laser drivers

- **Start with silicon mux/demux & hybridization platform**
  - **Silicon Photonics: Mux/demux, Hybridization platform**
  - Leverage existing chip sets at 10GE: TIA's, laser drivers
  - InP platform: 10X10GE CWDM DFB lasers array, monitors, detectors

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