Joint ITU-T/IEEE Workshop on The Future of Ethernet Transport

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Technologies & Architectures for Next Gen Ethernet Optical Client Interfaces

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Opnext

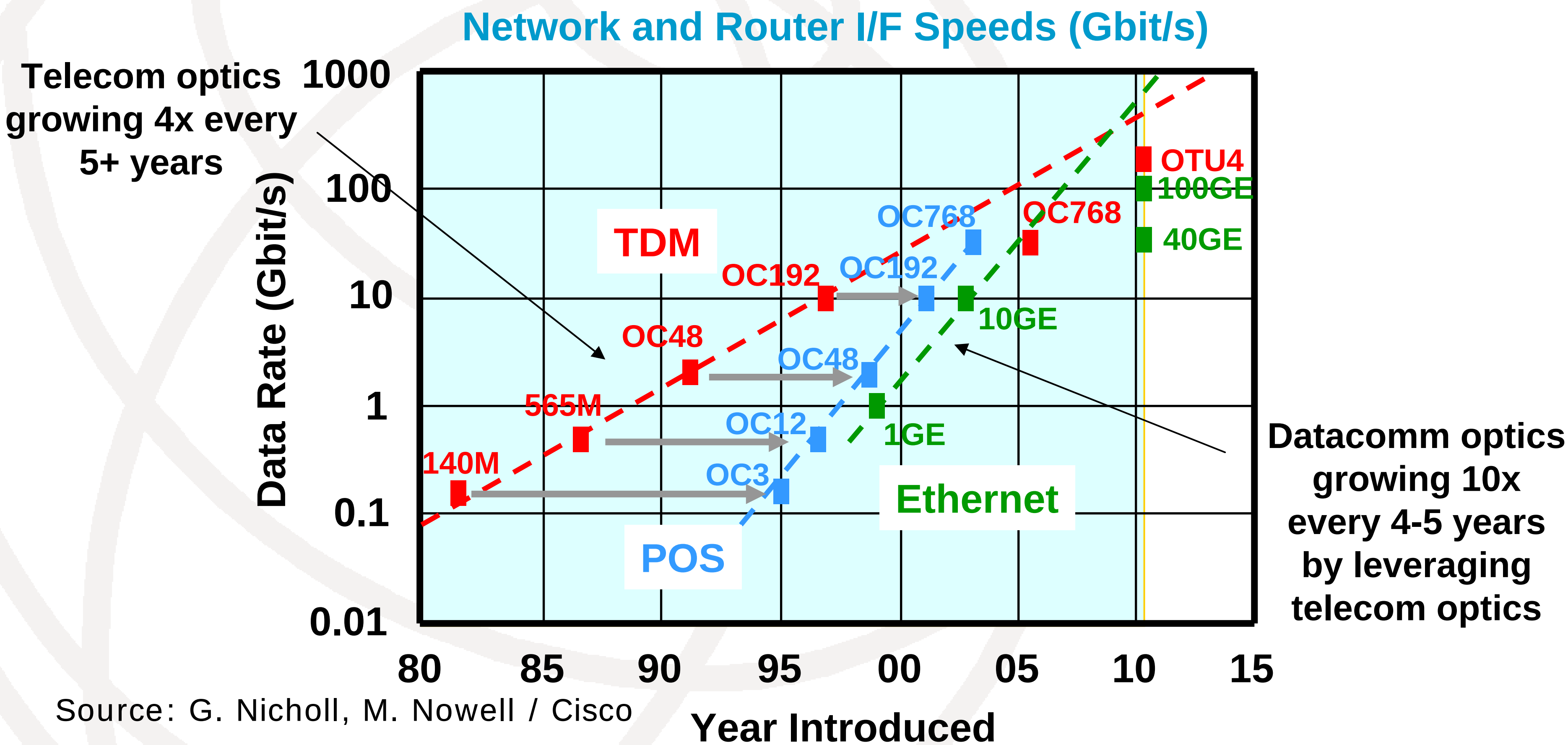
Outline

- Where have we been
- Where are we at
- Where are we going

- Acknowledgement
  - The following from Opnext and Hitachi CRL contributed to this presentation:
    - K. Hiramoto
    - M. Okayasu
    - T. Sugawara
    - M. Traverso

Client Optical Interface Evolution

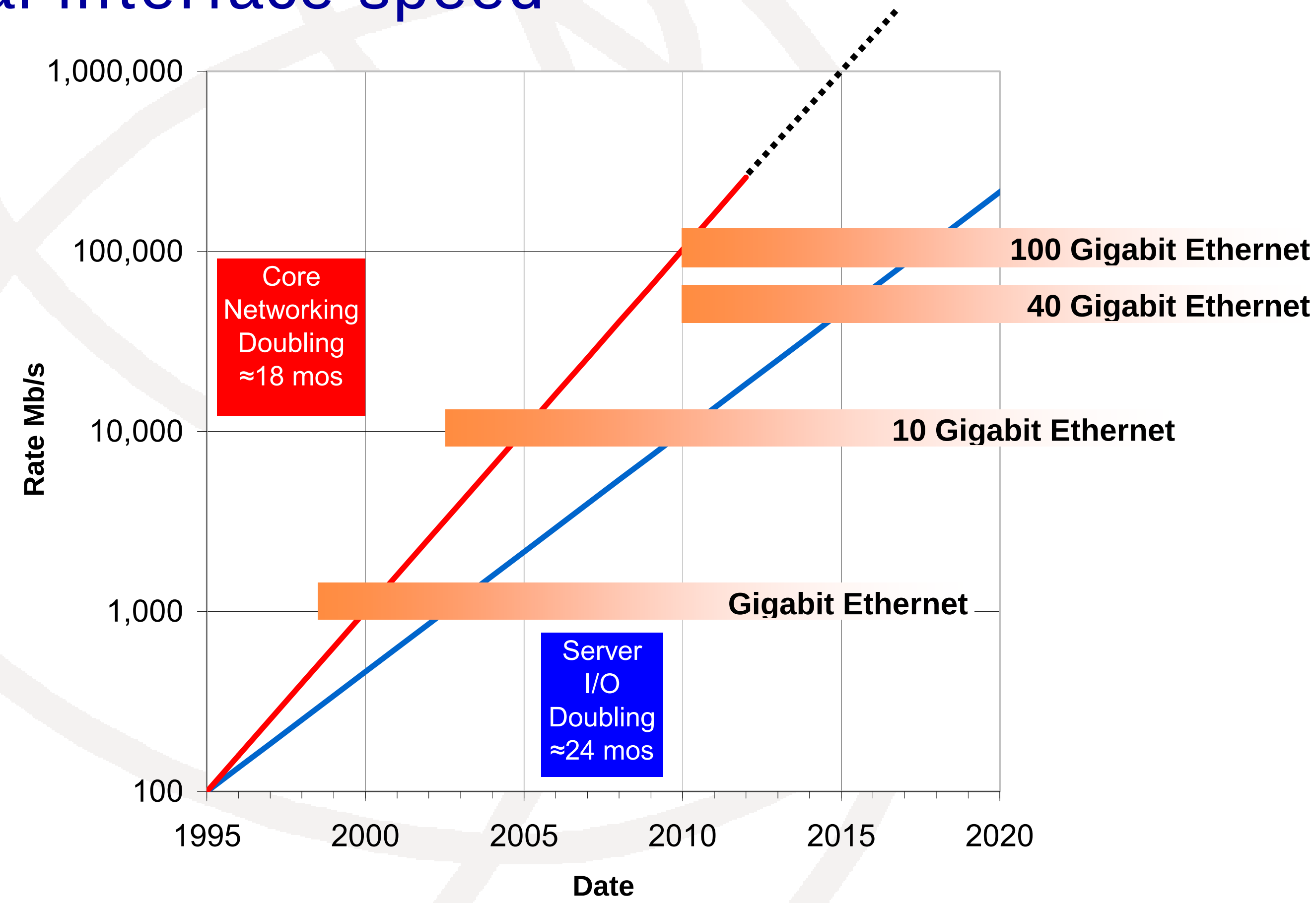
- In the past, Datacomm industry has leveraged Telecom optical technology
- We are now in a cross-over period.



Source: G. Nicholl, M. Nowell / Cisco

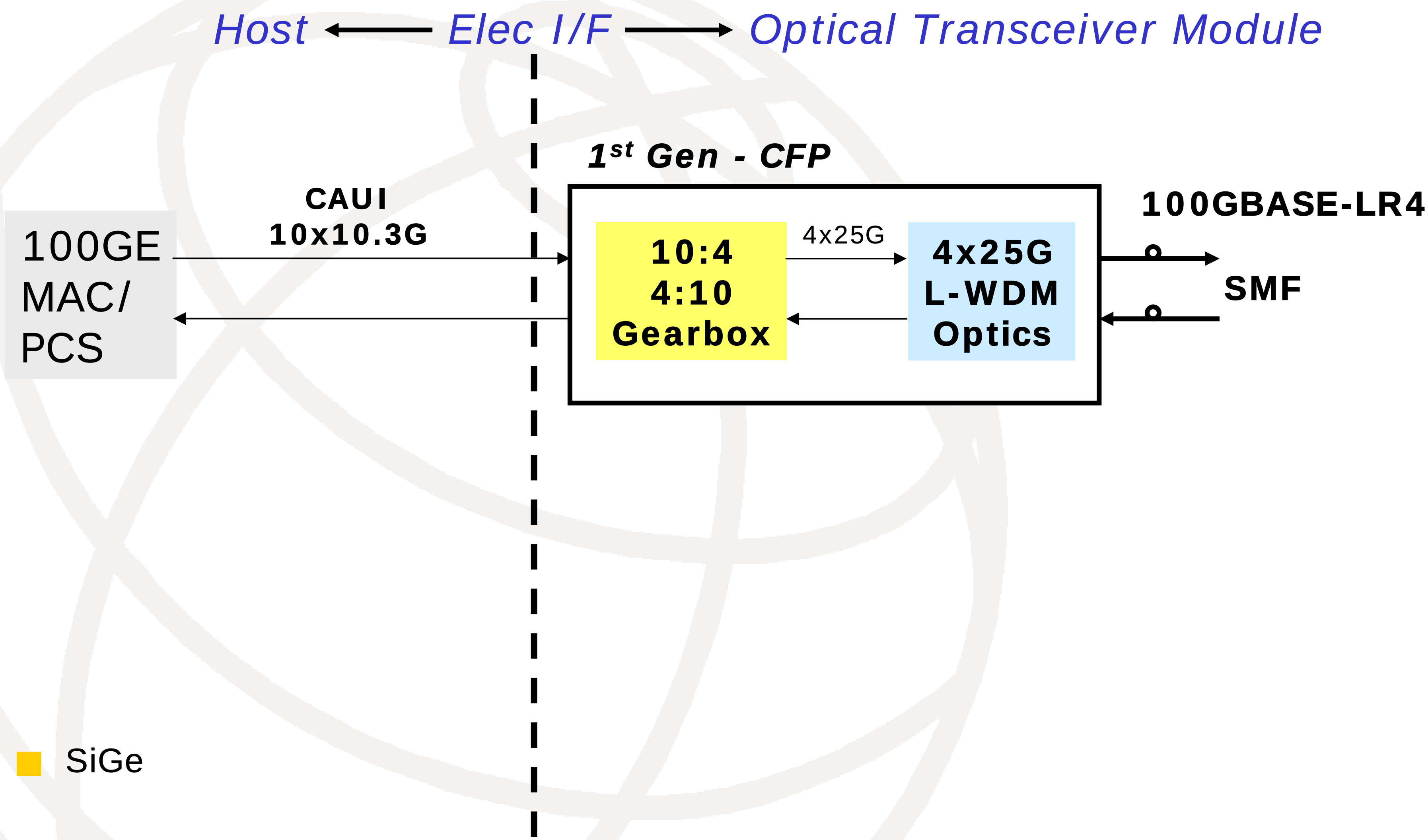
Computing & Networking Bandwidth Growth

- Core networking bandwidth demand is outpacing optical interface speed



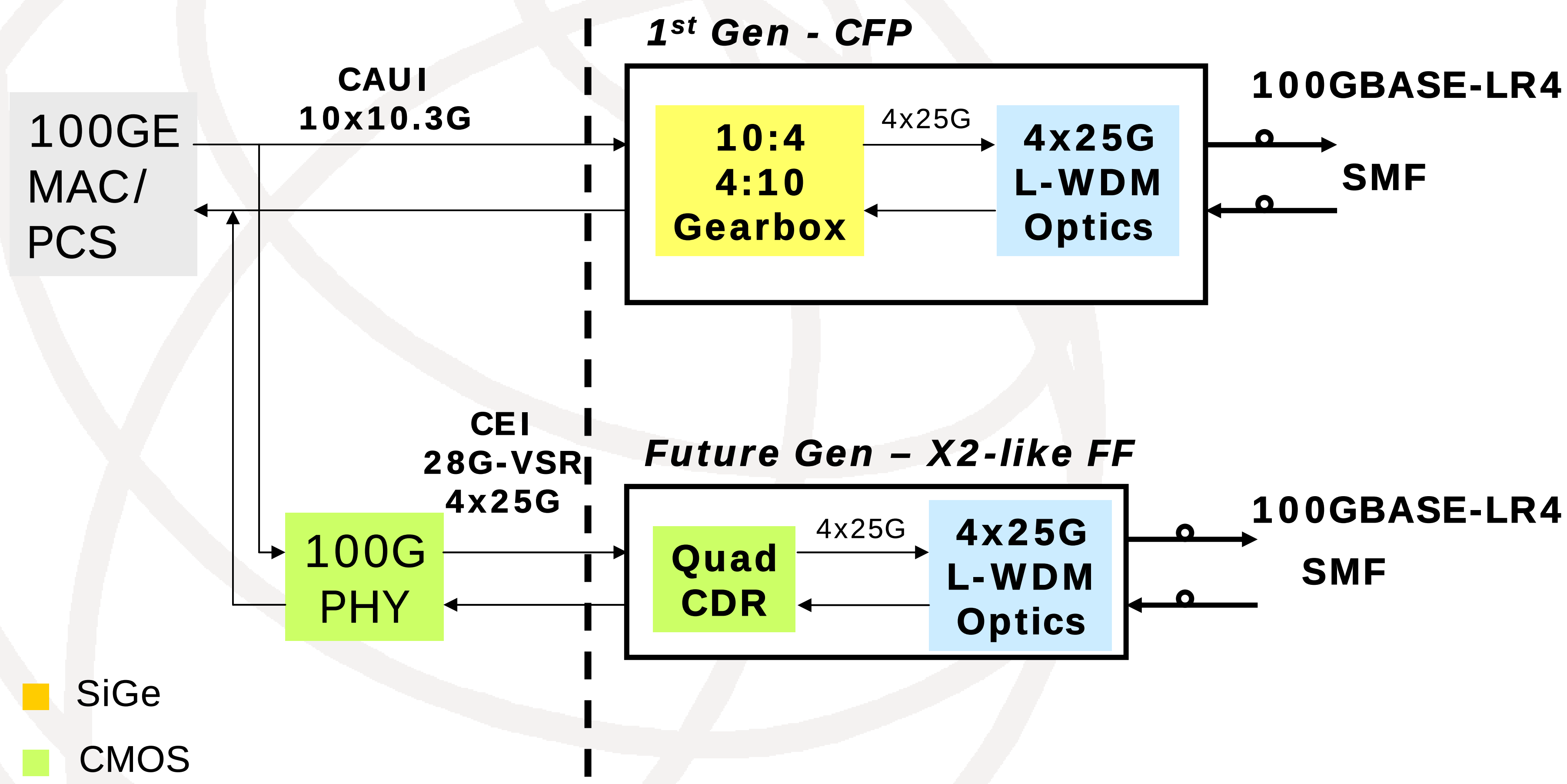
Source: IEEE 802.3 HSSG_Tutorial_1107, Nov. 2007

100GE LAN Interface 1st Gen



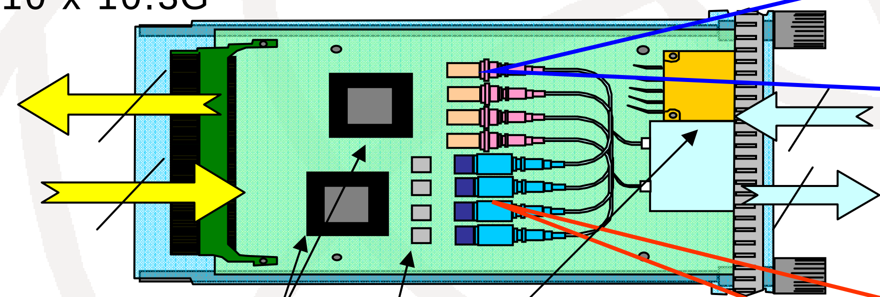
100GE LAN Interface Future Gen

Host ⟵ Elec I/F ⟶ Optical Transceiver Module



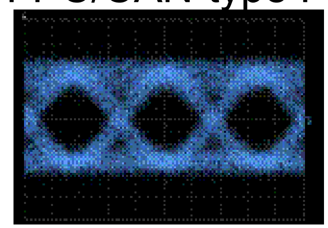
100GBASE-LR4 Optical Transceiver

1st Generation Technology & Architecture

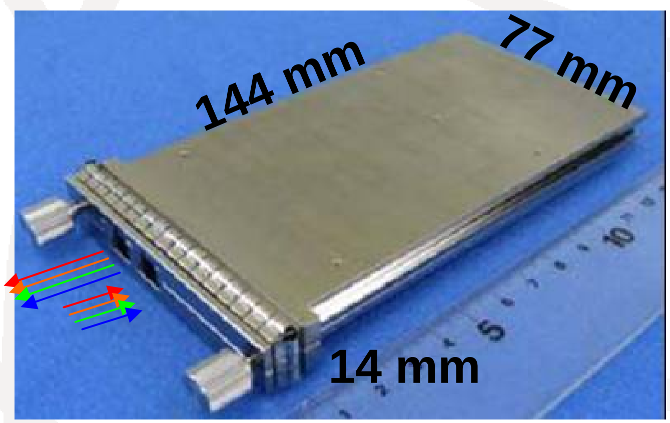


ROSA: TIA/PIN PD/Package
- High-speed/Reliable PIN photo diode
- High-speed (24GHz) FPC/CAN-type PKG

ROSA PKG

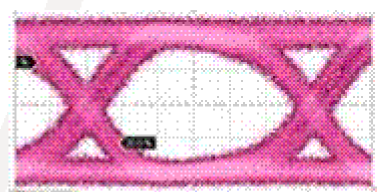


25G received waveform [-12dBm(OMA)]



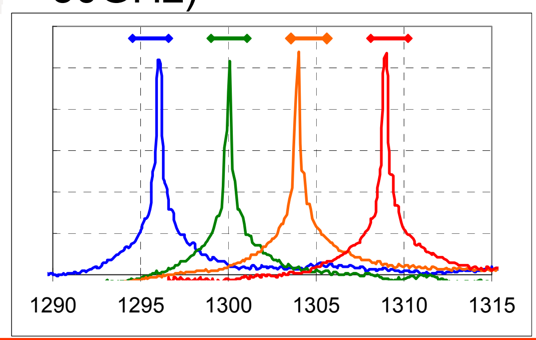
CFP MSA

TOSA: semi-cooled EA-DFB
- High output power (OMA=6.3dBm)
- Wide bandwidth (f_3dB > 30GHz)



25.8Gb/s
Optical waveform@60℃

LAN-WDM grid (800GHz pitch)



Ref: R. Arima, et al. OFC2010, PDPD3

100GBASE-LR4 Optical Transceiver

- Future Gen Technology
  - New technology is required for reducing transceiver power-consumption, form factor and cost.

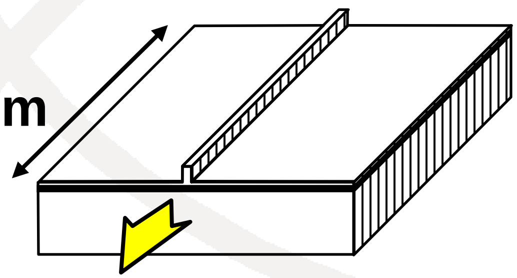
Examination item	Technological opportunity	Technology Approach
Optical devices	Low loss/ Low power consumption	Monolithic Lens integrated: LISEL, LIPD
		Short cavity laser
Analogue circuits	Low power consumption	25 Gb/s SiGe/CMOS IC
Digital circuits		Quad CDR IC
Optical module	Compact/high-density packaging	SIP (Optical MUX/DEMUX and TOSA/ROSAs in one Package)

Ref: T. Sugawara, et al. OFC2010, OThS4

25G Direct Modulated DFB Laser Technology

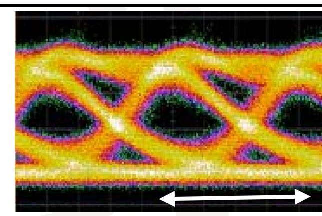
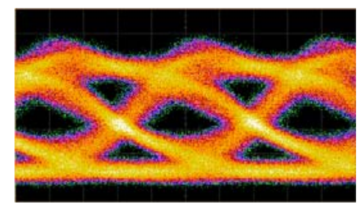
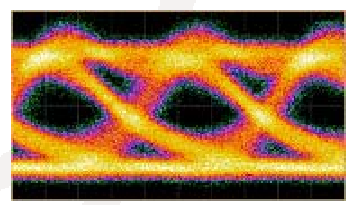
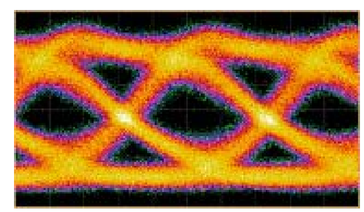
- Ridge Waveguide DFB-type InGaAlAs-MQW
- λ = 1300 nm
- Coating front: AR, rear: HR
- Cavity Length: *Lc* = 160 um

L_c = 160 um



Shortening L_c provides:

- High bit rate operation
- Lower threshold current
- Saturation power decreasing
- Increased slope efficiency

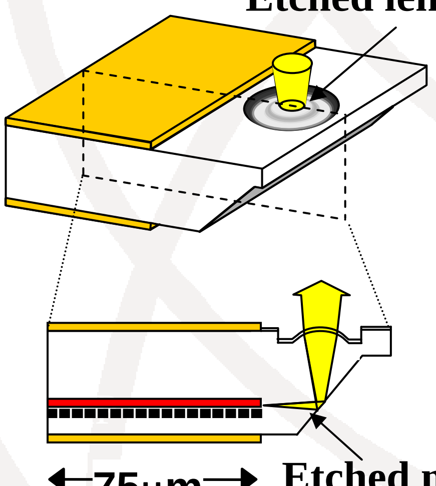
T_{LD}	25°C	95°C
I_b	36 mA	65 mA
ER	9.0 dB	7.0 dB
V_{pp}	2.0 V	2.0 V
BTB	 40ps	
10-km SMF		

Ref: T. Fukamachi et al., ECOC, paper 8.2.5 (2009).

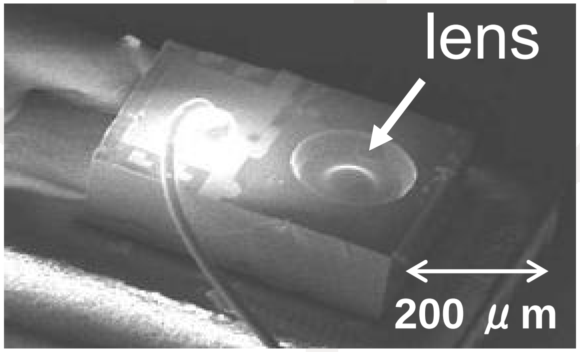
Lens-Integrated Surface Emitting Laser (LISEL)

- Assembly friendly, high-speed 1.3-μm surface emitting laser
- Monolithic integration of aspheric InP lens
- High output power exceeding 20mW at 85ºC
- May be extended to WDM array device

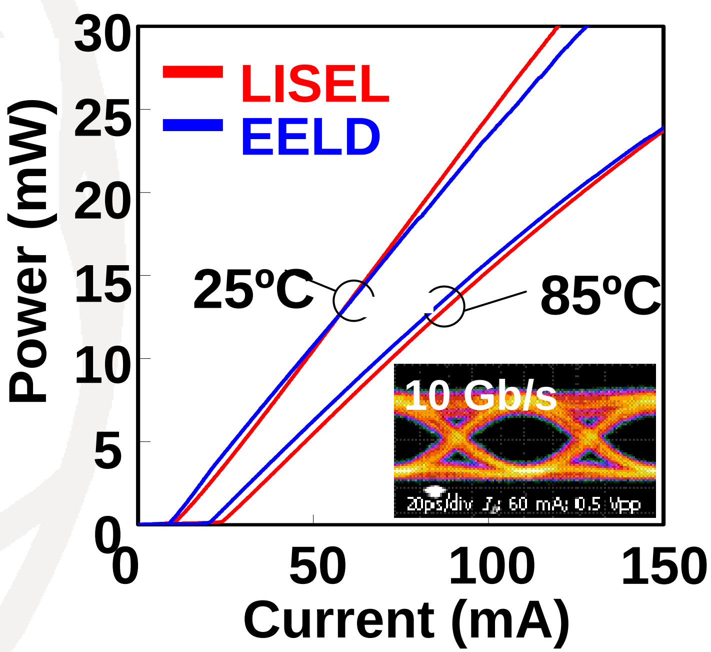
*Schematic of SC-LISEL**



*SEM image of LISEL**



I-L curves

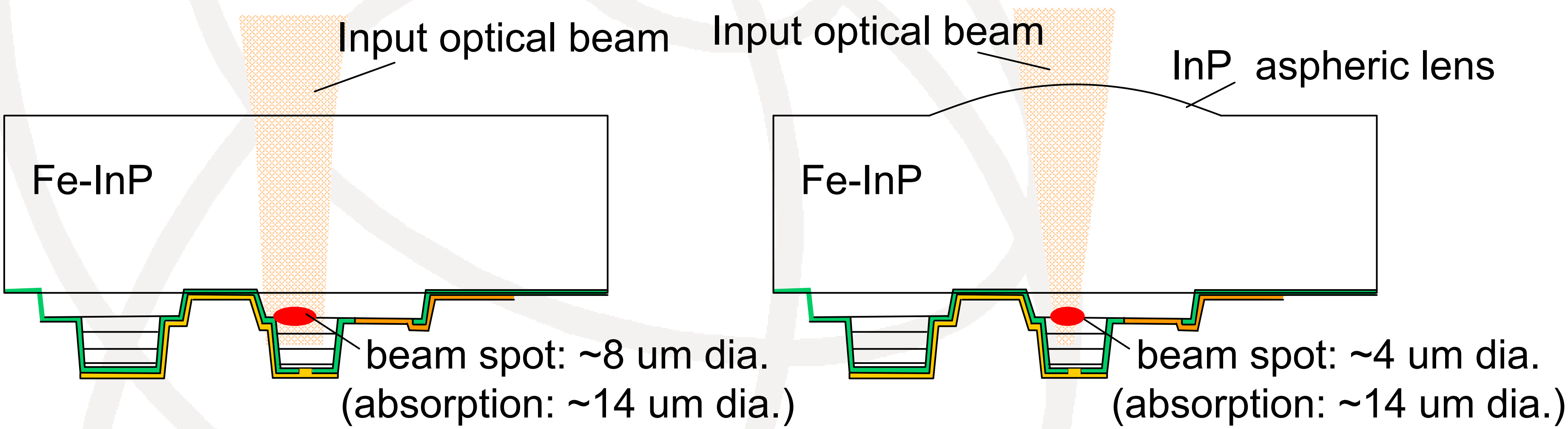


*LISEL : Lens-Integrated Surface-Emitting Laser
**EELD : Edge Emitting Laser Diode

Ref. K. Adachi et al., OFC, paper JthA31 (2009).

Lens Integrated PIN PD

- High optical coupling efficiency and wide tolerance with high speed PD
  - ⇨ Small beam spot: ~4um dia. < ~14 um dia. (absorption layer)



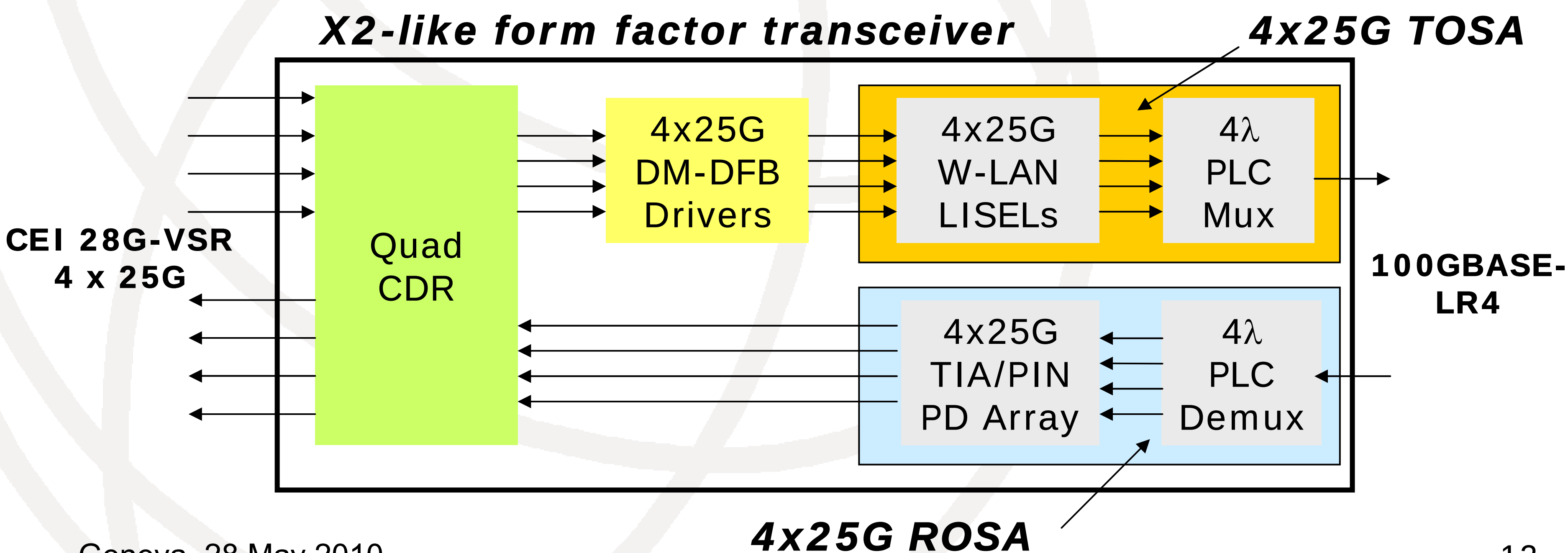
Conventional PIN PD

Lens Integrated PIN PD (LIPD)

Ref. Y. Lee et al., OECC, paper ThC4 (2009).

Future Gen 100GBASE-LR4 Optical Transceiver

- 4ch L-WDM 25G DM-LISELs, lens integrated PIN-PD integrated with PLC mux, demux:
  - Compact 100GE-LR4 TOSA/ROSA devices & transceiver
  - Low power consumption: DM-DFB array w/drivers (4.4W) + TIA/PIN-PD array (0.8W) + quad CDR (2.0W) + DC/DC (0.5) < 8W



Future Ethernet Optical Client Interface

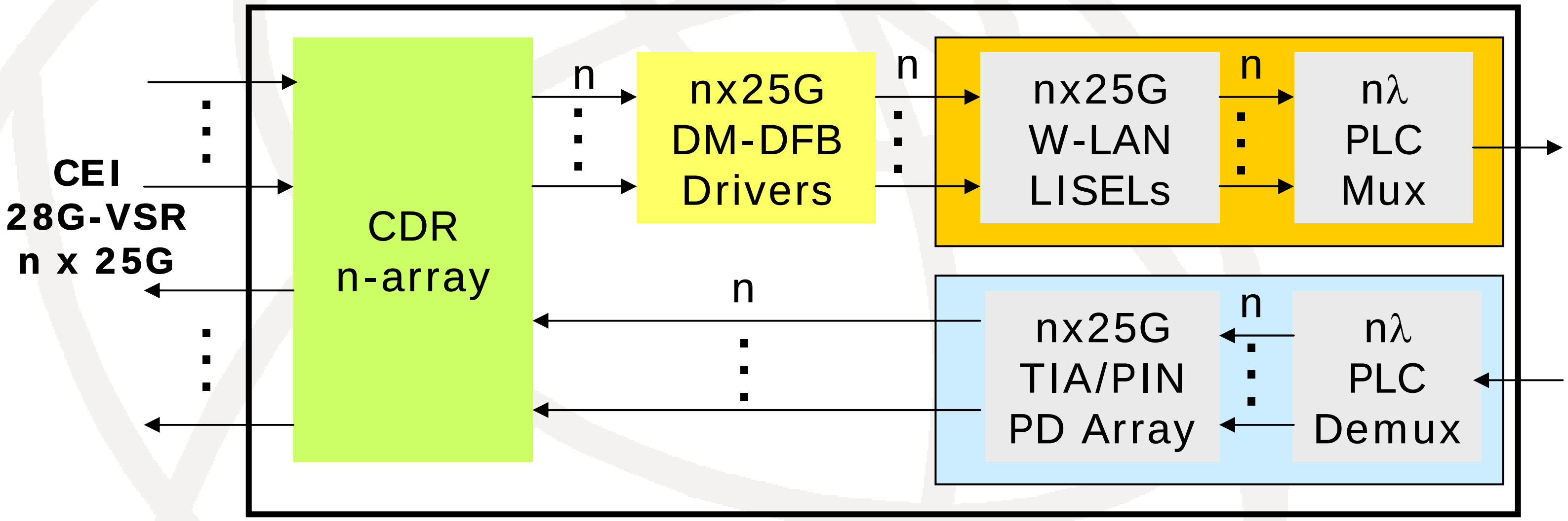
- Drivers:
  - Core Networking bandwidth demand scaling:
    - Core Transport Rate >> 100G; 1TB in 2015??
    - Ethernet Client Interface rates: 4x – 10x in 2015
- Constraints:
  - Cost
  - Power Consumption
  - Module Form Factor

Future Ethernet Optical Client Interface

- Design Approaches
  - Increase optics speed
  - Leverage line-side multi-level modulation, coherent detection technologies to increase spectral efficiency
  - Scale LR4 optical parallel architecture
  - Scale LR4 optical parallel architecture + increase optics speed
  - Others?

Future Ethernet Optical Client Interface

- Scaled LR4 Parallel Architecture: nx25GBASE-LRn

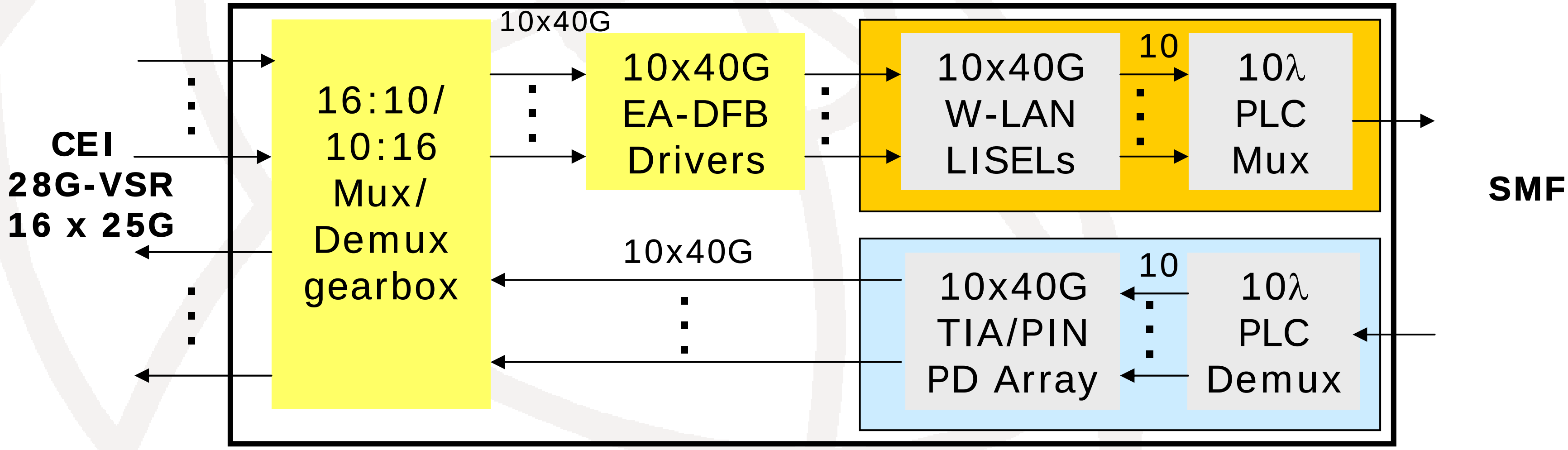


N	I/F Rate (Gb/s)
8	200
10	250
12	300
16	400

	Pro	***Con***
Pc		May be too high for: 4x (8W for 4ch 100BASE-LR4) = 32W
FF	Potentially CFP-like w/ improved connector	
Cost	Leverages new gen 100GE-LR4 25G optics, elec devices & integration, packaging processes	16λ L-WDM grid spans ~70nm, challenging for DFB mfg, (monolithic arrays ruled out), leads to high yield loss, higher TOSA cost

Future Ethernet Optical Client Interface

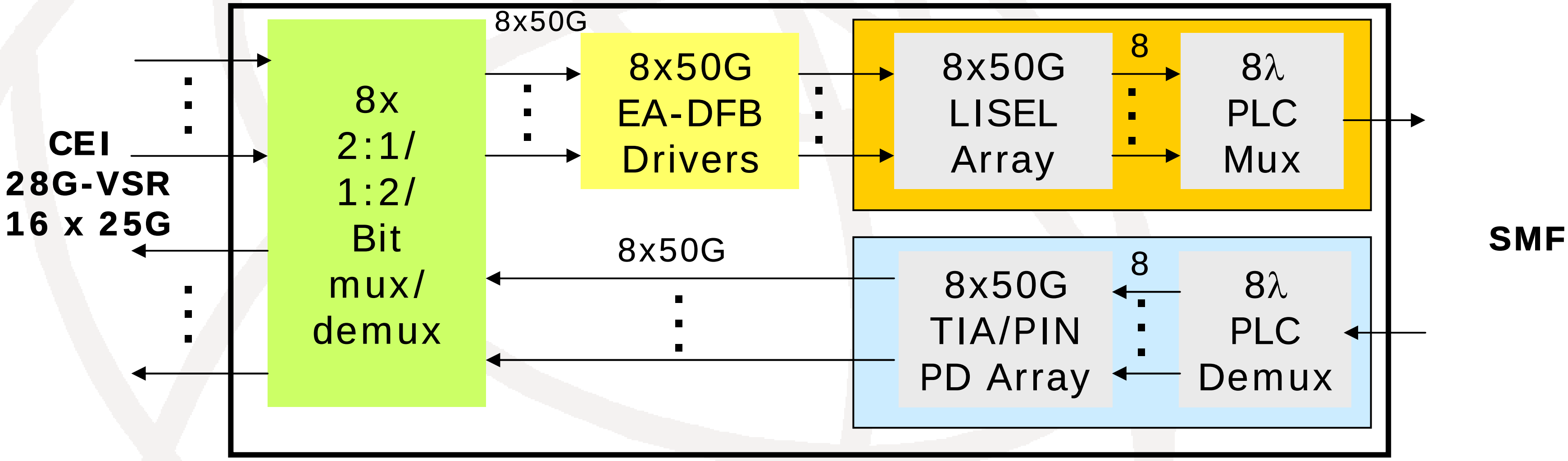
- Scaled LR4 Parallel Architecture with optics speed increase: 10x40GBASE-LR10



	Pro	Con
Pc		Gearbox IC is >>10Ws; expect module >> 32W
FF		Requires large volume for heat-sinking; probably not pluggable in 1st gen
Cost	Leverages 40G optics, electrical devices & 100G-LR4 integration, packaging processes	10λ L-WDM grid spans ~45nm, still challenging for DFB mfg, (monolithic arrays ruled out), leads to high yield loss, higher TOSA cost; higher cost new gen gearbox IC process needed to reduce power

Future Ethernet Optical Client Interface

- Scaled LR4 Parallel Architecture with optics speed increase: 8x50GBASE-LR8



	Pro	*Con*
Pc	Bit mux IC much easier to implement with much lower power consumption cf gearbox	
FF	Potentially CFP-like w/ improved connector	
Cost	8λ L-WDM or possibly CWDM laser yield much easier to manage, monolithic array may be in reach for lower cost	50G EA-DFB not yet proven technology

Conclusion

- Ethernet optical client interfaces have kept pace with core network demand by leveraging optical line side technology
- We are at a cross-over point now at 100GE with given core networking bw need projected to be 4x – 10x by 2015
- Integrated parallel optics technologies being developed for next gen 40G/100GBASE-LR4 will be leveraged for beyond 100GE client interfaces
- A combination of increased optics speeds (25G -> 50G) with 2x 100G-LR4 parallel optics may be the best approach to achieve > 100GE

Thank You!