Specification for 100GBASE-DR4

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Supporters

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Introduction

- MMF with 25G lanes using directly modulated 850 nm VCSELs is challenged beyond 100 m
  - Migrating to a longer wavelength may be a way forward
- SMF solution with minimal cost/size/power is desired
- Parallel single mode (PSM, proposed code 100GBASE-DR4) allows simple modules and easiest power budget
  - No wavelength mux or power combiner
  - No wavelength demux
  - Relaxed wavelength tolerances
  - Single laser or four identical lasers (can be integrated together)
  - No need for cooler
- Because most links are short (centroid near 150 m, kolesar_01a_0512_optx.pdf), PSM is an acceptable solution
- SMF is usable over a range of wavelengths e.g. 1310 nm or 1550 nm
- SMF costs are typically dominated by mechanical aspects
  - Small light spot in the fiber, even smaller light spot in the laser
  - Thermal, hermeticity
  - Standard should allow optimization for these aspects
- Want forwards compatibility with 50G lanes
- Which wavelength to choose?

Discussion 1

- Transmitter could be directly modulated lasers or laser(s) + optical modulator
- The same photodiodes can receive at both 1310 nm and 1550 nm
- If directly modulated, performance for 25G lanes over temperature is better at 1310 nm than 1550 nm
  - But for other transmitter types, it's different – see later
- Direct modulation is challenging for 25G lanes, looks extremely challenging for 40G or 50G lanes
- If optical modulator,
  - See next slide

Discussion 2

- If optical modulator,
  - Wider range of technology options at 1550 nm (C band):
    - 1 III-V with glass lensing
    - 2 III-V with waveguides on silicon (hybrid integration)
      - 2a Out of plane coupling e.g. gratings
      - 2b Edge coupling e.g. butt coupling
    - 3 SiGe modulators with glass lensing
    - 4 SiGe modulators with waveguides on silicon (hybrid integration)
      - 4a Out of plane coupling e.g. gratings
      - 4b Edge coupling e.g. butt coupling
    - 5 III-V with III-V lensing
  - Optical modulation has the potential for 40G or 50G lanes
  - Some Out of Plane coupling methods are wavelength selective
  - Fewer technology options at 1310 nm (O band):
    - 1 III-V with glass lensing
    - 2 III-V with waveguides on silicon (hybrid integration)
      - 2a Out of Plane coupling e.g. gratings
      - 2b Edge coupling e.g. butt coupling
    - ~~3 SiGe modulators with glass lensing~~
    - ~~4 SiGe modulators with waveguides on silicon (monolithic integration)~~ <- Technology restrictions or uncertainties
      - ~~4a Out of plane coupling e.g. gratings~~
      - ~~4b Edge coupling e.g. butt coupling~~
    - 5 III-V with III-V lensing
- The more traditional technologies (e.g. option 1) are appropriate for a small, moderate or uncertain market volume
  - Lower NRE
- Silicon photonics becomes interesting for a large volume
  - Higher NRE
- <u>Simpler kinds of silicon photonics are appropriate for cost reasons</u> (e.g. option 4b)

Recommendation

- A **wide range of technologies** should be allowed to enable a broad market and lower cost
- Both **1310 nm and 1550 nm** transmitters should be allowed

- While 1310 nm (O band) has served 802.3 for direct modulation, as we cost-optimise with optical modulation we should be in the 1550 nm (C) band

- Consequences for interoperability:
- Photodiode has to work at both 1310 nm and 1550 nm
- Not a significant problem; such photodiodes have been made for many years
  - Photodiodes respond to photons, not optical power. The optical power that delivers a particular photocurrent can be lower at 1530 nm than at 1310 nm
    - May be a concern for overload
- Receiver input coupling has to work at both 1310 nm and 1550 nm

Recommendation – detail 1

- In P802d3bm-96_PSM4_01.pdf
- 96.7.1 100GBASE-?R4 transmitter optical specifications
  - Table 96–6—100GBASE-?R4 transmit characteristics
  - Change
  - Lane wavelength (range) 1295 to 1325 nm
  - to
  - Lane wavelength (range) 1295 to 1325 or 1530 to 1550 nm
- 96.7.1.1 Transmitter OMA, each lane (min)
  - Add 1550 nm option: change
  - "Tx_OMA >= MAX(-8.65+((lambda-1310)^2)/100, -8.05) + MAX(TDP, 0.8) dBm"
  - to
  - "Tx_OMA >= {MAX(-8.65+((lambda-1310)^2)/100, -8.05) + MAX(TDP, 0.8) dBm
  - or
  - Tx_OMA >={MAX(-8.65+((lambda-1540)^2)/138.2, -8.05) + MAX(TDP, 0.8) dBm"
- 96.7.2 100GBASE-?R4 receive optical specifications
  - Table 96–7—100GBASE-?R4 receive characteristics
  - Change
  - Lane wavelengths (range) 1295 to 1325 nm
  - to
  - Lane wavelength (range) 1295 to 1325 and 1530 to 1550 nm
- 96.7.2.1 Receiver sensitivity (OMA), each lane (max)
  - Add 1550 nm option: change
  - "Rx_sens <= MAX(-11.89 + ((lambda–1310)^2)/100, -11.4) dBm"
  - to
  - "Rx_sens <= MAX(-11.89 + ((lambda–1310)^2)/100, -11.4) dBm
  - or
  - Rx_sens <= MAX(-11.89 + ((lambda–1540)^2)/138.2, -11.4) dBm"

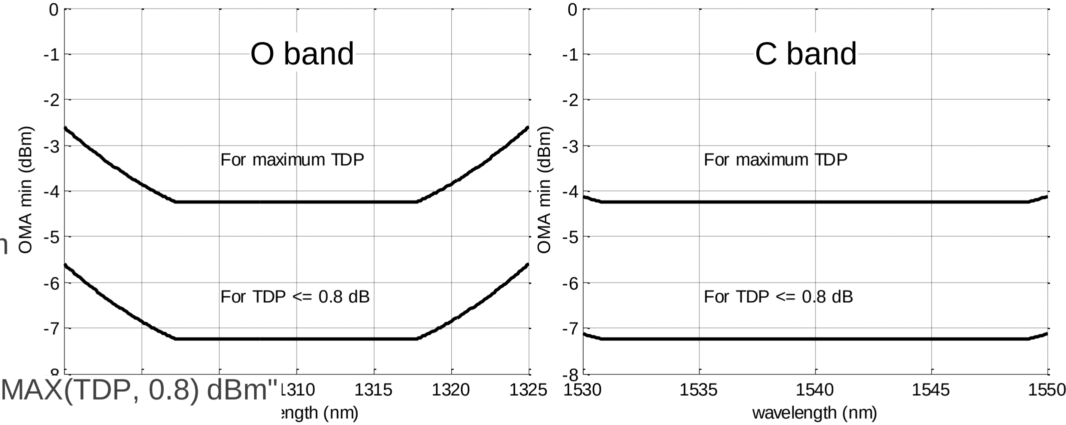


Figure 96–3—Transmitter minimum OMA

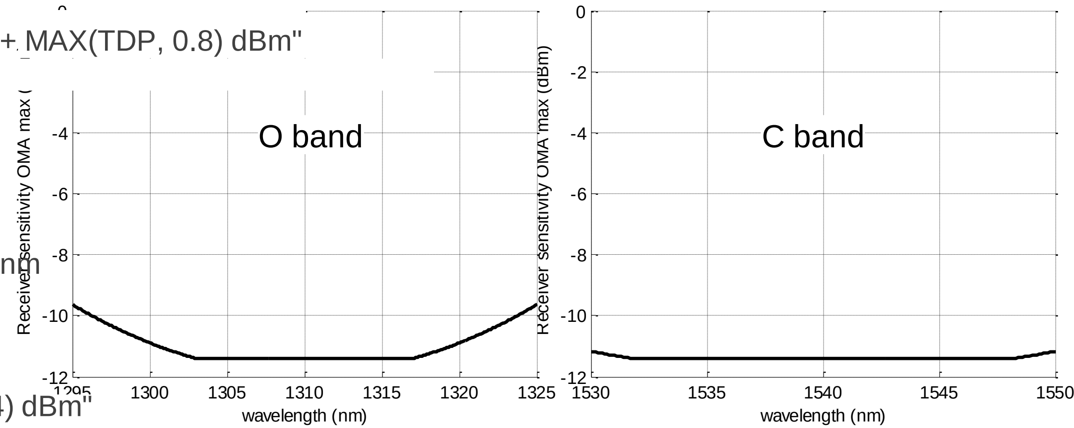


Figure 96–4—Receiver sensitivity

Recommendation – detail 2

- 96.7.3 100GBASE-?R4 illustrative link power budget
- Table 96–8—100GBASE-?R4 illustrative link power budget
  - No changes needed
- 96.8.5.2 Channel requirements
  - See next slide
- 96.10 Fiber optic cabling model
  - See table to right

Table 96–13—Fiber optic cabling (channel) characteristics for 100GBASE-?R4

Description	~~Value~~ O band	C band	Unit
Operating distance (max)	500		m
Channel insertion loss[a, b](max)	3.26	3.26	dB
Channel insertion loss (min)	0		dB
Positive dispersion[b] (max)	1.2	9.1	ps/nm
Negative dispersion[b] (min)	–1.4	8.5	ps/nm
DGD_max[c]	TBD		ps
Optical return loss (min)	TBD		dB

[a]These channel insertion loss values include cable, connectors, and splices.
[b]Over the wavelength range ~~1295 nm to 1325 nm~~ of Table 96–6.
[c]Differential Group Delay (DGD) is the time difference at reception between the fractions of a pulse that were transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.

Recommendation – detail 3

- 96.8.5.2 Channel requirements

Table 96–11—Transmitter compliance channel specifications

~~PMD type~~ Wavelength range	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD
	Minimum	Maximum			
~~100GBASE-?R4~~ O band	$0.011625 \times \lambda \times [1 - (1324 / \lambda)^4]$	$0.011625 \times \lambda \times [1 - (1300 / \lambda)^4]$	Minimum	TBD dB	TBD ps
C band	0 (maximum)				

[a]The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 500 m for 100GBASE-?R4.

[b]There is no intent to stress the sensitivity of the BERT’s optical receiver.

[c]The optical return loss is applied at TP2.

If overload is a concern

- If overload is a concern,
- 96.7.1 100GBASE-?R4 transmitter optical specifications
  - Table 96–6—100GBASE-?R4 transmit characteristics

  - Change
  - Total average launch power (max) 8 dBm
  - to
  - Total average launch power (max) 8 7.5 dBm

  - Change
  - Average launch power, each lane (max) 2 dBm
  - to
  - Average launch power, each lane (max) 2 1.5 dBm

  - Change
  - Optical Modulation Amplitude (OMA), each lane (max) 2.2 dBm
  - to
  - Optical Modulation Amplitude (OMA), each lane (max) 2.2 1.7 dBm

- 96.7.2 100GBASE-?R4 receive optical specifications
  - Table 96–7—100GBASE-?R4 receive characteristics

  - Change
  - Average receive power, each lane (max) 2 dBm
  - to
  - Average receive power, each lane (max) 2 1.5 dBm

  - Change
  - Receive power, each lane (OMA) (max) 2.2 dBm
  - to
  - Receive power, each lane (OMA) (max) 2.2 1.7 dBm

Other changes proposed

1. 96.7.1 100GBASE-?R4 transmitter optical specifications
   - Table 96–6—100GBASE-?R4 transmit characteristics

   - **Extinction ratio** spec can be relaxed: OMA and TDP (which includes optical return loss tolerance) provide the necessary protection. 100GBASE-SR4 has 3 dB
   - Change Extinction ratio (min) from 3.5 to 3 dB

2. 96.7.2 100GBASE-?R4 receive optical specifications
   - Table 96–7—100GBASE-?R4 receive characteristics

   - The MDI connector is an angled type, so **Receiver reflectance** (max) –12 dB is not necessary
   - Change Receiver reflectance (max) from –12 to –20 dB
   - In Table 96–6—100GBASE-?R4 transmit characteristics, adjust **Optical return loss tolerance** (max), presently 7.94 dB, appropriately
   - In Table 96–11—Transmitter compliance channel specifications, for **Optical return loss**, change TBD to the modified Optical return loss tolerance (max) from Table 96–6

3. Delete erroneous entry:
   - **Receiver 3 dB electrical upper cutoff frequency**, each lane (max) 12.3 GHz

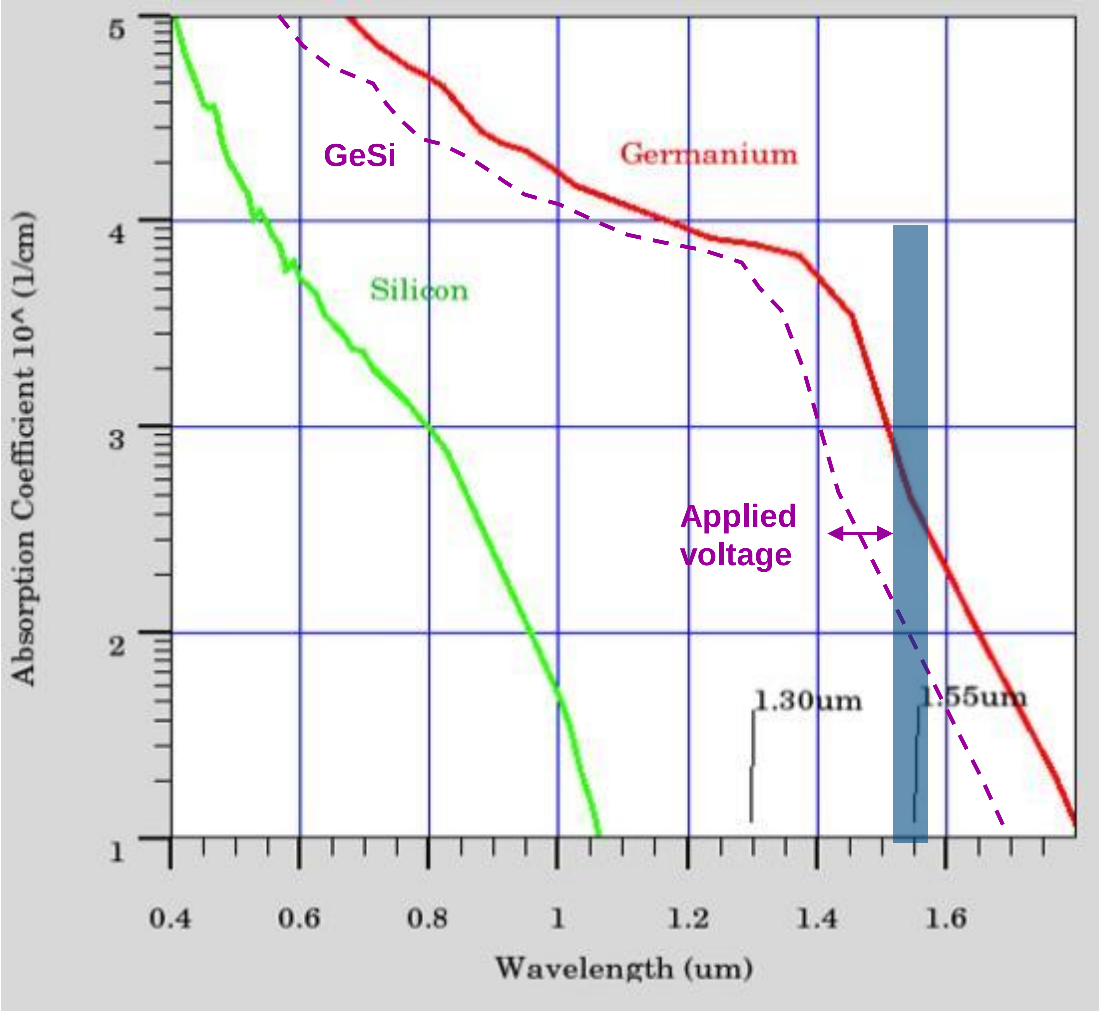
Conclusions

- Allowing both 1310 and 1550 nm transmitters broadens the market for 100GBASE-DR4
  - It also lays the foundations for 40G or 50G lanes

- Adopt P802d3bm-96_PSM4_01.pdf with the changes shown on slides 7, 8, 9, 10 and 11

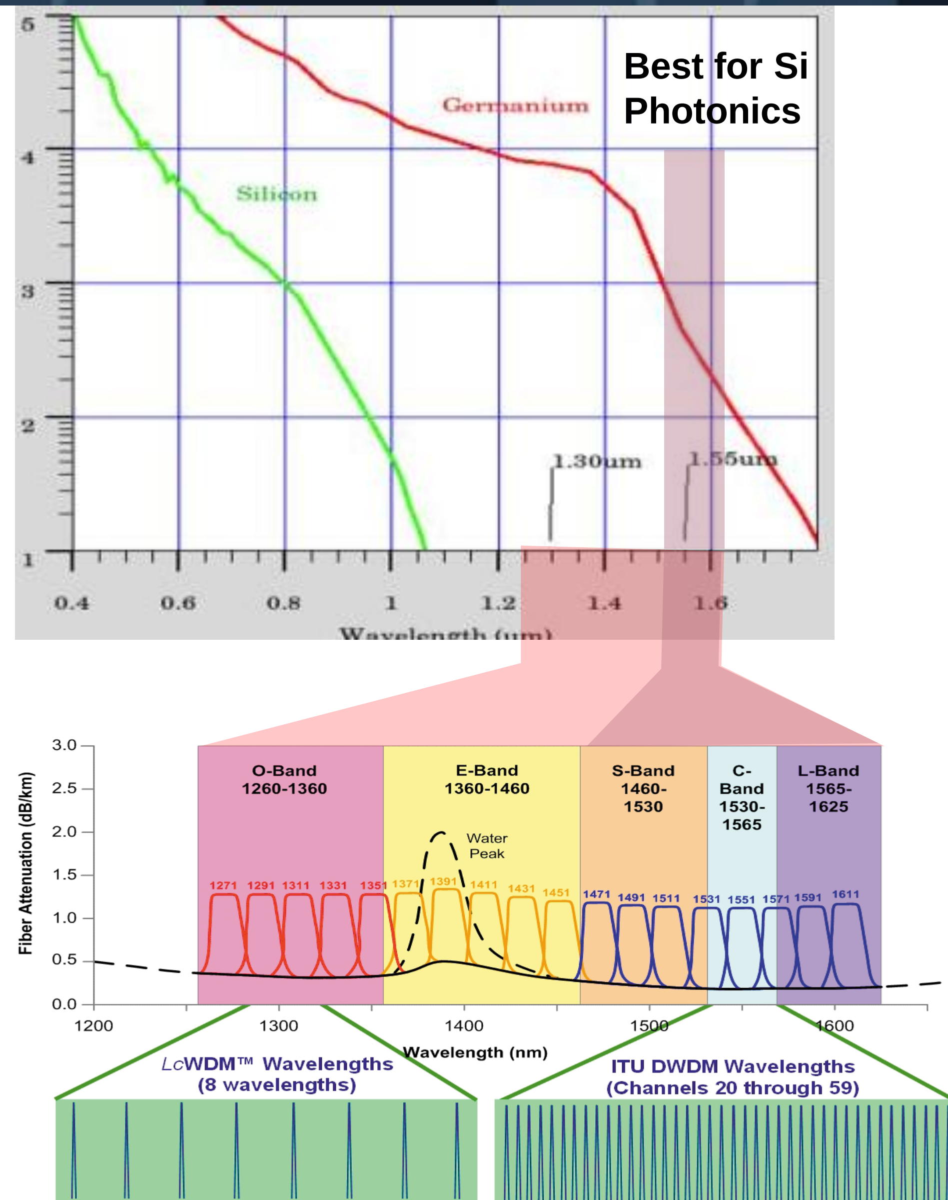
Silicon Photonics and wavelength

- Silicon is transparent at SMF wavelengths and enables low loss optical devices
- Ge absorbs at SMF wavelengths to enable detection
- Ge is CMOS compatible
- Working at 1.55 µm (band edge of Ge) enables the use of SiGe compounds for efficient modulation
  - Where the absorption curve is steep



Wavelength options and WDM

- Highly scalable: many WDM channels available, vision of a path to 1 Tb/s and beyond
- Components, test equipment and so on are available for a range of wavelengths
- Enables innovative technical solutions:
  - Silicon photonics
  - III/C PICS



Thank You