1310nm vs 1550nm

Session 1: Enabling the Data Center

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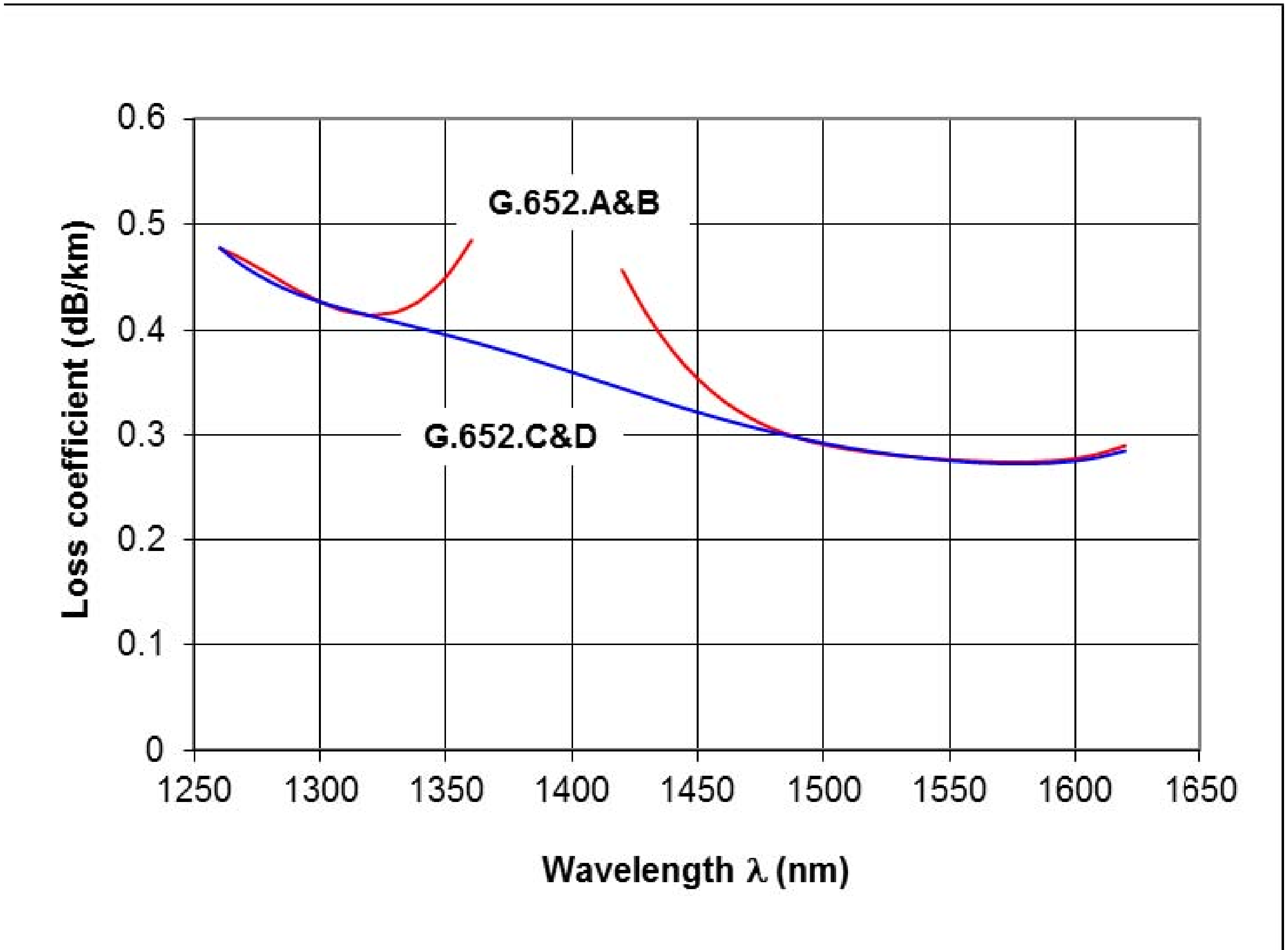
G.652 SMF Max Loss (α) dB/km



1270nm:
0.46 dB/km

1310nm:
0.42 dB/km

1550nm:
0.28 dB/km

Loss = α * L

G.652 SMF Losses for DC Reaches

Reach	500m dB	2km dB	10km dB	40km dB	80km dB
1310nm	0.21	0.84	4.2	16.8	33.6
1550nm	0.14	0.56	2.8	11.2	22.4
difference	insignificant			significant	

- SMF loss is independent of rate so significance does not change with time.

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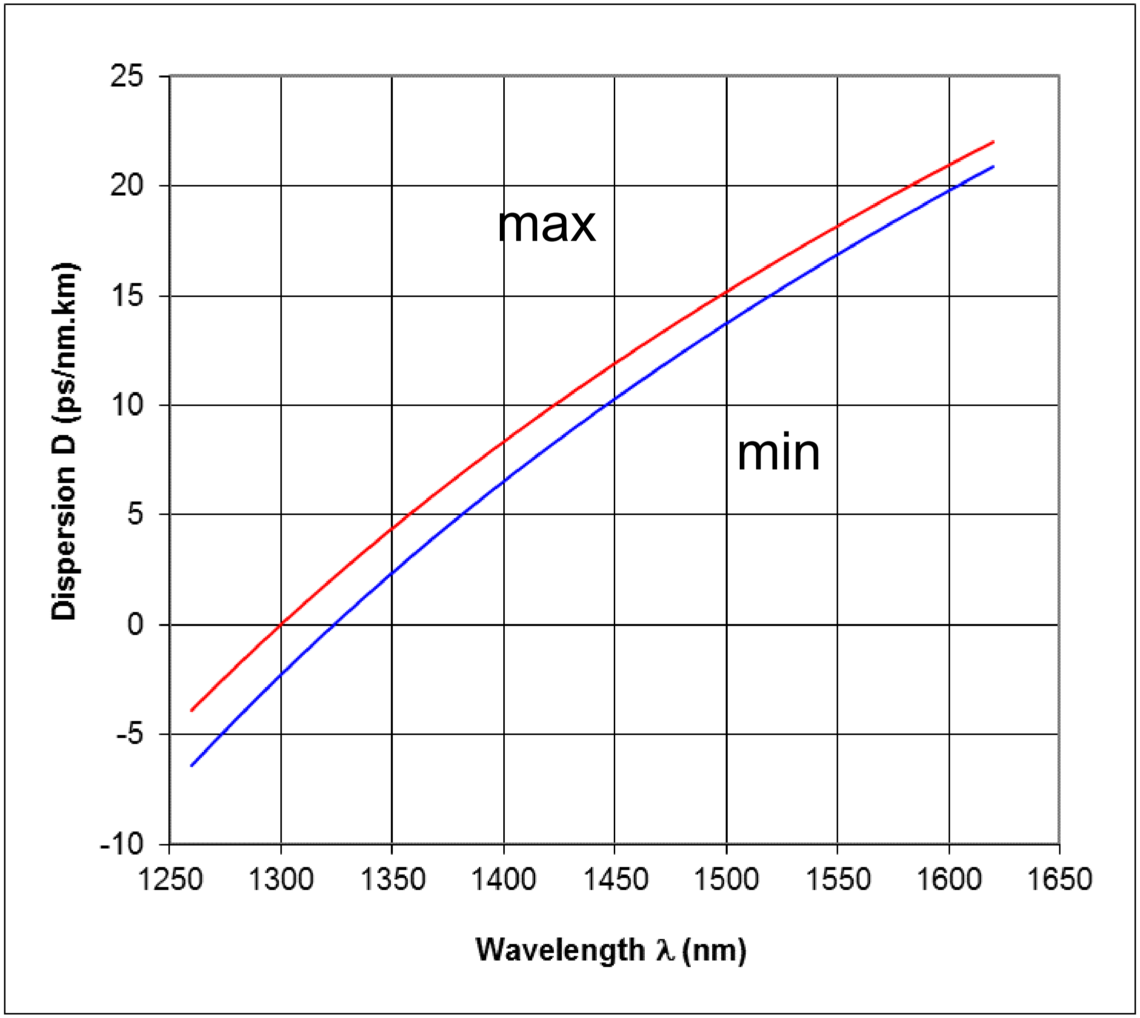
G.652 SMF Dispersion (D) ps/nm km



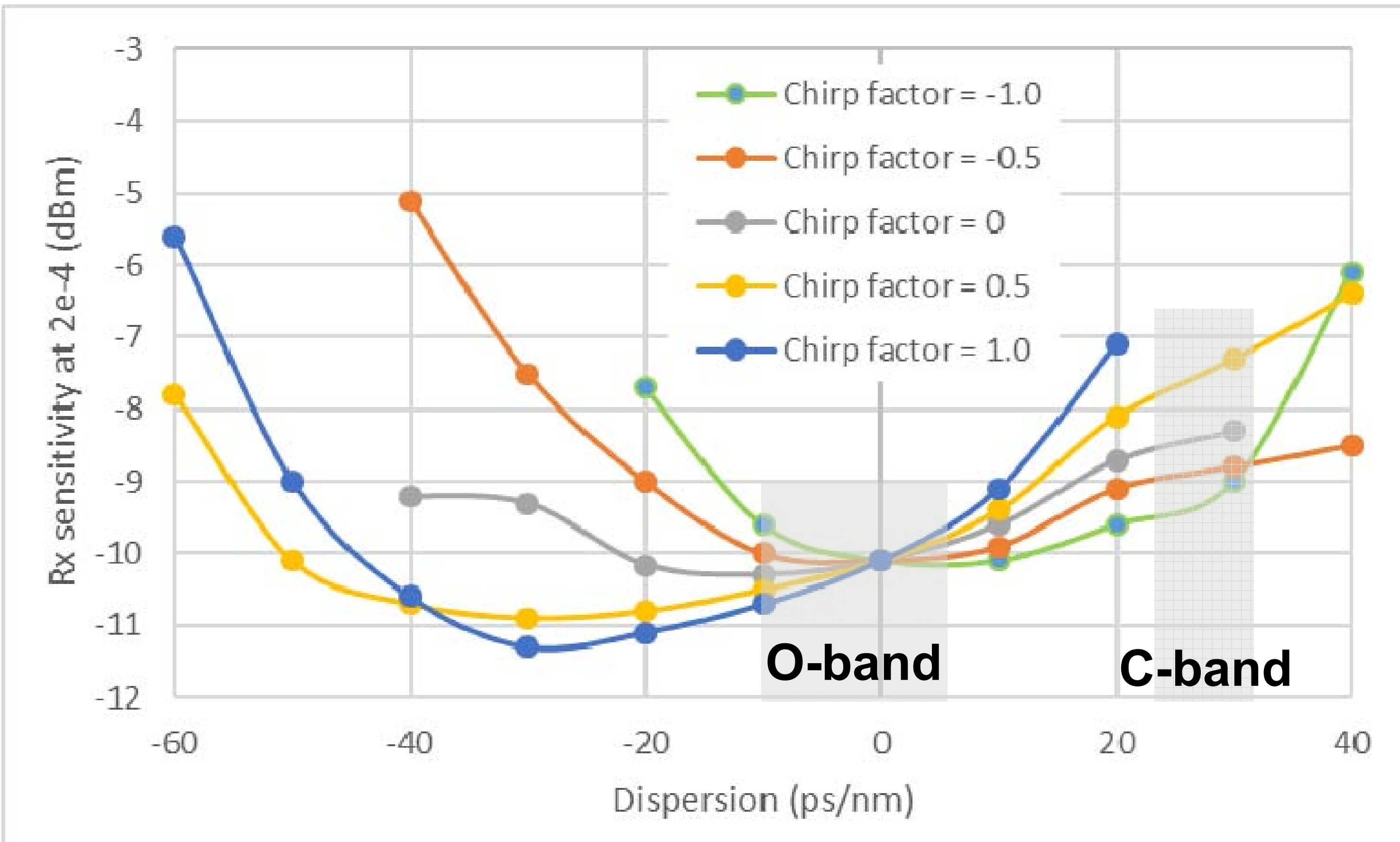
1310nm (max):
0.91ps/nm km

1330nm (max):
2.7 ps/nm km

1550nm (max):
18.2ps/nm km

CD ~ Bd^2 * D * L

Ex G.652 SMF CD Penalty 53GBaud PAM4



Simulation conditions:

40 GHz Tx

2 km SMF

40 GHz TIA

T FFE

- 2 - 3 dB 2km 1550nm band penalty requires equalizer
- Penalty increases with time as Baud rate goes up

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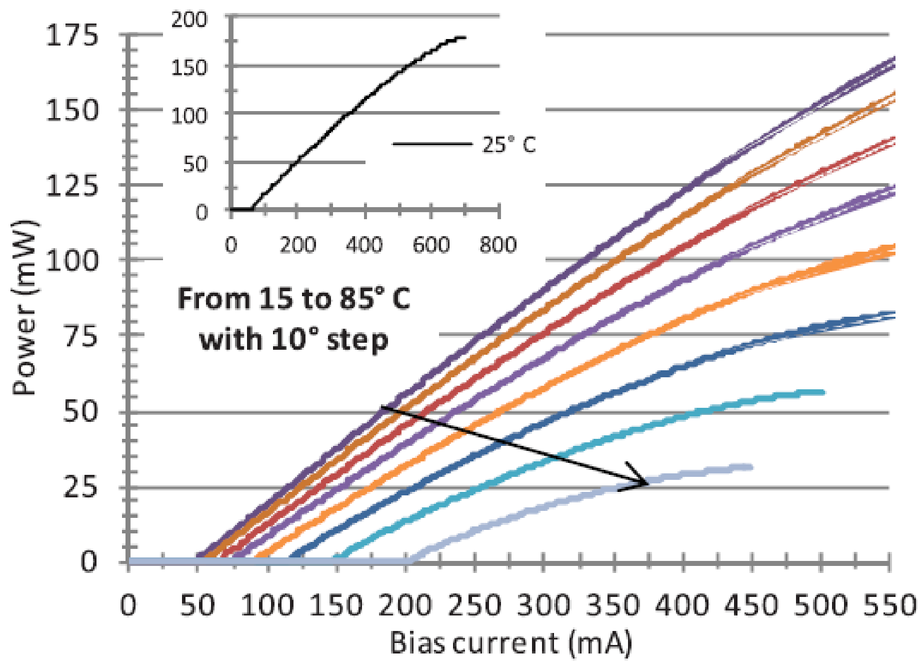
Fundamental TX Characteristics

- 1310nm
  - Higher operational temperatures enable uncooled operation at lower power and reduced cost (1550nm has difficult because of Auger recombination)
  - InGaAsP/InP (particularly InGaAlAs/InP) alloys easily emit at 1310nm at higher temperatures (vs 1550nm)
  - Higher differential gain enables better DML DFB performance
- 1550nm
  - Lower fiber loss significant at longer reaches
  - EDFA availability
  - Commoditized InP MZ and EA/EML modulators, tunable lasers, & narrow linewidth tunable sources
  - Frank Keldysh modulator has a temperature dependence which results in a penalty at hot

1550nm TX Temperature Dependence



Faugeron et. Al., IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 25, NO. 1, pp. 7-9, 2013

- 1-mm long ridge DFB laser
- Max output power at 85C is 30 mW@400 mA

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TX Performance & Power Efficiency

	DML 1310nm	DML 1550nm	EML	InP MZM	SiP MZM
3-dB BW	55 GHz	37 GHz	> 60 GHz	60 GHz	50 GHz
Output power	~ 10 mW	~ 10 mW	~ 2 mW	~ 4 mW	~ 1 mW
Bias	50 mA	50 mA	100 mA	120 mA	150 mA
ER	4 dB	4 dB	10 dB	10 dB	10 dB

- DMLs are the lowest power transmitters
- 1310 DMLs have higher bandwidth at the same power
- DML and EML power advantage is offset if TEC is required

SiP Considerations

- 1310nm band phase modulator advantages
  - 30% weaker plasma dispersion EO coefficient
  - 35% lower absorption loss at the same doping level
- 1310nm band has better confined optical mode, which enables more compact circuits and smaller chip
- 1310nm band requires smaller feature size, which causes inferior performance for some devices, most particularly grating coupler

Eye Safety Limits Considerations

- 1550nm limit: 10dBm
- 1310nm limit: 27dBm (used to be 12dBm)
- Edition 3.0 of IEC 60825-1 has 1310nm relaxation by taking detailed account of retinal damage threshold.
- Correction factor C7 used to be capped at 8, now it is calculated using the formula:

  $C_7 = 8 + 10^{0.04(\lambda - 1250)}$

- Eye safety power limits have implications for WDM

Limit	4λ WDM	8λ WDM	16λ WDM
Offset (dB)	9	12	15
1550nm (dBm)	1	-2	-5
1310nm (dBm)	26	15	12

- 1550nm has practical WDM power limits, 1310nm does not

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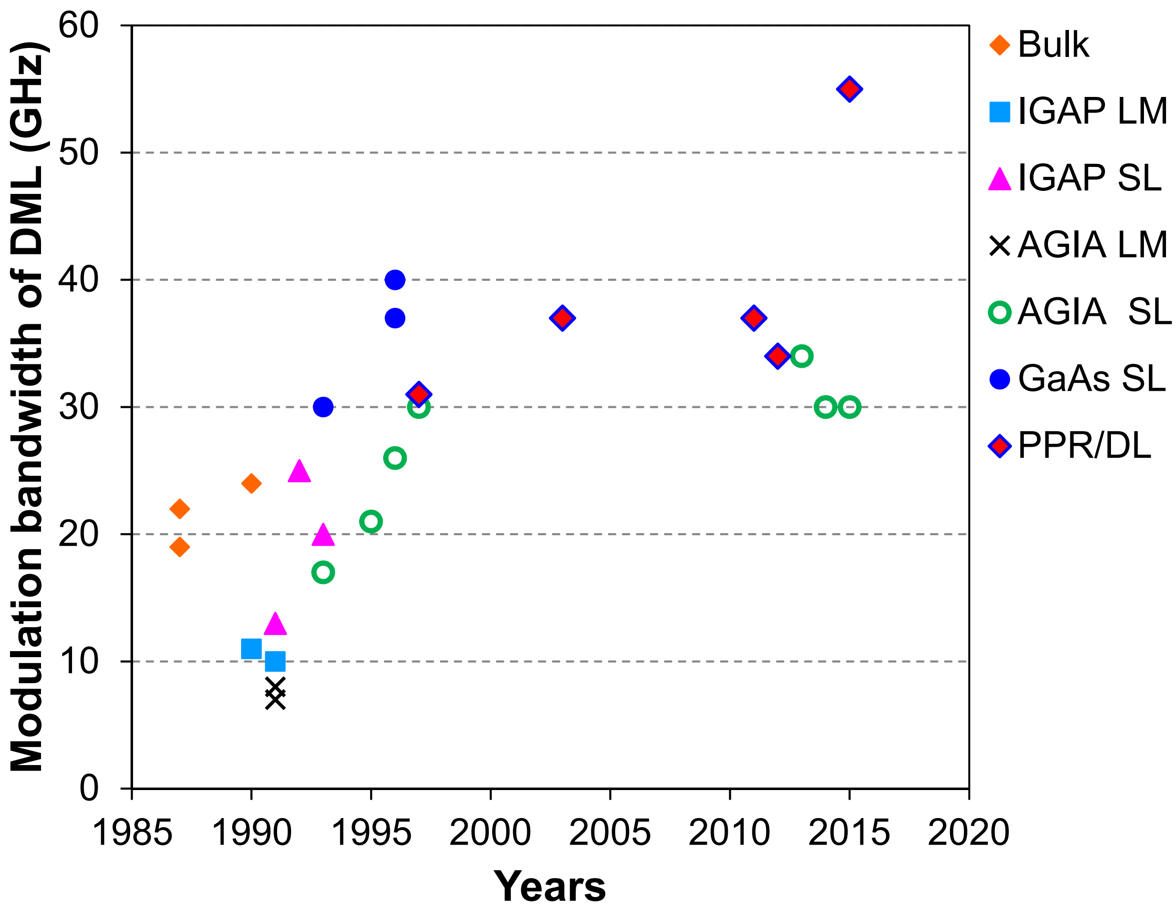
Progress on DML speed



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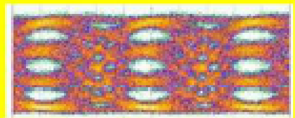
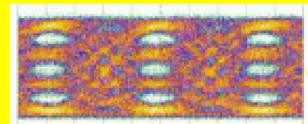
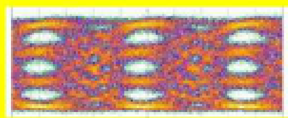
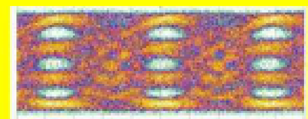
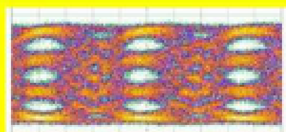
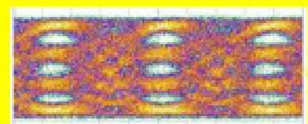
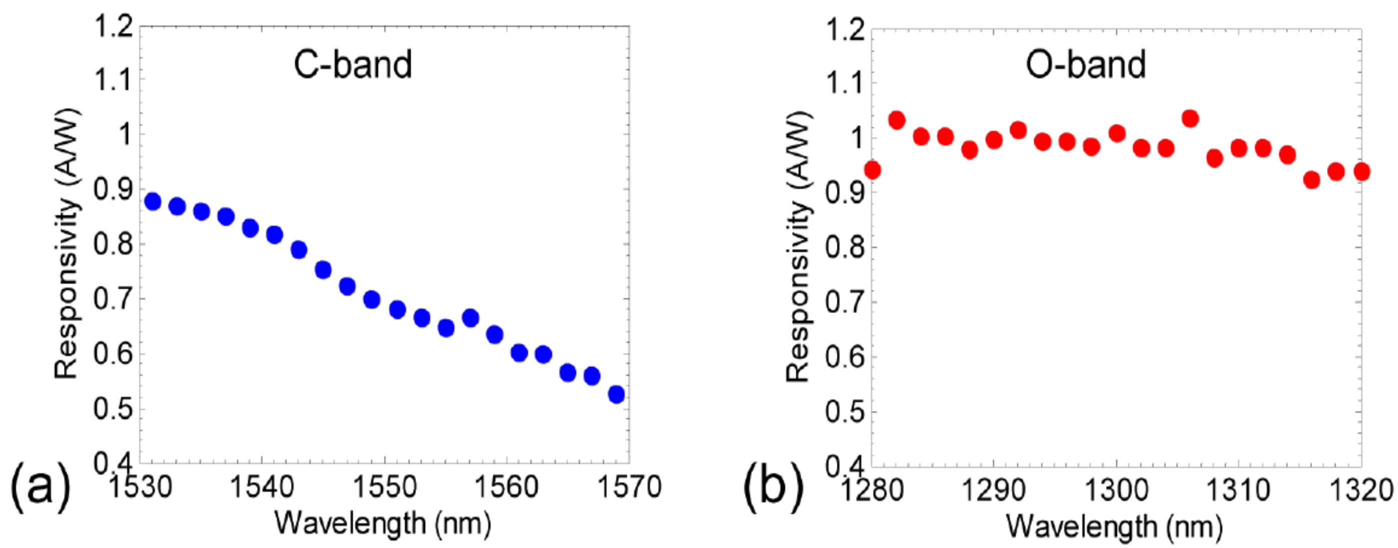
NTT 107 Gb/s over 10 km at 1305.4 nm

	Optical signal	Received electrical signal
BtoB	 Power: 4.0 dBm, ER_{outer}: 7.5 dB	
2 km		
10 km		

S. Kanazawa *et. al*., “Equalizer-Free Transmission of 100-Gb/s 4-PAM Signal Generated by Flip-Chip Interconnection EADFB Laser Module”, *Journal of Lightwave Technology, vol*. 35, *pp*. 775 - 780, 2017.

Ge PD responsivity at 1550nm and 1310nm



- Higher responsivity in 1310nm band due to better absorption coefficient

Mainstream Data Center SMF Optics

Reach	500m	2km	10km	40km	80km
10G	n.a.	n.a.	LR 1310	ER 1550	"ZR" 1550
40G	PSM4 1310	FR 1550 (niche)	LR4 1310	ER4 1310	1550
100G	PSM4 1310	CWDM4 1310	LR4 1310	ER4, ER4f 1310	1550
200G	DR4 1310	FR4 1310	LR4 1310	TBD *1310 (?)*	TBD *1550 (?)*
400G	DR4 1310	FR8, FR4 1310	LR8, LR4 1310	TBD 1310 / 1550 (?)	1550 (?)

Summary

- 400G & beyond in the DC
  - Mainstream 500m, 2km, 10km will stay at 1310nm
  - Mainstream 40km, 80km will be at 1550nm
- 1310nm is better for <10km for same reasons as before
  - 1310nm extra SMF loss is not significant
  - 1550nm Dispersion penalty is significant and requires extra power for equalization
  - 1310nm lasers are lower cost and lower power because of better over temperature efficiency and material systems
  - 1310nm DMLs are feasible for lowest power solutions

1310nm vs 1550nm

Thank you

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