Security Level:

# Considerations on 200GE SMF wavelength choice for 10km

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IEEE P802.3bs Task Force Meeting
Whistler, Canada

May 2016

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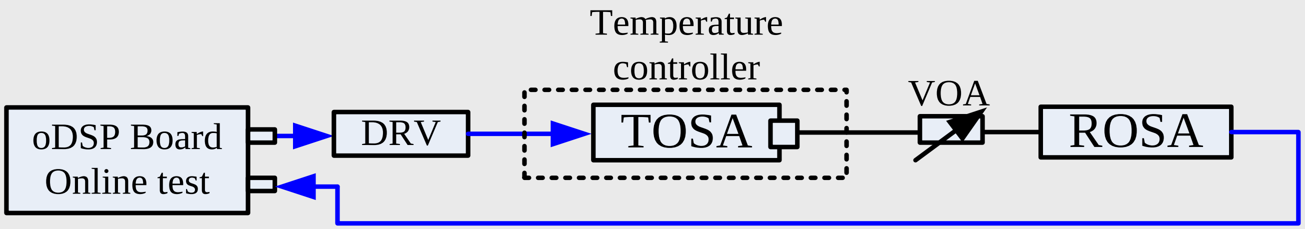
# Introduction

- **Objective**
  - Find an appropriate solution for 200GBASE-LR4 to enable near term deployment of 200 GbE with robust link performance over worst case 10km SMF.

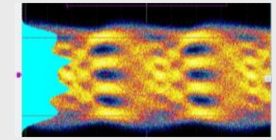
- **Satisfactory Technical Performance and near term deployment are the priority for the choice of 200GbE 10km wavelength grid**
  - Laser chirp in combination with worst case dispersion over the specified wavelengths range must be considered for robust-interoperable operation of the 200GBASE-LR4 link.

- **In this presentation both a LAN-WDM (worst case 1310nm) and CWDM (worst case 1337.5nm) link penalties are investigated.**

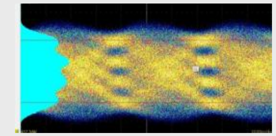
# Temperature Performance of Uncooled DML

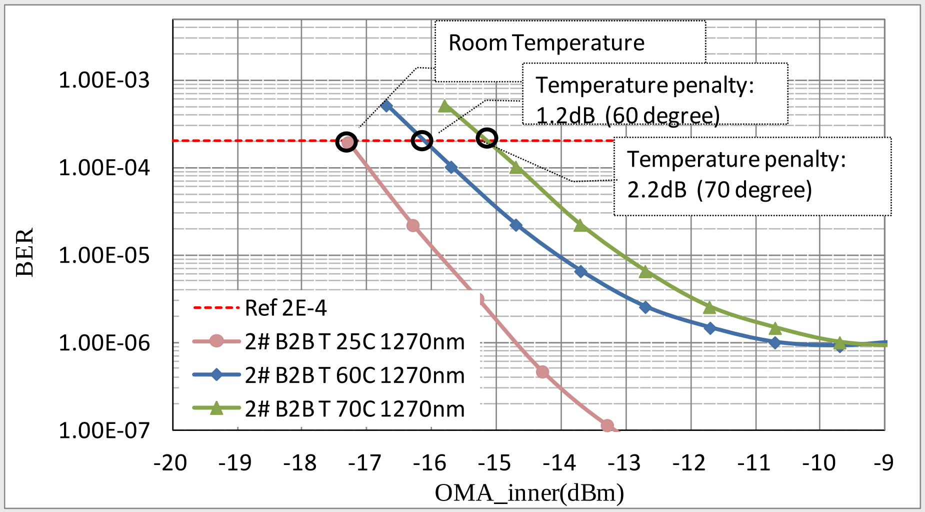


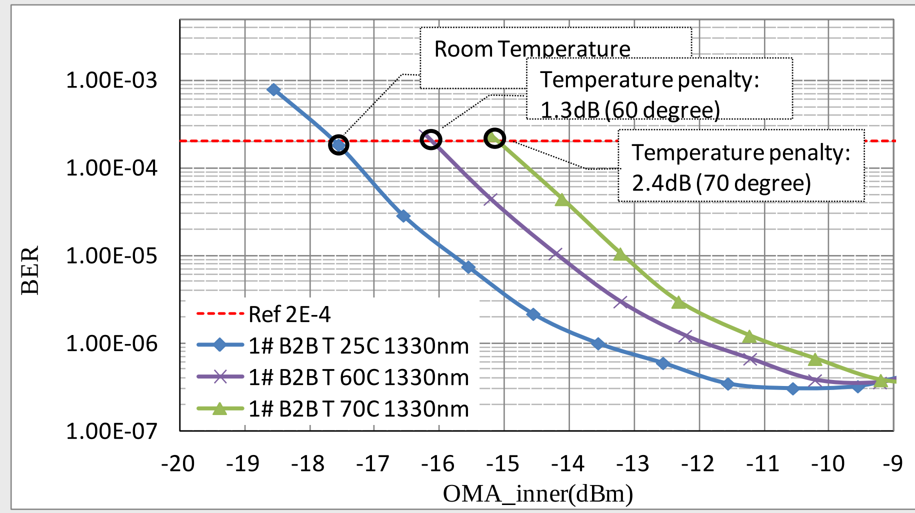

Room temperature



Temperature 60 degree



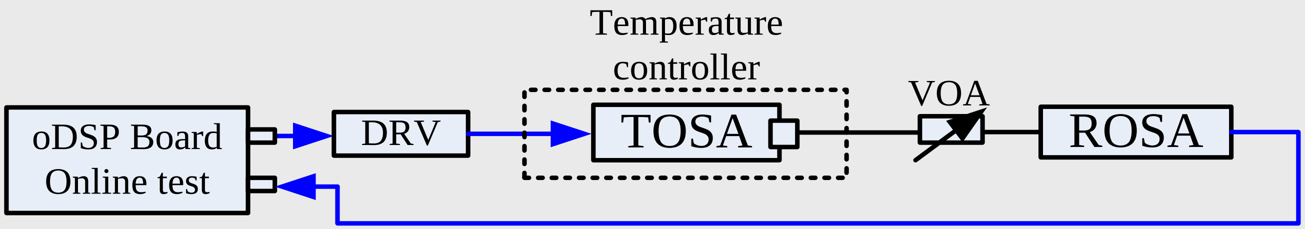


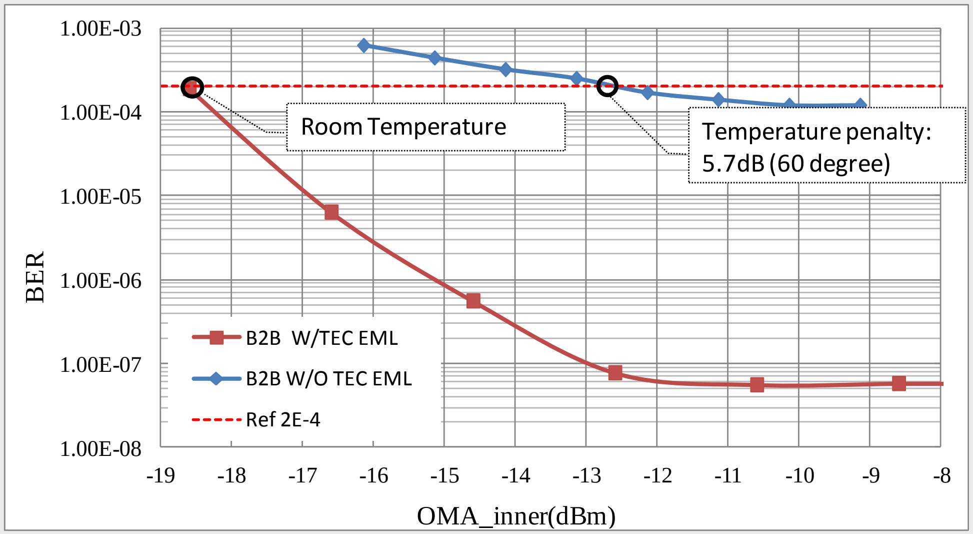



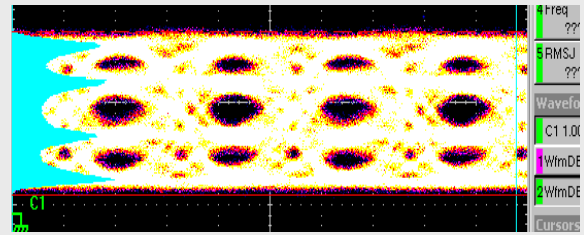

| | Temperature penalty @25C [dB] | Temperature penalty @60C [dB] | Temperature penalty @70C [dB] |
|---|---|---|---|
| DML1 no TEC | 0 | 1.2 | 2.2 |
| DML2 no TEC | 0 | 1.3 | 2.4 |

- The alpha parameter used in this test is 1.7
- Tested DMLs are from commercial DML suppliers
- High temperature performance degradation of the uncooled DML introduces unacceptable amount of penalty!

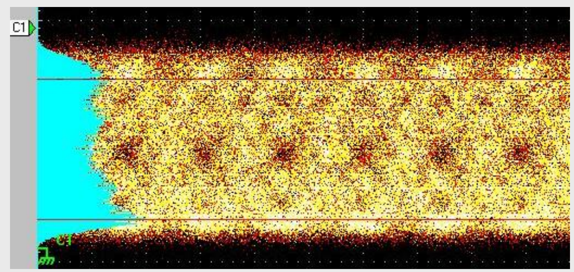
# High Temperature Performance (Uncooled EML)



Room temperature



Temperature 60 degree

| | Temperature penalty @25C [dB] | Temperature penalty @60C [dB] |
|---|---|---|
| EML1 no TEC | 0 | 5.7 |

- Tested EML is from commercial EML suppliers
- High temperature performance degradation of the uncooled EML introduces unacceptable amount of penalty!

# Alpha-factor in DFB laser and dispersion in CWDM

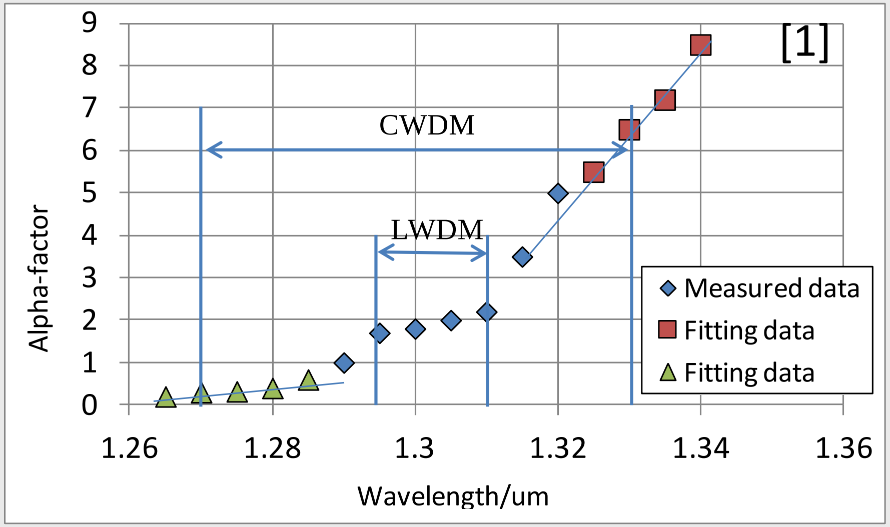
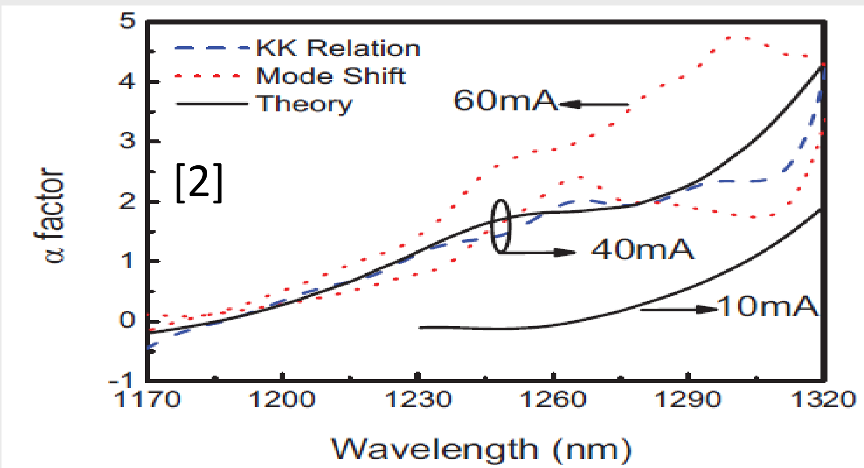
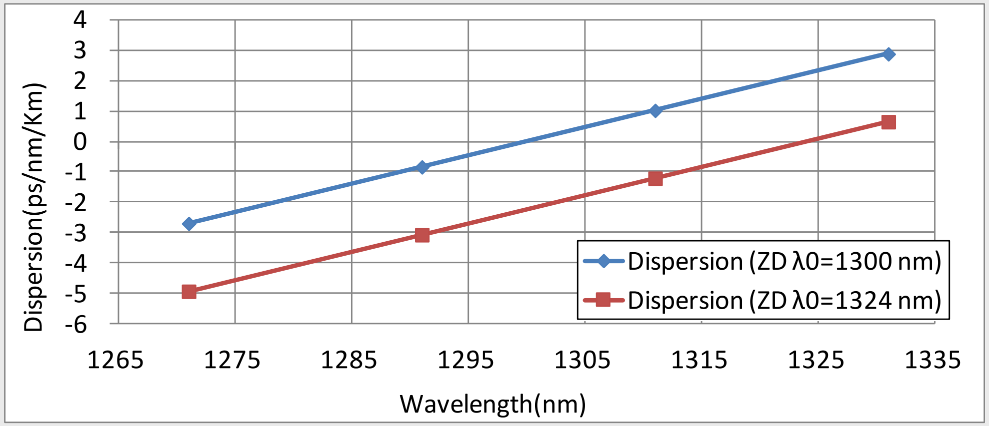



**Table 122–13—Optical fiber and cable characteristics**

| Description | Value | Unit |
|---|---|---|
| Nominal fiber specification wavelength | 1310 | nm |
| Cabled optical fiber attenuation (max) | 0.5[a] | dB/km |
| Zero dispersion wavelength ($\lambda_0$) | $1300 \le \lambda_0 \le 1324$ | nm |
| Dispersion slope (max) ($S_0$) | 0.093 | ps/nm$^2$ km |





[1] IEEE Photonics Technology Letters, Vol.3 No.10,1991

[2] IEEE Photonics Technology Letters, Vol.25,No.5,2013


**The Worst Case Situation in CWDM configuration**

1. **Fiber: ZDW:1300nm, 10km dispersion: 33.4 ps/nm @1337.5nm (Corner wavelength)**
2. **DML alpha-factor: >4.5 (@1337.5nm)**

# Dispersion penalty

**Online Test，Tx: DML, Rx EQ: 7-tap T/2 spaced FFE**

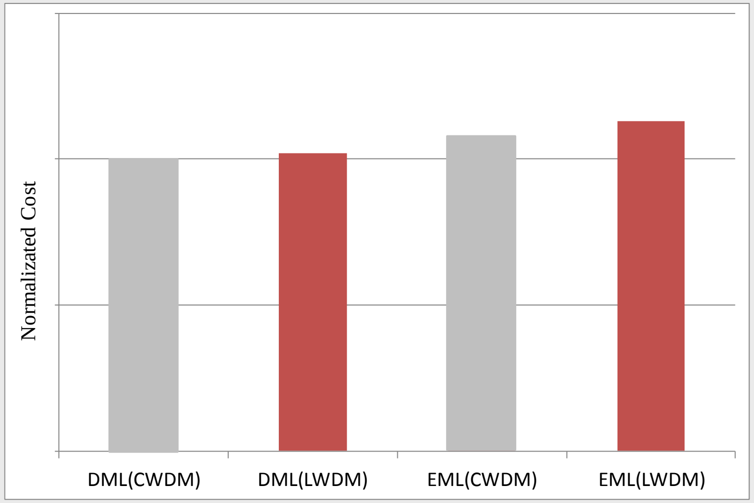
| Test Wavelength | Dispersion Parameter of fiber | Transmission length | Total dispersion | Alpha parameter | Dispersion Penalty |
|---|---|---|---|---|---|
| 1311 nm | 1.02 ps/nm*km | 33km | 33.66 ps/nm | 3.4 | 2.2dB |
| 1330 nm | 2.88 ps/nm*km | 12 km | 34.56 ps/nm | 4.7 | 3.5dB |

**Commercial simulation model，7-tap T/2 spaced FFE**

| Alpha-factor | Dispersion Penalty in dB @ CWDM corner wavelength 1337.5nm @10Km | Dispersion Penalty in dB @ LAN- WDM corner wavelength 1310.19nm @10Km |
|---|---|---|
| **3.5** | 2.1 | 0.3 |
| **4.5** | 3.2 | 0.4 |

- A transmitter with 1337.5nm wavelength is not available. Instead a transmitter with lower wavelength @1330nm was used to test under 34ps/nm worst case dispersion conditions
- Both offline test and simulation show the penalty for high dispersion with high alpha factor

# Cost analysis




- Main cost of  module is from COC chip
- The main cost difference between CWDM and LAN-WDM caused by TEC and optical Mux/De-Mux
- The cost of TEC is a small part in the whole BOM
- The cost difference between an EML and a DML capable of 50G PAM4 is not substantial
- Availability of uncooled DFB-DML TOSA meeting performance requirement may jeopardize early deployment!

# Wavelength options for 200GBASE-LR4

| | LAN-WDM | CWDM |
|---|---|---|
| Pros. | 1. Technically mature and stable<br>2. High stability with temperature variation .<br>3. Much smaller Dispersion penalty than CWDM at corner wavelength.<br>4. Reuse the components from 400GBASE-FR8 and 400GBASE-LR8 | 1. Could be uncooled<br>2. Technically feasible (but maybe not sufficiently robust) |
| Cons. | 1. TEC required | 1. Performance degeneration under high temperature<br>2. Large dispersion penalty at highest wavelength<br>3. Require low chirp temp stable DFB-DML otherwise force using TEC<br>4. Yield and component availability |

# Conclusions

- The cost difference between TOSA W/ TEC and W/O TEC is not significant
  - The LAN-WDM components are leveraged from 400GBase-FR8/LR8

- A (un)cooled DML transmitters may have insufficient and/or low yield for reliable link operation over worst case 10km SMF due to high dispersion penalty coupled with device alpha parameter

- Relying on (un)cooled DFB-DML transmitter may jeopardize near term deployment of 200GBASE-LR4

- We propose to use LAN-WDM wavelength grid for 200GBASE-LR4 to mitigate any risk and avoid any schedule impact to the IEEE P802.3bs.

# Baseline Proposal for 10km

| | Description | 200GBASE-LR4 （LWDM） |
|---|---|---|
| Tx | Reach/Km | **10** |
| | Signaling Rate/Gbaud | **26.56** |
| | Operating BER | **2.00E-04** |
| | OMA11-00,each lane(min)/dBm | **0.2** |
| | TDP each lane/dB | **2.4** |
| | OMA11-00-TDP, each lane(min)/dBm | **-0.8** |
| | Extinction Ratio (min)/dB | **4.5** |
| | | |
| Link | Channel loss/dB | **6.3** |
| | MPI/dB | **0.5** |
| | | |
| Rx | Signaling Rate,each lane/Gbaud | **26.56** |
| | Operating BER | **2.00E-04** |
| | Rx Sensitivity ($OMA_{11-00}$) | **-7.60** |
| | Rx Sensitivity ($OMA_{01-00}$) | **-12.4** |

# Refer to stassar_3bs_01_0516

# Baseline Proposal for 2km

| | Description | 200GBASE-FR4（CWDM） | 200GBASE-FR4（LWDM） |
|---|---|---|---|
| Tx | Reach/Km | **2** | **2** |
| | Signaling Rate/Gbaud | **26.56** | **26.56** |
| | Operating BER | **2.00E-04** | **2.00E-04** |
| | OMA11-00,each lane(min)/dBm | **-0.5** | **-0.5** |
| | TDP each lane/dB | **2.4** | **2.2** |
| | OMA11-00-TDP, each lane(min)/dBm | **-1.5** | **-1.5** |
| | Extinction Ratio (min)/dB | **4.5** | **4.5** |
| | | | |
| Link | Channel loss/dB | **4** | **4** |
| | MPI/dB | **0.3** | **0.3** |
| | | | |
| Rx | Signaling Rate,each lane/Gbaud | **26.56** | **26.56** |
| | Operating BER | **2.00E-04** | **2.00E-04** |
| | Rx Sensitivity ($OMA_{11-00}$) | **-5.80** | **-5.80** |
| | Rx Sensitivity ($OMA_{01-00}$) | **-10.6** | **-10.6** |

## Refer to stassar_3bs_01_0516

# Back-up slide

# Chirp in DFB laser and dispersion in optical fiber

**Laser Rate Equation Model**

$$\frac{dn}{dt}=\frac{i(t)}{qV_a}-r[n(t)]-g_m[n(t),p(t)]\cdot p(t)$$

$$\frac{dp}{dt}=\left[\Gamma g_m[n(t),p(t)]-\frac{1}{\tau_{ph}}\right]\cdot p(t)+r_{sp}[n(t)]$$

$$\Delta\omega(t)=\frac{d\phi}{dt}=\frac{1}{2}\alpha\Gamma[g_m[n(t),0]-g_m(N_{th},0)]$$

$$g_m(n,p)=G_0\ln\left(\frac{n}{N_0}\right)\cdot\frac{1}{1+\varepsilon p}$$

$$r(n)=\frac{n}{\tau_s}+Bn^2+Cn^3$$

$$r_{sp}(n)=\beta_{sp}Bn^2$$

The alpha-factor affects the chirp, linewidth and line shape

Dispersion: it represents a broad class of phenomena related to the fact that the velocity of the electromagnetic wave depends on the wavelength

**Worst Cases:**

1. **Positive chirp and Positive fiber dispersion.**
2. **Negative chirp and Negative fiber dispersion .**

**Linear Fiber Propagation Model**

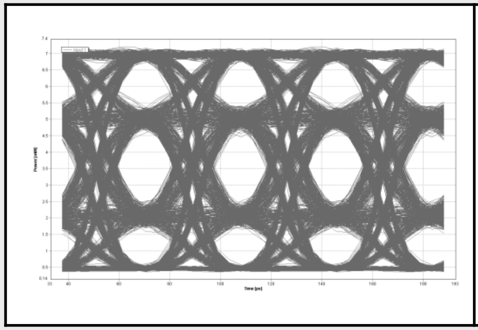
$$e(t,0)=\sqrt{p(t)}e^{i\phi(t)}$$

$$\tilde{E}(\omega,0)=\int_{-\infty}^{+\infty}e(t,0)e^{-i\omega t}dt$$

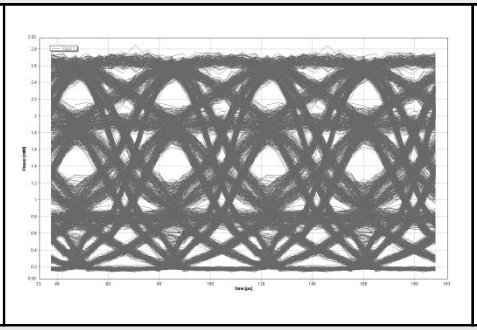
$$\tilde{E}(\omega,L)=\tilde{E}(\omega,0)e^{+i\beta_2\omega^2}$$

$$e(t,L)=\frac{1}{2\pi}\int_{-\infty}^{+\infty}\tilde{E}(\omega,L)e^{+i\omega t}d\omega$$

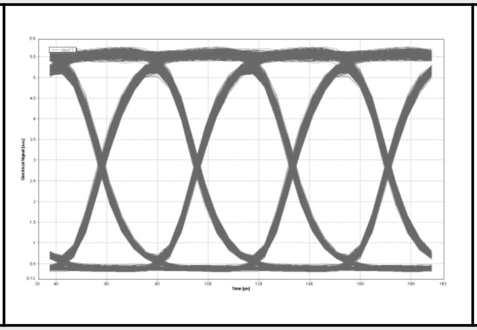
$$\beta_2=\frac{\lambda^2}{4\pi c}DL$$



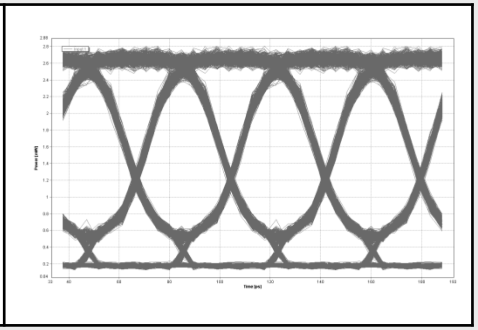
0Km, 1337.5nm DML Simulated result



10Km, 1337.5nm DML Simulated result



0Km, 1337.5nm DML Simulated result



10Km, 1337.5nm DML Simulated result

# Thank You