

Comparison of Experimental Data with Theoretical Prediction of EDC Performance

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Objective of presentation

- **Establish correlation between measured and simulated EDC performance of individual fibers**
 - Allows the extension from the specific case to the general case

Outline

- **Experimental results of EDC performance**
 - 2 different fibers (Corning[®] and Siecor[®])
 - Establishing the characteristics of the fibers
- **Simulation results based on impulse responses**
 - Estimation of path penalty for correlation
 - Description of model

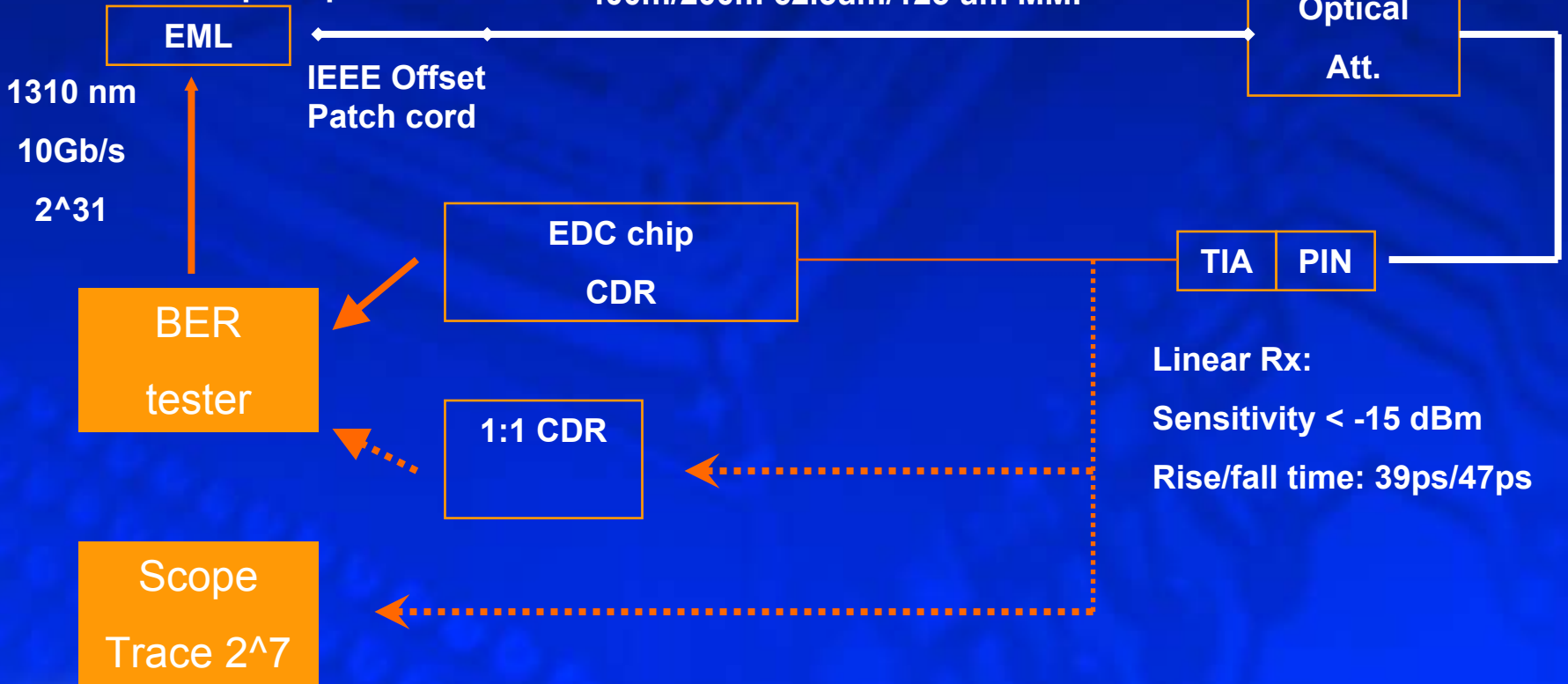


MMF link experiment

Ex. Ratio: 5.8 dB

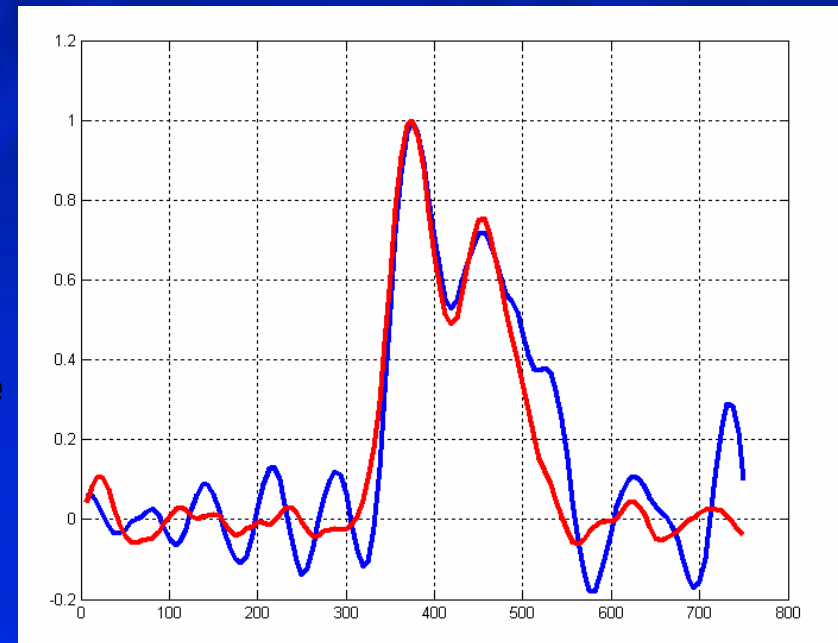
Rise/fall time: 41ps/50ps

400m/200m 62.5um/125 um MMF



Corning® 400m MMF fiber

- Corning® 62.5 MMF
 - Backup slide for spec details
- Overfill launch bandwidth*
 - 751 [MHz*Km] @ 1300 nm
- Measured Bandwidth (1310nm):
 - Center Launch: >5000 MHz*Km
 - Offset Launch: 1600 MHz*Km
- Bandwidths and impulse response are extracted from traces
 - 2⁷ PRBS (~128 bit periods)
 - See backup slides for details



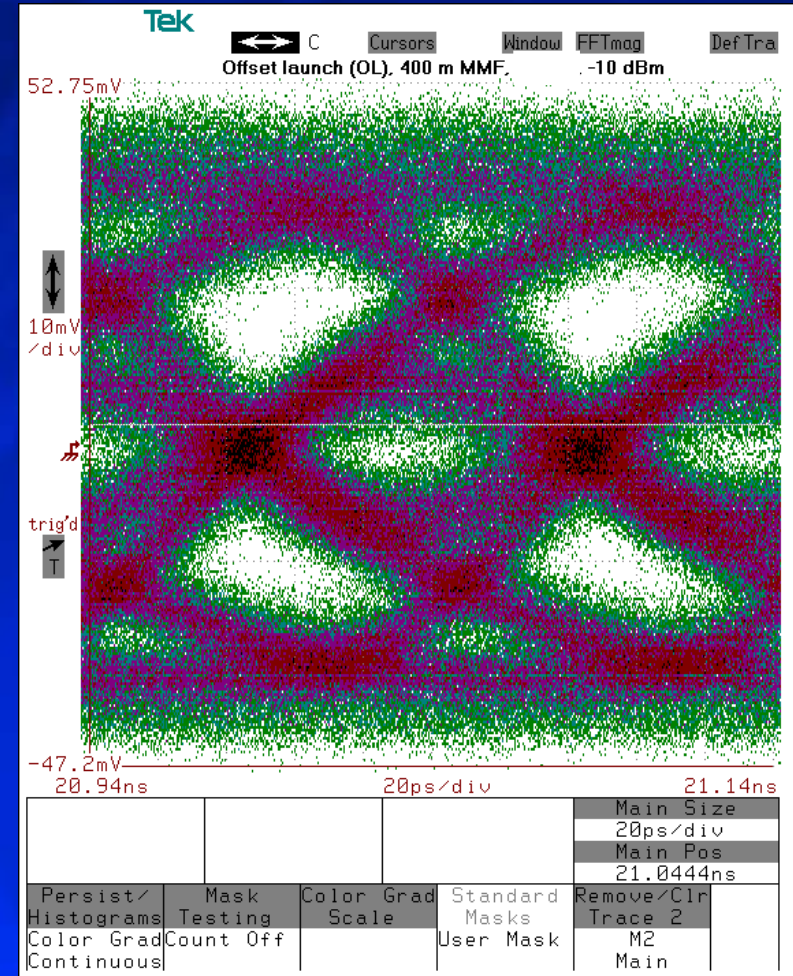
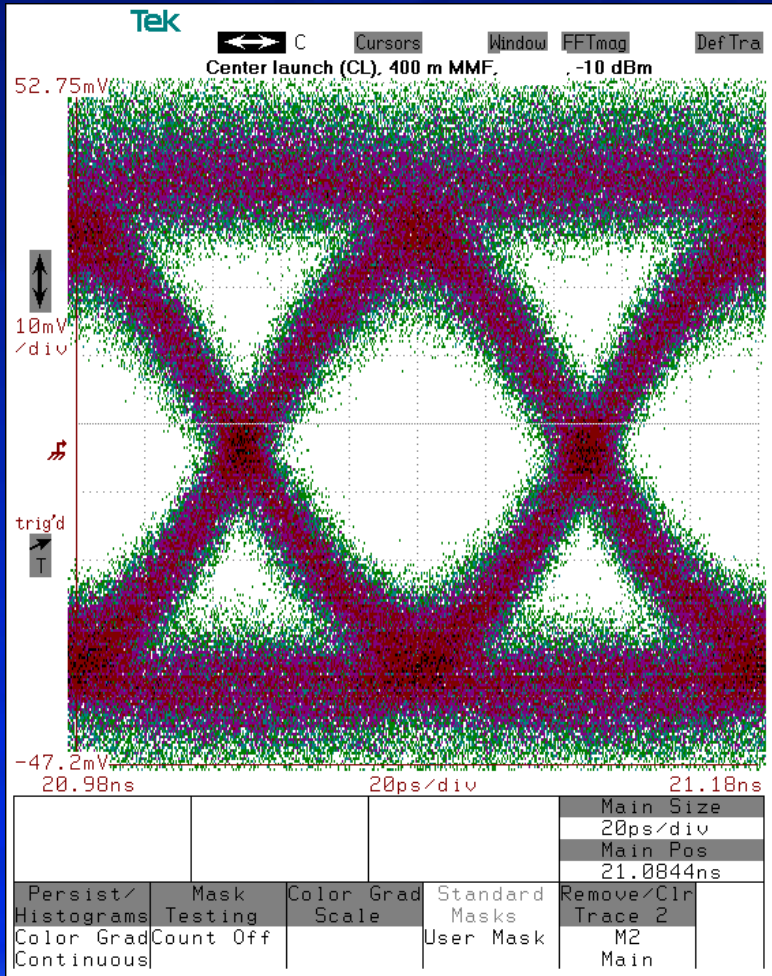
Impulse response for offset launch with 400 meter fiber

(2 measurements)

*According to data provided by fiber manufacture



Eye-diagrams after 400 m MMF

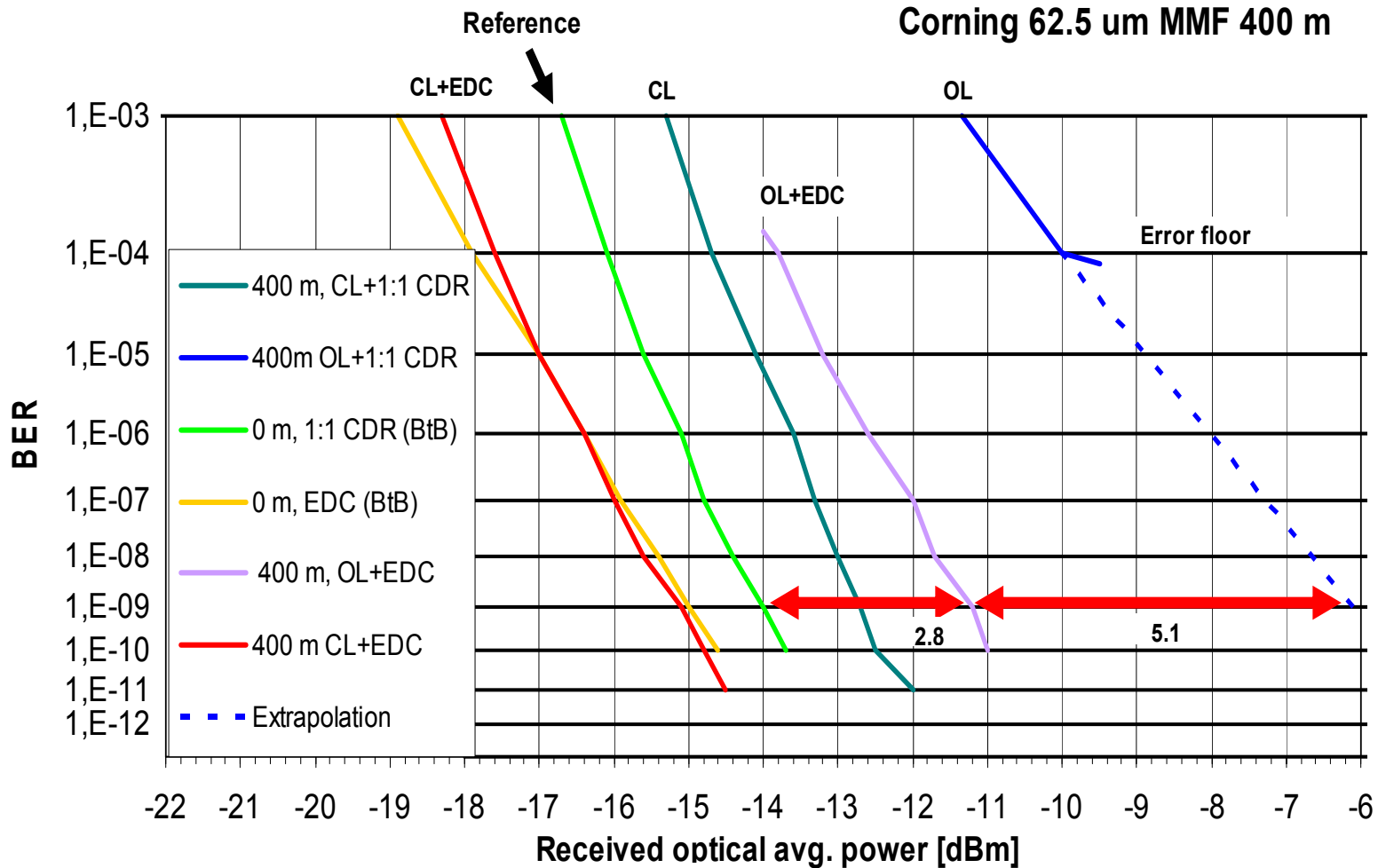


Center launch: >5000 MHz*km

Offset launch: 1600 MHz km



Sensitivity measurements – 400 m MMF



CL= center launch OL= Offset Launch BtB= Back-to-back



Relative Penalty

Penalty at BER=10 ⁻⁹	Back-to-Back	Center Launch 400 meter	Offset Launch 400 meter
State-of-art 1:1 CDR	<u>0 dB</u>	+1.4 dB	+7.9 dB*
With EDC	-1.0 dB	-1.1 dB	+2.8 dB

*Extrapolated value

Correlation between 3dB bandwidth and Penalty: Weiner 1_0504

Offset launch on 400 m of 1600 MHz*km → 4 GHz → Reciprocal 3 dB = 0.25 ns

Conventional Receiver: ~ 5-8** dB penalty <~6 dB>**

With EDC: ~1.8-3.5** dB penalty <~2.2dB>**

**Values are taken from the graph shown in Weiner_1_0504



Observations (w/Corning fiber)

- **Back-to-back sensitivity with EDC is better than conventional receiver**
 - Compensation for Tx/Rx bandwidth limitations
 - In line with theoretical predictions (not shown)
- **Sensitivity curves can be reproduced**
 - Leave setup with minimum disturbance during test
 - Not possible in case of fiber stress/long term changes
- **Different offset patch cords can give very different results**



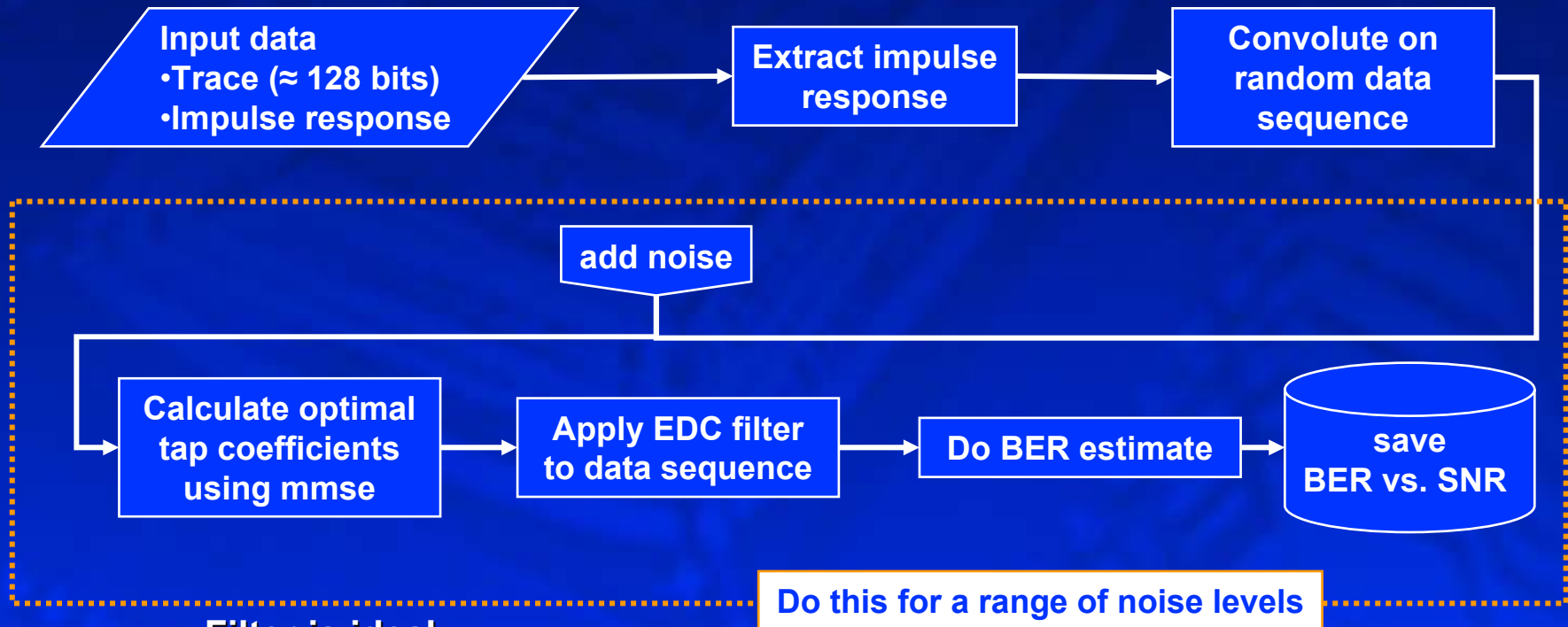
Infineon* measured dataset

- One fiber type
 - Siacor ® 62.5 µm
 - Approx. 500 MHz km bandwidth (Overfill launch)
- Fibers with lengths from 50 m - 550 m
 - Taken from same fiber spool
- Two types of test setup (impulse response)
 - Directly modulated DFB laser
 - External modulated laser (EML)
- Pulse pattern 0000000100000000
- Dataset includes calibration pulse measurements
- For details see hanberg_1_0304 (March meeting)



*Stefano.Bottacchi@infineon.com

EDC simulation path

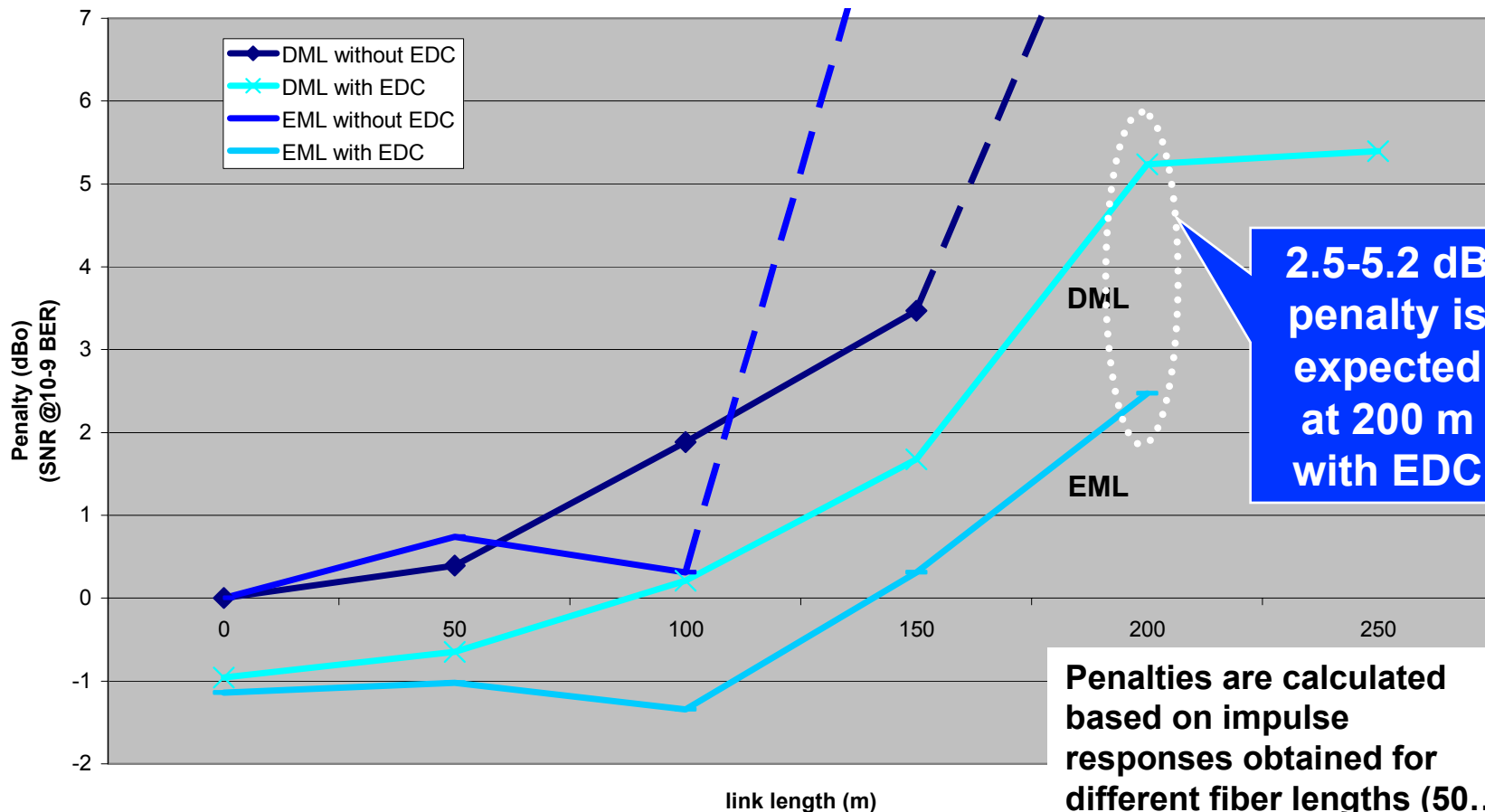


- **Filter is ideal**
 - Textbook FFE/DFE configuration
 - no bandwidth limitations
 - no noise contribution from filter
- **Jitter not considered in BER estimates**
- **Only receiver noise is considered (5 GHz BW). Noise added after PIN-TIA**



Siecor MMF fiber

Penalty [dB₀] @ BER 10⁻⁹



2.5-5.2 dB penalty is expected at 200 m with EDC

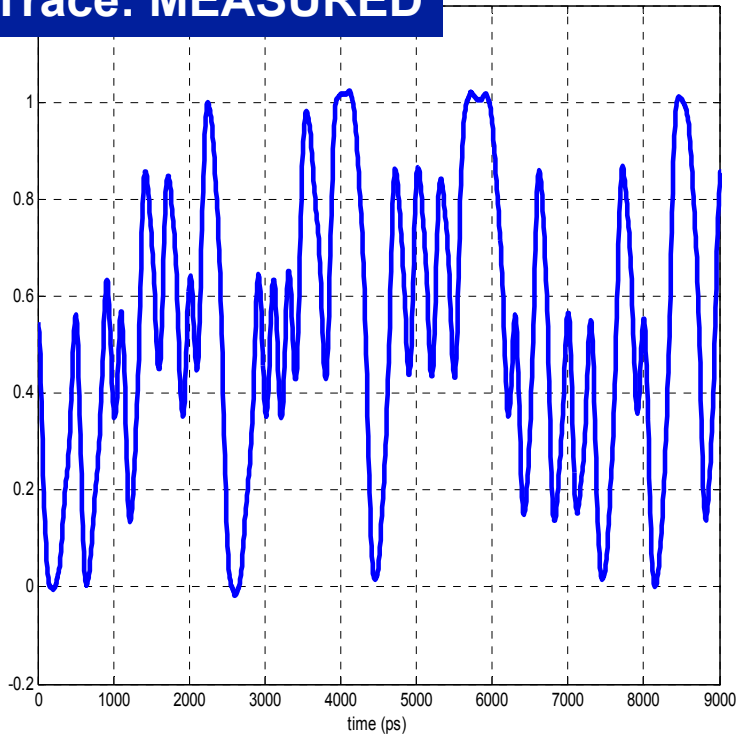
Penalties are calculated based on impulse responses obtained for different fiber lengths (50... 300m)

Simulations/Penalty with EDC include finite number of taps equal to EDC chip

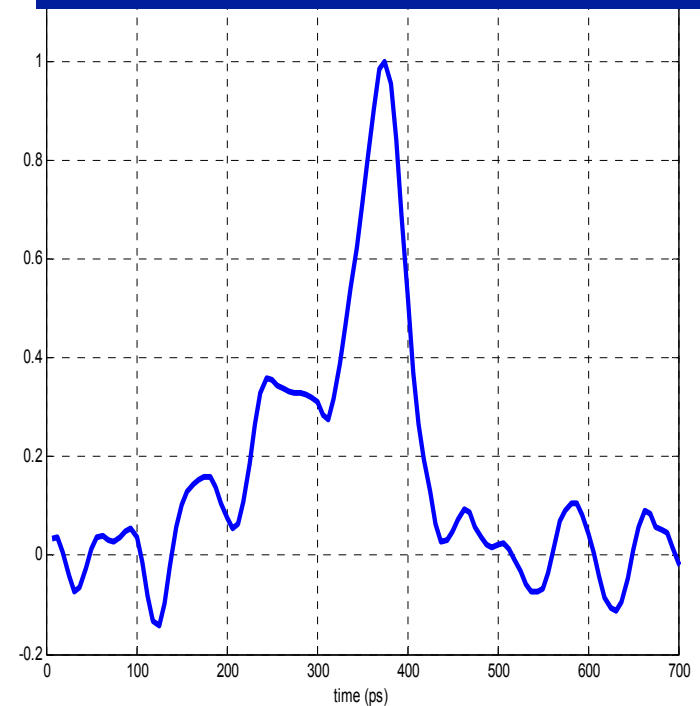


200m Siecor fiber (spool 9+10@100m)

Trace: MEASURED

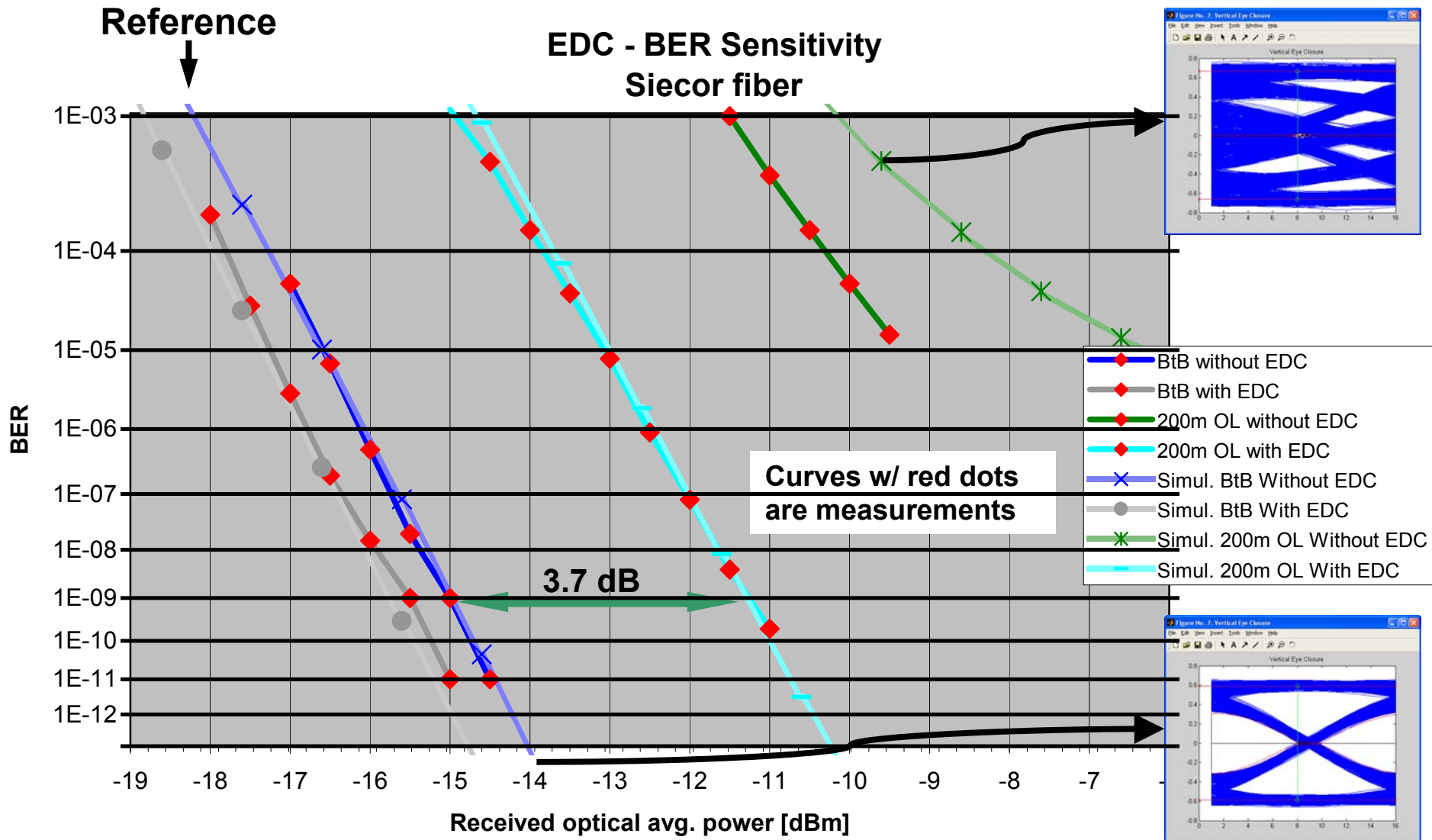


1. Extracted Impulse response



- Bandwidth of 600 MHz-km obtained from impulse response extracted from bit sequence
- See backup for eye diagram and impulse res. in freq.





- Simulated curves are shifted as a series for overlap at back-to-back point
- Simulations/Penalty with EDC include finite number of taps equal to EDC chip



Observations (w/200 m Siecor)

- Measured penalty of 3.7 dB for Offset launch matches theory in 2 ways:
 - Within expected range of 2.5-5.2 dB determined through direct measurements of impulse responses
 - Equals 3.7 dB determined through extracted impulse response from bit sequences
- Bit sequences must be recorded simultaneously with BER curves to ensure high correlation
 - Next-day measurements doesn't work
- Discrepancy between theory and measurements for eye diagrams having high ISI
 - Is the BER estimation good enough?
- Implementation penalty seems small compared to total penalty budget (~5 dB)



Conclusion

- **Good correlation between measured and simulated data demonstrated**
 - Reproducibility is a challenge due to the nature of MMF
- **Simple model with only Rx noise term seems sufficient for prediction of EDC performance.**
 - Model can be used to investigate expected coverage based on family of impulse responses
- **Model needs to be ratified by the group**
 - BER estimation may be a weak point.
 - Explore limitations of model



Backup



Fiber data - Corning

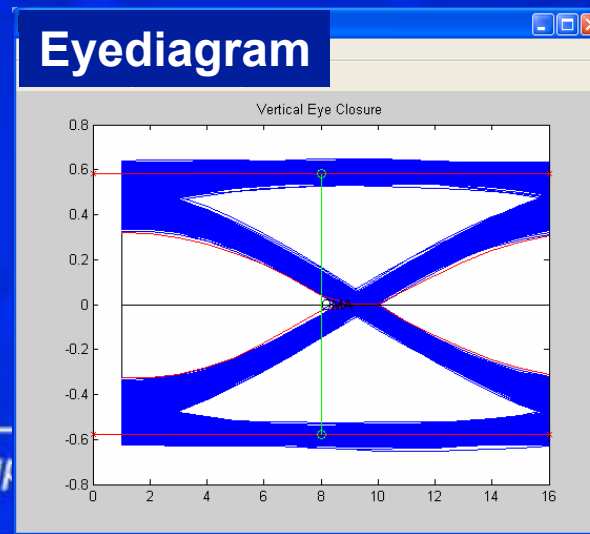
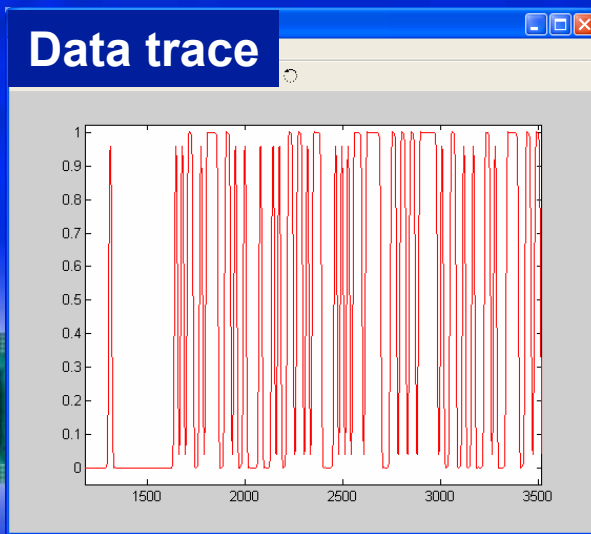
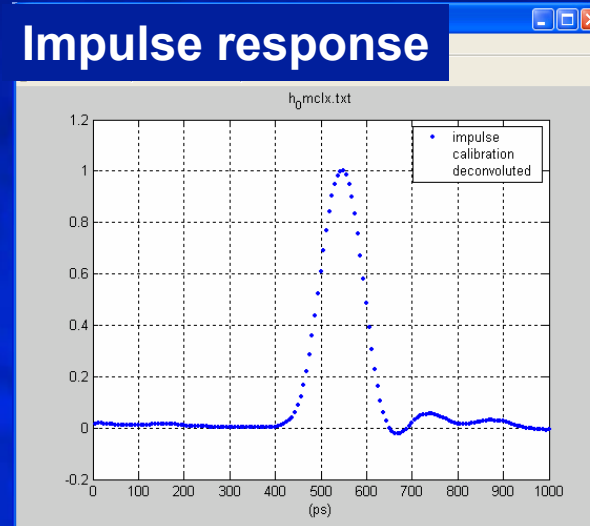
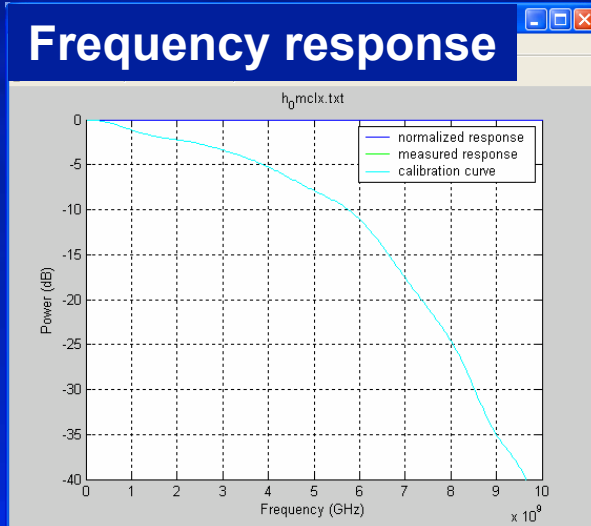
Product: Corning® 62.5/125um
Coating Type: CPC6 (245 um diameter)
Fiber ID 100010518479

Length	[meters]	1759
Attenuation	[dB/km]	2.73/0.57 (850nm/1300nm)
Bandwidth	[MHz*Km]	182/751 (850nm/1300nm)
Core dia.	[um]	61.7
Clad dia.	[um]	125.2
Num. Aperature		0.271

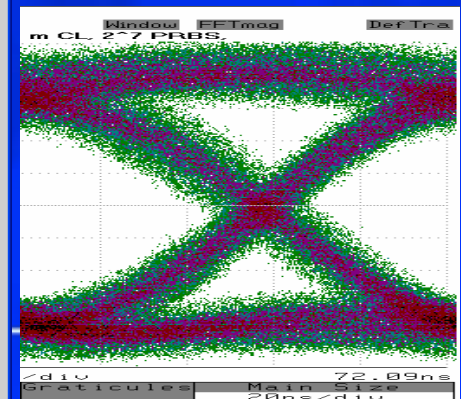


Back to Back - Center Launch (Corning)

- Ideal pulse (used as reference)
- Impulse response file: h_0mCLx.txt

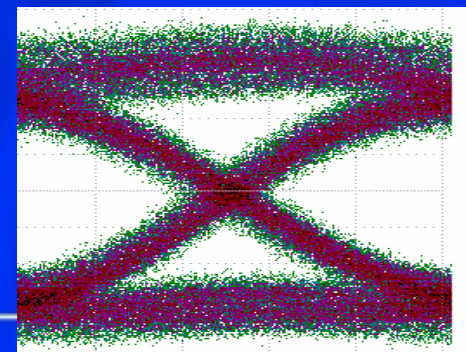
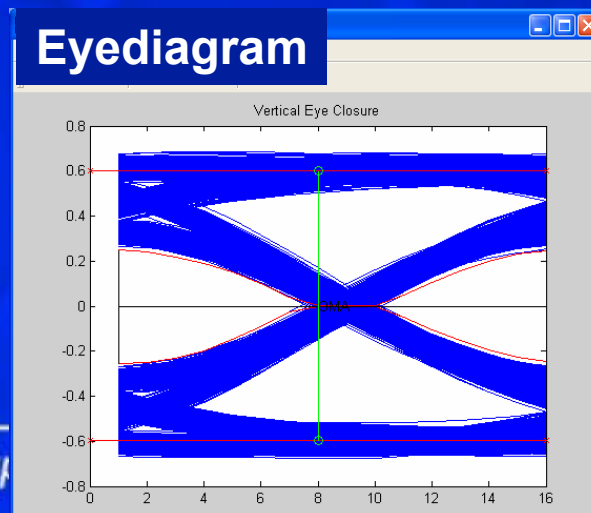
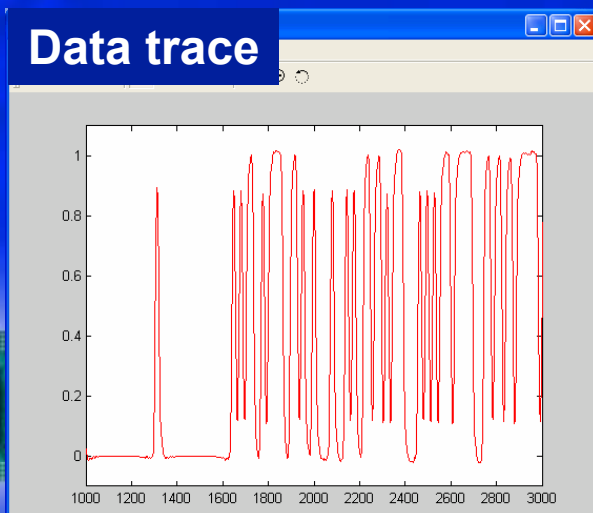
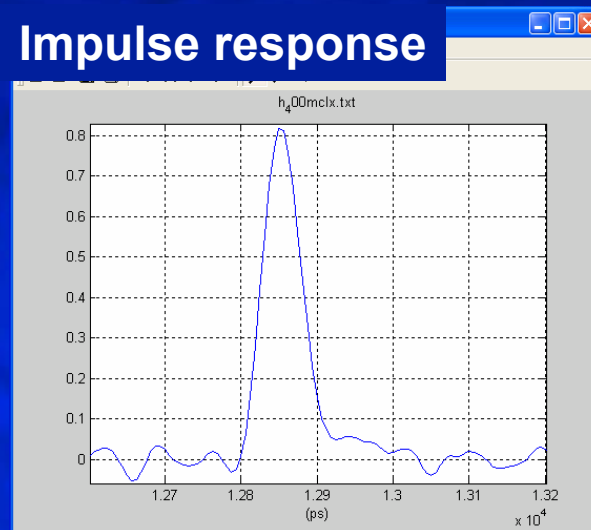
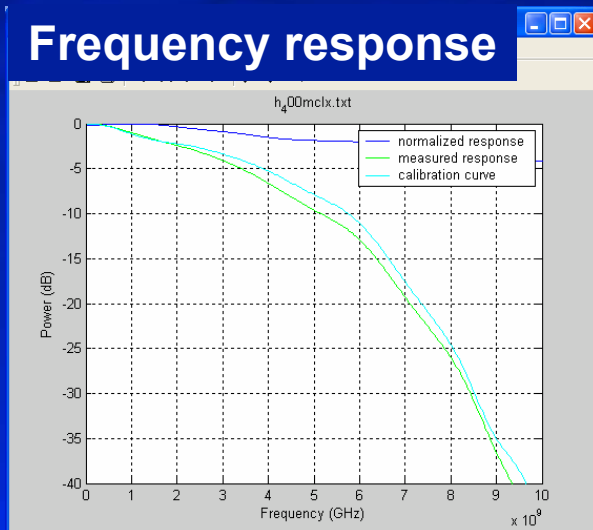


insnr (dBe): 30



Fiber: 400m Center Launch (Corning)

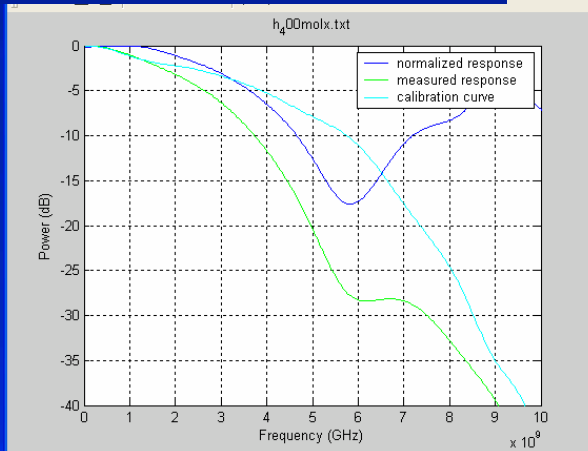
- De-convoluted pulse (0m CL used as reference)
- Impulse response file: h_400mCLx.txt
- Extracted bandwidth of impulse response CL : ~ 5000 MHz*km



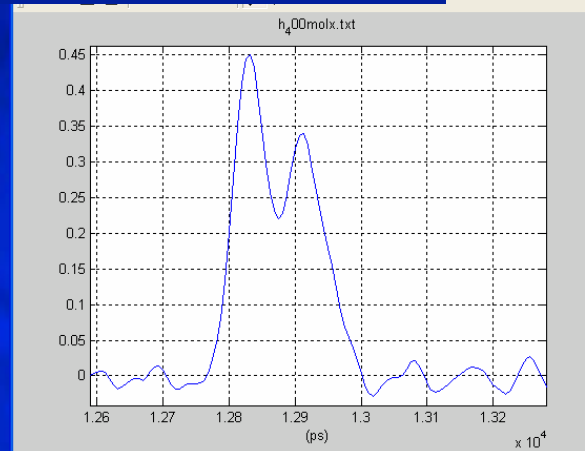
Fiber: 400m Offset Launch

- De-convoluted pulse (0m CL used as reference)
- Impulse response file: h_400mOLx.txt
- Extracted bandwidth of impulse response OL : 1600 MHz*km

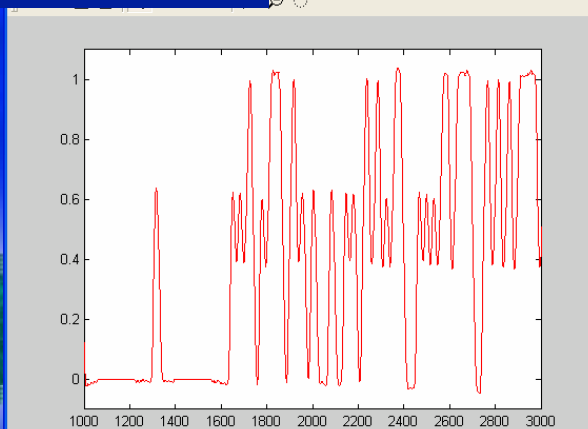
Frequency response



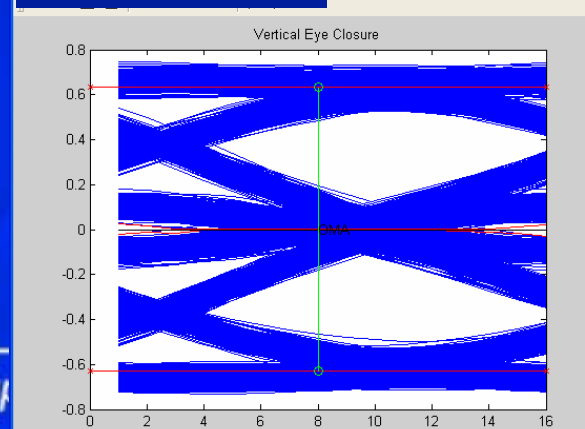
Impulse response



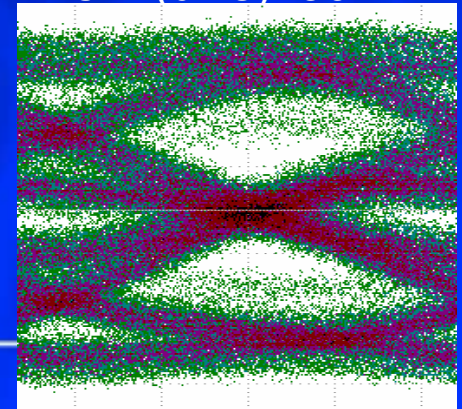
Data trace



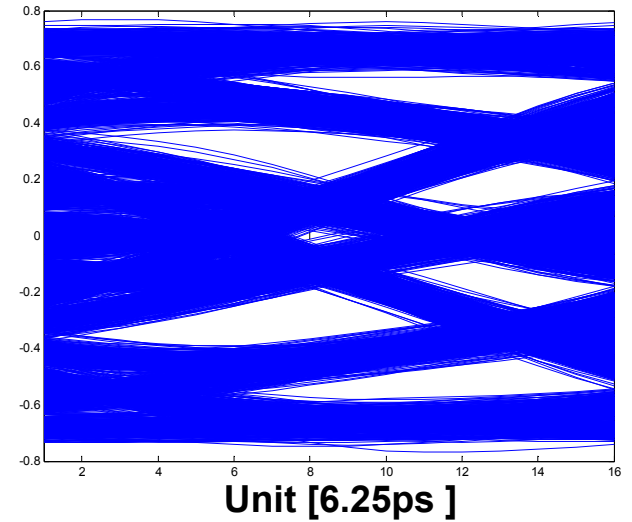
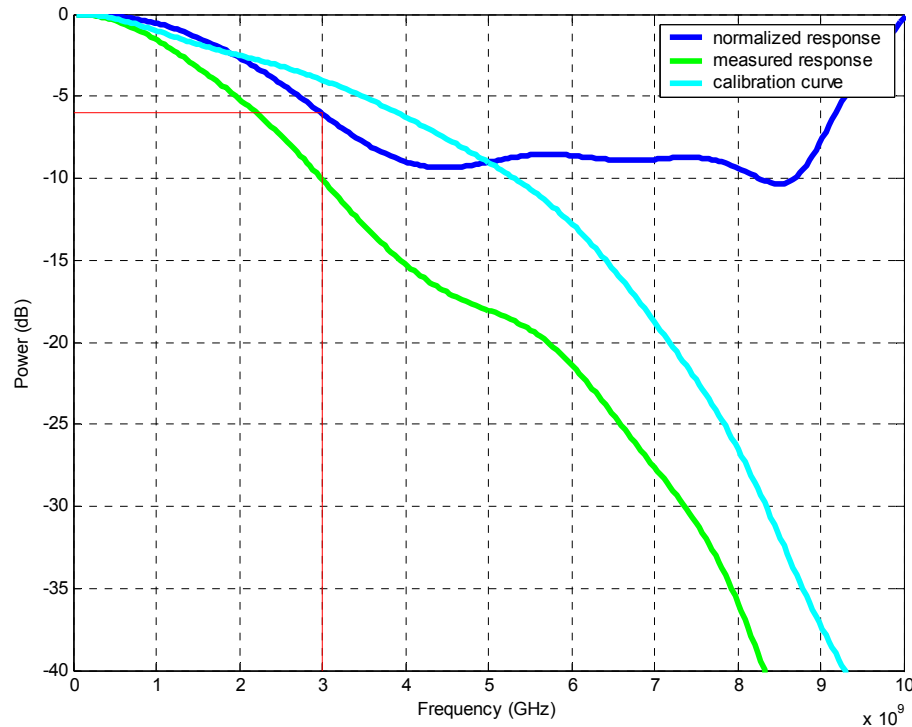
Eyediagram



insnr (dBe): 30



200m Siecor fiber (spool 9+10)



Eye diagram

Frequency response

- Bandwidth of 600 MHz-km obtained from impulse response extracted from bit sequence

