4x100GE through 2 and 10km SMF Using DMT and 1.3μm LAN-WDM EMLs

Winston Way, Trevor Chan, *NeoPhotonics, USA*

NeoPhotonics

Objectives

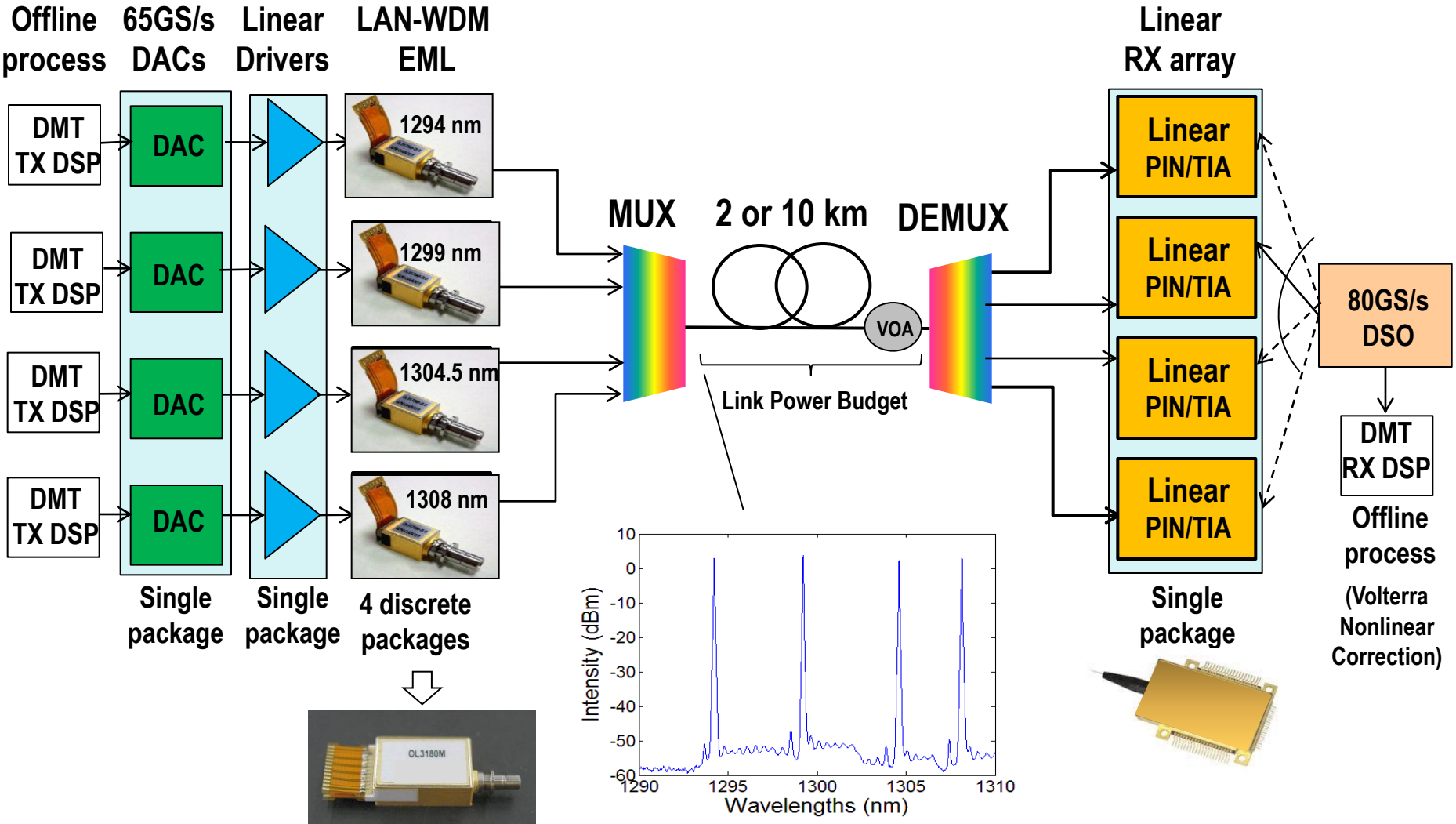
- Study the technical feasibility of using DMT to transport 4x100Gb/s through 2 and 10 km duplex single-mode fibers via four LAN-WDM 1.3μm EMLs
- At BER < 10^{-3}, transmission link power budget for 2 km ≥ 4 dB *(song_x_400_01a_1113)*
- At BER < 10^{-3}, transmission link power budget for 10km ≥ 6.3 dB *(IEEE802.3ba)*
- Power consumption consideration
- Discuss system margin and methods to improve it

DML-based 100Gb/s Experiments by Fujitsu

	λ	Link distance	Link budget w/o WDM	DML output power	DML 3-dB BW	Received optical power	RX 3-dB BW	# sub-carriers	Equalizer
OFC2013 (OM3H.1)	1540 nm	10 km	3 dB	+8 dBm	16 GHz	+5 dBm	22 GHz	4096	Volterra for NLE
Takahara_01a_0113_optx	1310 nm	0.5 km	4.5 dB	+6 dBm	--	+1.5 dBm	--	--	--
Tanaka_01_0113_optx	--	2 km (simulation)	6 dB	+10 dBm	25 GHz	+4 dBm	20 GHz	256 (simulation)	--
Takahara_01a_0313_optx	1310 nm	0.5km	4 dB	+2 dBm	14 GHz	-2 dBm	18 GHz	--	--
ECOC2013 (Th.1.F.3)	1310 nm	2 km	7 dB	+9 dBm	25.8GHz	+ 2dBm	30 GHz	512 (best) ~1024 (worst)	_

- All experiments without WDM mux and demux
- All results with BER slightly below 10^{-3}
- DSP power consumption and latency are proportional to the FFT size, and thus the number of subcarriers

Experimental Setup (I)

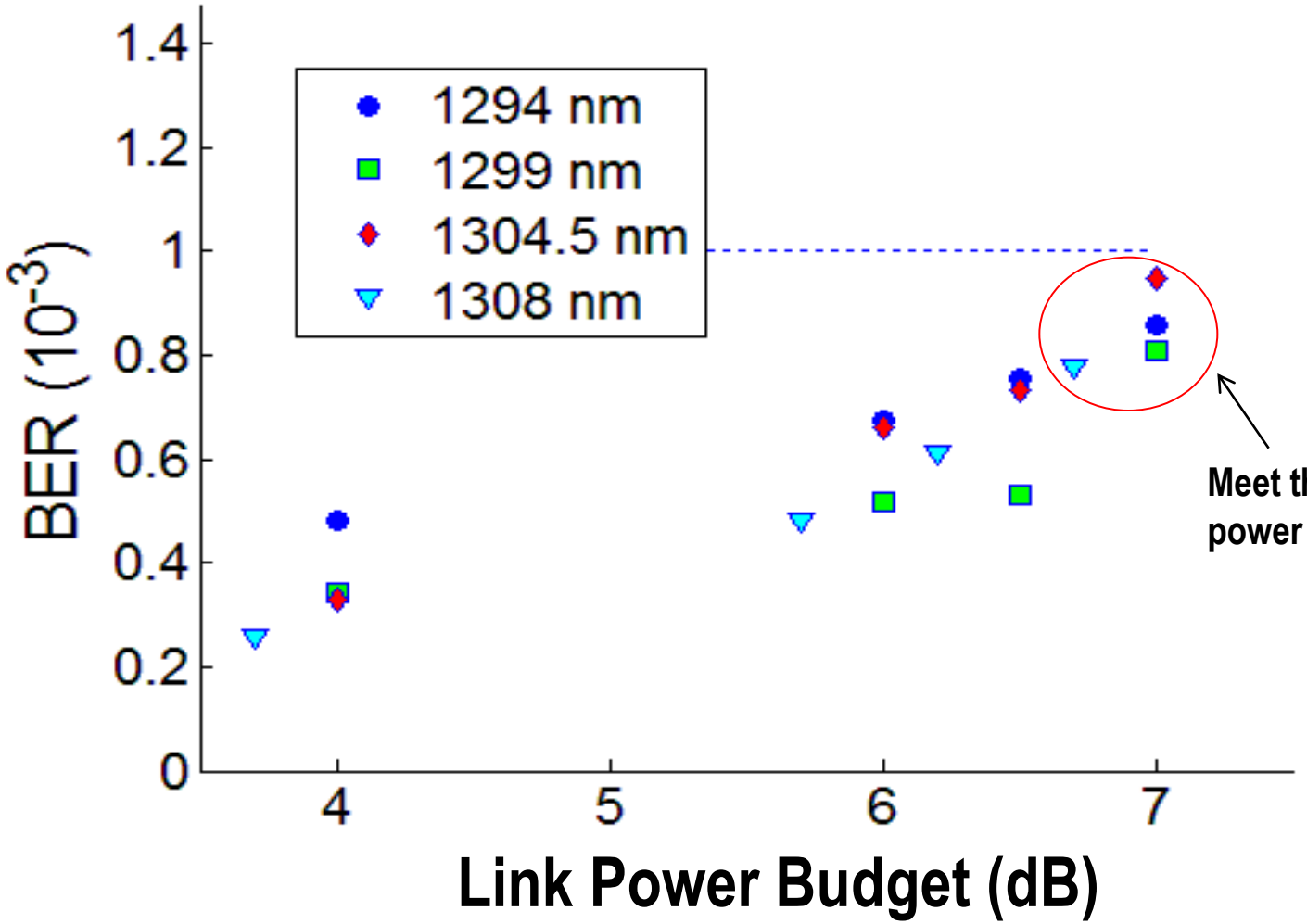


NeoPhotonics

Parameters for the Experiment

Parameters	Values
DAC EVB +linear driver EVB 3dB-bandwidth	13 GHz
DAC sampling rate	64 GSPS
ADC 3dB-bandwidth	25 GHz
ADC sampling rate	80 GSPS
1.3μm EML 3dB-bandwidth	21 GHz
1.3μm EML RIN	< -140 dB/Hz
Linear receiver 3dB-bandwidth	18 GHz
Receiver noise spectral density	40 pA/√Hz (estimated)
Receiver THD	< 5% (estimated)
Number of subcarriers	176
Total data rate	106 Gb/s
Net data rate	100.5 Gb/s

400Gb/s through 10km SMF



NeoPhotonics

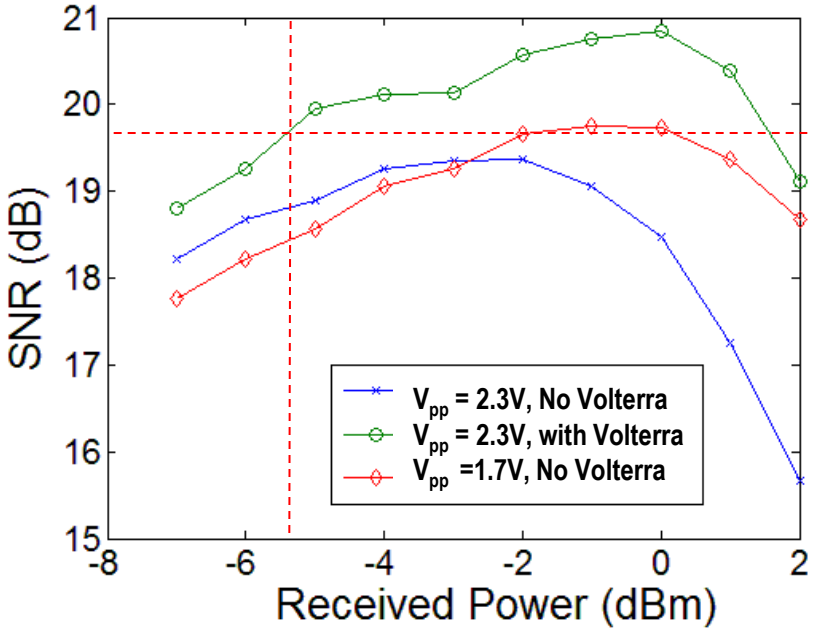
Measured Link Power Budget for each λ

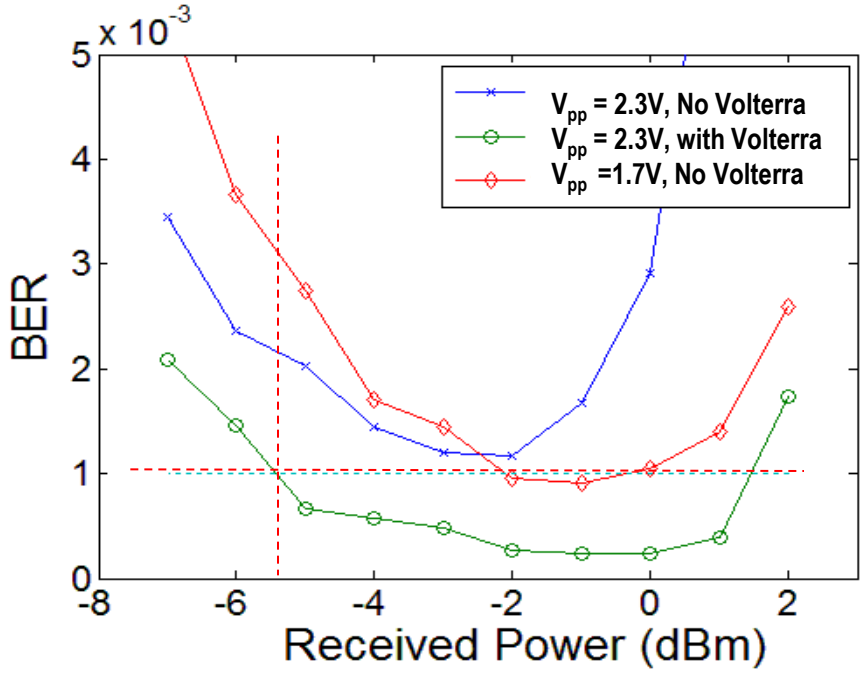
Wavelength (nm)	TX Power (dBm)	WDM Mux Loss (dB)	Link Power Budget (dB)	WDM Demux loss (dB)	Rx Power (dBm)
1294	4.9	1.45	6.96	1.04	-4.6
1299	5.5	1.66	6.98	0.83	-4.0
1304.5	5.0	1.66	6.95	1.31	-4.9
1308	5.9	2.22	6.71	1.01	-4.0

Optical fiber loss
+ VOA loss

SNR & BER versus Receive Optical Power

With and without Volterra nonlinear correction @ 1304.5 nm

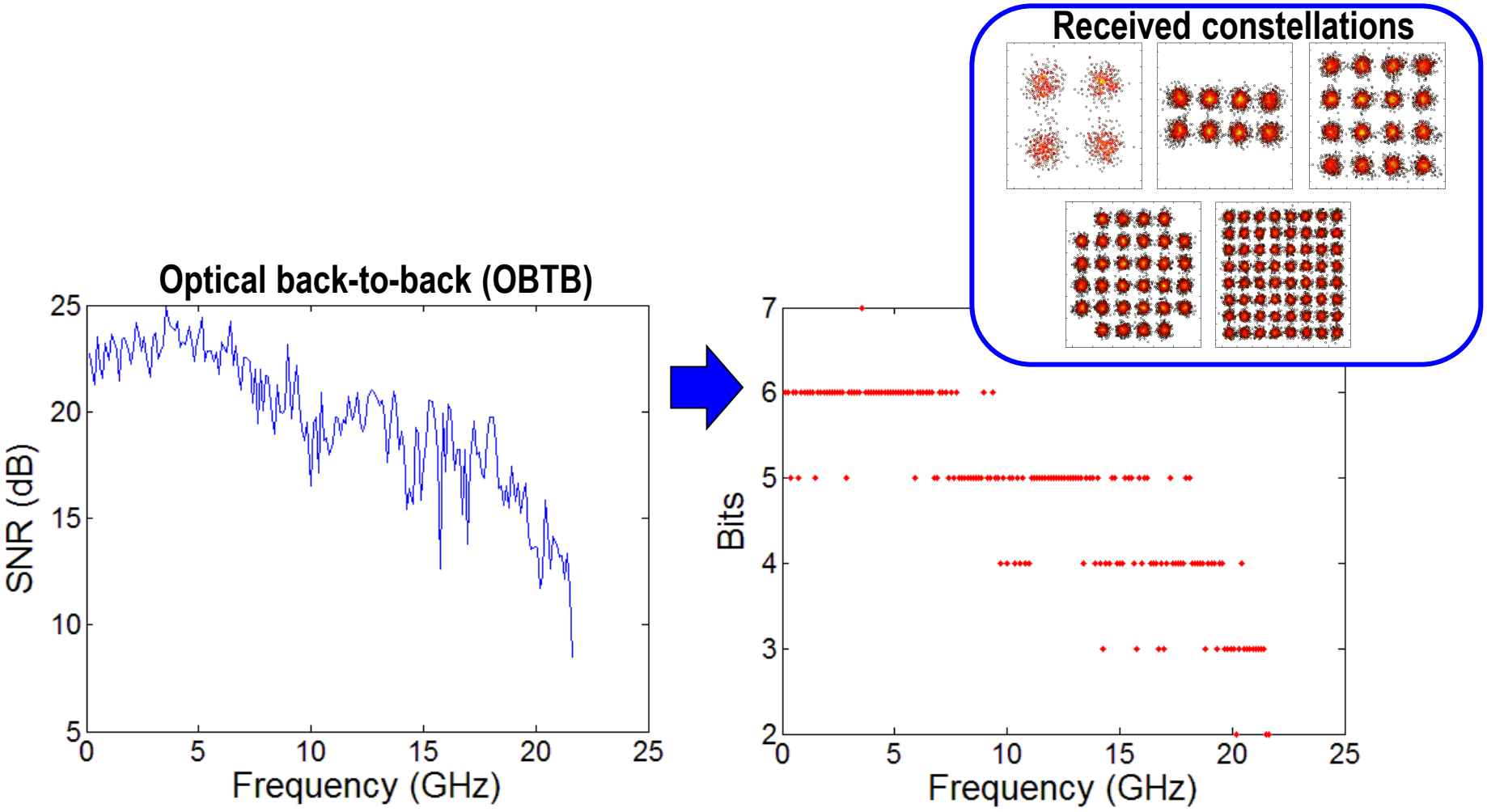




Volterra kernels: order =3, memory depth = 4

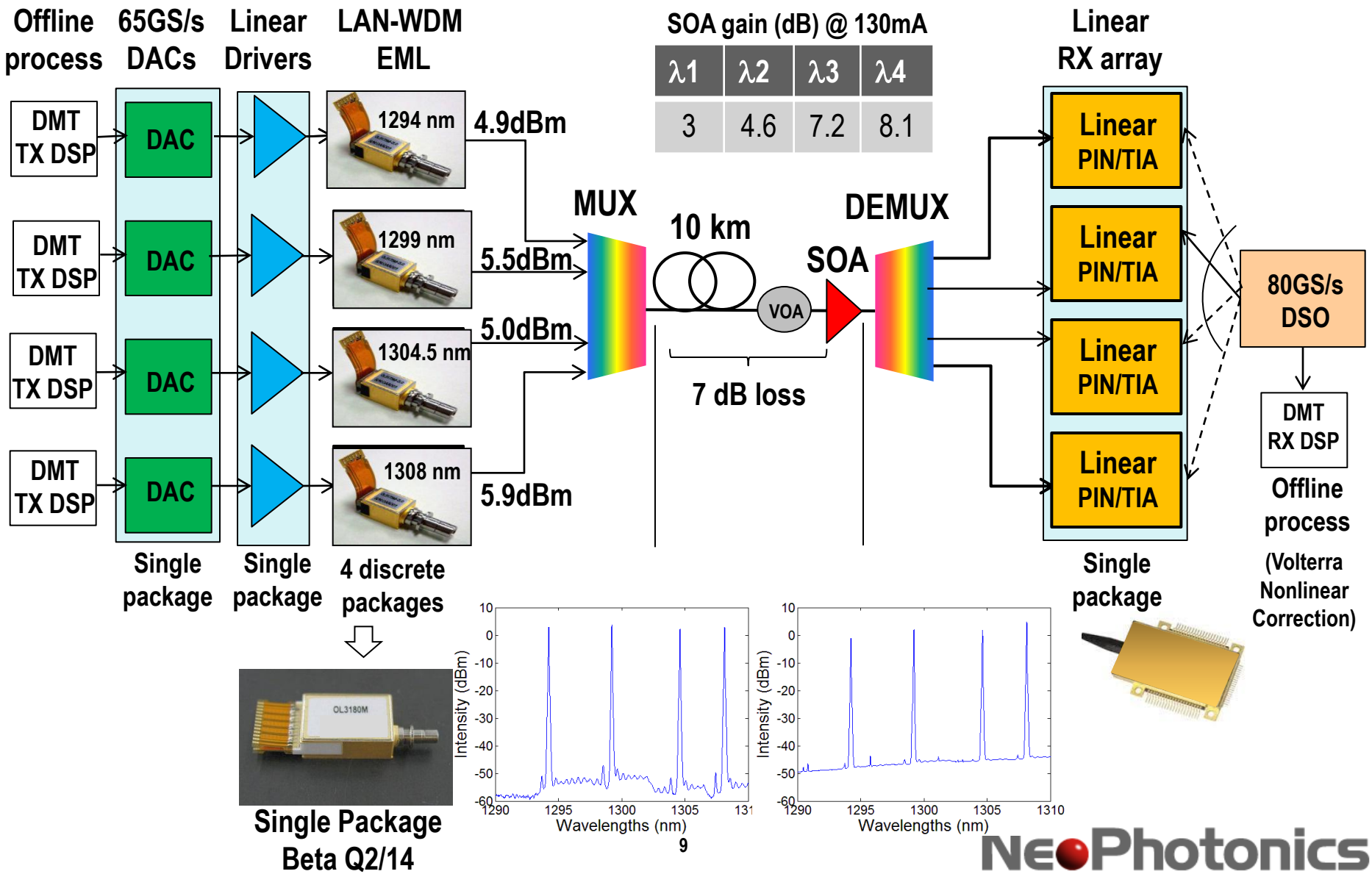
NeoPhotonics

1294 nm Optimum Bit Loading



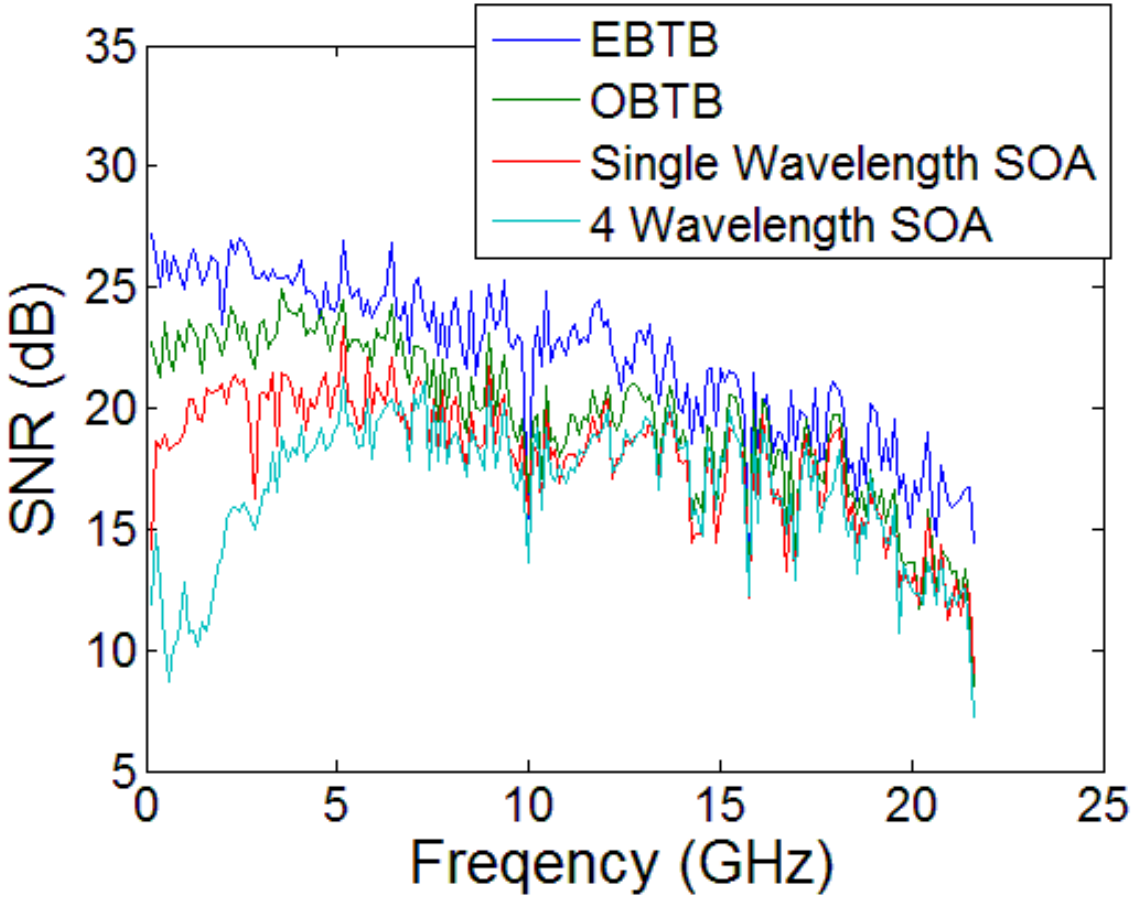
NeoPhotonics

Experimental Setup (II)



NeoPhotonics

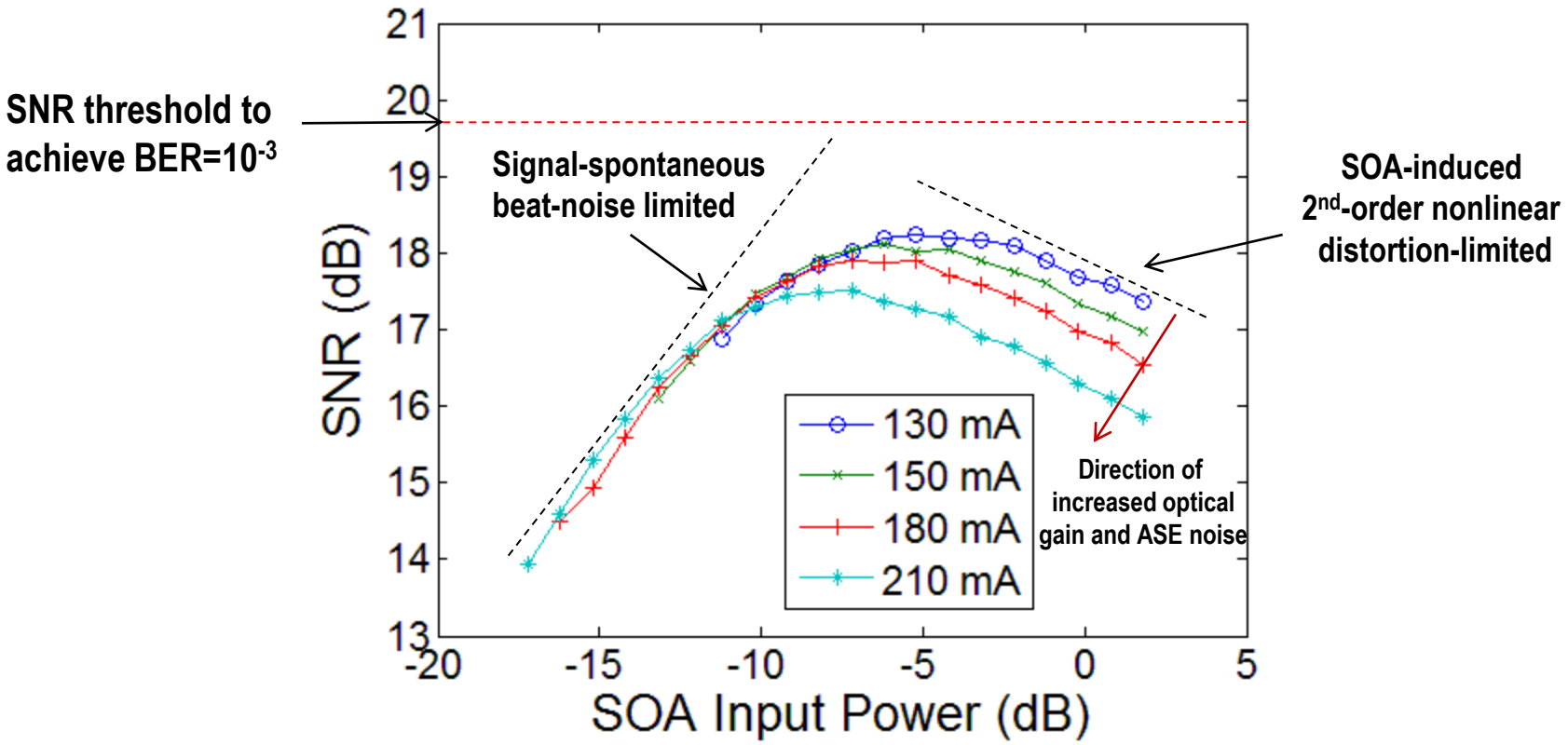
SNR as a function of Frequency



The addition of SOA presents significant SNR penalty

NeoPhotonics

Single-λ SNR vs SOA input Power



When all 4 λ's are present, cross-gain modulation pulls down the peak SNR by another ~2 dB

NeoPhotonics

Power Consumption Consideration

- Total 400GE power consumption can be lower than 24W
  (4xEML: 2W, 4xlinear receiver: 1W, 4xlinear driver: 4W,
  4x100Gbps DMT chip power < 3.5Wx4 using 28nm CMOS*)
- Difficult to enable breakout into 4 of 100GE QSFP28 module, which only allows a total of 3.5W per module.

* Bower_400_01_0114

Summary

- **4x100GE can be carried by 4x 1.3μm LAN-WDM EMLs through 2km with a comfortable link budget margin.**
- **Although we demonstrated that 4x 1.3μm LAN-WDM EMLs through 10km can meet the required ≥ 6.3dB link power budget, the system margin is small to allow device variations and aging**
  - MPI–induced RIN > -140dB/Hz can further reduce the system margin
- **Methods to improve 10km system margin:**
  - Next-gen DAC with a higher ENOB and analog bandwidth
  - Improved receiver sensitivity by using a higher-bandwidth TIA with a spectral noise density < 20 pA/√Hz and a low THD
- **SOA-induced cross-gain modulation, second-order intermodulations among subcarriers, and signal-spontaneous noise combined to limit four LAN-WDM DMT wavelengths to reach 10 or 40km transmission distance**