2 km SMF 400 Gb/s live traffic results using DMT test chips

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Summary

- Presenting live optical DMT transmission results showing 400Gb/s on LAN-WDM wavelengths using a single LR4 TOSA, four 28nm CMOS DMT Test-Chips, and linear receivers.

- Demonstrating the feasibility of using DMT modulation format for 400GE using 4 wavelengths each carrying 100Gb/s over 2km.

- Performance demonstrated, is inline with baseline proposal of lewis_3bs_01a_1114.

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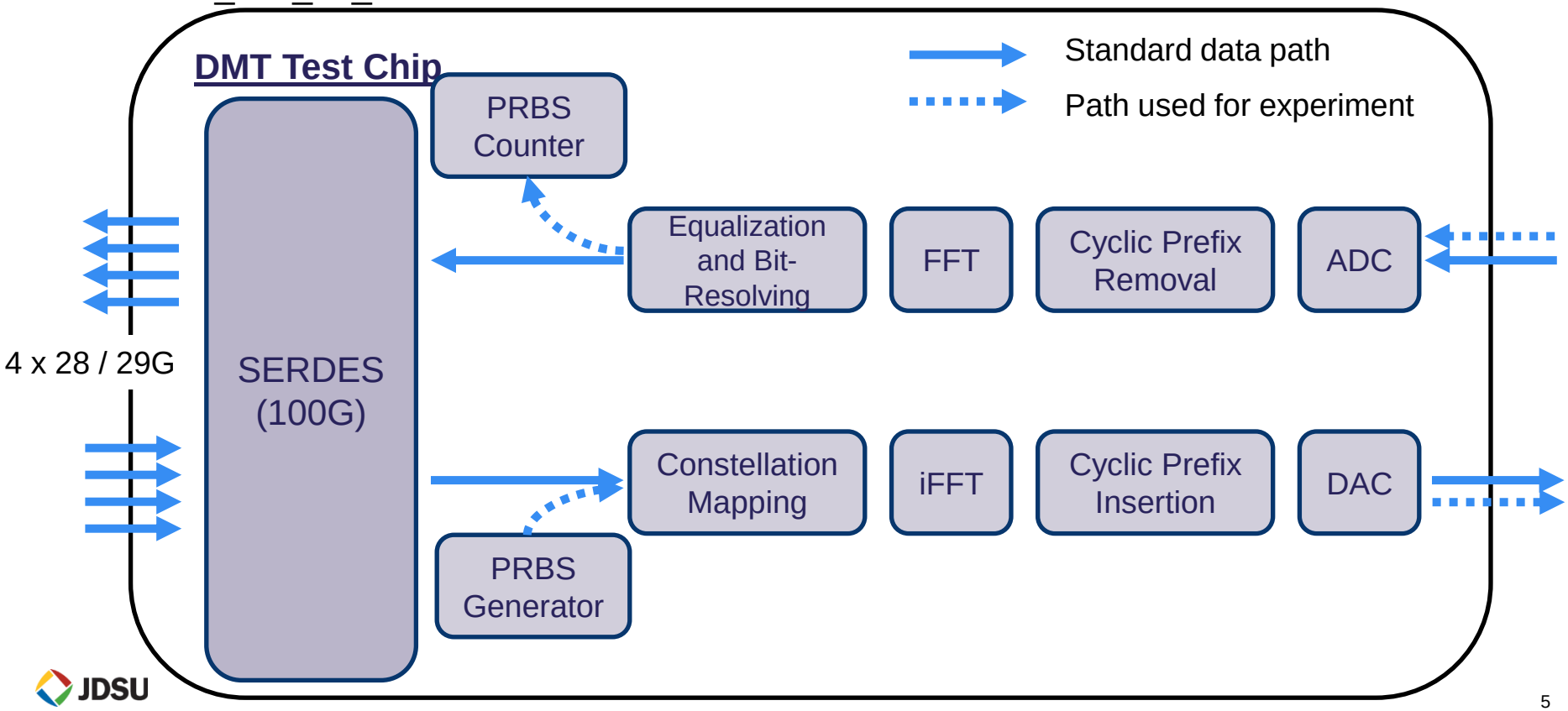
100 Gb/s Parameter Table

- A DMT test-chip incorporating the following features was used:
  - D/A and A/D sampling rates tied to bit-rate: simplifies DSP clocking architecture
  - SerDes of 4 x 28G lanes
  - DMT Engine mapping bits to QAM constellations on 256 subcarriers
  - DMT-Symbol frame-synchronization using 2 dedicated adjacent subcarrier tones
  - Implementation of CP of length 16, 32, 48 or 64 samples

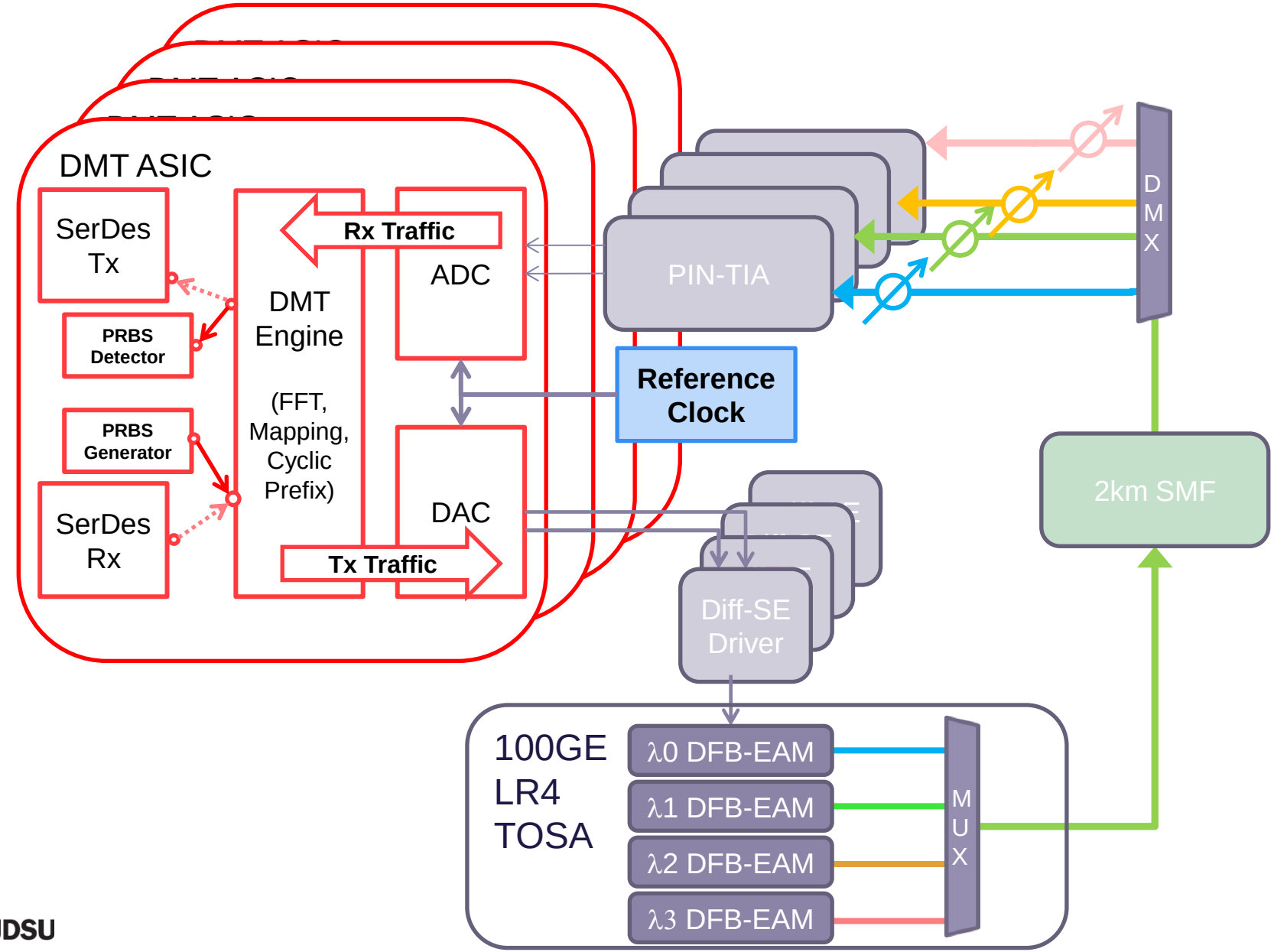
Parameter	Value
Data Rate	116 Gb/s
Sampling Rate	58 GS/s
Cyclic Prefix	16 samples
Clipping Ratio	3.16
DAC Bandwidth	14.5 GHz
ADC Bandwidth	19.3 GHz
FEC Overhead	12.5%
FEC input BER for output BER = 1e-15	3.3e-3 (9K BCH)

DMT Test Chip Architecture

- For this demonstration, four test-chips were configured in loopback operation, using the internal PRBS Generator / Counter.
- Frame-synchronization successfully achieved, using 2 dedicated adjacent subcarriers at 7.36 and 7.47GHz for this purpose.
- Link-negotiation was performed with external software control, for bit and power allocation and subcarrier equalization. Details in lewis_3bs_01a_1114
- This functionality to be moved to on-chip firmware in future. Details to be provided in corbeil_3bs_01_0115

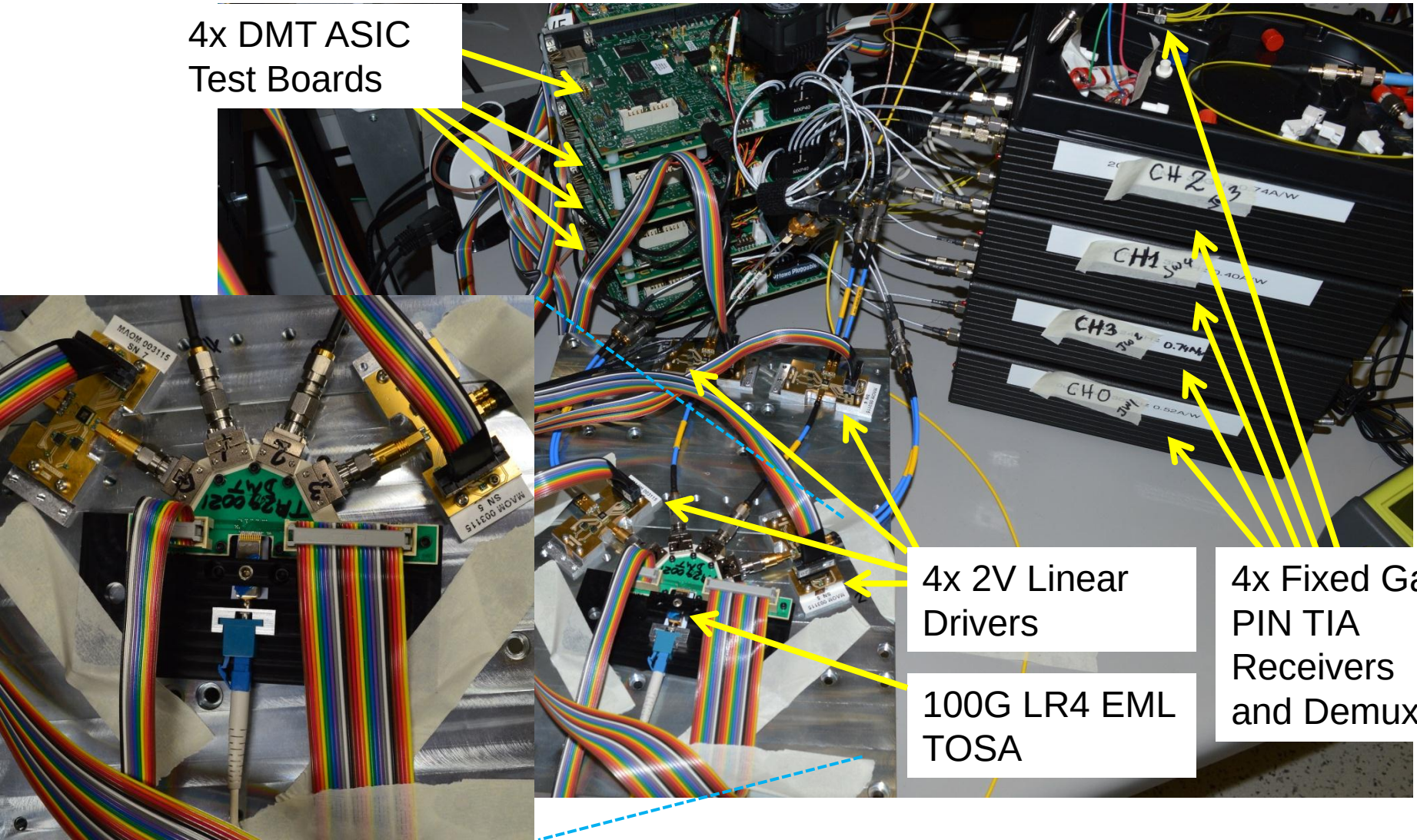


400GE DMT Traffic Configuration with Quad EML Transmitter



400G DMT Test Bed

- Picture below shows the 400G DMT test bed.
- Picture on left, zooms in on the 100G LR4 TOSA



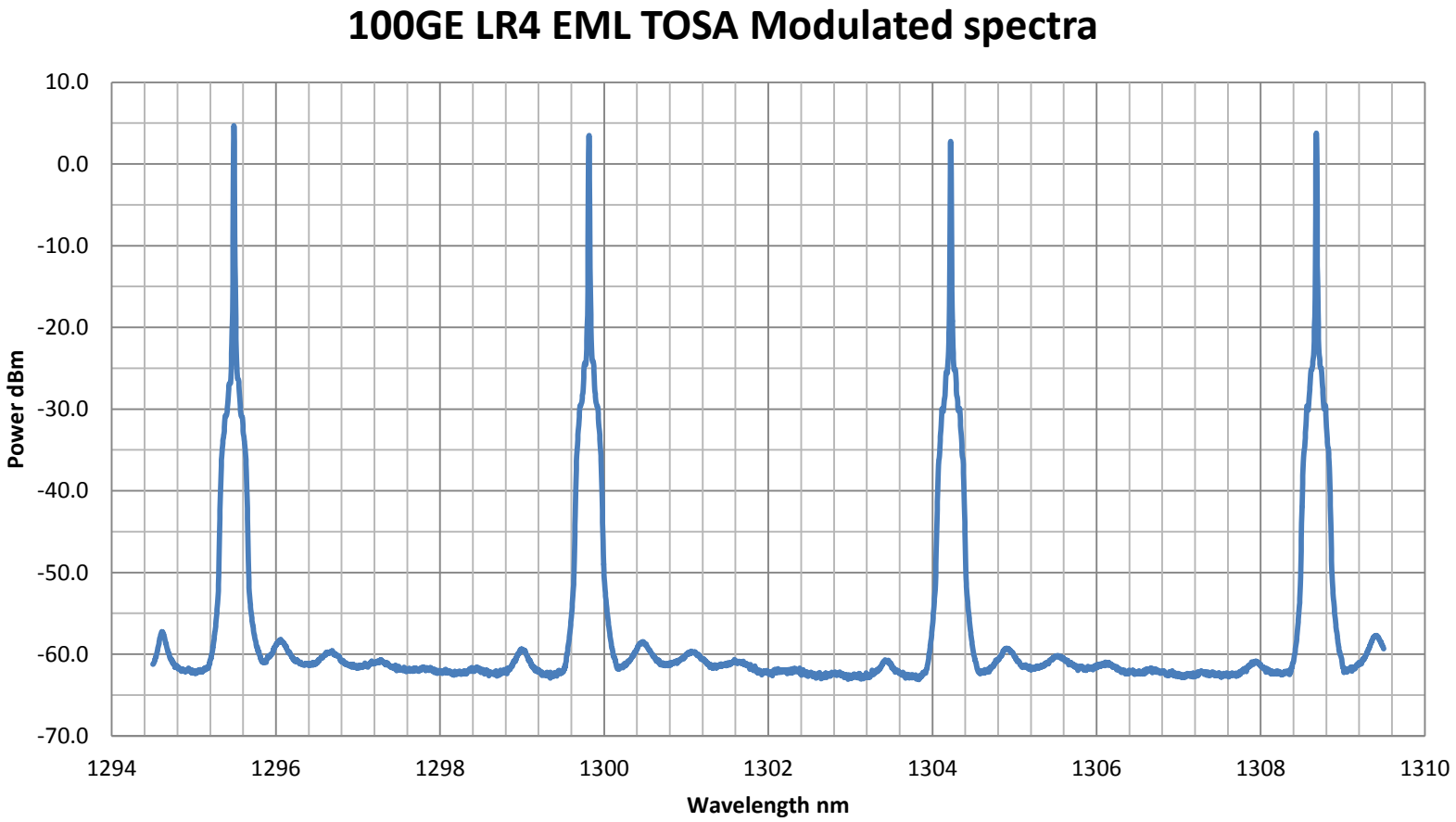
Optical Component: Tx

- Transmitter was an off the shelf 100G LR4 TOSA with integrated WDM and four EMLs
  - Typical bandwidth on all 4 Channels 26GHz
  - Using a MACOM differential input single-ended output linear driver, THD <5%.
  - Driver contains integrated broadband bias-tee for EAM reverse bias
  - EML driven to optimize RIN and DMT performance

CH	λ nm	RIN dB/Hz	Pout	Vmod	ER@2GHz
0	1295.5	-146.5	+4.9dBm	2.1Vpp	7.3dB
1	1299.8	-144.0	+3.8dBm	2.0Vpp	8.5dB
2	1304.2	-145.5	+2.8dBm	2.1Vpp	10dB
3	1308.7	-146.8	+3.8dBm	2.0Vpp	8.5dB

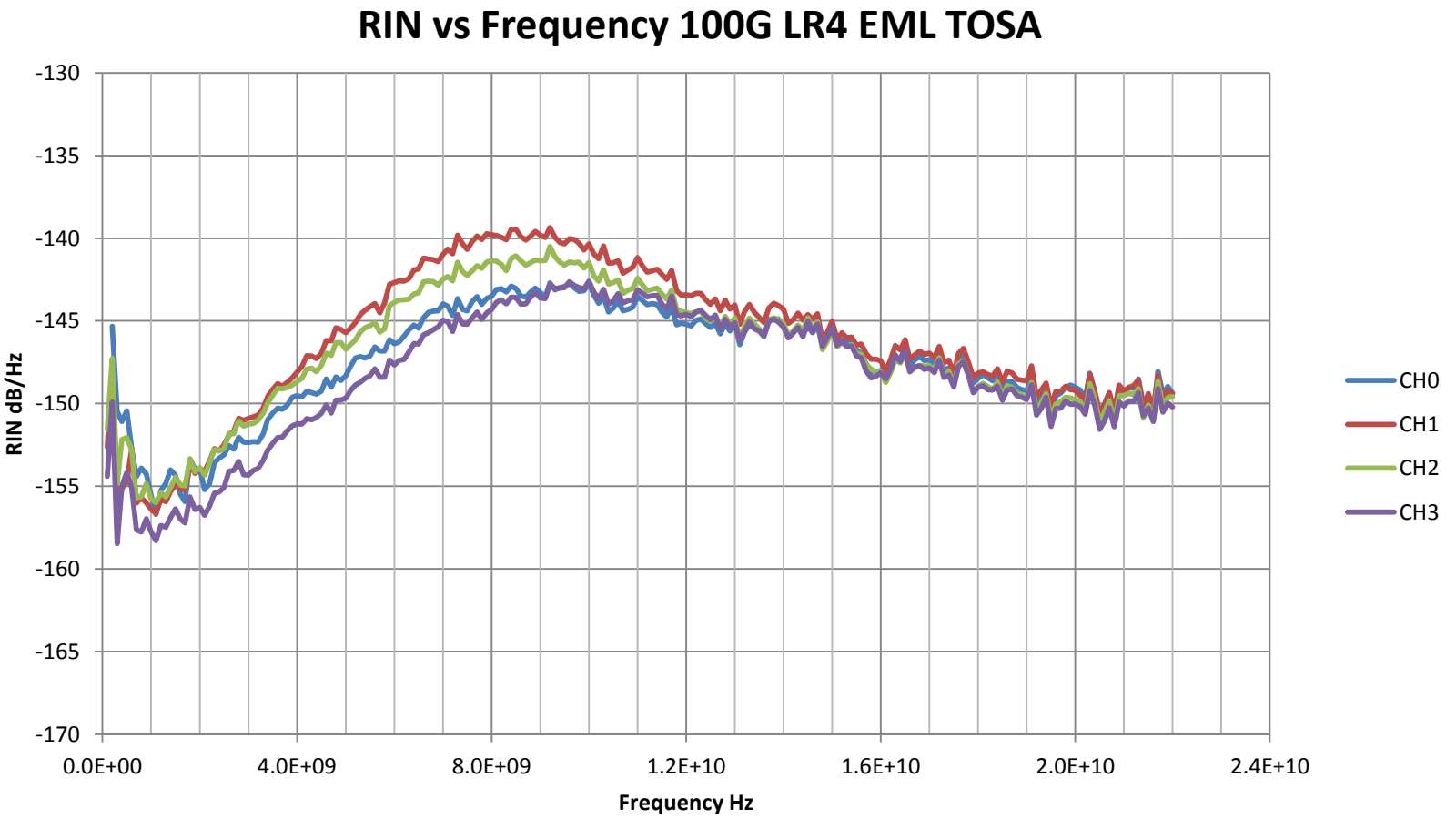
Optical Component: Tx Modulated Wavelength

- Peak Wavelengths
  - CH0: 1295.550nm
  - CH1: 1299.870nm
  - CH2: 1304.280nm
  - CH3: 1308.735nm



Optical Component: Tx RIN

- Integrated RIN:
  - CH0: -146.5dB/Hz CH1: -144dB/Hz
  - CH2: -145.5dB/Hz CH3: -146.8dB/Hz
- 0.75 to 1.0dB improvement in performance could be attained with 5dB lower RIN peak and integrated RIN.



Optical Component: Rx

- Prior to the receiver was a Cube Optics LAN-WDM 4 Ch. demux

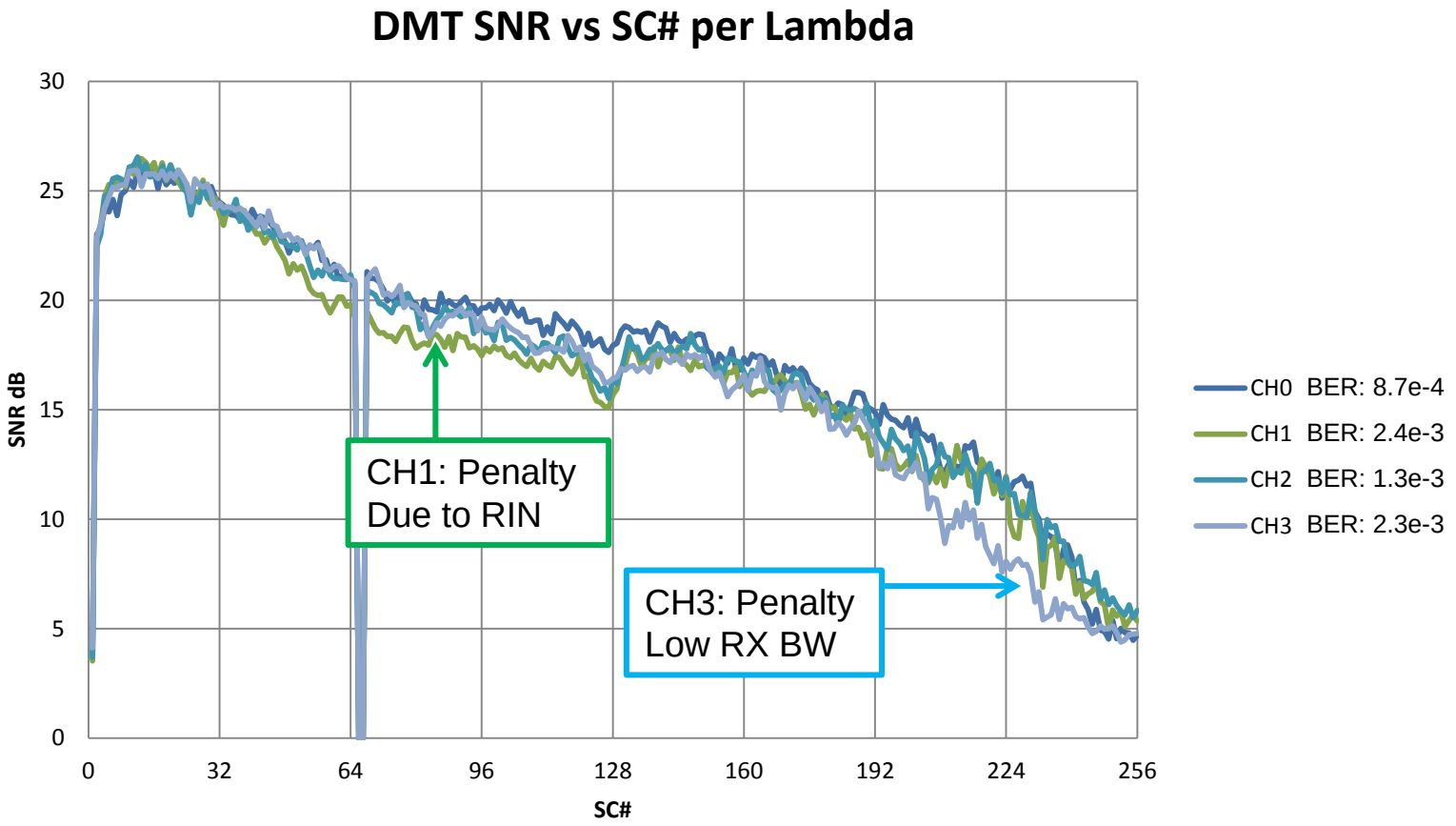
CH	WL	IL.
0	1295.56nm	1.0dB
1	1300.05nm	0.9dB
2	1304.58nm	0.9dB
3	1309.14nm	0.6dB

- Receivers consisted of Discovery R409 linear differential PIN-TIA, fixed gain, where one of the 4 receivers was of reduced bandwidth and also had higher noise.
- Since the transimpedance gain is fixed at ~500Ω each receiver's input power is optimized using an optical attenuator.

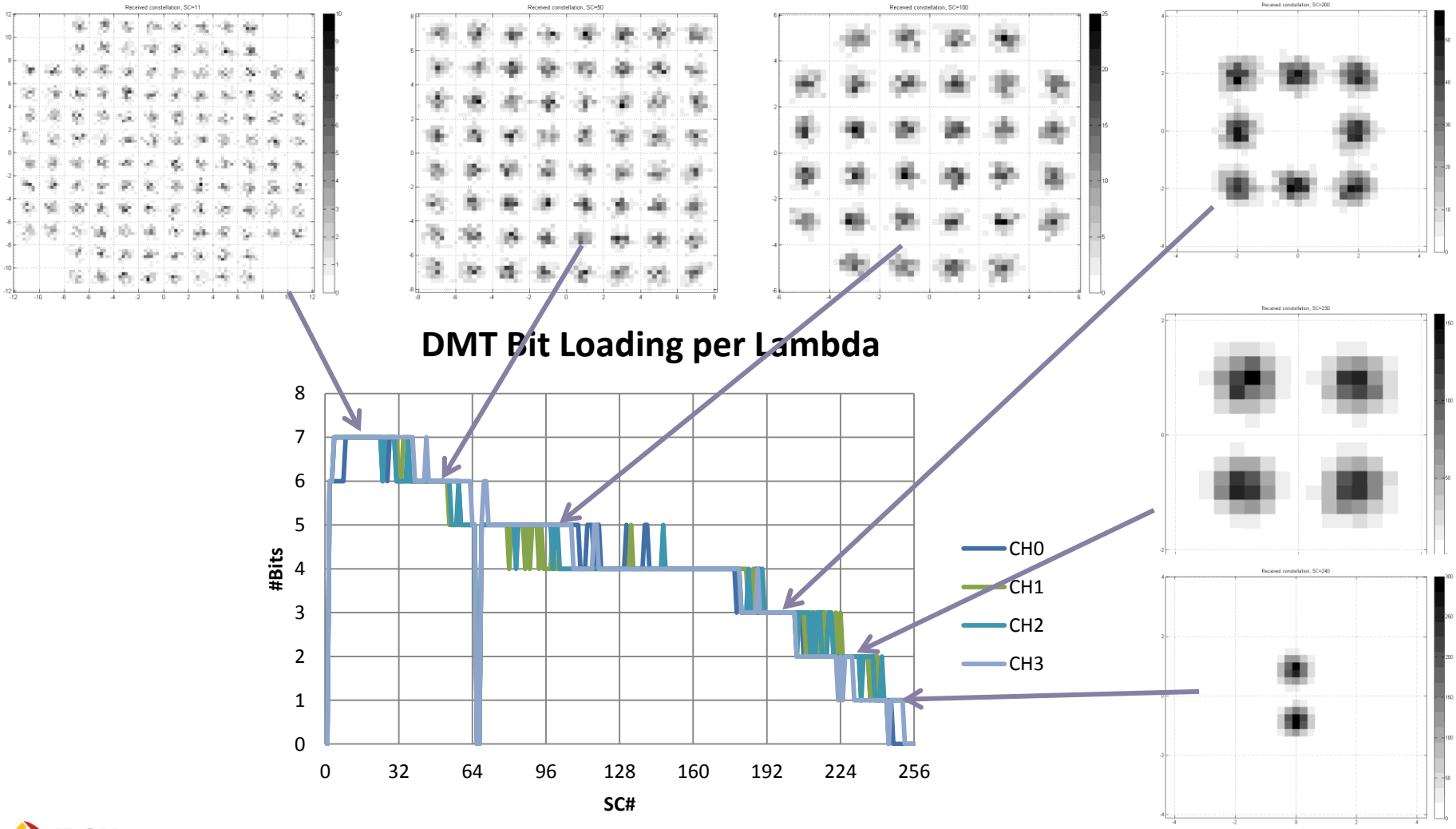
CH	Resp.	BW	IRN	Att dB	Pin dBm
0	0.52A/W	29.0GHz	23pA/√Hz	2.0dB	+0.95dB
1	0.4A/W	29.5GHz	23pA/√Hz	1.0dB	+1.50dB
2	0.74A/W	30.0GHz	23pA/√Hz	3.0dB	-1.90dB
3	0.72A/W	23.5GHz	30pA/√Hz	4.0dB	-1.20dB

SNR vs Subcarrier

- Channel with highest RIN shows lowest SNR near its RIN peak
- Channel with low bandwidth receiver shows degradation in SNR at highest SC#

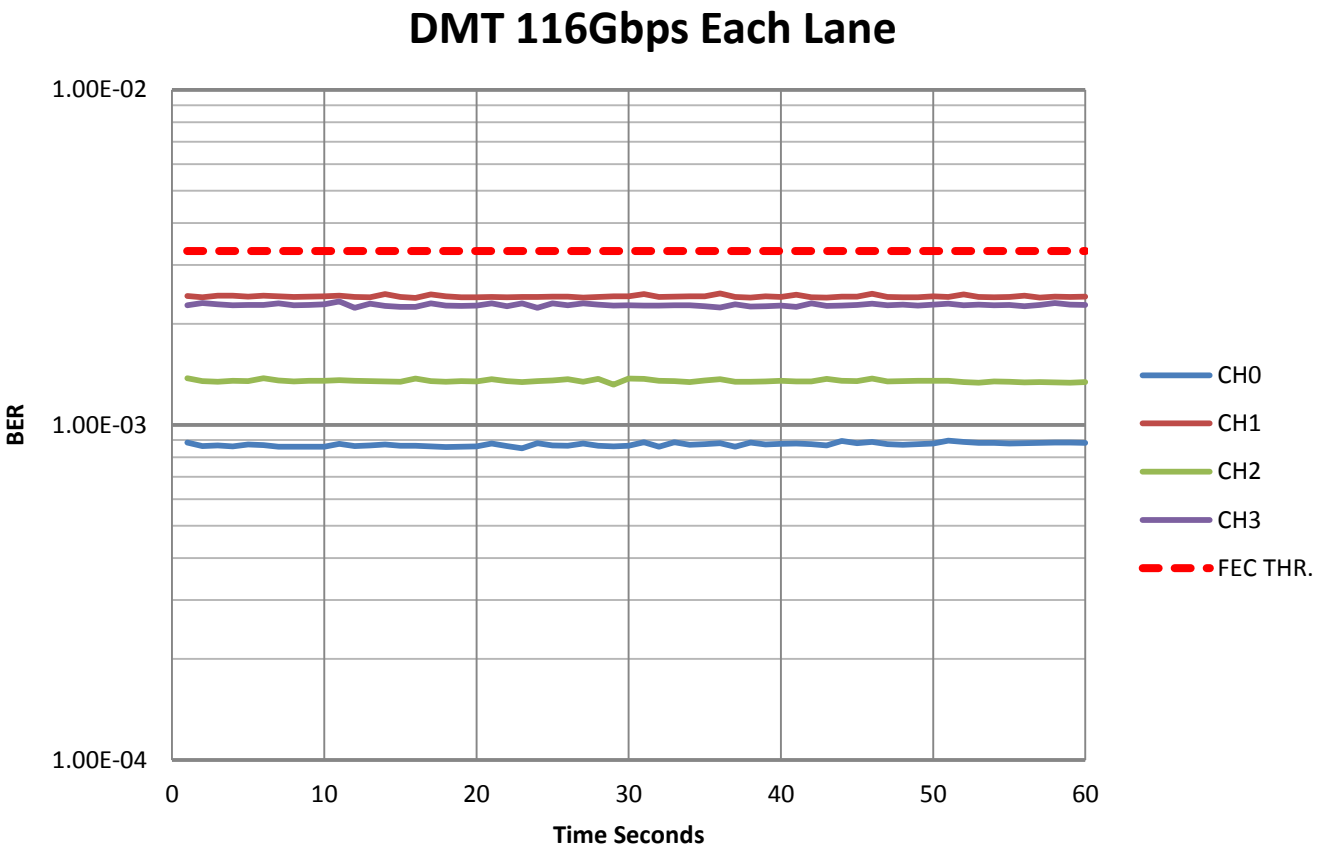


Bit Loading vs Subcarrier#



BER RESULTS

- Optical Traffic was run continuously over 2km of fiber
- Traffic (PRBS-31) is stable over 60 seconds.
  - BER integrated over 1 second.



Conclusion

- First successful live traffic demonstration of 400 Gb/s using DMT protocol and a 100G LR4 EML TOSA over 2km of fiber.
- Experiments were run using 4 functional DMT transceiver chip sets in 28nm CMOS
- Measured BER over 2km SMF-28 is stable and below the BCH FEC threshold
- Initial results limited by the capability of the available optical components
- These results confirm the feasibility of using DMT modulation format for 400GE transmission using 4 LAN-WDM wavelengths each carrying 100Gb/s.