



**2 km SMF 400 Gb/s live traffic results
using DMT test chips
Michael Vitic, David Lewis, Sacha Corbeil**

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.

Contributors and Supporters

- David Lewis JDSU
- Michael Vitic JDSU
- Sacha Corbeil JDSU
- Beck Mason JDSU
- Ian Dedic Fujitsu Semiconductor Europe
- Markus Weber Fujitsu Semiconductor Europe
- Patricia Bower Fujitsu Semiconductor Europe
- Vikas Manan MACOM
- Ray Moroney MACOM
- YK Park OE Solutions
- Moonsoo Park OE Solutions
- Bongsin Kwark OE Solutions
- Abhay Joshi Discovery Semiconductor

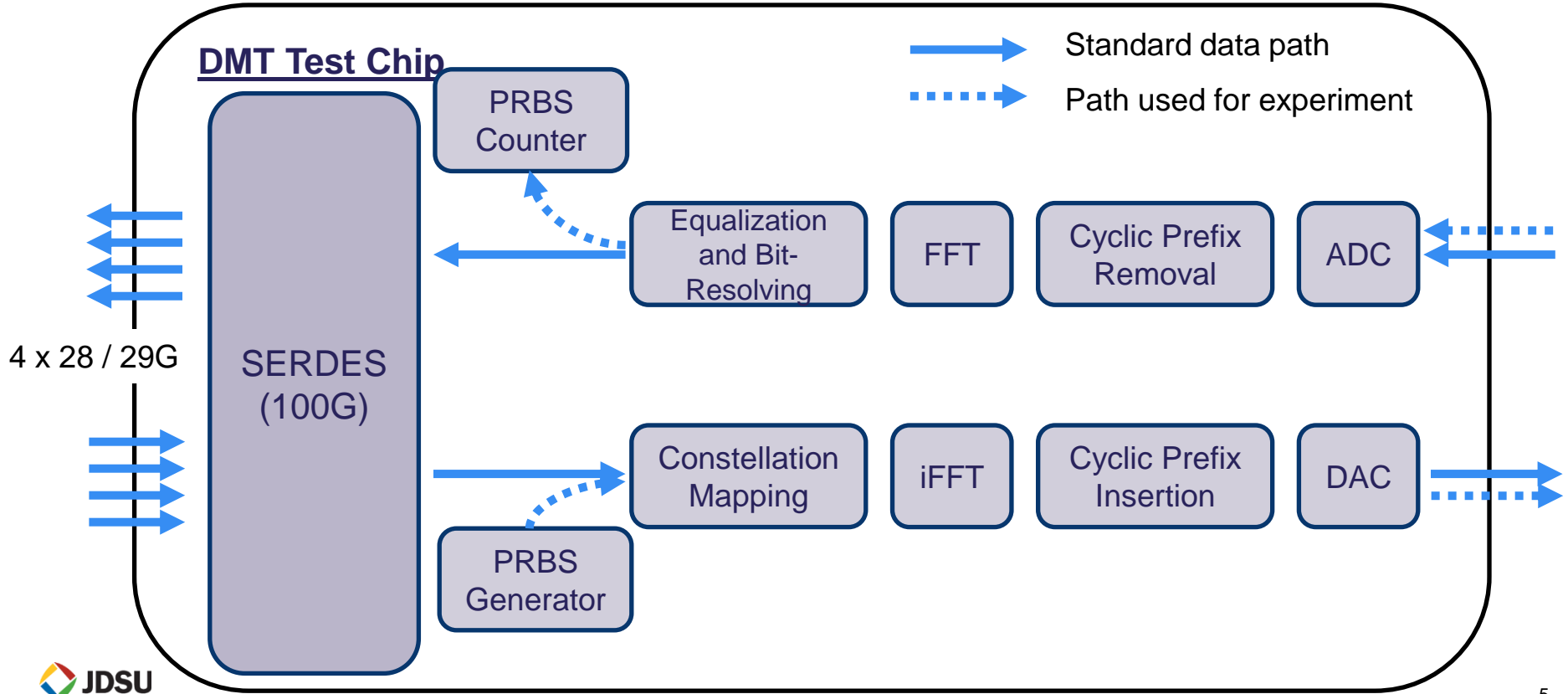
100 Gb/s Parameter Table

- 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

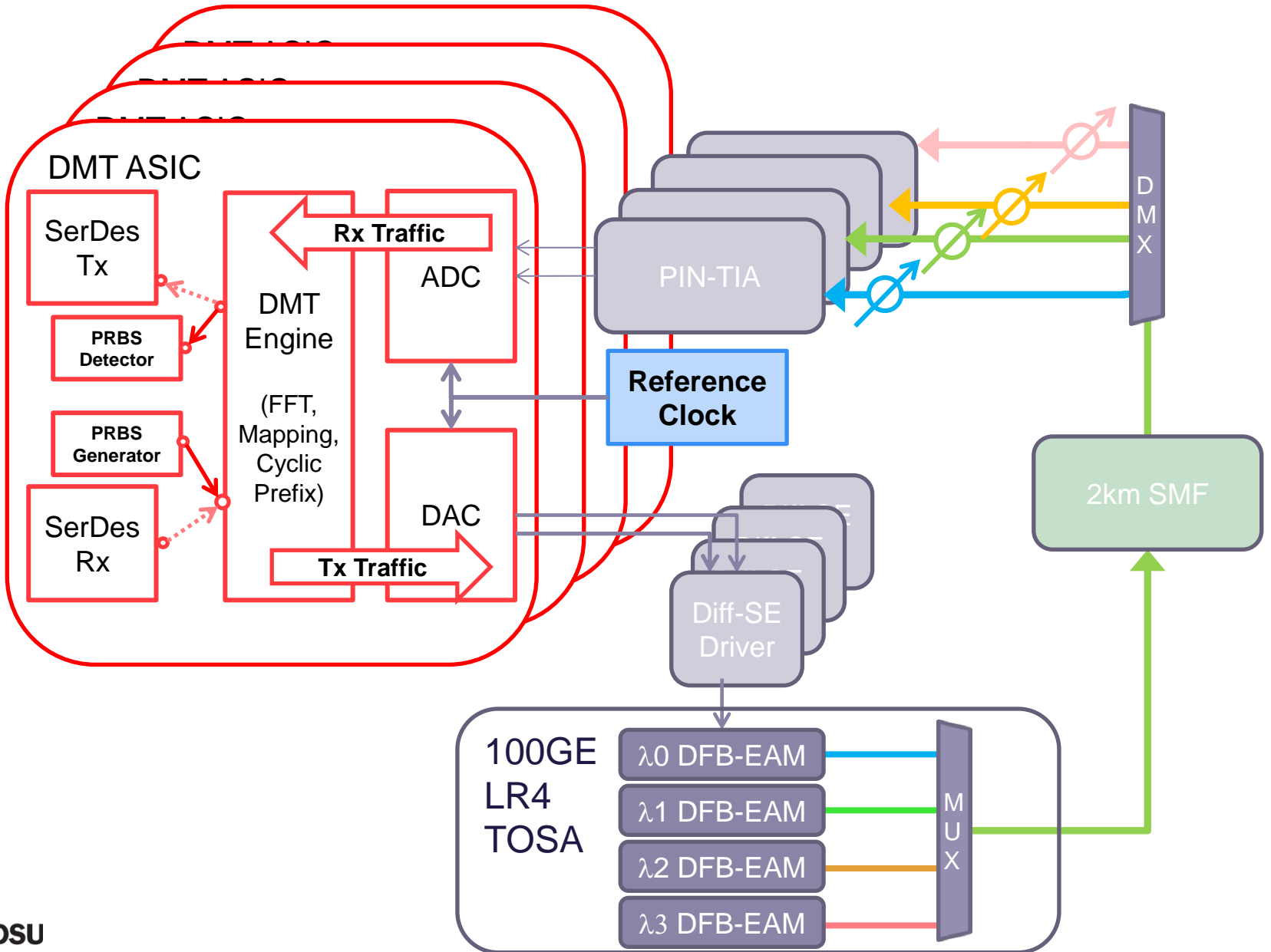
Parameter	Value
Data Rate	116 Gb/s
Sampling Rate	58 GS/s
Cyclic Prefix	16 samples
Clipping Ratio	3.16
DAC Bandwidth	14.5 GHz
ADC Bandwidth	19.3 GHz
FEC Overhead	12.5%
FEC input BER for output BER = 1e-15	3.3e-3 (9K BCH)

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_01_0514
- This functionality to be moved to on-chip firmware in future. Details to be provided in corbeil_3bs_01_0115



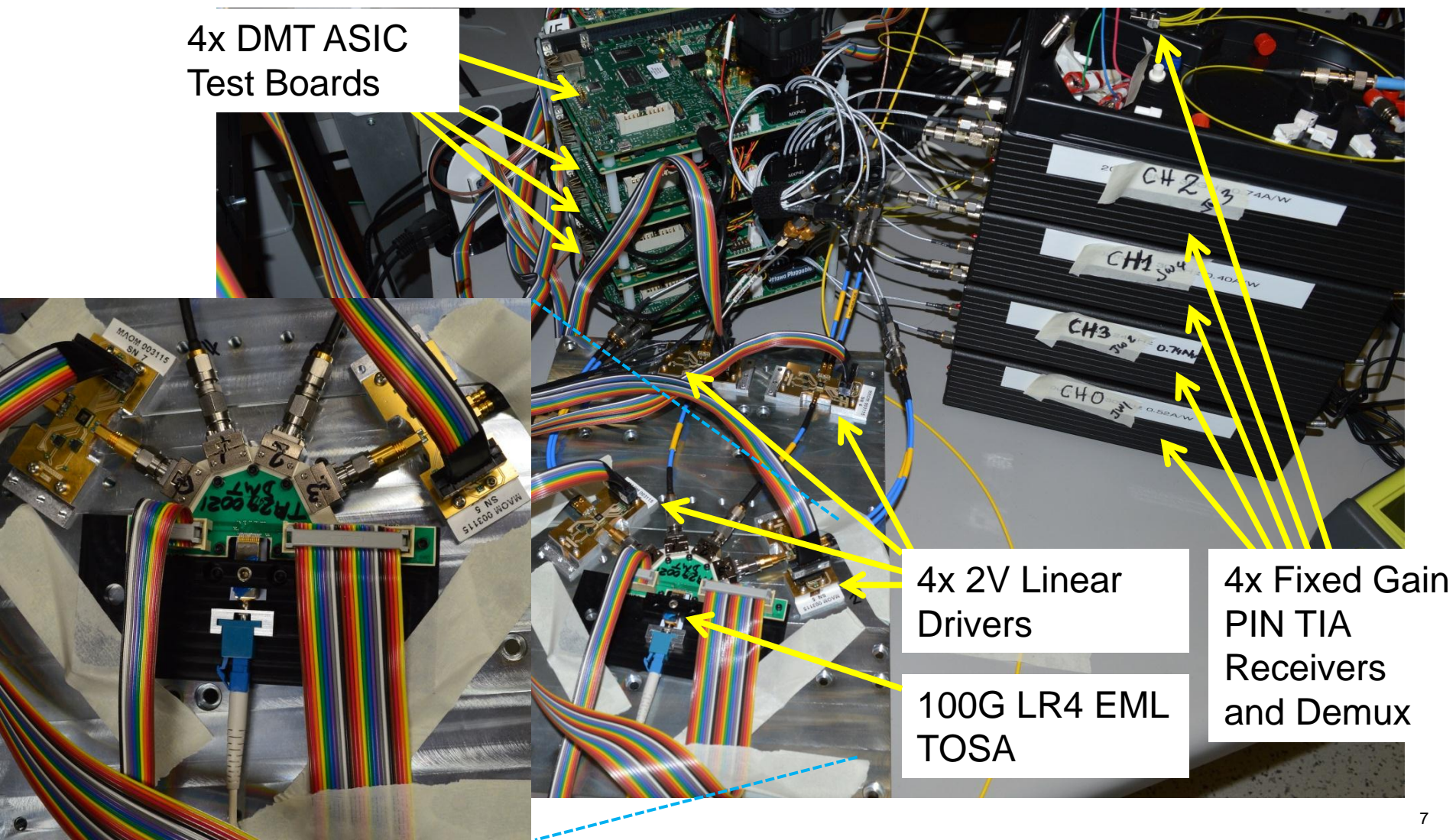
400GE DMT Traffic Configuration with Quad EML Transmitter



400G DMT Test Bed

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

4x DMT ASIC
Test Boards



4x 2V Linear
Drivers

100G LR4 EML
TOSA

4x Fixed Gain
PIN TIA
Receivers
and Demux

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

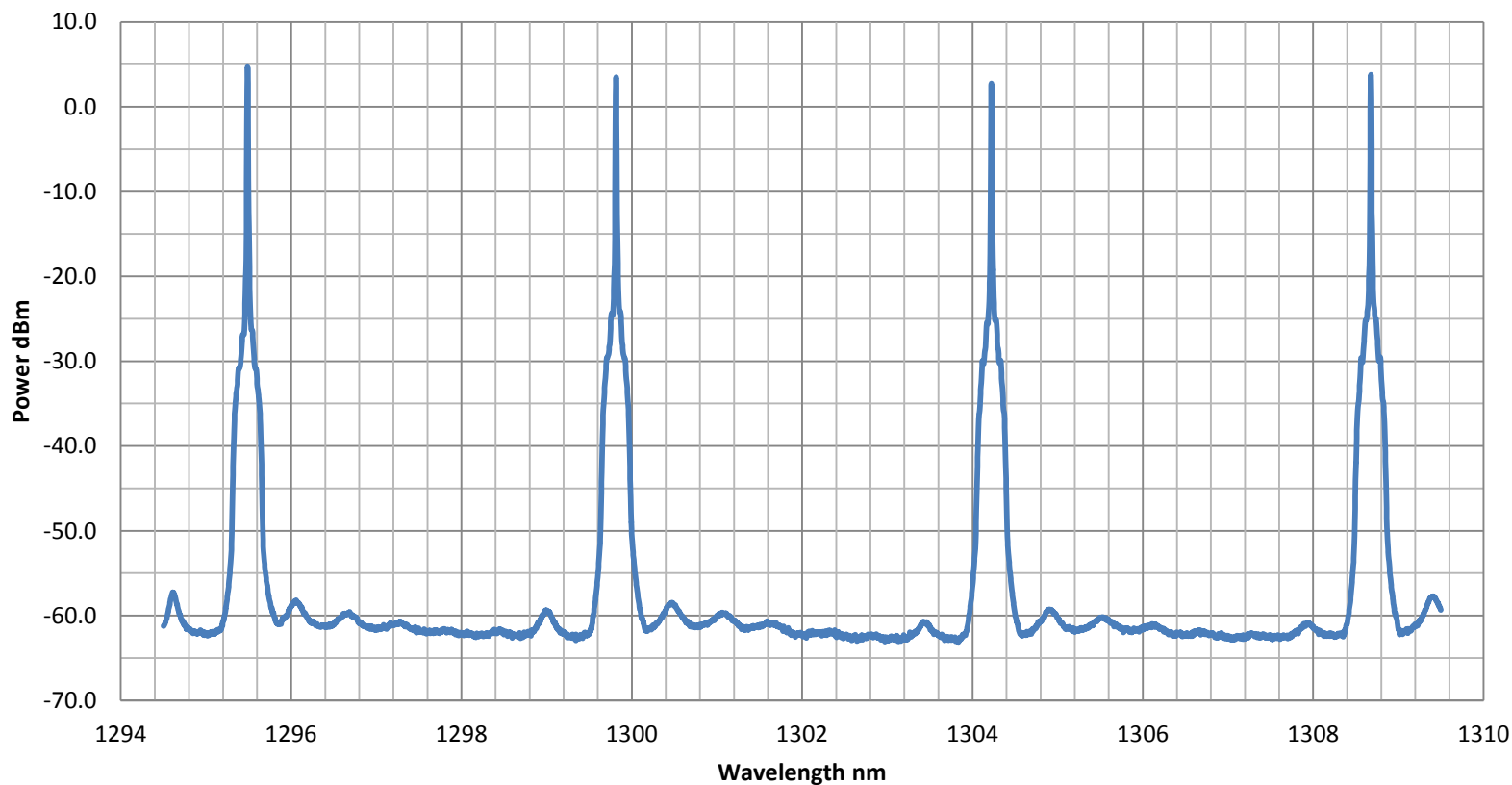
CH	λ nm	RIN dB/Hz	Pout	Vmod	ER @2GHz
0	1295.5	-146.5	+4.9dBm	2.1Vpp	7.3dB
1	1299.8	-144.0	+3.8dBm	2.0Vpp	8.5dB
2	1304.2	-145.5	+2.8dBm	2.1Vpp	10dB
3	1308.7	-146.8	+3.8dBm	2.0Vpp	8.5dB

Optical Component: Tx Modulated Wavelength

■ Peak Wavelengths

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

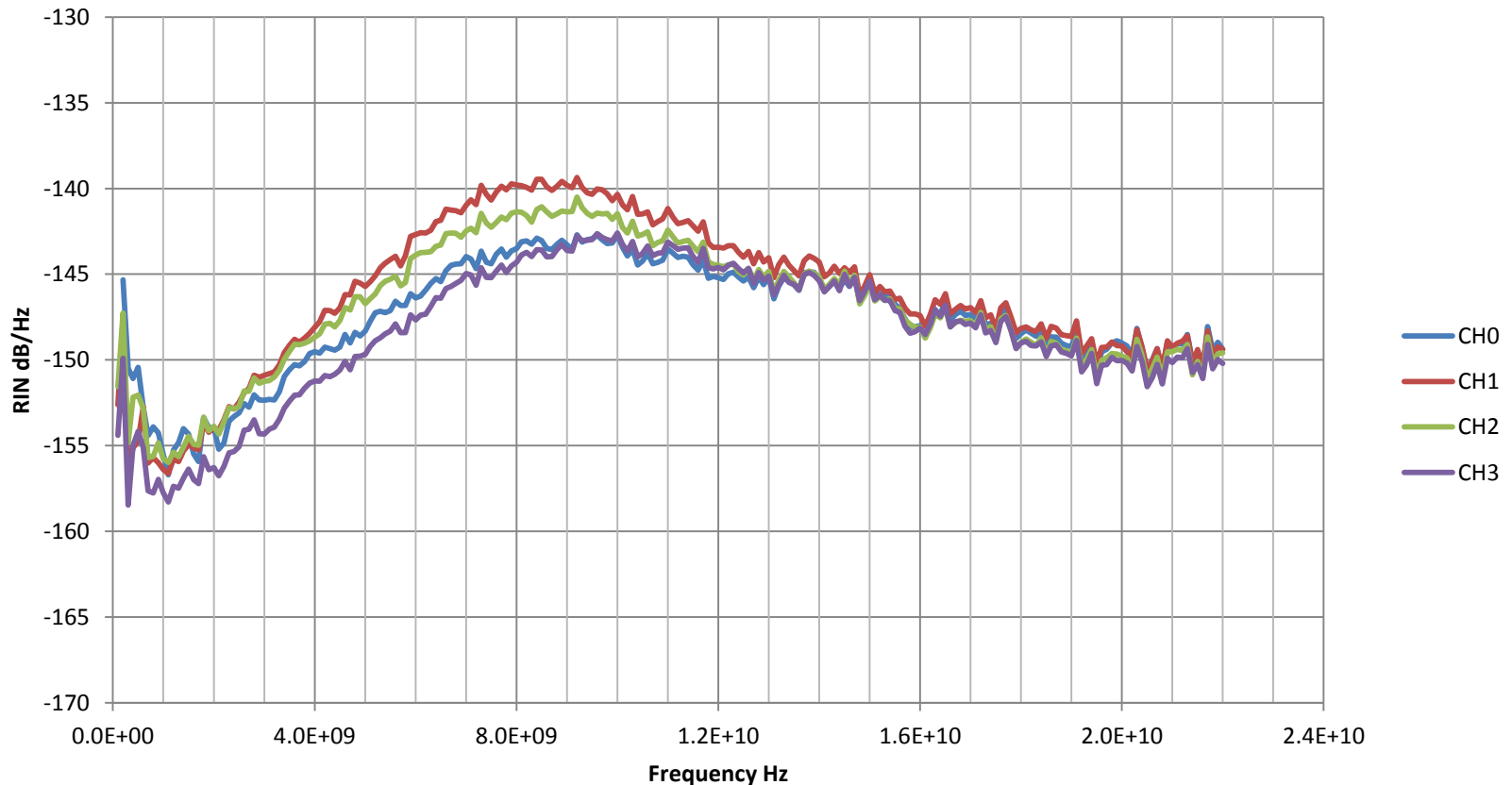
100GE LR4 EML TOSA Modulated spectra



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.

RIN vs Frequency 100G LR4 EML TOSA



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

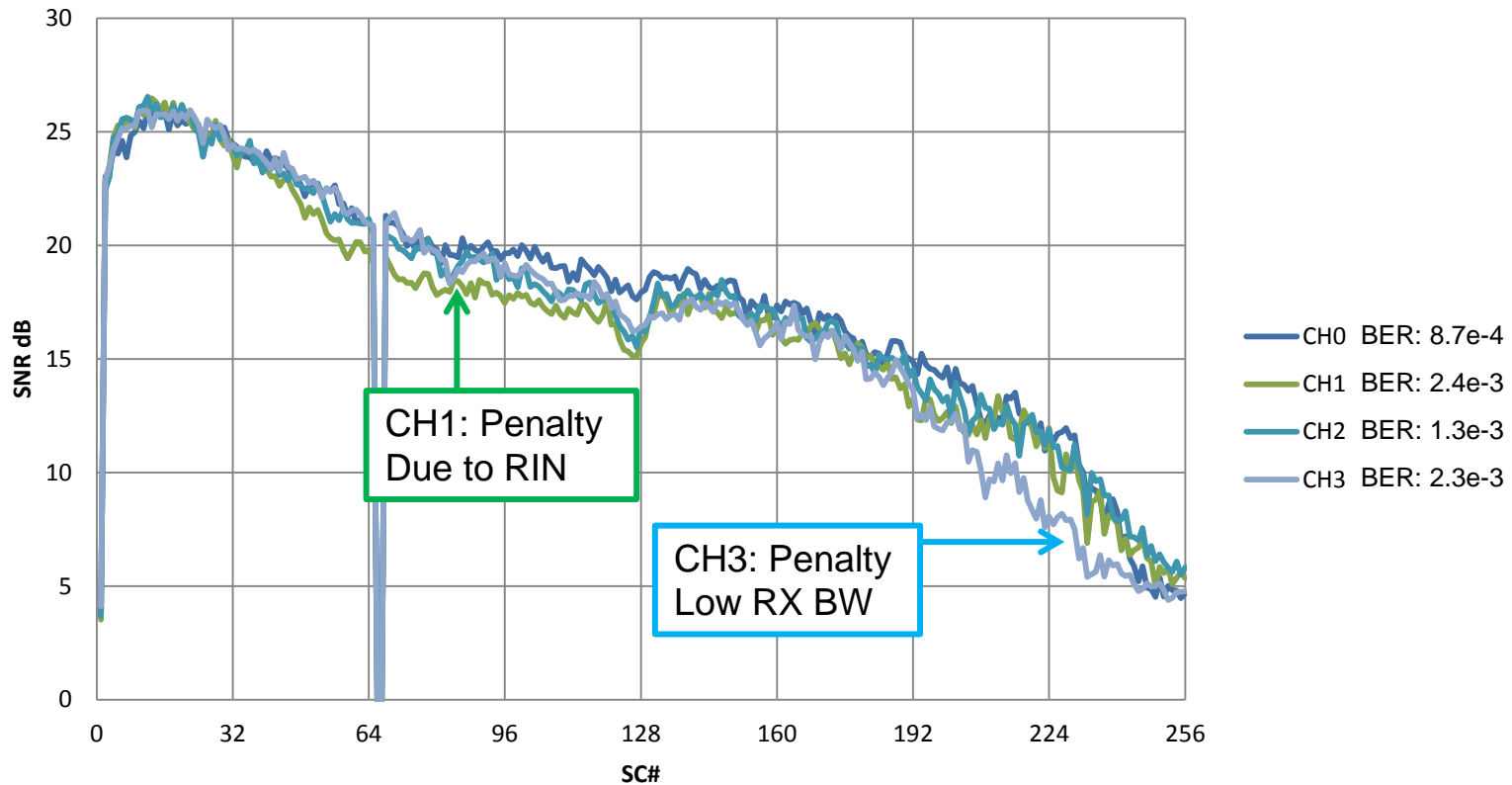
- Receivers consisted of Discovery R409 linear differential PIN-TIA, fixed gain, where one of the 4 receivers was of reduced bandwidth and also had higher noise.
- Since the transimpedance gain is fixed at $\sim 500\Omega$ each receiver's input power is optimized using an optical attenuator.

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

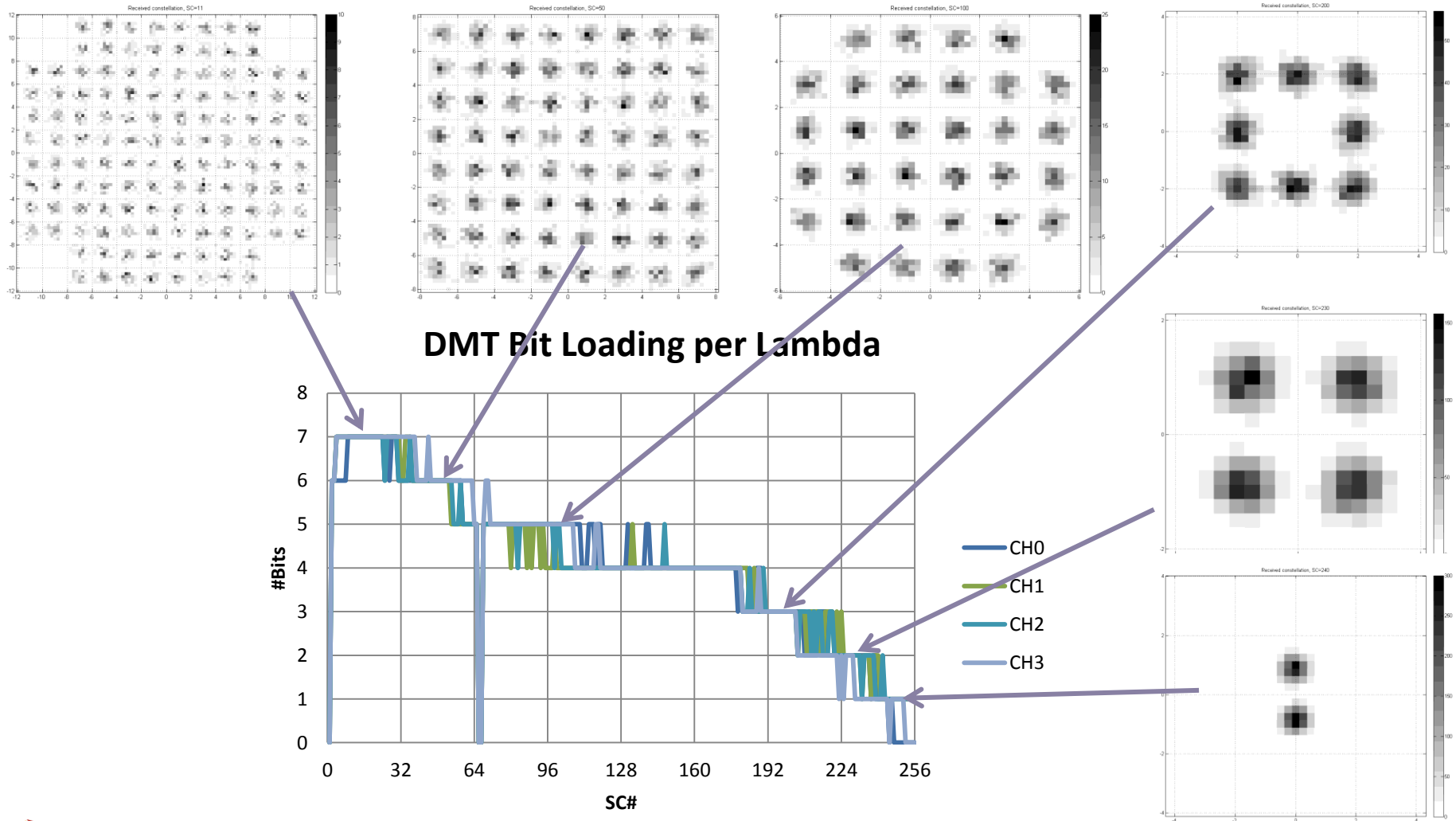
SNR vs Subcarrier

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

DMT SNR vs SC# per Lambda

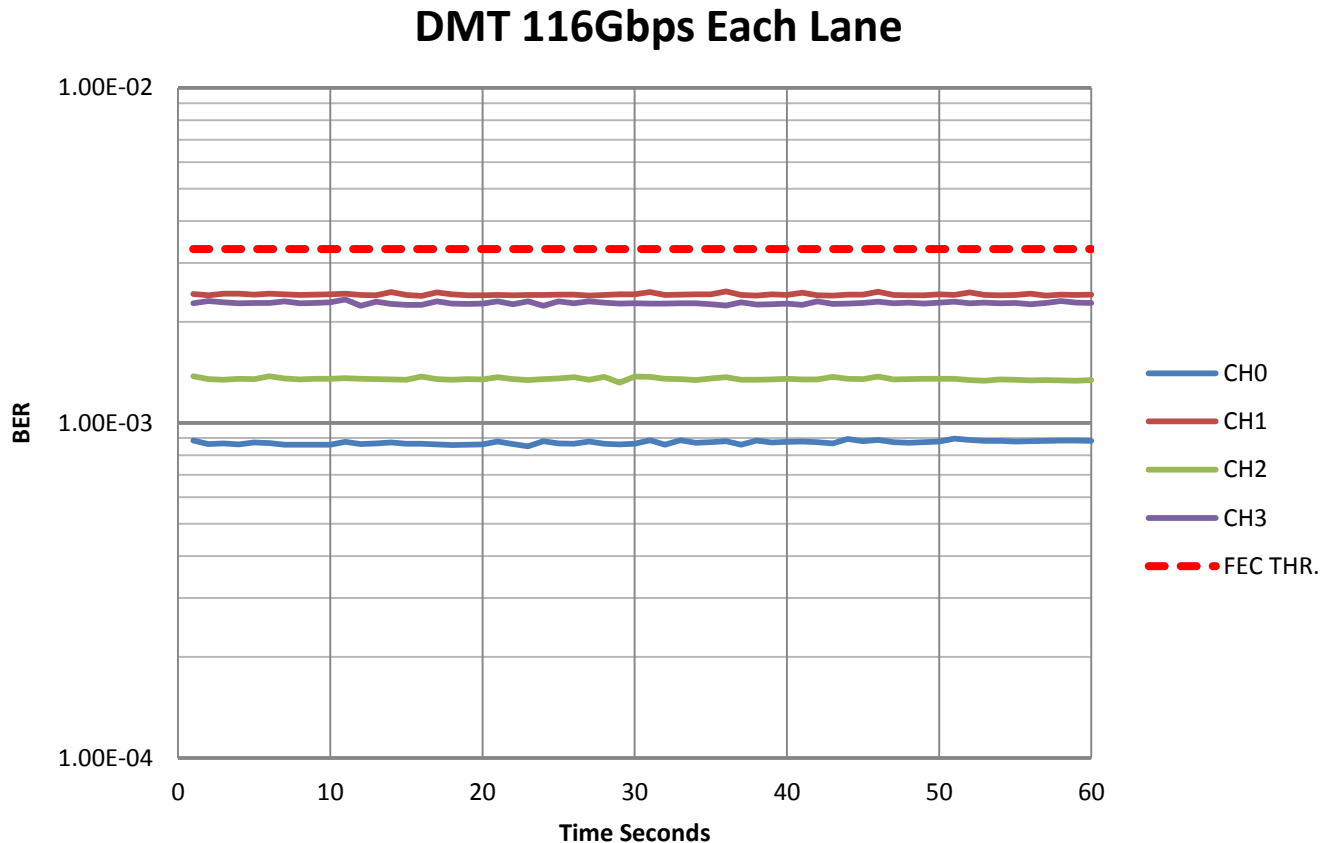


Bit Loading vs Subcarrier#



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.