Contribution to
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Duobinary for 25G-PON

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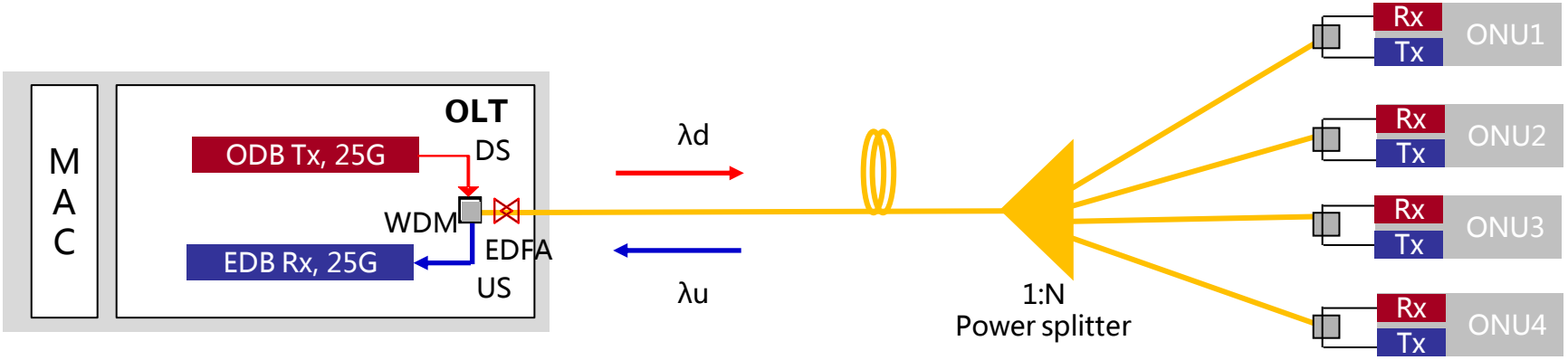
Agenda

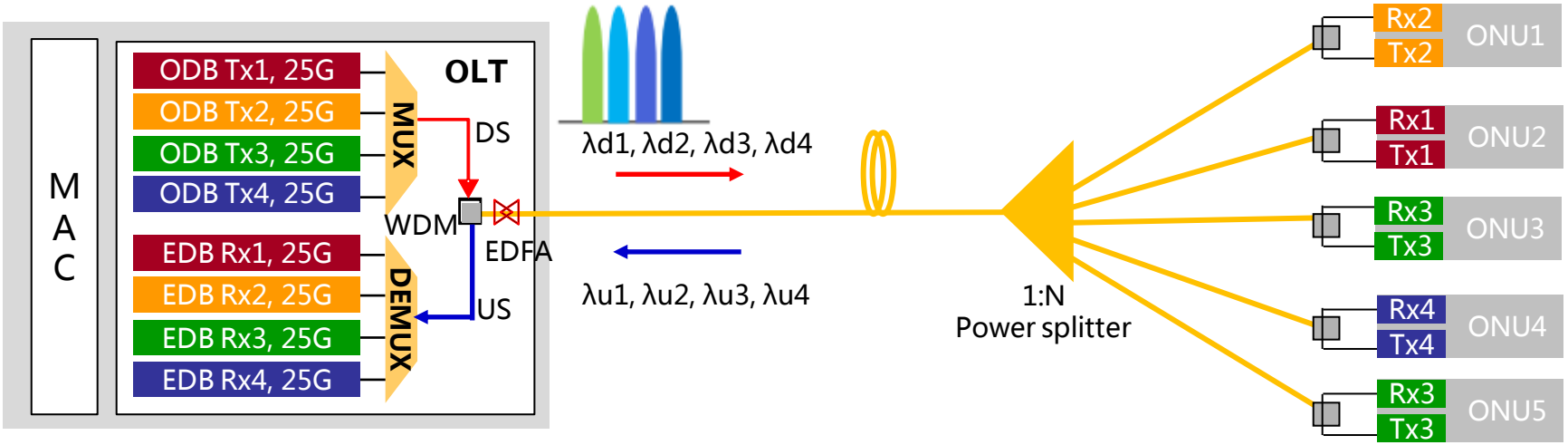
- 25G TDM-PON and 25G TWDM PON
- 25G Optical Duobinary (ODB) / Electrical Duobinary (EDB) Architecture
- Experimental Results
- ODB/EDB Advantages
- Summary

25G TDM-PON and 4*25G TWDM-PON

based on ODB modulation for downstream and EDB for upstream

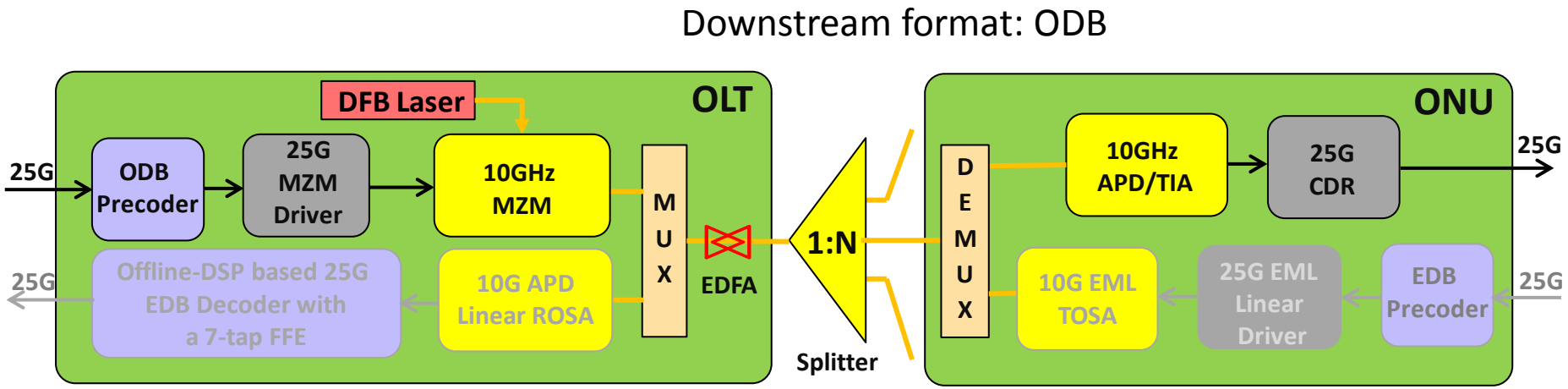


25G TDM-PON based on ODB and EDB modulation



4*25G symmetrical TWDM-PON structure

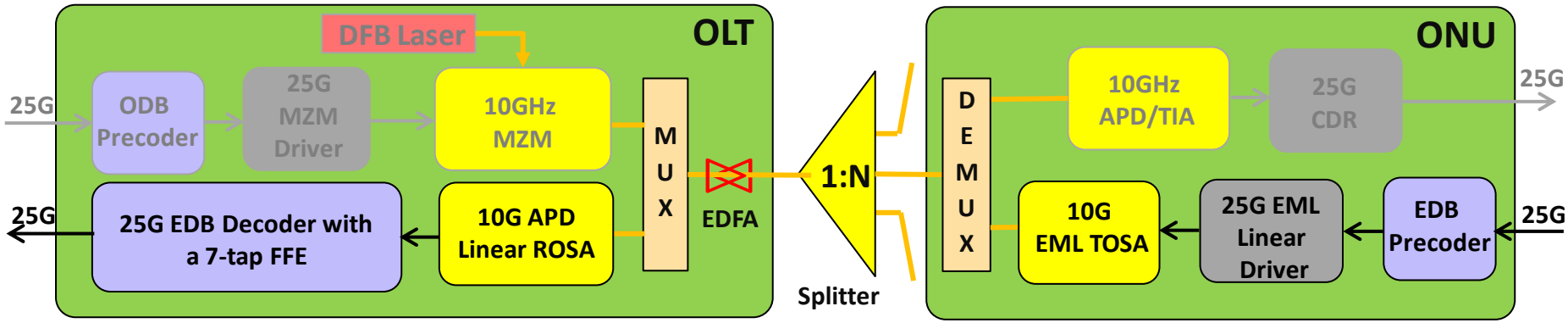
25G ODB/EDB Architecture – Downstream (DS)



- 25 Gb/s ODB Transmitter [1]
  - Differential precoding ensures recovered bits are same as original signal bits
  - The continuous wave output 1550 nm DFB laser is modulated by precoded signal
  - Mach-Zehnder modulator (MZM) with 3 dB bandwidth of 10 GHz biased at intensity null. Encoder uses low-pass filtering instead of 1-bit delay-and-add
  - EDFA at OLT achieves +10 dBm launch power
- 25 Gb/s ODB Receiver
  - High-bandwidth APD with 3 dB RF bandwidth of 10 GHz, plus 25 GHz TIA
  - The electrical signal is reshaped by a 25 Gb/s linear amplifier followed by clock and data recovery

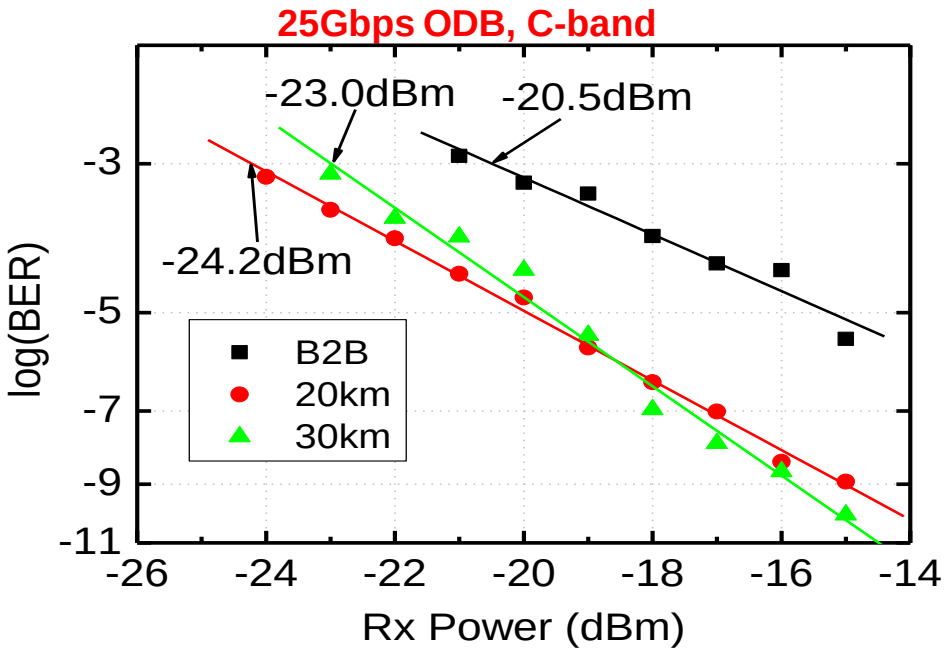
25G ODB/EDB Architecture – Upstream (US)

Upstream format: EDB



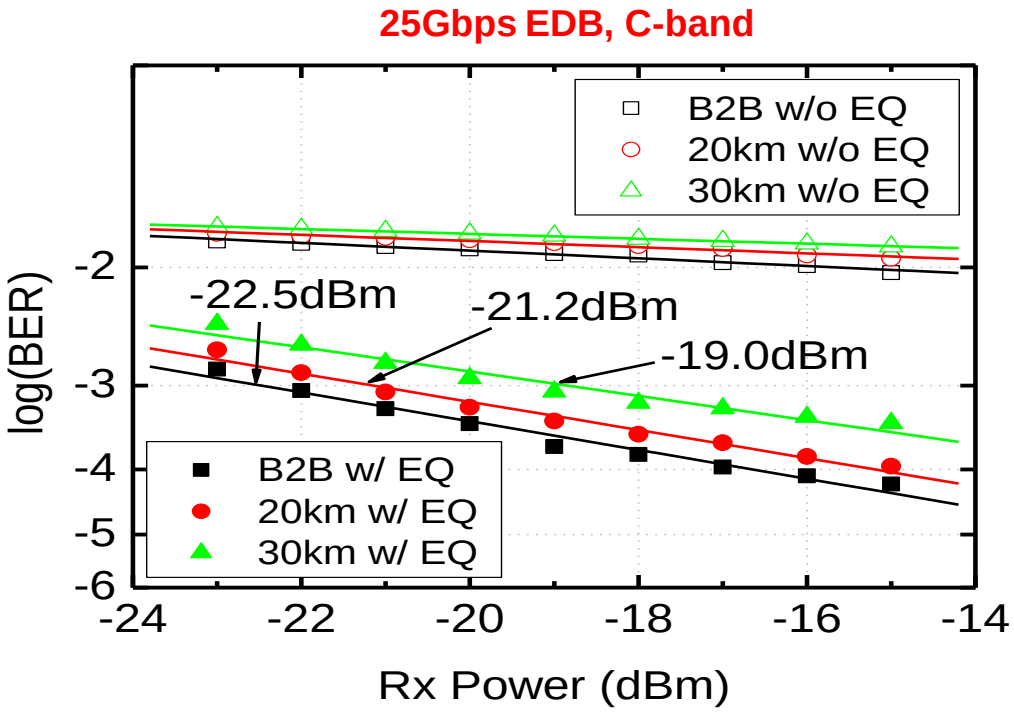
- ◆ 25 Gb/s EDB Transmitter [2]
  - Differential precoding ensures recovered bits are same as original signal bits
  - 10 GHz EML TOSA generates 3-level EDB signal due to bandwidth limitation
- ◆25 Gb/s EDB Receiver
  - 10 Gb/s linear APD ROSA with EDB decoder
    - EDB decoder consists of two threshold slicers and an exclusive-or
    - 7-tap feed-forward equalizer (FFE) for post-equalization (EQ), to improve the performance of EDB signal
  - EDFA pre-amplifier at OLT increases the power budget to 32.5 dB

25G ODB Experimental Results



- Fiber transmission results in a negative power penalty,
  - fiber dispersion acts like a low pass filter consistent with ODB characteristics
- At 10^{-3} BER (10^{-12} BER after standard FEC), the sensitivity is -24.2 dBm after transmission over 20 km in the C-band (around 1550 nm)
- EQ can further improve performance by 2 dB [3]
- With +10 dBm launch power, a loss budget of 34.2 dB after 20 km has been achieved

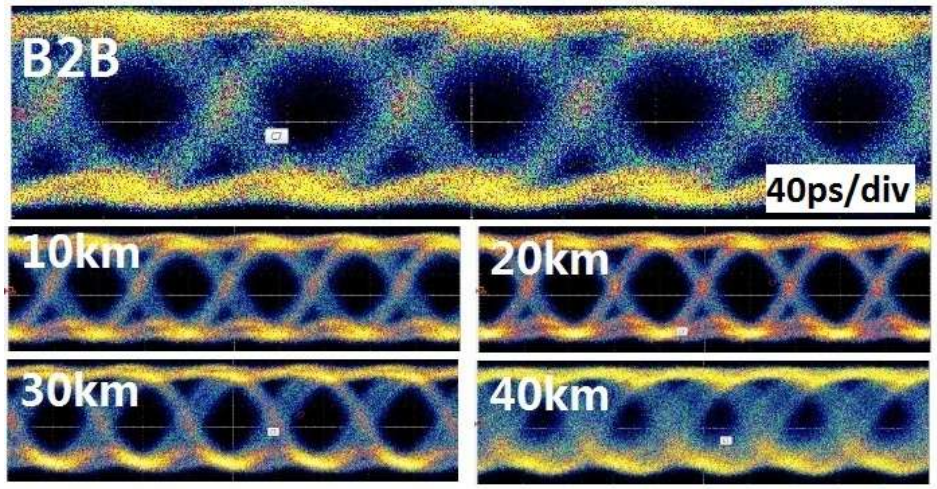
25G EDB Experimental Results



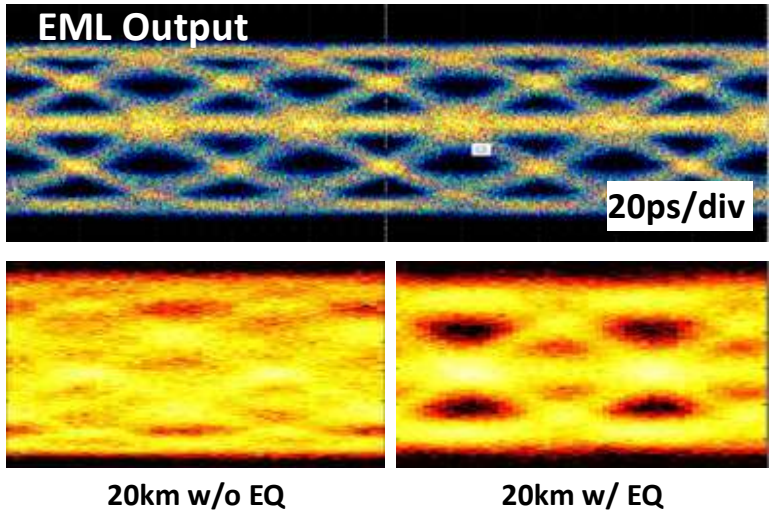
- After EQ, 10^{-3} BER receiver sensitivity are: -19.0, -21.2 and -22.5 dBm for B2B, 20 and 30 km, respectively in the C-band (around 1550 nm)
- Performance may be improved further, e.g., by better post EQ
- With +2 dBm launch power and an EDFA preamplifier at the OLT, a loss budget of 32.5 dB after 20 km has been achieved

25G ODB and EDB Experimental Results (cont.)

(a)



(b)



Experimentally measured eye diagrams of (a) 25 Gb/s ODB signals and, (b)25 Gb/s EDB signals

Receiver sensitivities at 10^{-3} BER for 25 Gb/s ODB and EDB signals at different reaches

Distance	ODB receiver sensitivity @10^{-3}	EDB receiver sensitivity @10^{-3}
0km (B2B)	-20.5 dBm	-22.5 dBm
20 km	**-24.2 dBm**	**-21.2 dBm**
30 km	-23.0 dBm	-19.0 dBm

Advantages of the ODB/EDB Architecture

- **General PON requirements (P2MP)**
  - ✓ ONU simple: ODB receiver and EDB transmitter are as simple as NRZ
  - ✓ OLT enhancements: ODB transmitter and EDB receiver with post-EQ
- **Low cost;** ODB/EDB realized with commercially available components
  - ✓ ODB Downstream: 10 Gb/s MZM and 10 GHz APD/TIA receiver
  - ✓ EDB US: 10 Gb/s EML and 10 Gb/s linear APD ROSA
  - ✓ Potential for additional cost reduction
    - 10G InP or silicon photonics MZM vs 10G $LiNbO_3$ DDMZ
    - 10GHz APD ROSA replacing 25G APD ROSA
- **High performance**
  - ✓ ODB/EDB high dispersion tolerance; 25G transmission up to 30km at C/L band
  - ✓ ODB/EDB offer high receiver sensitivity
  - ✓ Even higher ODB performance possible using 16 GHz APD ROSA and post-EQ[3]

Summary

- 25 Gb/s/λ TDM-PON system based on 25 Gb/s ODB modulation for DS and 25 Gb/s EDB for US transmission

- Provides high-performance solution with low cost
  - ✓ ONU: low-cost, similar to NRZ transceiver without optical amplification
  - ✓ ODB DS: about -24.2dBm sensitivity at 10^{-3} BER=1e-3 w/o EQ after 20km SSMF transmission in the C-band
  - ✓ EDB U/S: -21.2dBm sensitivity at BER w/ EQ after 20km in the C-band
  - ✓ Loss budget ≥ 32.5 dB at 1550 nm over 20-km w/o dispersion compensation for both DS and US

- This solution may provide an attractive evolutionary path for NG-EPON.

Thank you

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Bibliography

[1] D. van Veen et al., “40-Gb/s TDM-PON over 42 km with 64-way power split using a binary direct detection receiver,” ECOC’14, PD.1.4

[2] V. Houtsma et al., “APD-Based DuoBinary Direct Detection Receivers for 40 Gbps TDM-PON,” OFC’15, Th4H.1

[3] Z. Ye et al., “Demonstration of High-Performance Cost-Effective 100-Gb/s TWDM-PON Using 4x 25-Gb/s Optical Duobinary Channels with 16-GHz APD and Receiver-Side Post-Equalization,” ECOC’15, Mo.3.4.4