Experimental Results of Single Wavelength 50G PON

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Introduction

This contribution presents the test results of three candidate technologies for 50-Gb/s/λ TDM-PON

- Options and Requirements
- Sensitivity Analysis and Test Results
- Wavelength Options
- Challenges

Background

- In July 2017 Berlin meeting, the Task Force decided to analyze and study the solutions for single wavelength 50G PON, and compare it with two-wavelength 25G solution (wangbo_3ca_2_0717)
- In last meeting, there are two contributions on 50-Gb/s/λ TDM-PON (liu_3ca_2_0917, and houtsma_3ca_0917). Both presented analysis on modulation formats, power budget, challenges and potential solutions.
- In this contribution, we present experimental results and analysis on single wavelength 50G PON.

Four Modulation Format Options for 50-Gbps/λ

- NRZ at 50GBaud:
  - best performance with 50G optics, clock frequency at 50GHz
  - becomes Duobinary-like signal with 25G optics
- PAM-4 at 25GBaud:
  - requires 25G optics, clock frequency at 25GHz
- EDB at 50GBaud:
  - requires 25G optics, clock frequency at 50GHz
- DMT:
  - requires 10-20G optics, ~20GHz sampling rate
  - high PAPR penalty and computation complexity

Required Optics and Electronics

Optical Bandwidth

- 50G optics: can support 50G NRZ; however, very high cost and no commercial 50G APD available
- 25G optics: is a mature technology for 50Gbps in DCI
- 10G optics: low-cost, but with additional ISI penalty

Receiver

- APD: 25G APD is available now
- SOA+PIN: pre-amplifier becomes significant to improve the sensitivity

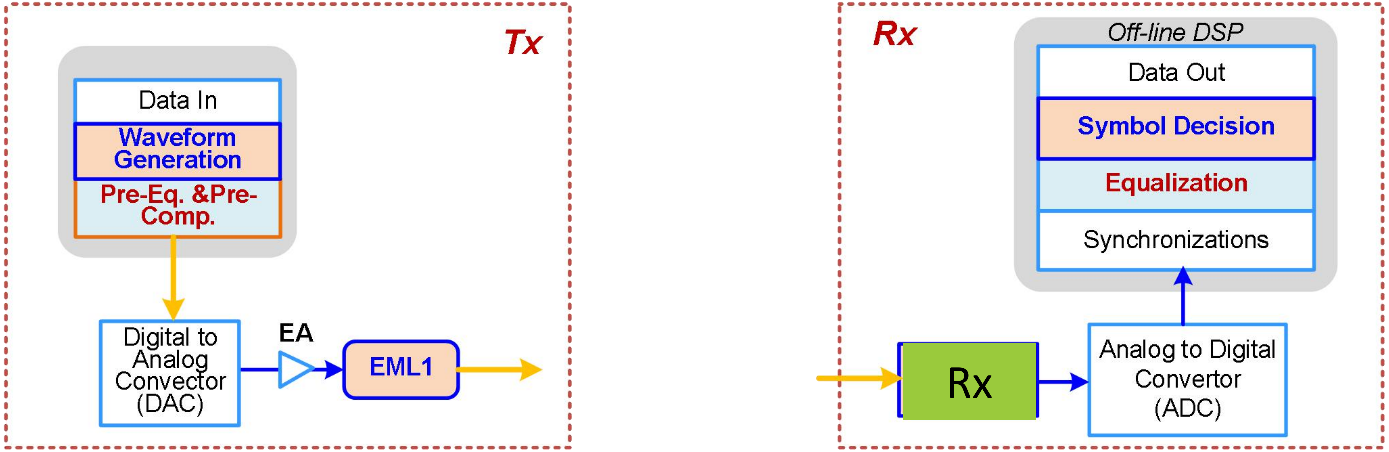
TIA

- PAM-4 and DMT require linear TIA
- DMT is much more sensitive to linearity impairments compared with PAM-4

DSP

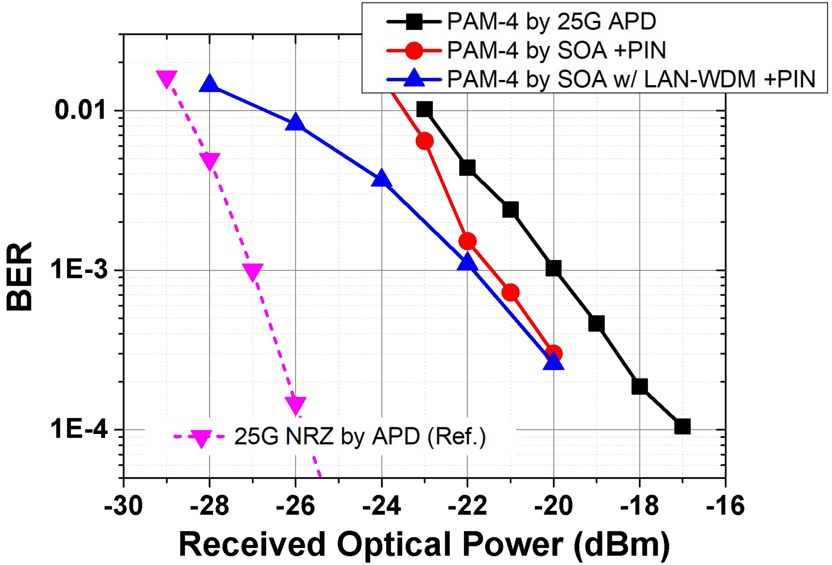
- Either pre- or post-equalization is required to improve performance

Transceiver Setup



- EML: O-band, BW ~20GHz, Output Power ~2.5dBm
- APD: O-band, BW~18GHz
- SOA: 25dB small signal gain
- PIN: BW ~12GHz
- DAC: BW <20GHz, ADC: BW ~30GHz

25GBaud PAM-4 test results



- 17-tap FFE is used at the Rx-side;
- The Rx Sensitivity of 50Gbps PAM-4 (25GBaud) :

BER\Rx	APD	SOA+PIN	SOA w/ LAN-WDM +PIN
1E-3	~-20dBm	~-21.5dBm	~-22dBm
1E-2	~-23dBm	~-23.5dBm	~-26.5dBm

- **Compared with 25G NRZ by APD, PAM-4 has 7dB penalty @1e-3, and 5.5dB penalty @1E-2**
- **PIN using SOA with LAN-WDM filter can compensate 3.5dB @ 1E-2**
- **Otherwise, Tx with optical power >6dBm is required to achieve 29dB power budget @1E-2**

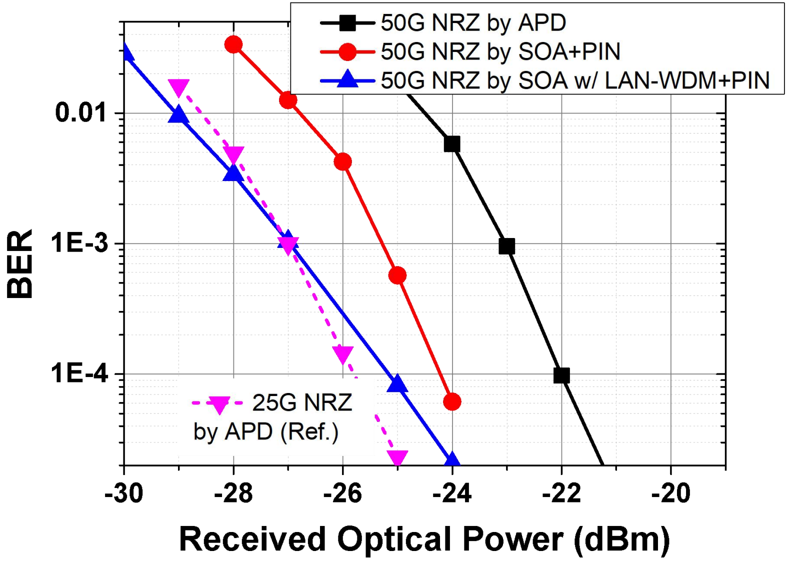
50GBaud NRZ/EDB based on 25G Optics

To transmit the 50GBaud signals of OOK, there are two methods:

- Method 1
  - Tx: NRZ signal, suffering narrow-bandwidth filtering, with large ISI
  - Rx: Advanced ISI processing, i.e.,MLSD for multi-symbols optimization;
- Method 2
  - Tx: Pre-coded EDB signals, signal bandwidth within 25GHz
  - Rx: EDB detection and regular signal equalization (FFE or FFE+DFE)

Both methods can work well to mitigate bandwidth limitation.

50GBaud NRZ test results

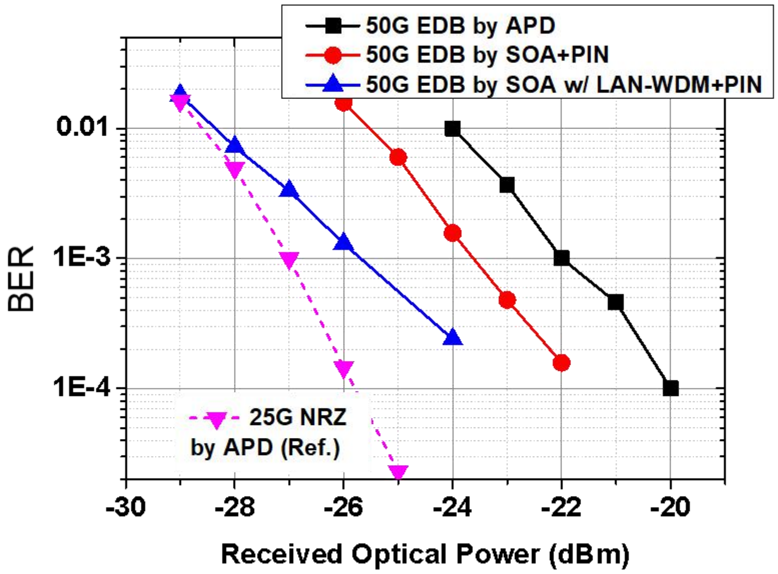


- 17-tap FFE is used
- The Rx sensitivity of 50G NRZ achieved:

BER\Rx	APD	SOA+PIN	SOA w/ LAN-WDM +PIN
1E-3	~-23dBm	~-25.2dBm	~-27dBm
1E-2	~-24.5dBm	~-26.8dBm	~-29dBm

- **Compared with the reference 25G NRZ by APD, 50G NRZ has 4dB power penalty**
- **PIN using SOA without filter can compensate >2dB, SOA with filter can compensate >4dB**
- **Otherwise, Tx with power >4.5dBm is required to achieve 29-dB power budget @1E-2**

50GBaud EDB (pre-coded) test results



- 17-tap FFE is used
- The Rx sensitivity of 50G EDB achieved:

BER\Rx	APD	SOA+PIN	SOA w/ LAN-WDM +PIN
1E-3	~-22dBm	~-23.6dBm	~-25.8dBm
1E-2	~-24dBm	~-25.5dBm	~-28.2dBm

- **Compared with the reference 25G NRZ by APD, 50G EDB has 4.5~5dB power penalty**
- **PIN using SOA without filter can compensate 1.5dB, and SOA with filter can compensate 3.5-4dB**
- **Otherwise, Tx with power > 5dBm is required to achieve 29-dB power budget @1E-2**

Wavelength Options

1. O-band wavelength is preferred, due to large chromatic dispersion penalty in C-band, especially for NRZ signals.

Simulation Results: Power Penalty (dB) @1 E-3 in C-band

CD (ps/nm)	0	16	80	160	240	320
Fiber length (km)	0	1	5	10	15	20
PAM-4	0	0	0.2	0.7	1.8	8.5
NRZ (w/ MLSD)	0	0	2.2	6.8	-	-

2. If advanced DSP is enabled, C-band is also possible with CD pre-compensation and nonlinearity compensation (J. Zhang, et al., ECOC 2017, Paper P2.SC8.53)

Challenges of 50-Gb/s/λ

1. Insufficient link power budget
   - Compared with 25G NRZ, 50Gbps/λ has high power penalty: 5.5dB (PAM-4), 4dB(NRZ), and 5dB (EDB) at 1E-2
2. Cost and complexity
   - Due to large power budget gap, optical amplifier is required
   - Equalization is required
   - ADC/DAC resolution is increased compared with 25G NRZ
   - Higher linearity requirement
3. Upstream burst receiver
   - No Burst linear TIA
   - No BCDR and burst equalization
4. Technology maturity
   - Key technologies may be available after 2020

Summary

1. Test results of single-wavelength 50G PON are presented:
   - Compared with 25G NRZ by APD, PAM-4 has 7dB penalty @1e-3, and 5.5dB penalty @1E-2
   - Compared with 25G NRZ by APD, 50G NRZ has 4dB penalty
   - Compared with 25G NRZ by APD, 50G EDB has 4.5~5dB penalty
2. Due to the large power budget gap, optical amplifier is required in the system, in either Tx or Rx side;
3. Challenges exist for single wavelength 50Gbps, including insufficient link power budget, cost and availability of burst receiver.

Thank You!

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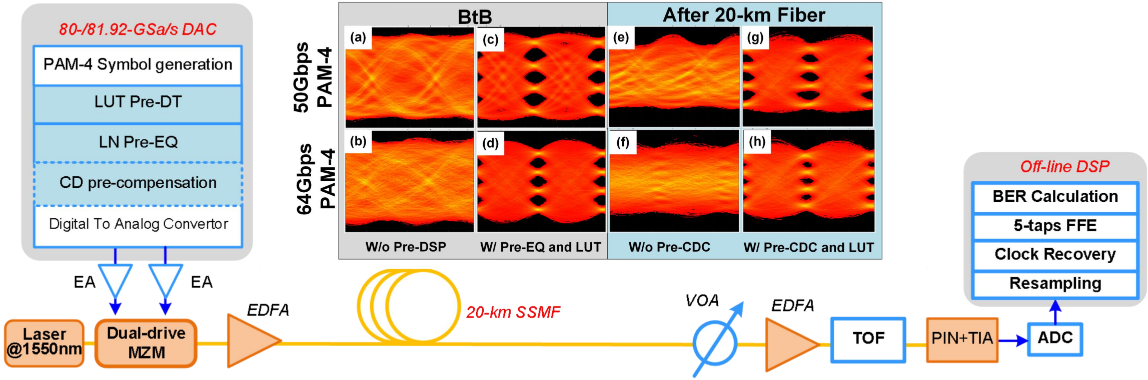
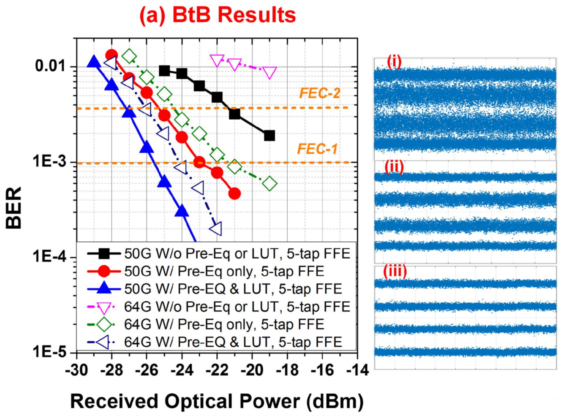
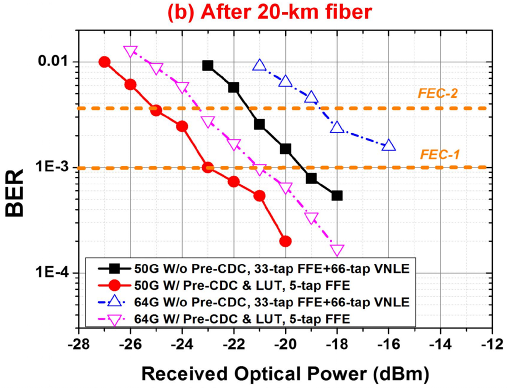
50/64-Gbps PAM-4 In C-band



J. Zhang, et al., ECOC 2017, Paper P2.SC8.53





- At the OLT, LD at 1550 nm is used as the light-source.
- A dual-drive MZM biased at quadrature point for complex signal modulations
- The 25- and 32-Gbaud PAM-4 signals are generated by a DAC at 80 and 81.92 Gsa/s, respectively.
- The 3 dB analog bandwidth of the DAC is 16 GHz The PAM-4 symbols, followed by the LN Pre-EQ and LUT-based Pre-DT algorithm to mitigate channel impairments.
- CD pre-compensation is used for fiber transmission