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NRZ-NFC for 28G-PON

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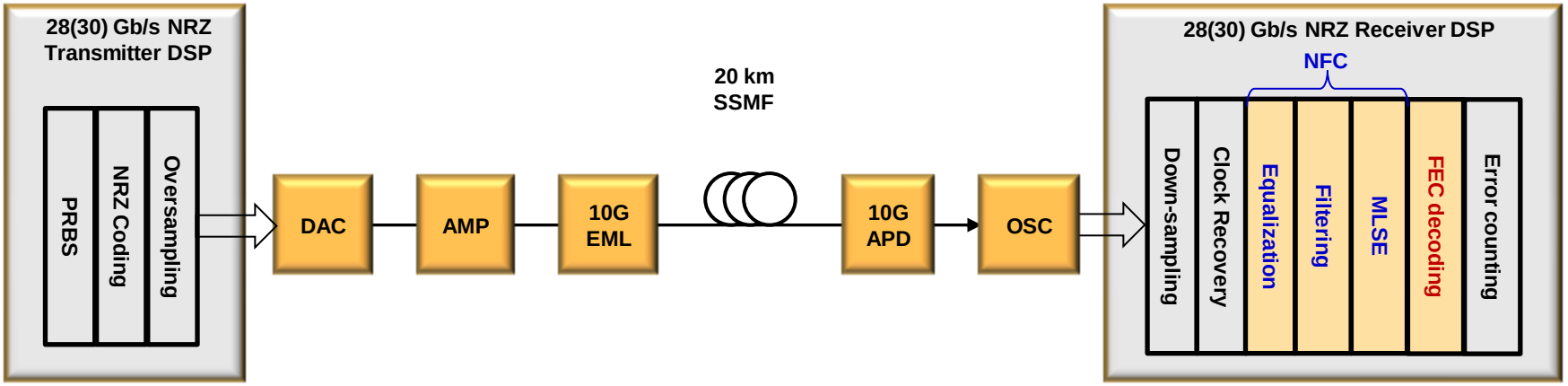
Potential 25G PON Solutions

- NG-EPON has a objectives for:
  - 25 Gb/s data rate
  - Same optical power budget as 10G-EPON (reuse ODN)
- Two main approaches being actively studied.
  - Use higher modulation formats such as Duobinary or PAM4
    - Using low cost, low bandwidth optical/electronic components
    - PAM4, 25 Gb/s DS based on 10G EML and APD demonstrated[1]
      - receiver sensitivity -19.5 dBm @ 10^{-3}, 20 km fiber, C-band
  - Use DSP to relax bandwidth needs of optical/electronic components
    - A Narrow filter compensation (NFC) technique was verified as a practical solution
    - Single-wavelength 488 Gb/s using components with a 3 dB overall bandwidth of about one quarter of the modulation baud has been achieved using NFC [2]

28G NRZ-NFC Study

- Use NRZ-NFC technique to achieve 25 Gb/s net data rate with the following benefits:
  - Higher receiver sensitivity due to NRZ and DSP
    - NRZ modulation provides high optical power budget due to its high receiver sensitivity.
  - Low dispersion penalty via NFC
  - Low cost via 10 GHz TOSA/ROSA (enabled by NFC)
- Optimize FEC overhead in this bandwidth-limited transmission

28G NRZ-NFC PON Proof-of-Concept



- DSP in NRZ-NFC transmitter & receiver mitigate inter-symbol interference caused bandwidth limitations & fiber dispersion
  - Commercially available 10G EML/APD minimize cost
  - No DSP at transmitter.
  - In receiver normal clock recovery algorithm (enabled by NFC); with simple DSP (less than 13 tap time domain equalization plus only 2 state maximum likelihood sequence estimation (MLSE))
- 20 km transmission using C-band conducted
  - Aims to accommodate any potential 25G-PON wavelength plan

28G NRZ-NFC PON Proof-of-Concept

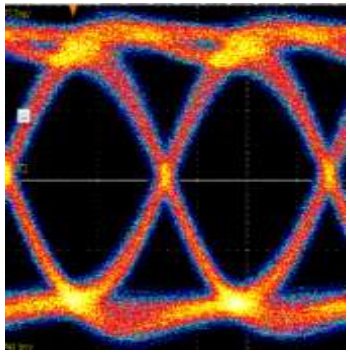
Transmitter

a. After transmitter DAC

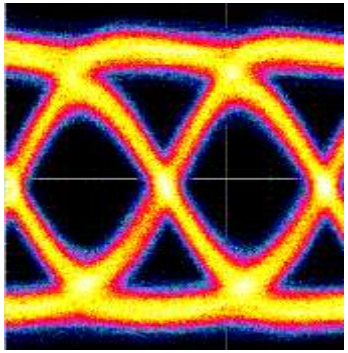
b. After transmitter AMP

c. Transmitter output of 10G EML

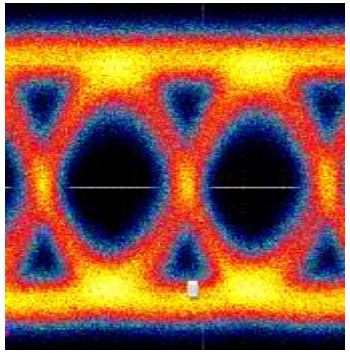
a



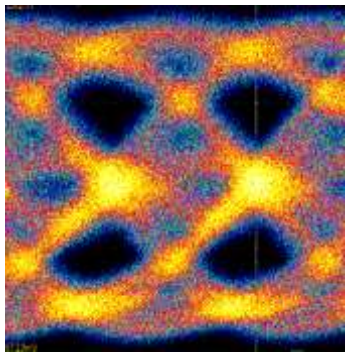
b



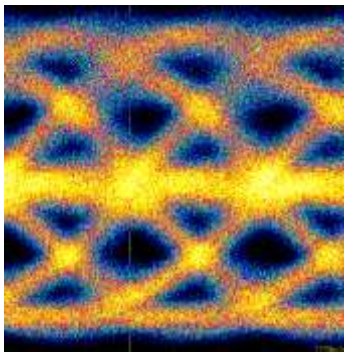
c



d (0 km)



e (20 km)

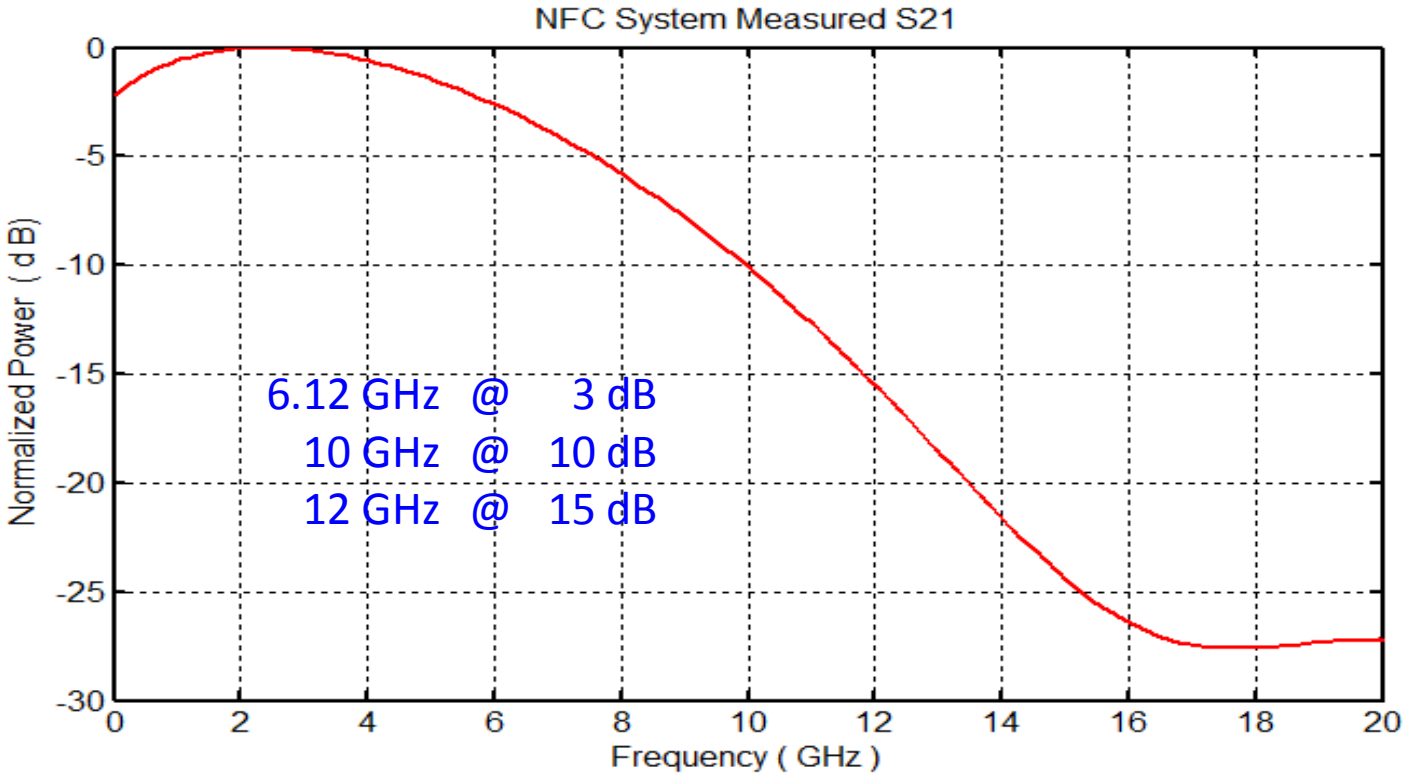


Receiver

d. Output of APD (0 km, B2B)

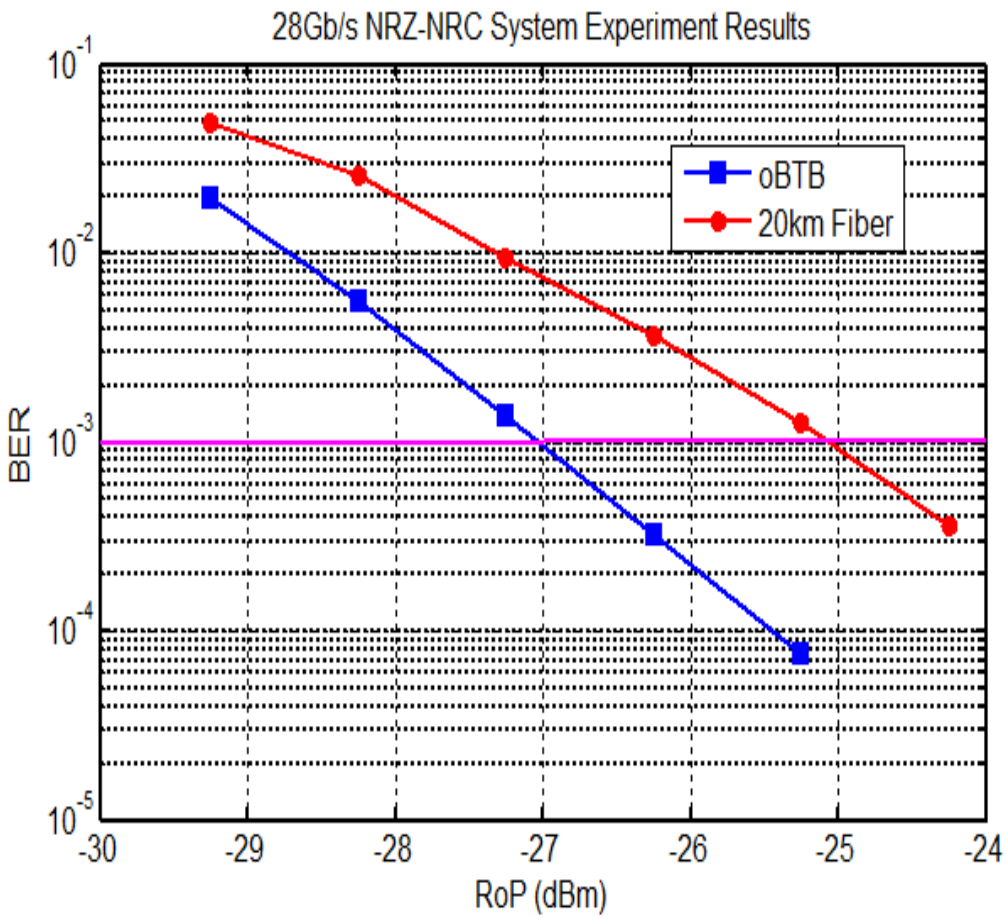
e. Output of APD (20 km)

Frequency Response of the Entire Link



- The 10 dB bandwidth of the entire link is only ~10 GHz
- It is important to specify the bandwidth at various attenuations (e.g., 3dB, 10dB, 20dB…) in order to reliably predict the transmission performance

28G NRZ-NFC Experiment Results



Key Performance

- Raw data rate: 28Gb/s
- Receiver Sensitivity：
  - - 27dBm @ $1X10^{-3}$, B2B
  - - 25dBm @ $1X10^{-3}$, 20km fiber
- Optical Power Budget

(with 5 dBm EML power):

  - 30dB @ 20km, C-Band

Advantages

- High receiver sensitivity

(advanced DSP and optics)

- High optical power

(high-quality EML)

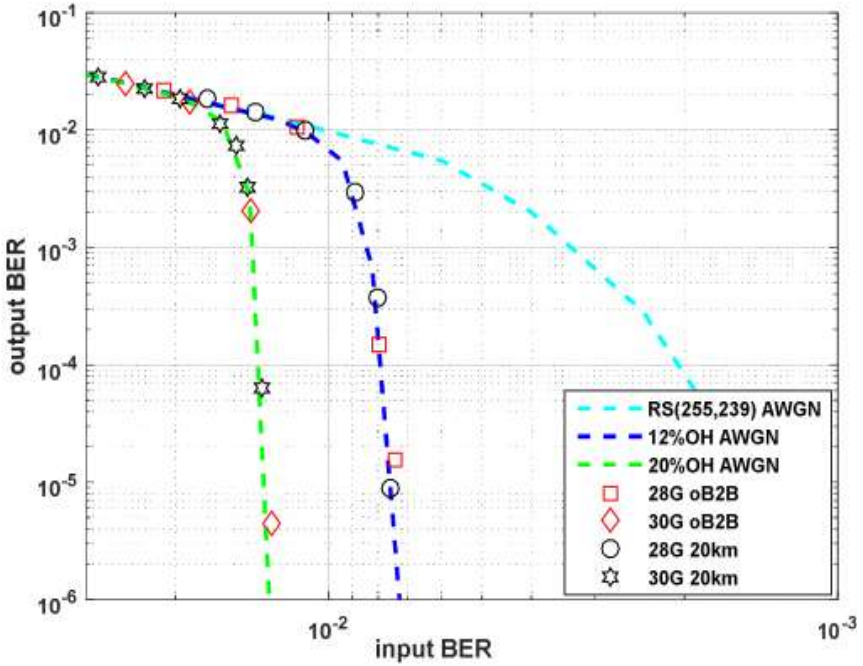
- Low CD penalty

(channel equalization in DSP)

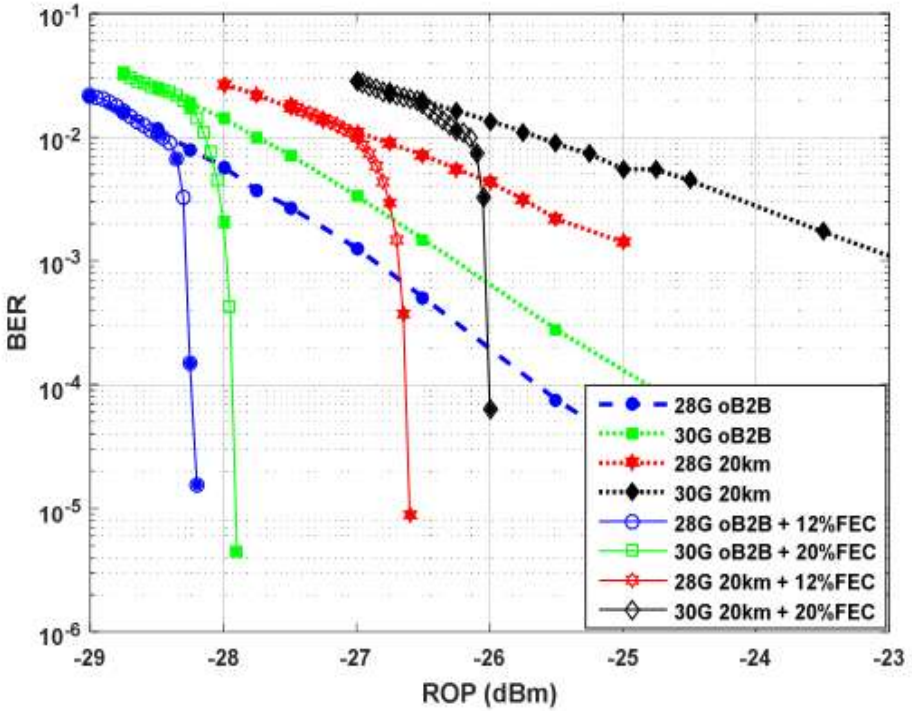
Impact of FEC Overhead on Performance

- Two product BCH codes compared for a data rate of 25 Gb/s
  - (508,480,3)×(508,480,3), 12% overhead, 28 Gbps
    BER threshold 5 ×10^{-3} for post FEC BER 10^{-12}
  - (480,434,5)×(472,435,4), 20% overhead, 30 Gbps
    BER threshold 1.1×10^{-2} for post FEC BER 10^{-12}
- 12% overhead FEC outperformed 20% overhead FEC by 0.2 dB and 0.6 dB @ B2B and 20km, respectively
- 12% overhead FEC strikes a good balance between FEC gain and bandwidth-limitation induced performance penalty for the hardware platform and DSP used, achieving
  - Receiver sensitivity: -26.5 dBm @ 5×10^{-3}
  - Power budget: 31.5 dB after 20 km in C-band

Impact of FEC Overhead on Performance



Experiment Measured post-FEC BER vs. pre-FEC BER



Experiment Measured BER performance versus ROP

Summary

- NRZ-NFC offers a high-performance/low-cost solution for 25G-EPON.
  - High receiver sensitivity: -28 dBm @ 5×10^{-3} (B2B)
  - High dispersion tolerance: -26.5 dBm @ 5×10^{-3} (20 km, C-band)
  - Low-bandwidth optics: 10 GHz class EML and APD
  - Power budget: 31.5 dB without optical amplifier (ODN reuse)
- 12% overhead FEC is a good option
- Experimental results show that 28G NRZ-NFC based EPON will offer co-existence with 1G/10G-EPON and can accommodate any wavelength plan to be chosen
- DAC/ADC/DSP may be implemented with low power consumption and small form factor, meeting the requirements for implementations in OLT and ONU.
- The use of DSP may enable a smooth upgrade path to 50G and 40G without changing the optics and PON infrastructure.
- Future work on upstream transmission is needed

Thank you

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Bibliography

[1] V. Houtsma and D. van Veen, “Demonstration of symmetrical 25 Gbps TDM-PON with 31.5 dB optical power budget using only 10 Gbps optical components,” in Proc. European Conference on Optical Communication, post-deadline paper PDP.4.3 (2015).

[2] Z. Zhang et al., “Coherent transceiver operating at 61-Gbaud/s,” Optics Express 23 (5), 18988-18995 (2015).