# Notes on EPON extender boxes and EPON PMDs

David Piehler
david.piehler@neophotonics.com

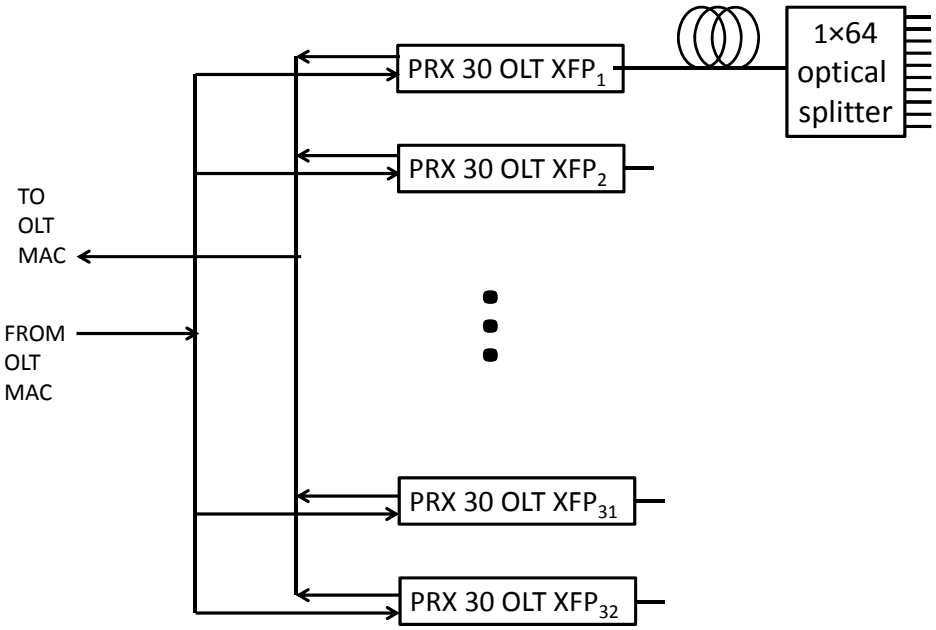
Extended EPON Study Group · IEEE 802.3 plenary meeting · Atlanta · 9 November 2011

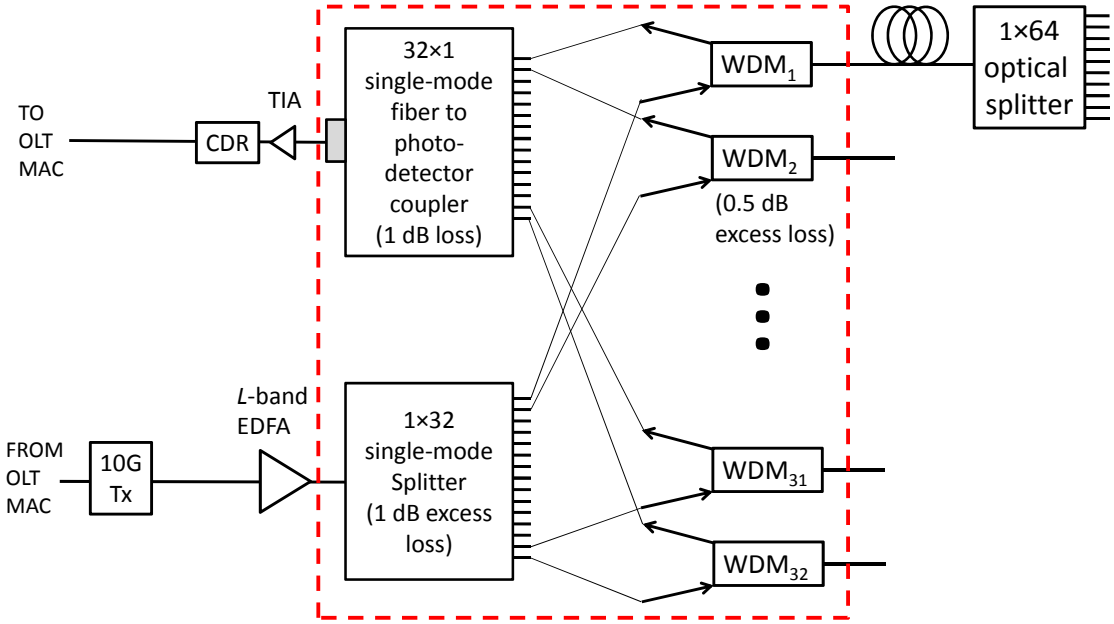
# In ***principle***, no limit to split ratio with active ExBox

NeoPhotonics

Loss-less (mostly noise-less) *electrical* signal splitting and *electrical* signal combination

Loss-less (mostly noise-less) *optical* signal splitting and *optical* signal combination




*See for example:*


Chanclou *et al*., "Investigation into Optical Technologies for Access Evolution," *OFC-2009*, paper OWH1.

Oishi *et al*, "Reconfigurable Multi-Port EPON Repeater," in *Asia Communications and Photonics Conference – 2009*, paper TuDD6.

D. Piehler, "Implementing High [>2048] Split Ratios in *any* PON," *OFC-2011* , paper NThF4.

# OEO *vs*. all-optical *vs*. hybrid ExBox approaches – ***downstream***

NeoPhotonics

- Downstream: cw signals from laser(s) can be regenerated by
  - Optical amplification and optical splitting
    - $RIN_{OA}$ = -157 dB/Hz + NF [dB] - $P_{in}$ [dBm]
    - *L*-band EDFAs exist at 1577 nm
      - Single wavelength operation simplifies and cost reduces.
    - Semiconductor optical amplifiers (SOAs) exist at 1490 nm.
      - Limited in output power by $P_{sat}$
  - Optical to electrical conversion (2R, 3R), (analog or digital) electronics splitting, electrical to optical transmission.
- *Both downstream approaches are fairly straightforward.*

# OEO vs. all-optical vs. hybrid ExBox approaches – *upstream*

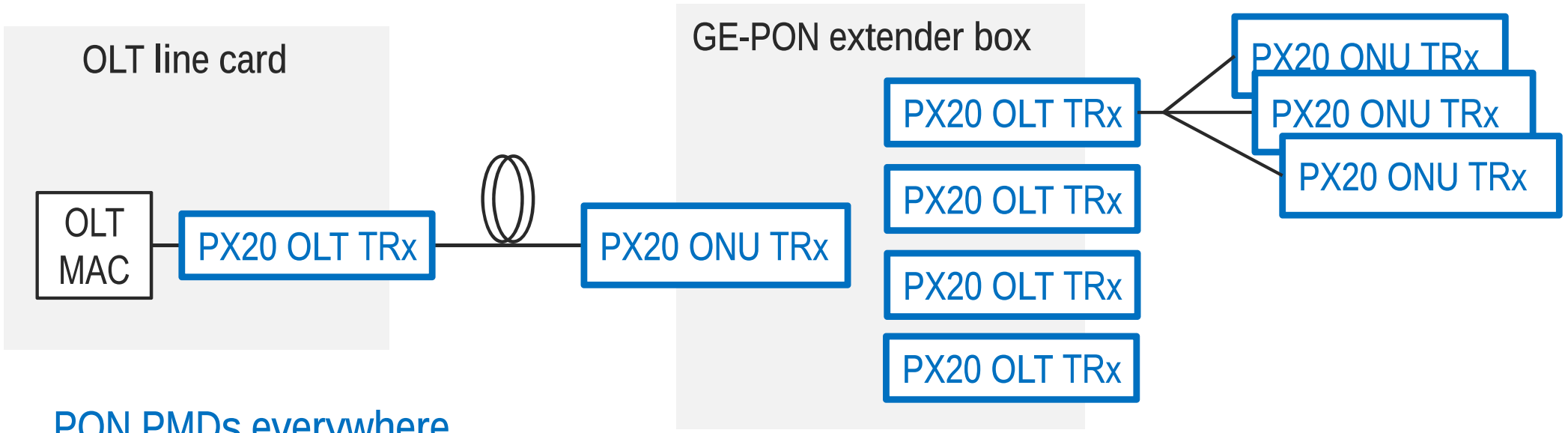
NeoPhotonics

- Upstream burst signals
  - Optical to electrical to electrical conversion
    - *In practice burst-mode receiver should be MAC-aware to reproduce PMD performance defined at OLT.*
    - If remote ExBox does not have data-rate information or reset information, performance can be compromised
    - *OEO can be enhanced by loss-less mode-coupling receiver.*
  - Optical amplification
    - SOA is OK for burst mode, fiber amplifiers require “adjustments”.
    - Praseodymium optical amplifiers possible at 1310 nm, SOAs available for all wavelengths.
    - *All* optical amplifiers challenged to meet 1260 – 1360 nm wavelength specification.
    - SOAs can act as a “limiting amplifier” improving upstream dynamic range.
      - Design rules are complex, but amenable to simplification
      - Noise is an issue that limits application of standard PMDs
        - » For $P_{in}$ ~ –30 dBm noise starts to dominate.
        - » (See RIN equation on previous slide and “Fujitsu” slide in backup)

# Backup

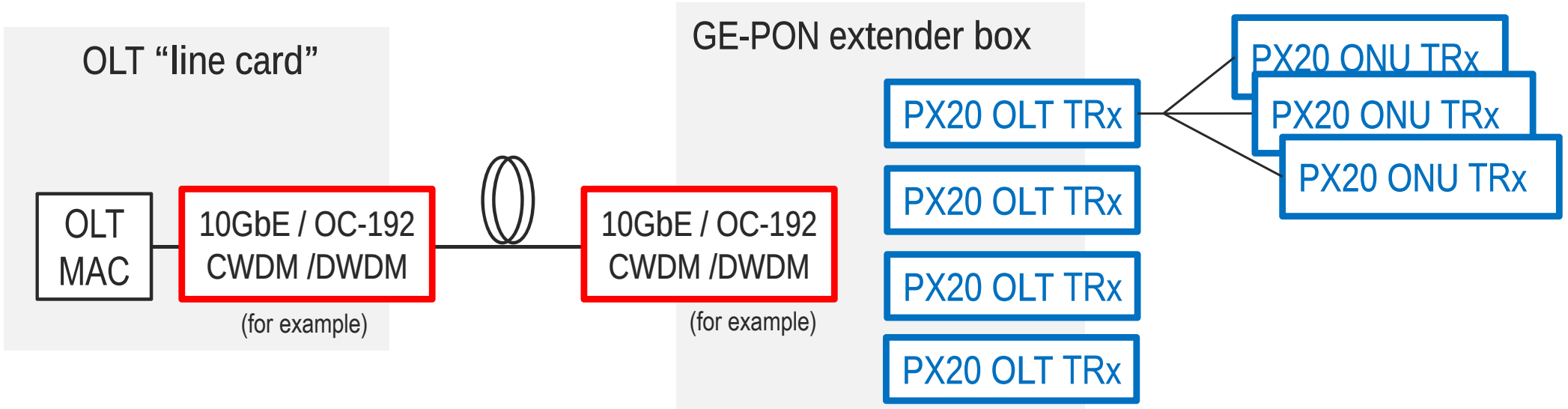
# OEO PON link extenders – two basic approaches

NeoPhotonics

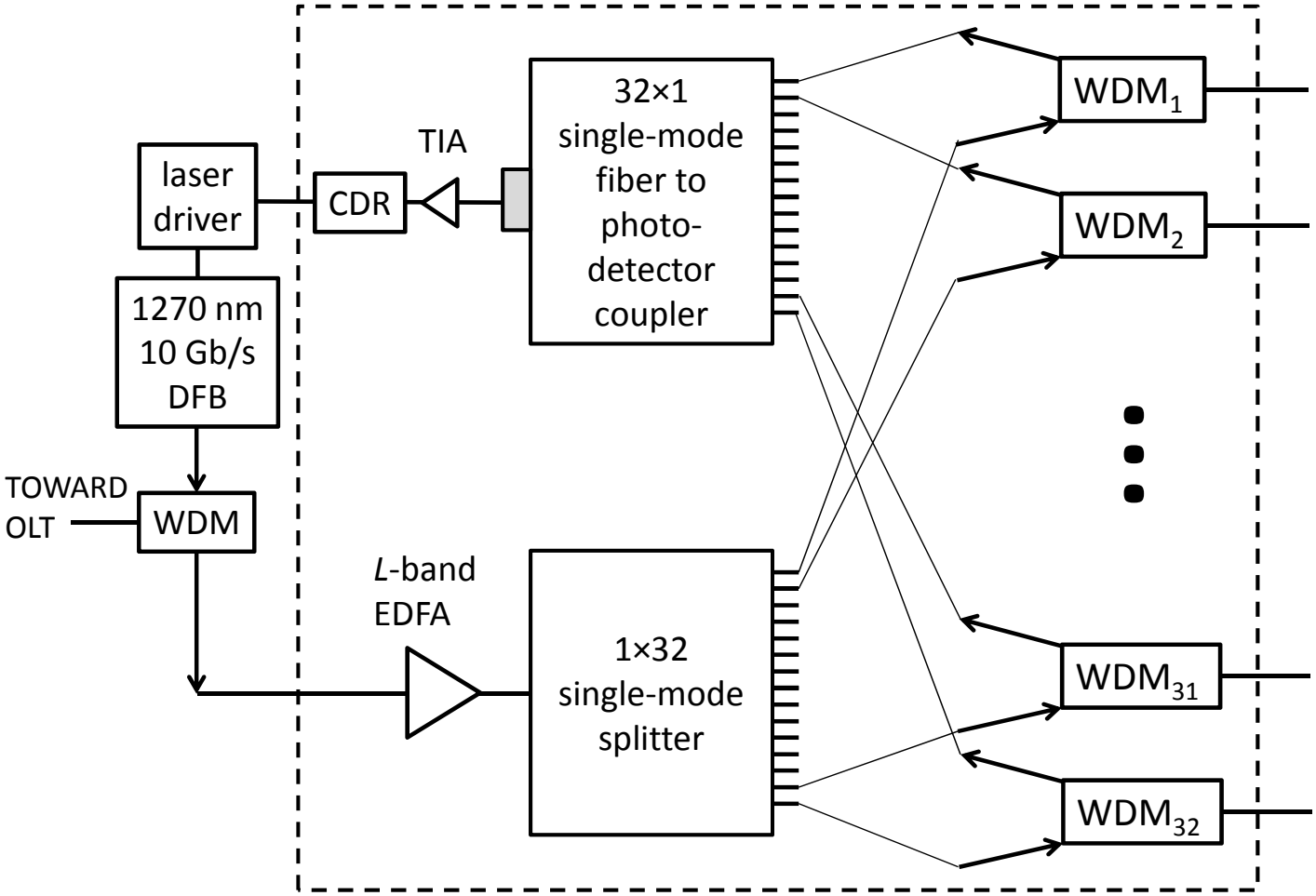



PON PMDs everywhere

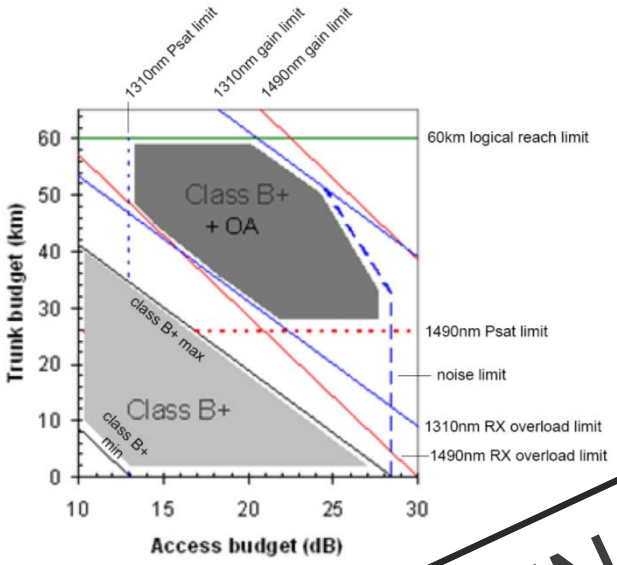
PON PMDs only on distribution side of extender

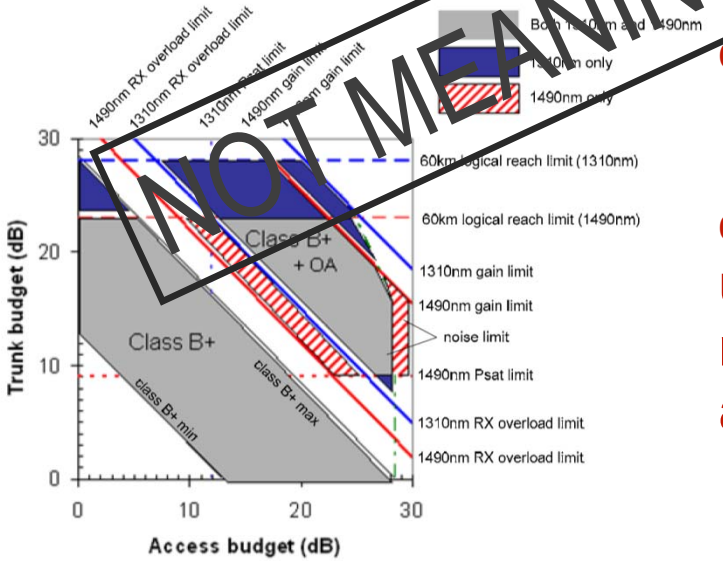


# OEO can be enhanced by *loss-less* mode-coupling receiver.



# System design with upstream SOAs – *Example*: G.984.6 (03/2008) Figure II-1 (page 32)




NOT MEANINGFUL

NOT SIMPLE

These charts send the message that

trunk budget = *f* (access budget)

and

access budget = $f^{-1}$(trunk budget)

and

*f* is complex

and

network engineering rules are

derived from

odd shaped polygons

derived from

upstream and downstream amplifier gain, saturation power, and noise figure, as well as PON receiver sensitivities and overloads, and transmitter launch power ranges.

# Simple and meaningful specification and design rule

## Optical Trunk Line

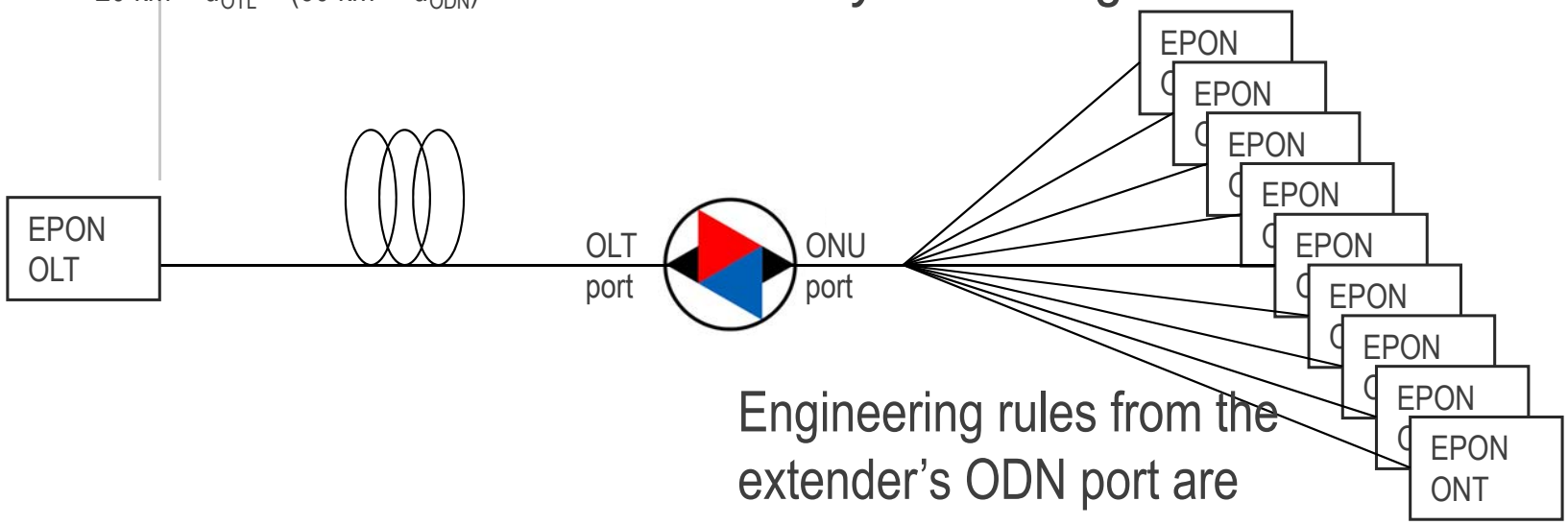
maximum link = 22* dB @ 1310 nm

20 km ≤ $d_{OTL}$ ≤ (60 km – $d_{ODN}$)

## Optical Distribution Network

minimum link = 14 dB
maximum link = 29 dB
0 ≤ $d_{ODN}$ ≤ 20 km

**dynamic range = 15 dB**




Engineering rules from the extender's ODN port are *exactly the same* PX 30 OLT port

* this depends on the user's maximum OTL link / distance requirements

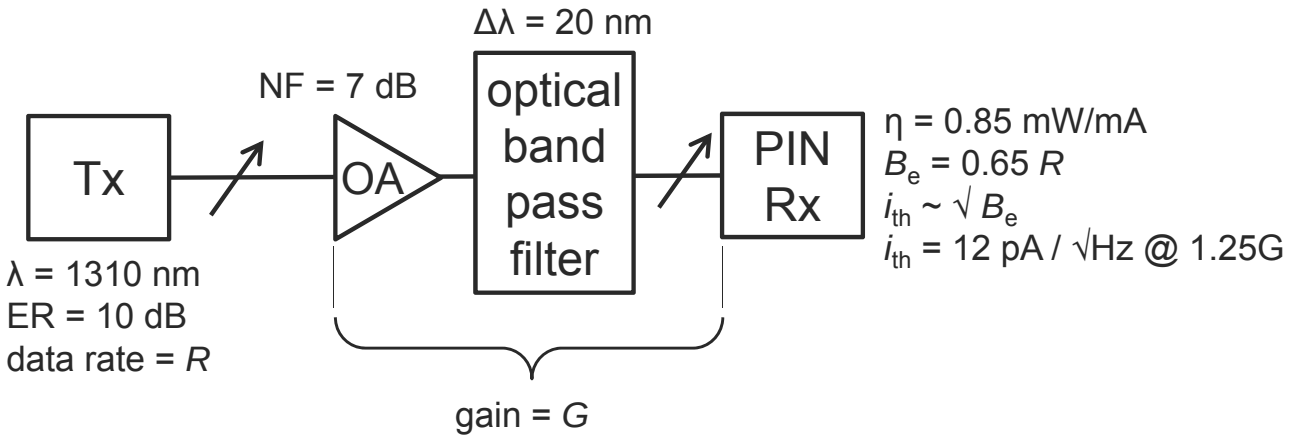
# **Do the math**:
# Optical pre-amplifier vs. APD

**Numerical model** of optical pre-amplifier sensitivity (@$10^{-12}$ BER) for various data rates with the listed parameters.

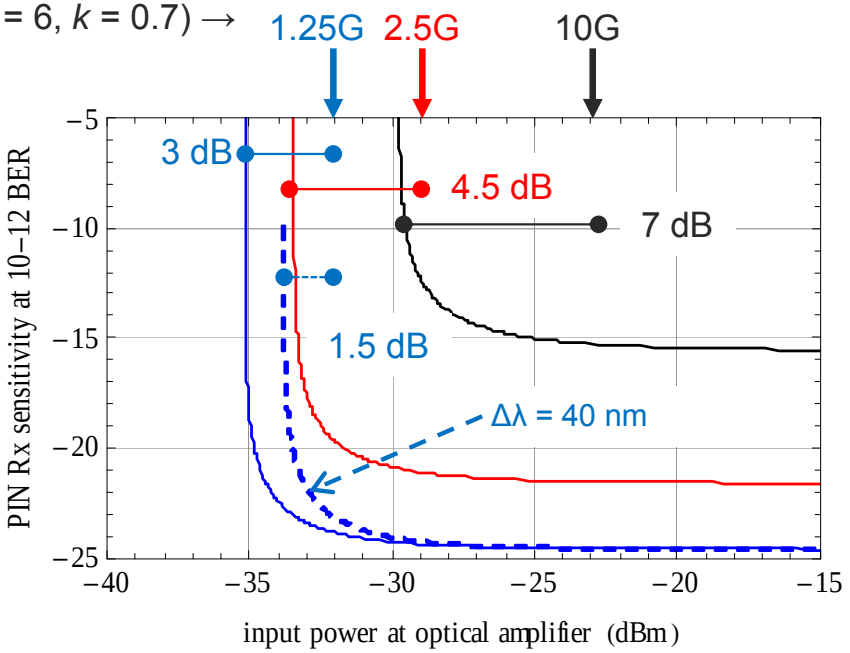
In the asymptotic[1] limit, an optical pre-amplifier improves the net receiver sensitivity by
3 dB at 1.25 G
4.5 dB at 2.5G
7 dB at 10G

[1]Realistic improvement is about 1 dB lower than the asymptotic improvement.

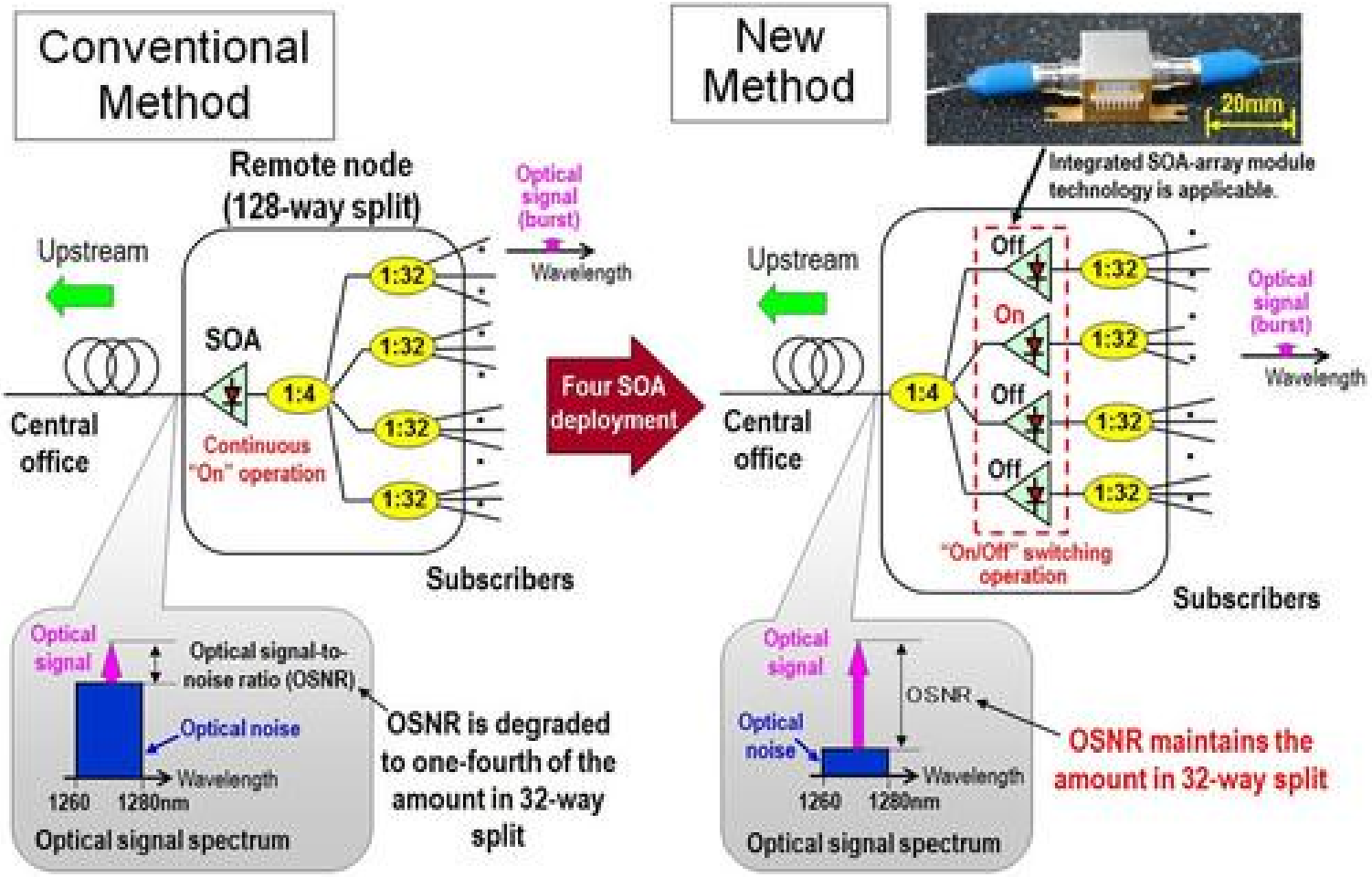
Also shown is the relevant GPON (blue dashed) curve (Δλ = 40 nm)




Sensitivity with APD only
($M$ = 6, $k$ = 0.7) →



# Upstream burst-mode SOAs




Source: "Fujitsu pushes PON splitting", www.lightreading.com, 13 October 2011.