EXPERIMENTAL DEMONSTRATION OF IN-FIELD 400G COHERENT METRO-ACCESS CONVERGENCE

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Acknowledgments

- This work was funded by the European Union's Horizon Europe research and innovation programme under grant agreement No. 101092766 (ALLEGRO Project)

- Mrs. Casasco's PhD is sponsored by TIM

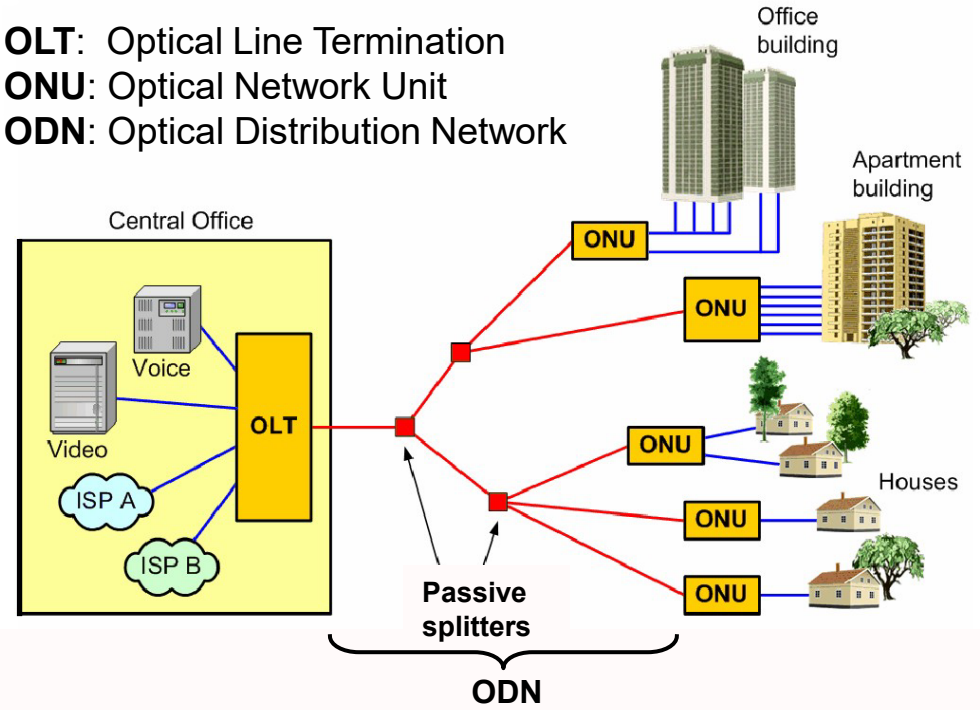
- Experiments were carried out in the PhotoNext Center laboratoryat Politecnico di Torino
  www.photonext.polito.it

Current State of Affairs

- **Fiber-to-the-X** worldwide: estimated more than 1 billion optical broadband subscribers
  - nearly all of them on the Passive Optical Network (PON) architecture

- **PON standardization roadmap**:
  - ITU-T G.9807 XG(S)-PON
    - 10G, OOK, O-BAND, PIN → COMMERCIAL
  - ITU-T G.9804 50G-PON
    - OOK, O-BAND, APD → RELEASED in 2021
  - ITU-T G.suppl.VHSP
    - 100G? 200G? PAM-4? DSP? Coherent? → UNDER DISCUSSION

OLT: Optical Line Termination
ONU: Optical Network Unit
ODN: Optical Distribution Network



Coherent in the Access Segment?

- Intensity Modulation Direct Detection (IMDD) PON limitations
  - OOK not suitable for beyond 50G/λ due to optoelectronic bandwidth limitations
  - typical target distance is 20-40 km due to chromatic dispersion
  - stringent power budget requirements (**> 29 dB**) to allow for high splitting ratios
  - limited launch power to avoid nonlinear effects (typically 11 dBm at most)

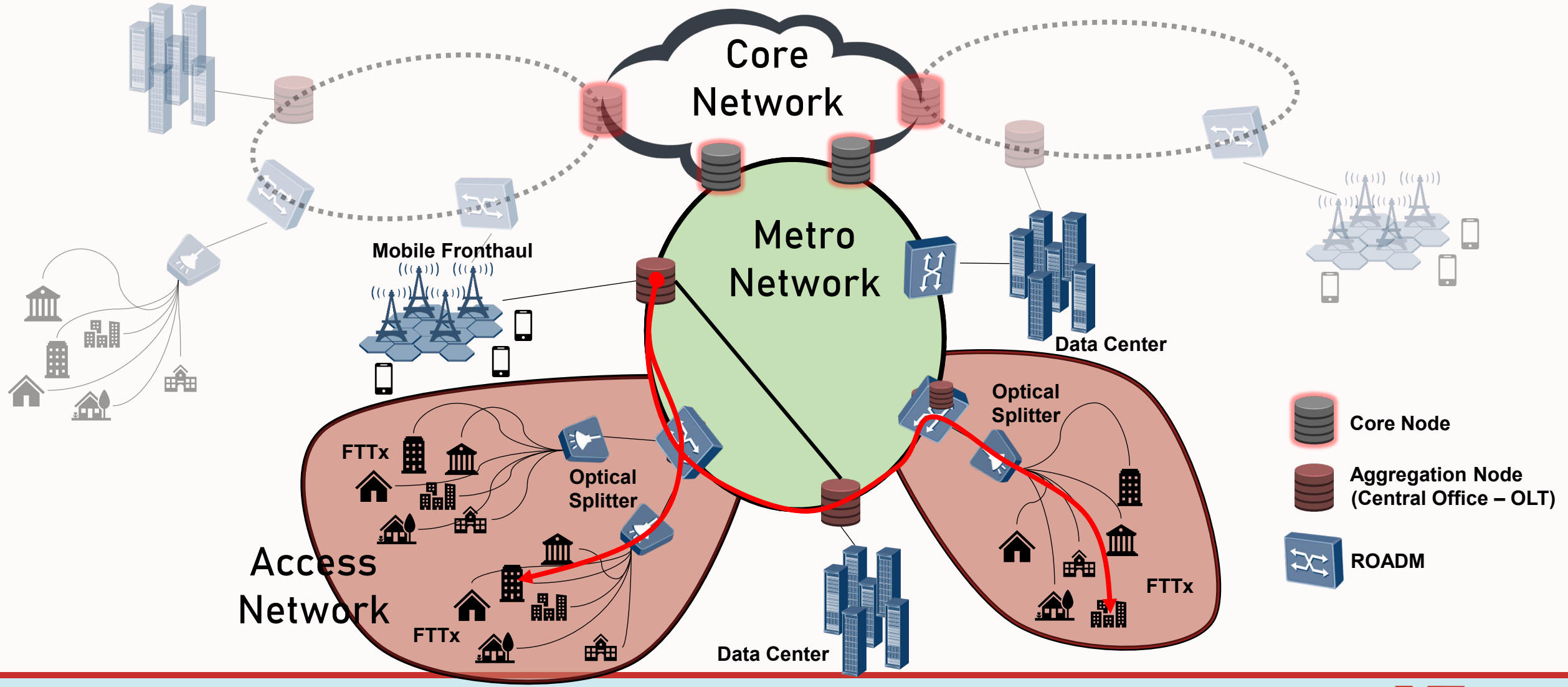
- Can **coherent detection** help?
  - may enable not only 200G-PON but even 400G-PON
  - can break the traditional 20-40 km "PON barrier" towards extended reach PON
  - can even break the 1x64-split barrier, allowing more than 64 ONUs

But, the cost of coherent transceivers is still too high for PON applications

Metro-Access Convergence

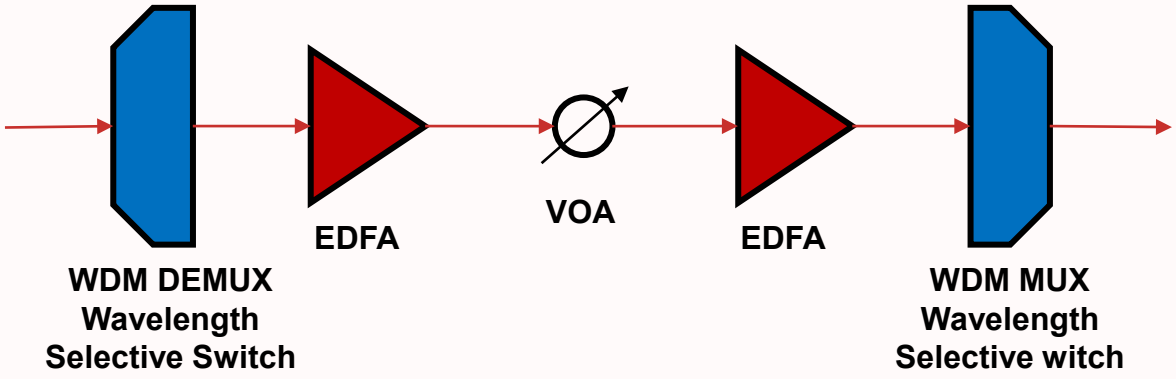
- Commercial demand for such high speeds in PON can be expected in several years from now
  - Possible cost reduction of coherent technologies
- A significant **network-level re-organization** would also be possible, employing the same transmission/detection/switching technologies in the Metro and Access segments
  - Full-coherent ultra-high-speed system
  - All-optical with less O-E-O conversion stages
  - Reduced number of central offices and simplified network management
- A converged solution must meet requirements imposed by both segments
  - Constraints on the required OSNR
  - Filtering effects inside ROADMs
  - PON imposed **>29 dB Optical Power Budget** (OPB)

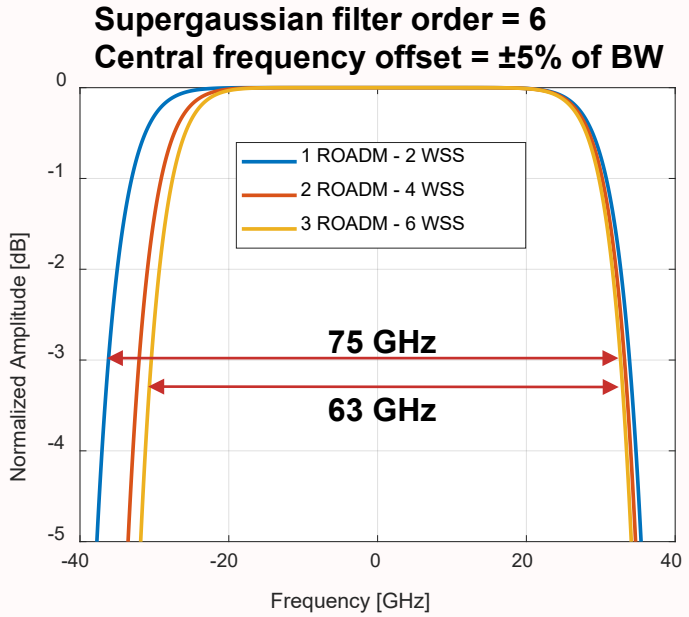
Metro-Access Converged Network



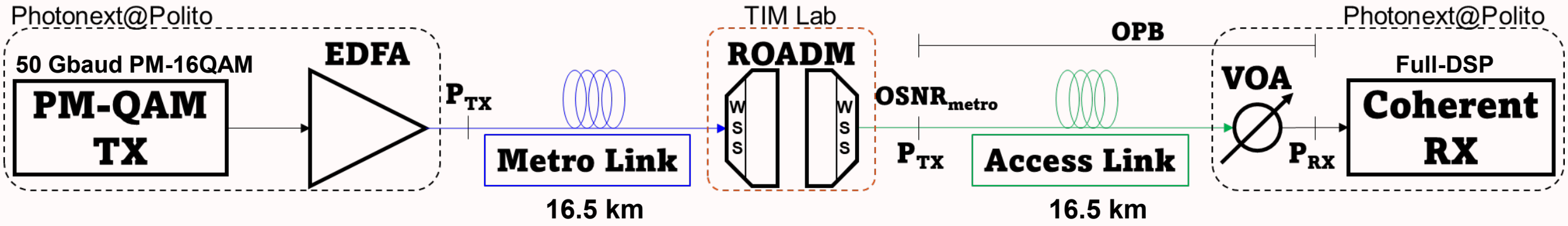
Experimental Setup @ PHOTONEXT

WSS-Based ROADM





Emulated Metro-Access Scenario (Downstream)



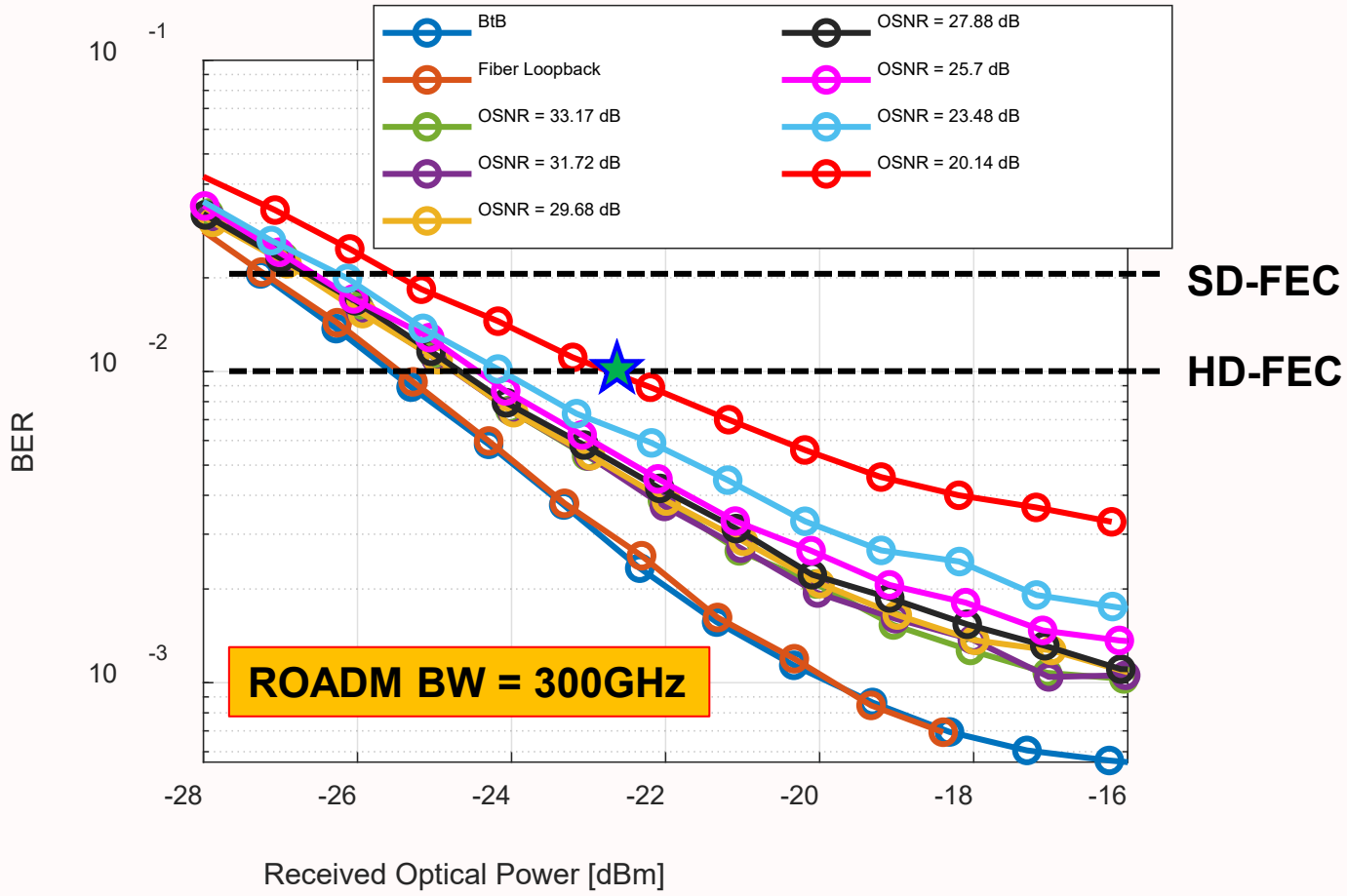
400G Transmission - Sensitivity

OSNR is **defined** on a bandwidth equal to the baud rate (50 GHz)

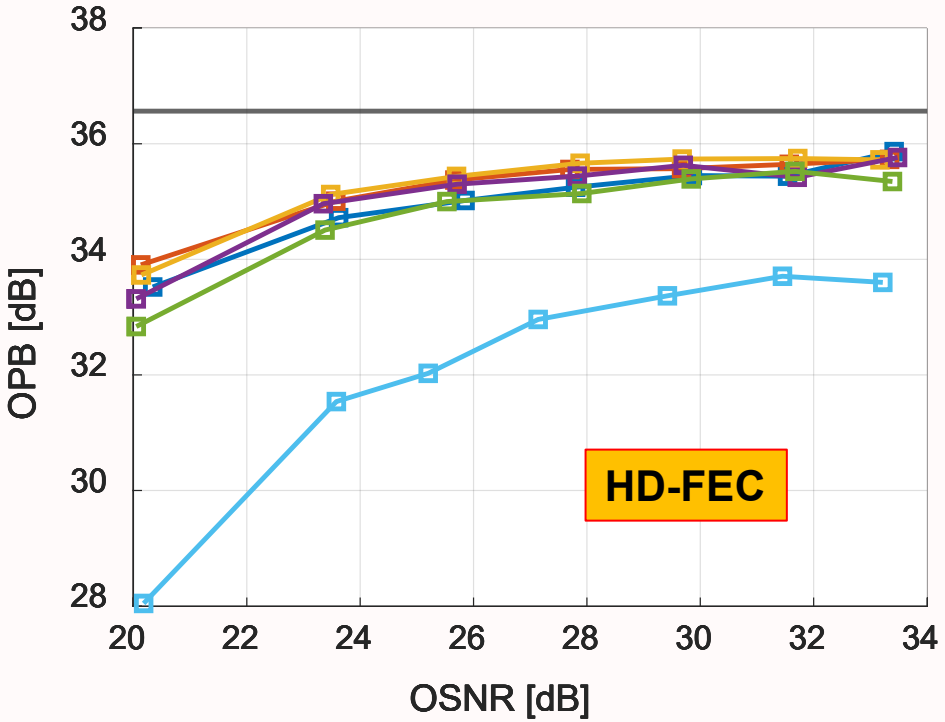
Fiber Loopback configuration is without ROADM

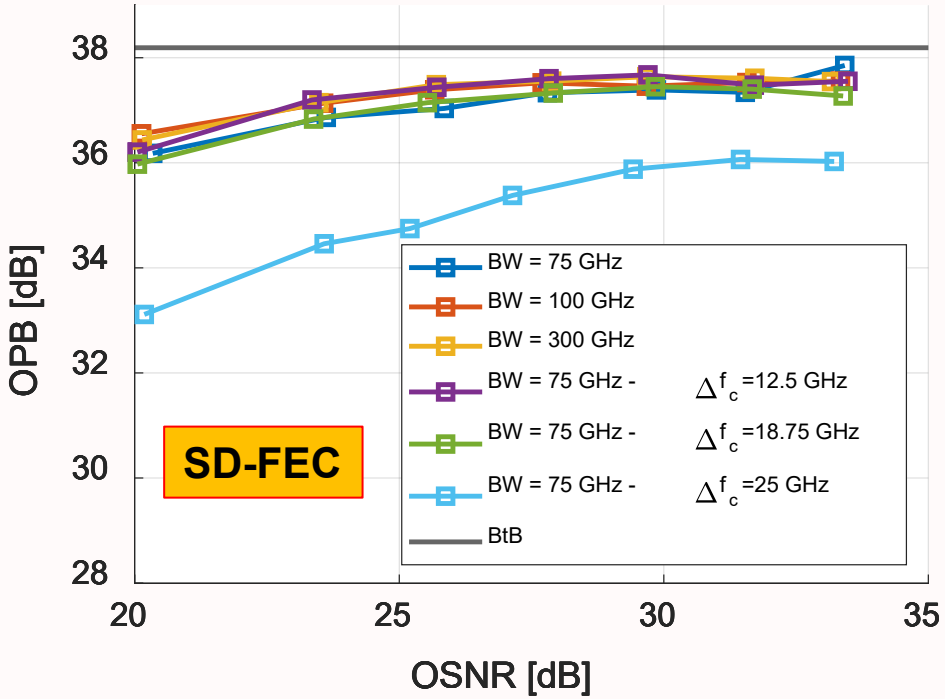
$$P_{TX} = 11\ dBm$$

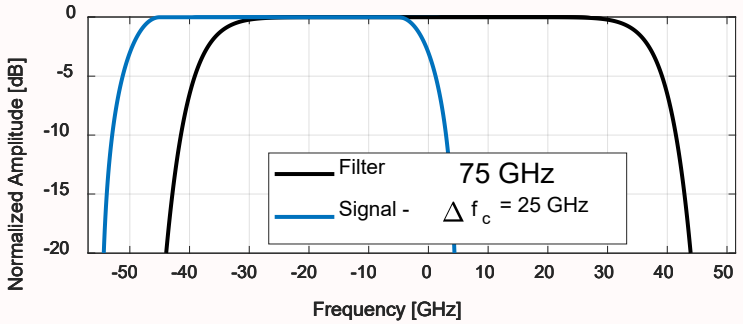
OPB is more than 33 dB at the lowest OSNR for HD-FEC



400G Transmission – Filtering Effect on the Power Budget







- The model was presented in JLT in 2021
  - For unamplified systems
  - Optical amplification can also be accounted for

JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 39, NO. 18, SEPTEMBER 15, 2021 5805

Scaling Laws for Unamplified Coherent Transmission in Next-Generation Short-Reach and Access Networks

Giuseppe Rizzelli Martella, Antonino Nespola, Stefano Straullu, Fabrizio Forghieri, and Roberto Gaudino, *Senior Member, IEEE*

$$\sigma_{th}^2 = \frac{i_{TIA}^2 \cdot B_{eq}^{RX}}{8 \cdot R^2}$$

$$\sigma_{shot}^2 = \frac{q \cdot B_{eq}^{RX}}{2 \cdot R}$$

$$B_{eq}^{RX} = 60\% \cdot R_s$$

$$SNR_{RX} = \frac{P_s}{\frac{\sigma_{th}^2}{P_{LO}} + P_{LO} \cdot \sigma_{n_{LO}}^2 \cdot CMRR + \sigma_{shot}^2 + \frac{P_s}{SNR_Q} + \frac{P_s}{OSNR_{ASE}}}$$

$$\sigma_{n_{LO}}^2 = RIN \cdot \frac{B_{eq}^{RX}}{2}$$

"Quantization" Noise Accounting for power-independent effects (BER floor)

ASE-induced Optical Noise

Fitting of Experimental Results and Scalability

Goals

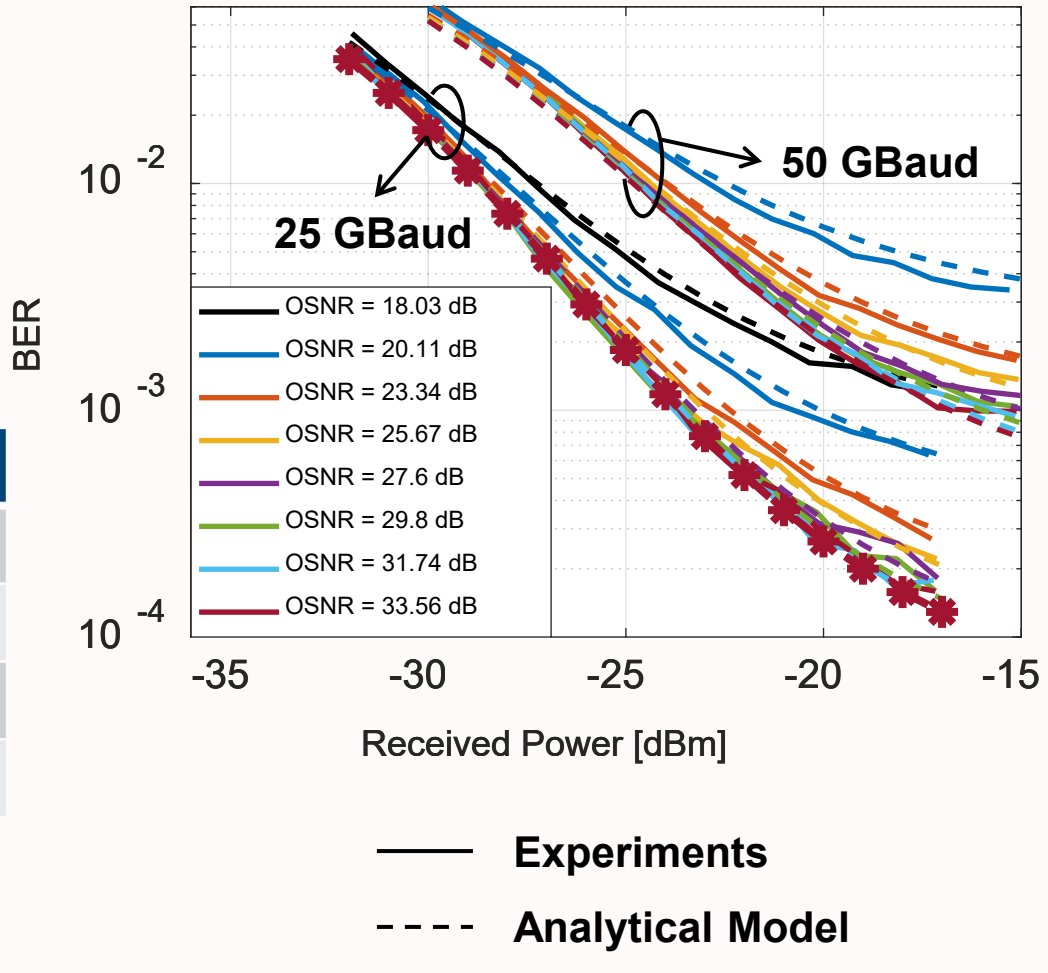
- find *R*, *CMRR*, i_{TIA} and SNR_Q with the minimum number of experimental data
- Validate scalability with OSNR and symbol rate

Procedure

- Use experimental curve at maximum OSNR for fitting
- Apply analytical formula for SNR
- Convert SNR into BER

$$BER_{16-QAM} = \frac{3}{8} erfc\left(\sqrt{\frac{SNR_{RX}}{10}}\right)$$

Parameter	Value	Unit
R	0.067	A/W
CMRR	-18.35	dB
i_{TIA}	20.73	$pA/\sqrt{Hz}$
SNR_Q	17.7	dB



Scalability Analysis

400G PM-16QAM performs well (> 29 dB OPB)

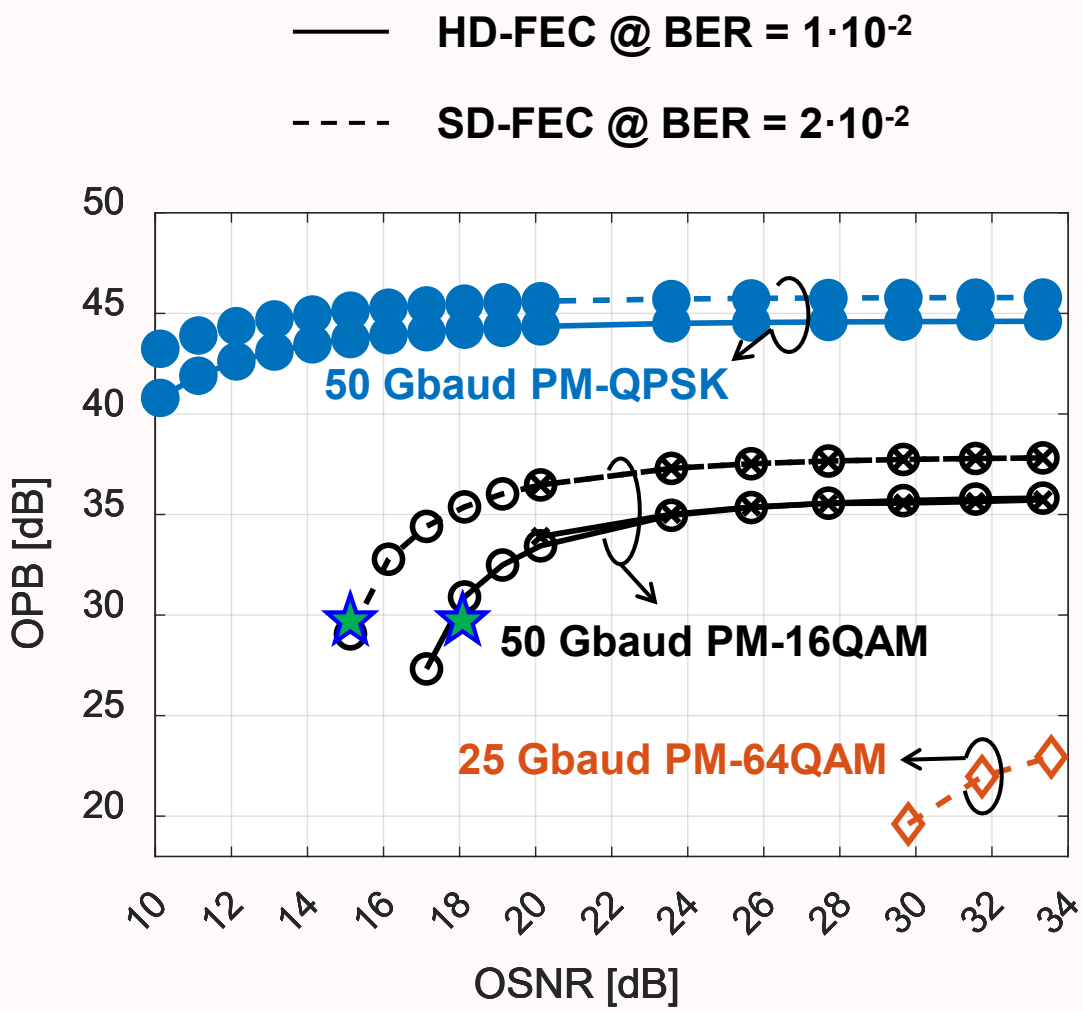
At least for

- OSNR > 18 dB for HD-FEC
- OSNR > 15 dB for SD-FEC

200G PM-QPSK is very robust even at extremely low OSNR levels

OPB > 40 dB

PM-64QAM very critical even at lower 25 Gbaud symbol rate (**300G**)



Conclusions

- We have experimentally validated the all-optical coherent metro-access converged scenario
  - Up to 400G transmission using commercial coherent transceivers
  - WSS-based ROADM filtering effect

- We have shown a scalability analysis using a fitting-based analytical model
  - 400G PM-16QAM requires non-critical OSNR levels > 18 dB (15 dB for SD-FEC)
  - 200G PM-QPSK coherent solution has excellent performance (OPB > 40 dB)
    - Higher splitting factors and longer reach can be envisioned

THANK YOU FOR YOUR ATTENTION!!

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Our papers on PON

Our JLT on the model

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