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Paper Th.2.6.3

Reflective FDMA-PON with 32 Gbps upstream capacity per wavelength and more than 32 dB ODN loss

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FP7-ICT-2011-8 Challenge 3.5 – STREP project n. 318704 – FABULOUS
FDMA Access By Using Low-cost Optical Network Units in Silicon photonics

Outline

- The EU project FABULOUS: proposed architecture
  - Focus of the paper: upstream physical layer
- Optimization of several transmission parameters
- Experimental results
- Conclusion

FABULOUS at-a-glance

FDMA
Access
By
Using
Low-cost
Optical network
Units in
Silicon photonics

FP7-ICT-2011-8 – Objective 3.5:
Core and disruptive photonic technologies

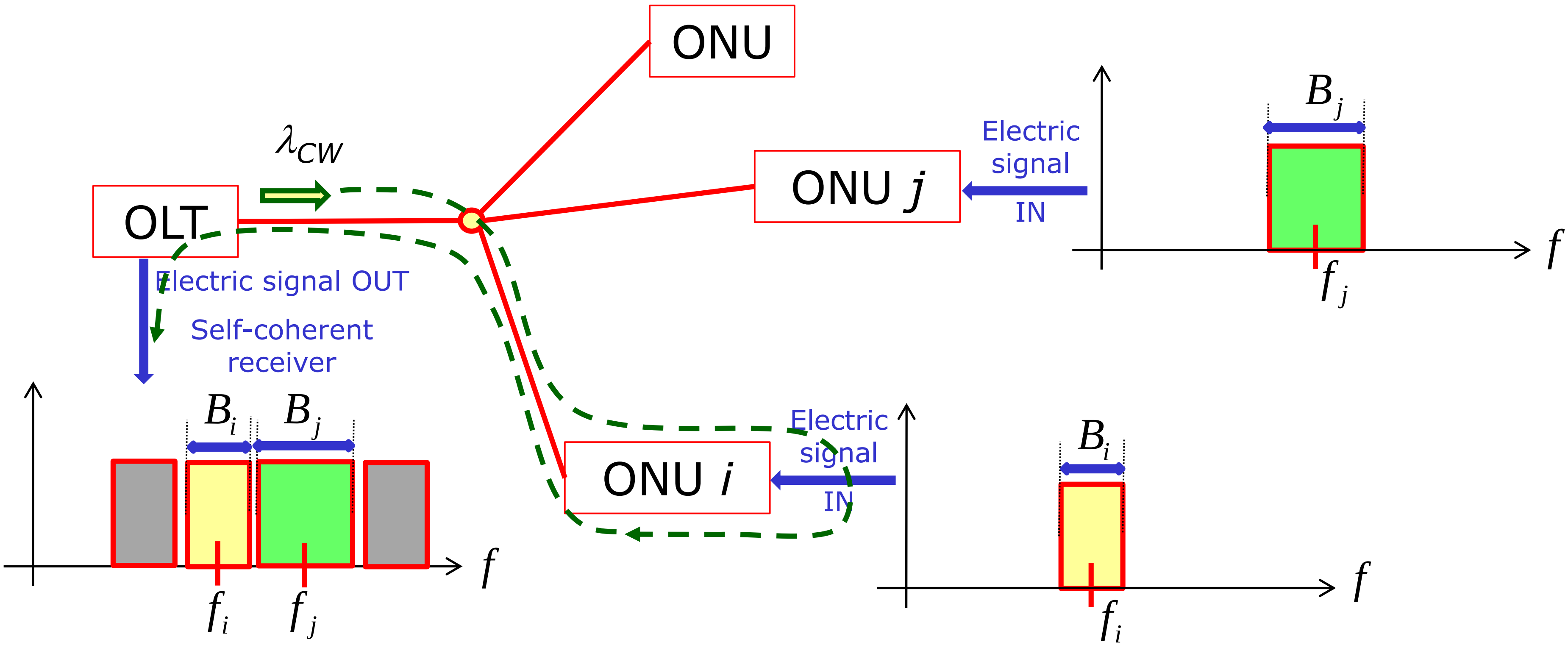
"Application-specific photonic components and subsystems"

"For access networks, the goal is affordable technology enabling 1-10 Gb/s data-rate per client"

System architecture

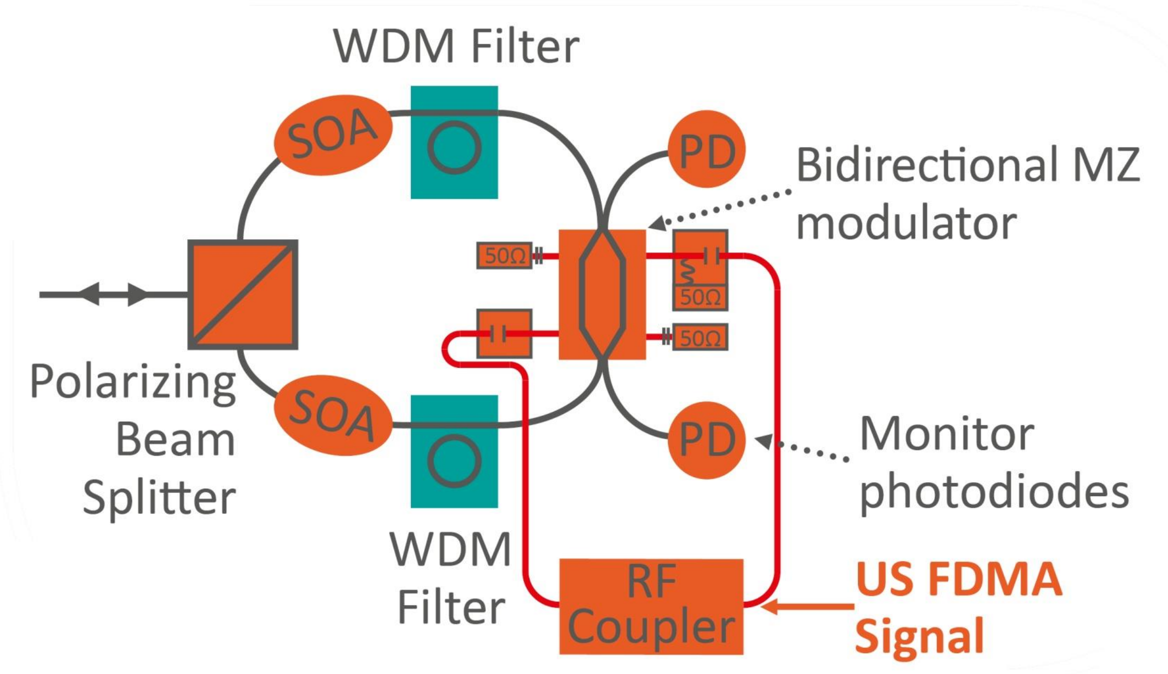
Frequency division multiplexed (FDMA) PON

- PON based on electrical subcarrier FDM/FDMA in both directions
- This presentation: focus on upstream



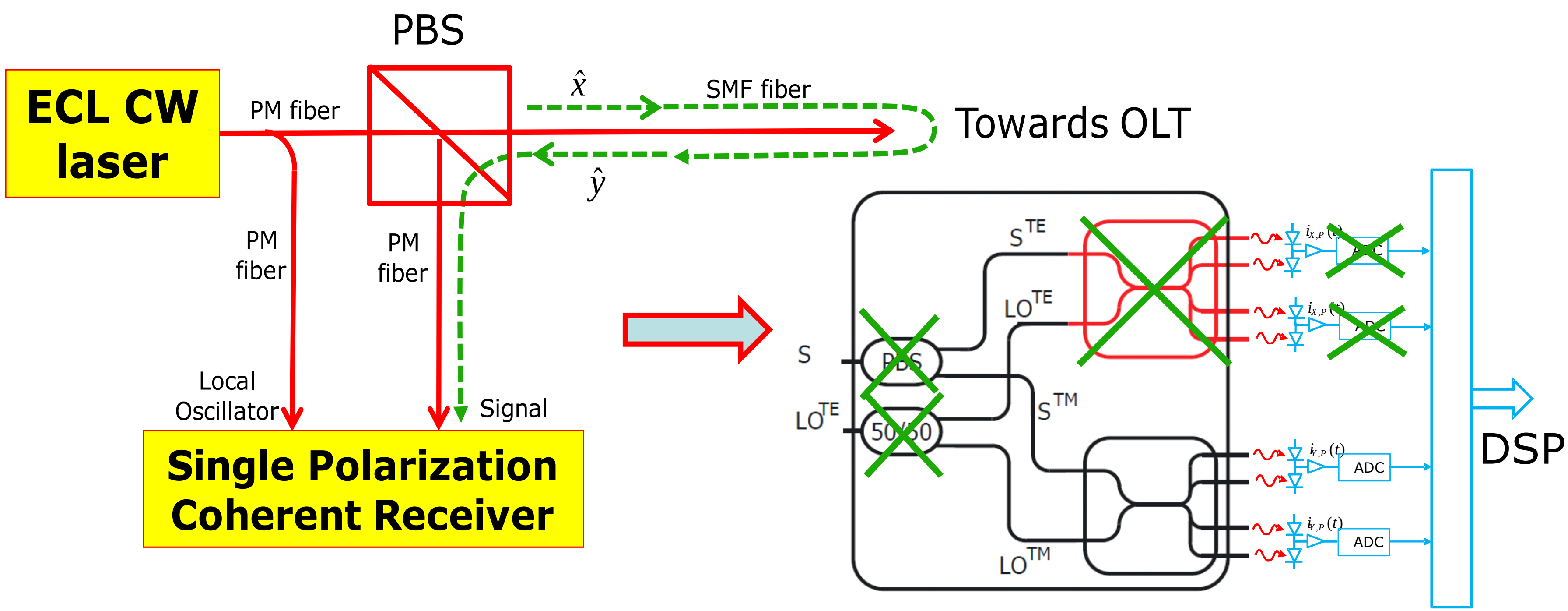
Detail on the ONU

One of the main purposes of the project is to integrate the required reflective ONU on a Silicon Photonics platform



Self-coherent detection at OLT

- Self-coherent detection at OLT enables high ODN loss achievements even in a reflective architecture
  - Intrinsic Faraday rotation at R-ONU allows simplified single polarization coherent detection at the OLT



Novelty of this work

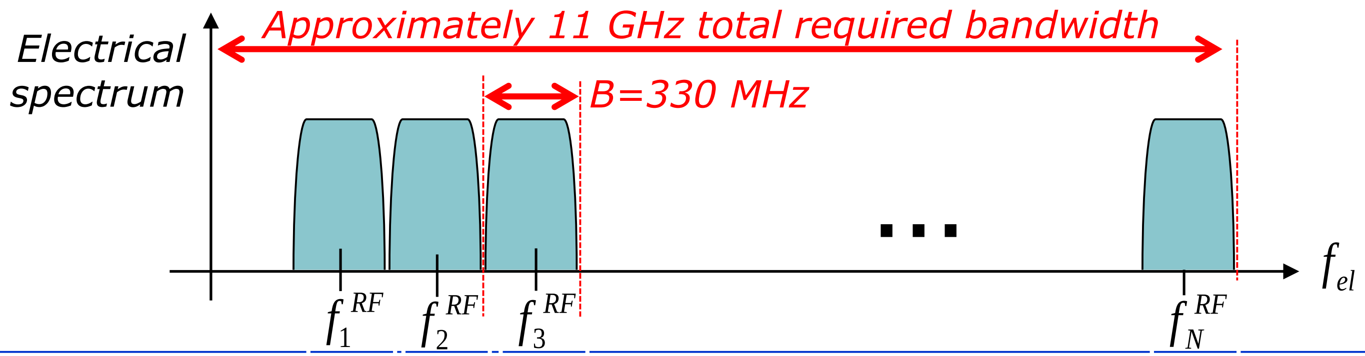
The novelty of this work compared to previous papers of the FABULOUS project consortium is related to:

- Focus on maximum possible ODN loss
  - To be compliant with ITU-T ODN loss classes
  - high bit rate per user (all users at 1 Gbps)
- Optimization of several ONU free parameters

System Upstream Experiments

Main physical layer parameters

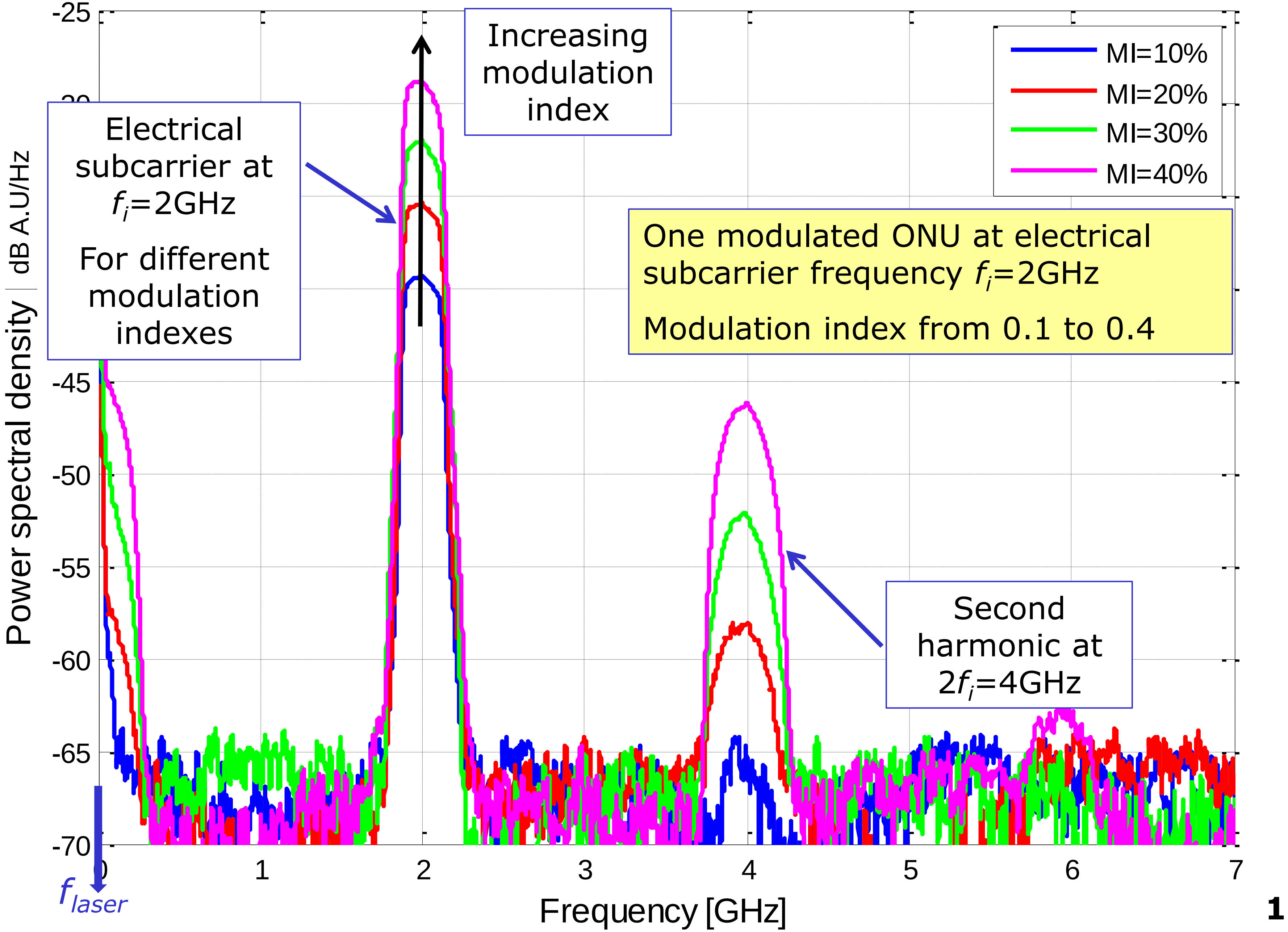
- Data rate per user fixed at 1 Gbps
  - (net data rate, giving a gross rate of 1.2 Gbps including FEC, overhead and line coding)
- Modulation format fixed at 16-QAM
  - Raised cosine spectrum, roll-off=0.1
  - Requires *B*~330 MHz per user
- 32 users per wavelength
  - the modulator has 11 GHz cut-off



Parameters to be optimized

- Modulation index $$MI = \frac{V_p}{V_\pi}$$
  Peak voltage of the electrical signal (V_p)
  V_p of the Mach-Zehender modulator (V_π)
- Electrical channel allocation $f_1 \cdots f_N$
- Electrical frequency spacing $\Delta f = f_{i+1} - f_i$
- SOA biasing current I_{bias}

Optical spectrum (high resolution OSA)

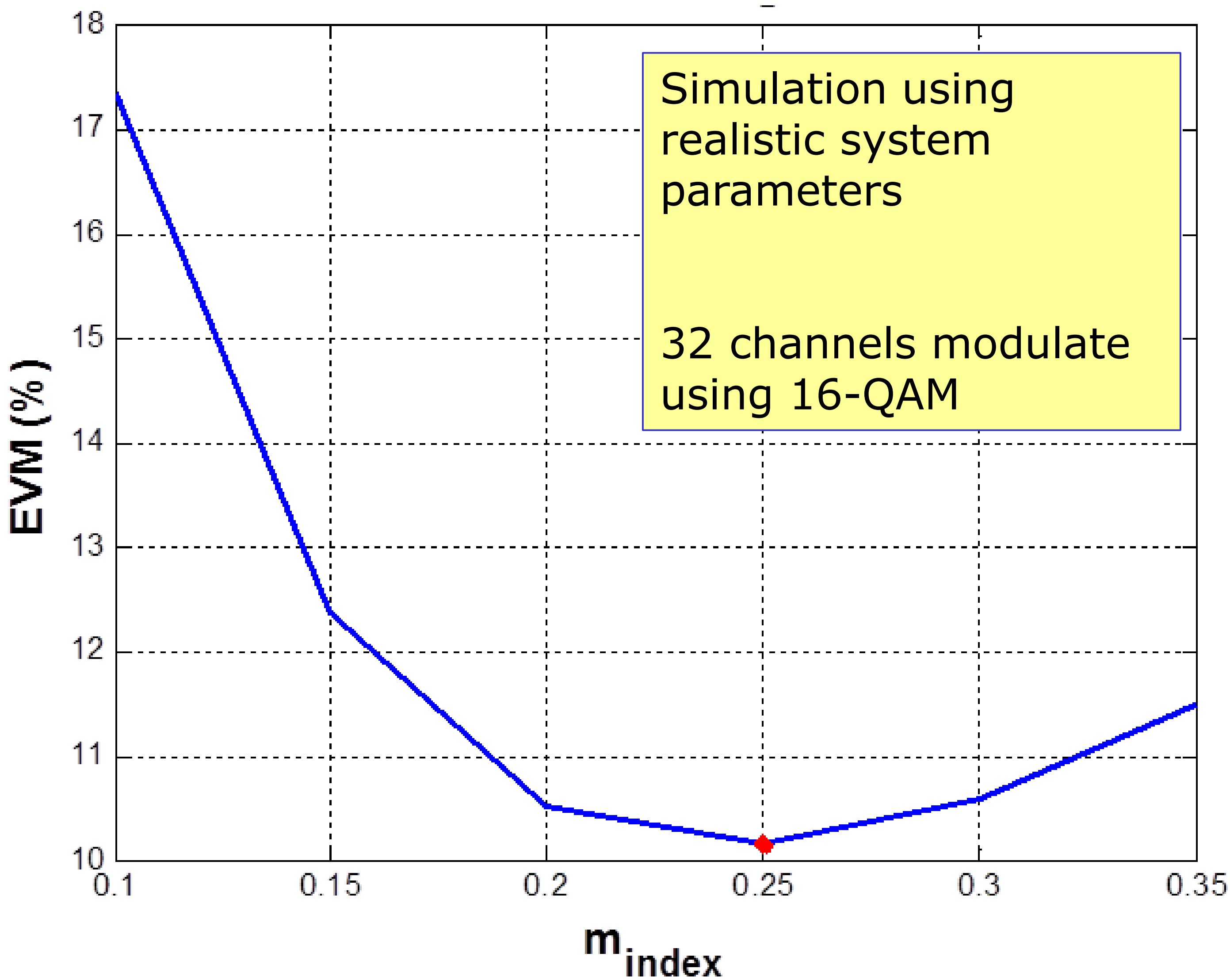


Minimizing the nonlinear effects

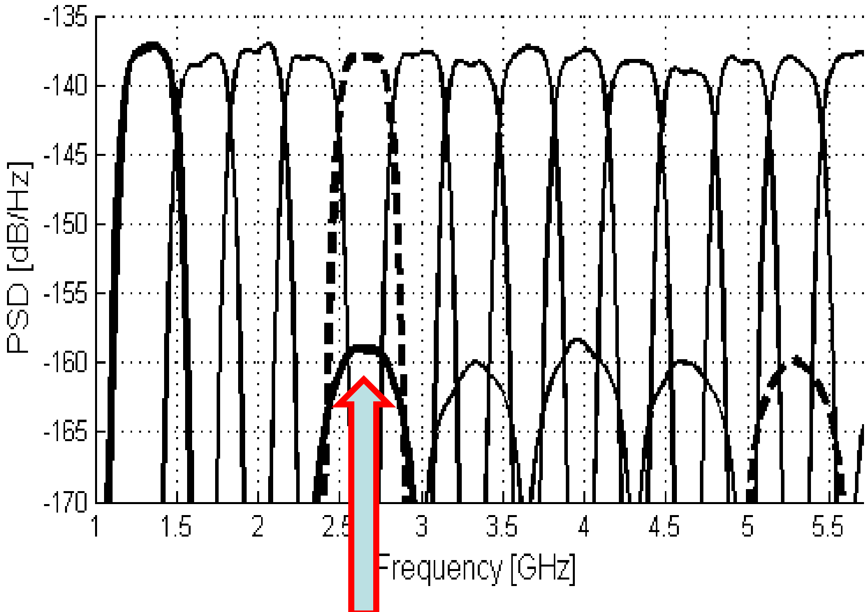
- The second harmonic can generate crosstalk on a higher frequency useful subcarrier, used by another ONU

- We thus theoretically and experimentally found:
  - An optimized modulation index
  - An optimized position for the comb of subcarriers

Optimizing the modulation index

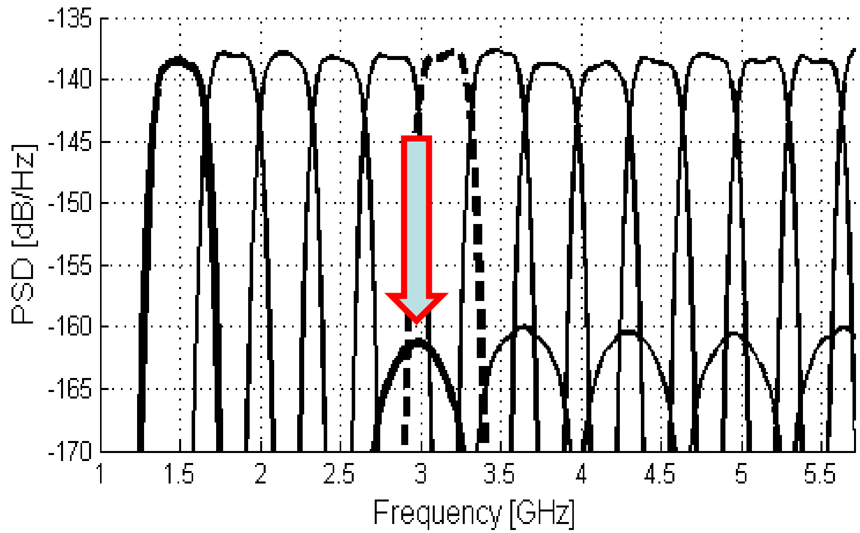


Subcarrier frequency allocation

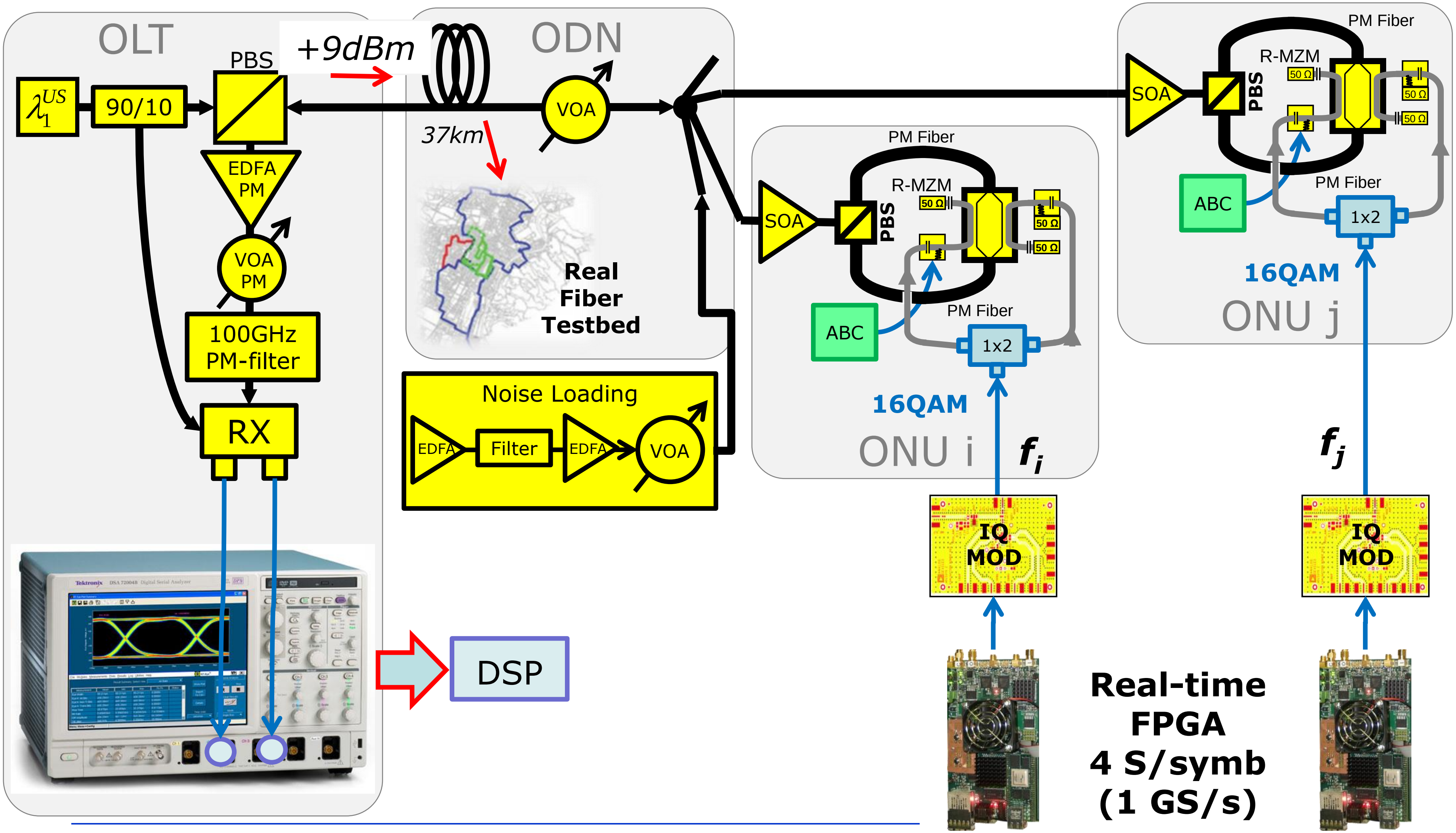


Worst frequency allocation: second harmonic falls exactly at the center of another modulated channel

Best frequency allocation: second harmonic falls exactly at in the middle of two another modulated channels

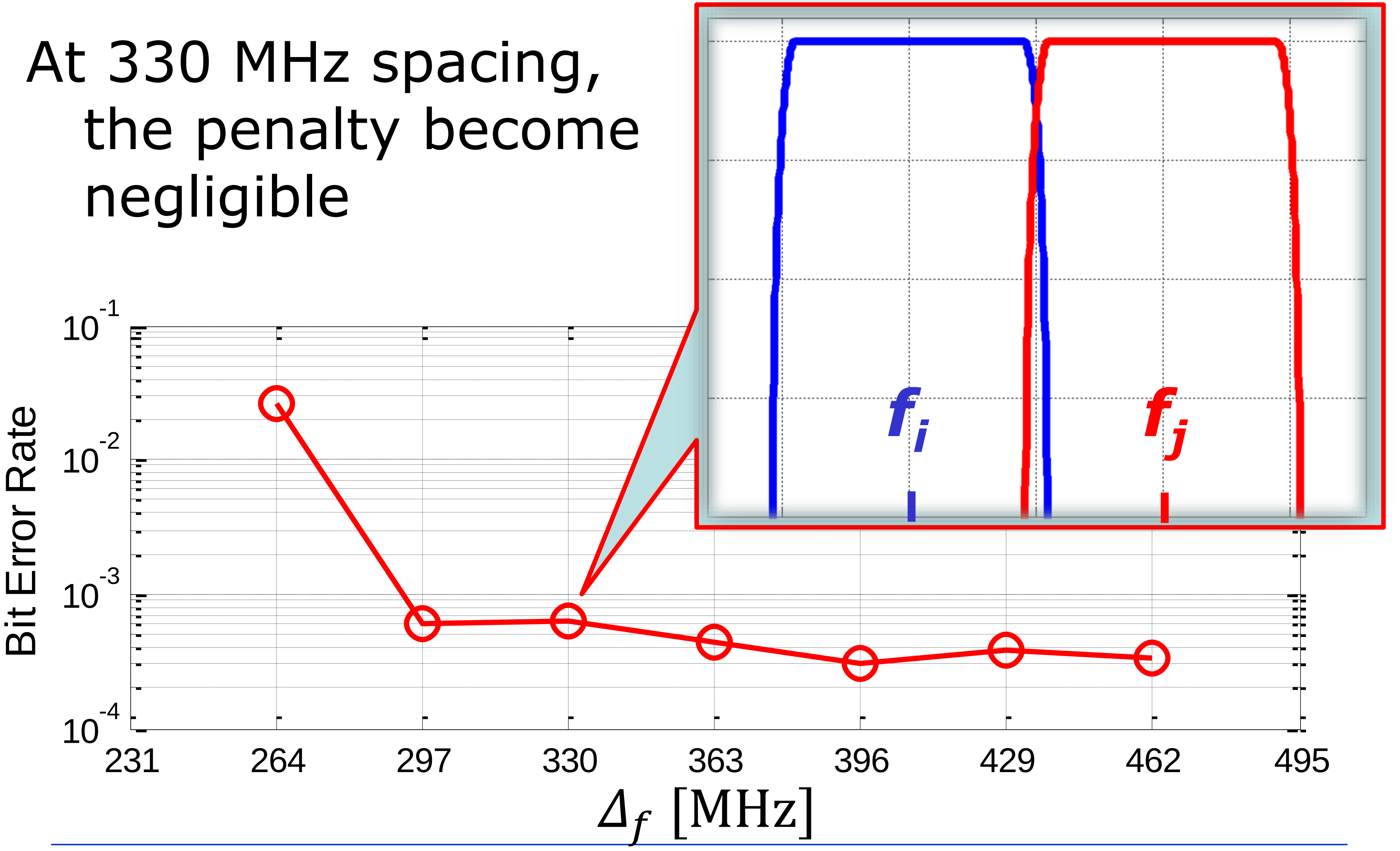


Upstream setup – 2 active ONUs

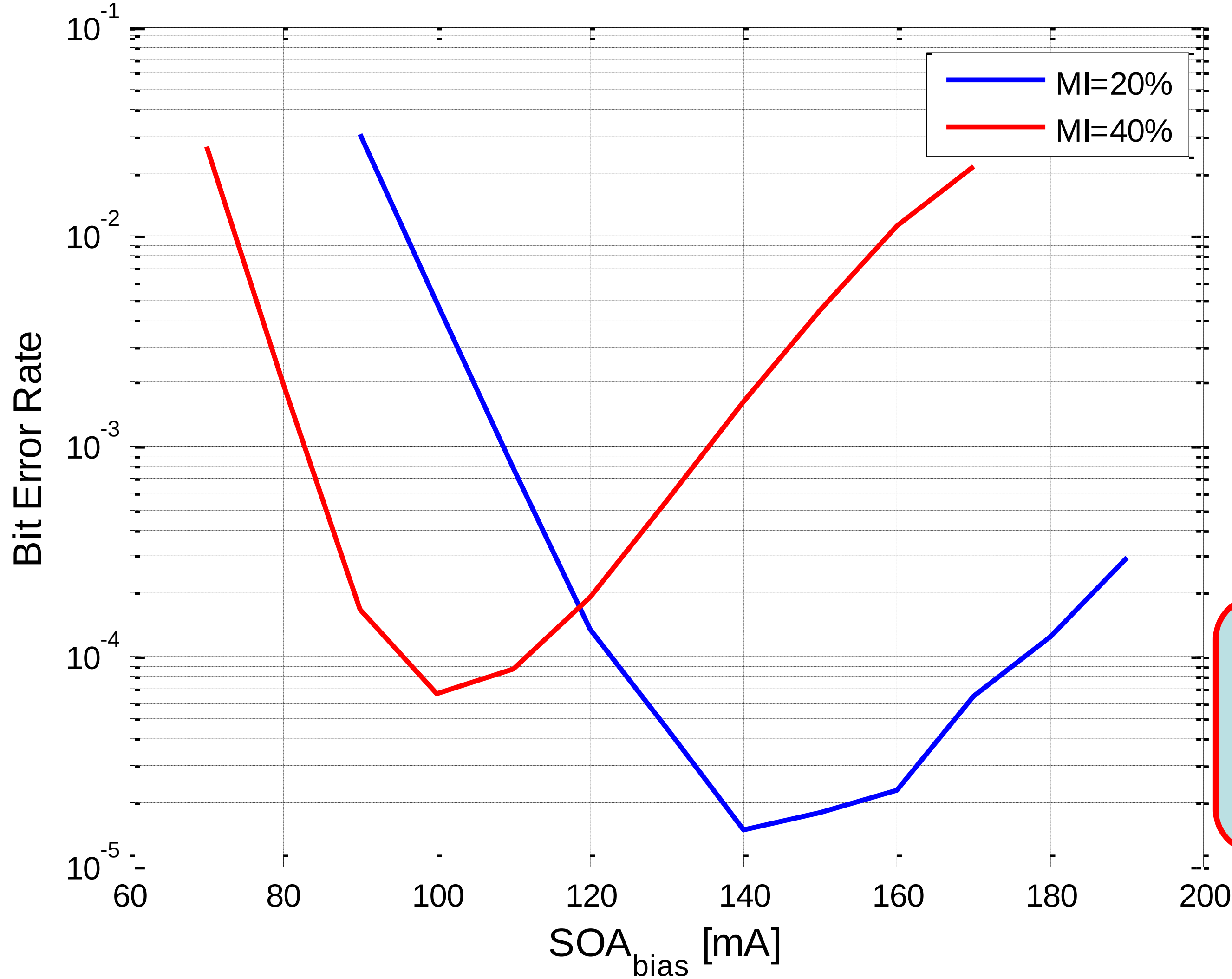


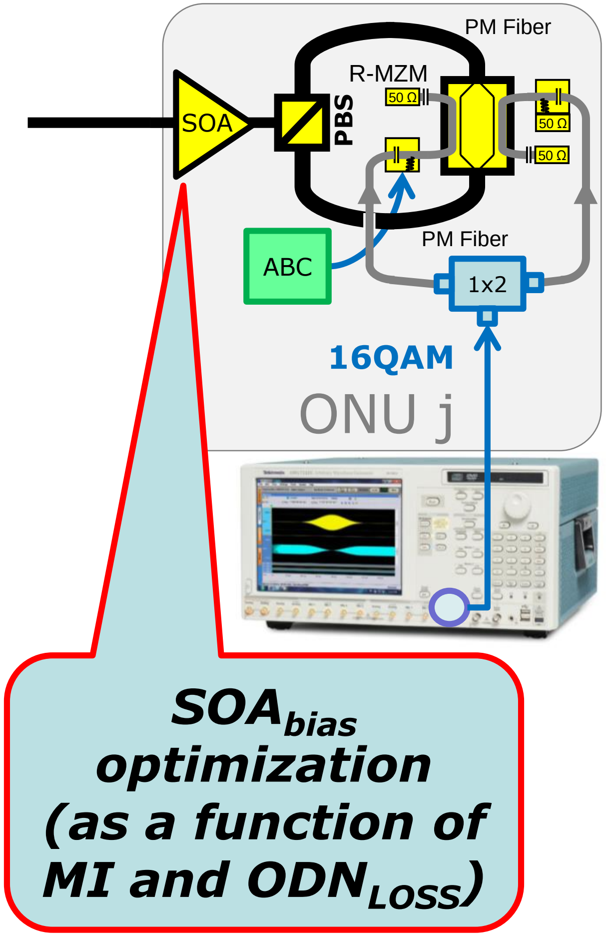
Electrical channel spacing optimization

At 330 MHz spacing, the penalty become negligible

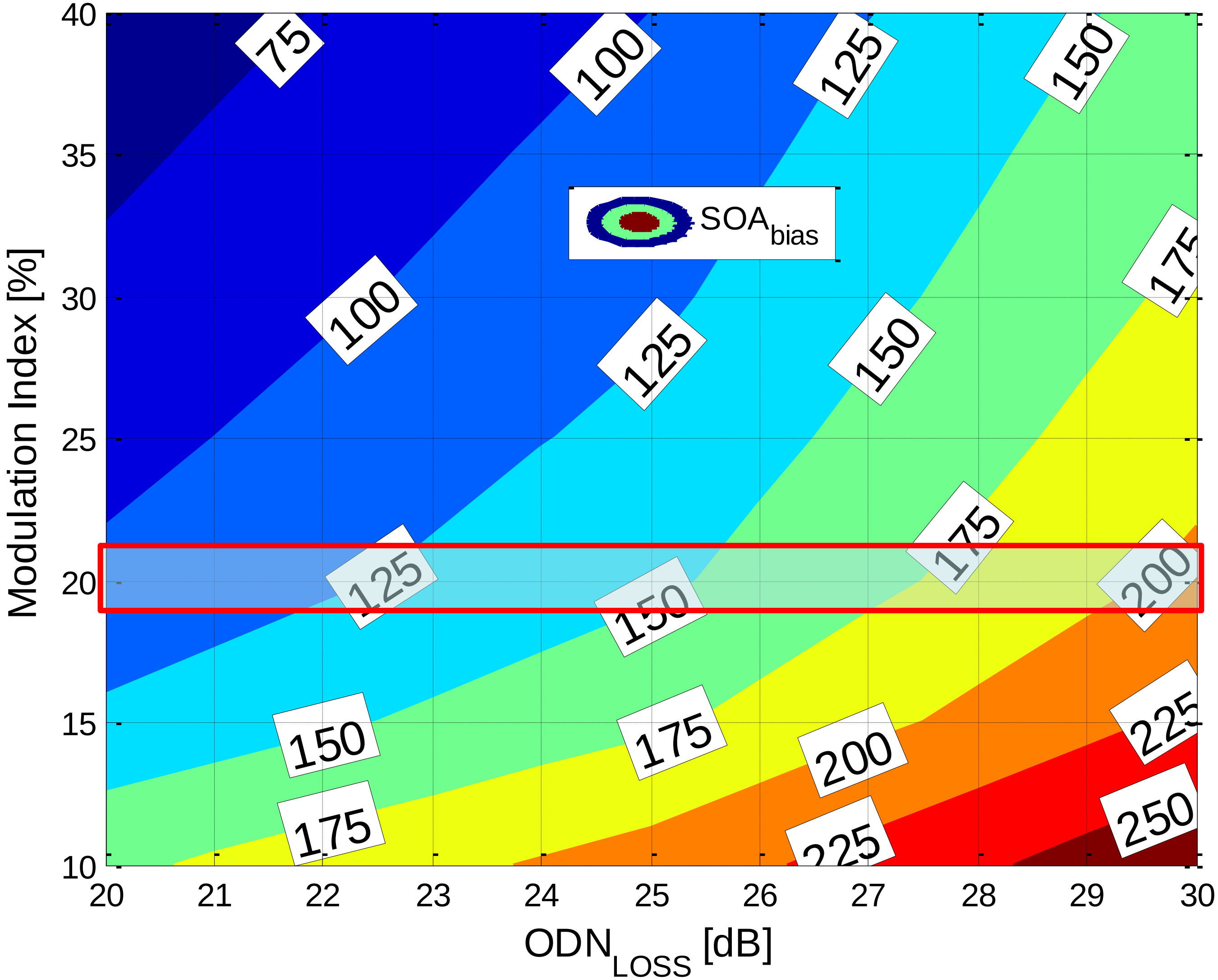


SOA biasing current optimization





SOA biasing current optimization vs. ODN loss

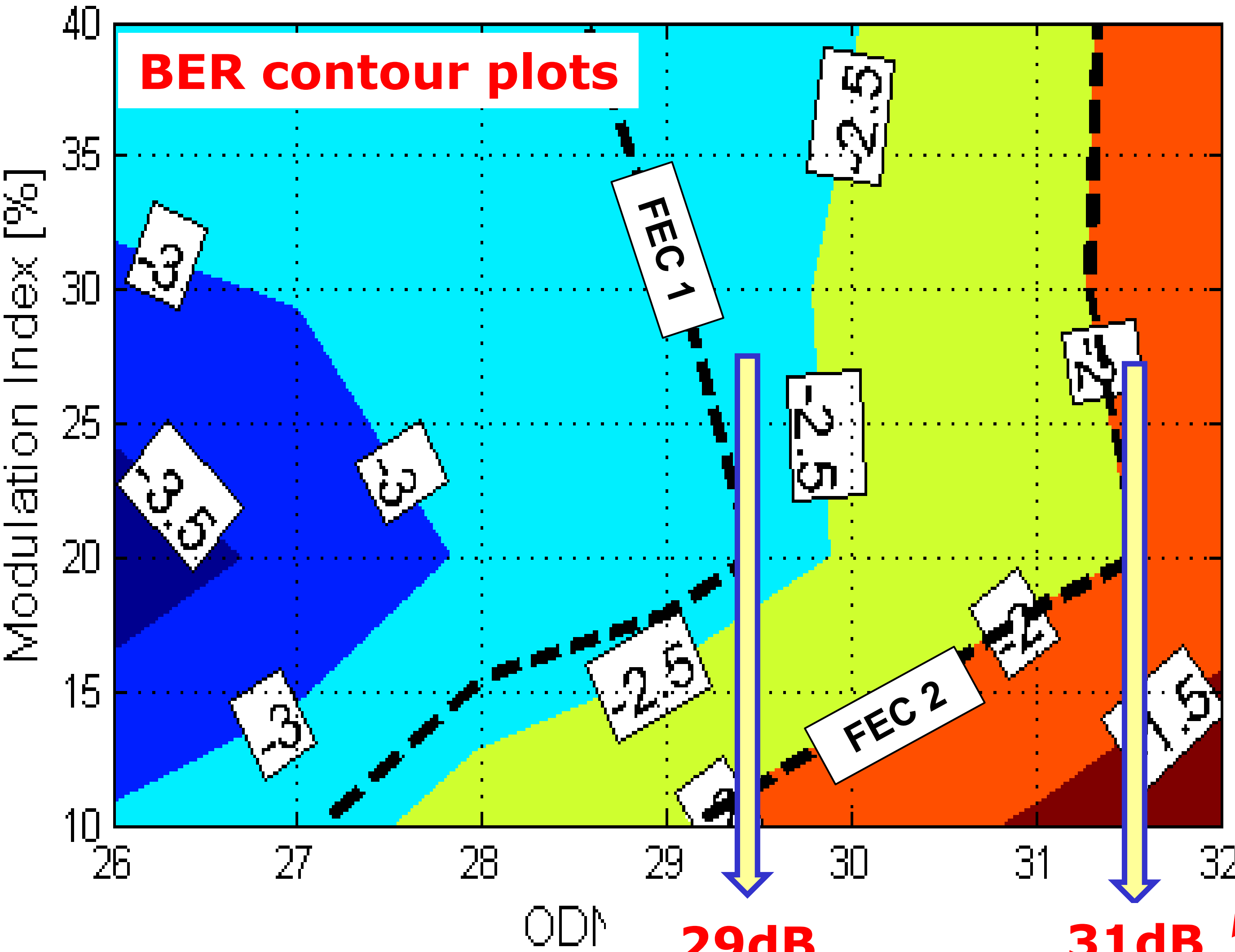


Choice of the Forward Error Correction

- As a starting point for our reference, we considered two FEC with correction ability for BER post-FEC of 10^{-15}
  - a FEC defined in ITU-T G.975.1 for high bit rate DWDM submarine systems (FEC 1)
  - a third generation code featuring concatenated FEC with soft decision (FEC 2)

FEC	Code	Overhead	BER pre-FEC threshold
FEC 1	RS(1023,1007) + BCH(2047,1952)	6,69%	$2.17 \cdot 10^{-3}$
FEC 2	RS(992,956) + LDPC(9216,7936)	20,5%	$1.0 \cdot 10^{-2}$

BER vs. ODN loss and modulation index



29dB

N1 class

31dB

N2 class

Small inaccuracy in the title (we are sligthly below 32 dB)

... our fault!

Conclusions

We demonstrated

- with a launched power of P_F*=9dBm* (same as in TWDM-PON highest classes)
- using an installed metropolitan fiber network

that the **FABULOUS** upstream reflective FDM PON supports:

- ✓ a total capacity of **32 Gbps** per wavelength
- ✓ more than **31 dB** of ODN loss (satisfying **N2-class** of TWDM-PON standard)

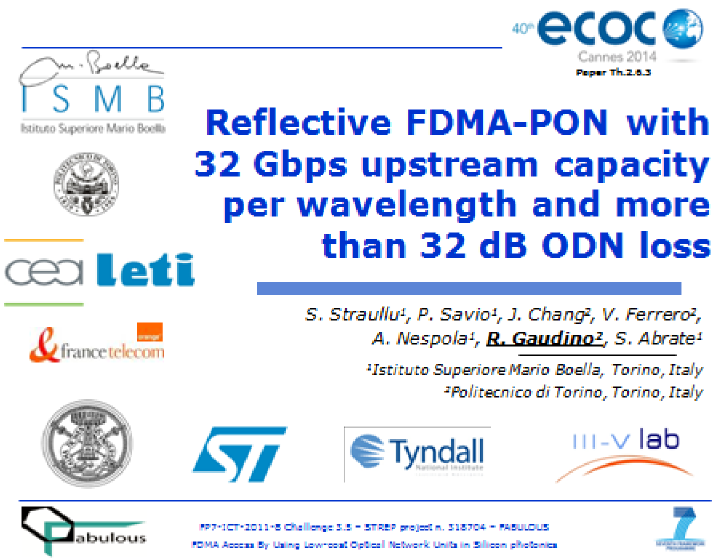
Comments

- 32 Gbps net capacity upstream is significantly better than what is today envisioned for the first implementations of TWDM-PON (4λx2.5 Gbps)
- This is **WITHOUT requiring WDM**, but only single wavelength operation
- DSP is required at ONU, but at very reasonable speed (<1Gsample/s)
  - In fact, the Orange Lab Demo at this conference implemented this DSP using consumer electronic chipsets coming from wireless-USB applications

Acknowledgments

The research leading to these results has received funding from the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement n°318704, titled:

FABULOUS: "FDMA Access By Using Low-cost Optical Network Units in Silicon Photonics"



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Backup slides