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Extended TWDM-PON demonstration up to 100 km and 35 dB ODN loss on Burst-Mode Coherent Reflective PON

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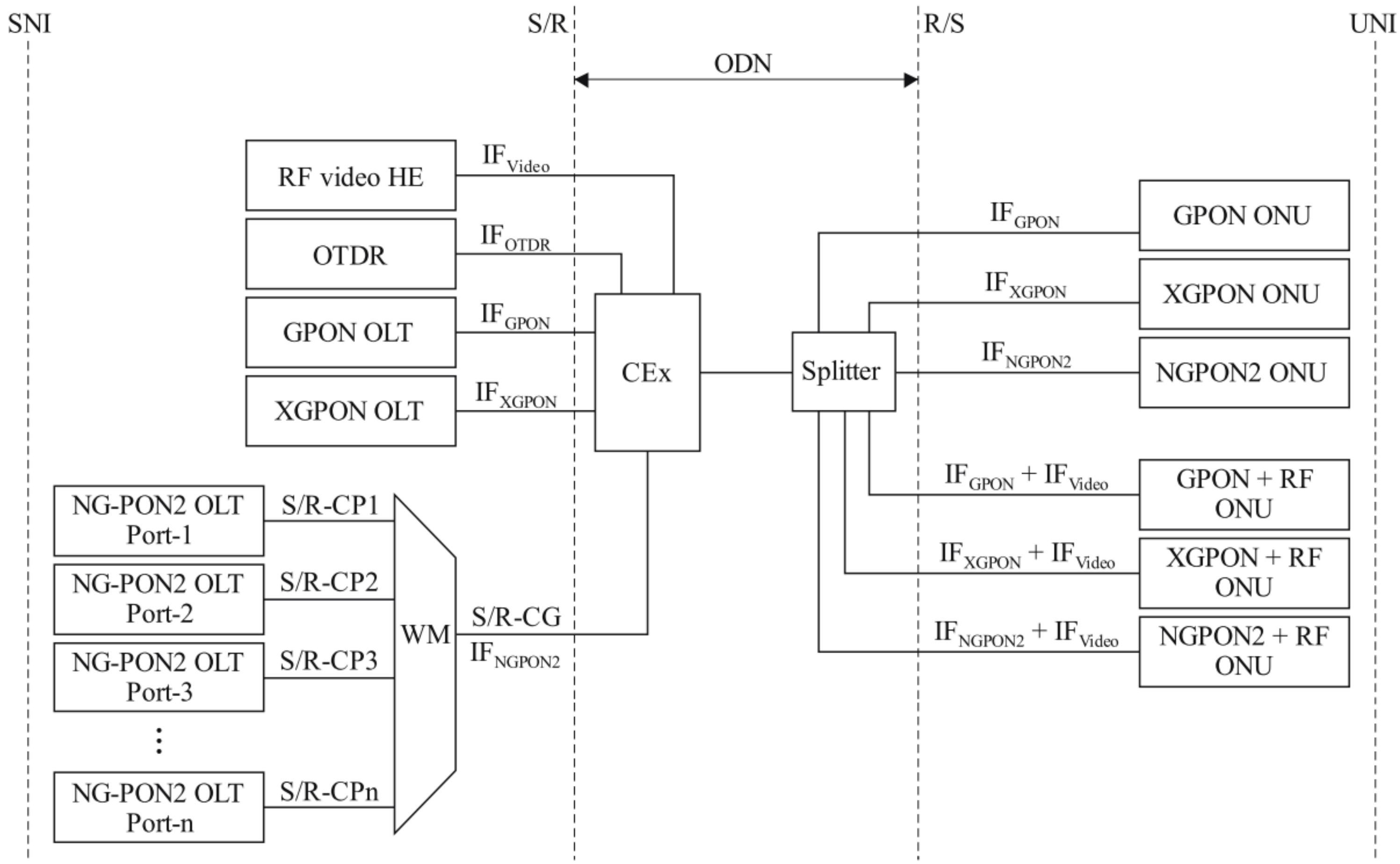
FSAN TWDM-PON architecture

- Defined by FSAN and ITU-T in the Recommendation G.989.1 **“40-Gigabit-capable passive optical networks (NG-PON2)”**

FSAN
Full Service
Access Network



http://www.itu.int/rec/T-REC-G.989.1-201303-I/en

FSAN TWDM-PON architecture

- **4 wavelengths** per direction, 100 GHz spacing
  - Upgradeable to 8 wavelengths (50 GHz)
- **TDMA** on each of the 4 wavelengths
  - Each wavelength is treated as an independent **XG-PON**

DS: 10 Gbps
US: 2.5 Gbps

- Splitter-based PON
  - **No AWG** and amplification in the ODN
  - Backward compatibility with **ODN loss classes**

	Nominal 1 (N1 class)	Nominal 2 (N2 class)	Extended 1 (E1 class)	Extended 2 (E2 class)
Minimum loss	14 dB	16 dB	18 dB	20 dB
Maximum loss	29 dB	31 dB	33 dB	35 dB

DOPL

Differential **O**ptical **P**ath **L**oss = Maximum loss – Minimum loss

Can reflective PON be applied in such scenario?

- TWDM-PONs need for **ultra-low cost** tunable **lasers** at the ONU side
- Several WDM **reflective PON** architectures have been proposed in the last ten years, but:
  - AWG inside the ODN
  - poor receiver **sensitivity**
  - **dedicated wavelength** per ONU

The results of our work

- In our last work, we demonstrated a reflective PON architecture which solves all the previous points, allowing **high-ODN loss**, **splitter-based ODN** and **TDMA**

Coherent Reflective PON architecture: can it be made compatible with TWDM-PON?

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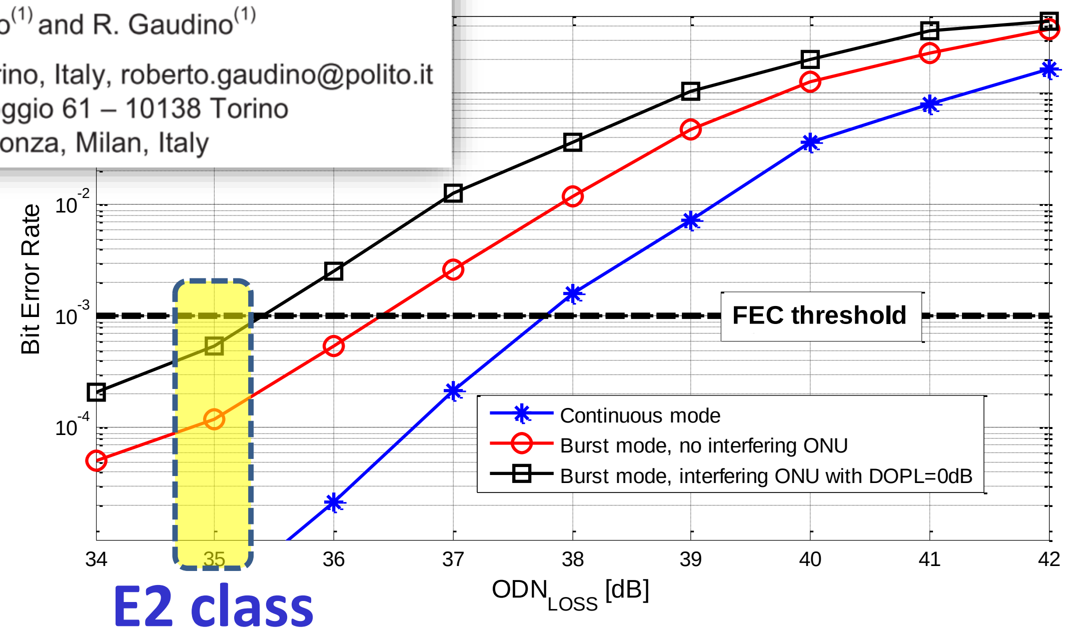
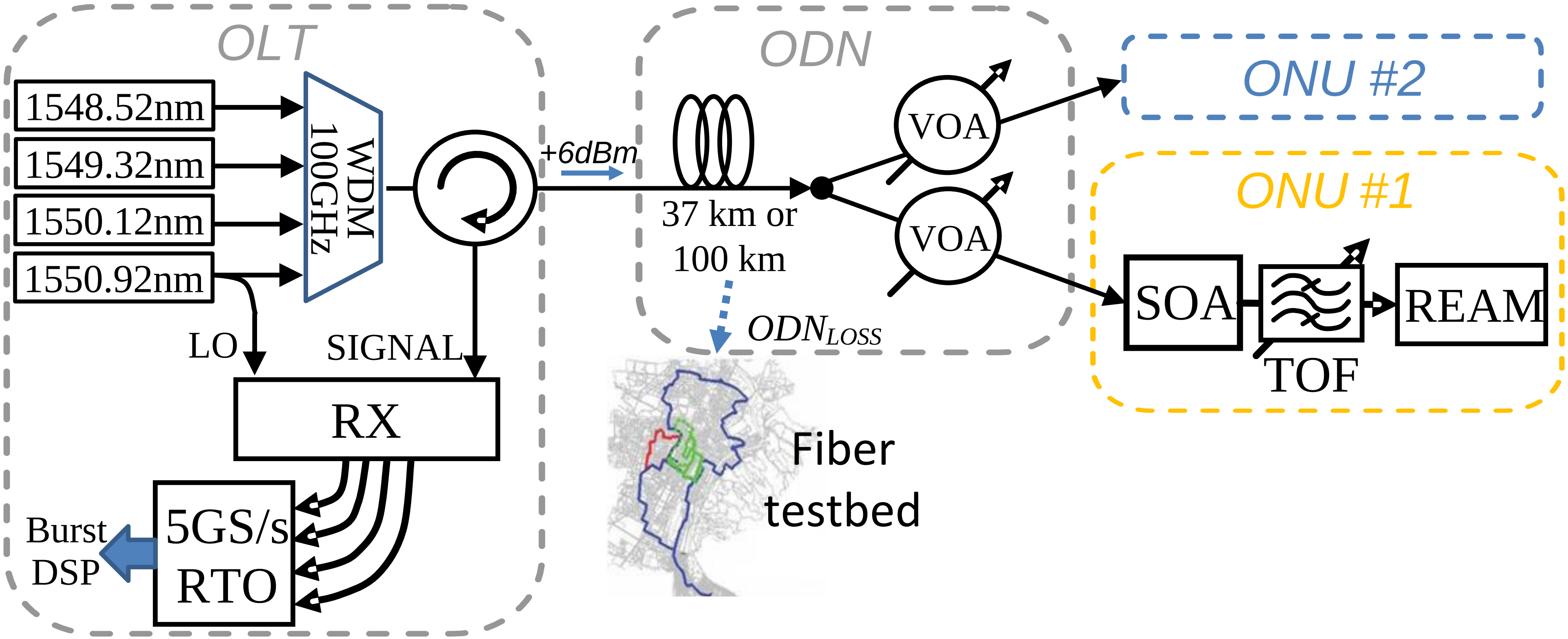
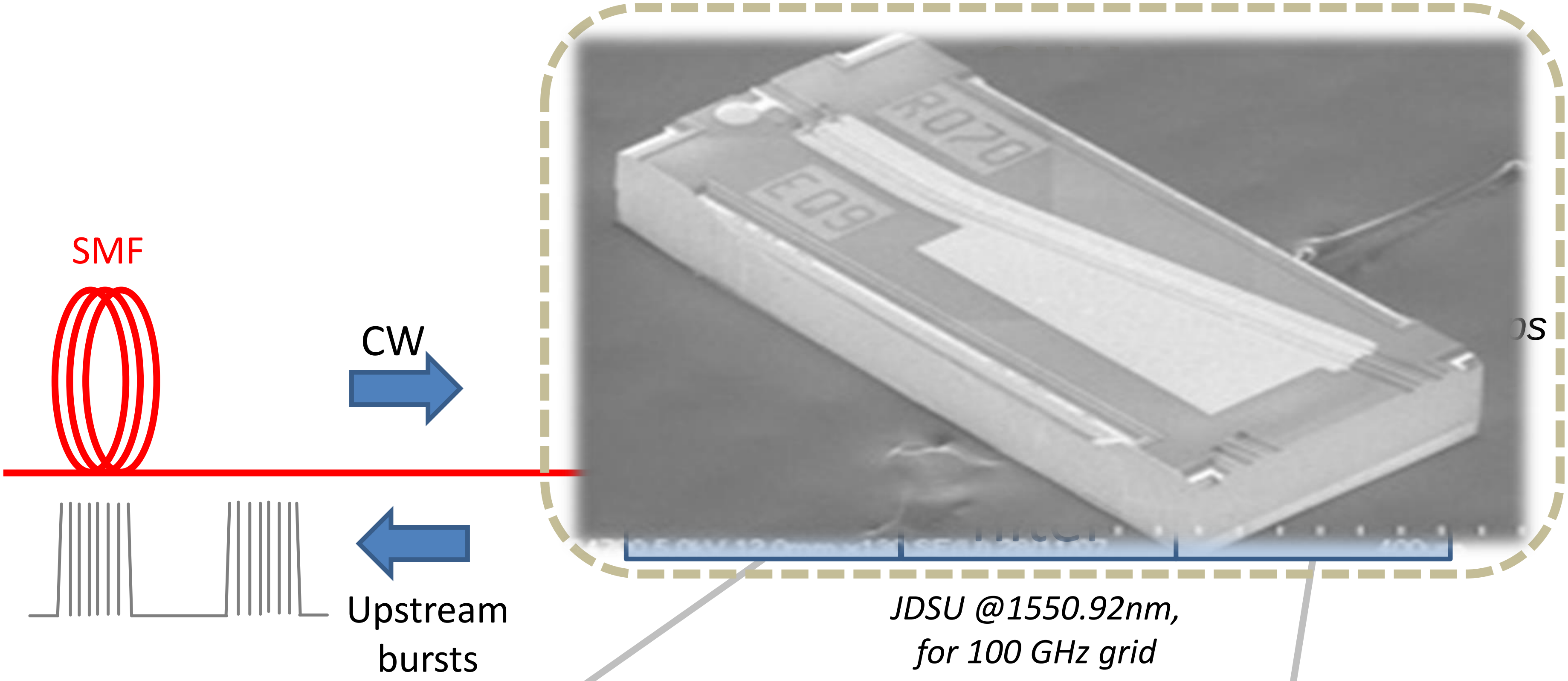


- The goal of this **new work** is to demonstrate a **complete compatibility** with the main characteristics of **ITU-T G.989.1** (class E2, distance DD40)

System setup



BURST-MODE TX: new structure for the ONU



Semiconductor Optical Amplifier

CIP SOA-S-C-14-FCA

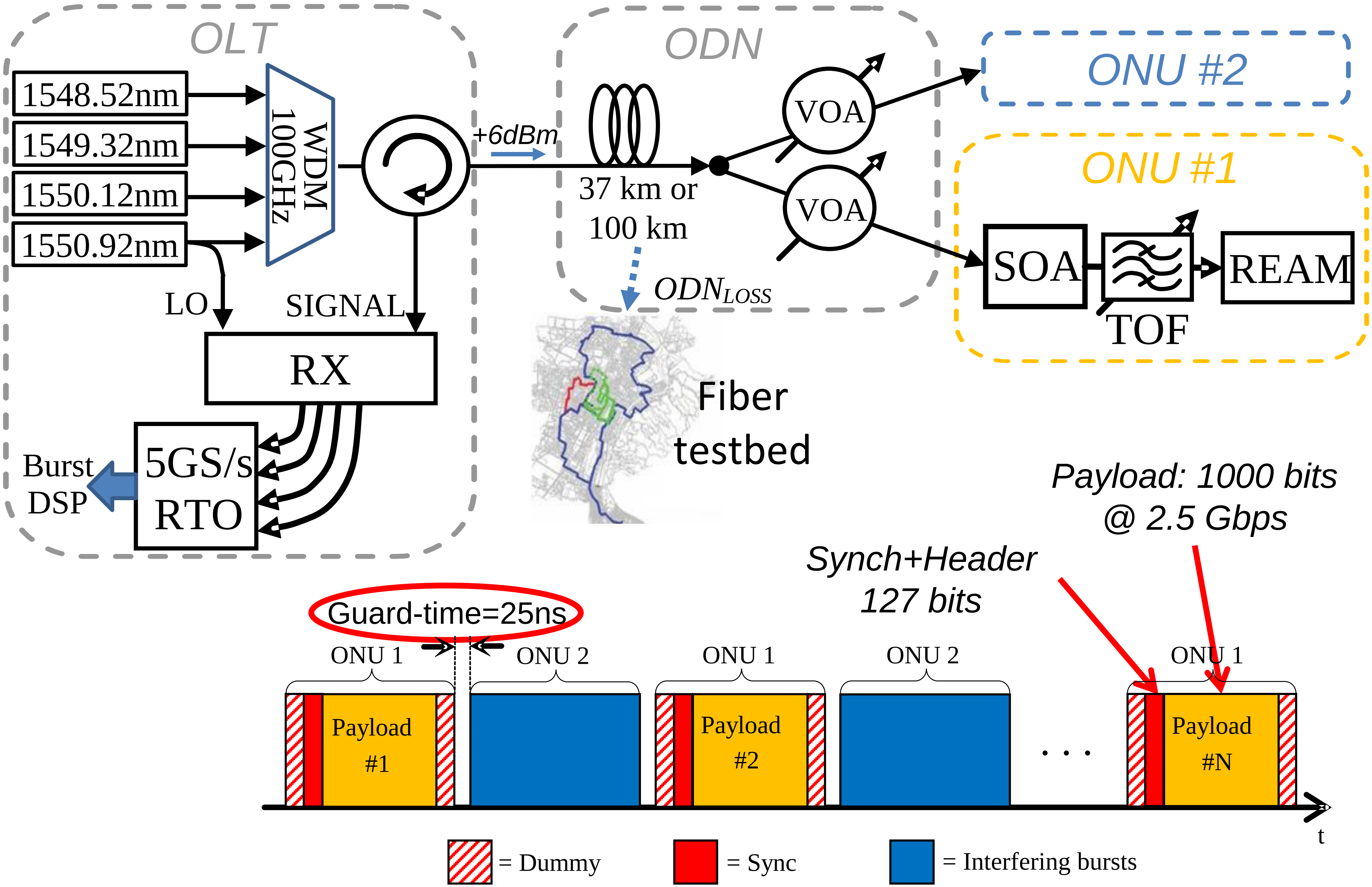
- *Amplification* (20 dB per single pass for 90 mA bias current)
- *Gating on the packets* (2÷3 ns raising time)

Reflective Electro Absorption Modulator

CIP R-EAM-1550-LS

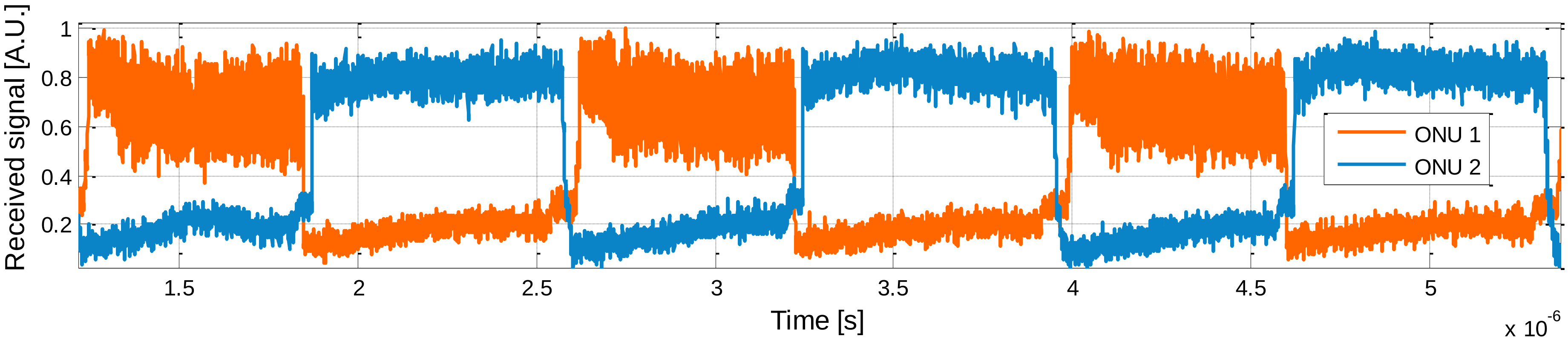
- *Modulation bandwidth* (up to 6÷7 GHz)

System setup: upstream transmission

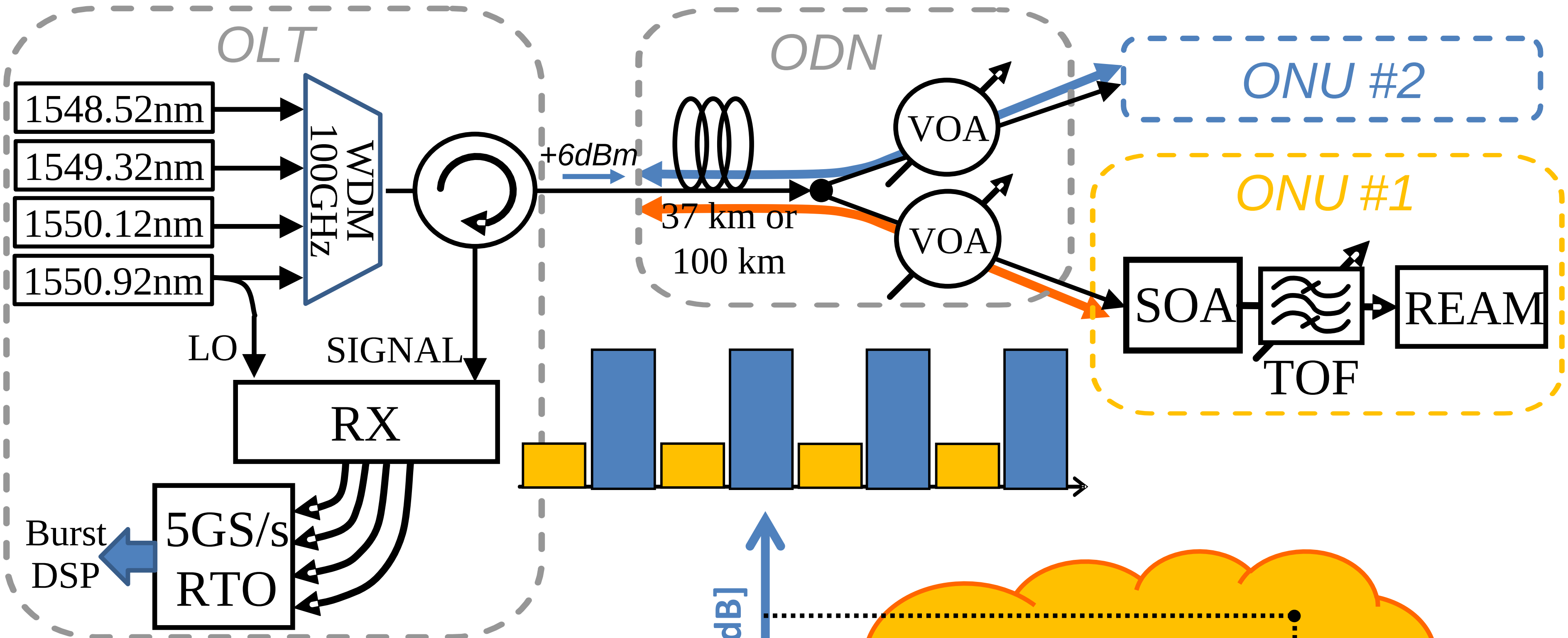


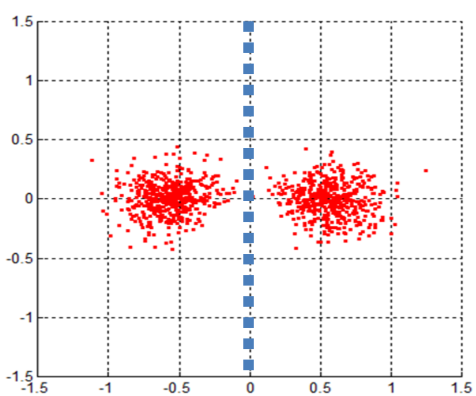
The DOPL issue

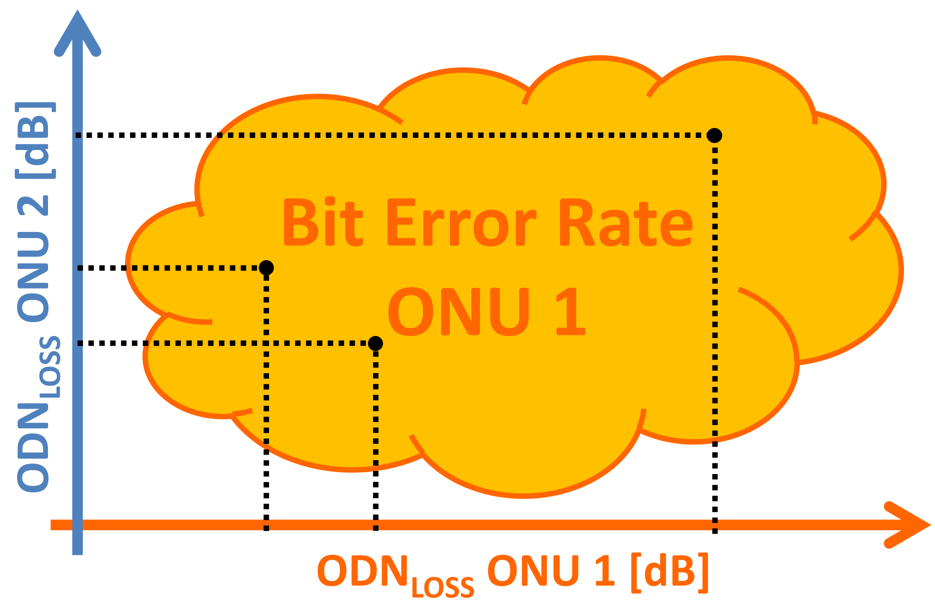
- The **Differential Optical Path Loss** in a reflective PON architecture **counts twice** in terms of optical power at the OLT receiver input
- In a TDMA situation, the **received packets** can have a **power variation** of **twice the DOPL** (in dB)
- Since the ITU-T specifies the **DOPL** up to **15 dB**, this would mean a completely unacceptable **RX power variation** among TDMA packets of **up to 30 dB**, which would put any coherent receiver out of service
- Therefore, we propose to implement an OLT-centralized **automatic control algorithm** on the ONUs **SOA gain**, whose target is to **equalize** the received optical power at OLT



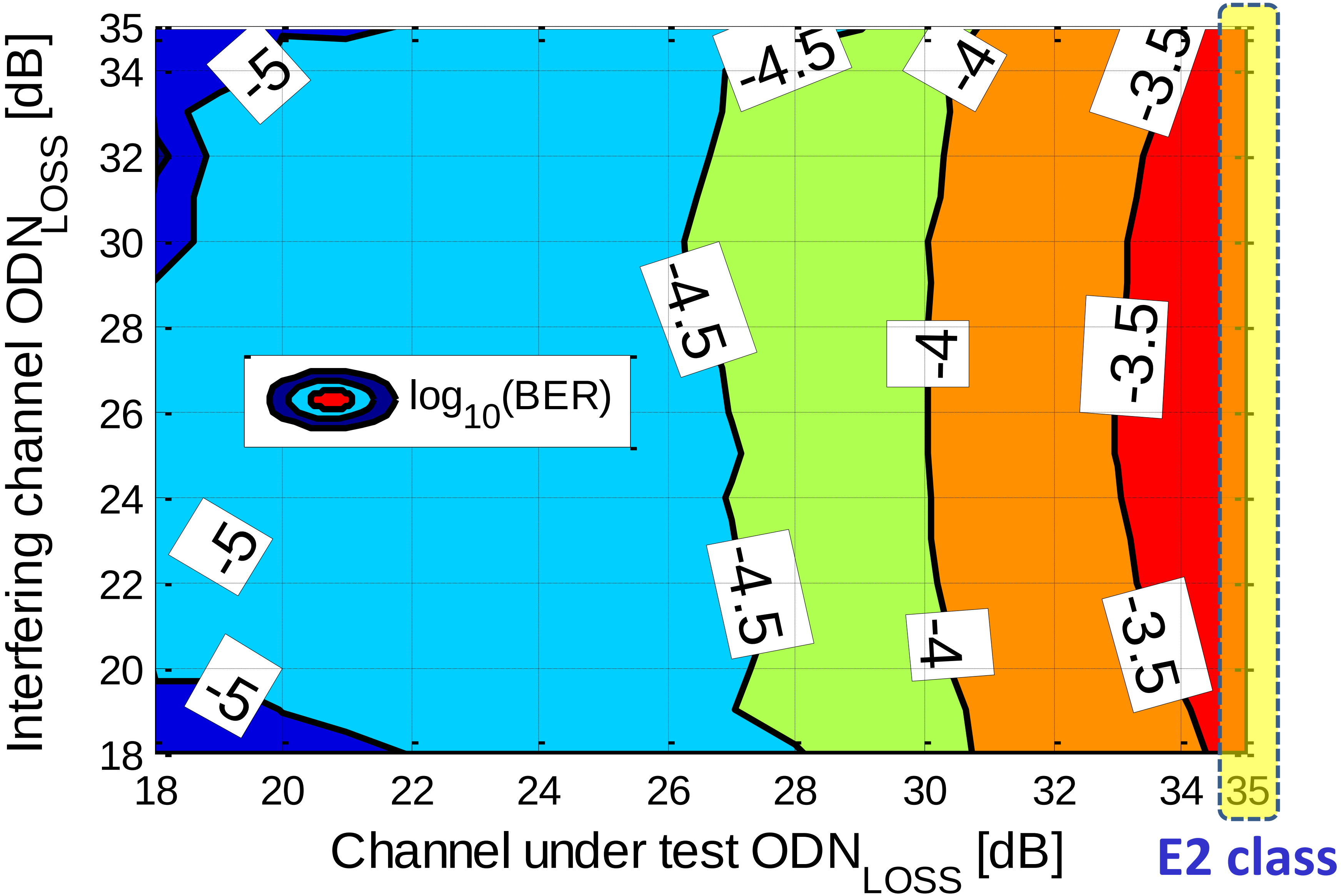
System measurement



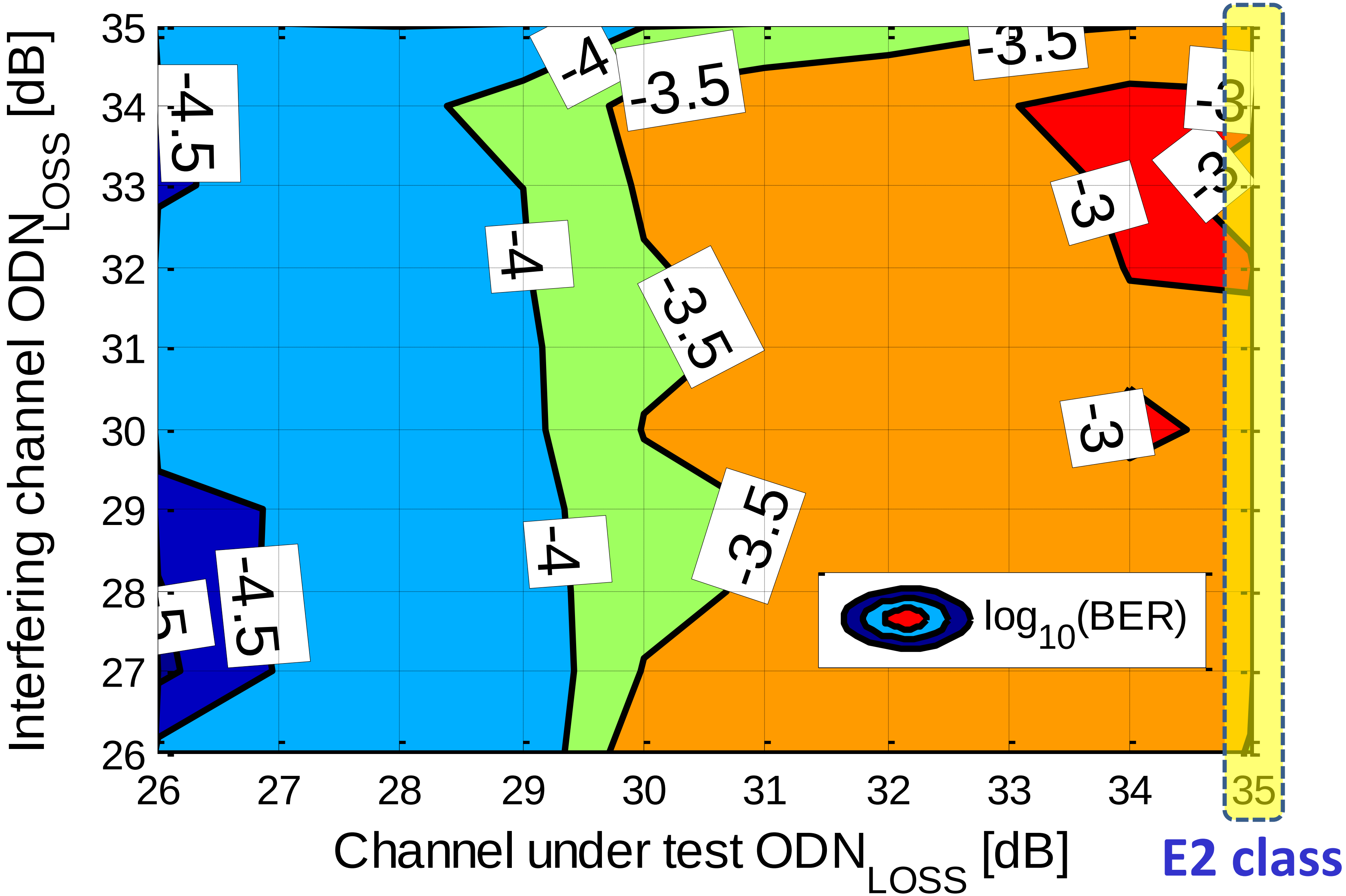




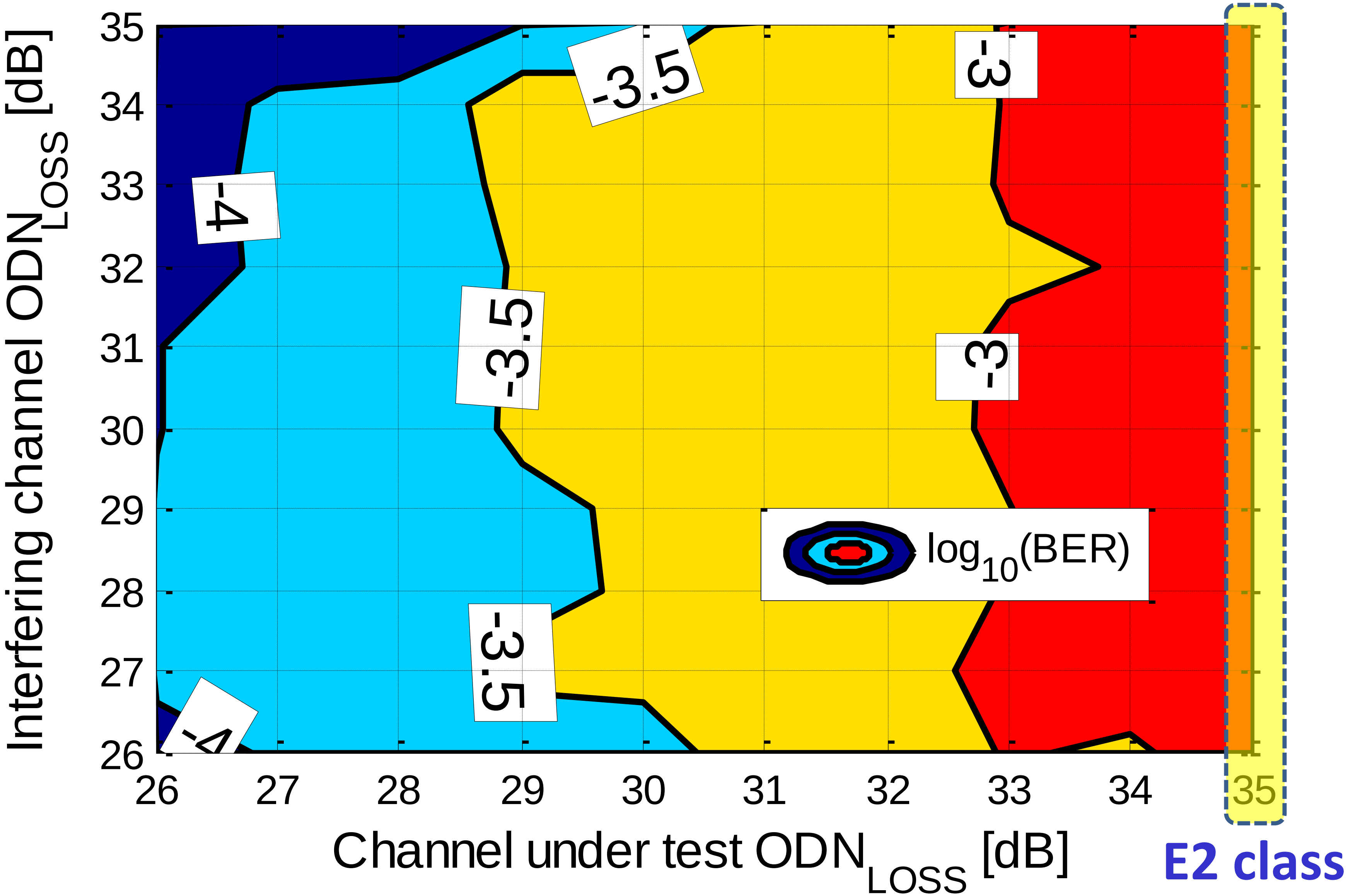
Experimental results: 37 km, single wavelength



Experimental results: 100 km, single wavelength



Experimental results: 100 km, 4 wavelengths

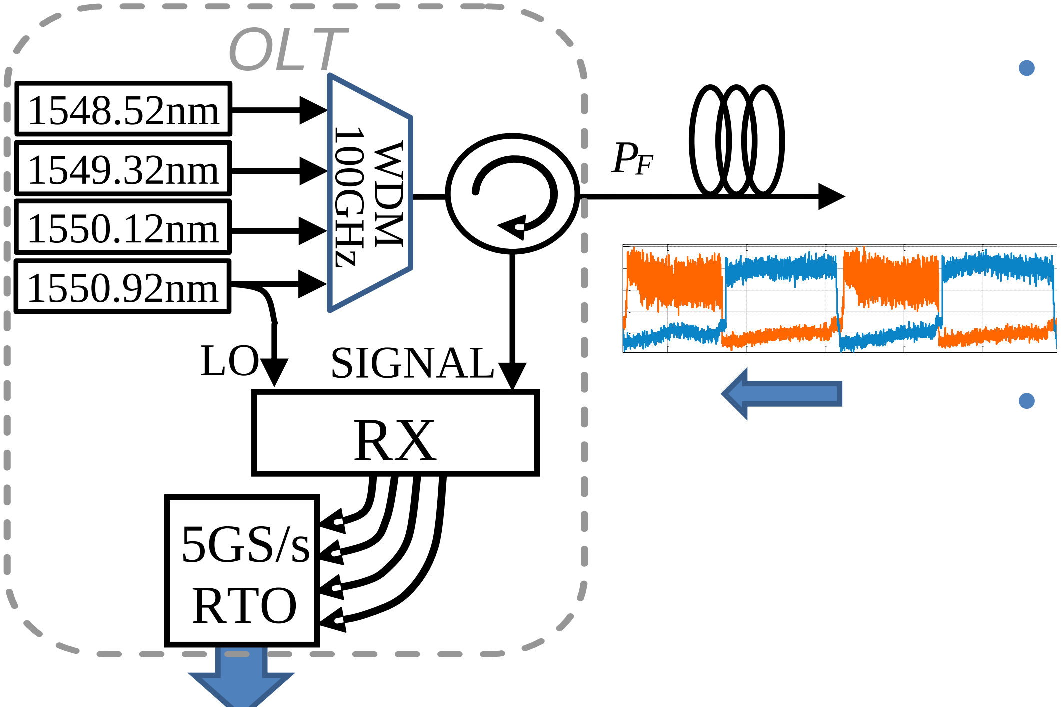


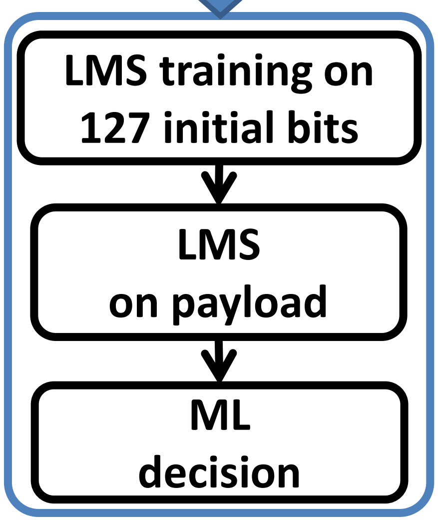
Conclusions

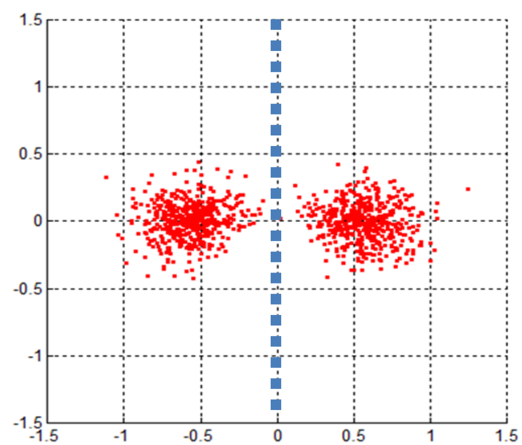
- We demonstrated that our TWDM-PON upstream architecture supports:
  - **35 dB** of **ODN loss**
  - more than **15 dB** of **DOPL**
  - **37 km** of SMF (showing potential extension up to **100 km**)
- This was possible thanks to:
  - the **reflective, burst-mode ONU** (no tunable lasers)
  - the **coherent burst-mode detection** at the **OLT**
- We hope that this paper can contribute to future PON generations, particularly if **DWDM** with significantly more than 4 wavelengths on a 50 GHz grid will be adopted, which would make **tunable lasers** at ONU even more critical

Back-up slides

BURST-MODE RX: coherent burst-mode detection







- **LMS (training)**

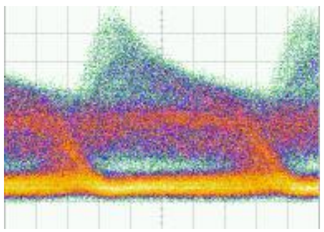
  The first **127 bits** in each bursts are used for **synch** and for an LMS equalizer algorithm in **training** mode
- **LMS (tracking)**

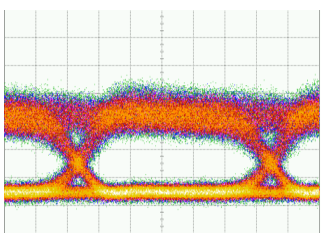
  After the first 127 bits, the LMS algorithm is switched to **“decision directed”** to elaborate the **payload** of the burst
- **Experiments used an off-line processing approach**

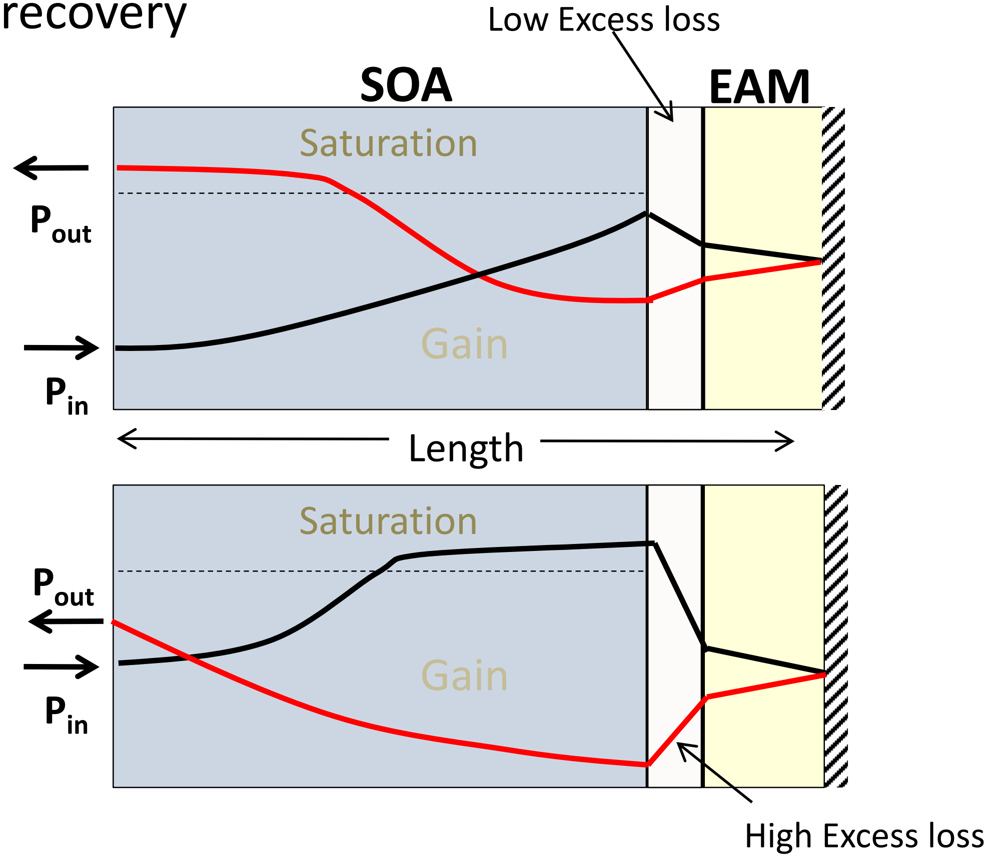
  To obtain stable BER values, we estimate and average it over a large number of packets (approx. 1800 packets for each BER estimation)

SOA saturation

- If excess loss is low the SOA is driven into saturation by the modulated signal and this induces patterning
- If loss is high the carrier saturates the SOA, acts as a “CW holding beam” which speeds up gain recovery







[ref] E. K. MacHale et al., “Extended-Reach PON employing 10Gb/s Integrated Reflective EAM-SOA,” ECOC) Brussels, Belgium, 2008, Paper Th.2.F.1