

L-Band Unrepeated WDM Experiment over 451 km using all-Raman Amplification and ROPA

A.Puc, D.Chang, G. Grosso, J. Ellison, R. Oberland, S. Burtsev,
P.Perrier, W. Pelouch, S. Webb
apuc@xtera.com

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L-band transmission 22 x 10.7 Gb/s and 3 X 43 Gb/s DPSK channels over 451 km and 80 dB span loss

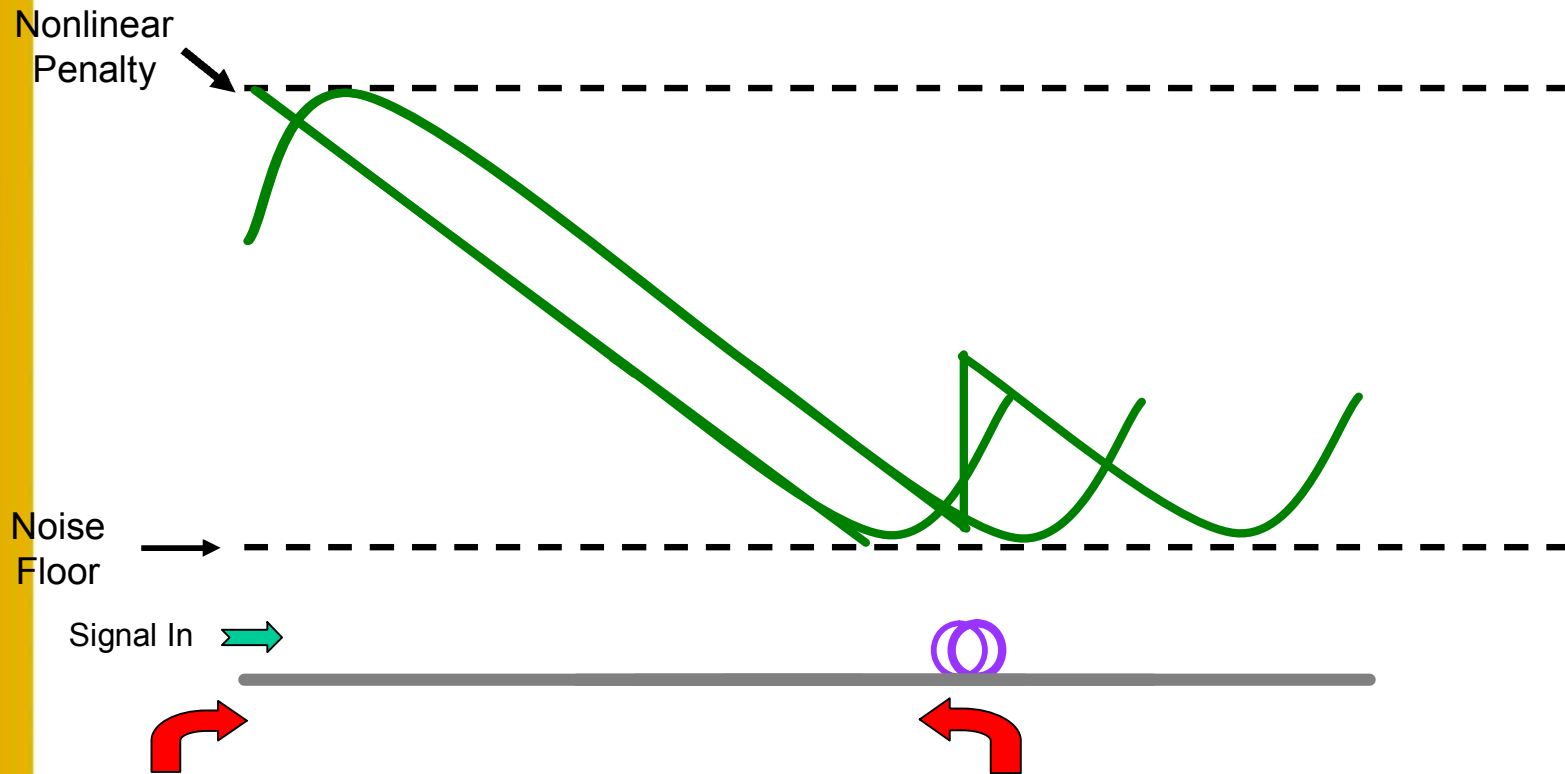
- Motivation
- Background on extended UR reach
 - Forward + backward Raman pumping
 - Remote optical amplifier (ROPA)
 - L-band transmission vs. C-band
 - modulation format and FEC
- Experimental Setup
- Results
- Concluding remarks



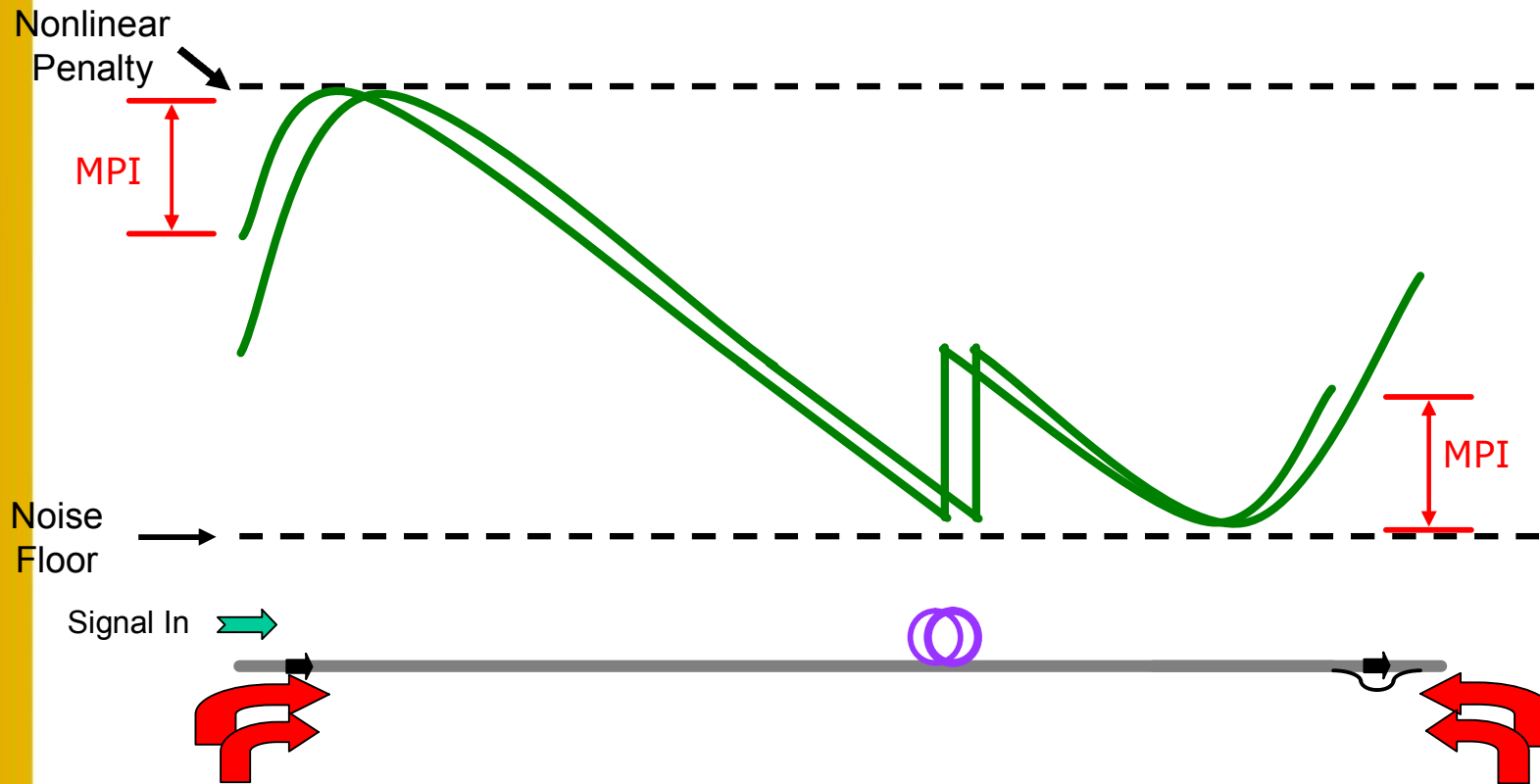
motivation

- Unrepeated optical links are cost effective solution for:
 - undersea coastal and archipelago networks
 - terrestrial spans across area with no, or little infrastructure
- Need to upgrade existing systems in capacity by number of channels and higher transmission rate
- Take full advantage of distributed Raman gain
- Unrepeated spans longer than 400 km are of particular interest

extend reach
Raman Pumping with ROPA

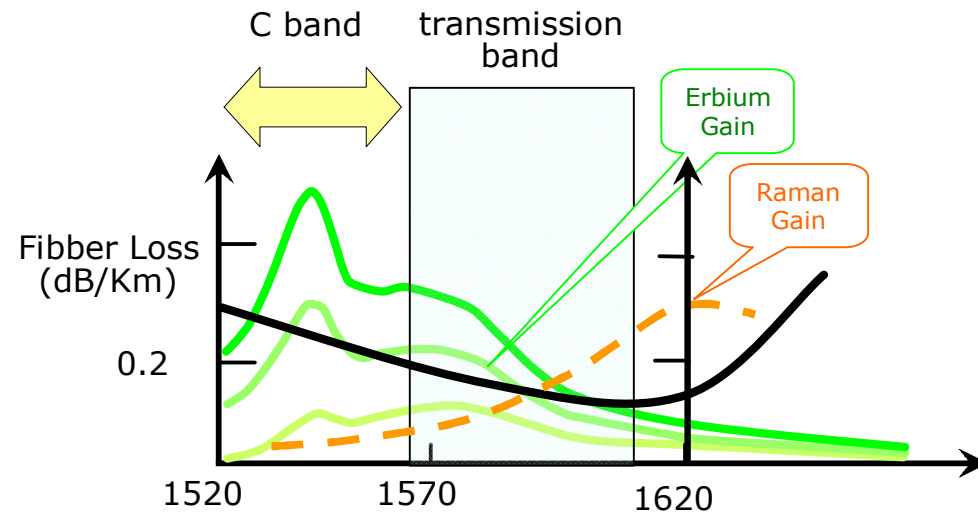


extend reach
Raman Pumping with ROPA + ISOs



extend reach

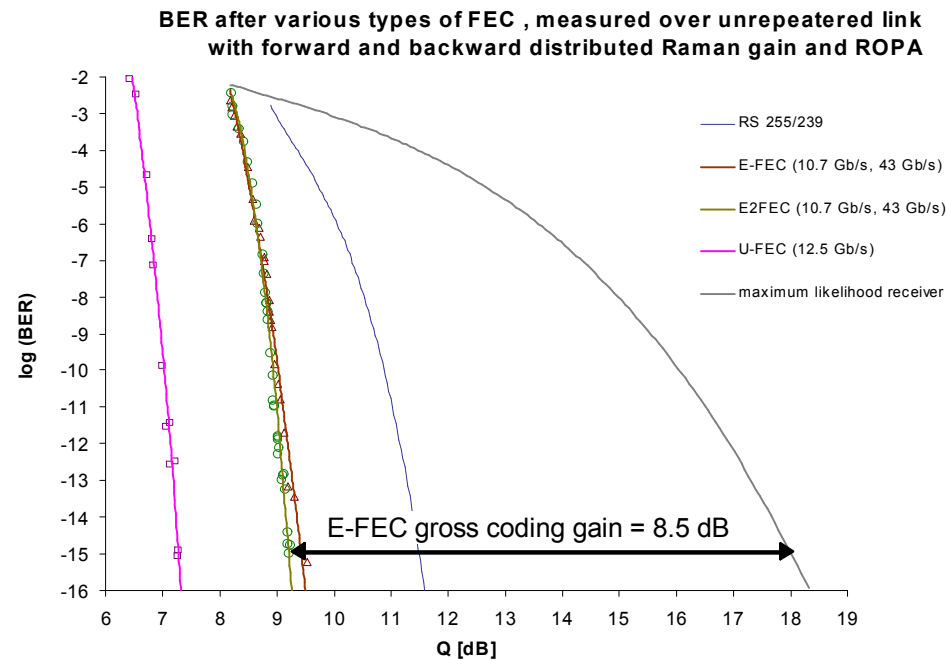
Raman Pumping with ROPA in L-band



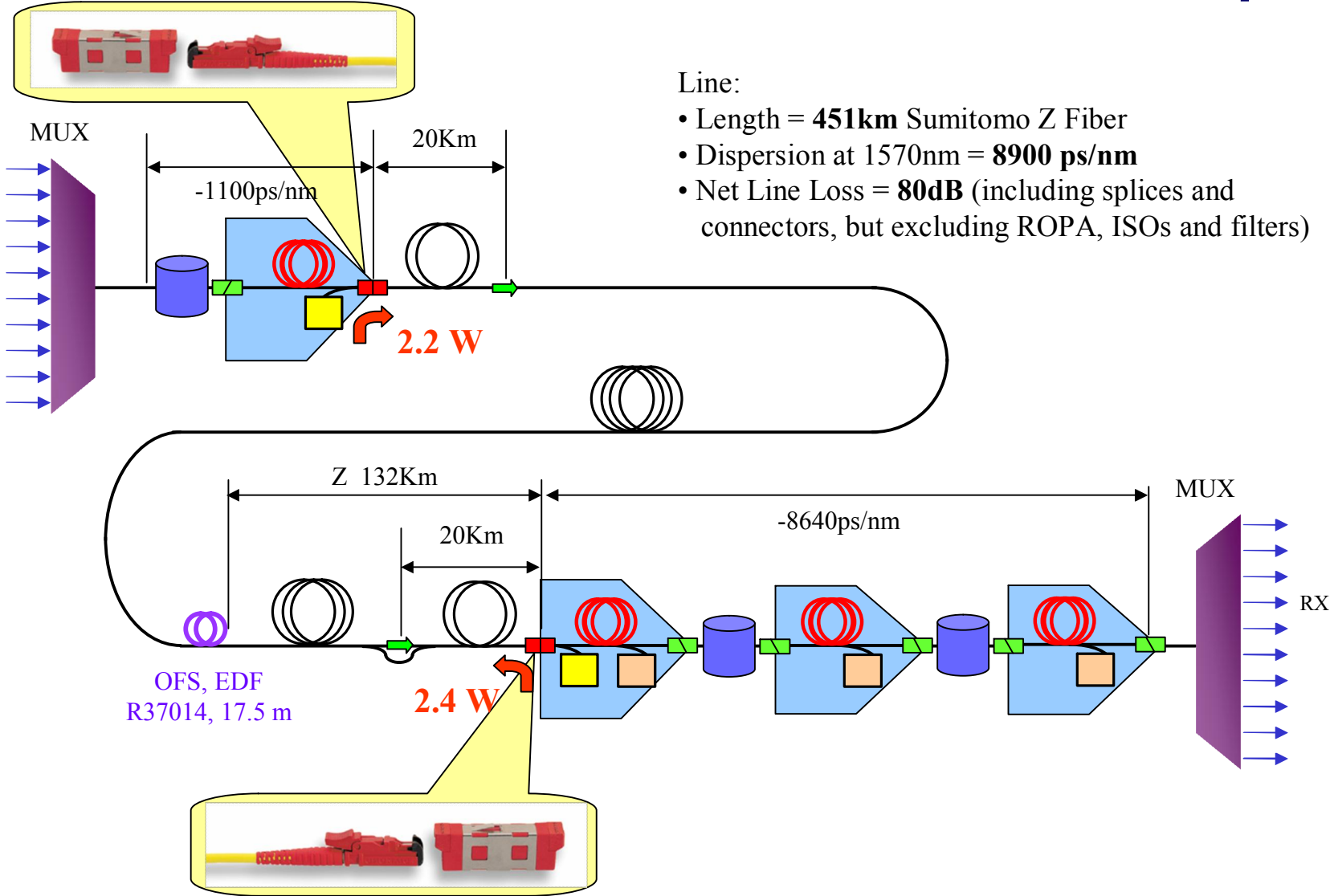
- By combining several Raman pumps at different wavelength it is possible to tailor the overall gain such that it complements, to a large extent, Erbium ROPA gain tilt and fiber loss slope

extend reach modulation format and FEC

- **Signal modulation format: DPSK NRZ**
 - up to 3 dB modulation gain and good dispersion tolerance
 - no SBS suppression needed
- **Error correction code: Iterative BCH (E-FEC):**
 - BER < 10^{-15} at Q = 9.5 dB



451km Test Set Up

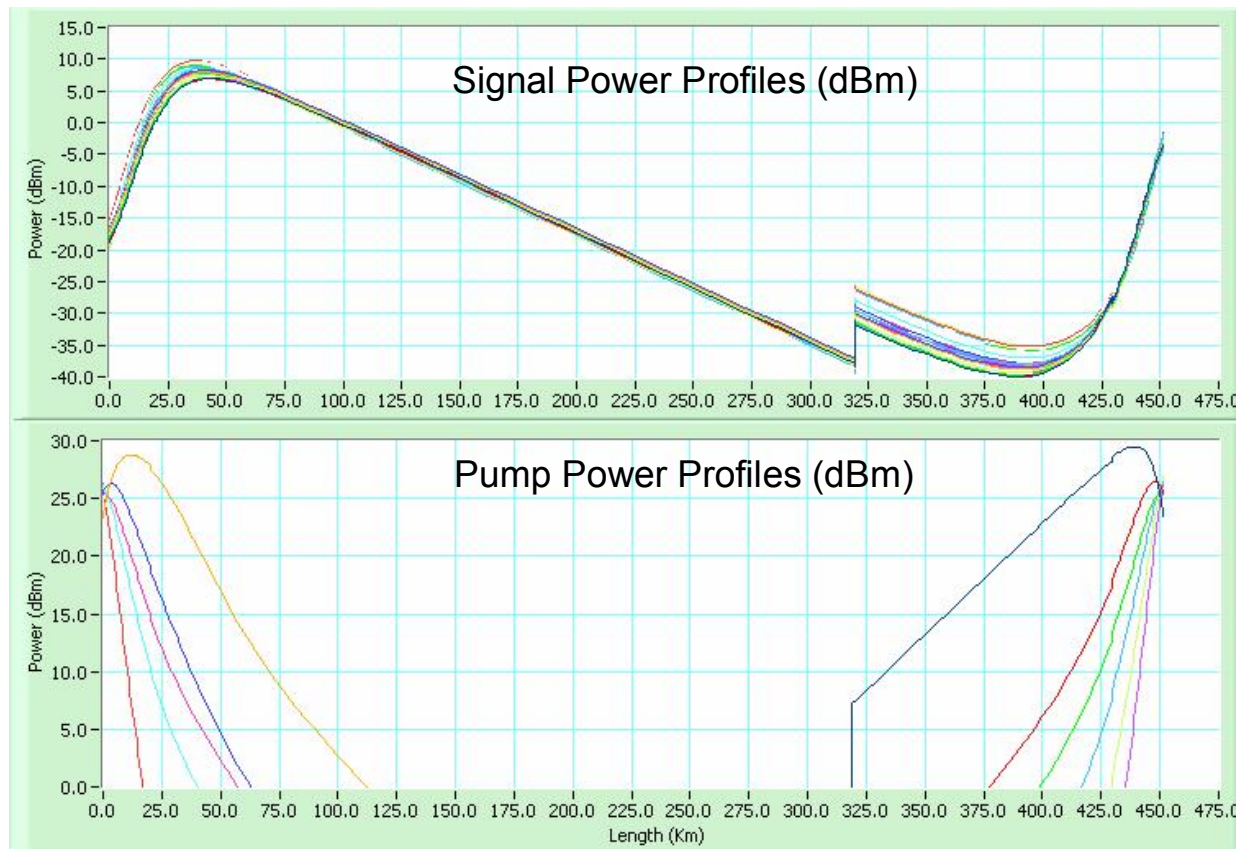


- Line:
- Length = **451km** Sumitomo Z Fiber
 - Dispersion at 1570nm = **8900 ps/nm**
 - Net Line Loss = **80dB** (including splices and connectors, but excluding ROPA, ISOs and filters)



Power Management

- Signal launch power shall be small (< -17 dBm) for a better distribution along the line



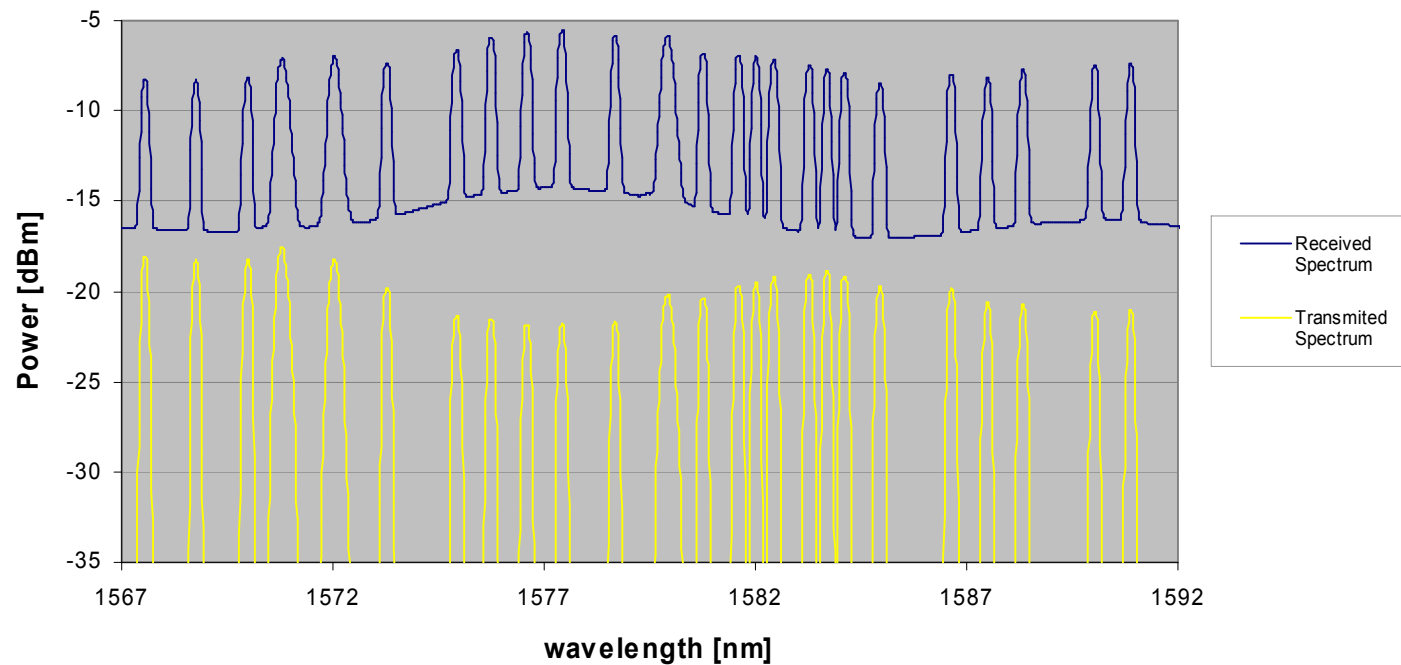
6 pump wavelengths in the range {1412 - 1488}



results

Signal Spectra

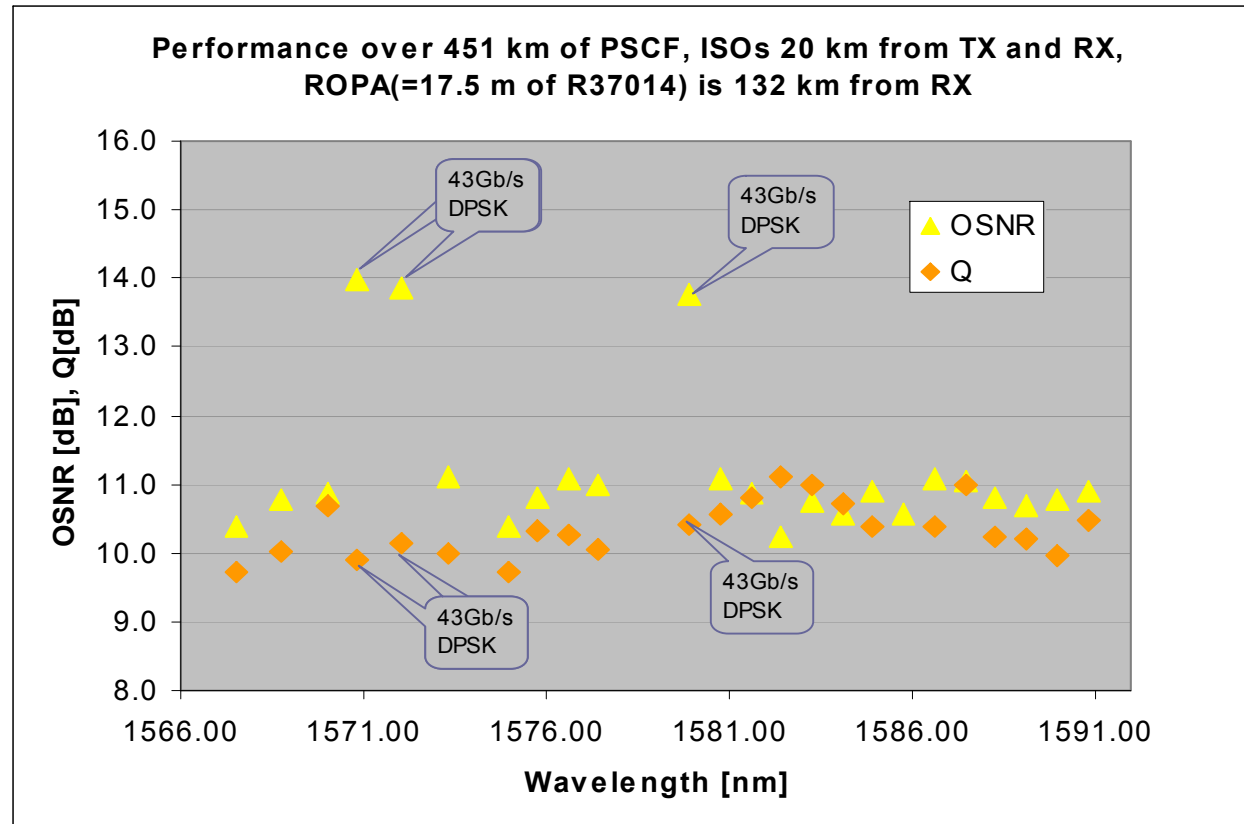
451km Spectra, Pumps = scenario B RBW=0.2 nm
3 x 43 Gb/s DPSK NRZ (reduced BW) and 22 x 10.7 Gb/s DPSK NRZ
channels



- Pre-emphasis on the transmitted signals of about 4.5 dB is required to achieve flat OSNR (and Q) at the receiver side



OSNR and Q Measurement



- average OSNR (0.1nm RBW) = 11.1dB
- average Q = 10.3 dB



concluding remarks

AP1

- Distributed Raman gain in L-Band and Erbium ROPA provide an effective method for a wide band unrepeated transmission.
 - Error free transmission of 22 x 10.7 Gb/s and 3 X 43 Gb/s DPSK channels over 451 km and span loss of 80 dB.
 - Results achieved with high power, commercially available laser diodes as Raman pumps, legacy PSC fiber and legacy erbium fiber for ROPA.
 - The use of < 3 W of total pump power/fiber end is well within power handling capability of high power connectors
- Further improvements are possible:
 - by use of a large effective area core fiber (Z+)
 - more powerful FEC, perhaps concatenated with a suitable line code.



Slide 12

AP1

Bullet 1:

We have demonstrated that L-band distributed Raman amplification in combination with Erbium ROPA is an efficient method to implement 40 Gb/s ultra long UR systems.

Bullet 2:

With less than 5 W of total counter- and co-propagating pump power an "error free" transmission of 10 X 43 Gb/s over 468 km long span, consisting of mostly standard PSCF, was achieved.

Bullet 3:

For Raman pumps we used commercially available high power, multimode laser diodes

Bullet 4:

The method allows for an improvement in both, capacity and reach, by using a longer sections of large core area fiber (new Z+) in co-and counter propagating directions.

Andrej Puc, 18/09/2008

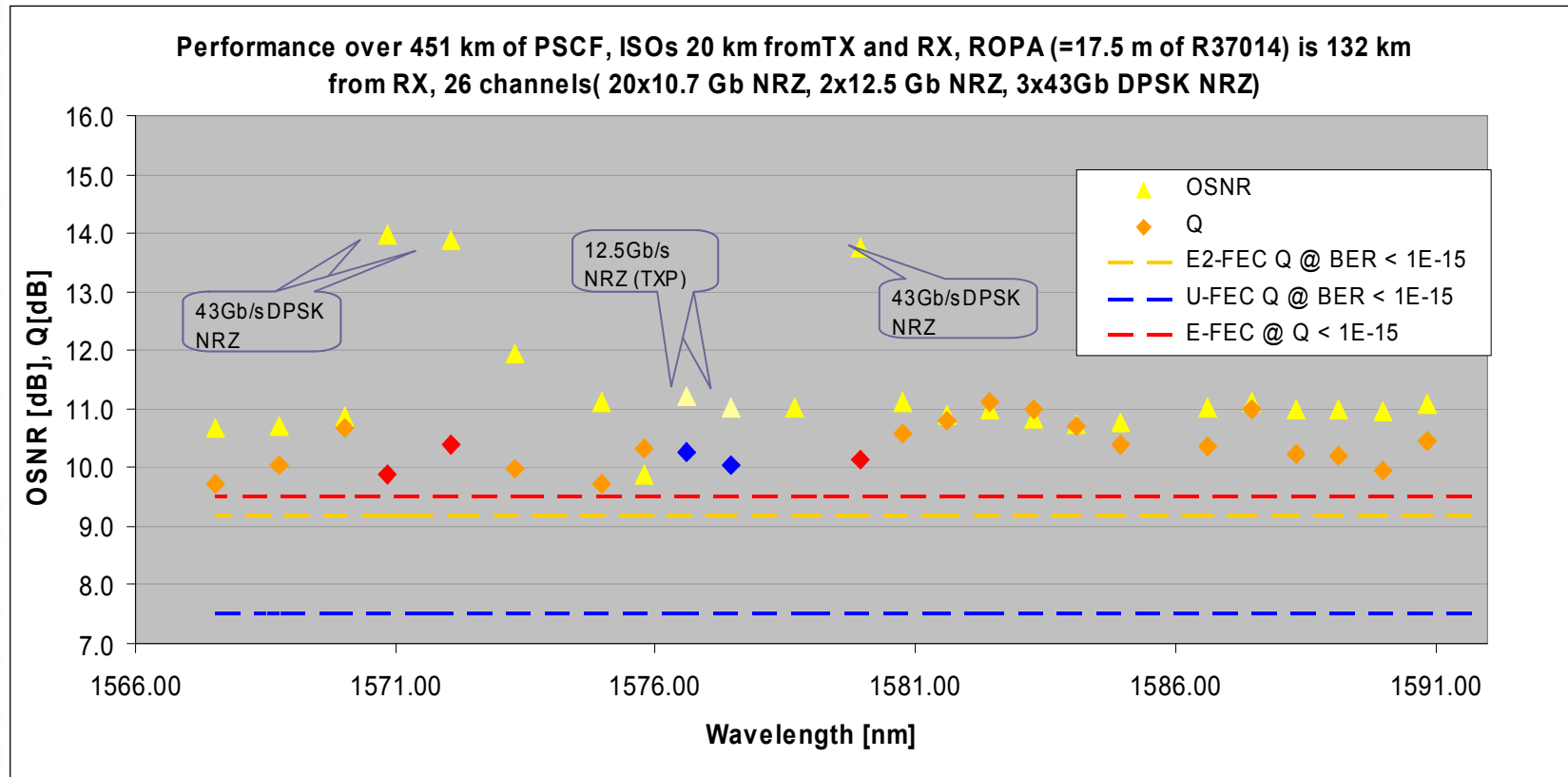
extend reach managing nonlinearities and RIN transfer

- SBS is very pronounced with distributed forward Raman pumping:
 - Traditional SBS suppression methods are insufficient for plain intensity modulation format like NRZ and RZ.
 - DPSK (QPSK) signals, and to a large extent duobinary, are practically free of SBS
- SPM, XPM and FWM require large local dispersion fiber (SSMF, Z, Z+) and large core effective area:
 - Dispersion management with respect to signal power distribution along the line is important; for good results pre- vs. post-compensation ratio needs to be optimized.
 - large local dispersion fiber and large core effective area(SSMF, Z, Z+, etc.) are way to go for long UR links.
- Forward Raman Pump RIN transfer is manageable with modern high power laser diode pumps in dispersive fibers say > 10 ps/nm



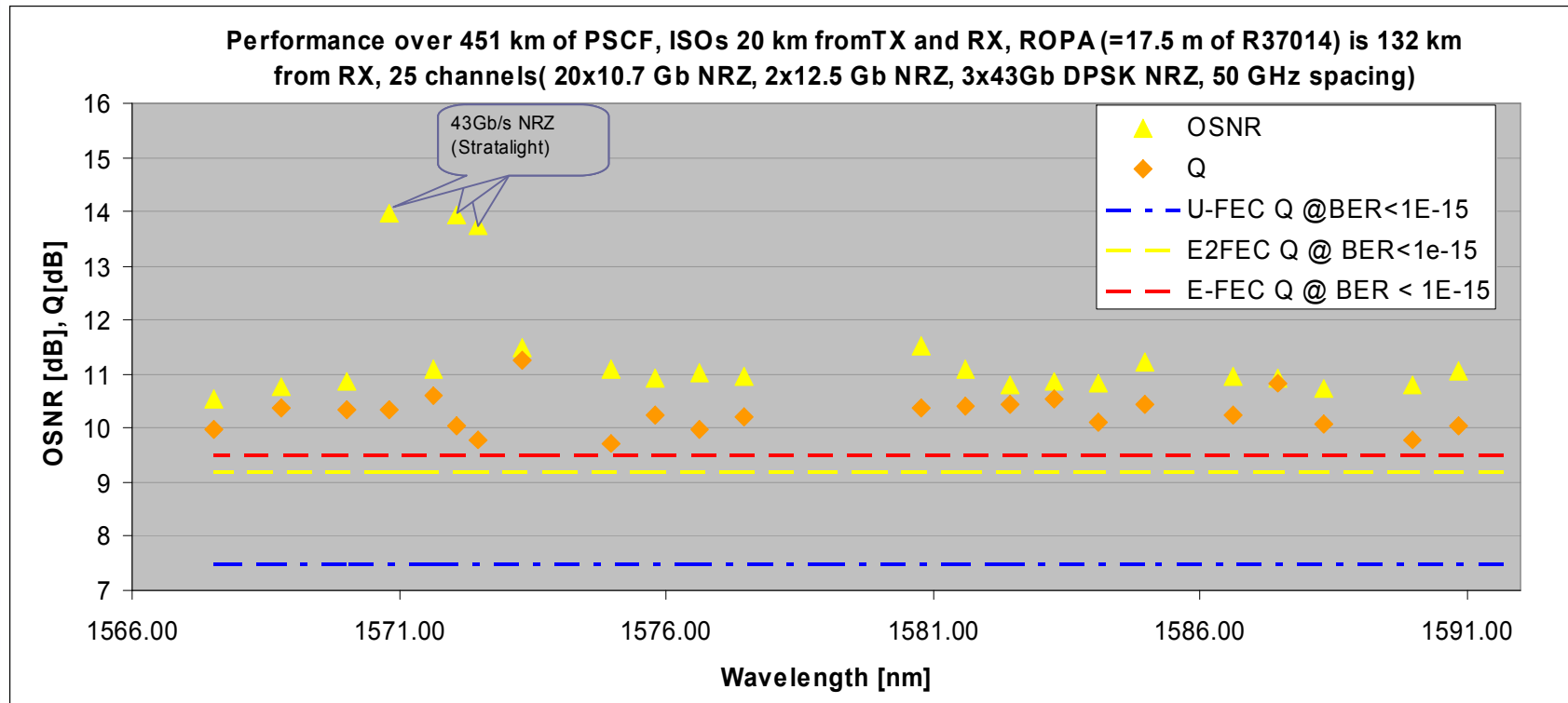
Additional Slides

Related Experiments



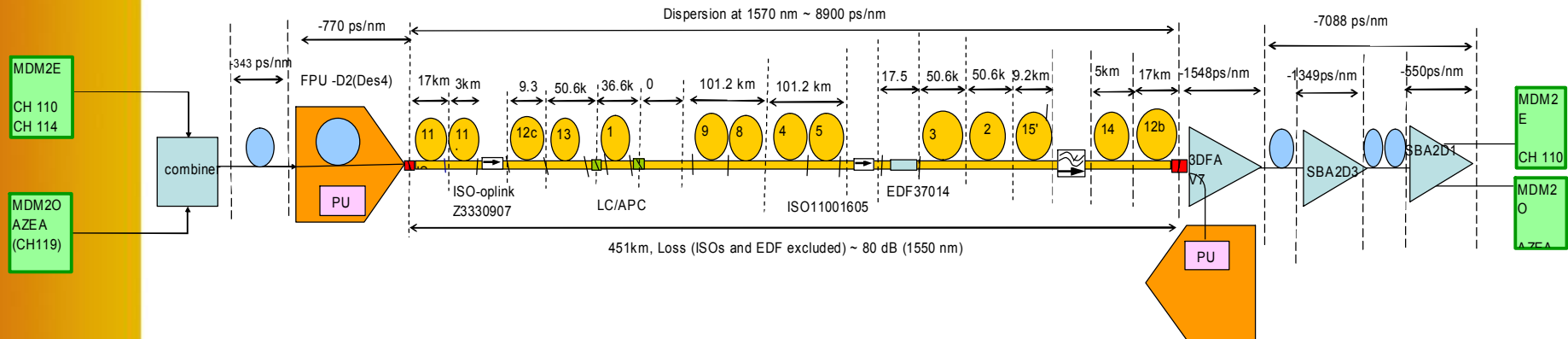
additional slides

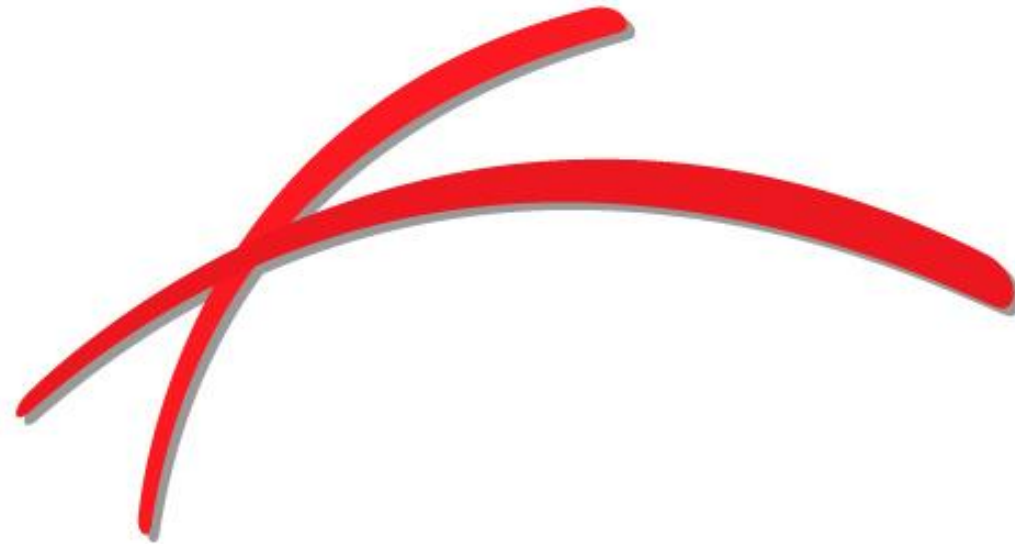
Related Experiments



additional slides

Detailed Configuration





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