# Studio sperimentale dell'impatto di ridotte spaziature inter-canale sulla trasmissione di un super-canale a 1Terabit/s


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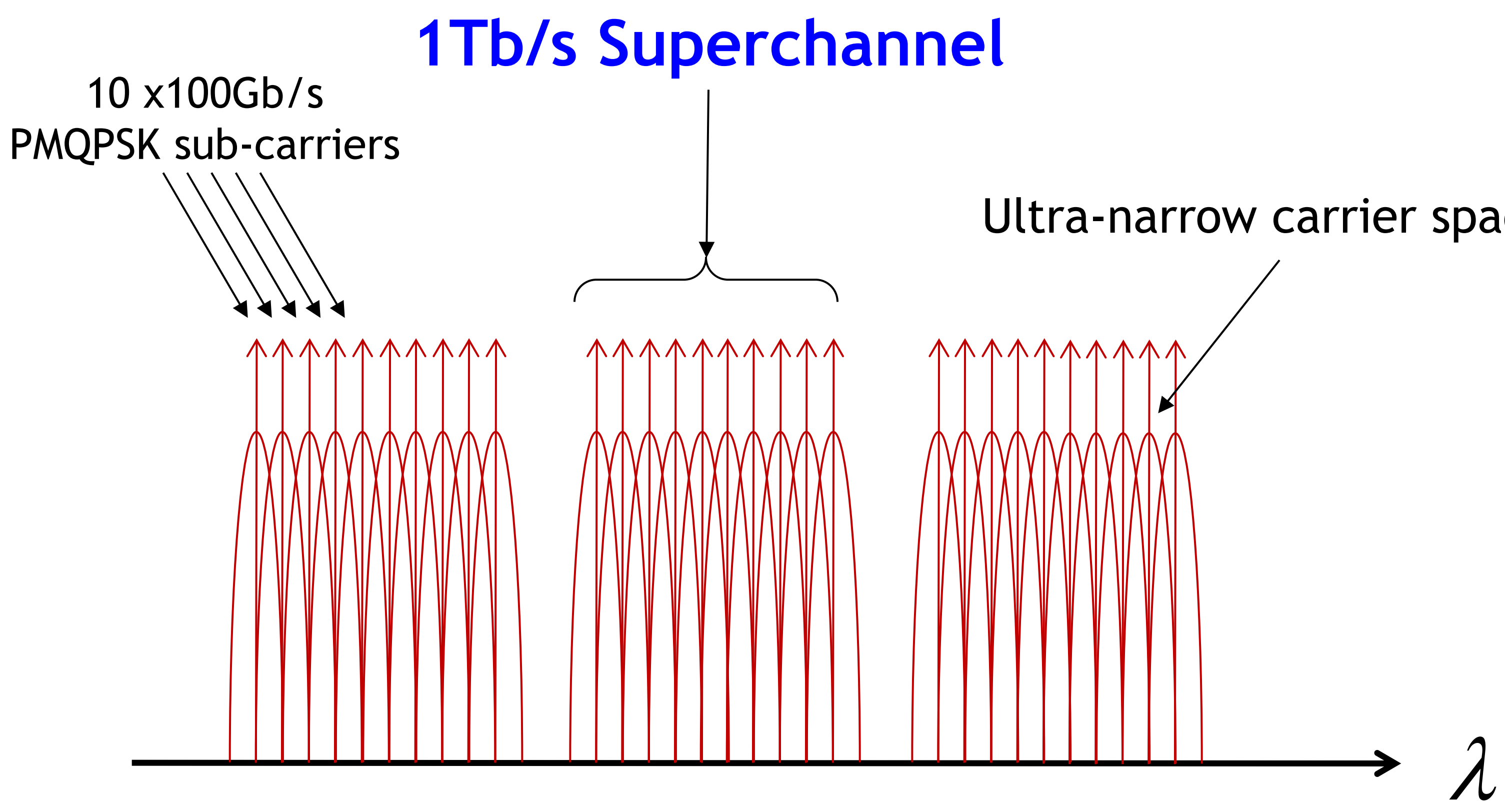
# Aims of the work

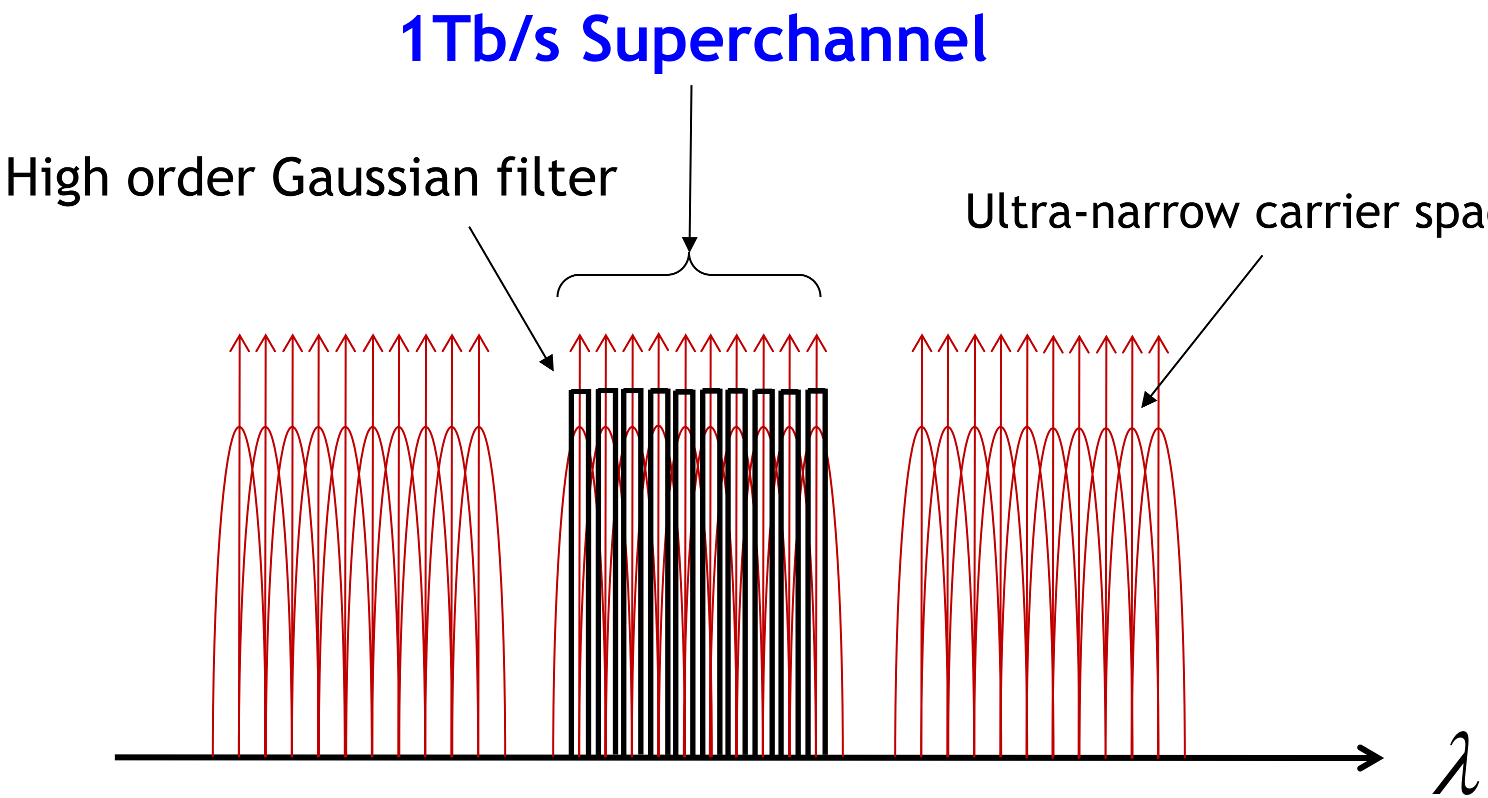
- High spectral efficiency is needed to generate Terabit “super-channels” for a future Terabit Ethernet Standard. It can be obtained by:
  - Higher order modulation formats (QAM 8-16)
  - Decreasing the channel spacing (OFDM, Co-OFDM)
- Co-OFDM operates with sub-carriers spaced at the Baud rate
  - 1T/s Co-OFDM transmission over 7200km has been recently demonstrated (Record Spectral Efficiency x Distance of 27000 km·b/s/Hz)
- However, Co-OFDM requires a complex transceiver architecture:
  - Frequency synchronization of the sub-carriers
  - Symbol transition alignment and a broadband RX
- **Here, we investigate a novel technique to generate 1Tb/s Superchannel by multiplexing sub-carriers close to Baud-Rate spacing using optical spectral reshaping to minimize cross-talk**

# 1Tb/s multi-subcarrier Superchannel




**CONCEPT:** Before combining into a Superchannel the sub-carriers are narrow-filtered (high order Gaussian filter) to remove the cross talk.

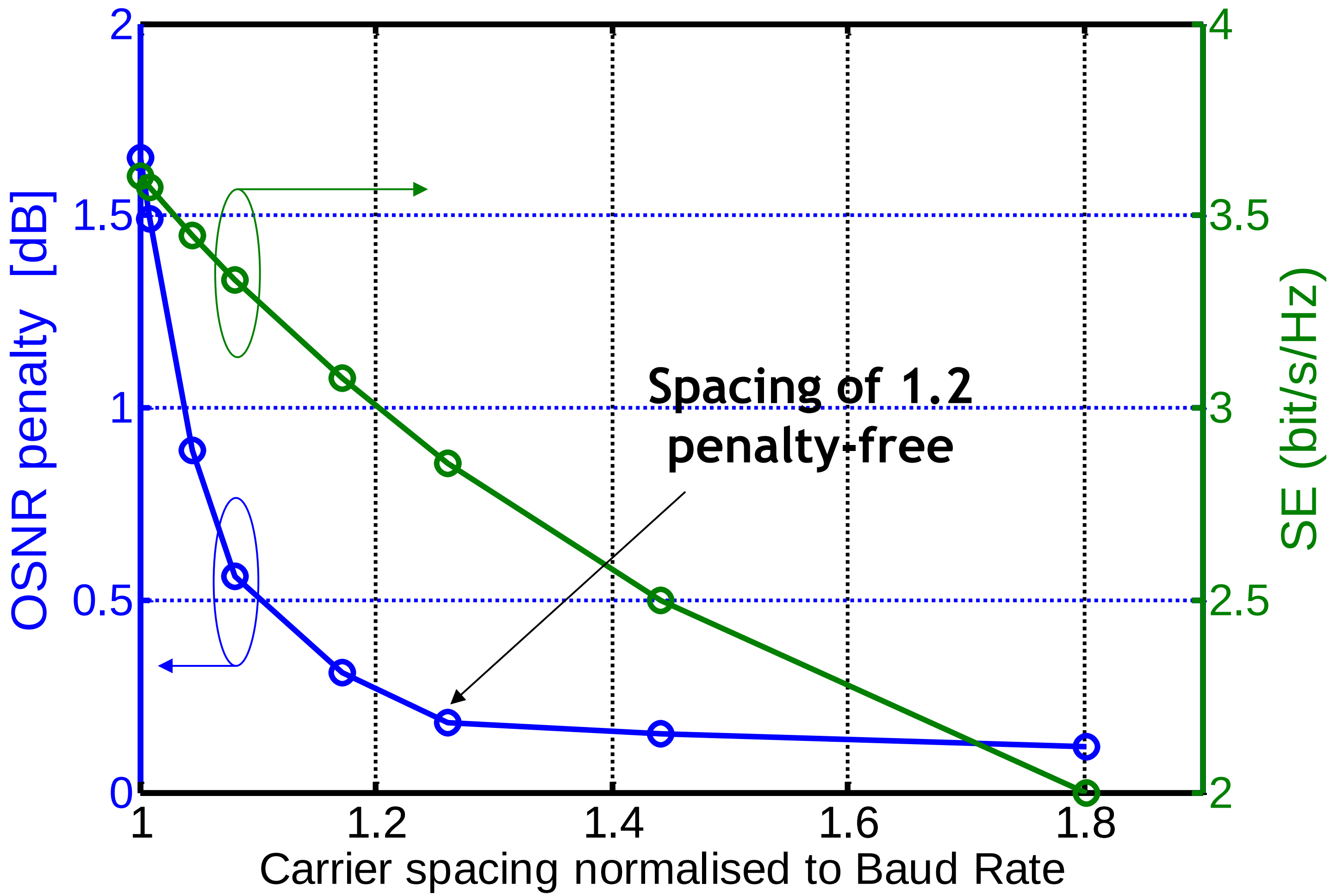
# 1Tb/s multi-subcarrier Superchannel




This approach is also known as **"Nyquist-WDM"**
*(G. Bosco et al., "Performance Limits of Nyquist-WDM and CO-OFDM in High-Speed PM-QPSK Systems", to appear in Photonics Technology Letters ).*

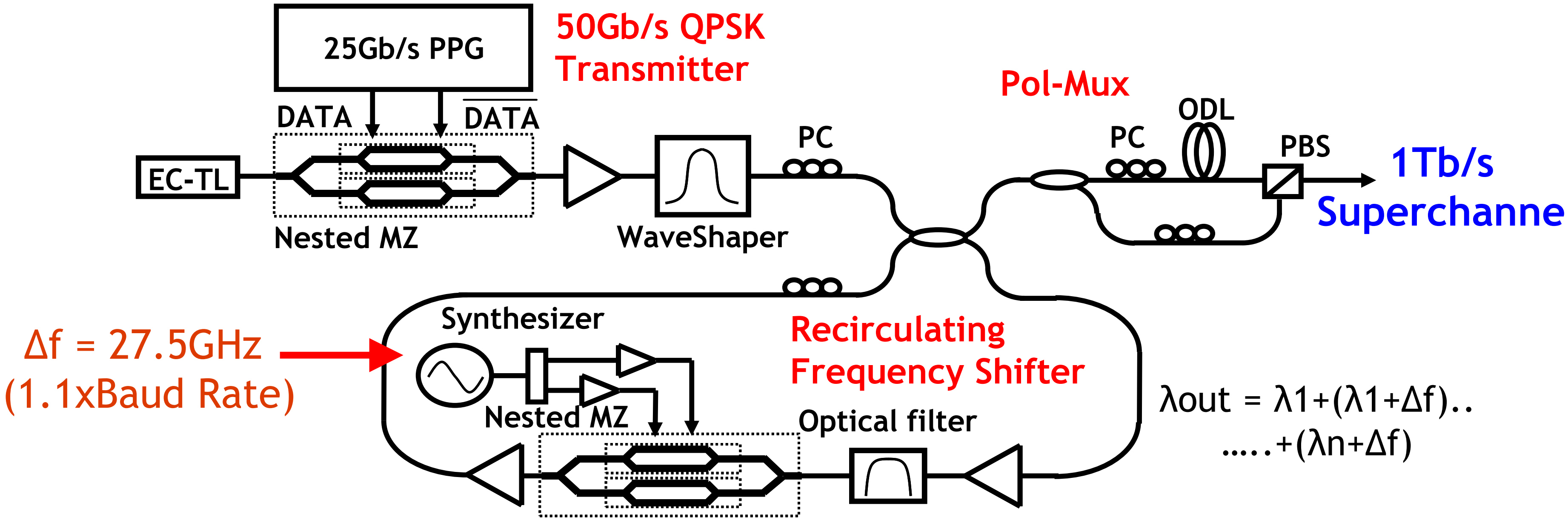
# OSNR penalty vs. carrier spacing

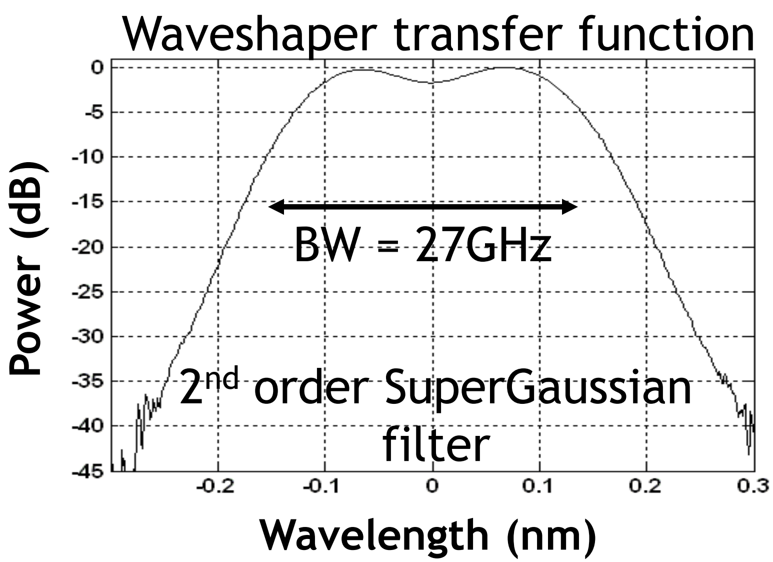
Contour plot for BER = $4 \cdot 10^{-3}$ (Baud Rate = 27.75 Gbaud)

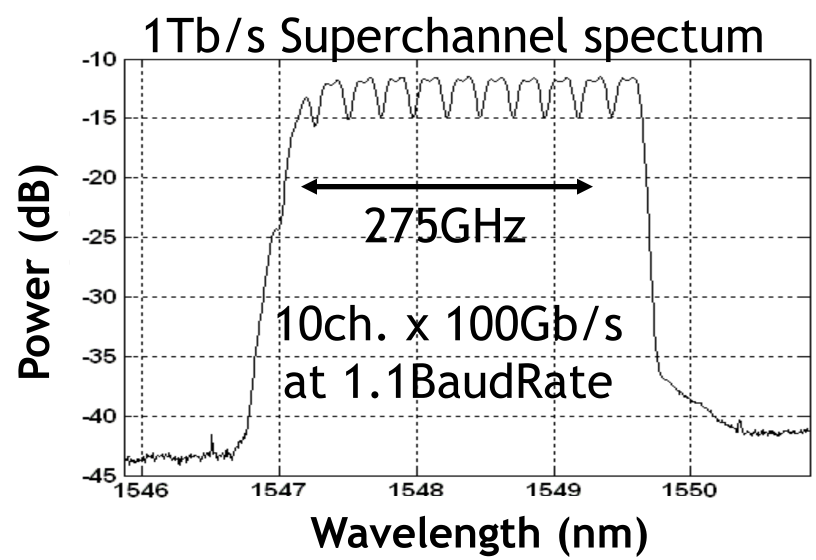



In this work channel spacing of 1.1 and 1.2 x Baud Rate is investigated

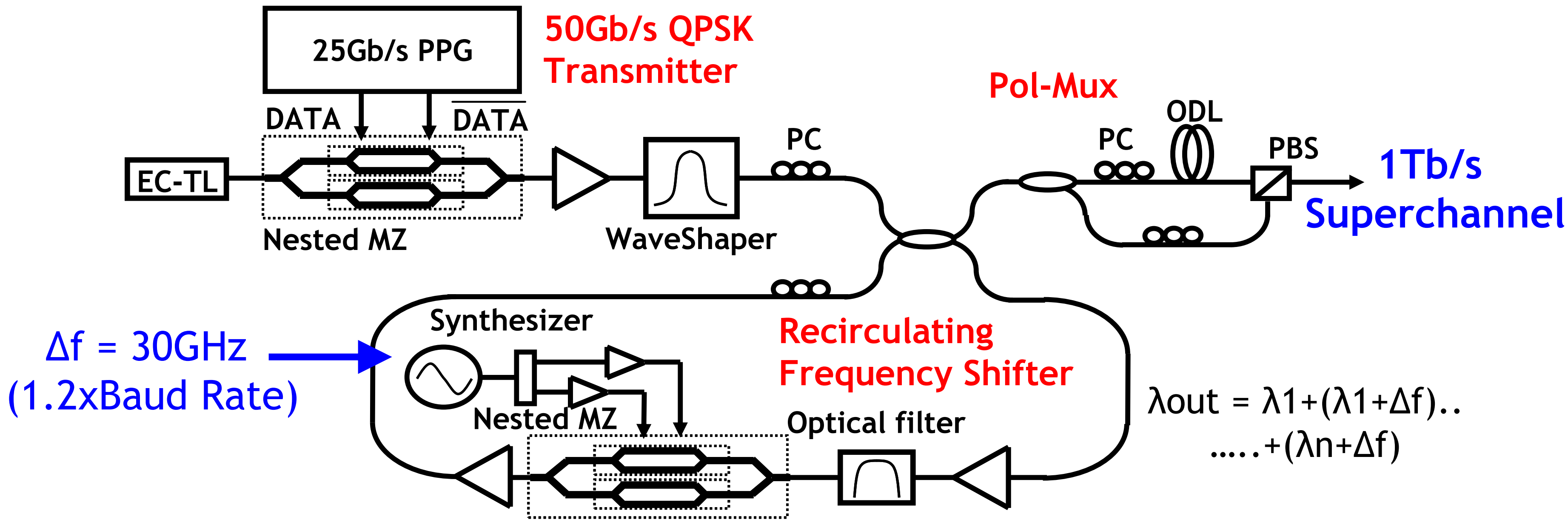
# Sub-carriers generation at 1.1xBaudRate

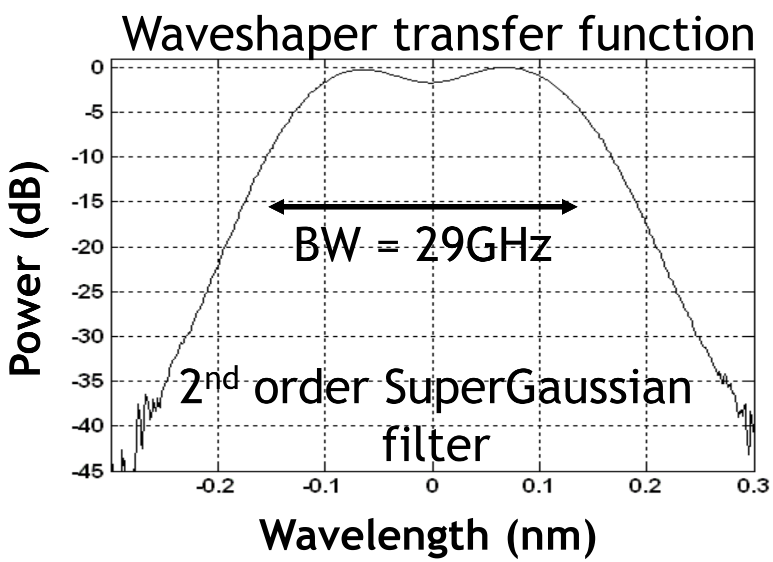


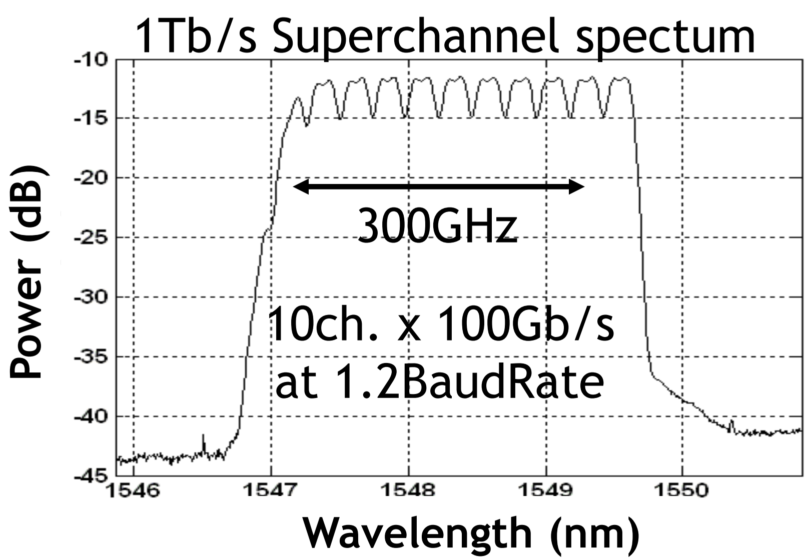



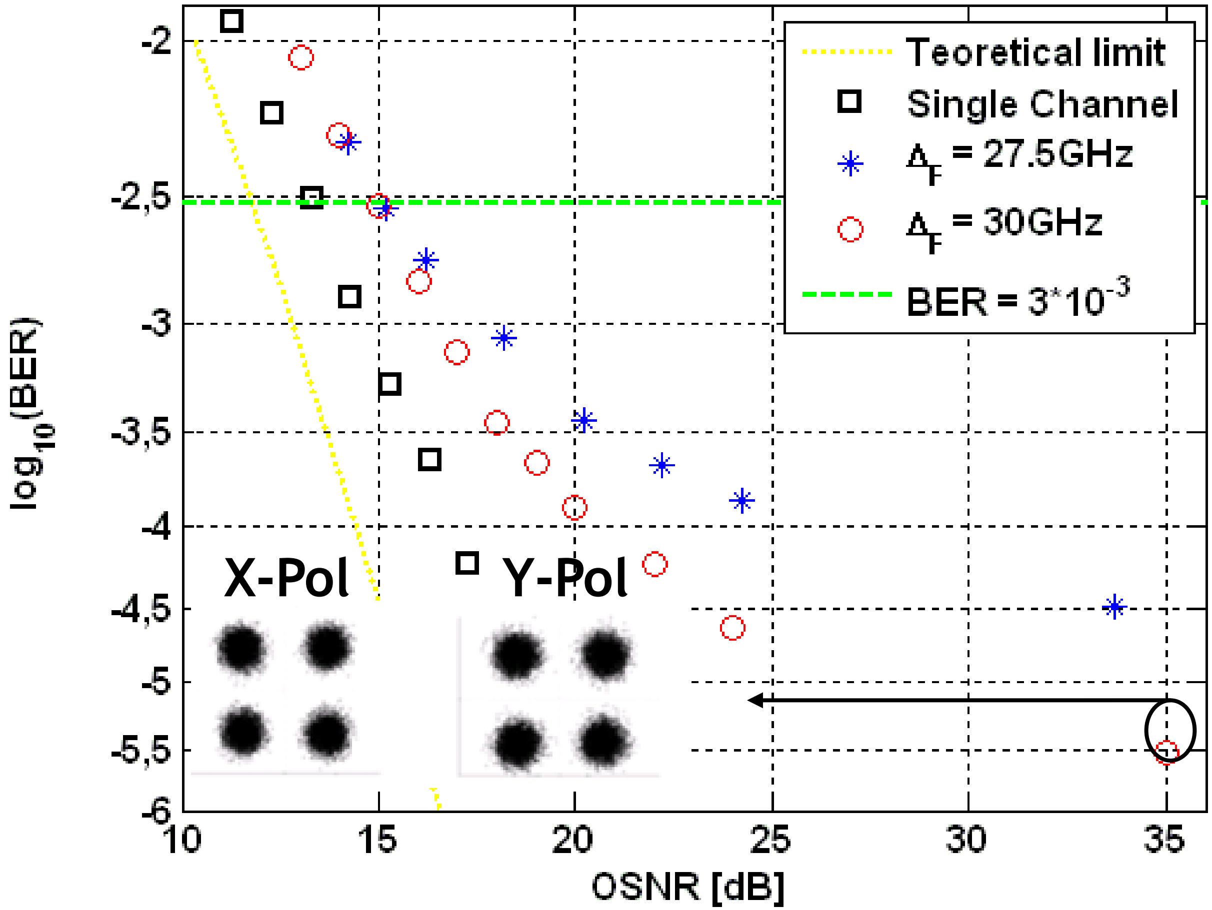
# Sub-carriers generation at 1.2xBaudRate



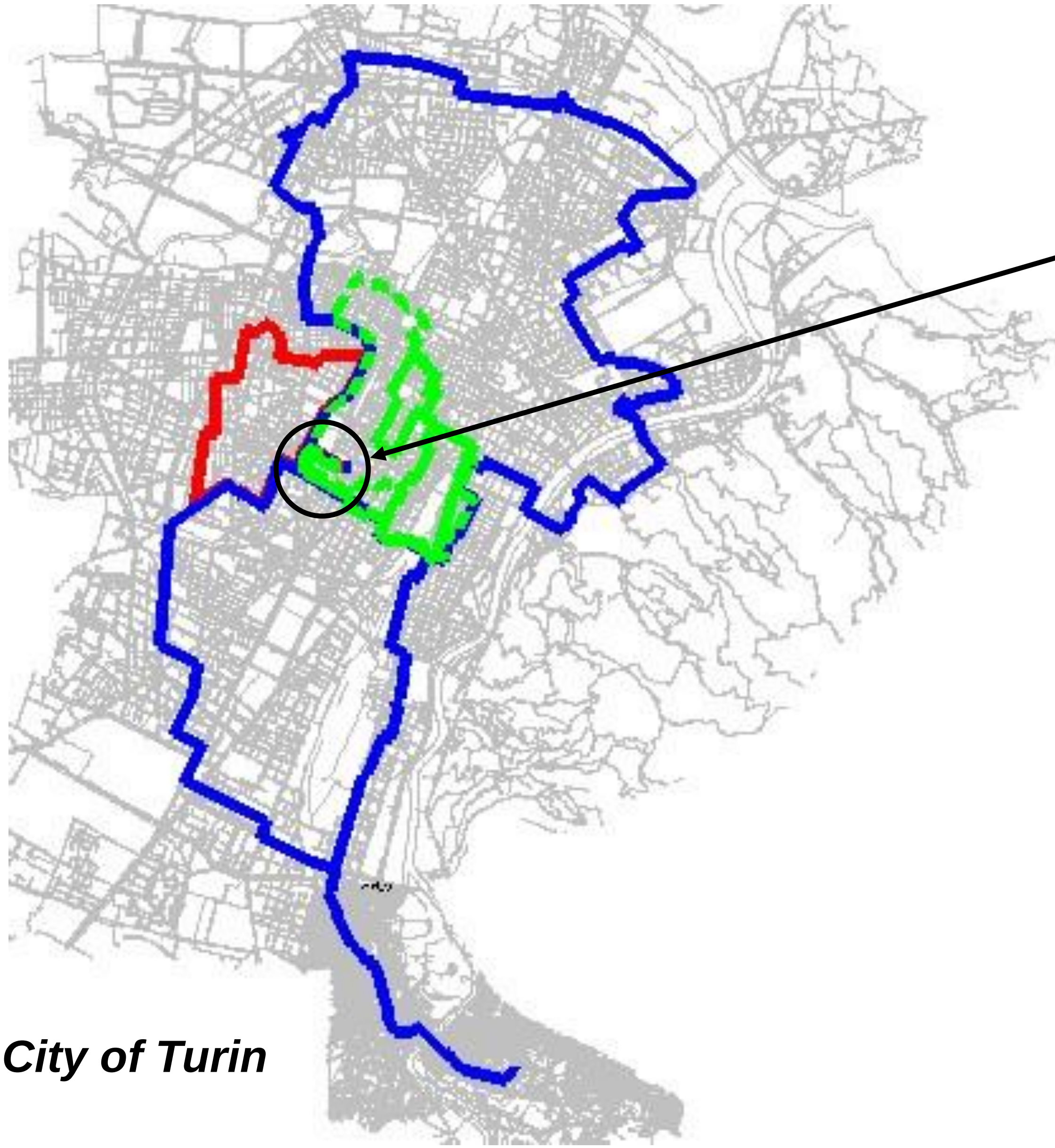
# Back to back sensitivity for 5th carrier




Sensitivity ($3 \cdot 10^{-3}$) measured on a single sub-carrier at 25 GBaud:

- 15 dB for Waveshaper BW = 29GHz (channel spacing 1.2 $B_R$)
- 15.1dB for Waveshaper BW = 27GHz (channel spacing 1.1 $B_R$)

# Test-bed: Installed transmission fiber

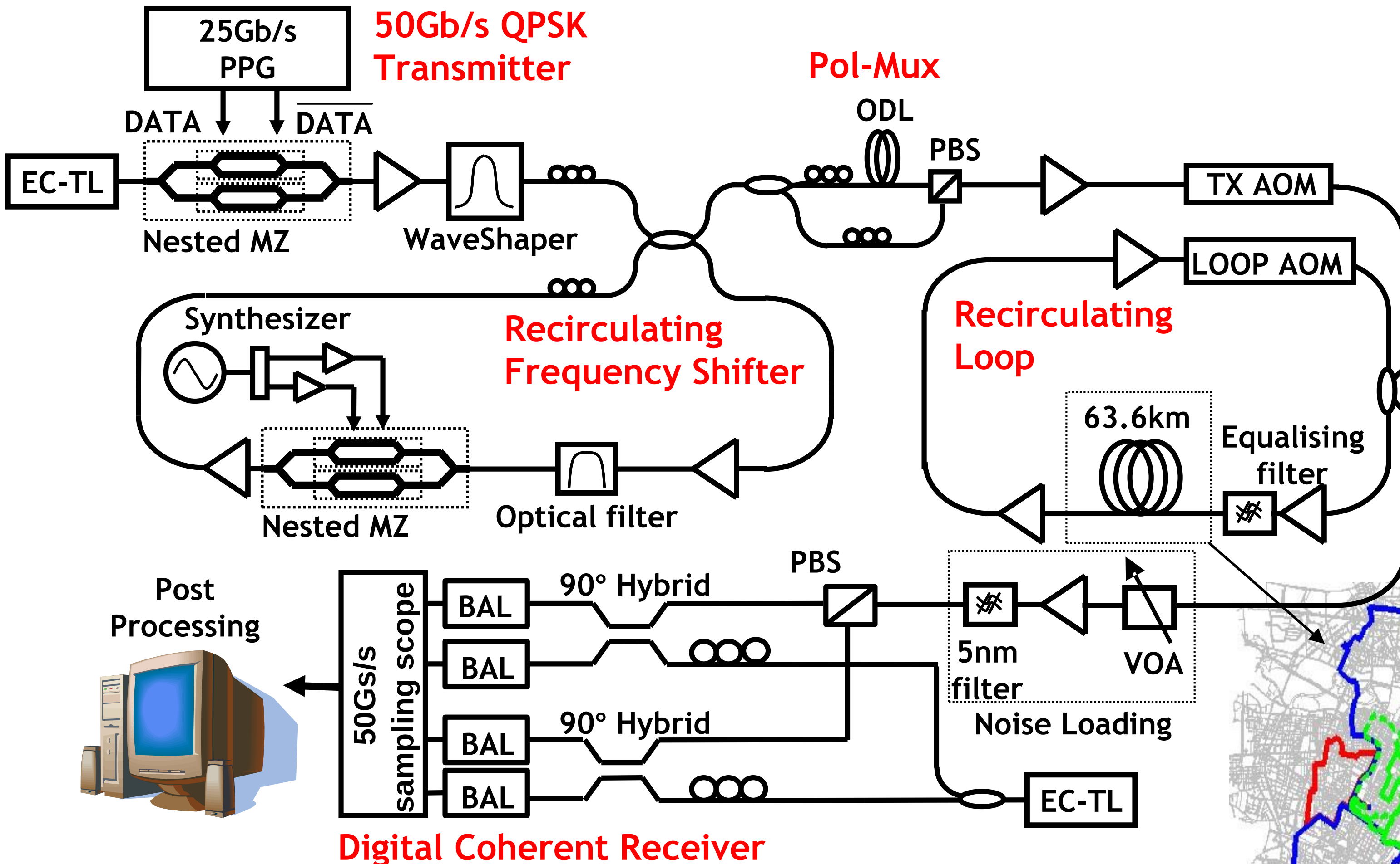


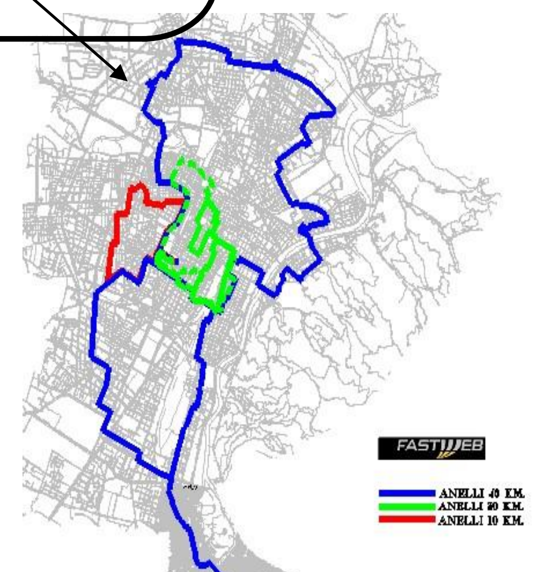

**Photon Labs**
**Politecnico of Turin**

***Installed SSMF fibre rings***
***Metro network Fastweb***

| Length (km) | Loss (dB/km) | D |
|---|---|---|
| 2x40 | 0.245 | 16.14 |
| 2x20 | 0.235 | |
| 2x10 | 0.264 | |

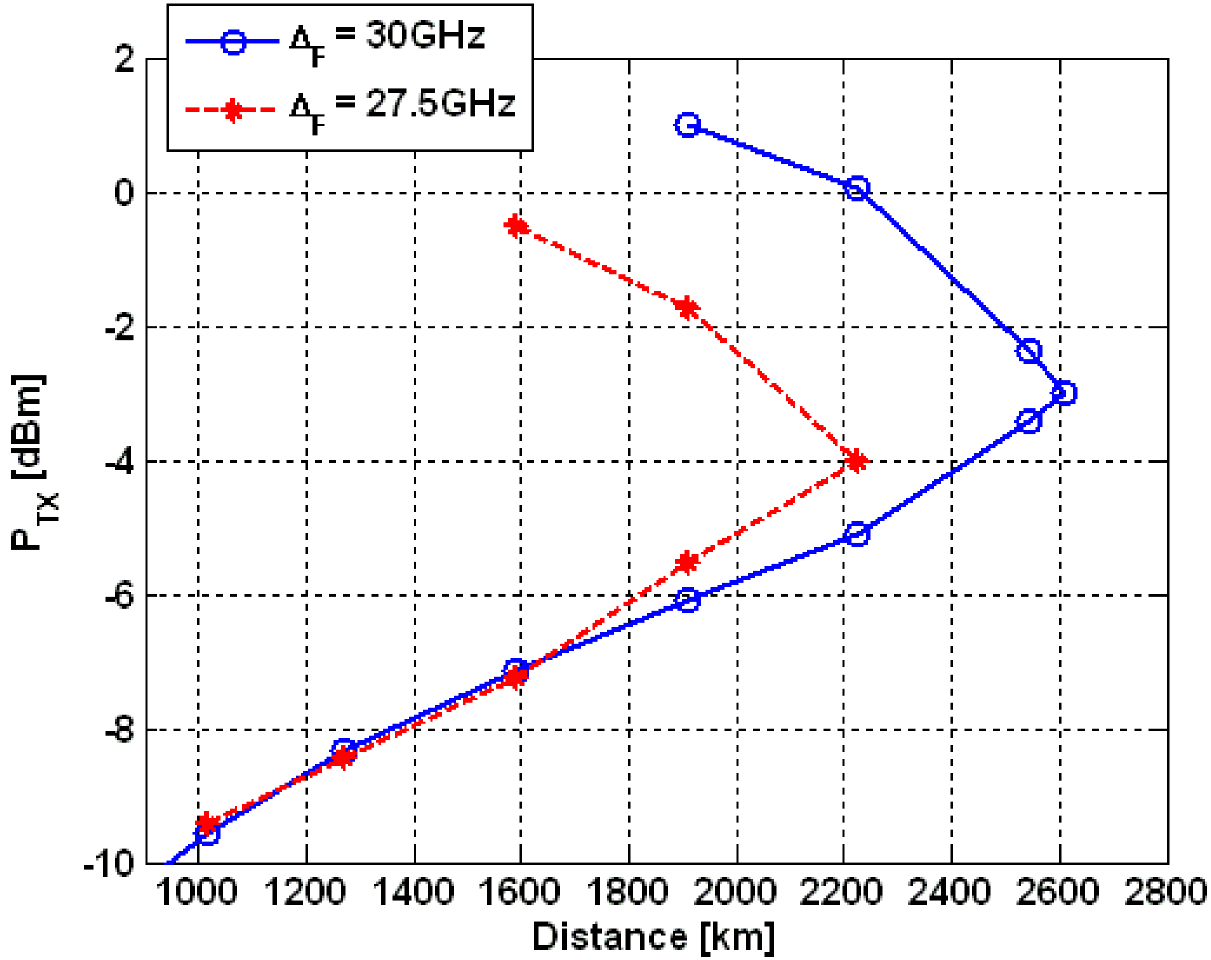
# 1Tb/s Transmission over installed fibre



**FASTWEB SMF dark fibre installed in the city of Turin**
**Span lenght 63.6km (42Km + 21.6Km) Loss 18dB**

# 1Tb/s Transmission over installed SMF fibre

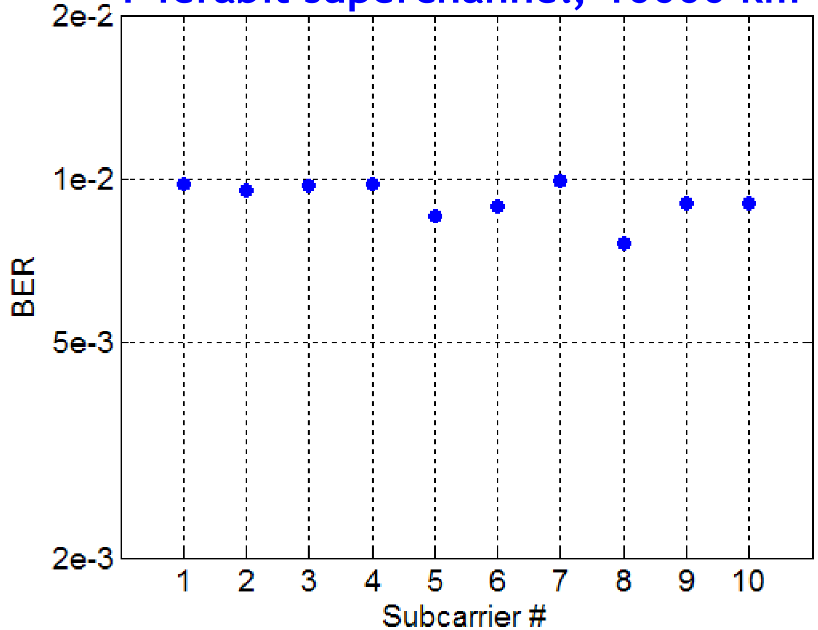



The maximum reach: from 2600 km to 2200 km when carrier spacing is reduced from 1.2 to 1.1 x Baud rate due to inter-channel nonlinearity

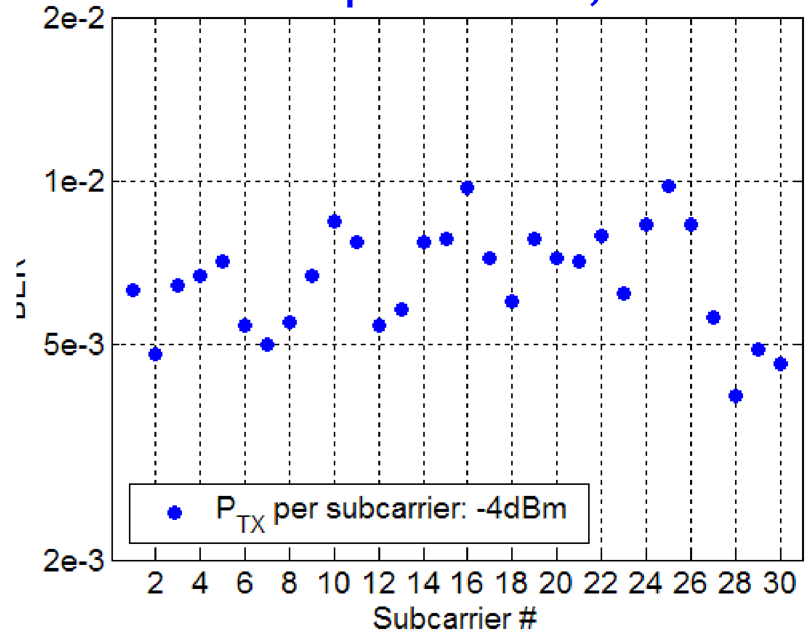
# Recent developments

- Experimental results of transmission of PM-QPSK Terabit superchannels over **Pure-Silica-Core Fiber (PSCF)** with **Raman amplification**
  - 30 Gbaud, 33 GHz spacing (1.1 x baud-rate)

**1 Terabit superchannel, 10000 km**




**3 Terabit superchannels, 8000 km**



# Conclusions

- We have experimentally demonstrated the generation of a Terabit Superchannel using  a novel multi-carrier transmitter based on sub-carriers spectral reshaping to minimize cross-talk

- Superchannel transmission experiments have demonstrated:
  - Maximum reach of 2600 km over SMF + EDFA only
  - Maximum reach increased to 10000 km over PSCF + hybrid Raman/EDFA amplification

- Our experiments show that, thanks to optical carrier reshaping at the transmitter, a spectral efficiency close to Co-OFDM can be achieved with a simpler transceiver architecture.

# Acknowledgments

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