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OPTCOM

Ultra-Long-Haul Transmission of 16x112 Gb/s Spectrally-Engineered DAC-Generated Nyquist-WDM PM-16QAM Channels with 1.05x(Symbol-Rate) Frequency Spacing

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Motivations of this work

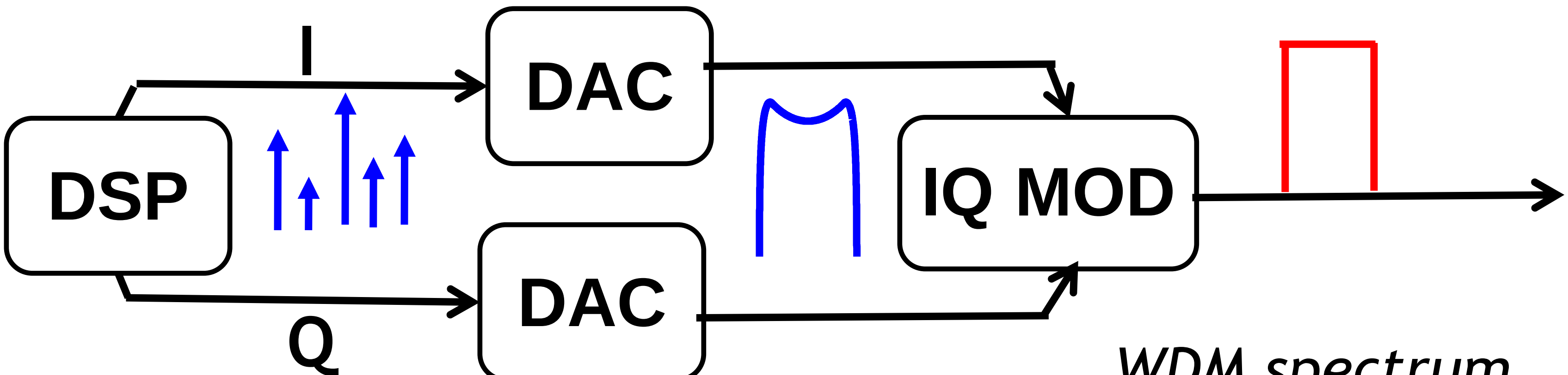
- **Nyquist-WDM** technique has been successfully employed in ultra-long-haul experiments with **PM-QPSK**, reaching transoceanic distances with channel spacing equal to the symbol-rate → gross SE=**4 b/s/Hz**
  - *J. -X. Cai et al.," ECOC 2010, paper PD2.1*
  - *E. Torrengo, et al.," ECOC 2010, paper We.7.C.2.*

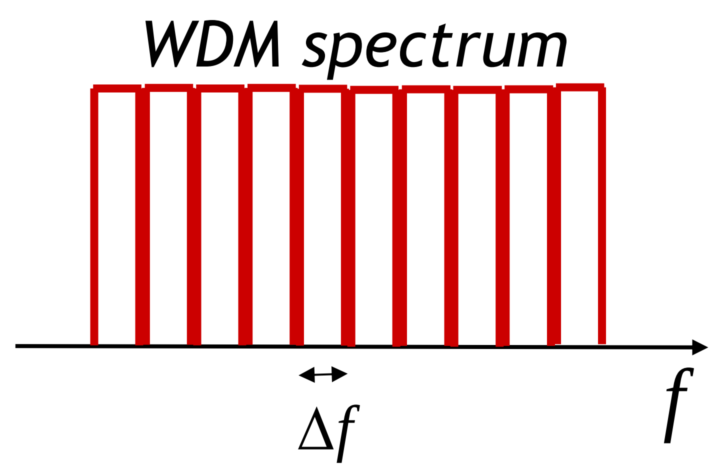
- The gross SE of **PM-16QAM** is potentially equal to **8 b/s/Hz**.

  However, in practice it is limited by the high sensitivity of PM-16QAM to **inter-channel crosstalk**
- The maximum gross SE recorded to-date for WDM ultra-long-haul PM-16QAM transmission is **6.85 b/s/Hz** (spacing = 1.17 x symbol-rate)
  - *Shogo Yamanaka et al.," ECOC 2010, paper We.8.C.1*

Motivations of this work

- The goal of our experimental study was to demonstrate that Nyquist-WDM with PM-16QAM can closely approach Nyquist-limited spectral efficiency, thanks to accurate spectral engineering in the digital domain



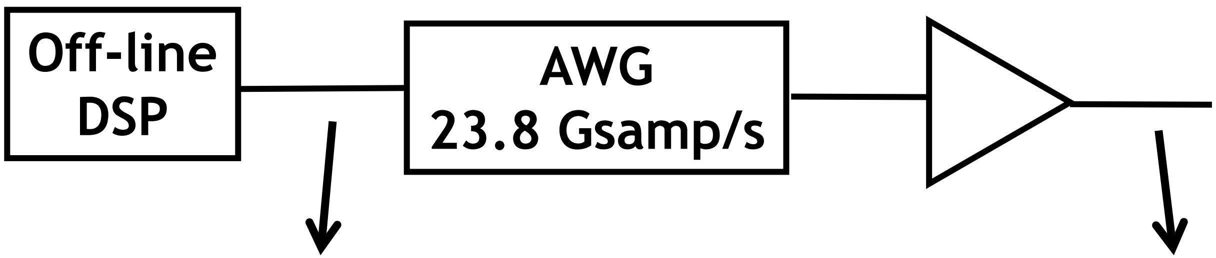


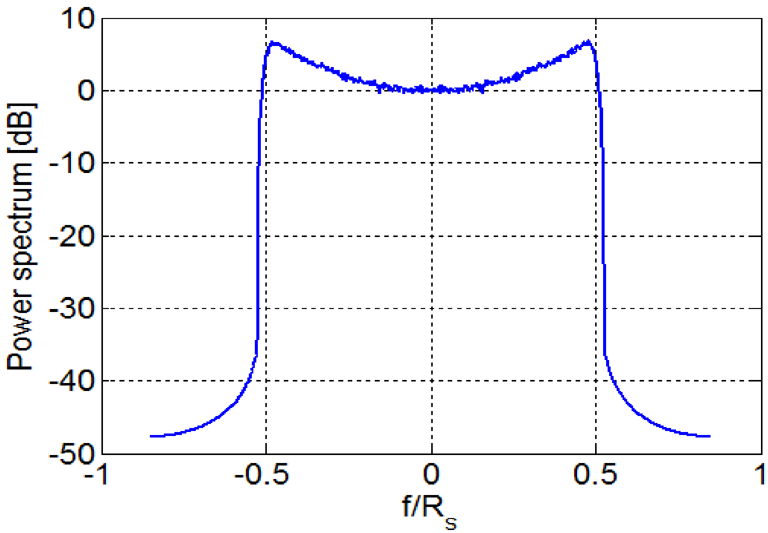
Channel spacing = 1.05 R_s

Gross SE = 7.62 b/s/Hz

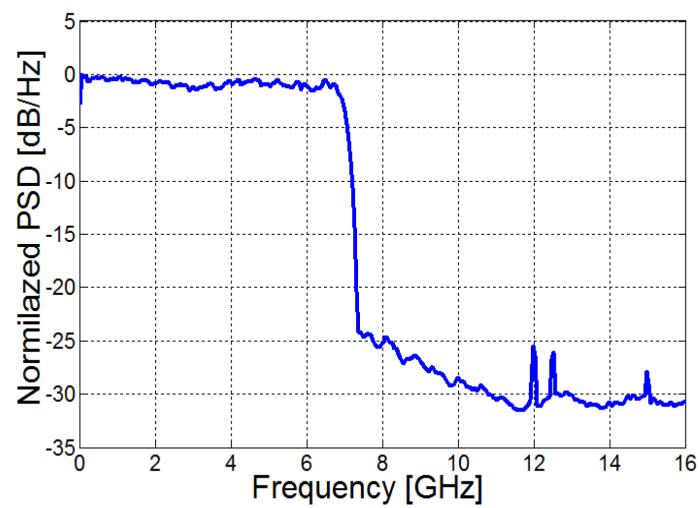
Experimental set-up - DAC

4-level ASK
1.7 samp/symb



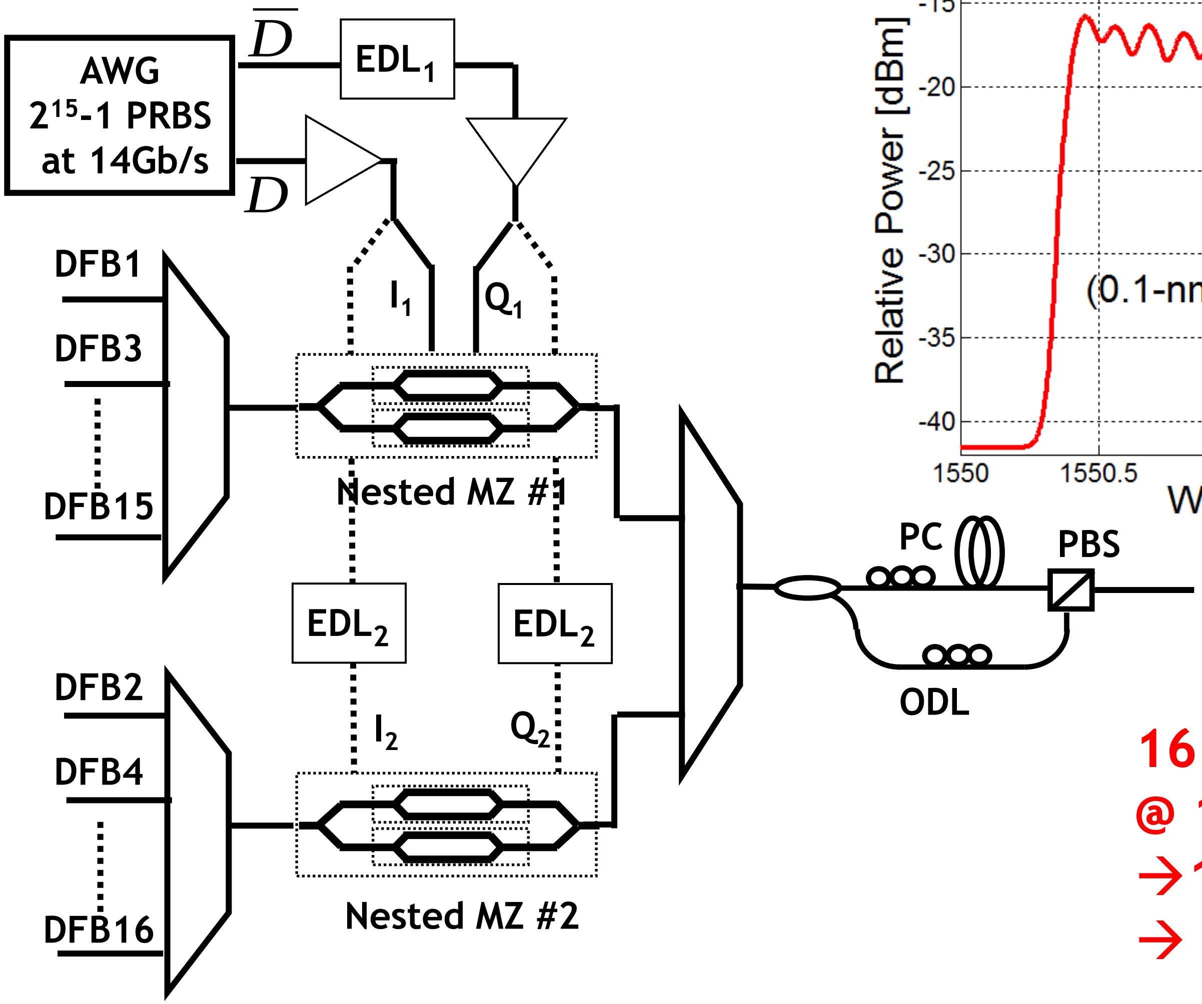


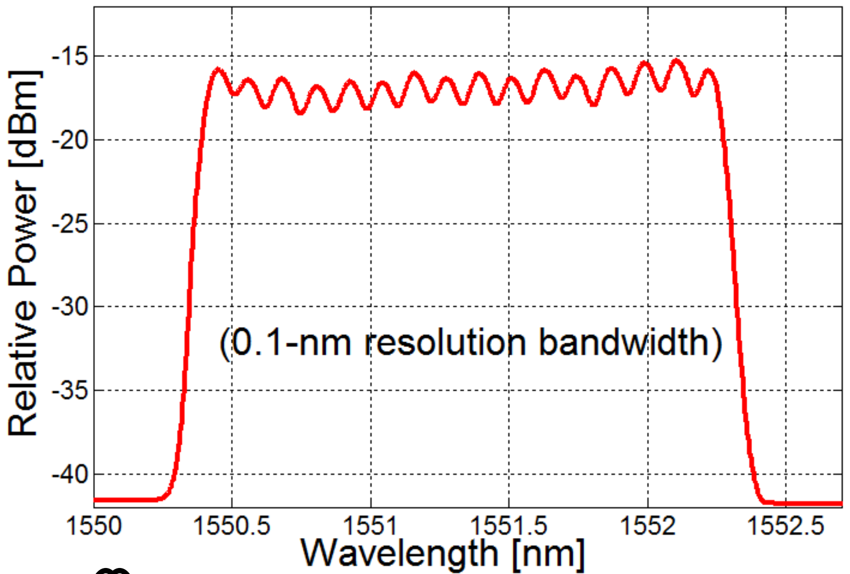
R_s=14 Gbaud



Square-root raised-cosine
(roll-off 0.05)
+ pre-enhancement

Exp. set-up - Transmitter

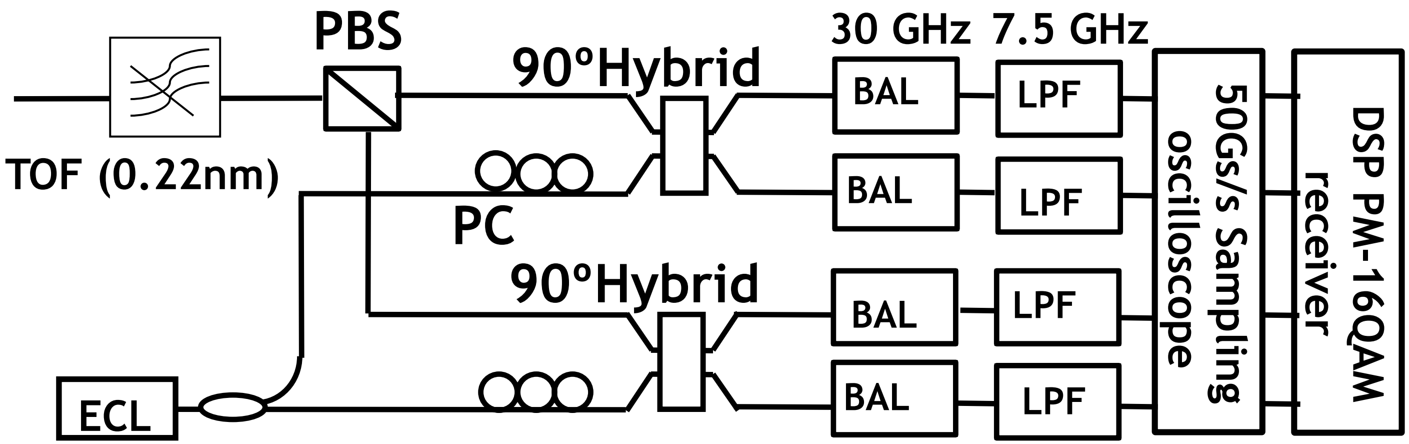




16 PM-16QAM subcarriers
@ 14Gbaud spaced 14.7GHz
→1.05 R_s spacing
→ Gross SE = 7.62 b/s/Hz

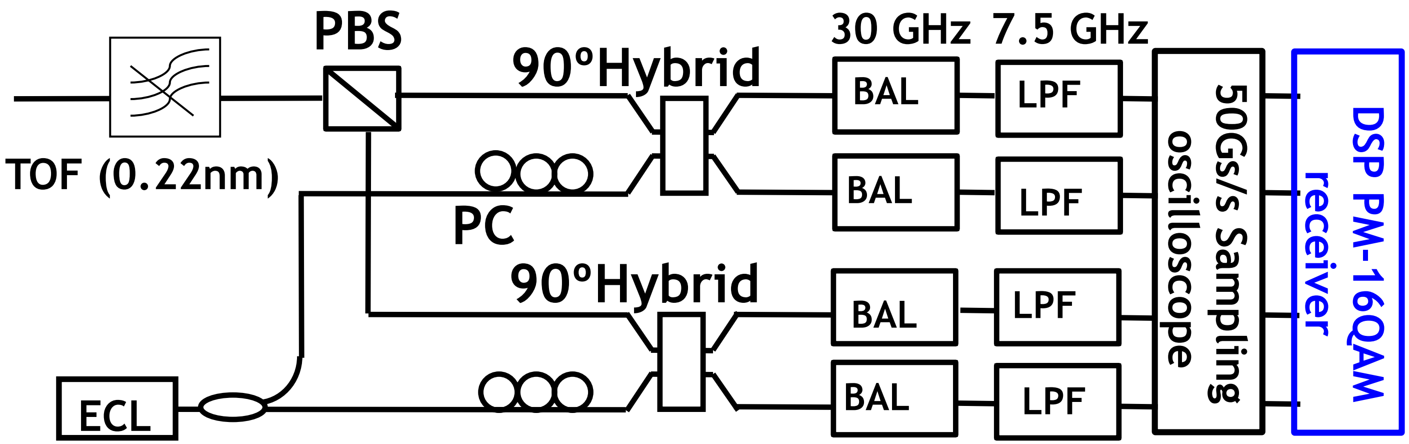
Exp. set-up - Receiver

Digital Coherent Receiver



Exp. set-up - Receiver

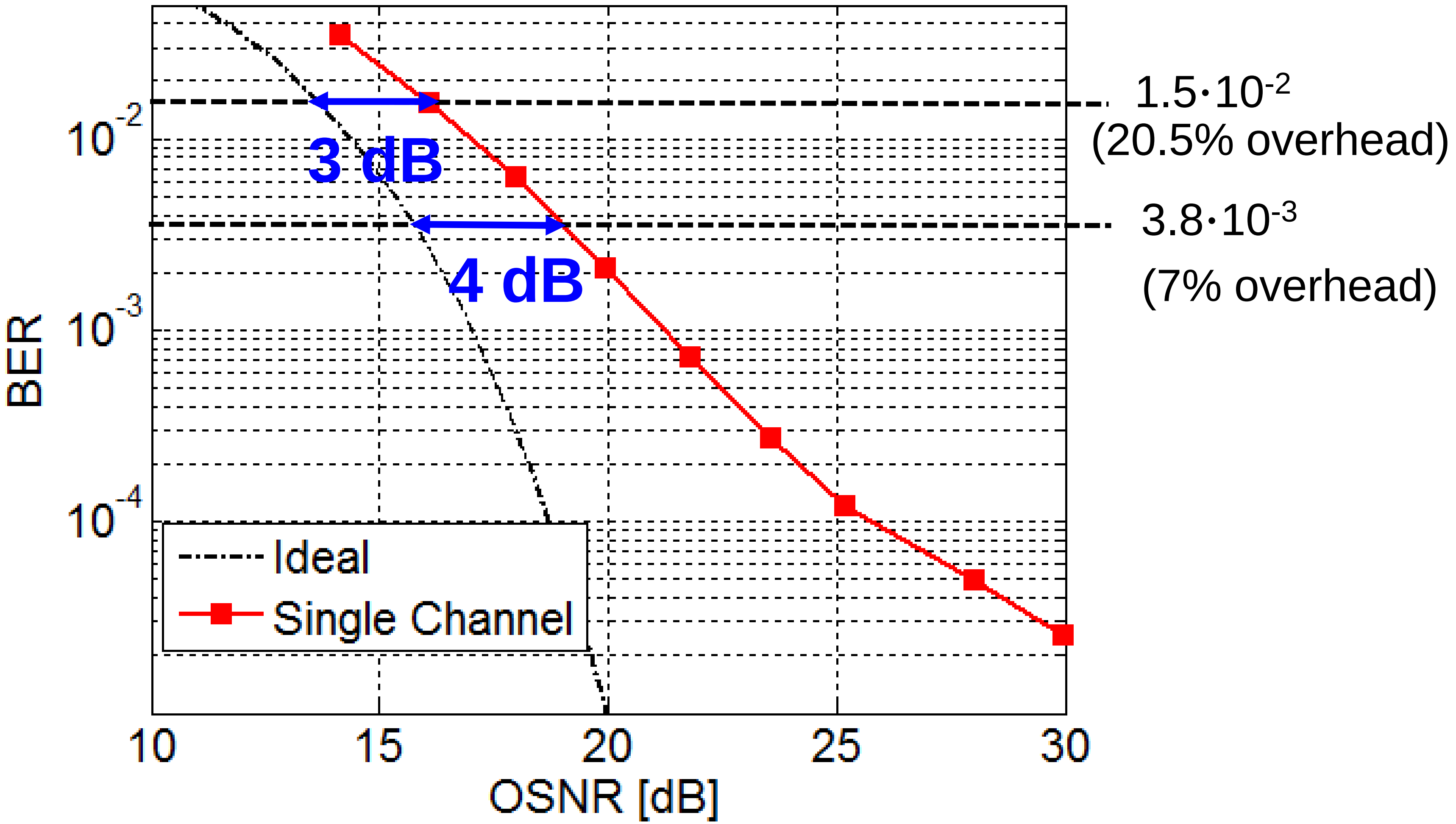
Digital Coherent Receiver



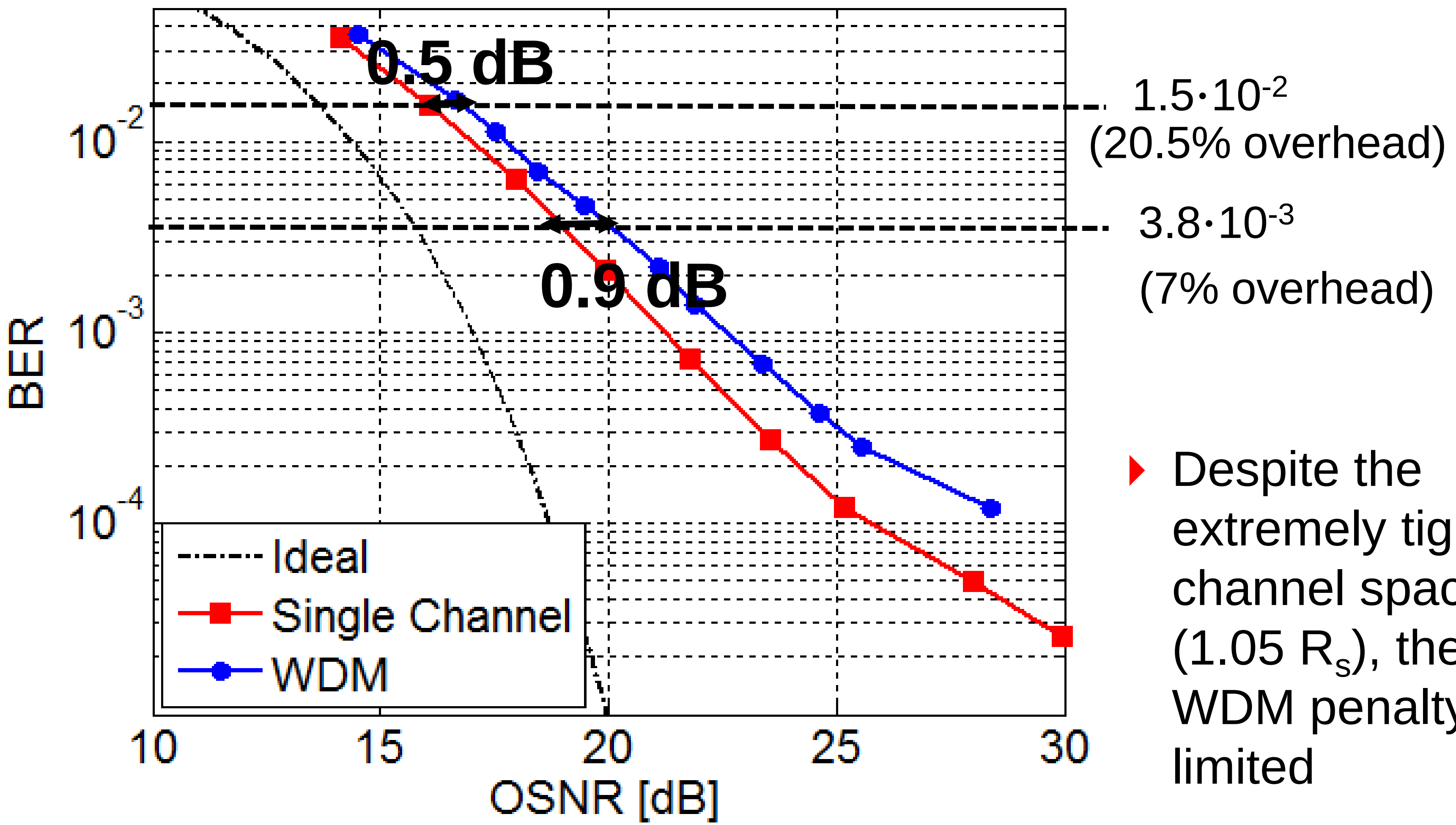
POST-PROCESSING

- Re-sampling stage: 50GS/s → 28GS/s (2 samples per symbol)
- First equalizer stage to perform bulk CD compensation
- 43-taps 2x2 MIMO stage, adjusted through multi-modulus CMA
- Viterbi&Viterbi stage for frequency offset estimation and compensation
- Maximum-likelihood (minimum distance) decision stage.

Back-to-back performance

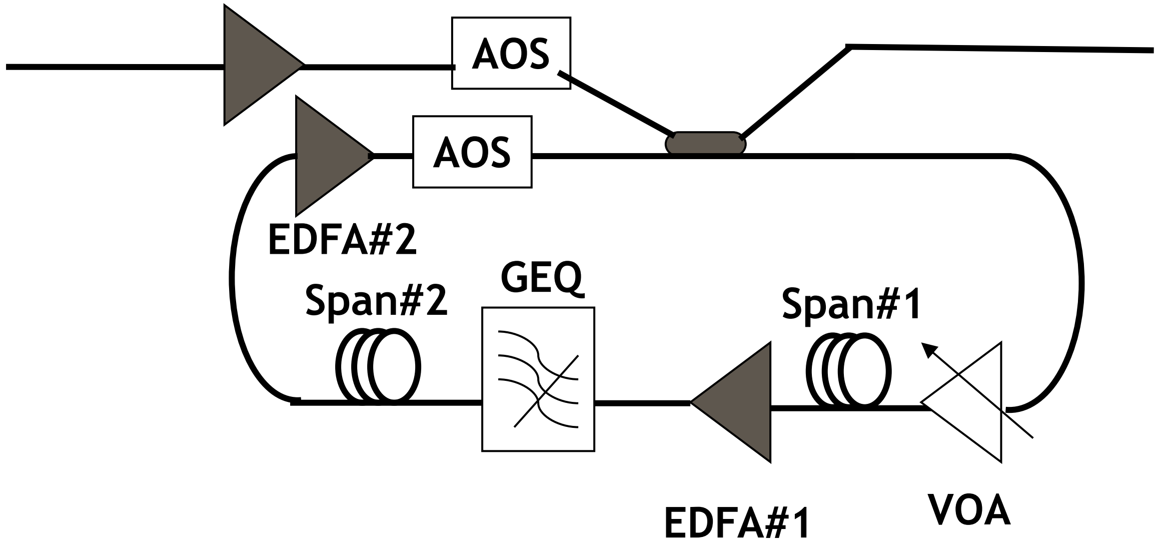


Back-to-back performance



- Despite the extremely tight channel spacing (1.05 R_s), the WDM penalty is limited

Exp. set-up - Loop

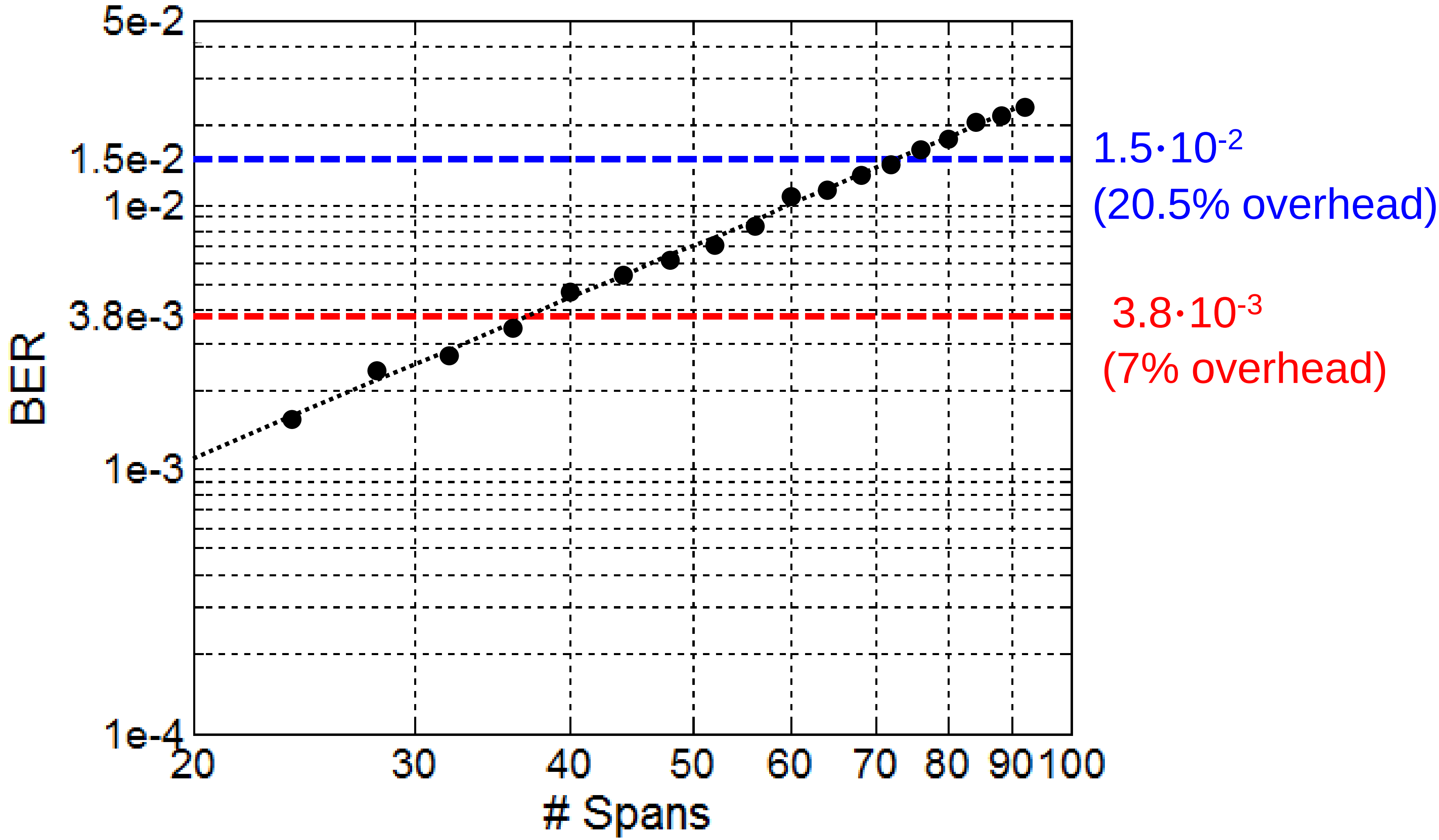


Power launched into the fiber:
-6 dBm per channel

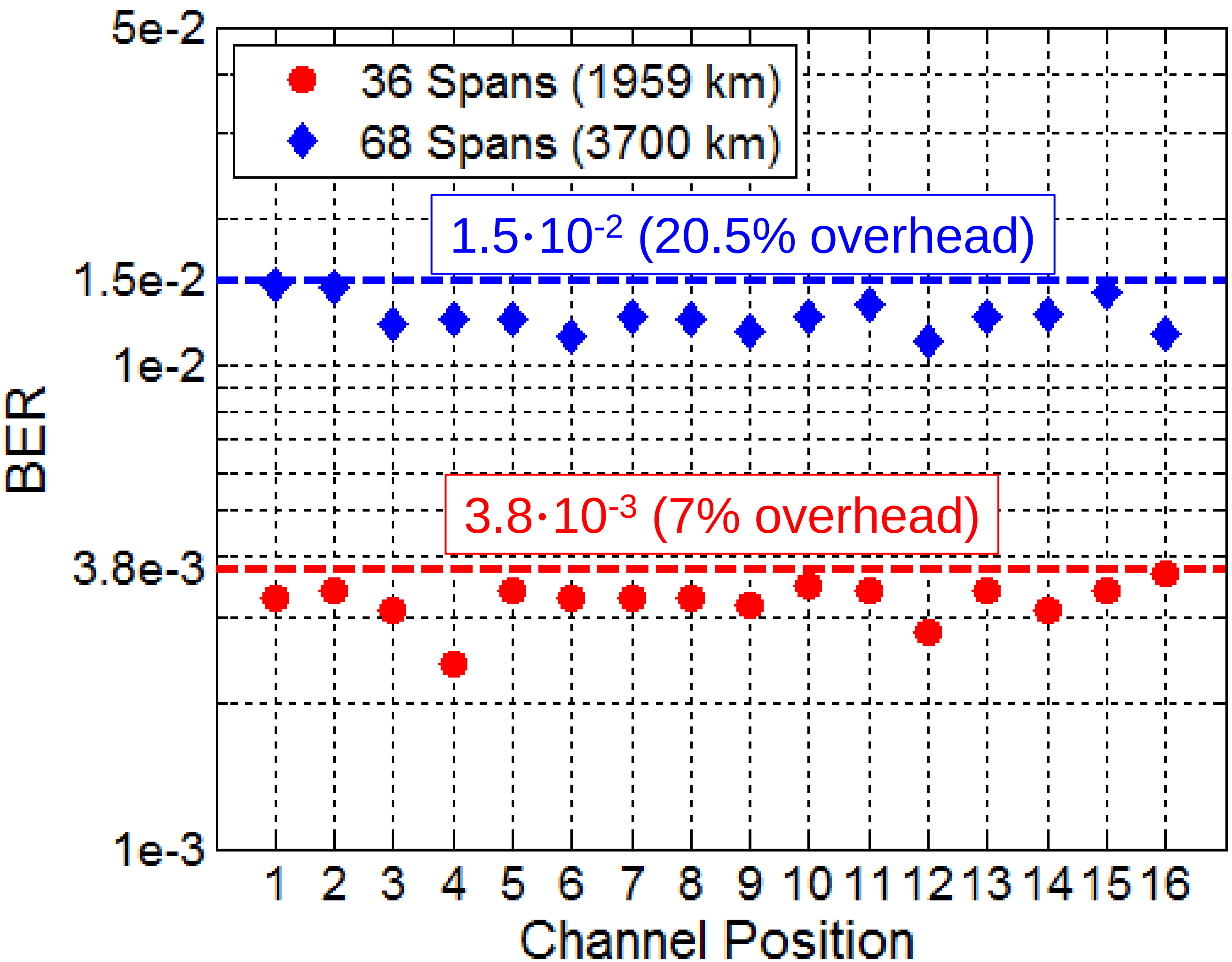
- Typical submarine system segment:
  - EDFA-only amplification
  - Average span length of 54.42 km
  - Advanced PSCF with: α=0.162 dB/km, A_{eff}=130μm^2, D=21 ps/nm/km @ 1550 nm (slope 0.061 $ps/nm^2/km$).

BER vs. number of spans

- Measured on the center channel (# 8):



Maximum reach

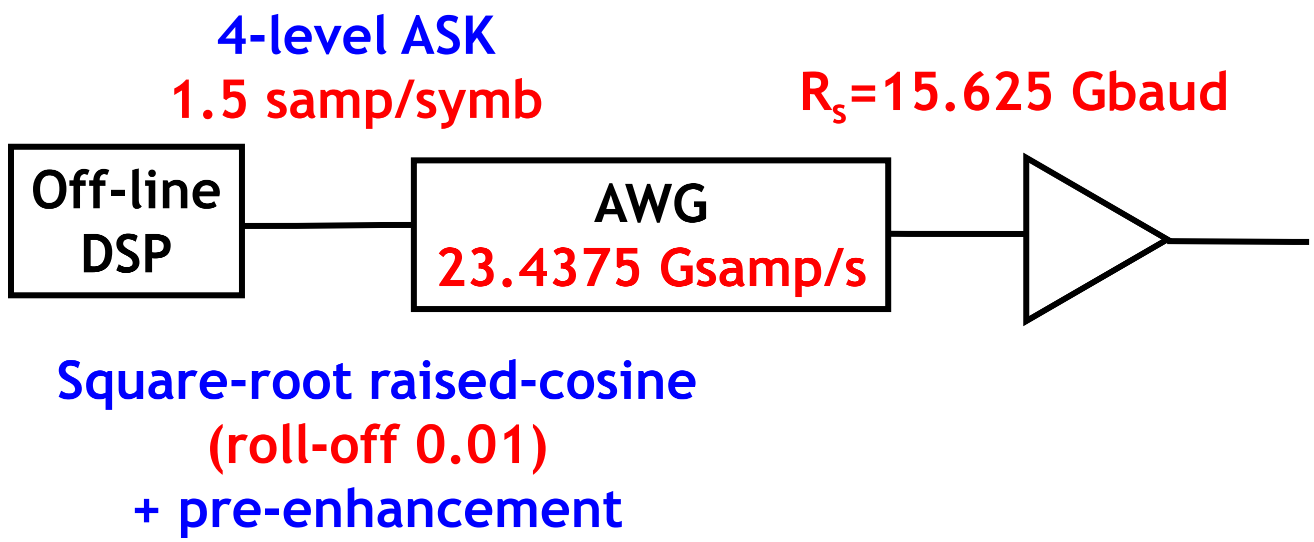


Net SE:
6.32 b/s/Hz
Net SEx(distance):
23,396 b/s/Hz·km

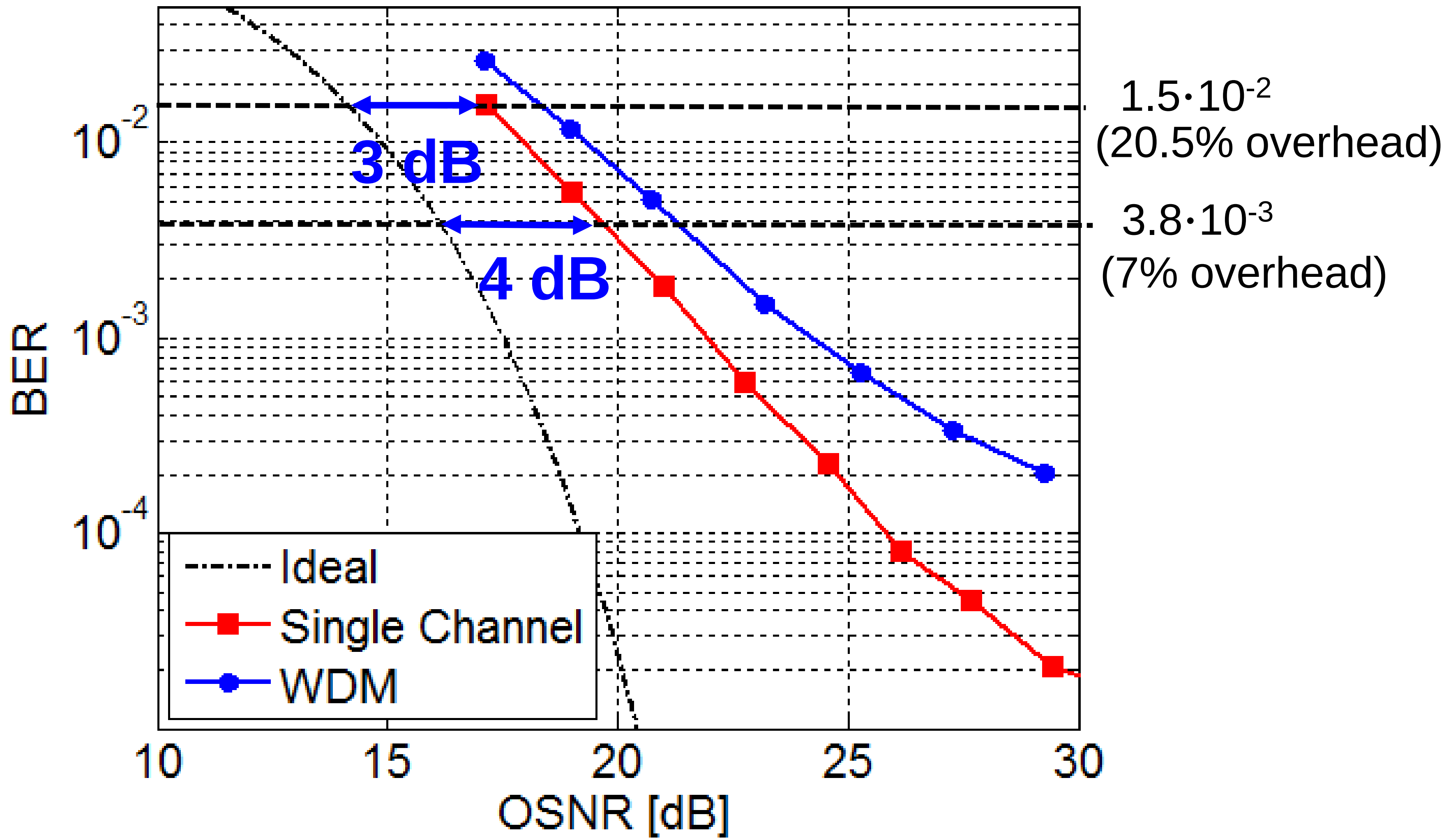
Net SE:
7.12 b/s/Hz
Net SEx(distance):
13,949 b/s/Hz·km

Follow-up experiment

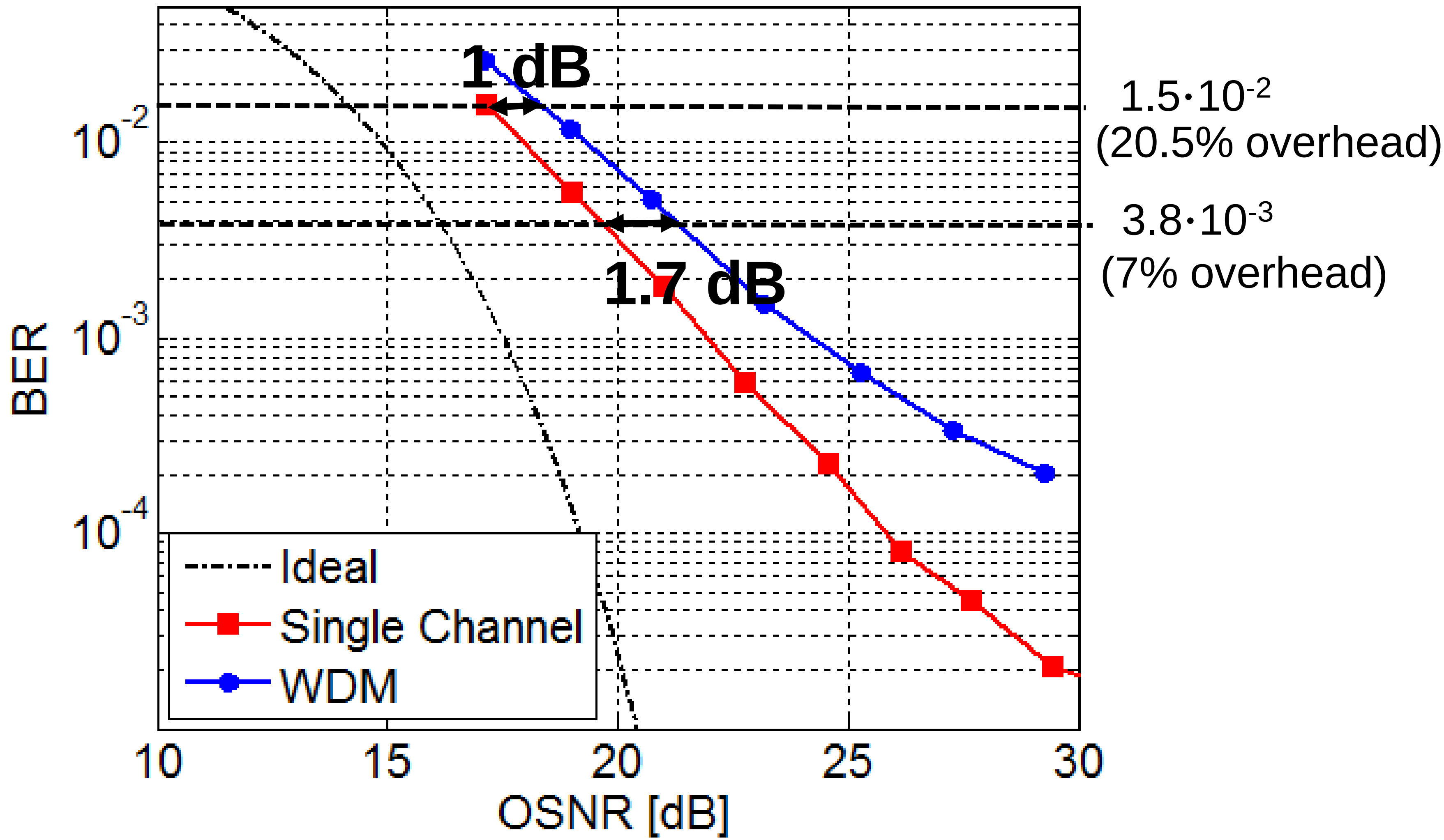
- Symbol rate: 14 Gbaud → 15.625 Gbaud
- Channel spacing: 1.05 R_s (14.7 GHz) → 1.024 R_s (16 GHz)
- Gross SE: 7.62 b/s/Hz → 7.81 b/s/Hz



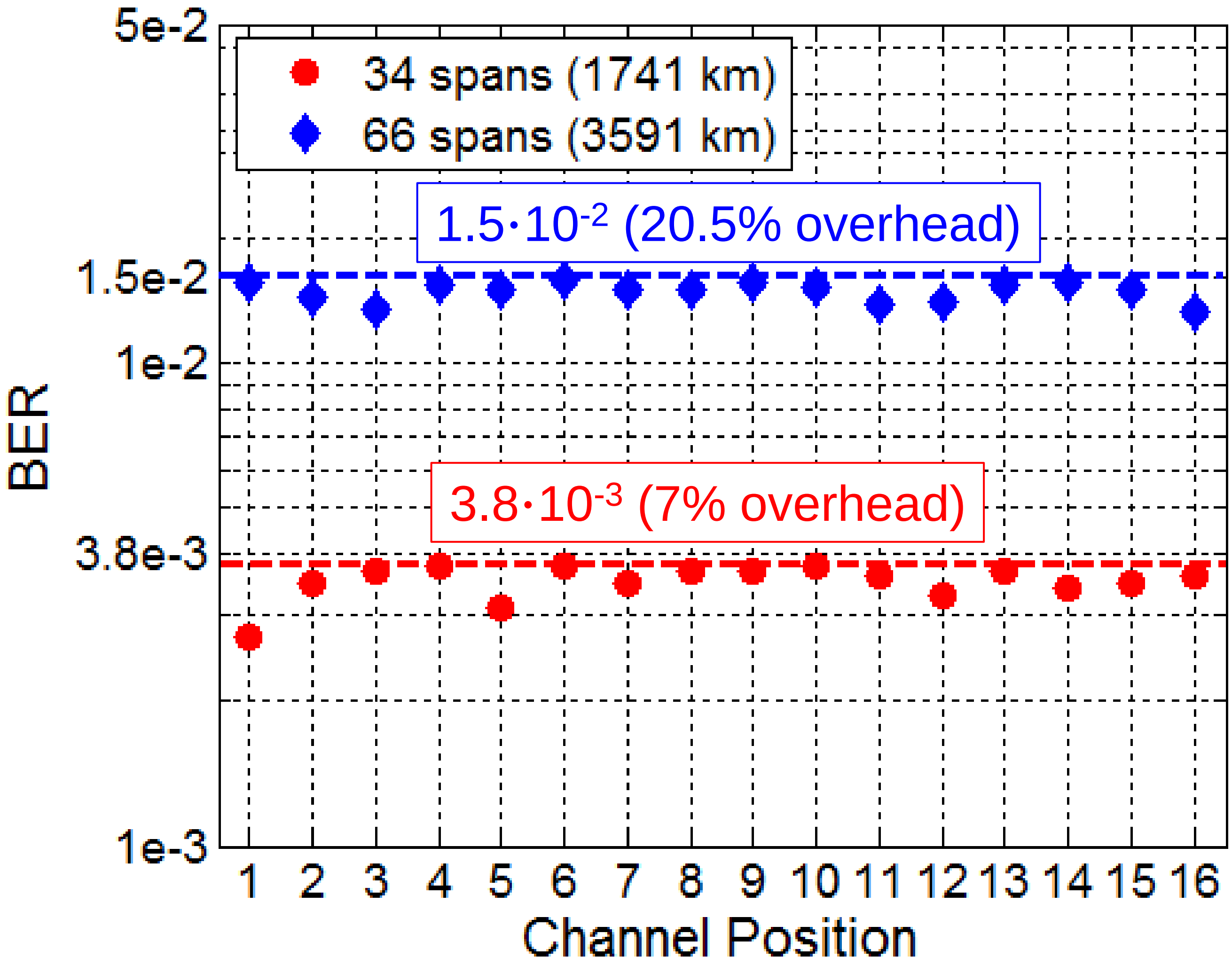
Back-to-back performance



Back-to-back performance



Maximum reach



Net SE: 6.48 b/s/Hz

Net SE: 7.30 b/s/Hz

Conclusions

- In our experiments, we demonstrated that Nyquist-WDM PM-16QAM, thanks to accurate spectral engineering, can closely approach Nyquist-limited SE performance → **record gross SE = 7.62 b/s/Hz (7.81 b/s/Hz in the new experiment)**

- Despite the extremely tight channel packing, ultra-long-haul transmission over PSCF with EDFA amplification was achieved, showing the high potential of PM-16QAM for future high-capacity systems

Acknowledgments

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