Foton
CNRS UMR 6082

Fonctions Optiques pour les
Technologies de l'informatiON

Mitigation of Mode Partition Noise in Quantum-dash Fabry-Perot Mode-locked Lasers using Manchester Encoding

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Motivation

❑ Silicon photonics technology

- Compatibility with CMOS-based technologies
- Silicon-based modulators, filters and photo-detectors have been demonstrated
- Heterogeneous integration of III/V materials

→ Integrated transceivers with reduced footprint and low power consumption

❑ Silicon based WDM transmitter

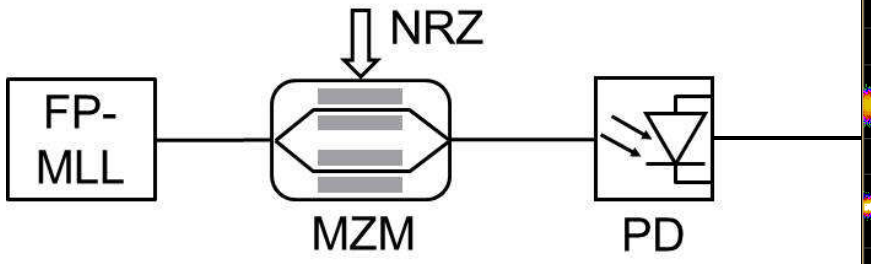
- Frequency comb generated by a Fabry-Perot mode-locked laser (FP-MLL)
- Array of silicon modulators

Mode partition noise (MPN) limitation

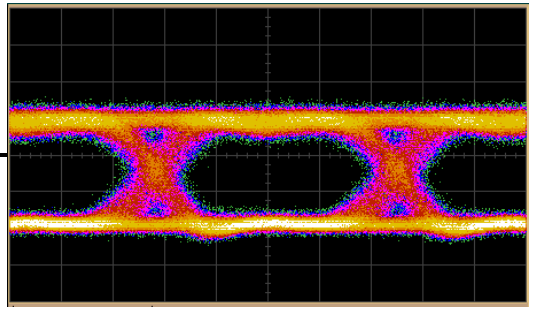
Mode partition noise

- The optical power in one mode fluctuates much more than the total power
- Optical modes compete with each other for a common injected carrier population

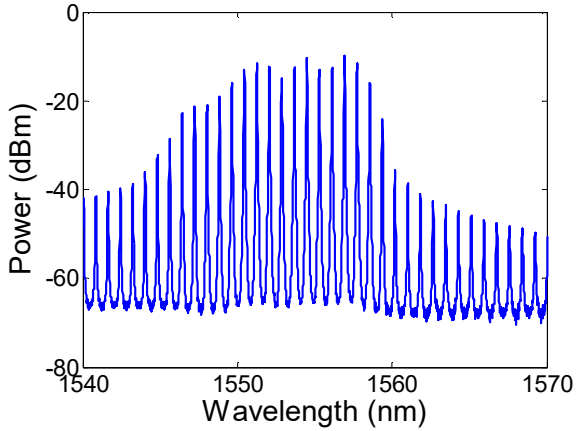
All modes detected



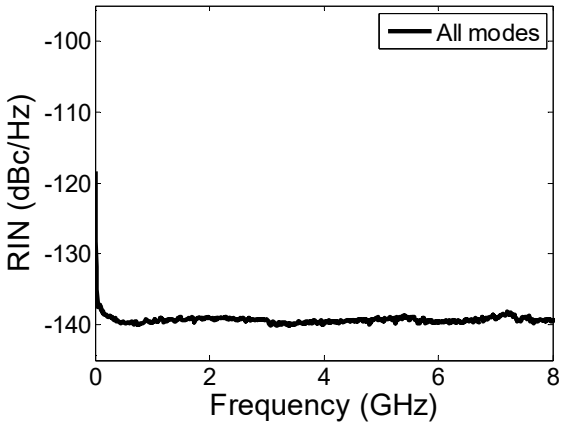
Eye diagram



Optical Spectrum



Relative intensity noise



Mode partition noise

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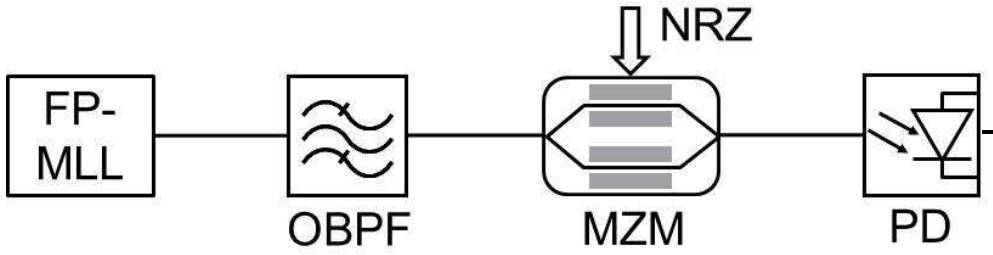
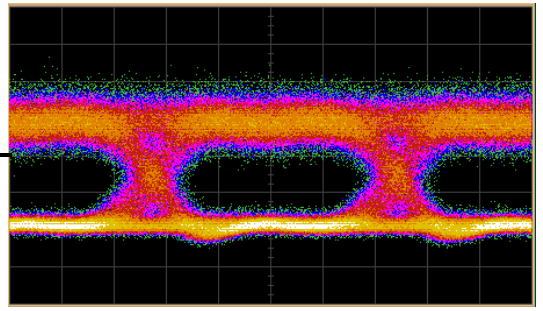
- Optical modes compete with each other for a common injected carrier population

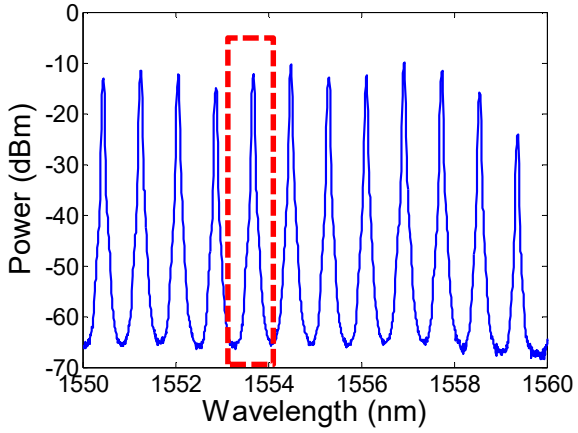
Mode 1 detected



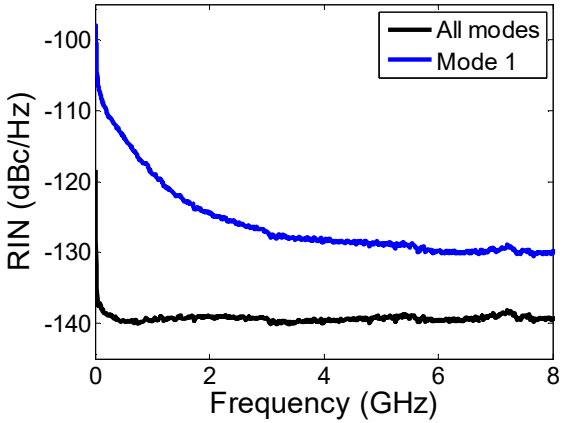
Eye diagram



Optical Spectrum



Relative intensity noise



Mode partition noise

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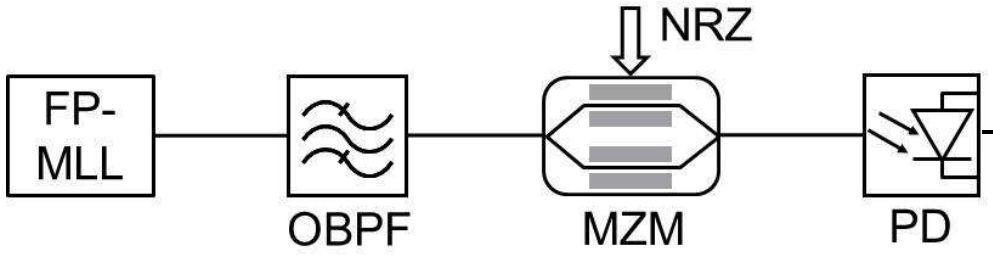
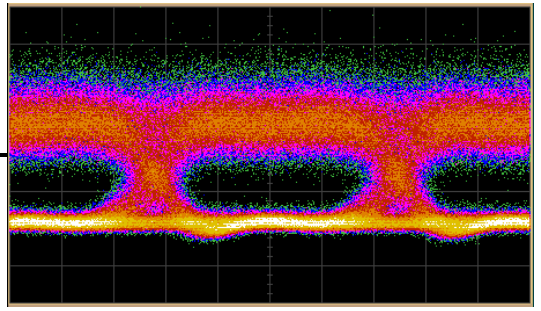
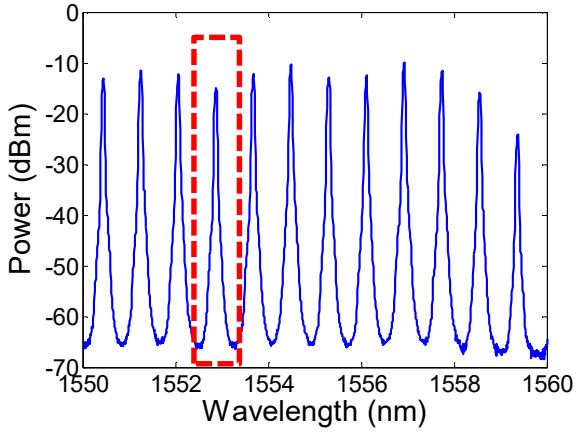
Mode 2 detected



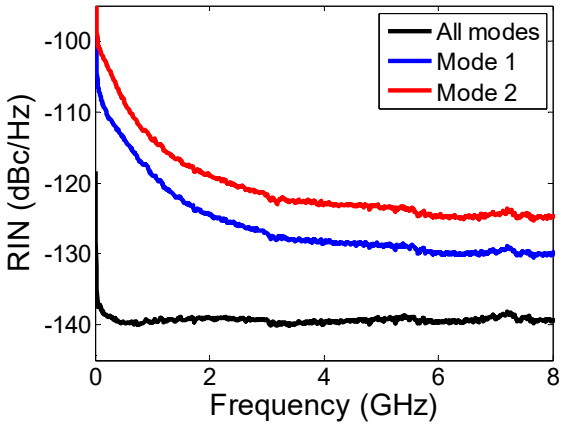
Eye diagram



Optical Spectrum



Relative intensity noise

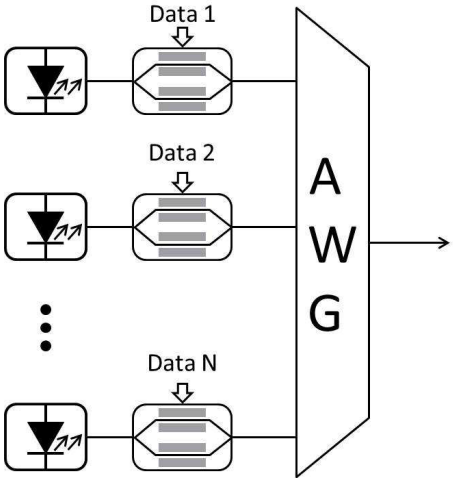


Outline

1) Serial ring resonators based WDM transmitter
2) New approach to mitigate mode partition noise
   - Balanced detection
   - Manchester encoding
3) Experimental setup
4) Comparison between NRZ and Manchester
5) Performance using RIN-emulated source
6) Conclusions

WDM transmitters

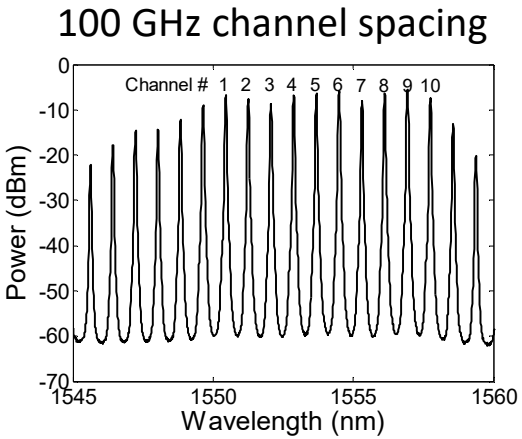
❑ Common WDM architecture

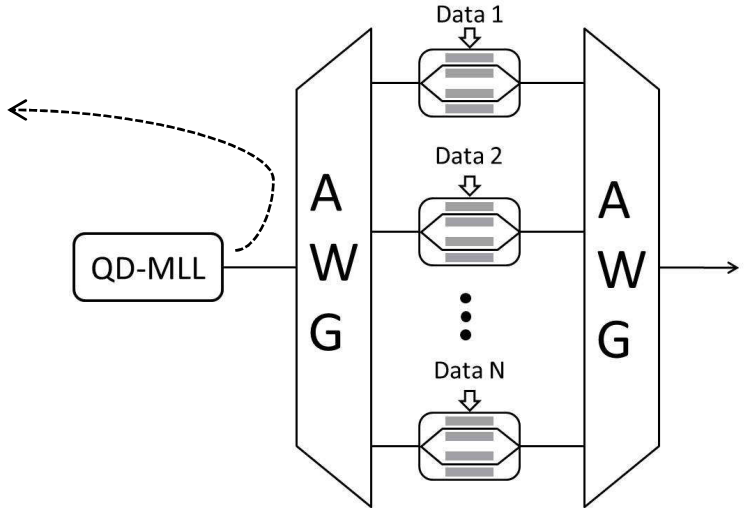


- Bulky structure
- Need for line-by-line frequency control

WDM transmitters

❑ Quantum-dash MLL (QD-MLL) based transmitter





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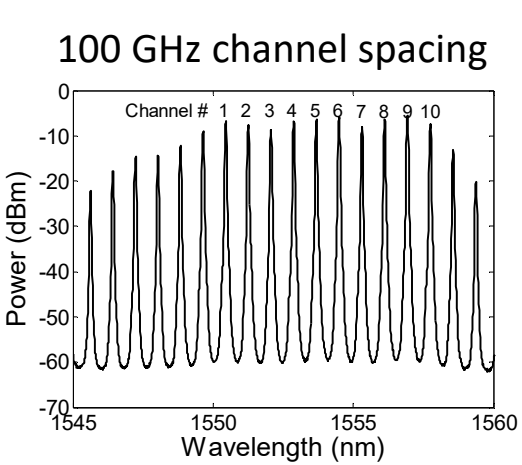

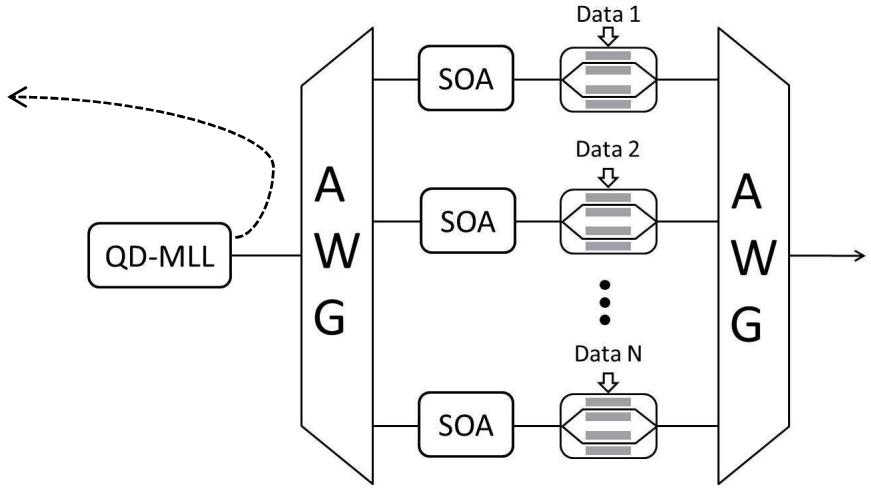

- Use of saturated SOA to mitigate the MPN [M. Gay et al., Tu2H.5, OFC 2014]

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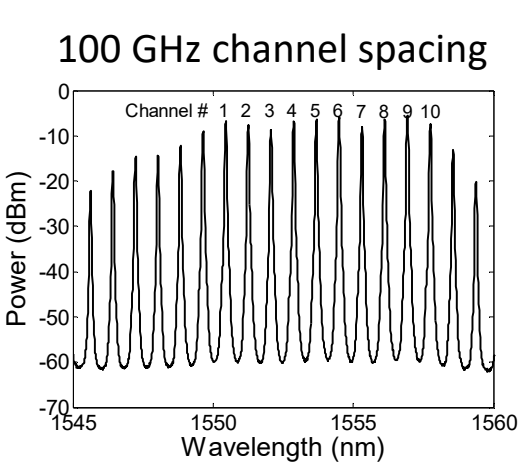

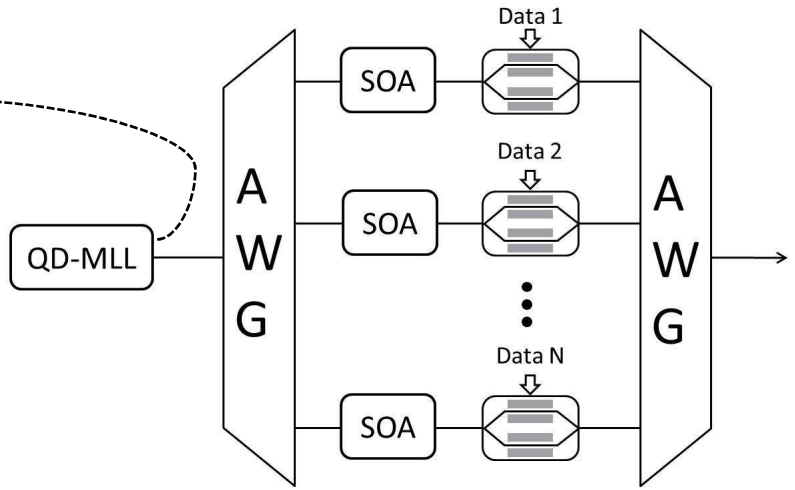

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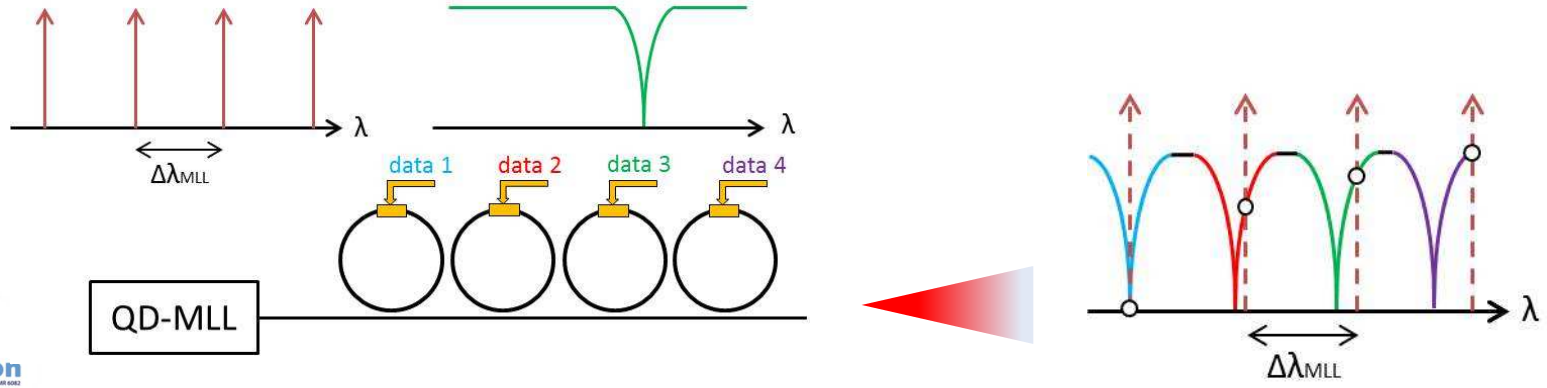
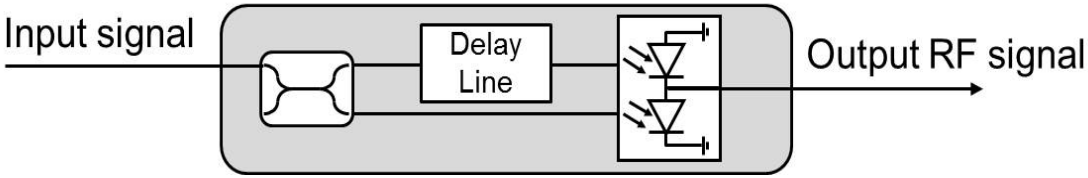
❑ Focus on serial ring resonators based transmitter

- Each MRR modifies the intensity of a single line [Q. Xu et al., 9431, Opt. Express 2015]



Mitigation of mode partition noise

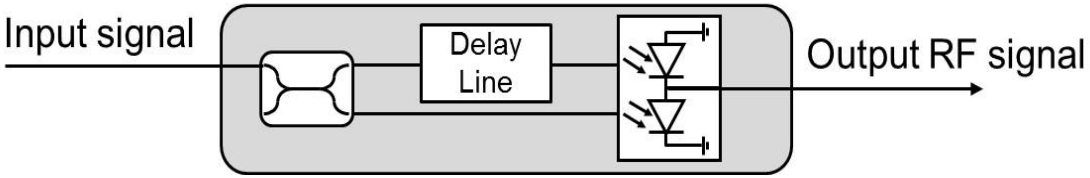
❑ Balanced detection



- Reduction of MPN impact for analogue links [A. Joshi et al., 5814, SPIE 2005]
- Not compatible with non-return to zero (NRZ) modulation

Mitigation of mode partition noise

❑ Balanced detection



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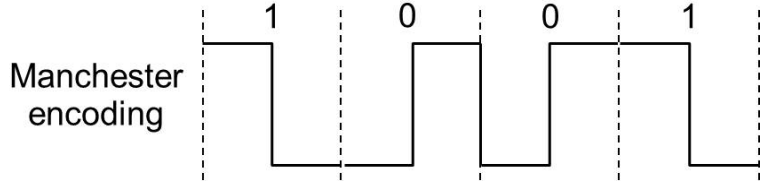
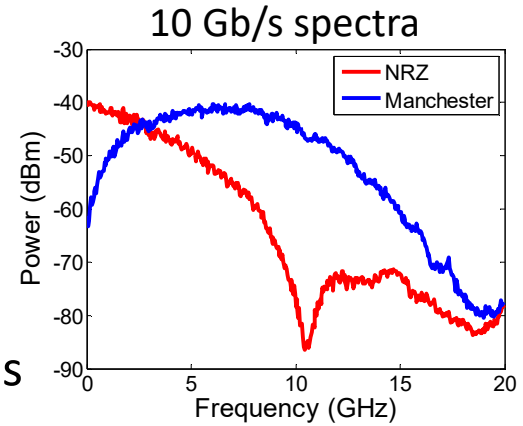
❑ Manchester encoding



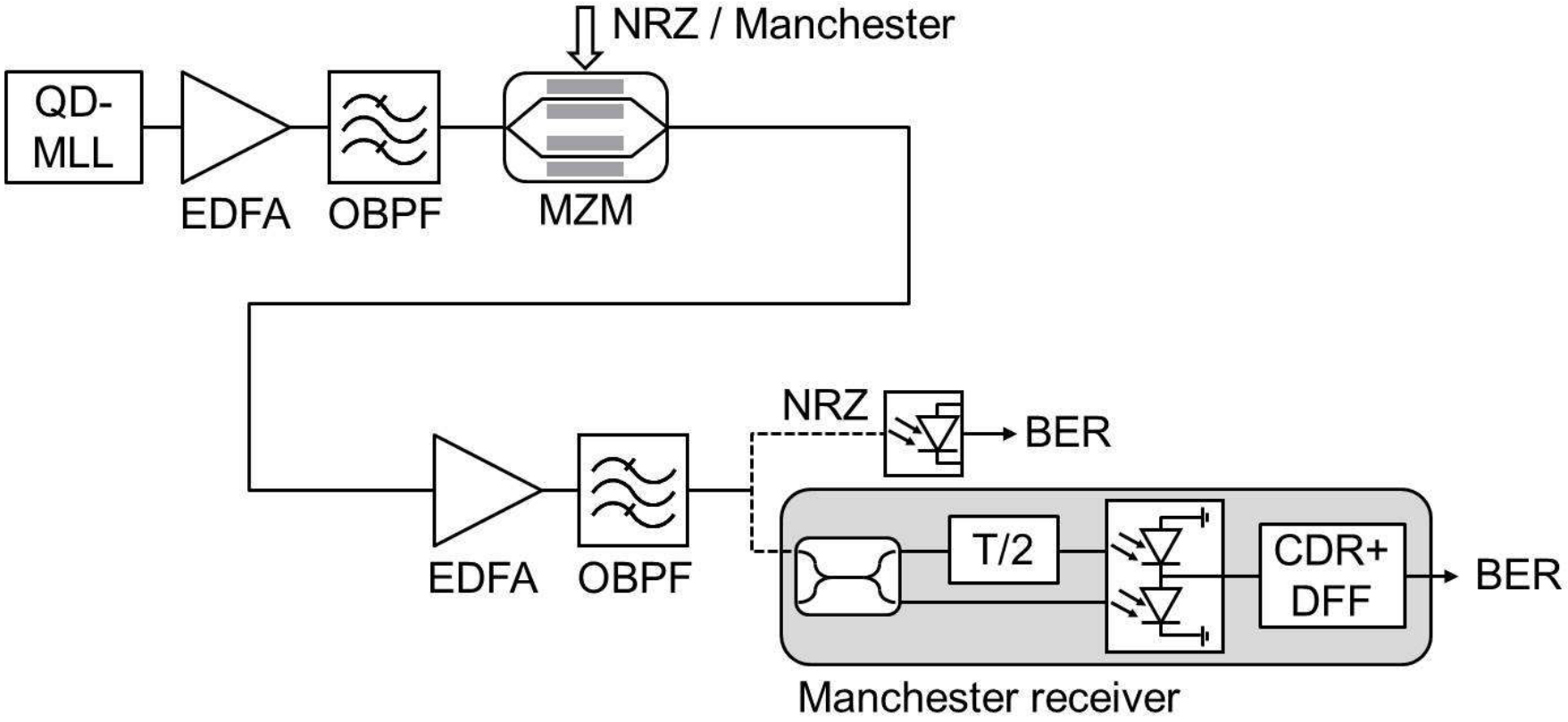


→ Compatible with balanced detection

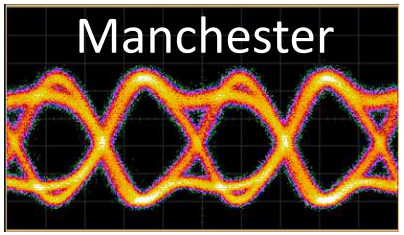
- The spectral content is shifted towards high frequencies
- Doubled bandwidth with respect to NRZ

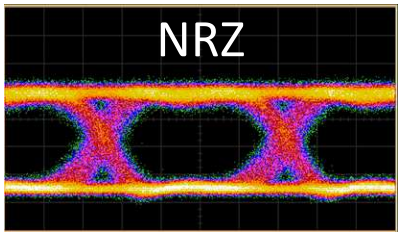
→ Combining balanced detection and Manchester encoding to mitigate MPN

Experimental setup

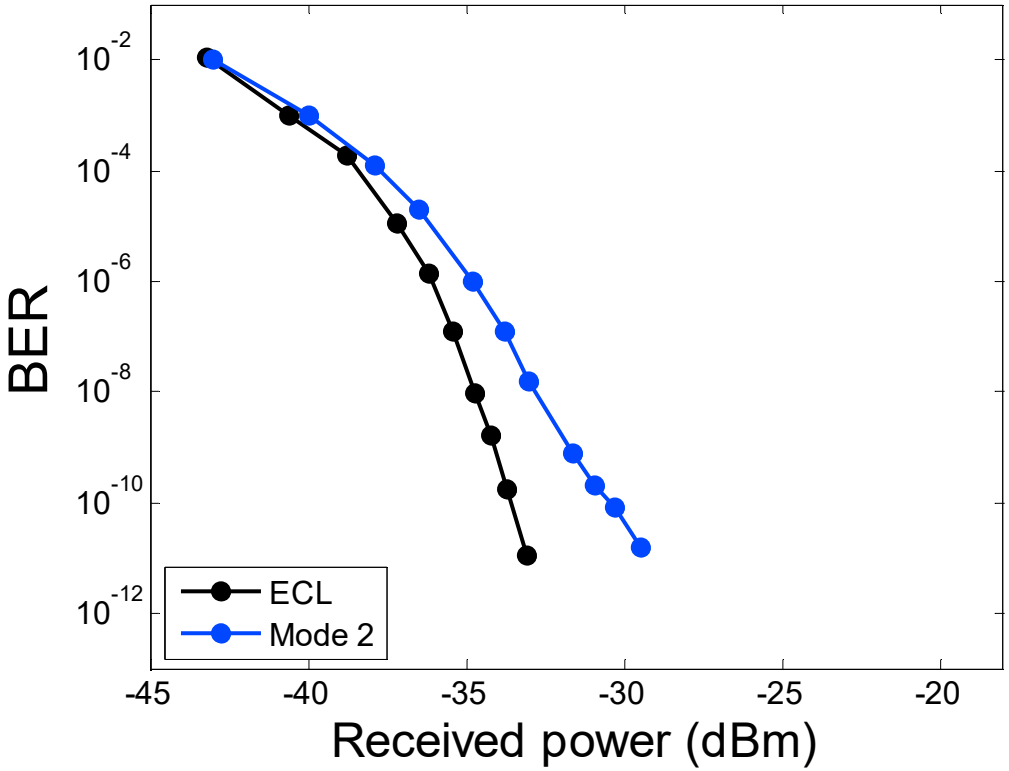


- 10 highest OSNR modes of the QD-MLL are considered
- Pseudo-random binary sequence length: 2^{31}-1
- Bitrate per mode: 10 Gb/s
- External cavity laser (ECL) used as reference



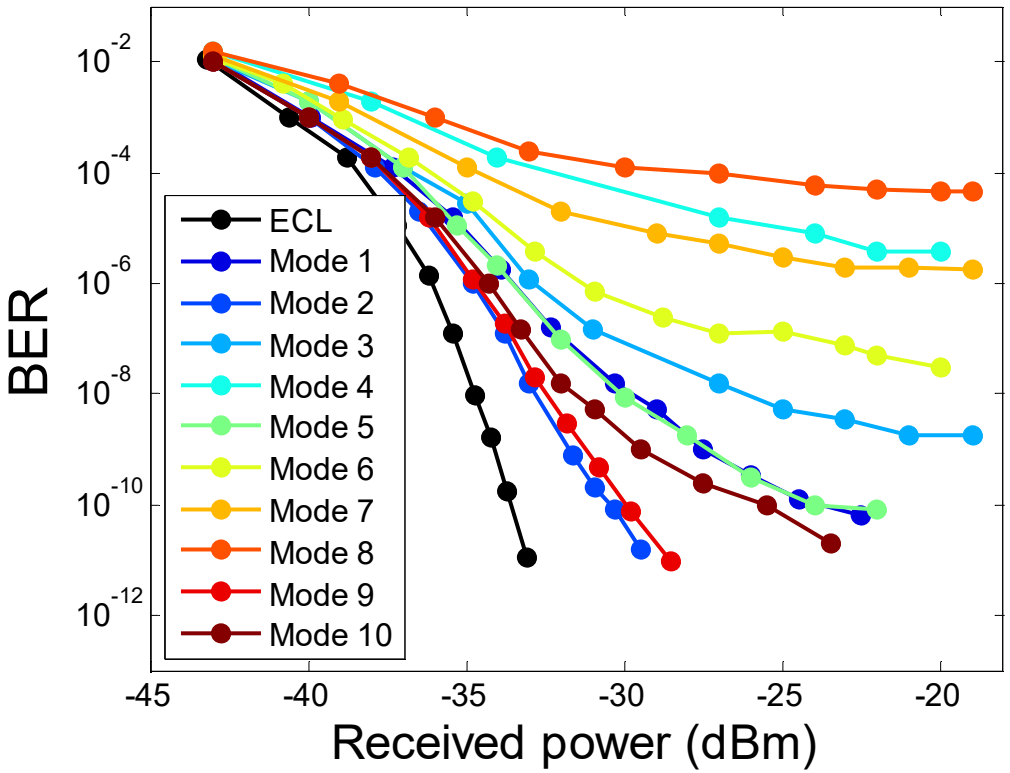


NRZ with single ended-detection



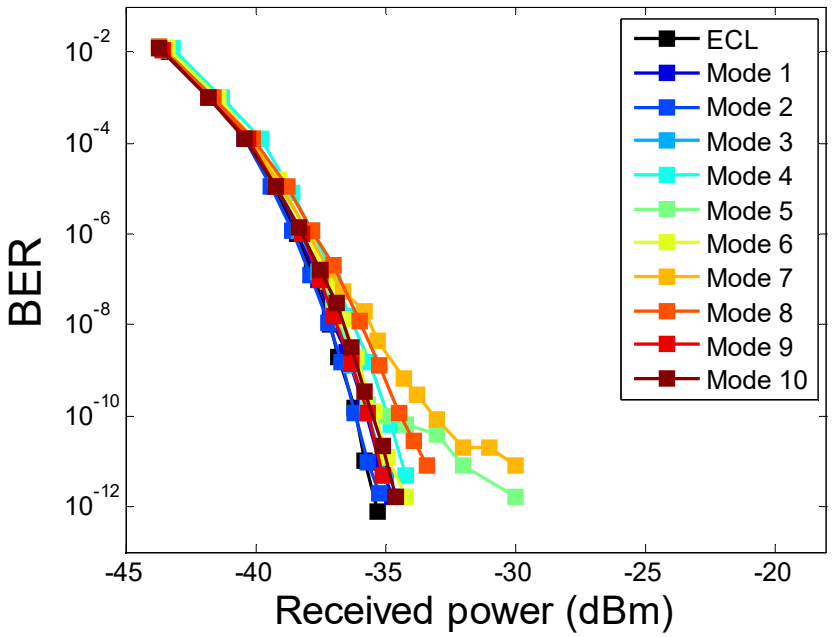
- More than 2 dB penalty for the best mode at a BER of 10^{-9}

NRZ with single ended-detection



- More than 2 dB penalty for the best mode at a BER of 10^{-9}
- Large dispersion of the BER performance
- BER floors as high as 10^{-4}

Manchester encoding with balanced detection



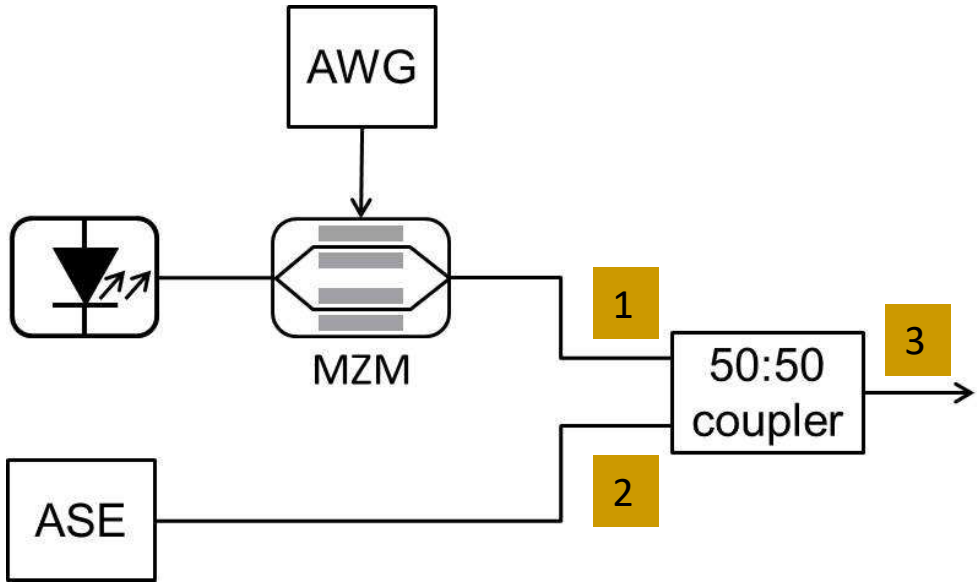
- Improvement of the BER performance
- Less than 2 dB penalty at a BER of 10^{-9} for the worst mode
- BER floors appear below 10^{-10}

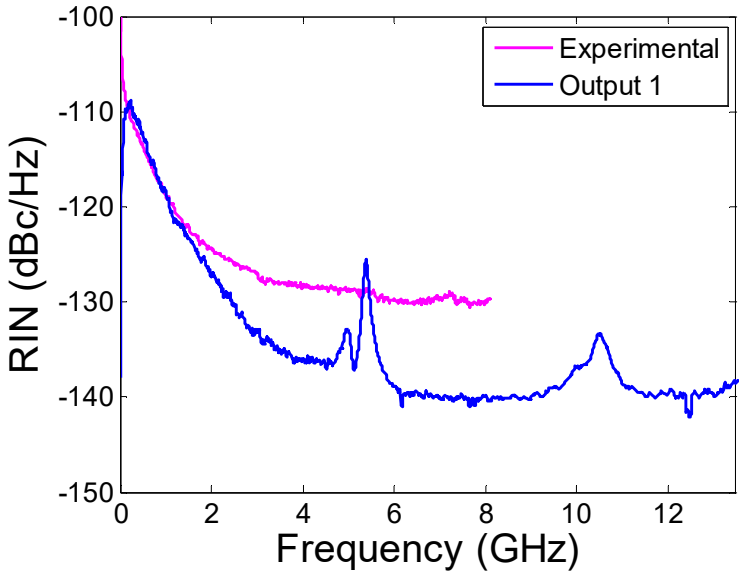
→ At this stage, it is still not clear whether the balanced detection or the use of Manchester encoding is responsible of this improvement

→ Need for an optical source with adjustable RIN behavior

How to emulate the RIN?

- An arbitrary waveform generator (AWG) generates the low-frequency part of the RIN
- An amplified spontaneous emission (ASE) source generates the constant level of the RIN





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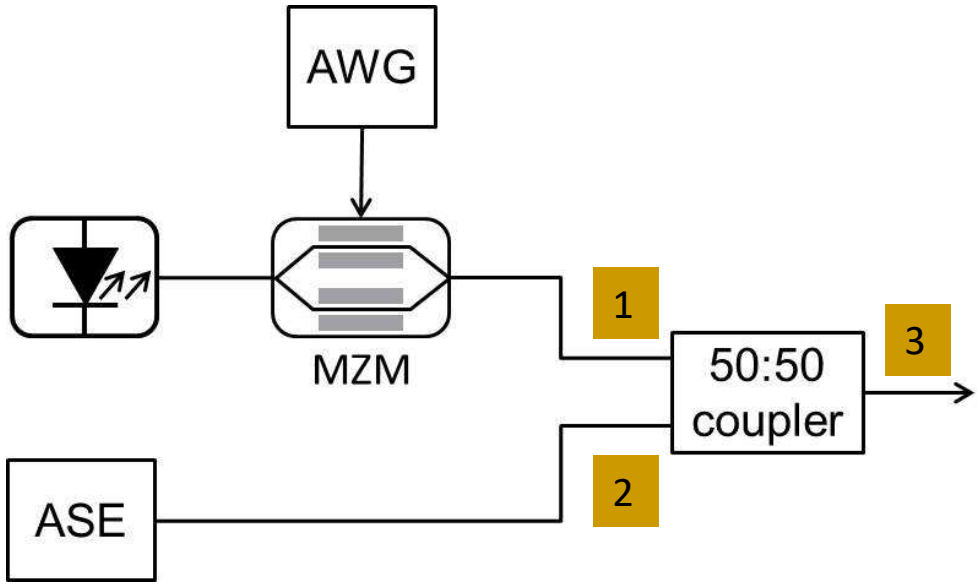

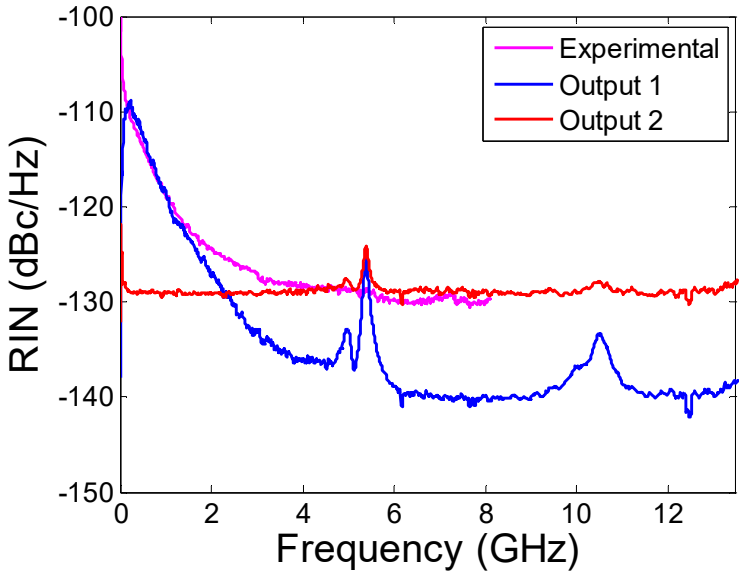

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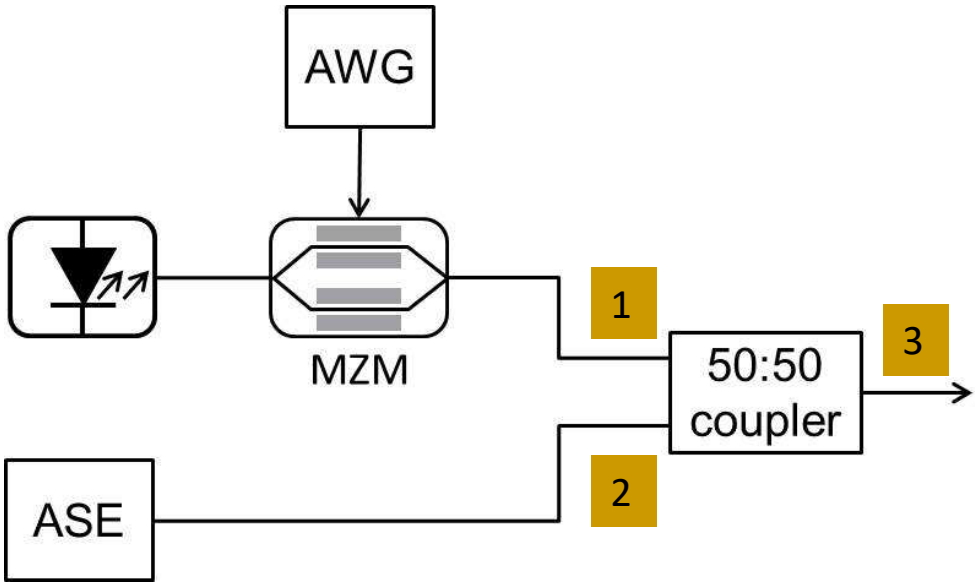
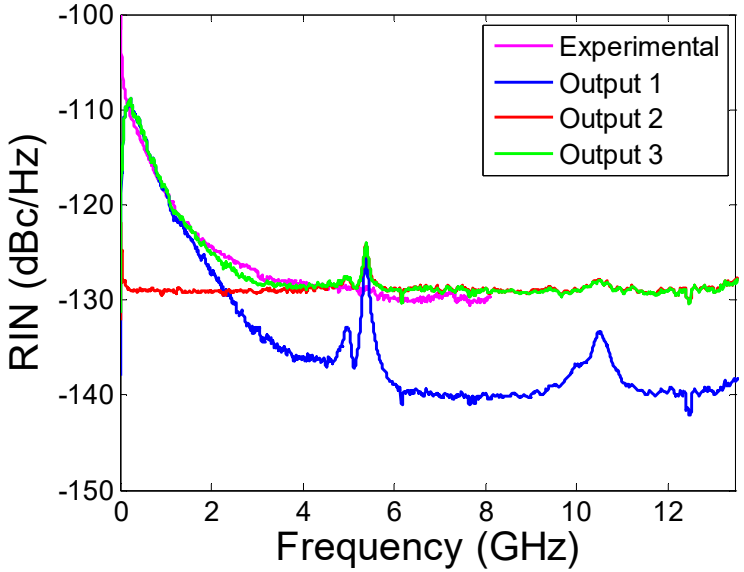
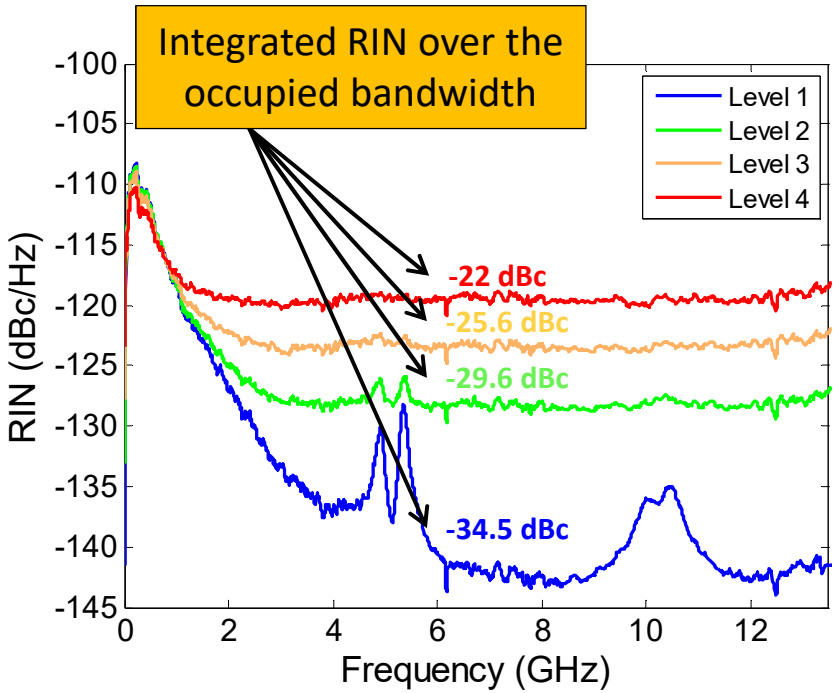
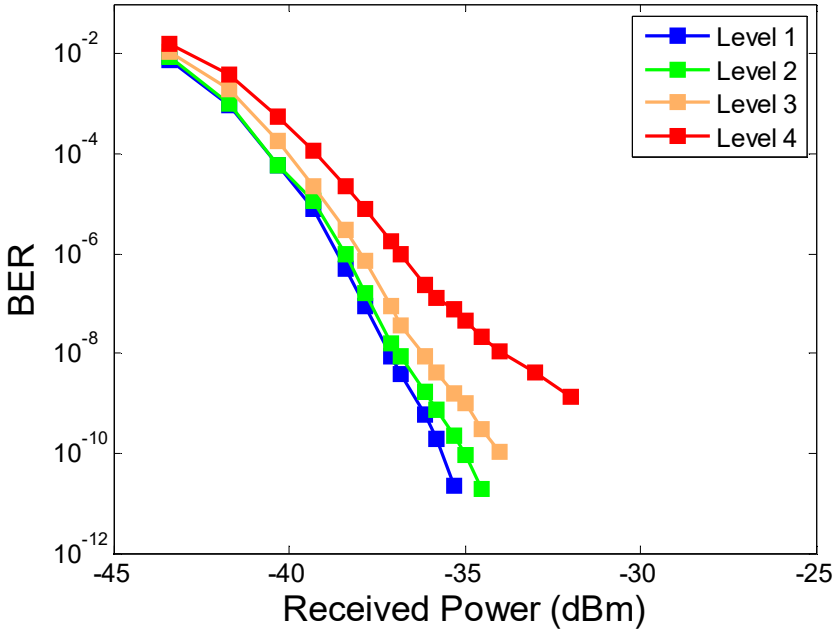




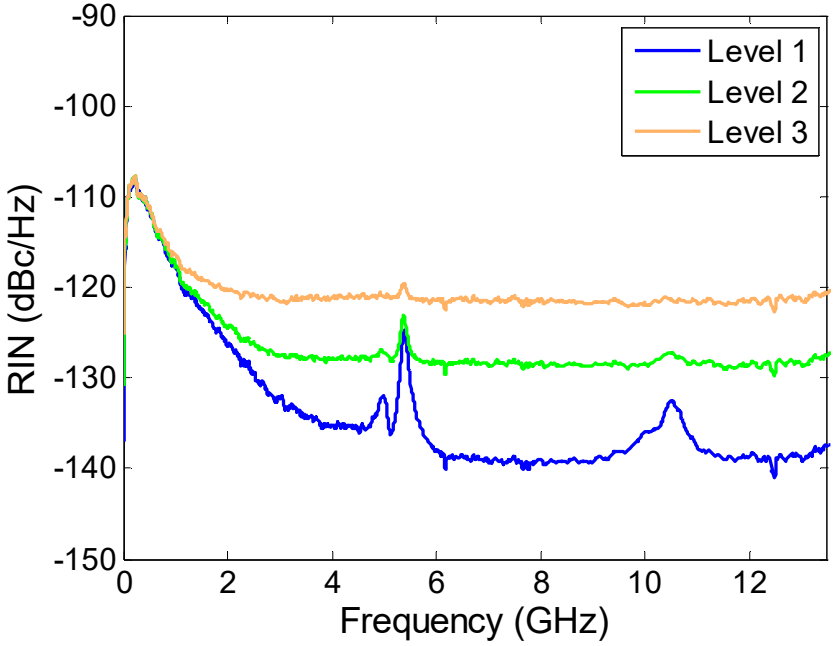
BER for different RIN levels: balanced detection



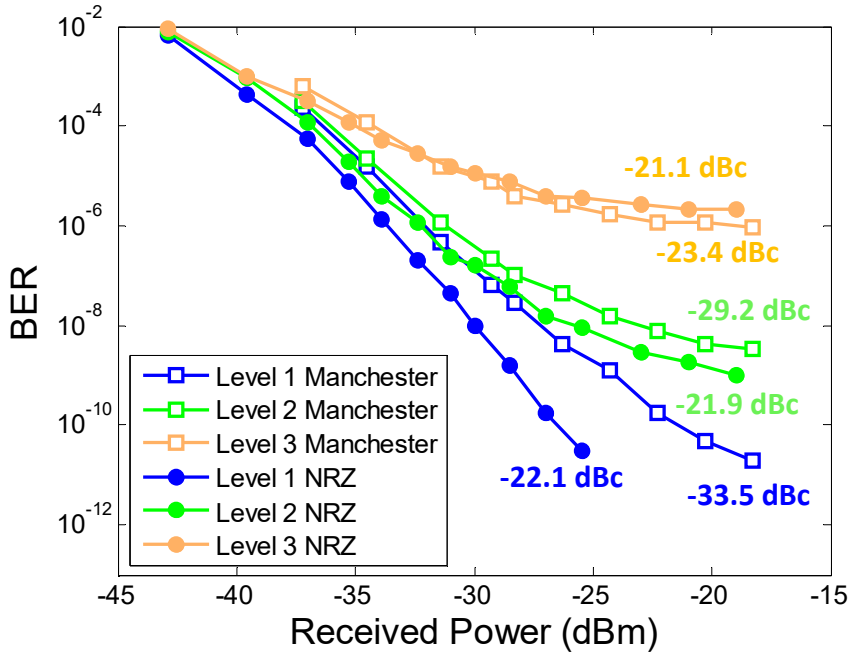


→ Increasing the RIN level slightly decreases the balanced detection sensitivity

BER for different RIN levels: single ended-detection



BER performance with single ended-detection for NRZ and Manchester encoding



→ Introducing Manchester encoding is not sufficient to provide better performance than NRZ

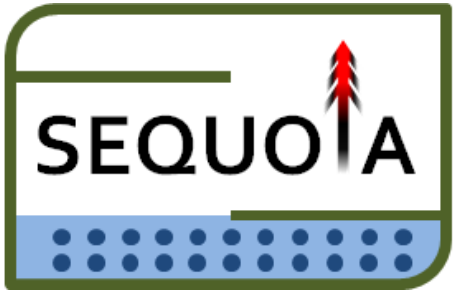
Conclusions

- WDM transmitters based on a QD-MLL and a serial array of of ring resonators
- Mitigation of MPN using Manchester encoding and balanced detection
- 10 modes modulated at 10 Gb/s are used to demonstrate the approach
- Effectiveness even at high RIN levels
- Manchester encoding alone is unable to provide better performance than NRZ

  $\Rightarrow$ benefit essentially stems from balanced detection

Acknowledgements

Funded by the
European Union



Energy efficient silicon transmitter using heterogeneous integration of III-V quantum dot and quantum dash materials