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POLITECNICO DI TORINO

DIRECT-DETECTION SINGLE-SIDEBAND SYSTEMS: PERFORMANCE COMPARISON AND PRACTICAL IMPLEMENTATION PENALTIES

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OPTCOM

OUTLINE

- Introduction to single-sideband (SSB) systems
- Practical implementation penalties of an SSB transmitter
  - Using DMT modulation

INTRODUCTION TO SINGLE-SIDEBAND SYSTEMS

WHICH MODULATION FORMAT FOR DATA-CENTER?

http://imagebank.osa.org/getImage.xqy?img=LmZ1bGwsam9jbi0xMC03LUIyNS1nMDAy&article=jocn-10-7-B25-g002

Source: R. Nagarajan et al., J. Opt. Commun. Netw. 10, B25-B36 (2018)

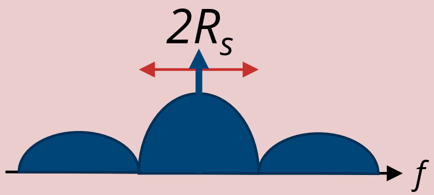
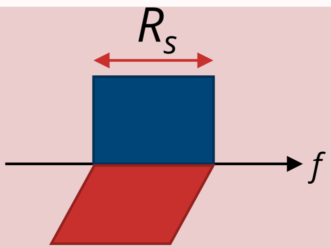
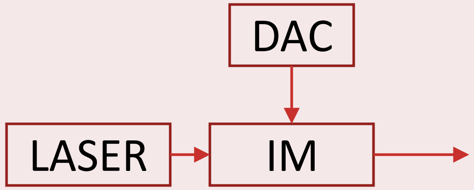
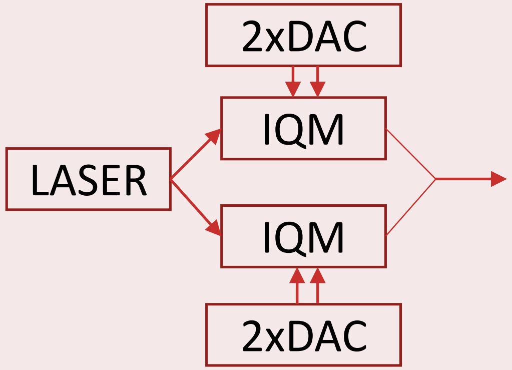
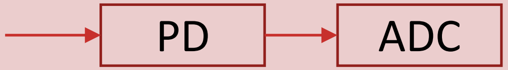
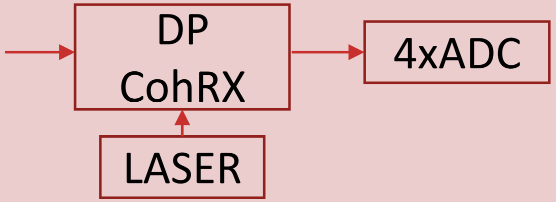
Inphi and Microsoft: PAM-4 (current), PM-16QAM (future)

Main characteristics for this scenario

- Standard single-mode fiber (SSMF) up to 100km
- C-band (EDFAs required at TX and RX)
  - Dispersion must be compensated
- High spectral efficiency not required
- Low cost and power consumption

Coherent or direct detection?

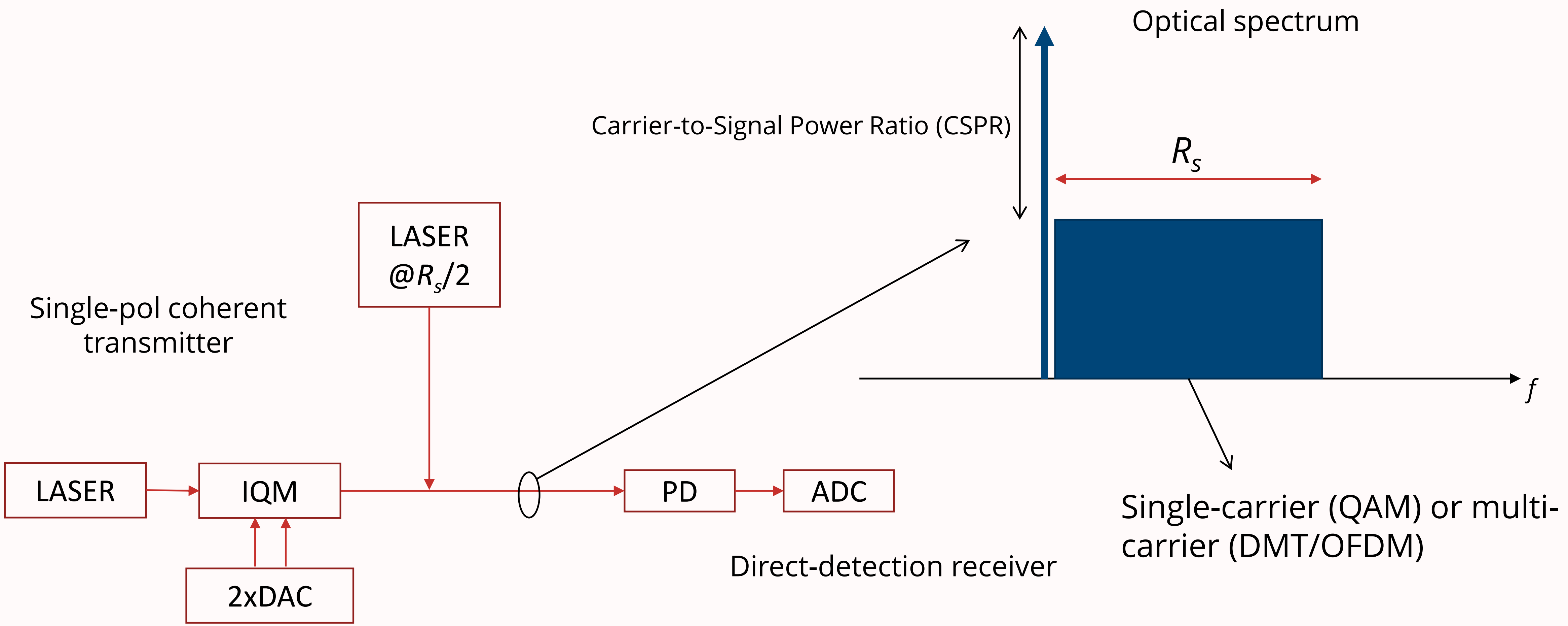
COHERENT OR DIRECT DETECTION?

	PAM-4 (direct detection)	**16-QAM (coherent detection)**
Spectral efficiency		
TX architecture		
RX architecture		
Dispersion compensation	Optical	Electrical

THE SEARCH FOR COMPROMISE

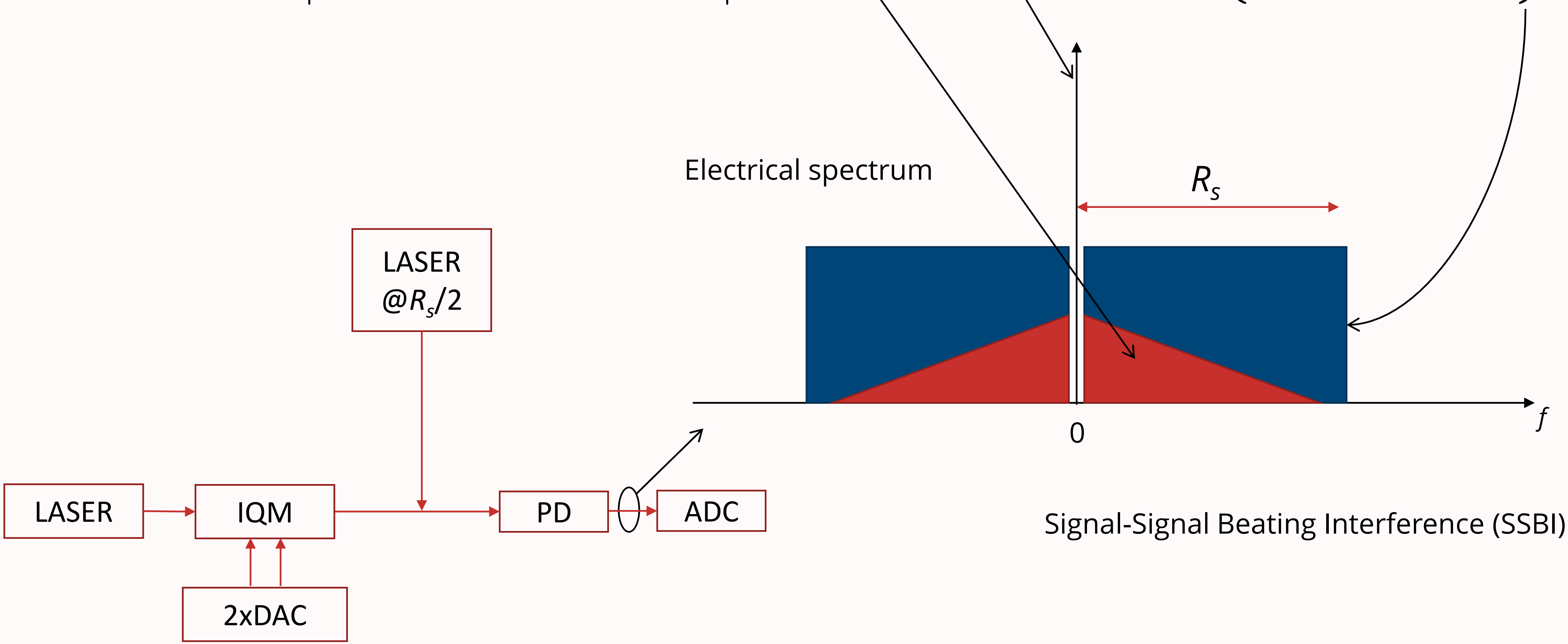
1. Direct detection
2. Higher spectral efficiency
3. Electronic dispersion compensation

SINGLE-SIDEBAND SELF-COHERENT TRANSMITTER



SINGLE-SIDEBAND SELF-COHERENT RECEIVER

$$\left|x(t) + c \cdot e^{-j2\pi t R_s/2}\right|^2 = |x(t)|^2 + c^2 + 2c \cdot \Re\left\{x(t)e^{j2\pi t R_s/2}\right\}$$



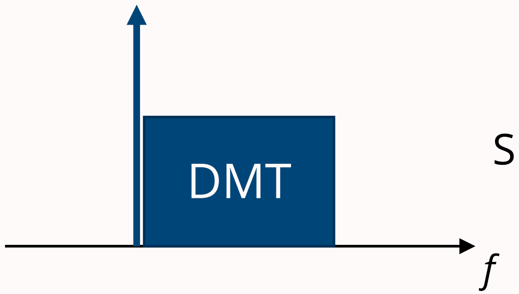
SSB TRANSMISSION: PROS AND CONS

1. Direct detection ✓
2. Higher spectral efficiency ✓
3. Electronic dispersion compensation ✓

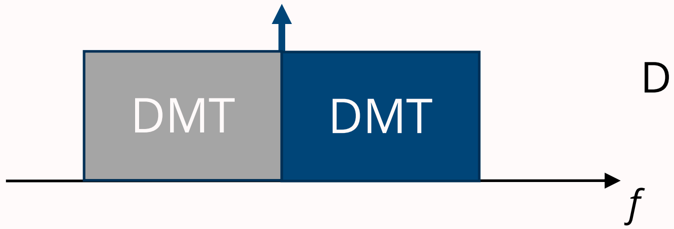
1. Complex transmitter structure ✗
2. High receiver analog bandwidth ✗
3. Reduced OSNR sensitivity ✗

EXAMPLE: DISCRETE-MULTITONE WITHOUT OPTICAL DISPERSION COMPENSATION

Source: T. Takahara et al., Proc. OFC 2014, M2I.1

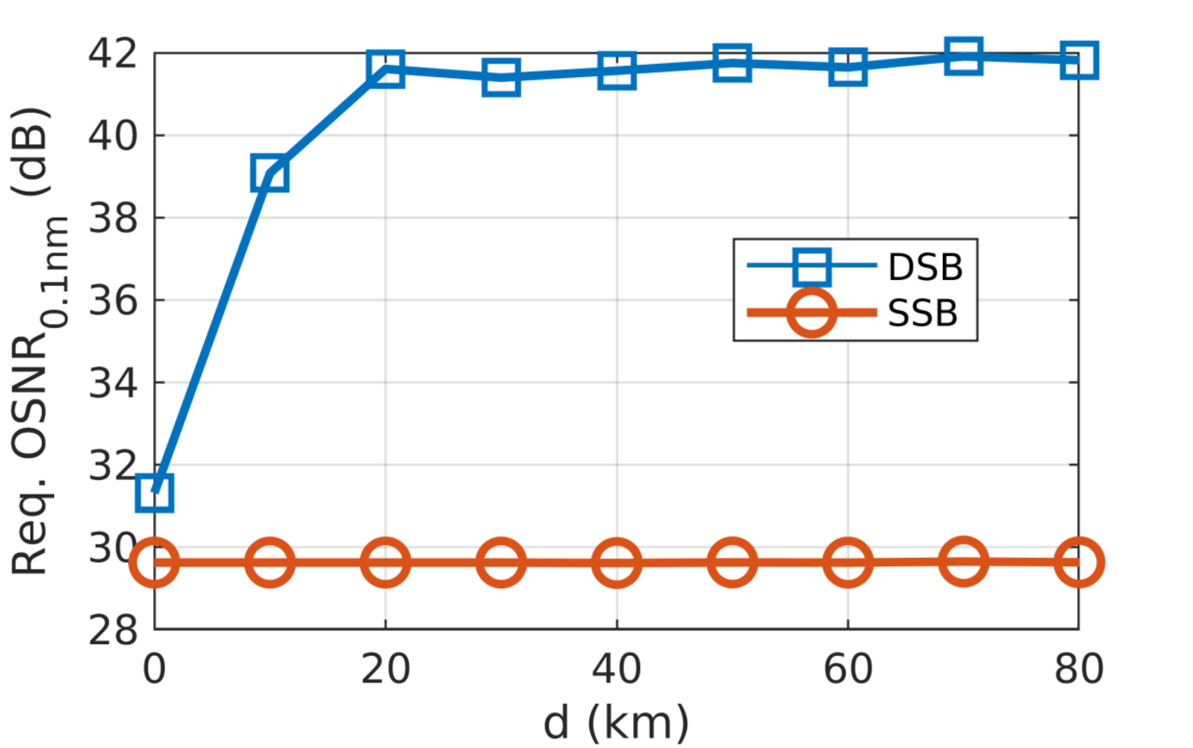


Single Side-Band (SSB)



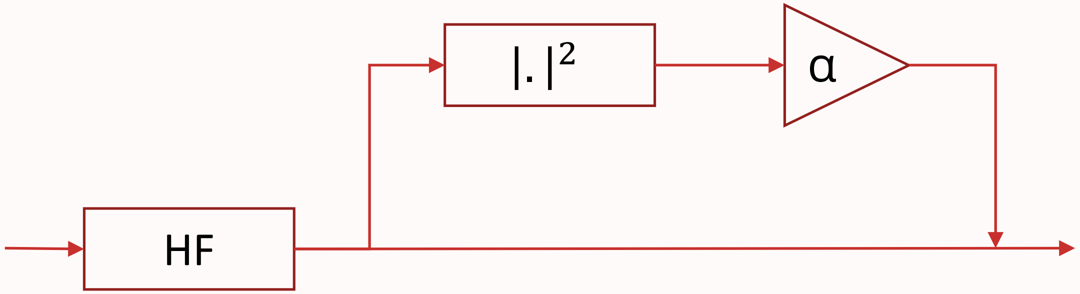
Dual Side-Band (DSB)

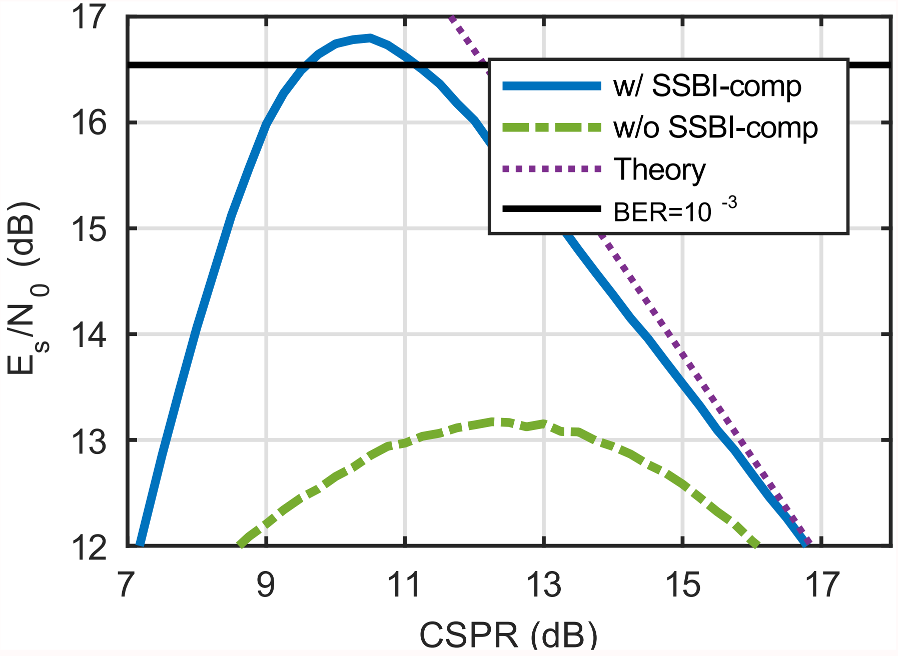
(IM/DD, like PAM-4)



SIGNAL-SIGNAL BEATING INTERFERENCE

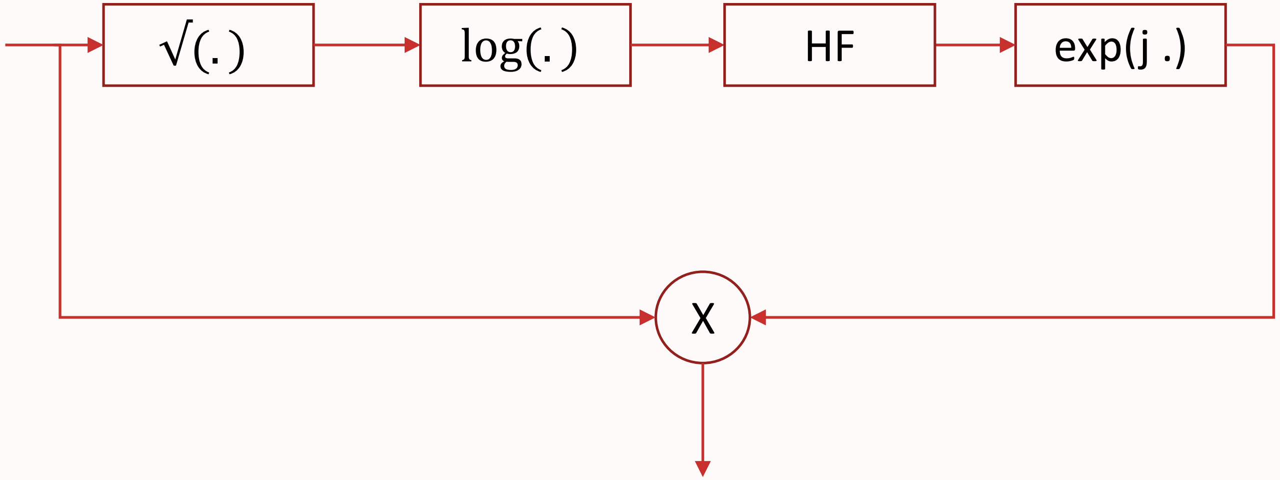
SSBI mitigation algorithms[1,2]





100 Gb/s DMT, B2B OSNR=30 dB

Kramers-Kronig receiver[3]



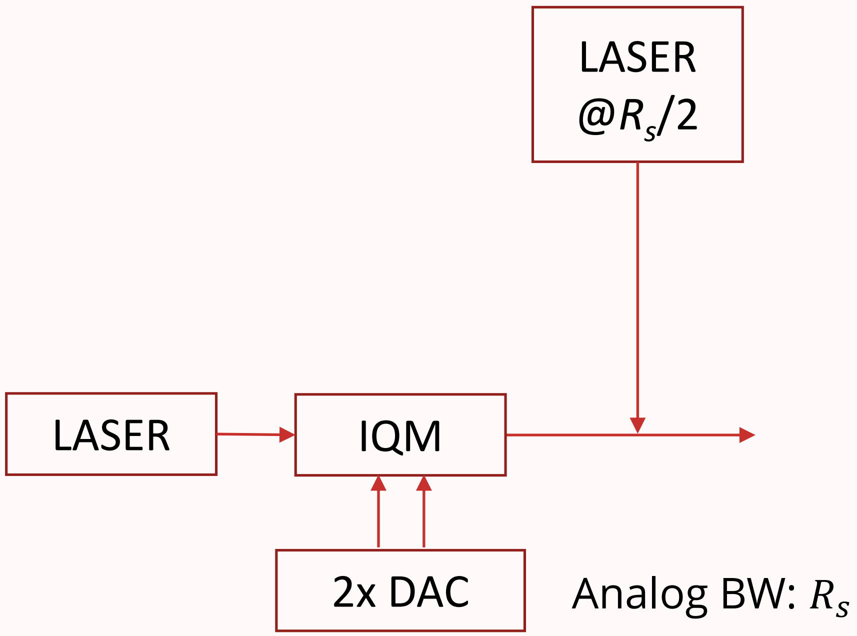
- Higher performances with lower CSPRs ✔
- Higher receiver complexity ✖

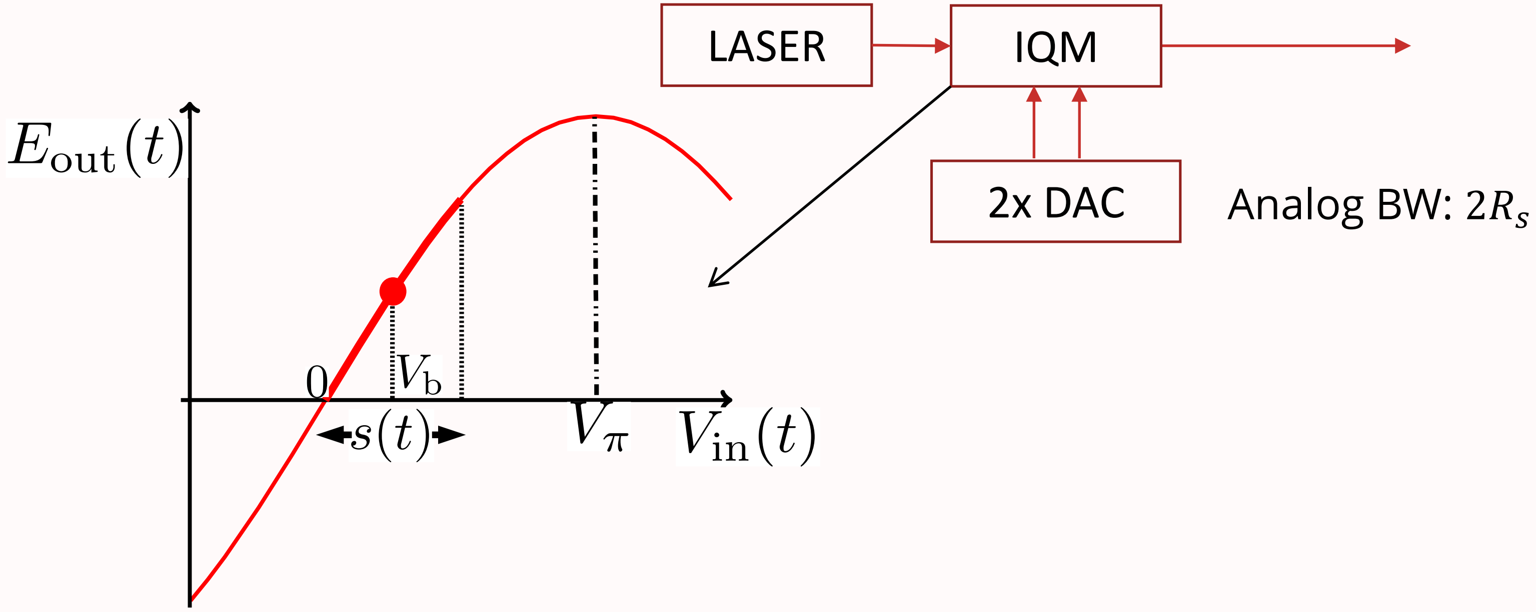
1. S. Randel, D. Pilori et al., Proc. ECOC 2015, Mo.4.5.2
2. Z. Li et al., J. Lightw. Technol. 35(10), 1887-1893 (2017)
3. A. Mecozzi et al., Optica 3(11), 1220-1227 (2016)

PRACTICAL IMPLEMENTATION PENALTIES

IMPLEMENTATION OF A DMT-BASED SINGLE SIDE-BAND TRANSMITTER

SSB TRANSMITTER ARCHITECTURES

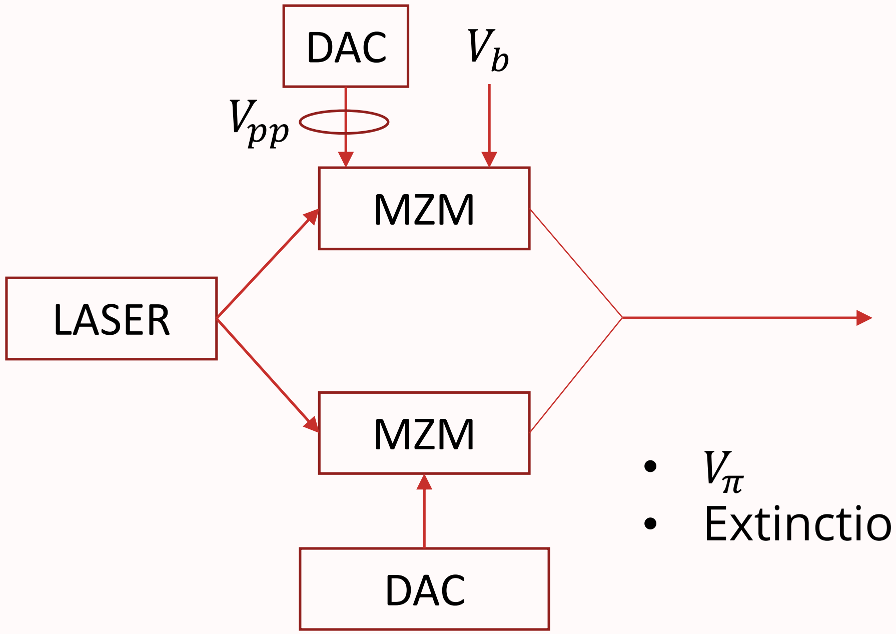




- Two lasers ✗
- Control of frequency difference ✗
- Receiver phase recovery ✗

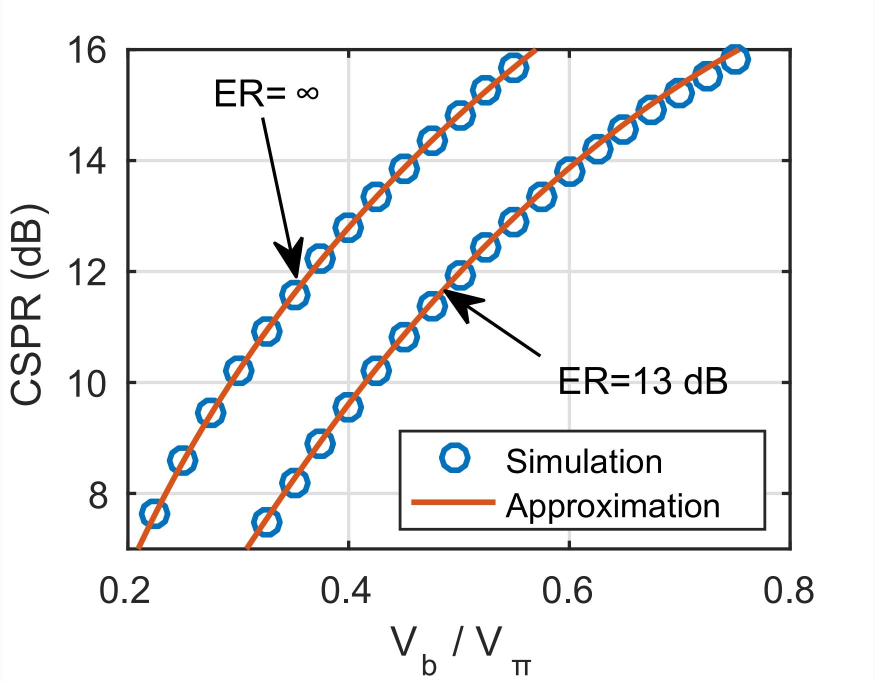
- One laser ✓
- No receiver phase recovery ✓
- Twice DAC bandwidth ✗
- Signal distortions at high CSPR ✗

EVALUATION OF CARRIER-TO-SIGNAL POWER RATIO



- V_π
- Extinction ratio (ER)

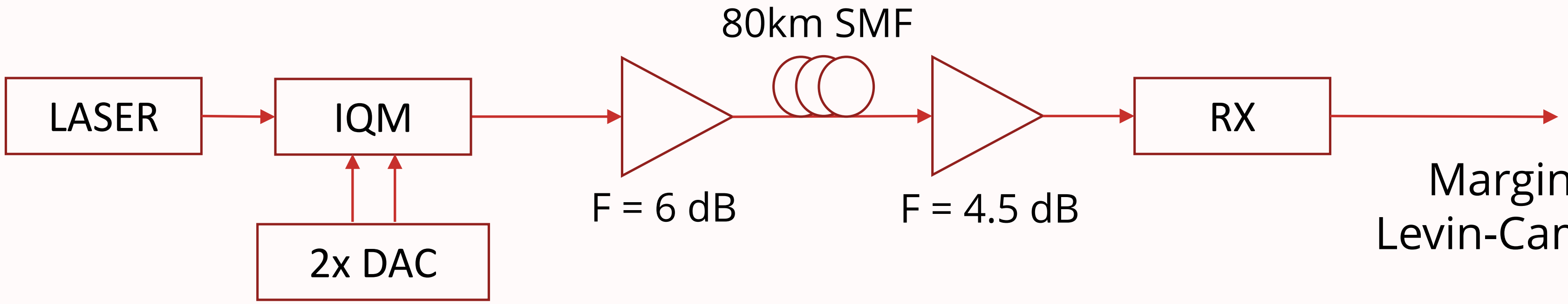
$$\mathrm{CSPR} \approx \frac{2e^{-\frac{\pi^2\sigma^2}{V_\pi^2}}\left[\sin^2\left(\frac{\pi V_\mathrm{b}}{2V_\pi}\right) - \frac{2\sin\left(\frac{\pi V_\mathrm{b}}{2V_\pi}\right)}{\mathrm{ER}} + \frac{1+\cos^2\left(\frac{\pi V_\mathrm{b}}{2V_\pi}\right)}{\mathrm{ER}^2}\right]}{\left[1-e^{-\frac{\pi^2\sigma^2}{2V_\pi^2}}\right]\left[2+\cos\left(\frac{\pi V_\mathrm{b}}{V_\pi}\right)e^{-\frac{\pi^2\sigma^2}{2V_\pi^2}}+e^{-\frac{\pi^2\sigma^2}{2V_\pi^2}}\right]}$$



APPLICATION EXAMPLE TO DISCRETE-MULTITONE (DMT)

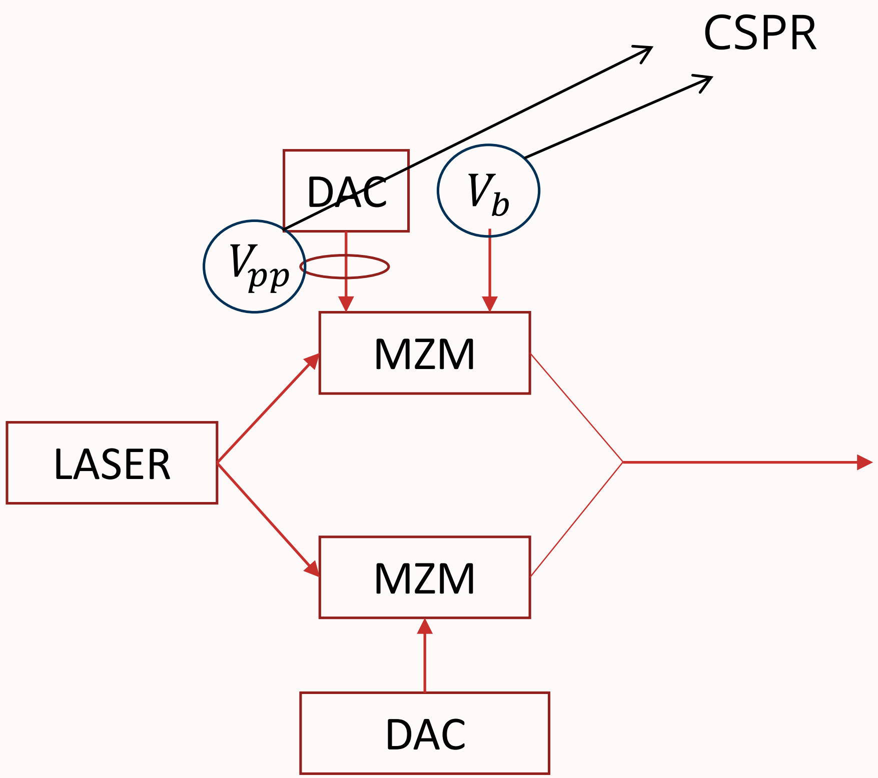
Parameter	Value
FFT size	1024
Bitrate	120 Gbit/s
DAC sampling rate	64 GS/s
BER threshold	10^{-3}
DAC 3-dB bandwidth	13 GHz
DAC resolution	6 bit

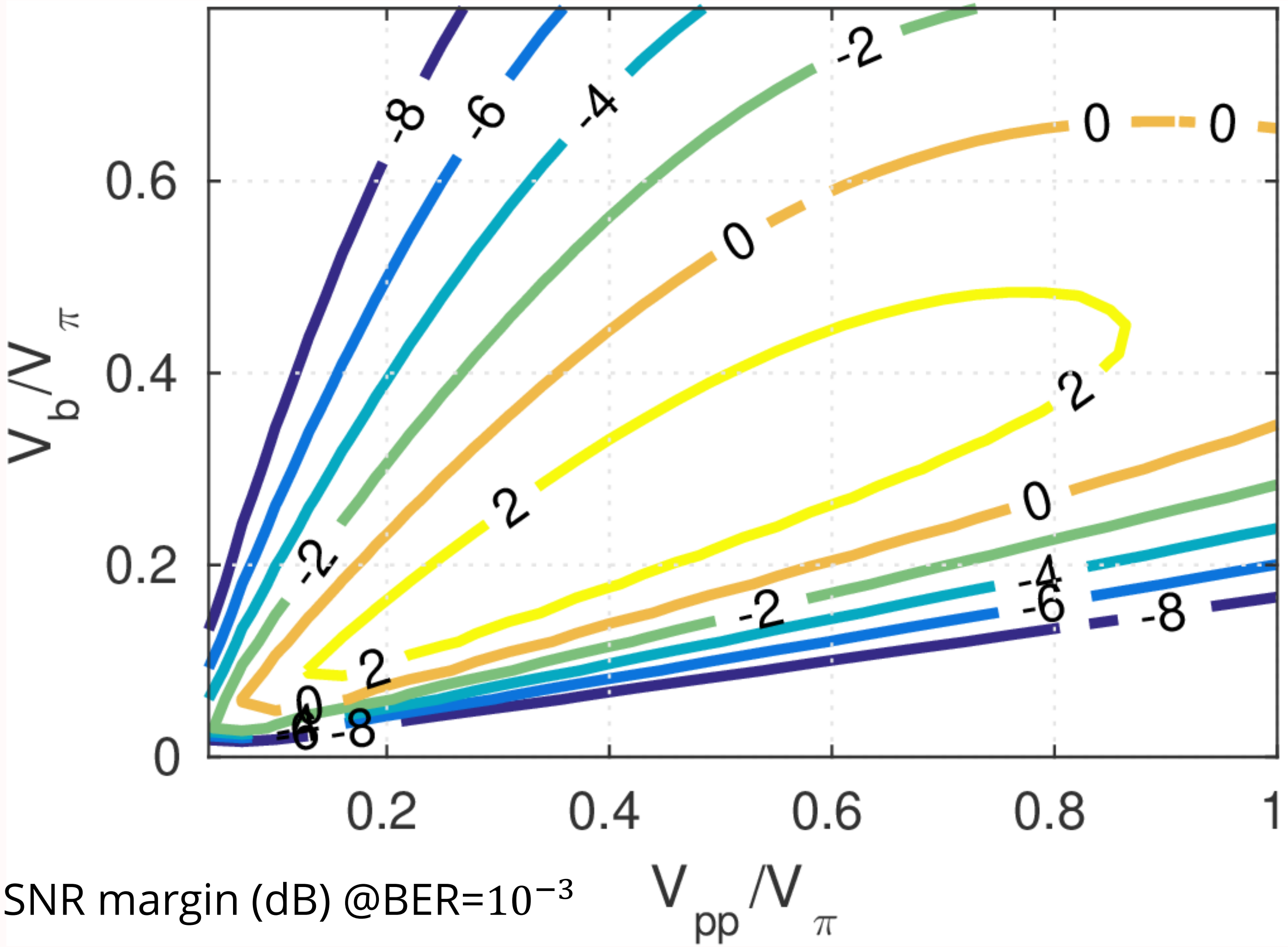
Source: T. Takahara et al., Proc. OFC 2014, M2I.1



Margin-Adaptive (MA)
Levin-Campello bit-loading

IDEAL (INFINITE EXTINCTION RATIO) MODULATOR





SNR margin (dB) @BER=10^{-3}

CONCLUSIONS AND KEY TAKE-AWAYS

- Single-sideband self-coherent systems are a possible compromise between coherent and direct-detection for DCI
- Transmitter structure is the most critical part of these systems
- With proper use of a Mach-Zehnder modulator, transmitter structure can be simplified

THANK YOU FOR YOUR ATTENTION!

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THANK YOU

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