



NEFERTITI

Network of Excellence on broadband **FibEr** Radio Techniques and its integration Technologies

VCSELs for Analog Applications

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Outline

- Introduction
- Analog requirements
- Performance
 - Bandwidth
 - RF Loss
 - Noise
 - Distortion
 - Dynamic range
- Summary and Conclusion

Outline

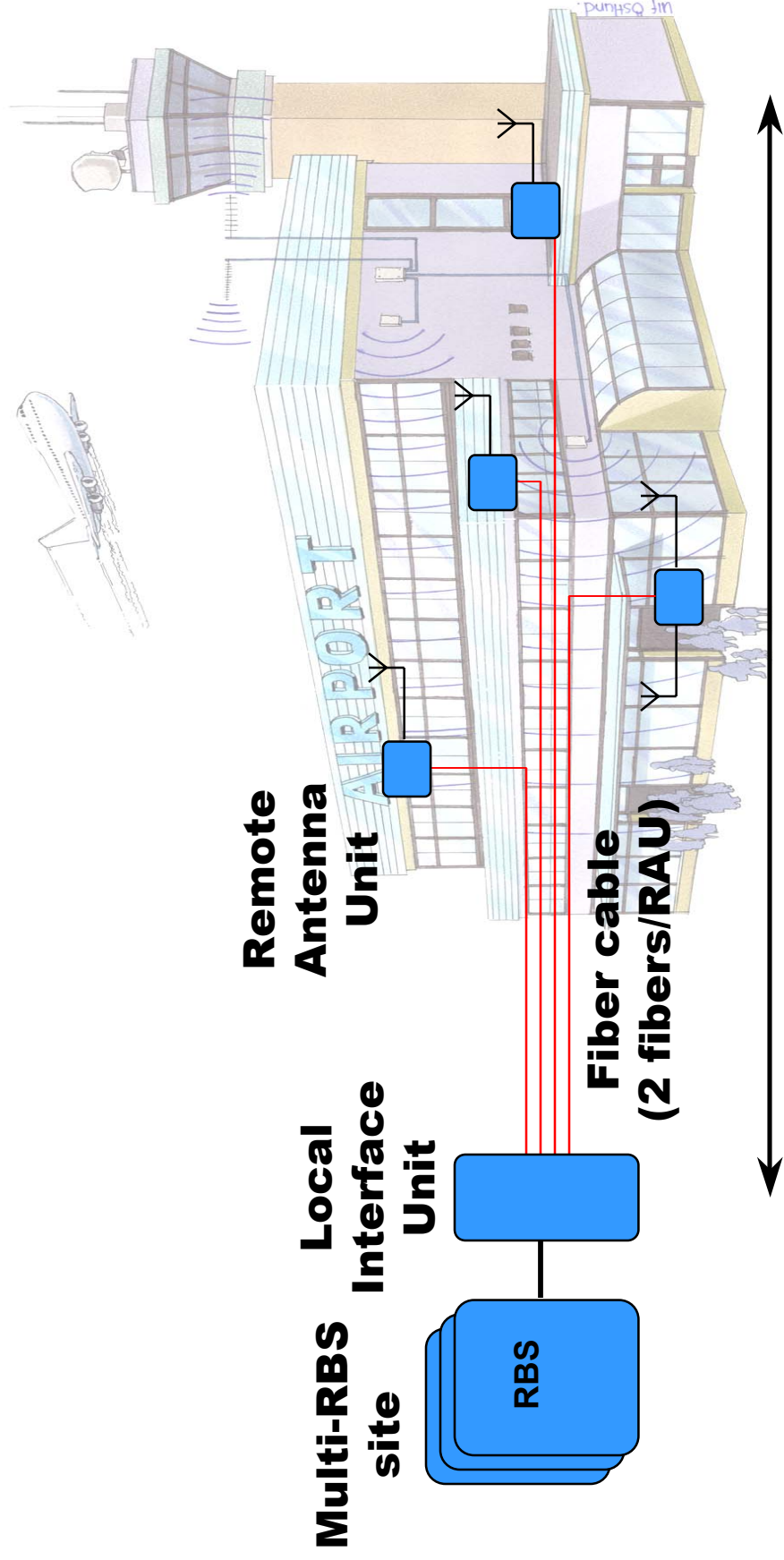
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- **Summary and Conclusion**

Applications

- CATV 400 – 800 MHz
- Cellular phone 800 – 2100 MHz
- SATCOM/TVRO 1, 4, 12 GHz
- Wireless LAN 2.5, 5.1, ... GHz
- Radar 1, 3, 5, 10, 35, ... GHz
- EW, ECM 2 – 18 GHz

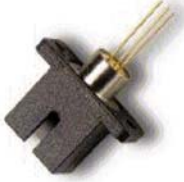
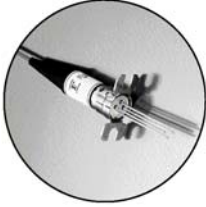
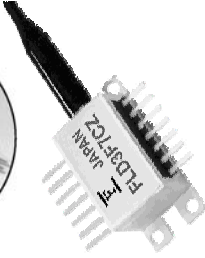
Applications

Radio-over-Fiber



Laser diodes

Cost vs. performance

LD type	Package	Data	Price
850nm VCSEL for sensors		SMT (w. lens) (> 3 Gbps)	\$2-\$4 USD
840nm VCSEL for datacom		TO-46 (w. lens) MMF SC receptacle RIN = -130 dB/Hz	\$10 USD \$20 USD
1310nm MQW F-P for digital applications		SMF pig-tail RIN = -150 dB/Hz	\$65 USD
1310nm MQW DFB for CATV		SMF butterfly RIN = < -155 dB/Hz - 170 dB/Hz (typ)	\$2,200 USD

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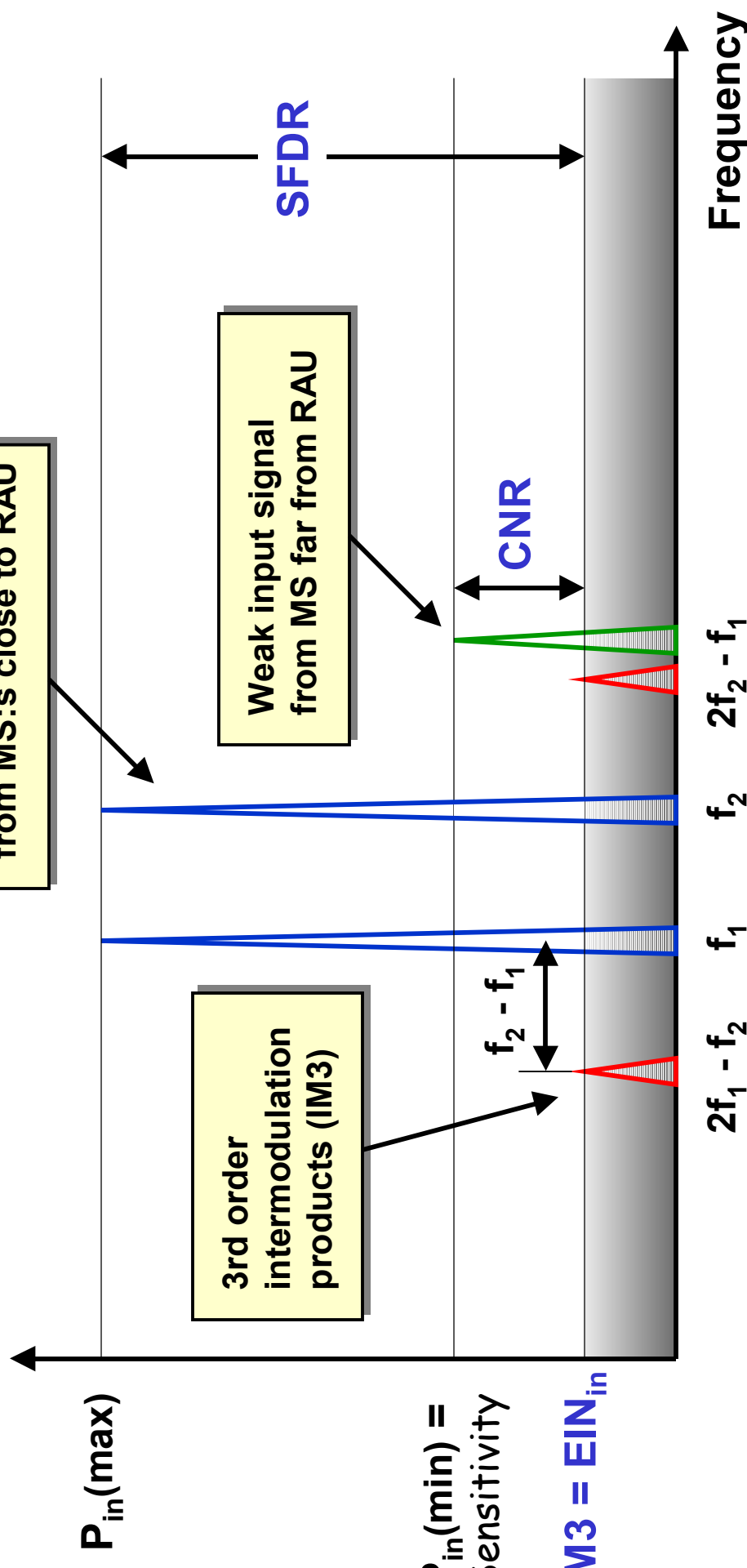
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Requirements

- **Bandwidth**
- **RF loss**
- **Noise**
- **Distortion**
- **Dynamic range**

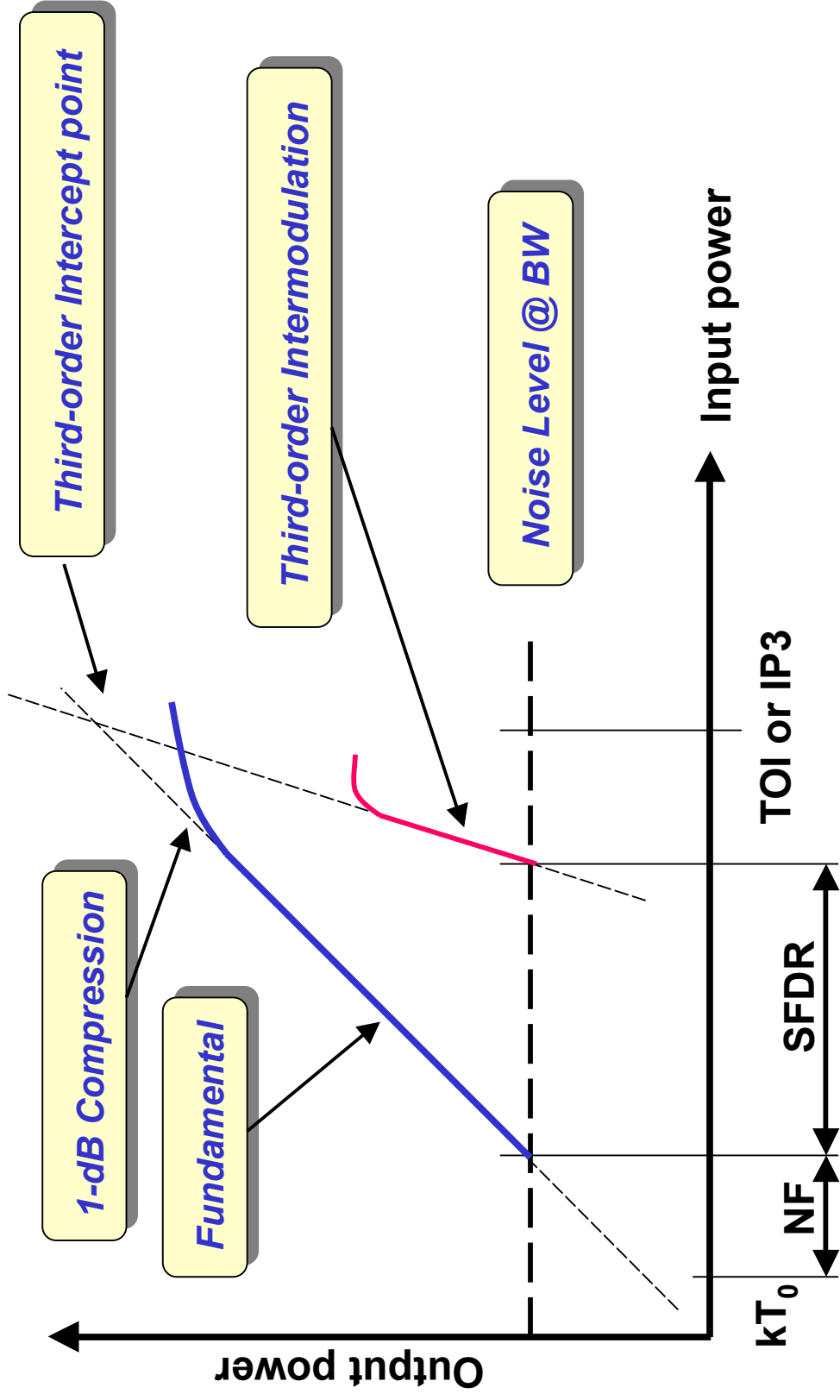
Dynamic range (1)

SFDR requirements



Dynamic range (2)

SFDR definition



Requirements (3)

Dynamic range

- 900 MHz GSM systems (indoor)¹⁾ > 100 dB/Hz^{2/3}, > 65 dB @ BW = 200 kHz
- 900 MHz GSM systems (outdoor)¹⁾ > 106 dB/Hz^{2/3}, > 71 dB @ BW = 200 kHz
- 1 900 MHz PCS (WACS/PACS)²⁾ > 72-83 dB/Hz^{2/3}, > 36-47 dB @ BW = 270kHz
- 900 MHz AMPS (single antenna)³⁾ > 91 dB/Hz^{2/3}, > 61 dB @ BW = 30 kHz
- 900MHz AMPS (multiple antennas)³⁾ < 80 dB/Hz^{2/3}, > 50 dB @ BW = 30 kHz
- 3-band GSM/UMTS (commercial) > 105 dB/Hz^{2/3}, > 70 dB @ BW = 200 kHz

References

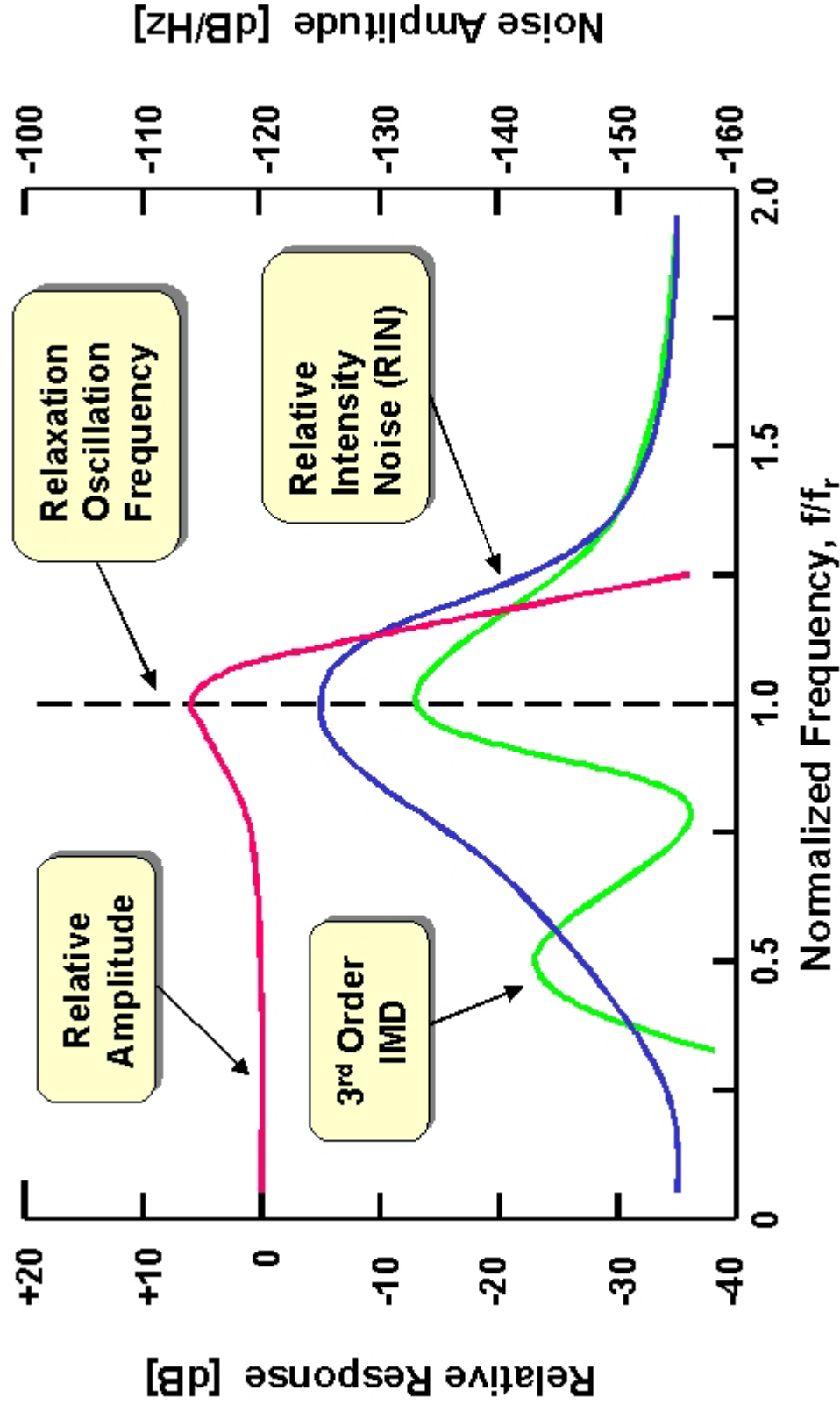
- Hunziker and W.Baechtold, "Cellular Remote Antenna Feeding: Optical Fibre or Coaxial Cable", *Electronics Letters*, Vol. 34, pp. 1038-1040, May 1998 (Swiss Federal Inst. Tech.)
- C.Fan, et al, "Dynamic Range Requirements for Microcellular Personal Communication Systems using Analog Fiber-Optic Links", *IEEE Trans. on MTT*, Vol.45, pp.1390-1397 (Stanford University)
- M.Cutrer, et al, "Dynamic Range Requirements for Optical Transmitters in Fiber-Fed Microcellular networks", *IEEE Photonics Tech. Letters*, 7 (5), pp.564-566, May 1995 (UC Berkeley)

Outline

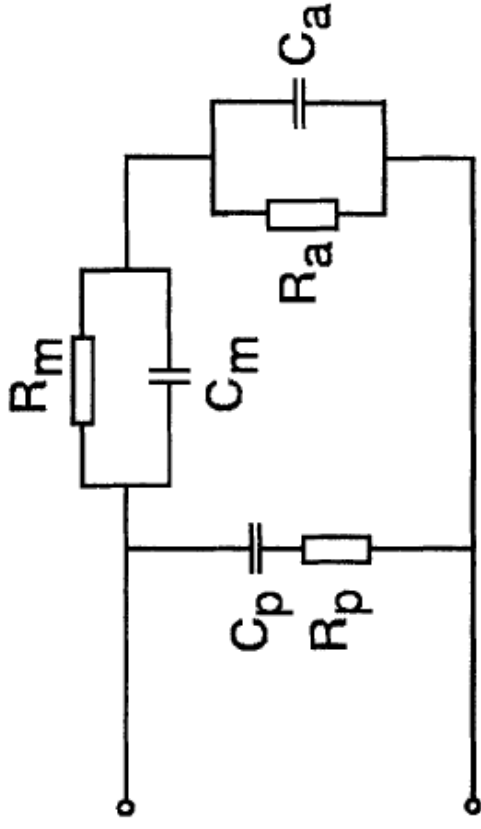
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Laser diodes

Analog performance



Equivalent circuit



6- μm MM-VCSEL

$C_p = 0.9 \text{ pF}$

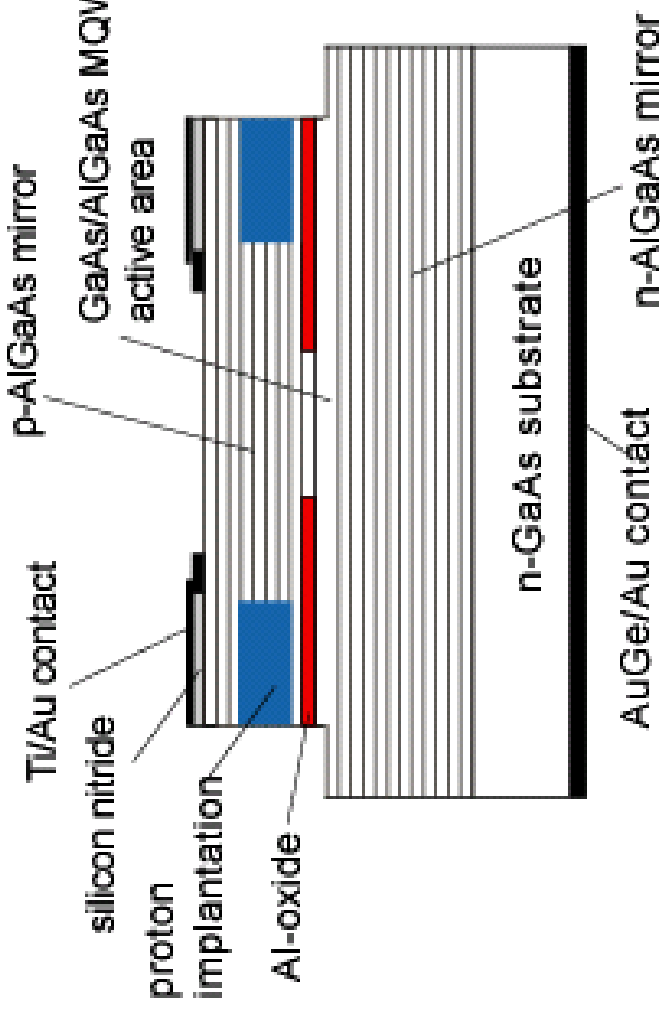
$R_m = 90 - 70 \text{ ohm}$

$R_a = 150 - 45 \text{ ohm}$

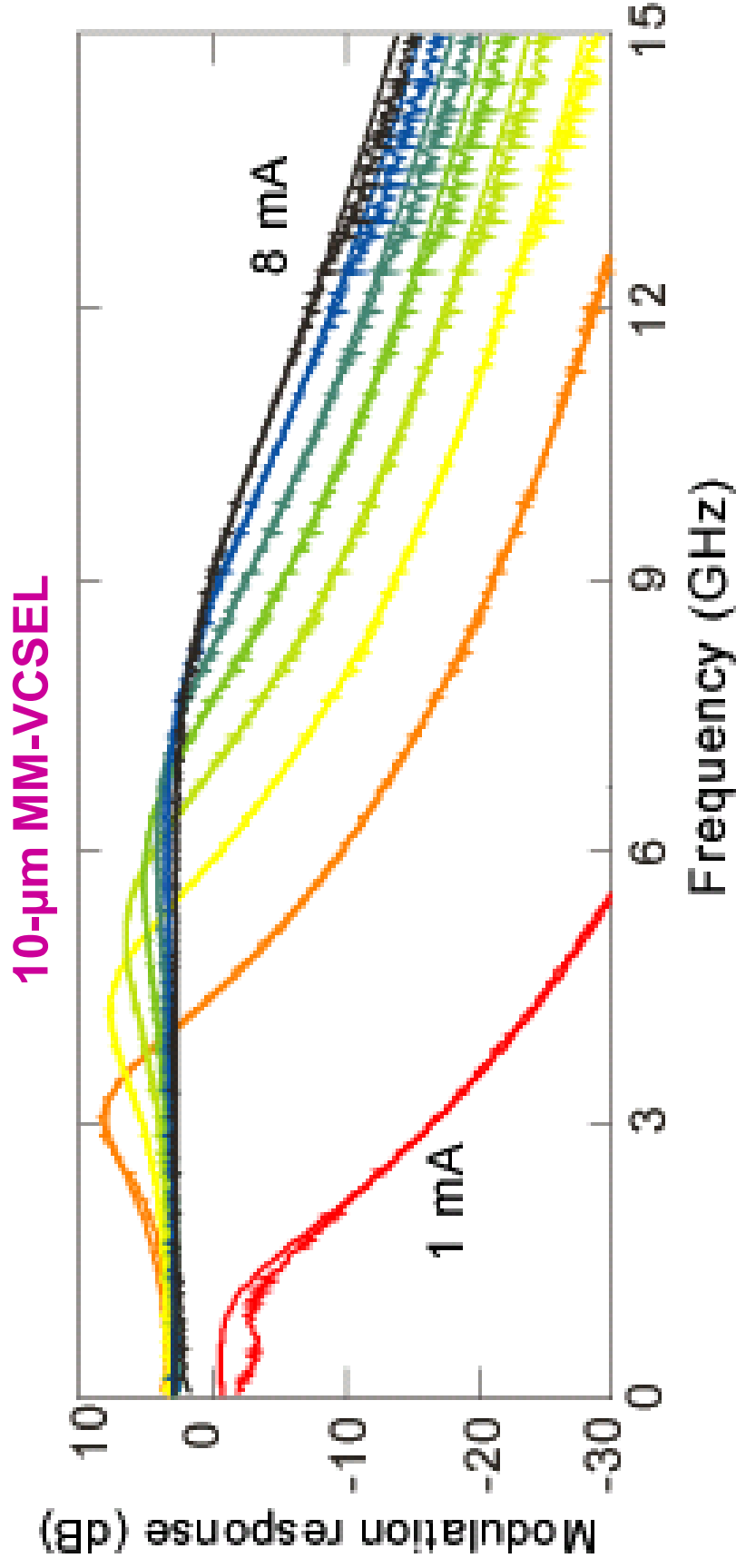
$C_a = 0.6 - 1 \text{ pF}$

$I_B = 0.5 - 4 \text{ mA}$ ($I_{th} = 0.4 \text{ mA}$)

Carlsson, et al, JLT, Sept. 2002



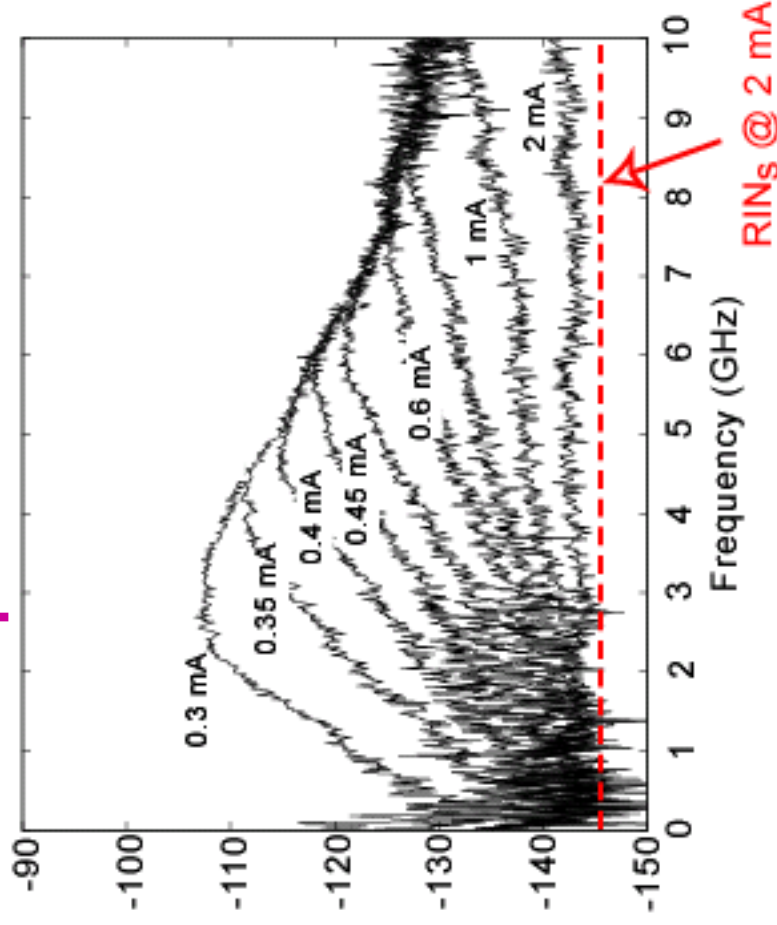
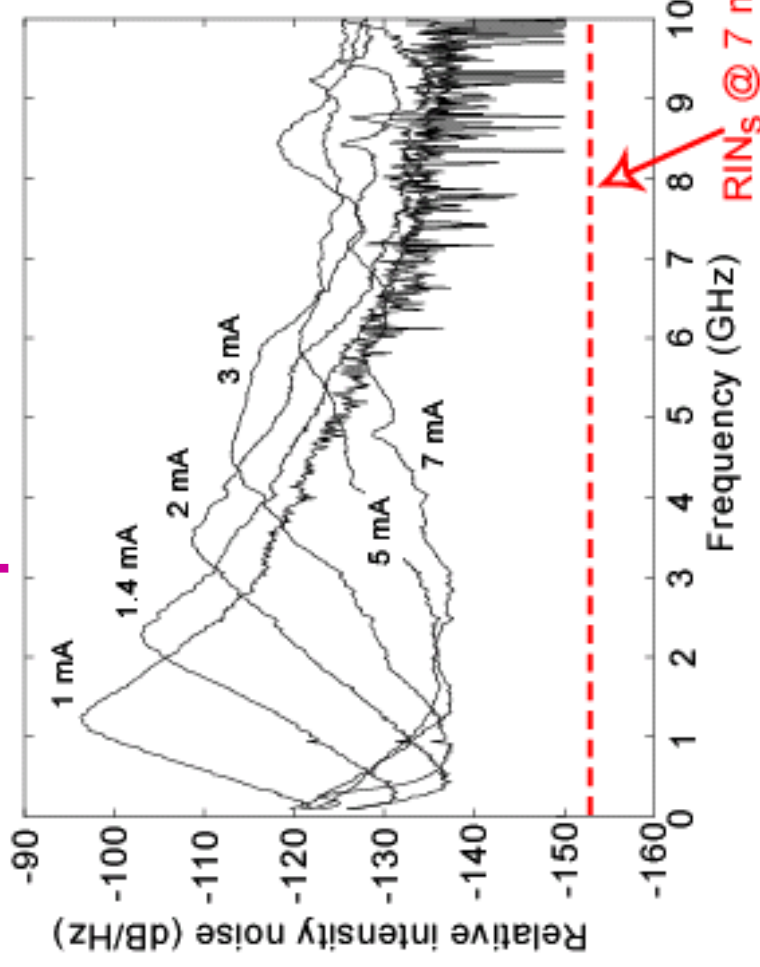
Bandwidth



Carlsson, et al, JLT, Sept. 2002



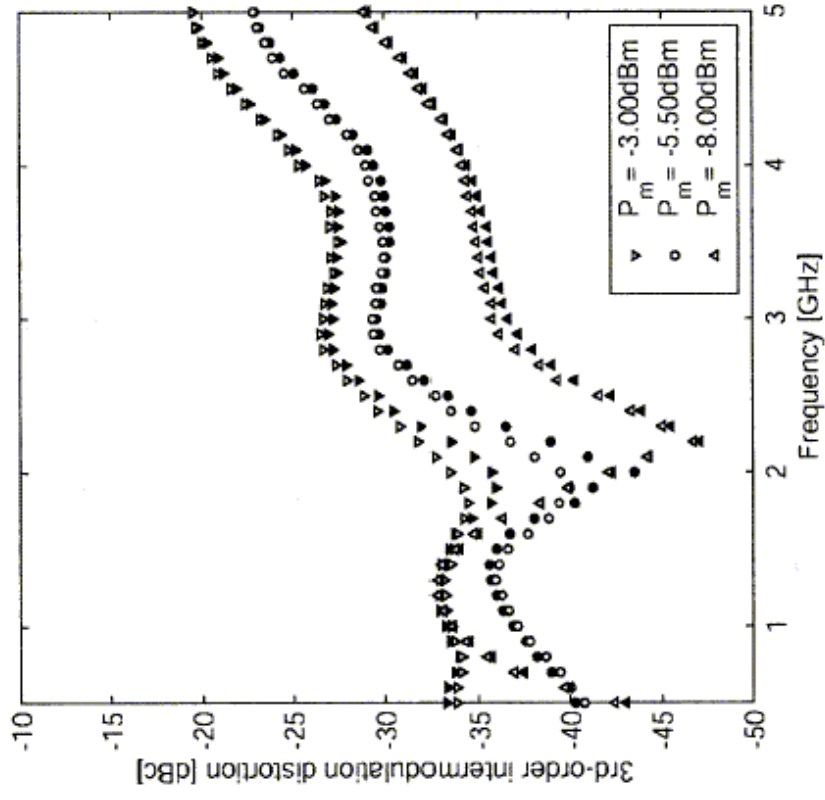
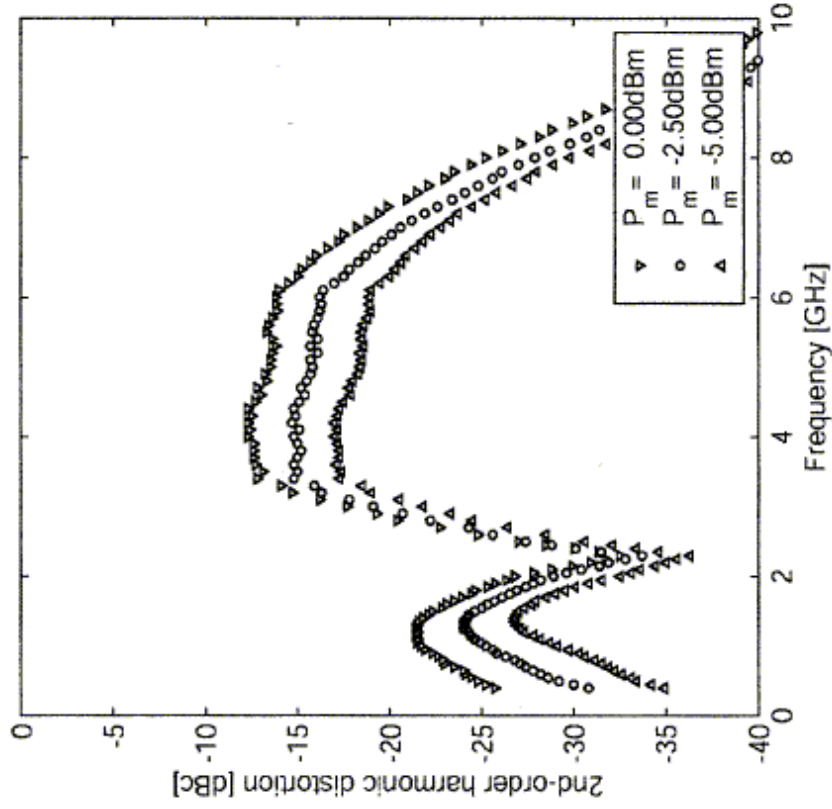
Noise

2- μm SM-VCSEL10- μm MM-VCSEL

Carlsson, et al, JLT, Sept. 2002

Distortion 2HD and IMD3

6- μm MM-VCSEL



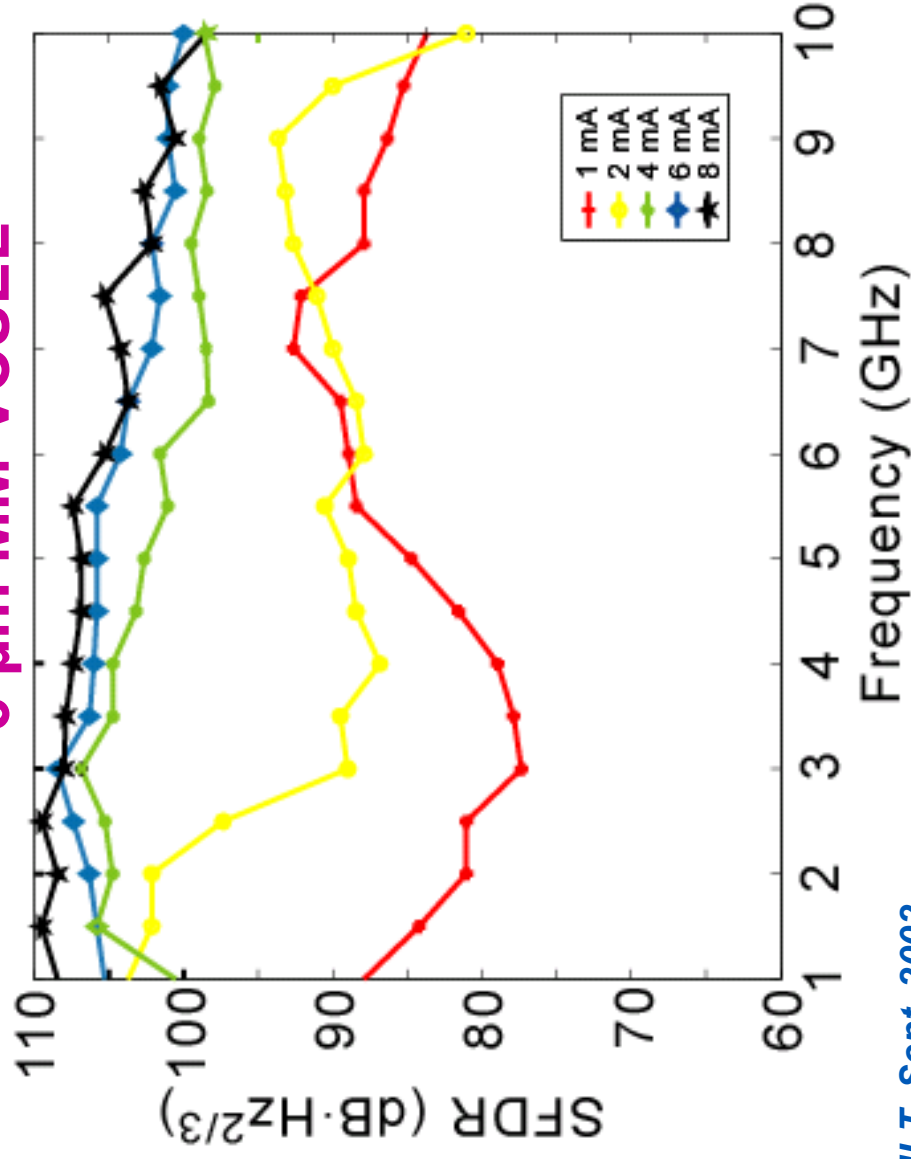
Gustavsson, et al, JQE, Aug. 2003



Dynamic range (1)

Spurious-Free DR (SFDR)

6- μm MM-VCSEL



Carlsson, et al, JLT, Sept. 2002



Dynamic range (2)

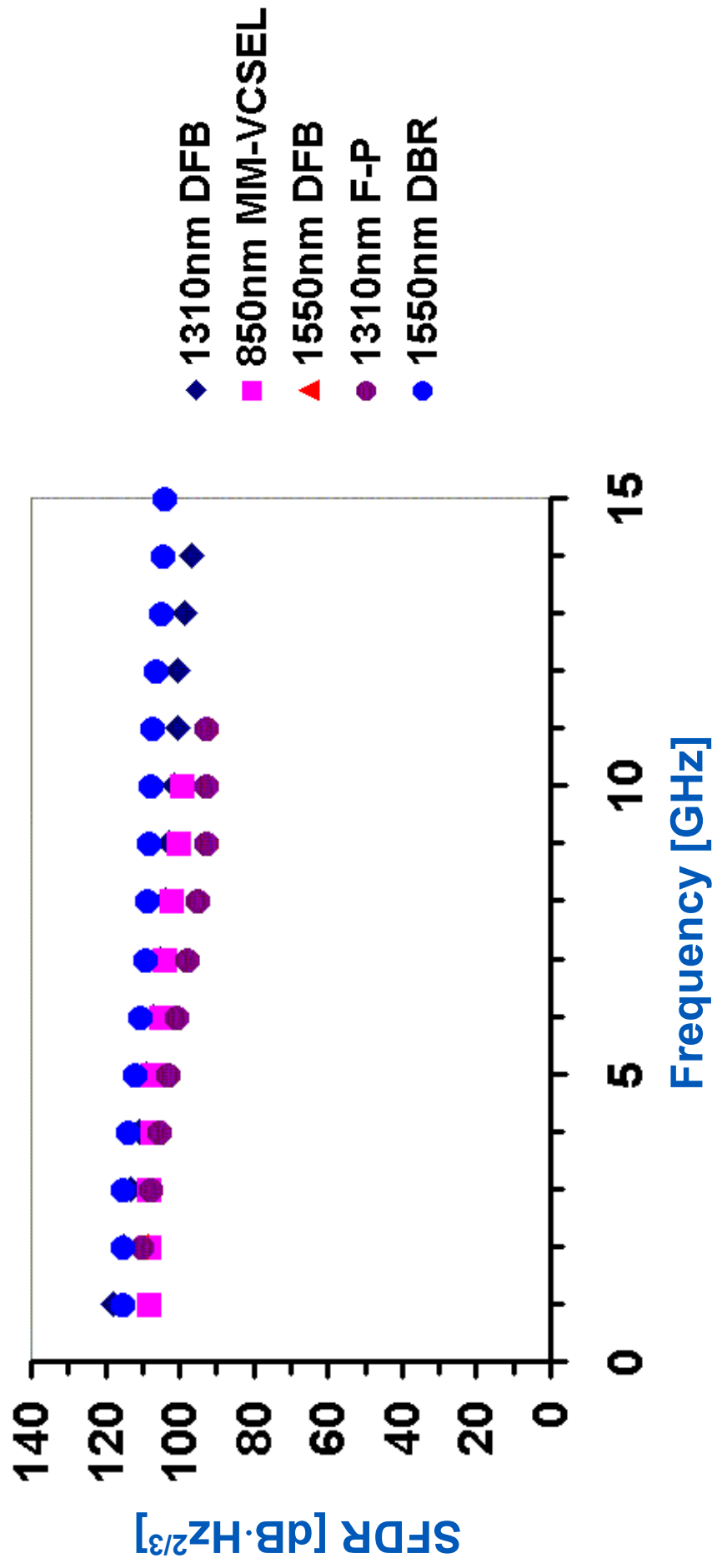
SFDR comparison

Laser type	2 GHz	5 GHz	10 GHz
850nm MM-VCSEL	108	107	99
850nm SM-VCSEL	101	100	97
1310nm F-P	110	103	93
1310nm DFB	115	109	101
1550nm DFB	112	--	--
1550nm DBR	115	112	107

Unit: SFDR is in dB·Hz^{2/3}

Dynamic range (3)

SFDR comparison



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Summary Performance

Size	f_R	R_M	RIN	IP3	SFDR
Small (2- μm)	H	H	L	L	L
Large (6- μm)	L	L	H	H	H

H = Higher
L = Lower

Conclusion

- RF performance of VCSELs is now comparable to other laser types (F-P and DFB)
- Potentially a low-cost device
- 850-nm VCSELs only usable over shorter distances
- 1300-nm VCSEL is now coming to the market
- All VCSELs on the market are optimized for digital applications

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<http://fotonik.pitch.se>

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