ER Dependency of APD Receiver Sensitivity

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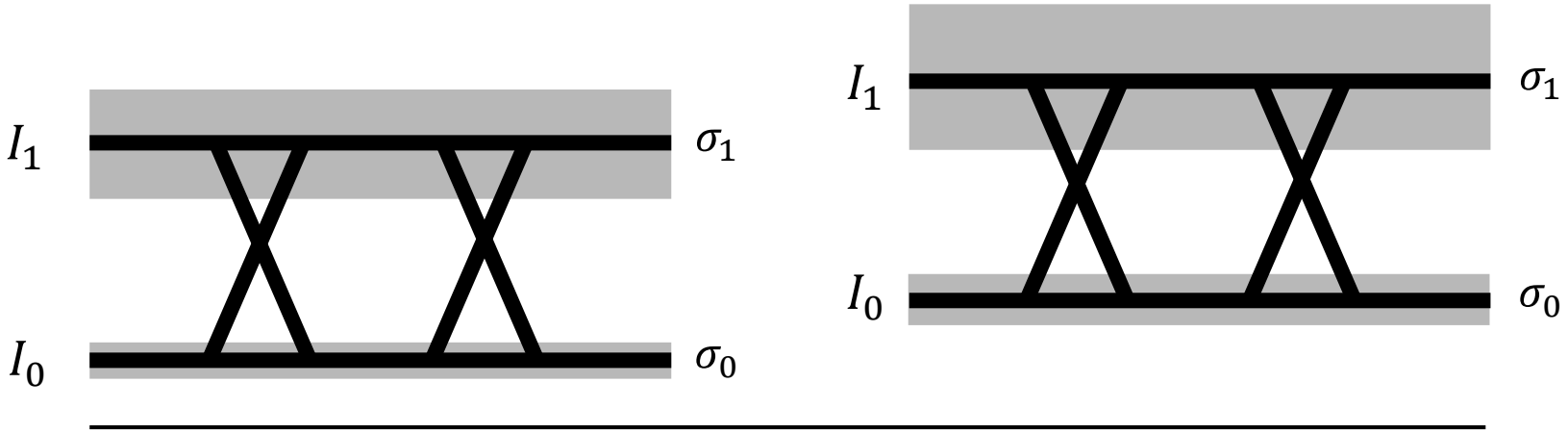
Motivation

- OMA sensitivity of APD receiver shows ER dependency due to APD shot noise. In this presentation, I'll show calculated ER penalties.



$$I_1 = MRP_{OMA}\frac{ER}{ER-1} \quad \text{(A)}$$

$$I_0 = MRP_{OMA}\frac{1}{ER-1} \quad \text{(A)}$$

R : O/E Responsivity (A/W)

M : APD multiplication gain

P_{OMA} : Received Optical Power in OMA (W)

ER : Extinction Ratio

APD Current Noise Calculation

$$\sigma_{APD} = \sqrt{2q(i + i_d)FM^2B} \qquad \text{(A)}$$

q : elementary charge (=1.602x10^{-19} C)

M : APD multiplication gain

i : APD current (M=1) (A)

i_d : APD dark current (M=1) (A)

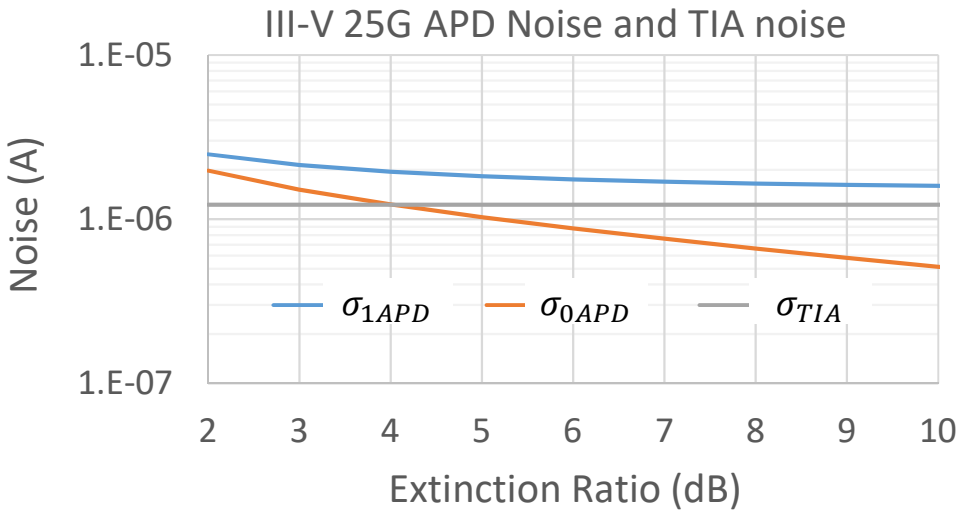
B : receiver bandwidth (Hz)

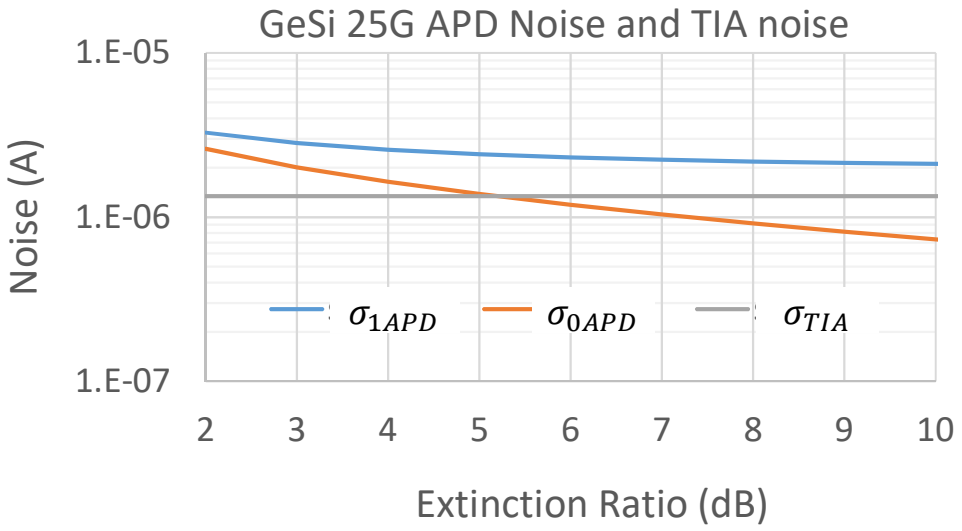
F: excess noise factor

$F = kM + (2 - 1/M)(1 - k)$ $\qquad$ k : ionization-coefficient ratio

Reference: http://www.ieee802.org/3/ca/public/meeting_archive/2016/09/pan_3ca_1_0916.pdf

ER Dependency of APD Noise





Representative parameter values

Parameter	III-V	GeSi	Unit
P_{OMA} (1)	-24.83		dBm
k	0.45	0.13	
i_d (2)	10	60	nA
M (2)	7	10	
R	0.7		A/W
B (2)	15	18	GHz
σ_{TIA} (3)	1.22	1.34	uA

Note
(1) OLT sensitivity at BER=1e-2
(2) GeSi APD has wider bandwidth with high M, but dark current is larger than III-IV.
(3) Assumed TIA noise is constant over frequency for simplicity.

$$\sigma_{TIA} = 10\ pA/\sqrt{Hz} \times \sqrt{B} \quad (A)$$

ER Dependency of APD Noise

Total noise of APD and TIA is:

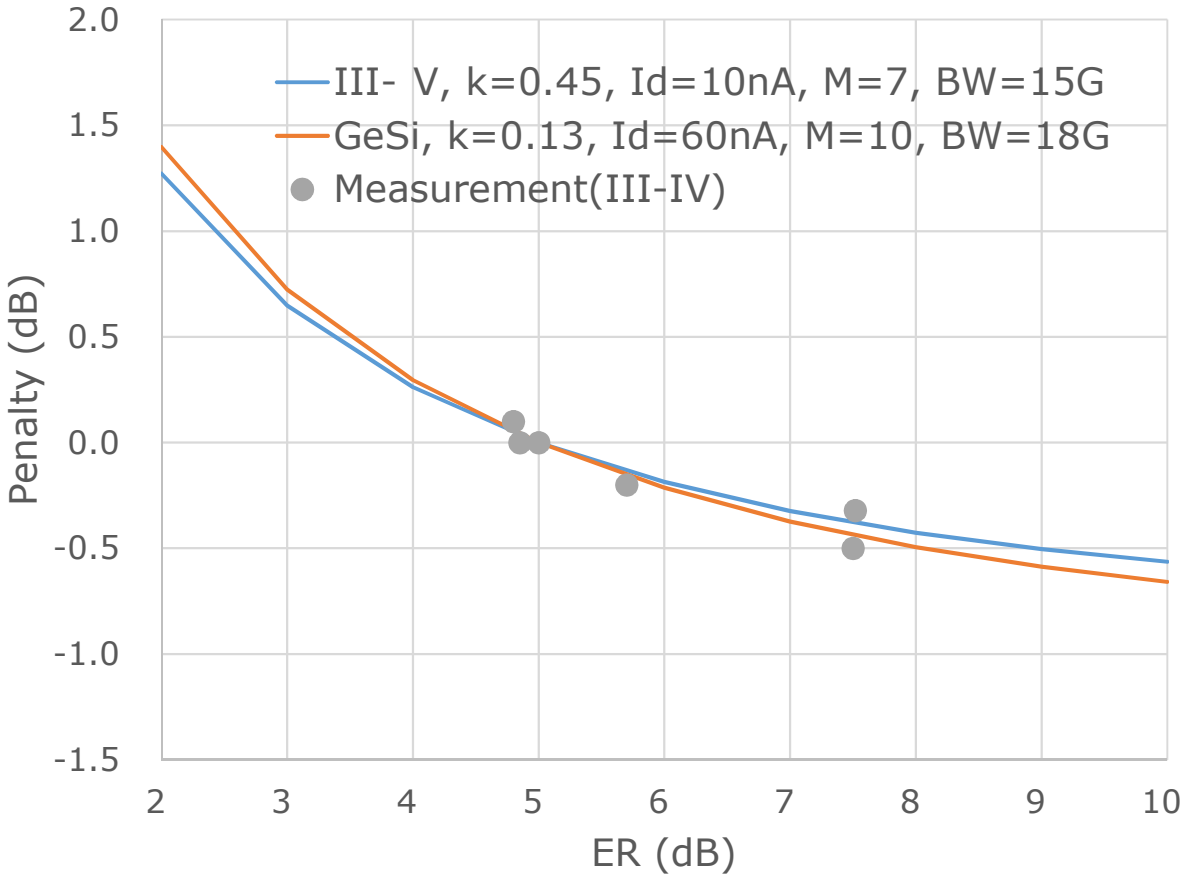
$$\sigma_1 = \sqrt{{\sigma_{1APD}}^2 + {\sigma_{TIA}}^2}$$

$$\sigma_0 = \sqrt{{\sigma_{0APD}}^2 + {\sigma_{TIA}}^2}$$

ER dependent penalty of OMA sensitivity is:

$$Penalty = 10\log\left(\frac{Q(ER)}{Q(\,ER{=}5dB\,)}\right)$$

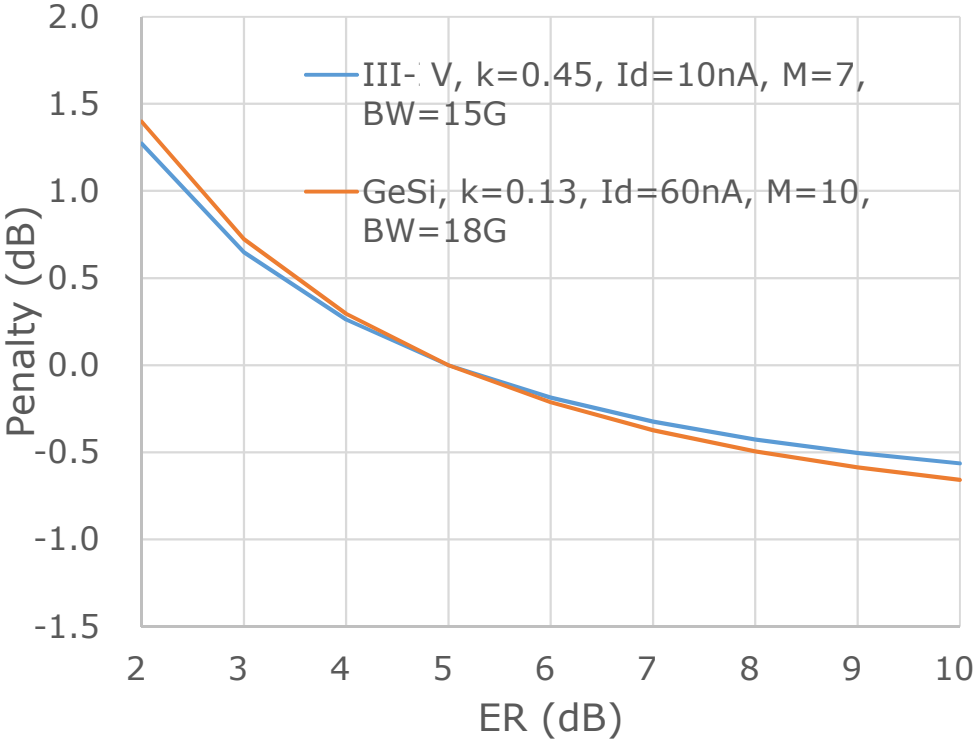
$$Q(ER) = \frac{I_1 - I_0}{\sigma_1 + \sigma_0}$$



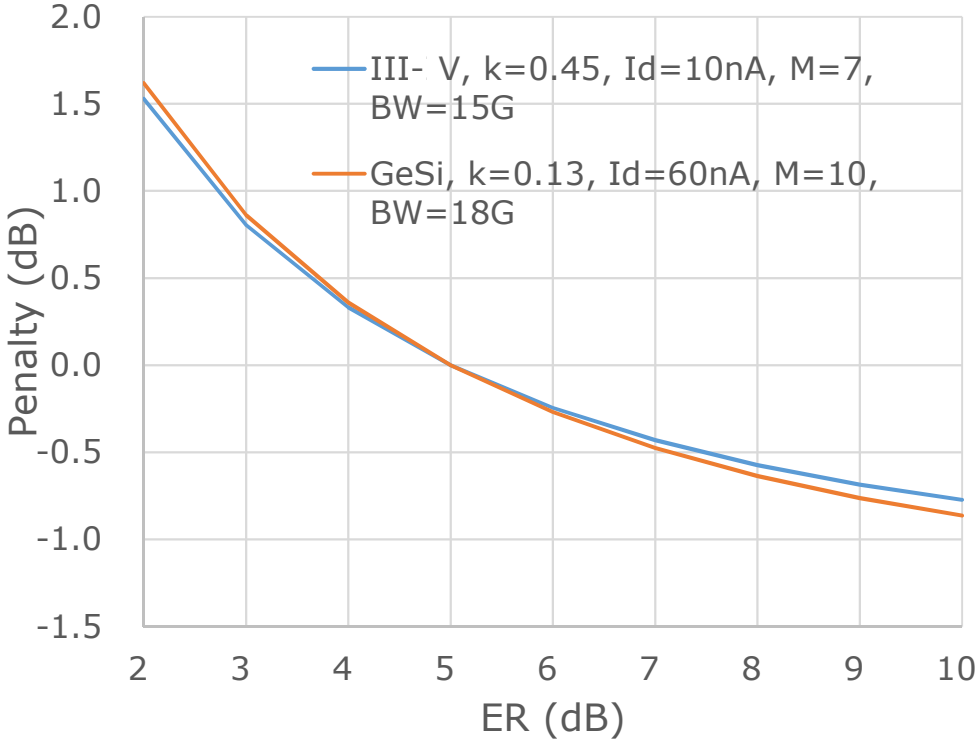
Measurement plots are from tanaka_3ca_1_1116.pdf

ER Dependency of APD Noise

The penalty has dependency on received power level.



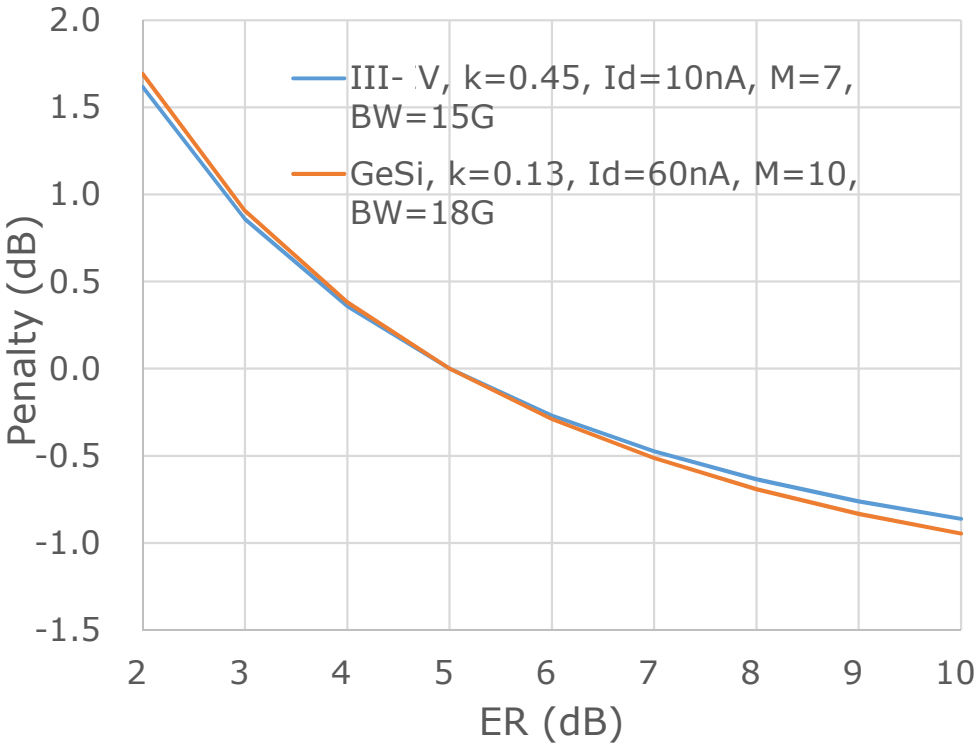
P_{OMA} = -24.83 dBm
(25G OLT sensitivity @BER=1e-2)



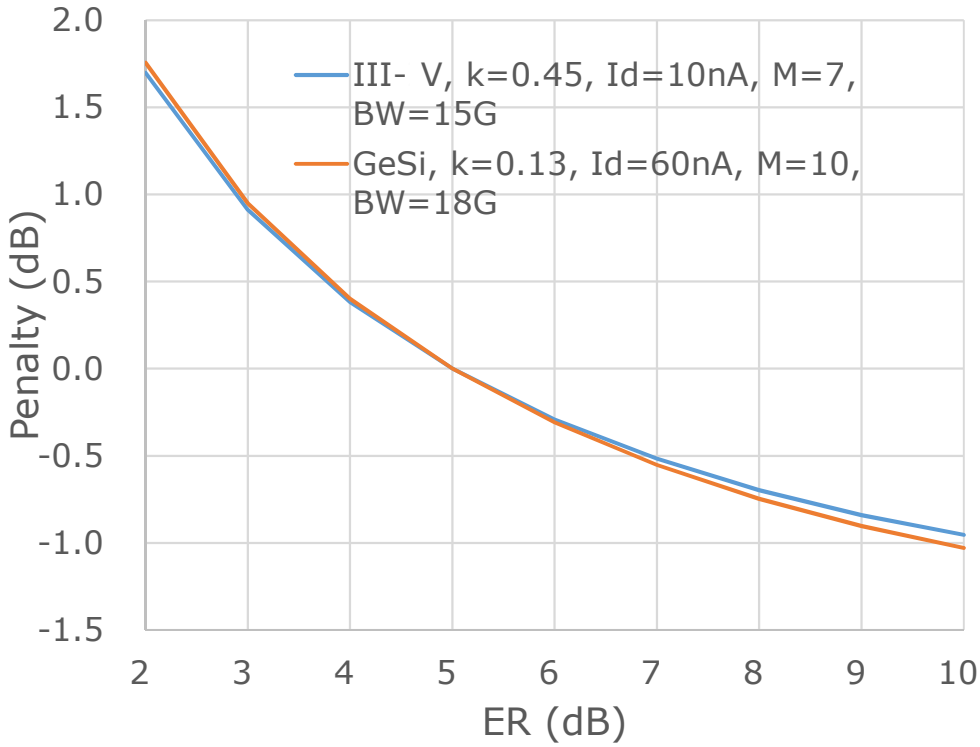
P_{OMA} = -21.83 dBm
(25G OLT sensitivity + 3dB)

ER Dependency of APD Noise

The penalty has dependency on received power level.



P_{OMA} = -20.5 dBm
(4WDM MSA 40km)



P_{OMA} = -19.0 dBm
(25GBASE-ER)

Summary

- OMA sensitivity of APD receiver has ER dependency and showed calculated ER penalties for III-V and GeSi APD.

- Need to consider the penalty to relax ER specification.