DEP. OF SIGNAL THEORY AND COMMUNICATIONS

Chap.5. Lidar Link Budget

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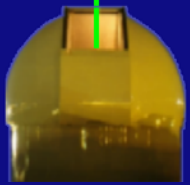


O/E CONVERSION AND RESOLUTION

O/E SIGNAL CONDITIONING

- *O/E Conversion*

$$V(R) = R_i G_T P(R) L + V_{OS} = R'_V P(R) + V_{OS}$$

$$V_{OS} = R'_V P_{back} + V_{drift} + V_{user}$$

- *where Ri* [A/W], *RV* [V/W], GT [Ω], L=ξ(λ) (optical losses [ ]), Pback [W]

$$R_V = R_i G_T \,, \qquad R'_V = R_V L$$

- *An offset (VOS) calibration/restoration system is necessary (...)*

SPATIAL RESOLUTION (pulsed lidar)

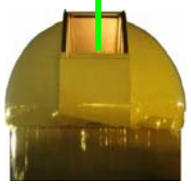
- *Considering the two-way optical path (go and return), t=2R/c, so that sampling at $f_s=1/\tau$,*

$$\Delta R = \frac{c}{2 f_s}$$

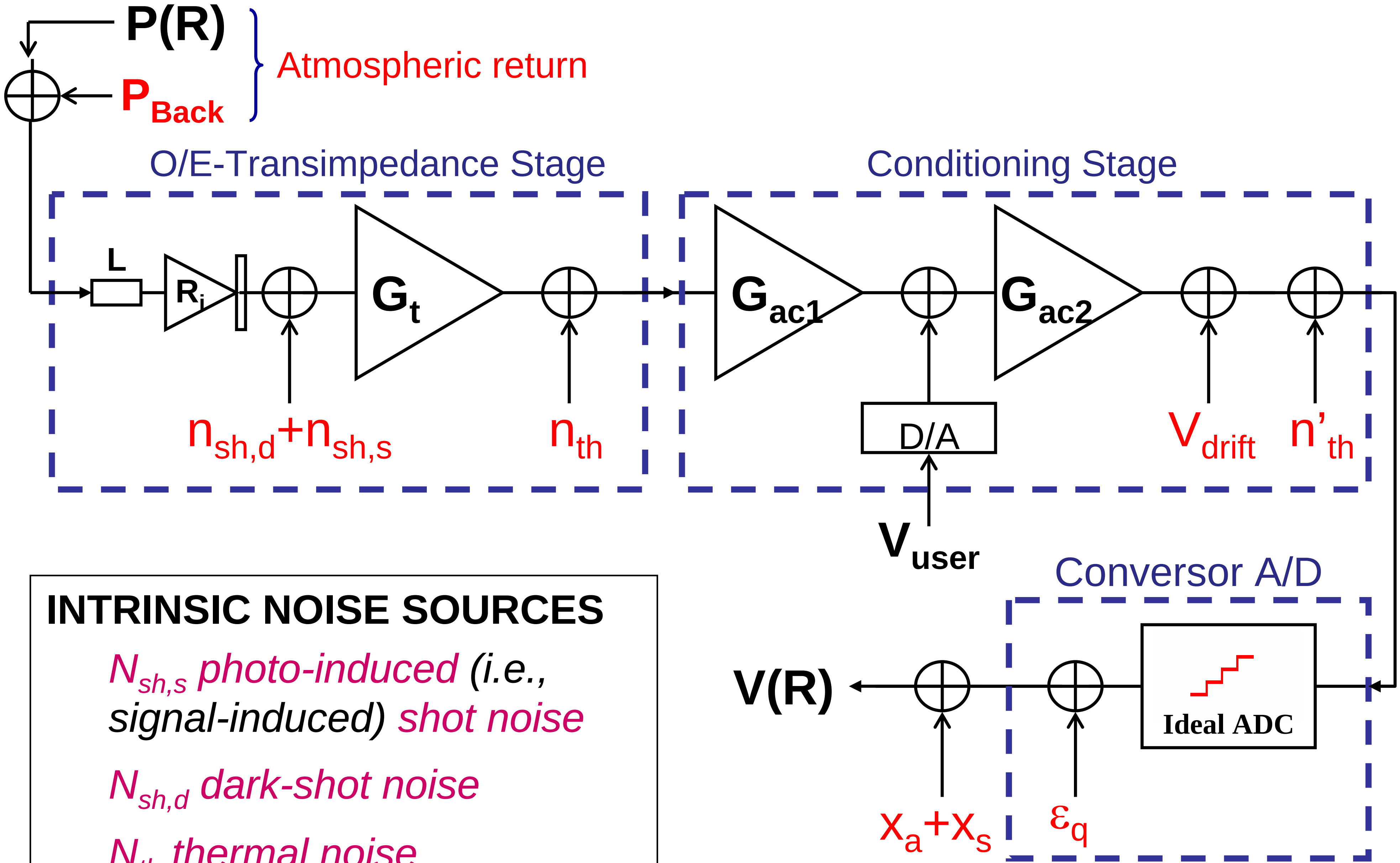
TEMPORAL RESOLUTION (pulsed lidar)

- *Largely dominated by the mean visibility, which defines the averaging time, n_i,*

$$\Delta T = n_i PRF$$



SIGNAL-TO-NOISE RATIO (I)



INTRINSIC NOISE SOURCES

$N_{sh,s}$ photo-induced (i.e., signal-induced) shot noise

$N_{sh,d}$ dark-shot noise

N_{th} thermal noise

SIGNAL-TO-NOISE RATIO (II)

DEFINITION

$$SNR_V(R) = \frac{\text{useful voltage}}{\text{noise voltage}} = \frac{R_V L P(R)}{\sigma_V(R) B^{1/2}}, \qquad \frac{[V]}{[V]}$$

NOISE SOURCES

$$\sigma_V^2 = \sigma_{sh,s}^2 + \sigma_{sh,d}^2 + \sigma_{th}^2 \qquad \left[\frac{V^2}{Hz}\right]$$

where (...):

$$\sigma_{sh,s}^2(R) = 2qG_T^2 FM^2 R_{io}\left[P(R) + P_{back}\right]L$$

photo-induced (i.e., signal-induced) shot noise

$$\sigma_{sh,d}^2 = 2qG_T^2\left(I_{ds} + FM^2 I_{db}\right)$$

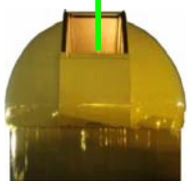
dark-shot noise

$$\sigma_{th}^2 = \sigma_{th,i}^2 G_T^2$$

thermal noise

OPERATION MODES

- *sh,s dominant,* $SNR \propto P(R)^{1/2}$
- *th dominant,* $SNR \propto P(R)$



SIGNAL-TO-NOISE RATIO (III)

NOISE-LIMITED MODES

1) Shot-dominant mode

→ SNR does not depend on receiver chain gain G_T

$$\frac{S}{N} = \left(\frac{R_{io}L}{2qB_N F}\right)^{\frac{1}{2}} P(R)^{\frac{1}{2}}$$

2) Thermal-dominant mode

→ the larger M, the better the SNR

$$\frac{S}{N} = \left(\frac{R_i L}{\sigma_{th,i}\sqrt{B_N}}\right) P(R)$$

3) Likewise, dark and background-ltd. modes can be formulated

NOISE EQUIVALENT POWER

A) Photodiode NEP

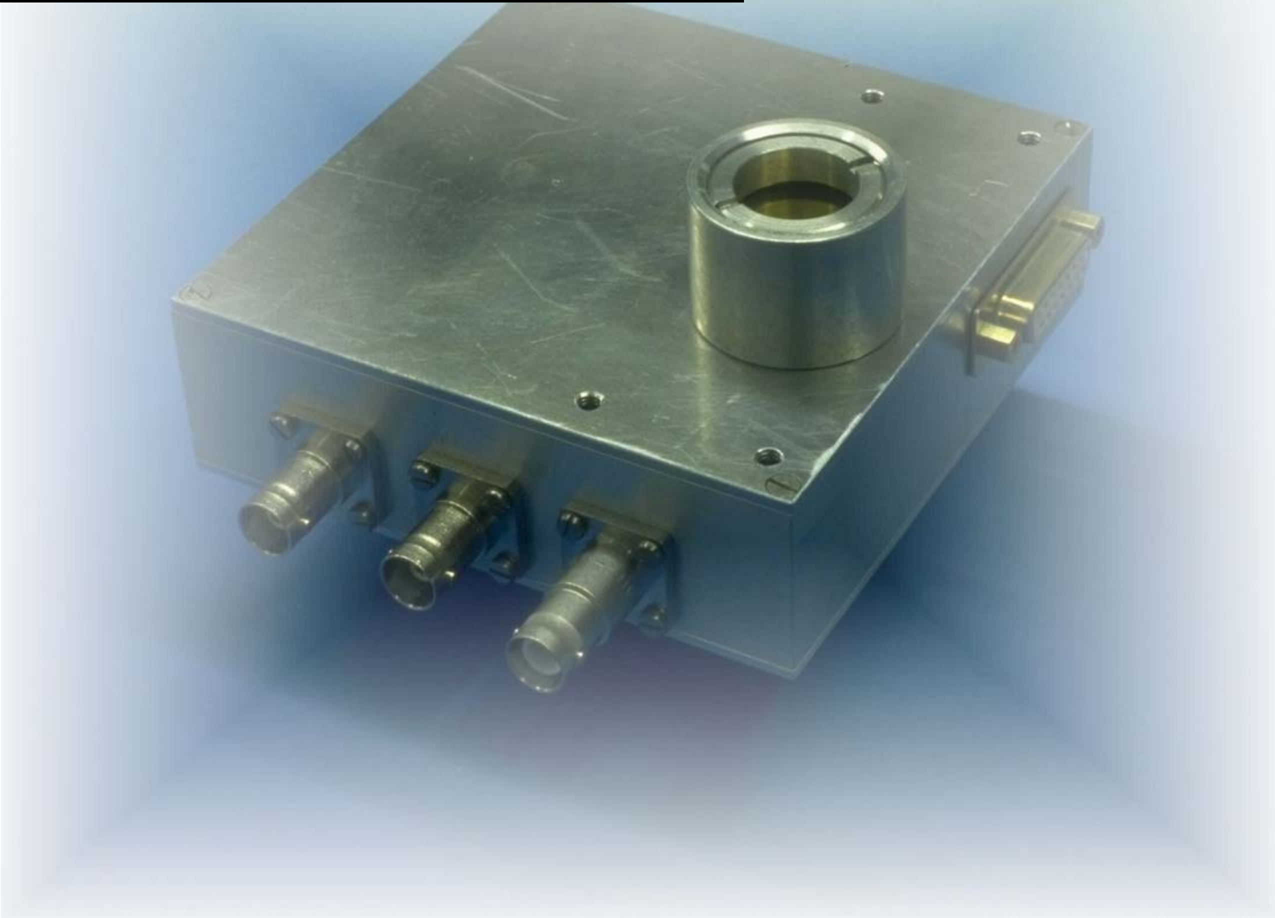
$$NEP_s = \frac{\left(\sigma_{sh,d}^2 + \sigma_{th}^2\right)^{1/2}}{R'_V} \quad \left[\frac{W}{\sqrt{Hz}}\right]$$

B) System NEP

$$NEP = \frac{\sigma_{sh,d}^{PH}}{R_i^{PH}} = \frac{\left[2q\left(I_{ds} + FM^2 I_{db}\right)\right]^{1/2}}{\frac{\eta q \lambda}{hc} M} \quad \left[\frac{W}{\sqrt{Hz}}\right]$$

OPTOELECTRONIC RECEIVER

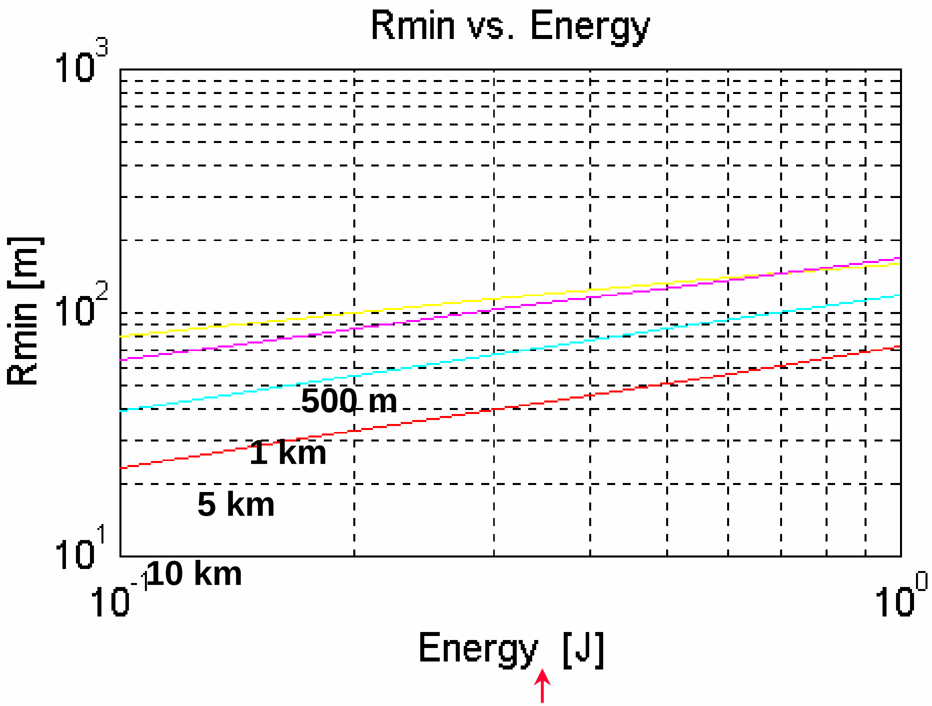
LIDAR RECEIVER	
Aperture	2 m
FOV	0.2-0.75 mrad
Detector	APD (EGG C30956 E)
Net Responsivity	10^3-10^8 V/W
Bandwidth	10 MHz

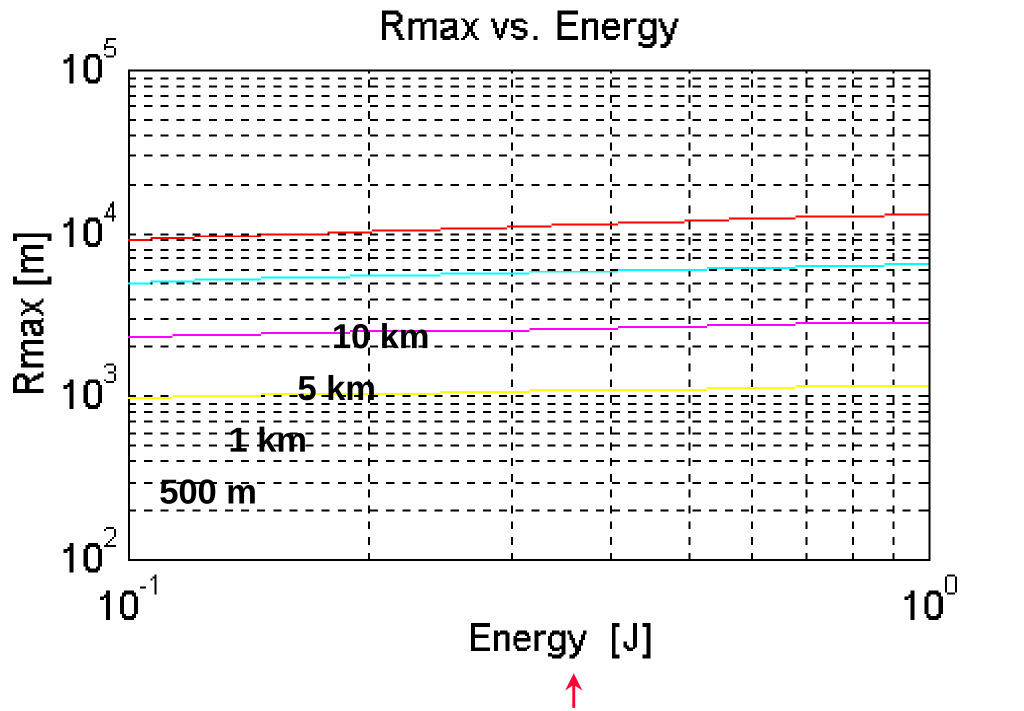


High-performance OPTO-ELECTRONIC receiver

- *low-noise (NEP » 40 fW·Hz-1/2)*
- *very high GBP*
- *wide dynamic range (responsivity 103-108 V/W)*
- *digital control (e.g. AGC, offset)*
- *built-in A/D*
- *window operation*
- *self-calibration*
- *can be coupled to optical instruments*
- *many applications*

LIDAR RANGE ESTIMATION





RMIN **SYSTEM PARAMETERS:**

M=1

GT=5700 W; GA= 0.49 V/V

ni=1 pulse

Condition: No saturation

R_{MAX} **SYSTEM PARAMETERS:**

M=400

G_T=5700 Ω; G_A= 88.4 V/V

n_i=1 pulse

Condition: SNR(R_{max})=1