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PDV/MPDV APPs

Modeling Tools to Predict System Performance for Design and Experimentation

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Purpose: To predict system performance

What do we mean by system performance?

- *Sensitivity … Do we have enough optical (return) signal to see anything on the spectrogram (i.e., are we above the noise floor?)?*
- *Signal-to-noise ratio … How far above the noise floor is the anticipated optical signal?*

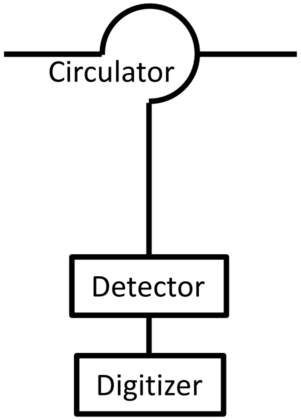
What can we apply this to?

1. Fielding. Given a PDV/MPDV system deployed to an experiment, the experimenter would like to know what kind of signal levels they can expect. ➔ SHOT APP
2. Design. Design an MPDV system to your needs. ➔ DESIGN APP

Architecture – progression of PDV to MPDV

Basic geometry and components that determine performance

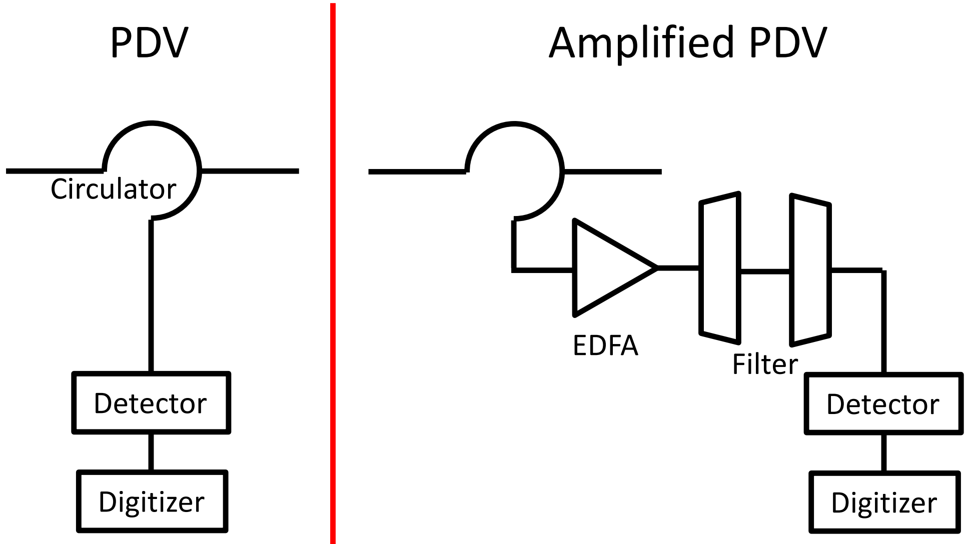
PDV



Digitizer
+
Detector

Architecture – progression of PDV to MPDV

Basic geometry and components that determine performance

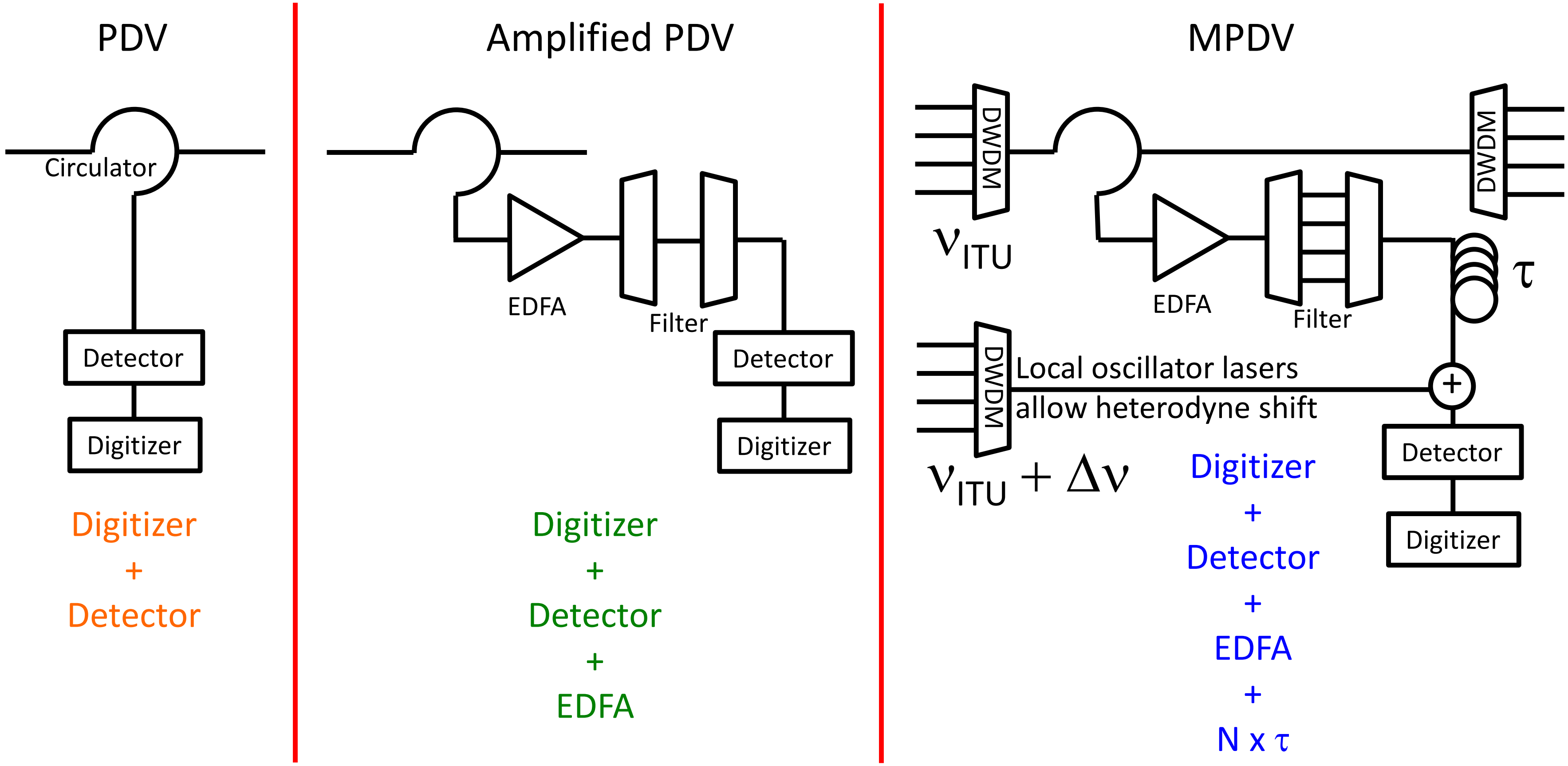


Digitizer
+
Detector

Digitizer
+
Detector
+
EDFA

Architecture – progression of PDV to MPDV

Basic geometry and components that determine performance

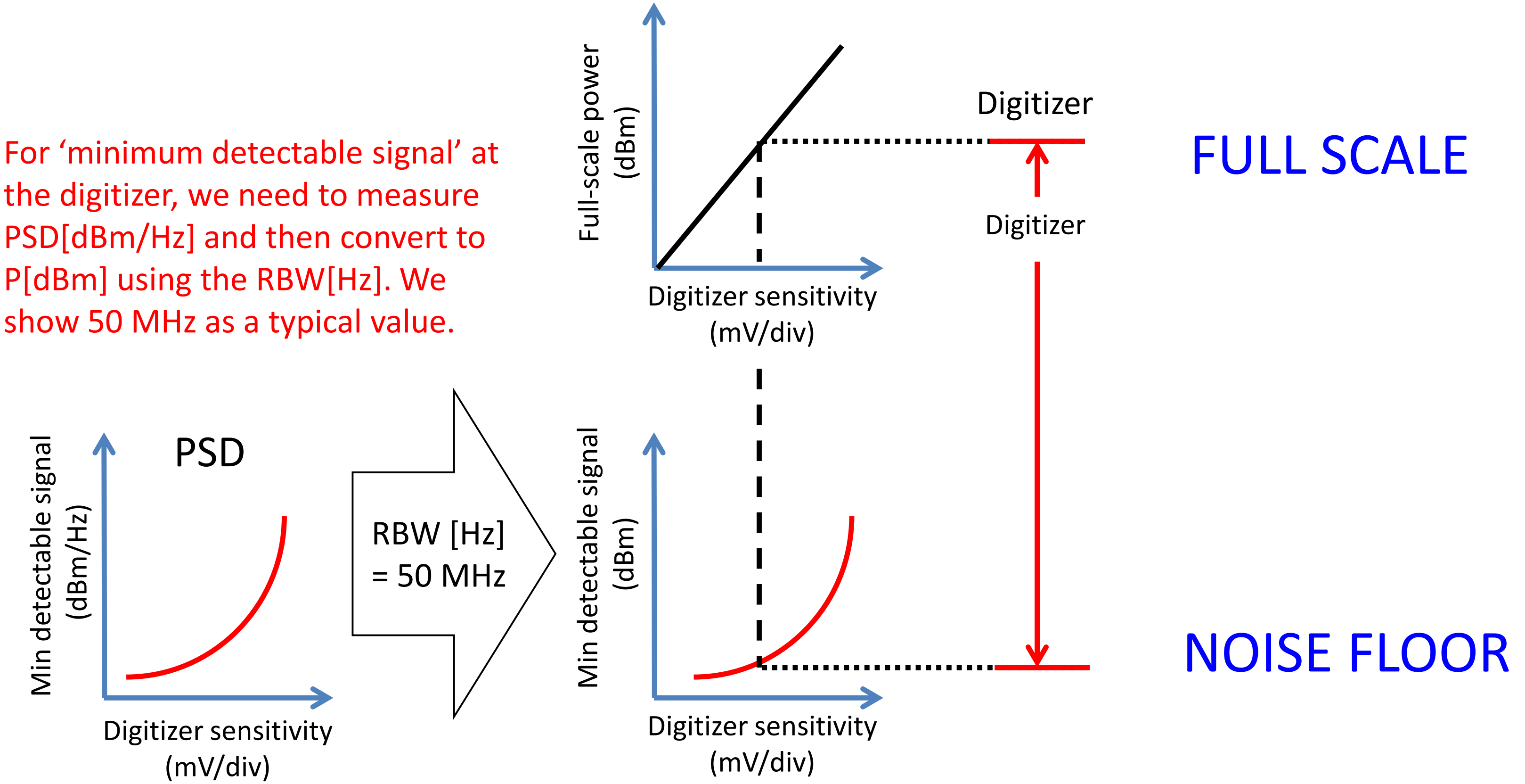


Dynamic Range: Scope

Definition of dynamic range:

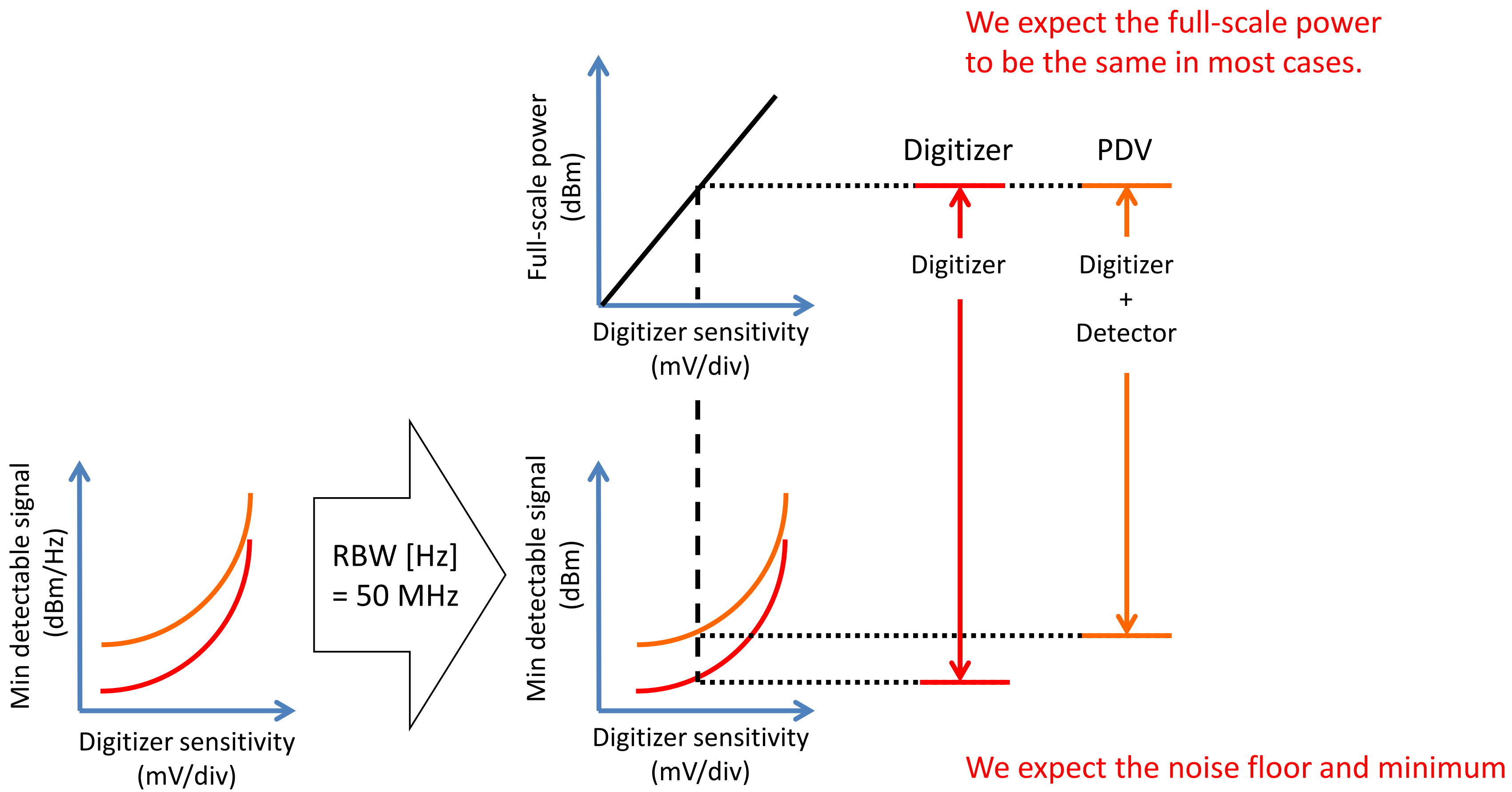
Full-scale power [dBm] minus minimum detectable signal [dBm]

For 'minimum detectable signal' at the digitizer, we need to measure PSD[dBm/Hz] and then convert to P[dBm] using the RBW[Hz]. We show 50 MHz as a typical value.



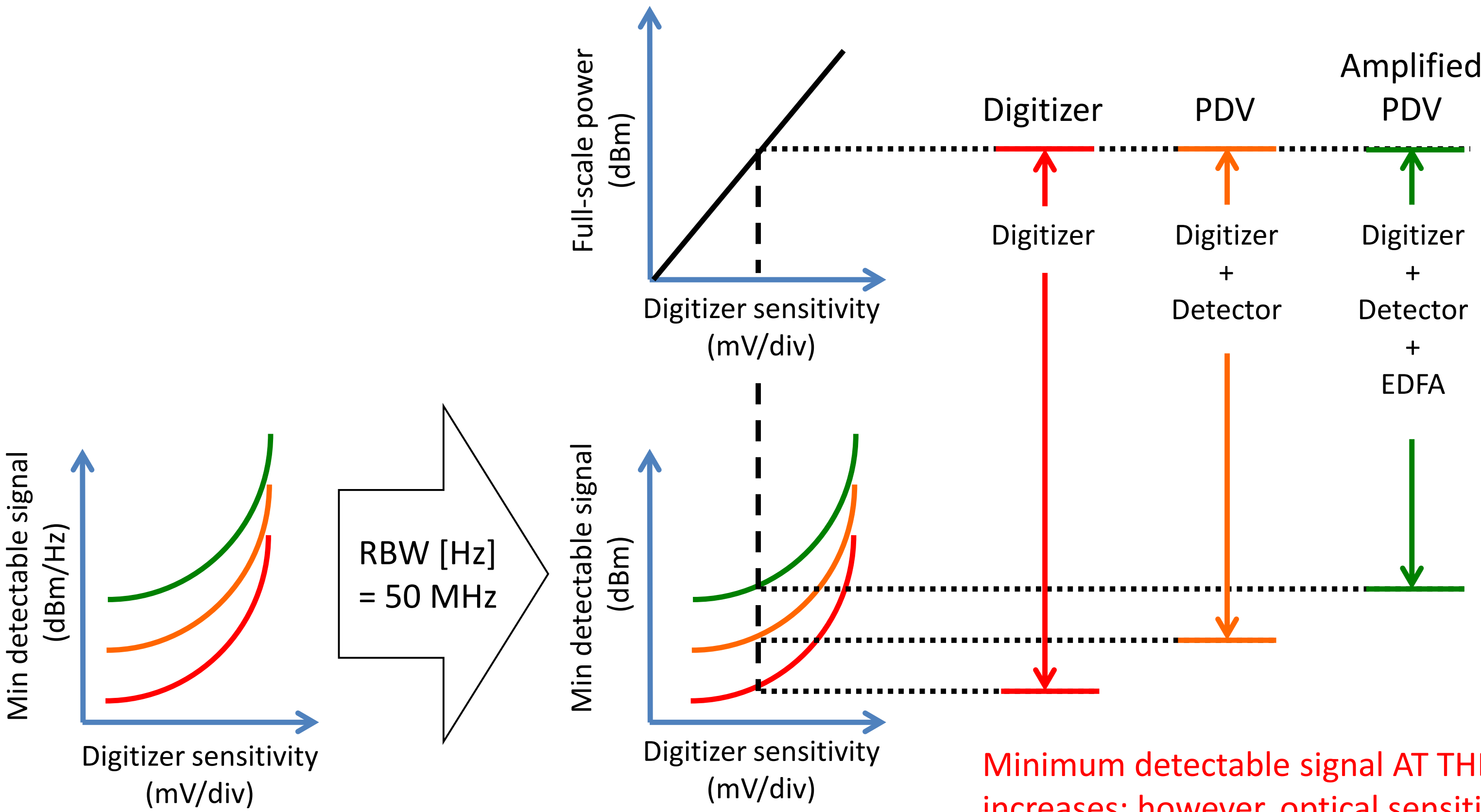
PSD = Power Spectral Density (dBm/Hz)

Dynamic Range: Scope & Photodetector



PSD = Power Spectral Density (dBm/Hz)

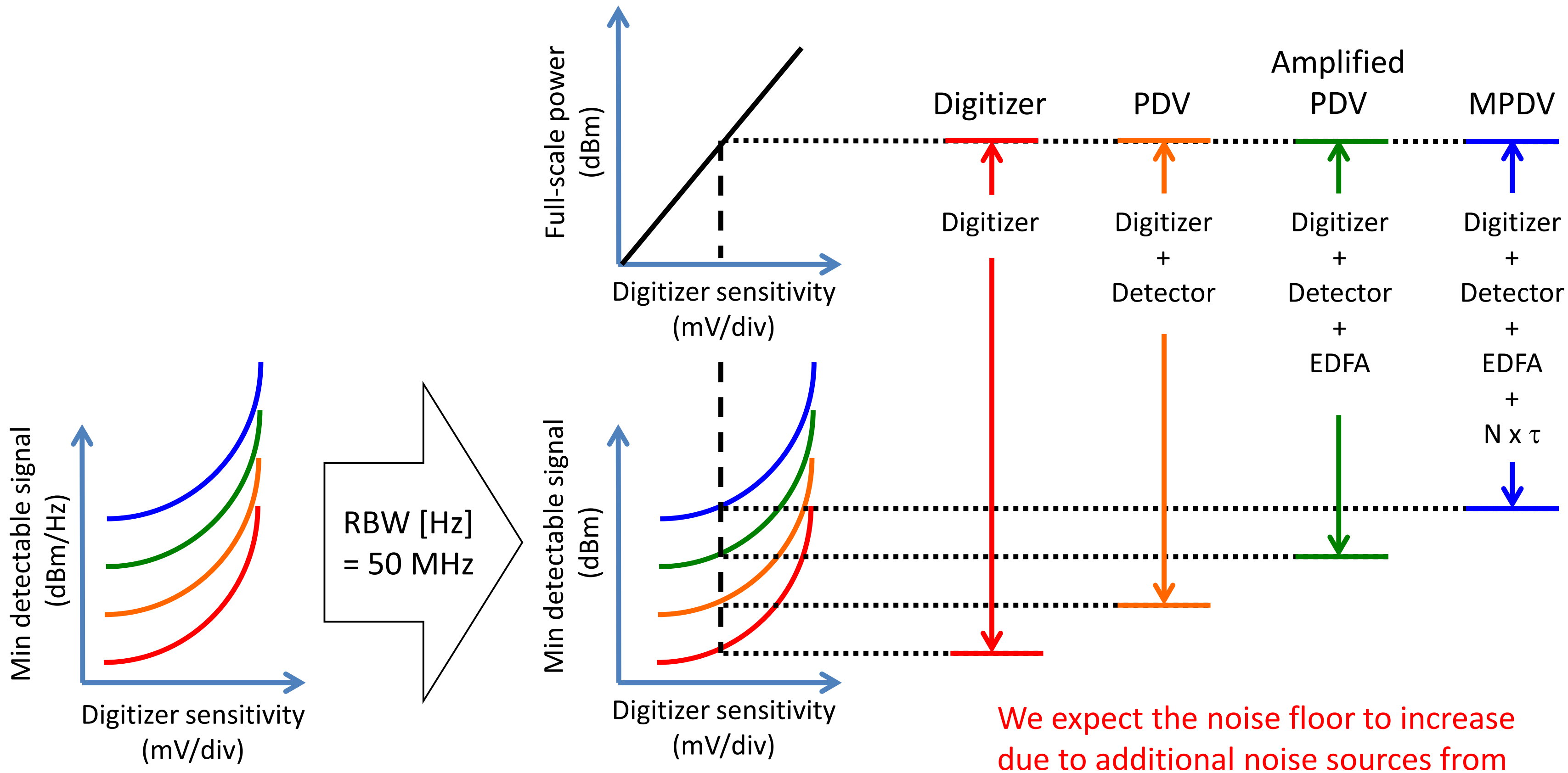
Dynamic Range: Scope, Detector & EDFA



PSD = Power Spectral Density (dBm/Hz)

Minimum detectable signal AT THE SCOPE increases; however, optical sensitivity (i.e., detection of photons returned from the target surface) may improve with application of EDFA.

Dynamic Range: Scope, Detector, EDFA & Multiplexing

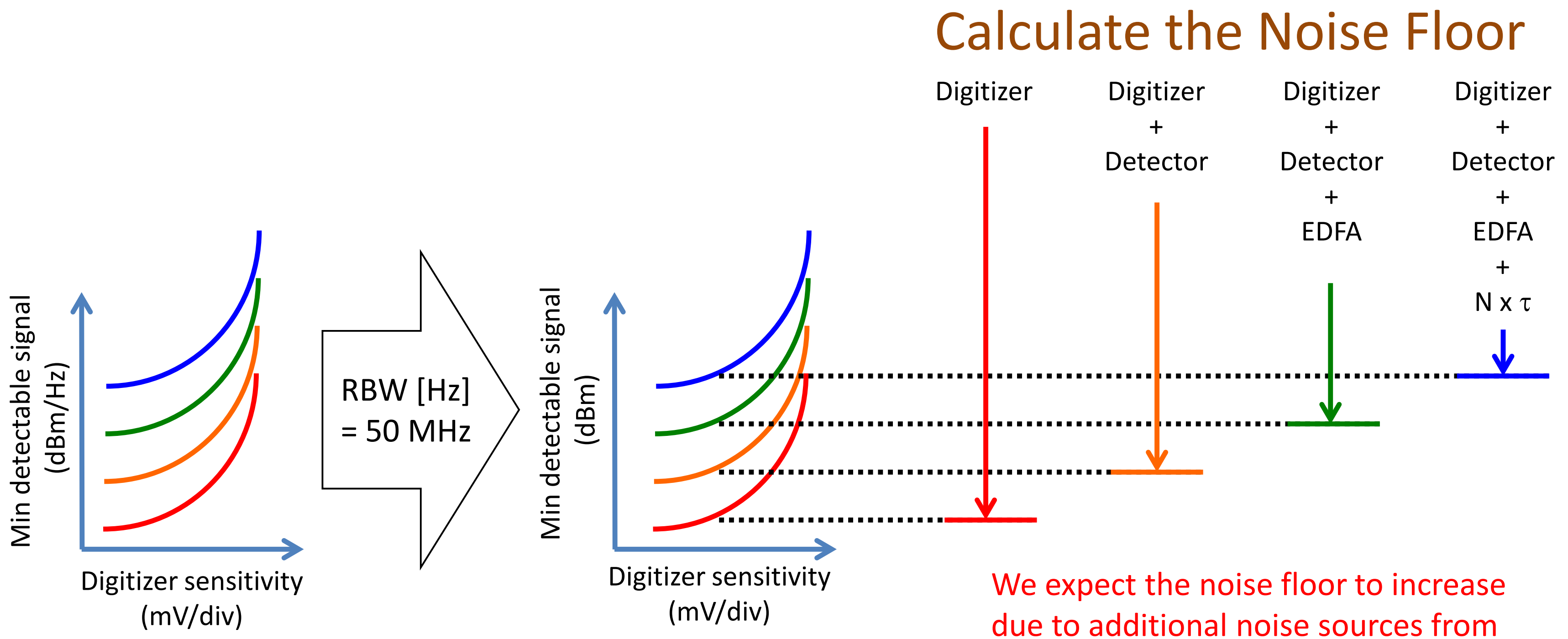


We expect the noise floor to increase due to additional noise sources from MPDV multiplexing; LocOsc – ASE noise will typically dominate.

PSD = Power Spectral Density (dBm/Hz)

Today let's look at *Sensitivity*: the Pmin APP

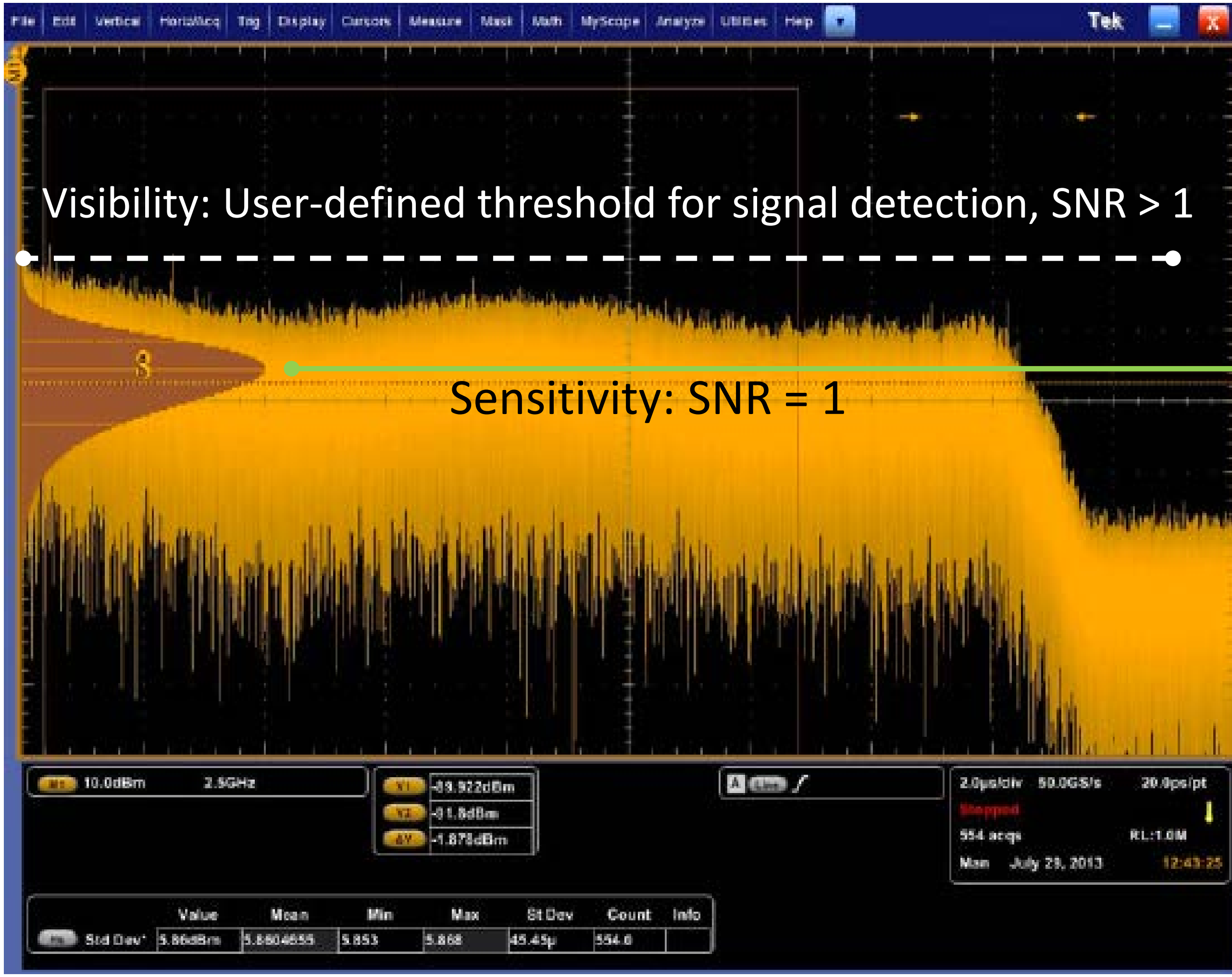
What is the minimum optical power (Pmin) necessary to detect a signal, that is SNR = 1 ?



We expect the noise floor to increase due to additional noise sources from MPDV multiplexing; LocOsc – ASE noise will typically dominate.

PSD = Power Spectral Density (dBm/Hz)

Let’s define Sensitivity and Visibility

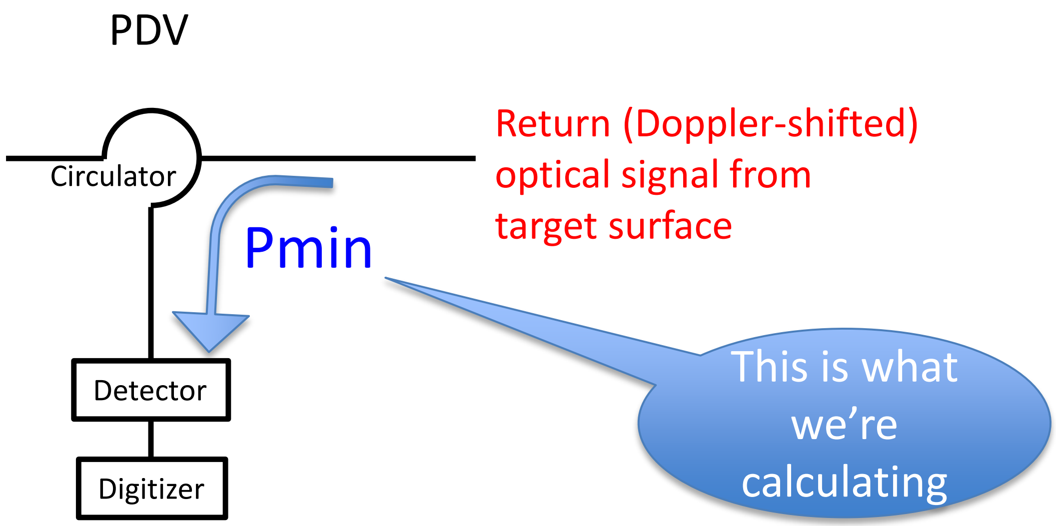


FFT Noise Floor

FFT Amplitude vs. Frequency

Inputs for Pmin APP

Pmin = minimum optical power reflected from the target surface (returning to the PDV/MPDV) necessary for SNR = 1. **THIS IS WHAT IS CALCULATED!**

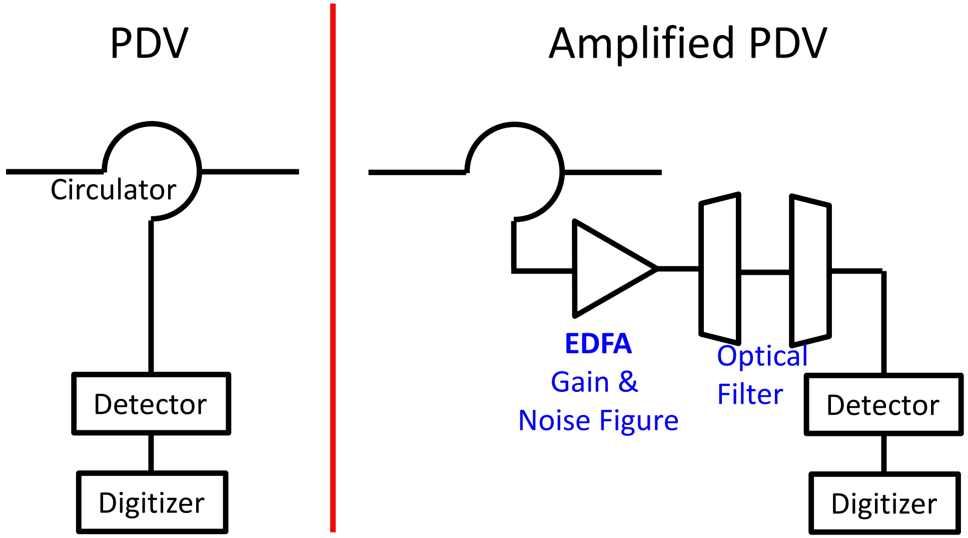


INPUTS

Detector & Digitizer: noise floor PSDs, range responsivity, bandwidths, and sample rate

Inputs for Pmin APP

CALCULATE: Pmin = minimum optical power for SNR = 1

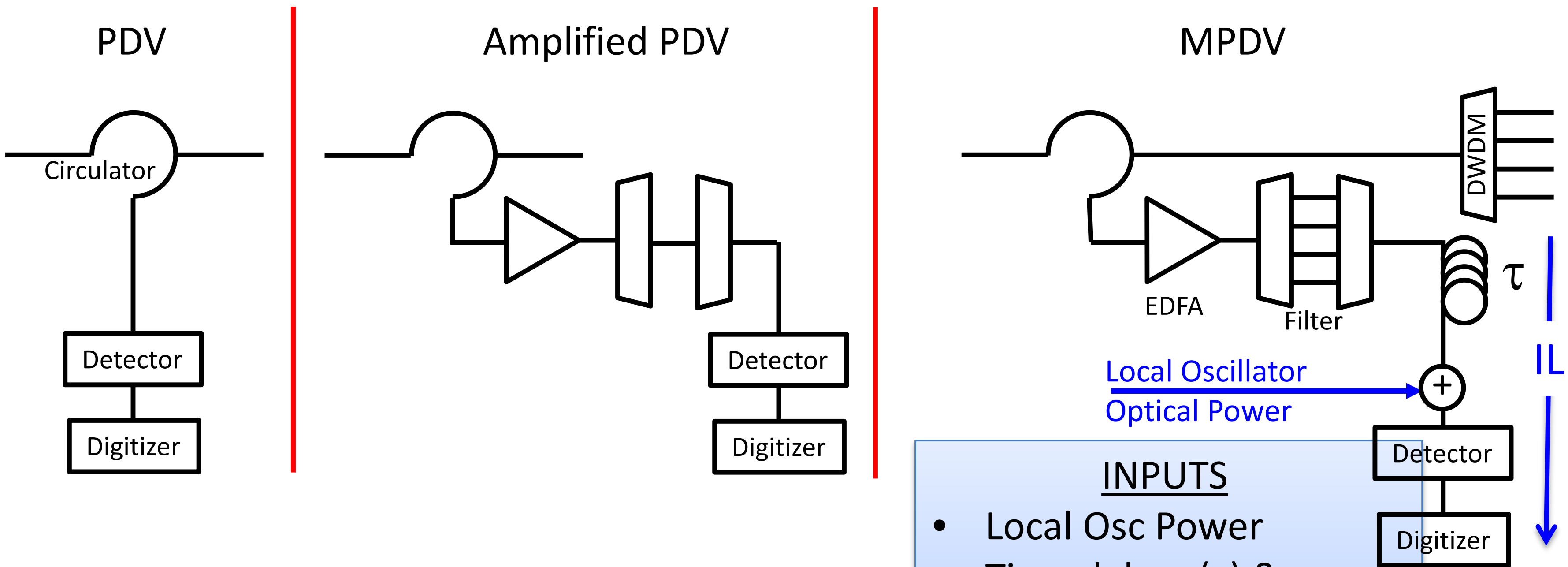


INPUTS

- EDFA: Gain & Noise Figure
- Optical Filtering: optical bandpass

Inputs for Pmin APP

CALCULATE: Pmin = minimum optical power for SNR = 1



<u>INPUTS</u>

- Local Osc Power
- Time delays (τ) & associate fiber optics: Insertion Losses (IL) following EDFA

What does the APP look like?

Pmin SHOT APP

Pmin Shot

Pmin = f(IL, Gain, PD Responsivity): Minimum Optical Power Necessary for SNR = 1.

variables: system insertion loss (following EDFA), EDFA gain, & Photo-diode Responsivity

OPTICAL SYSTEM INPUTS

Optical Signal Power,	Psig =	N/A	dBm
LocOsc Power (at PD)	P(LO) =	0.0	dBm
System Insertion Loss*	IL(Sig) =	3.0	dB
Bandwidth (optical filter),	B_o =	1.00E+11	Hz
EDFA Gain	G =	23.0	dB
EDFA Noise Figure	F =	4	dB
Fiber-optic combiner	ε(f/o) =	0.5	ratio

** Insertion Loss is after EDFA, Not including f/o combiner*

PHOTO-DIODE & DIGITIZER INPUTS

Scope Range, V(max) =	1.00	Volt Full Scale
Scope Sample Rate	50	(Gs/s)
P-D Responsivity, R =	1800	V/W
Photo-diode noise, PSD=	-125	(dBm/Hz)
Scope noise, PSD =	-135	(dBm/Hz)
Bandwidth (elec), B_e =	2.00E+10	Hz

ANALYSIS INPUT

N(FFT) =	1024	pts
RBW =	97.7	MHz

SENSITIVITY (SNR = 1)

PDV Pmin	MPDV Pmin	
2.09E-09	7.33E-11	W
-56.8	-71.4	dBm

Sensitivity == minimum optical signal necessary for SNR = 1 (mean of noise floor)

VISIBILITY (Min. Detectable Optical Signal)

	PDV Pmin	MPDV Pmin	
	-45.8	-60.4	dBm
Visibility Factor =		11	dB

User inputs for the optical system

User inputs for the photodetector, digitizer, and FFT analysis

User input visibility factor

Calculated values for sensitivity & visibility

What does the APP look like?

Pmin DESIGN APP

Pmin Design

Feb - April 2016

E.D.

Pmin = f(IL, Gain, PD Responsivity): Minimum Optical Power Necessary for SNR = 1.

variables: system insertion loss (following EDFA), EDFA gain, & Photo-diode Responsivity

OPTICAL SYSTEM INPUTS			
Optical Signal Power,	Psig =	N/A	dBm
LocOsc Power (at PD)	P(LO) =	0.0	dBm
System Insertion Loss*	IL(Sig) =	20.0	dB
Bandwidth (optical filter),	B_o =	1.00E+11	Hz
EDFA Gain	G =	30.0	dB
EDFA Noise Figure	F =	4.5	dB
Fiber-optic combiner	ε(f/o) =	0.5	ratio

** Insertion Loss is after EDFA, Not including f/o combiner*

Calculation approximation: Strong Local Oscillator P(LocOsc) >> P(signal)

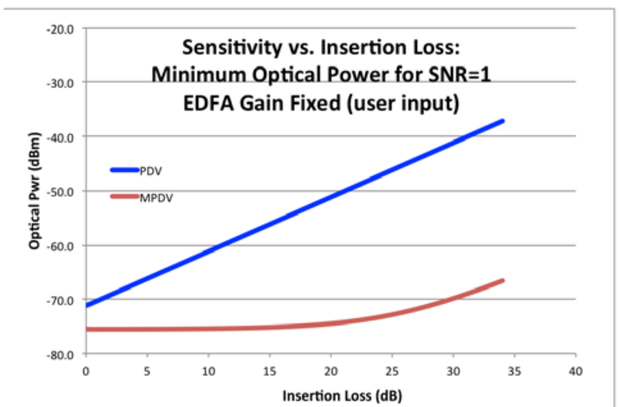
PHOTO-DIODE & DIGITIZER INPUTS		
Scope Range, V(max) =	1.00	Volt Full Scale
Scope Sample Rate	20	(Gs/s)
P-D Responsivity, R =	1800	V/W
Photo-diode noise, PSD=	-135	(dBm/Hz)
Scope noise, PSD =	-135	(dBm/Hz)
Bandwidth (elec), B_e =	2.00E+10	Hz

ANALYSIS INPUT		
N(FFT) =	1024	pts
RBW =	39.1	MHz

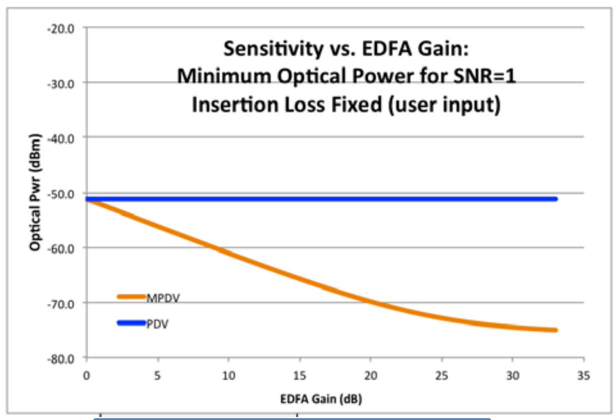
SENSITIVITY (SNR = 1)		
PDV	MPDV	
Pmin	Pmin	
7.63E-09	3.58E-11	W
-51.2	-74.5	dBm

Sensitivity == minimum optical signal necessary for SNR = 1 (mean of noise floor)

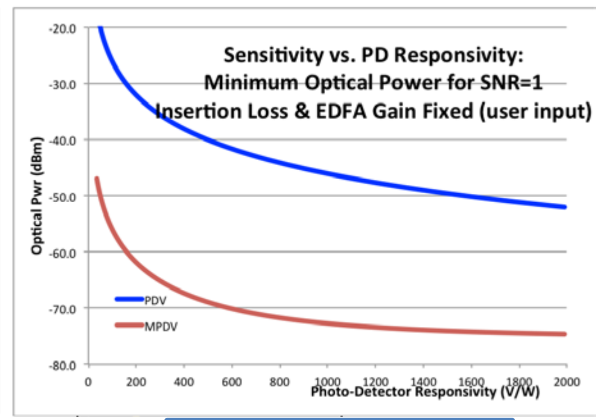
VISIBILITY (Min. Detectable Optical Signal)		
PDV	MPDV	
Pmin	Pmin	
-40.2	-63.5	dBm
Visibility Factor =	11	dB



Pmin vs. IL



Pmin vs. Gain



Pmin vs. PD

Let’s try it (time permitting)… Audience interactive session