Free-Space Laser Communication and Atmospheric Propagation XXVIII
SPIE Photonics West 2016

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Novel photon-counting detectors for free-space communication

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AGENDA

I. NASA applications/requirements

II. Silicon Geiger-mode avalanche photodiode array

III. Mercury Cadmium Telluride (HgCdTe) linear-mode avalanche photodiode array

IV. Summary

NASA Goals for Near-Earth Free-Space Communication

Photon-counting wavelengths	Favor 1550 nm, exploring 850 nm
Detection efficiency:	> 10%
Detector size:	> 200 μm diameter
2-D arrays	Act as single detector w/high speed output
Dark counts:	< 100 kcps
Maximum Count Rate:	>1 Gbps (through multiplexing)
Electrical bandwidth:	>1 GHz
Linearity:	> 98% fit
Timing jitter:	< 100 ps
Afterpulsing	< 1% in 1 μs
Operating temperature:	prefer thermo-electric cooler range
Space-qualifiable:	rad-hard, reliable, overlight protection

Sensl Silicon APD Array

Detector: Sensl MicroFM-SMA-10020
Lot # 131218

Active Area: 1mm x 1mm
# of Cells: 1144
Fill Factor: 48%

Biased at -32V unless noted otherwise

NOTE: New “Red” version available with higher near-IR QE. NOT used in these tests.

Commercial transmitter 850 nm VCSEL (4 x 28G)

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FINISAR

Optical Transceivers

100GBASE-SR4 and OT

FTLC9141SENM

Distance:	100 m
Data Rate (max):	112 Gb/s
Protocol:	OTN OTU4 Compliant, 100G Ethernet Compliant
Low End Case Temperature (°C):	-5
High End Case Temperature (°C):	75
Diagnostics:	Digital
Transmitter:	4x VCSEL Array
Receiver:	PIN
Voltage Supply:	3.3
Connector:	MPO (MTP12)
Wavelength:	850nm Band

We used 10G version in this work.

Detected photon number discrimination

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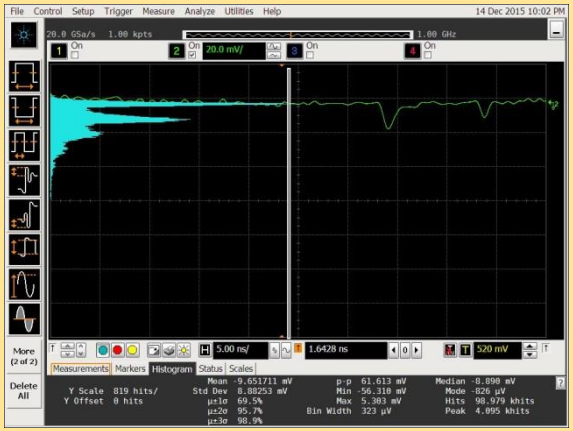
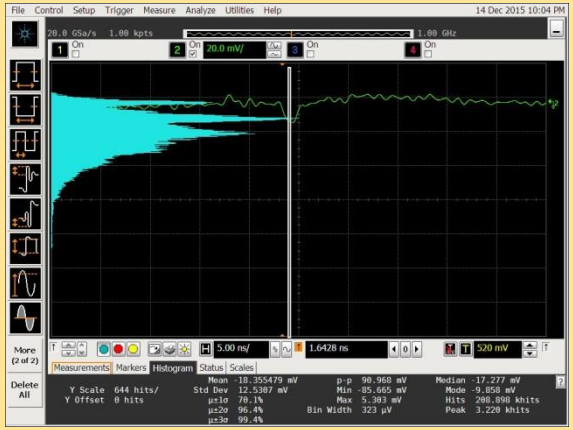
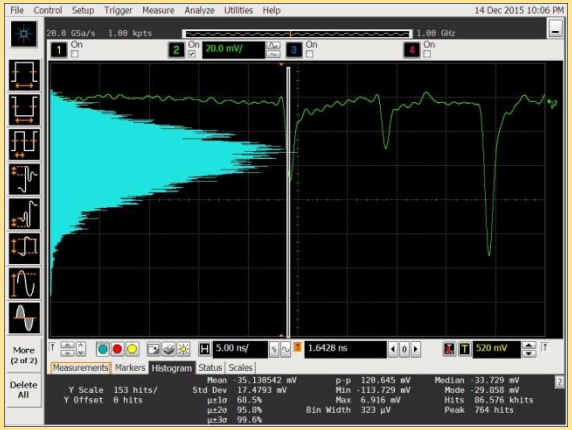


$\lambda = 0.8$

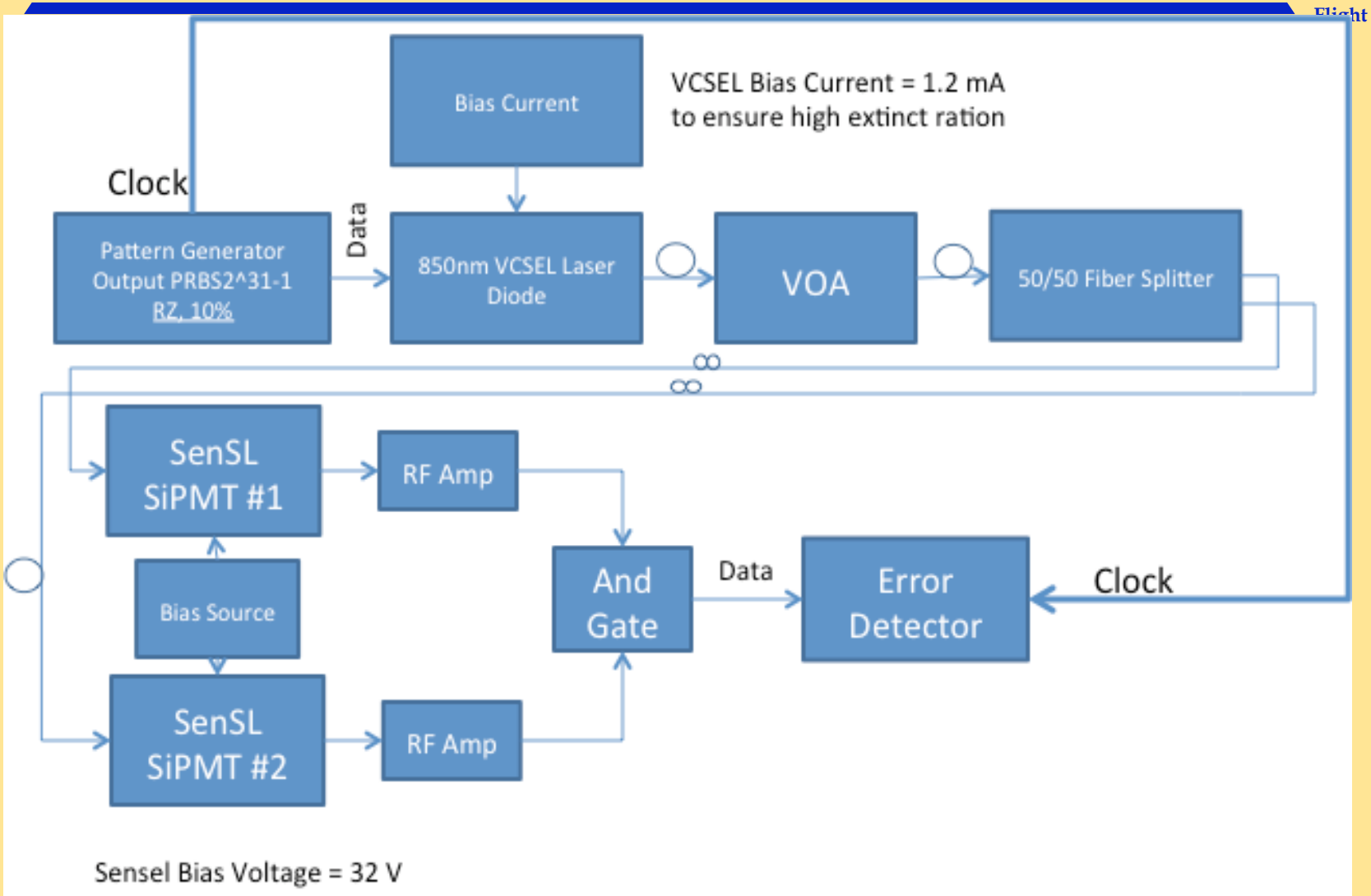


$\lambda = 1.7$



$\lambda = 3.2$

Free-space optical communication bench test diagram for the Sensl APD arrays using coincidence detection.



Sensl APD array
Communication performance (@850 nm)

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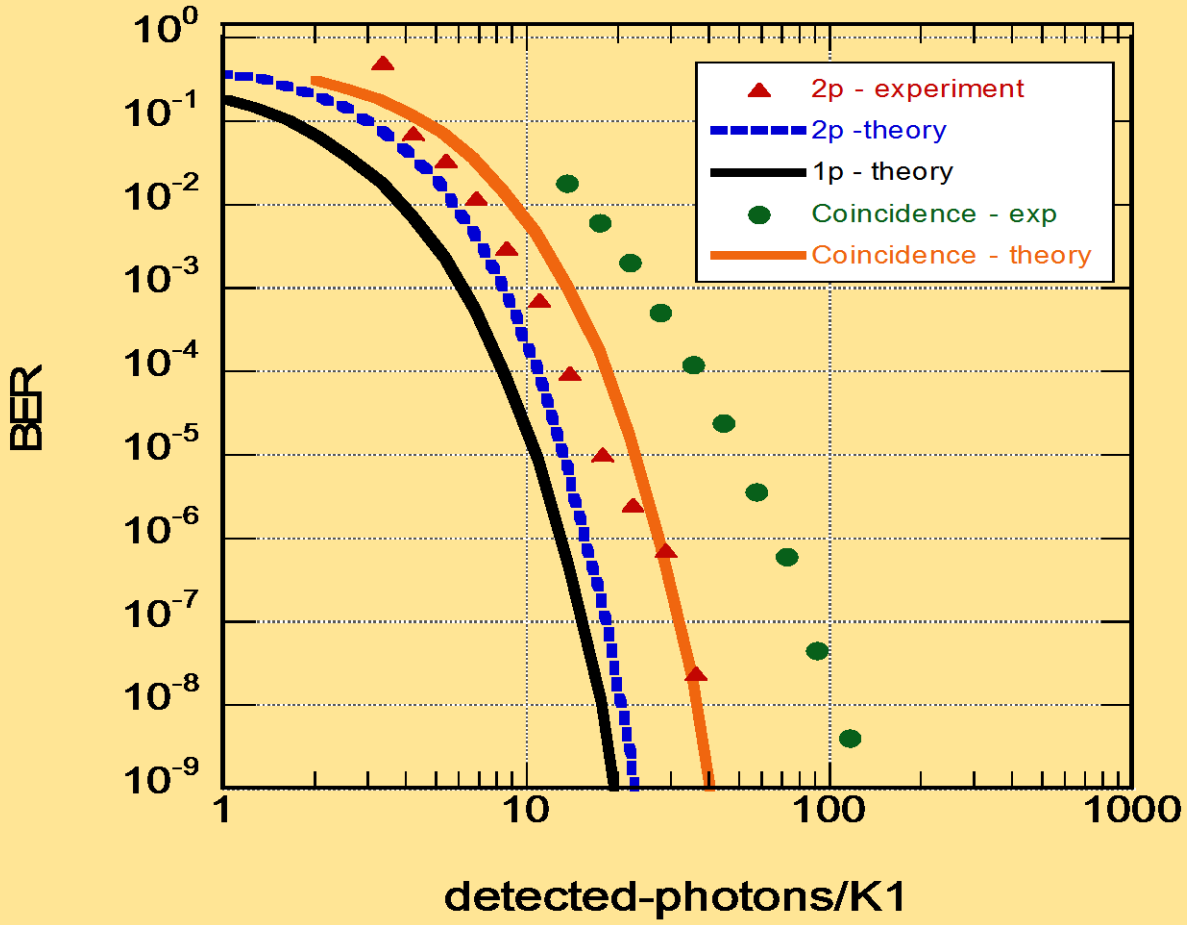

RZ-OOK 100 Mbps data rate with PRBS=2^31-1

Sensl APD array
Communication performance
with coincidence detection at various rates

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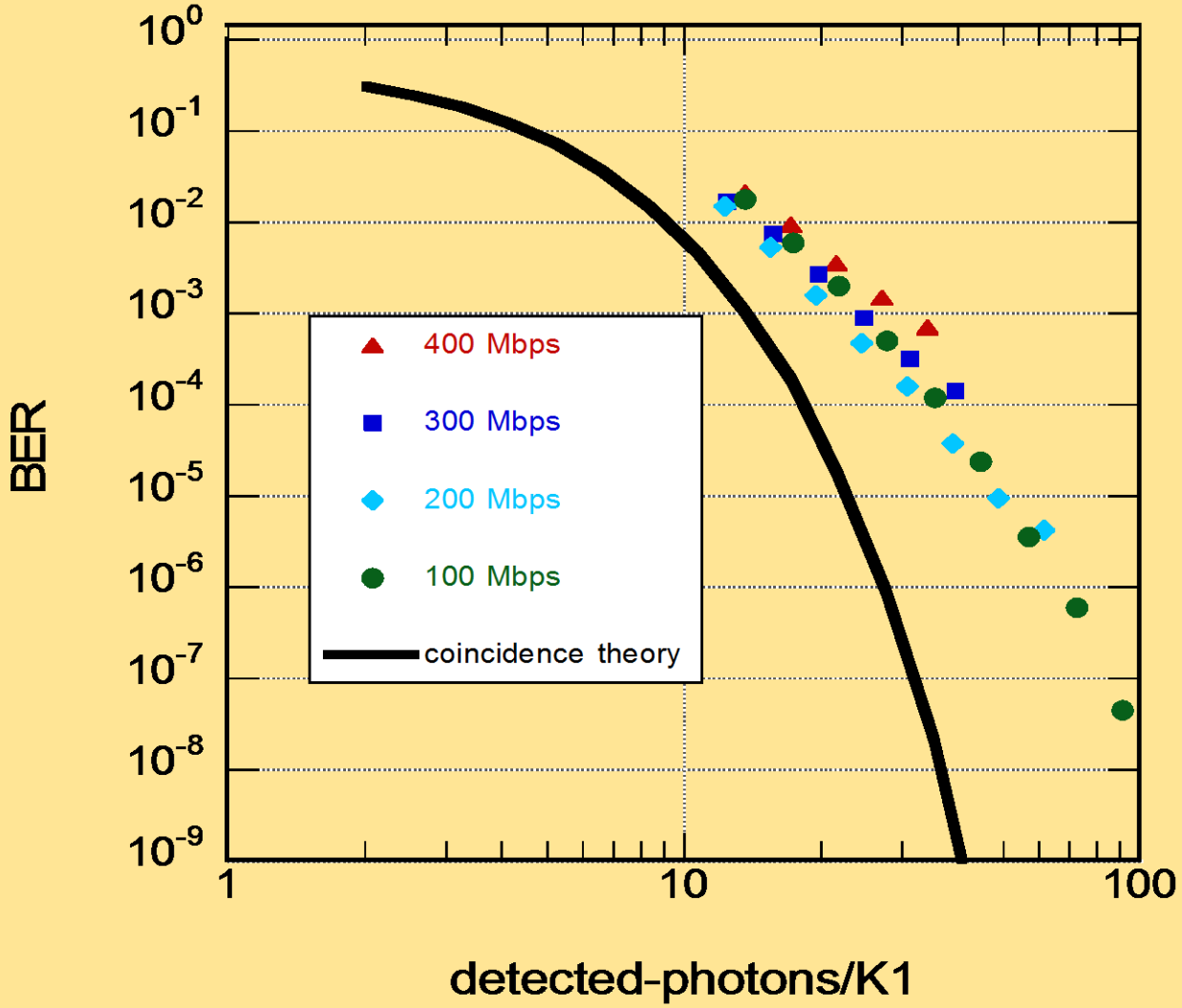
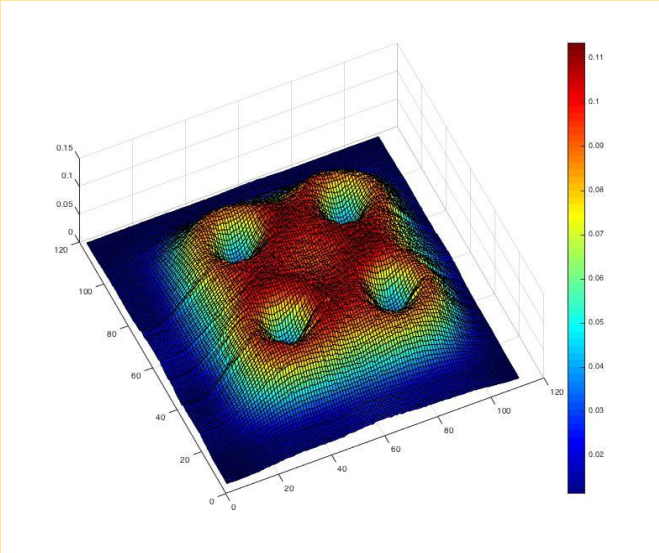
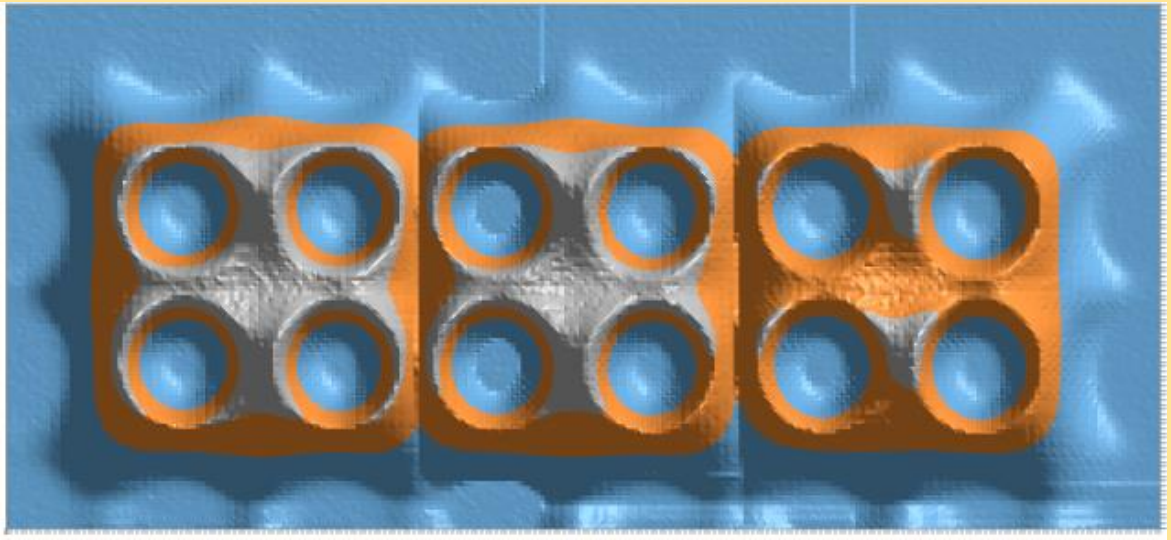


DRS Inc. HgCdTe APD





single pixel
consisting of
4 mesas with 11 V

3 pixels

DRS HgCdTe APD
Intensity Pulse Height Distribution

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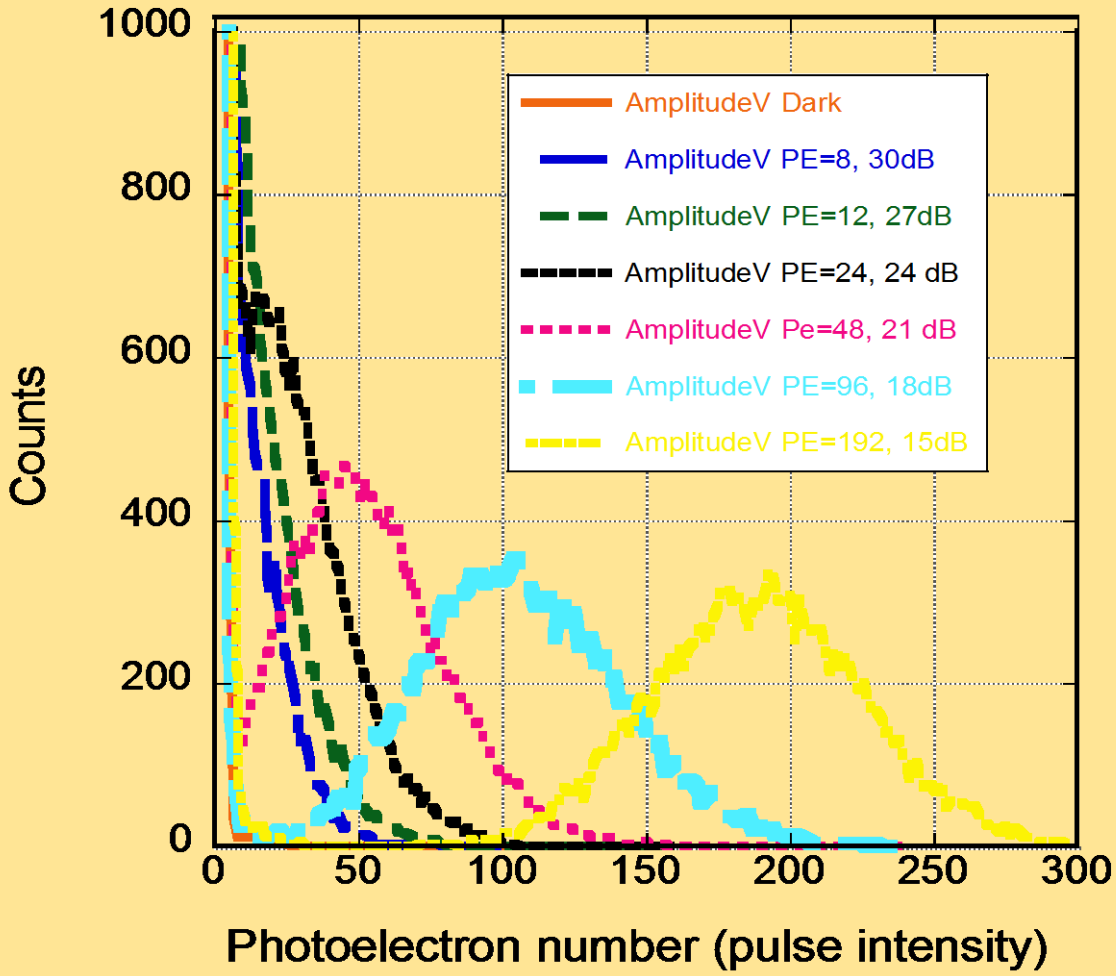

Communication performance (@1550 nm) test with DRS HgCdTe APD receiver

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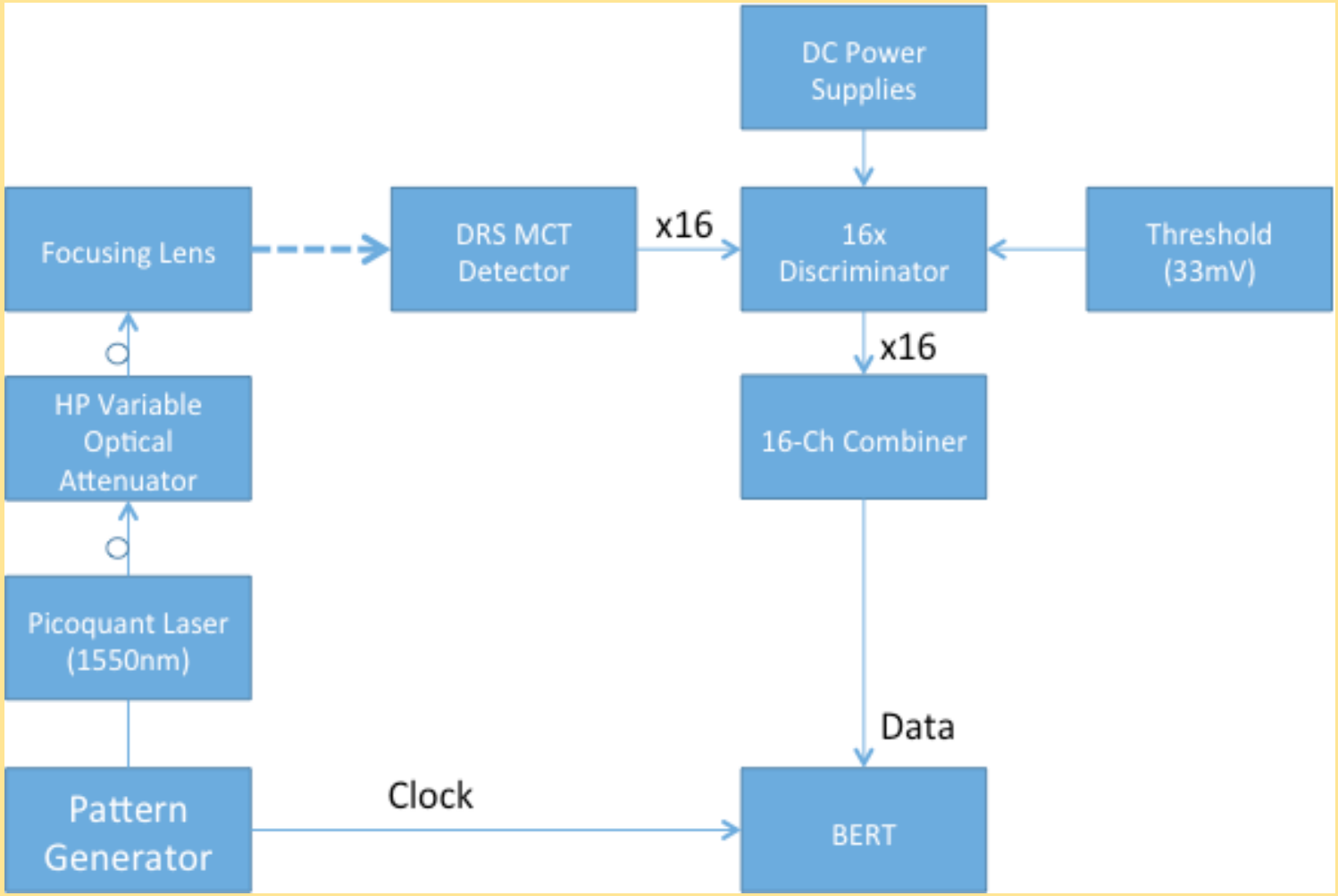
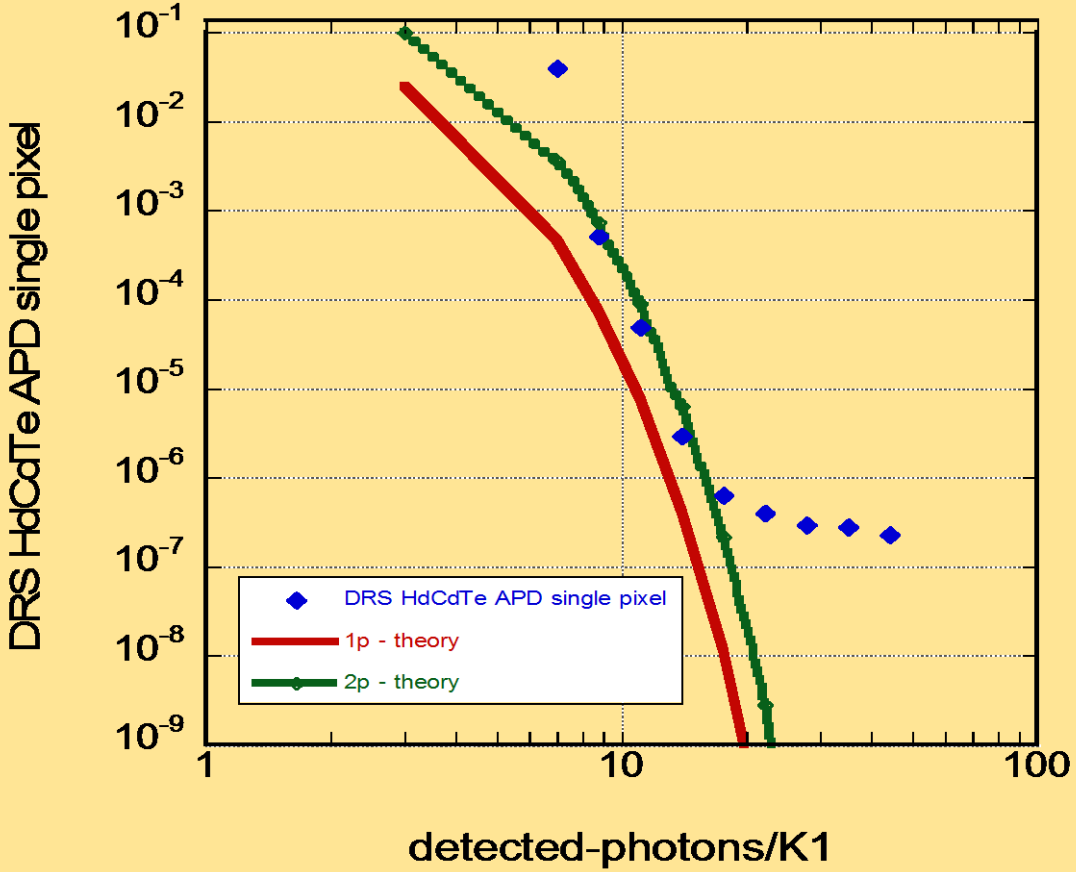


DRS HgCdTe APD experimental BER data from a single pixel



RZ-OOK 50 Mbps data rate with PRBS=2^31-1

SUMMARY

I. Demonstrated photon-counting communication using three ideas:

1) use an array of photon-counting elements wired together as a single detector

2) use a high pass filter, ideally on each array element (or on the array output to only preserve the information-bearing portion of the waveform)*

3) depending on the photon-counting element excess noise, use either a "two-photon" intensity threshold level or an AND-gate with coincidence detection.

* Pavlov, N. "Silicon Photomultiplier and Readout Method" USPTO Patent Application Publication, No. US2013/0099100 A1 (2013).

II. Commercial components

Commercial 850 nm VCSEL transmitters and silicon APD Geiger-mode arrays provide a viable path to low-cost high-rate (500 Mbps) free-space optical communication links.

III. HgCdTe APD

Demonstrated excellent communication performance at 50 Mbps @1550 nm with single-pixel HgCdTe APD.

IV. Future

>1 Gbps with single array (in InGaAs) and multi-Gbps with WDM should be viable.