High Sensitivity AlGaAsSb Avalanche Photodiodes for 1550 nm Long Range Optical Communication

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phluxtechnology.com


PHLUX

About Phlux

- Est in 2020 by Prof Chee Hing Tan, Prof. Jo Shien Ng and Ben White
- Based in Sheffield, UK
- World leading infrared sensors for imaging and communication systems.
- £4M Seed round in 2022 from major UK VCs.

1550 nm Detection

- The detector (avalanche photodiode) is a key part of optical systems.

✓ 1550 nm is eye safe or easy transmission.

✓ 1550 nm laser technology is very mature

✗ Commercially available APDs are too noisy

Automotive

Gas Sensing

Telecom

Surveying

Quantum Tech

Fibre sensing

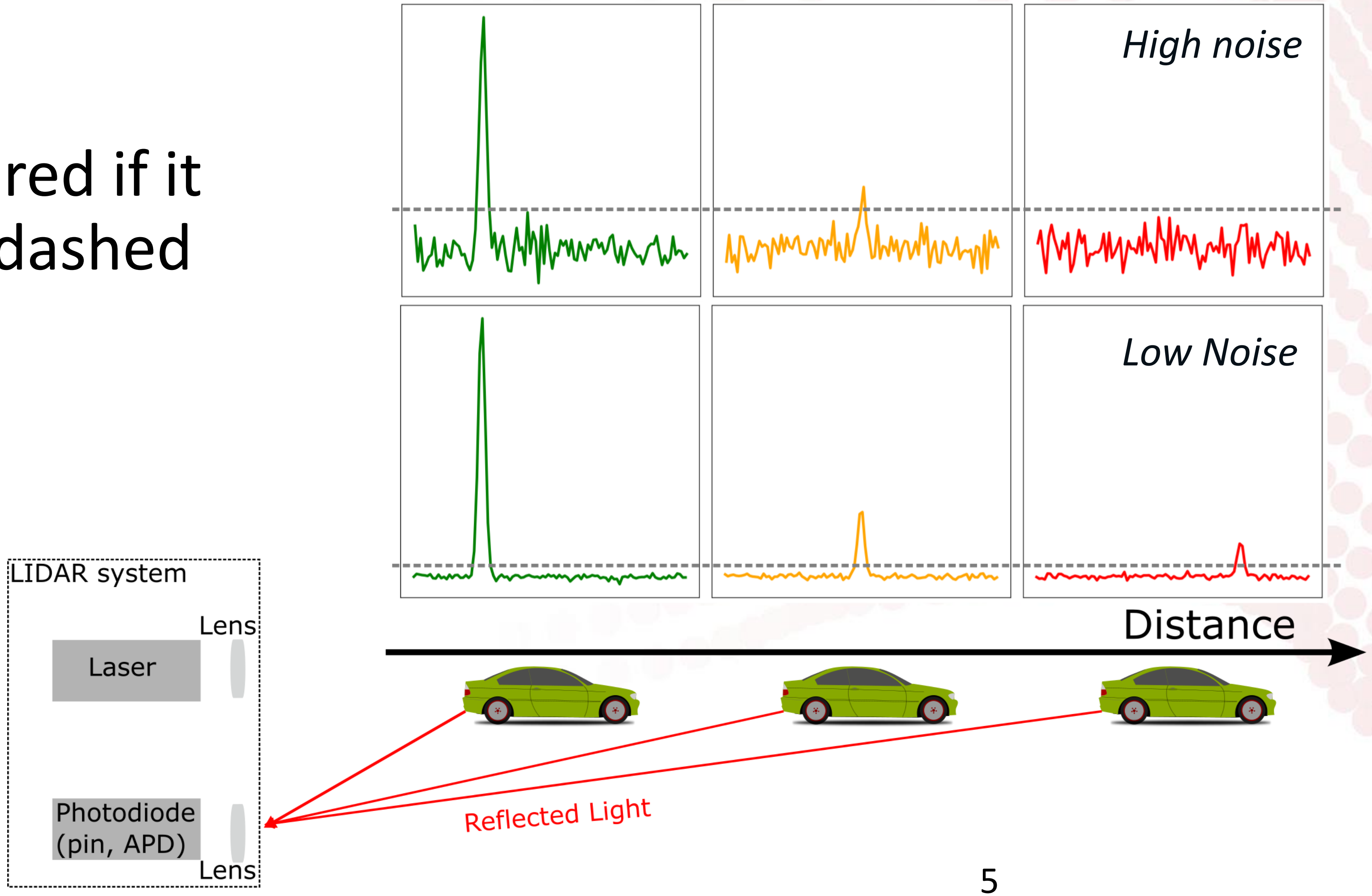
Defence

Free Space Comms

Noise Limitations

- The signal is measured if it reaches above the dashed line.

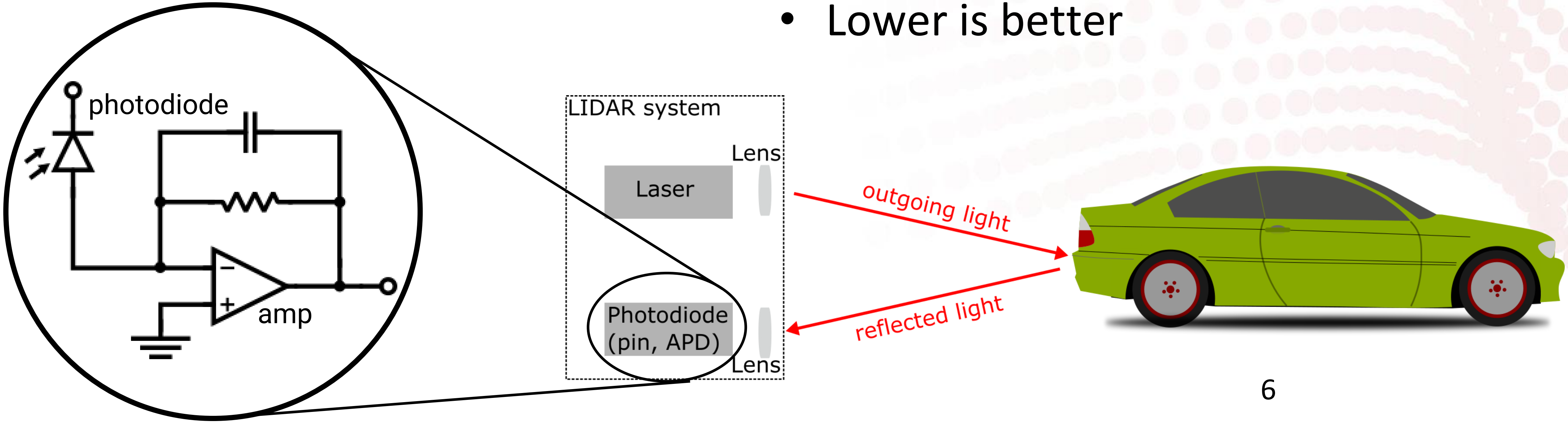
- High noise detector cannot detect the furthest away car.



Noise Equivalent Power

- $\frac{1}{R_{M=1}}\left(\sqrt{2qI_{M=1}F(M) + {n_{amp}^2}/{M^2}}\right)$

- Lowest optical power measurable at a certain operating bandwidth
- Units W/√Hz
- Power_{min}= NEP x √BW
- Lower is better



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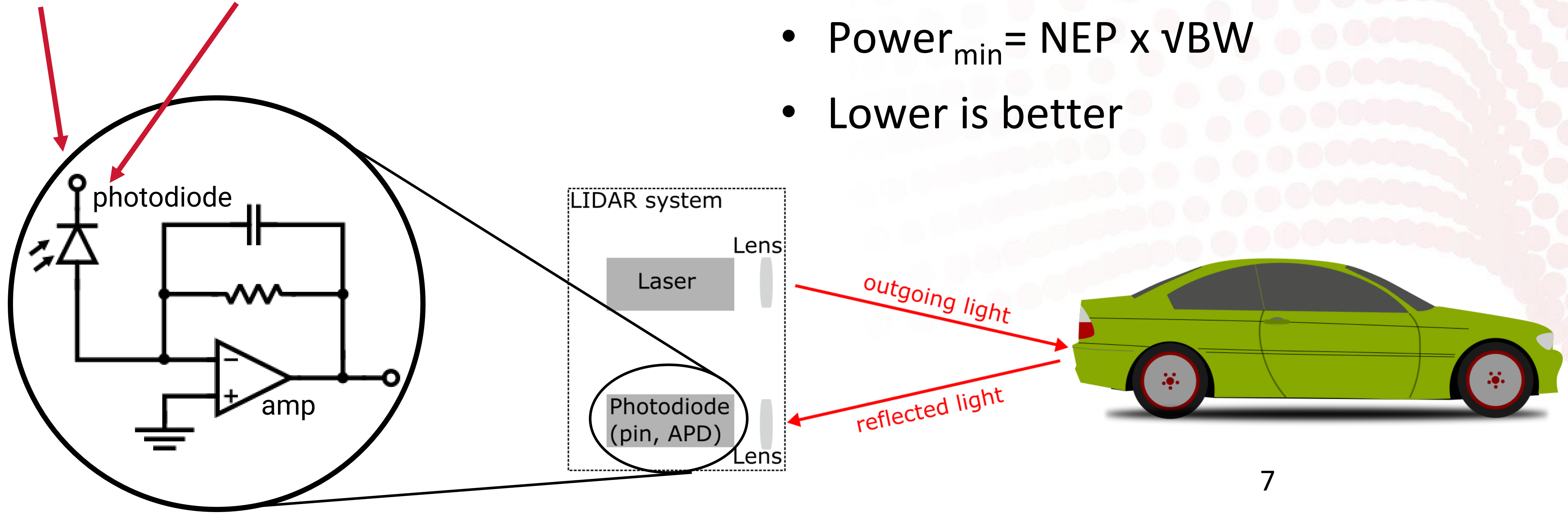

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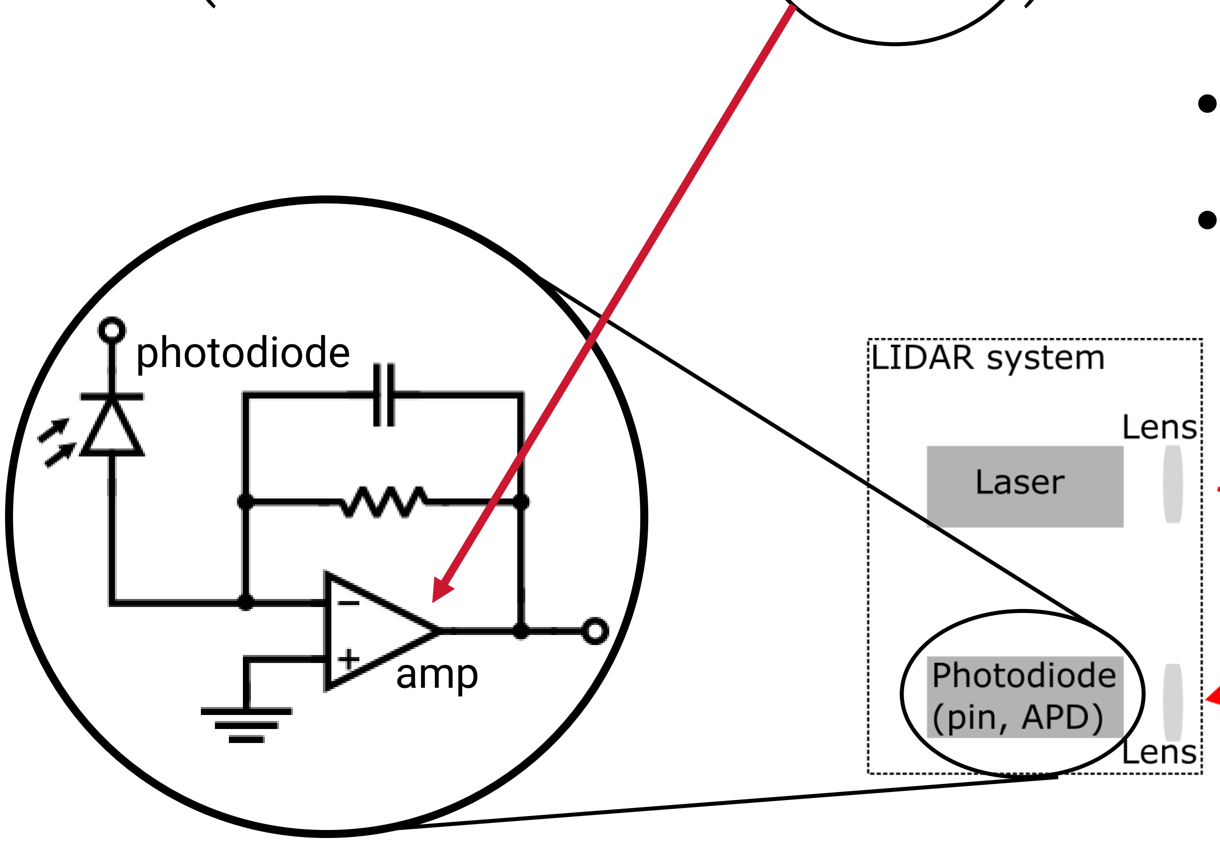

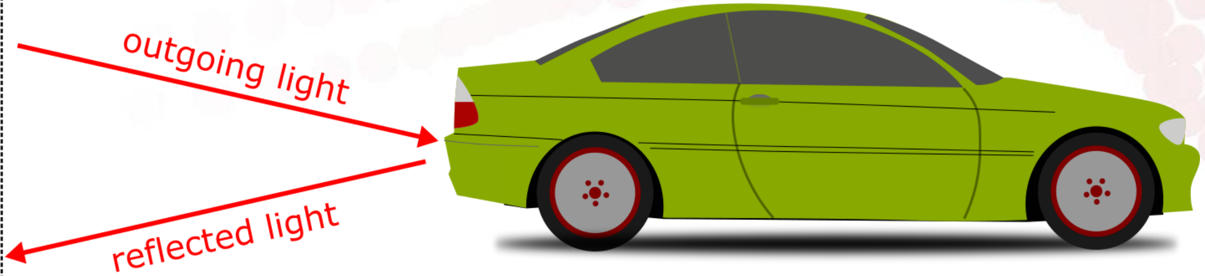

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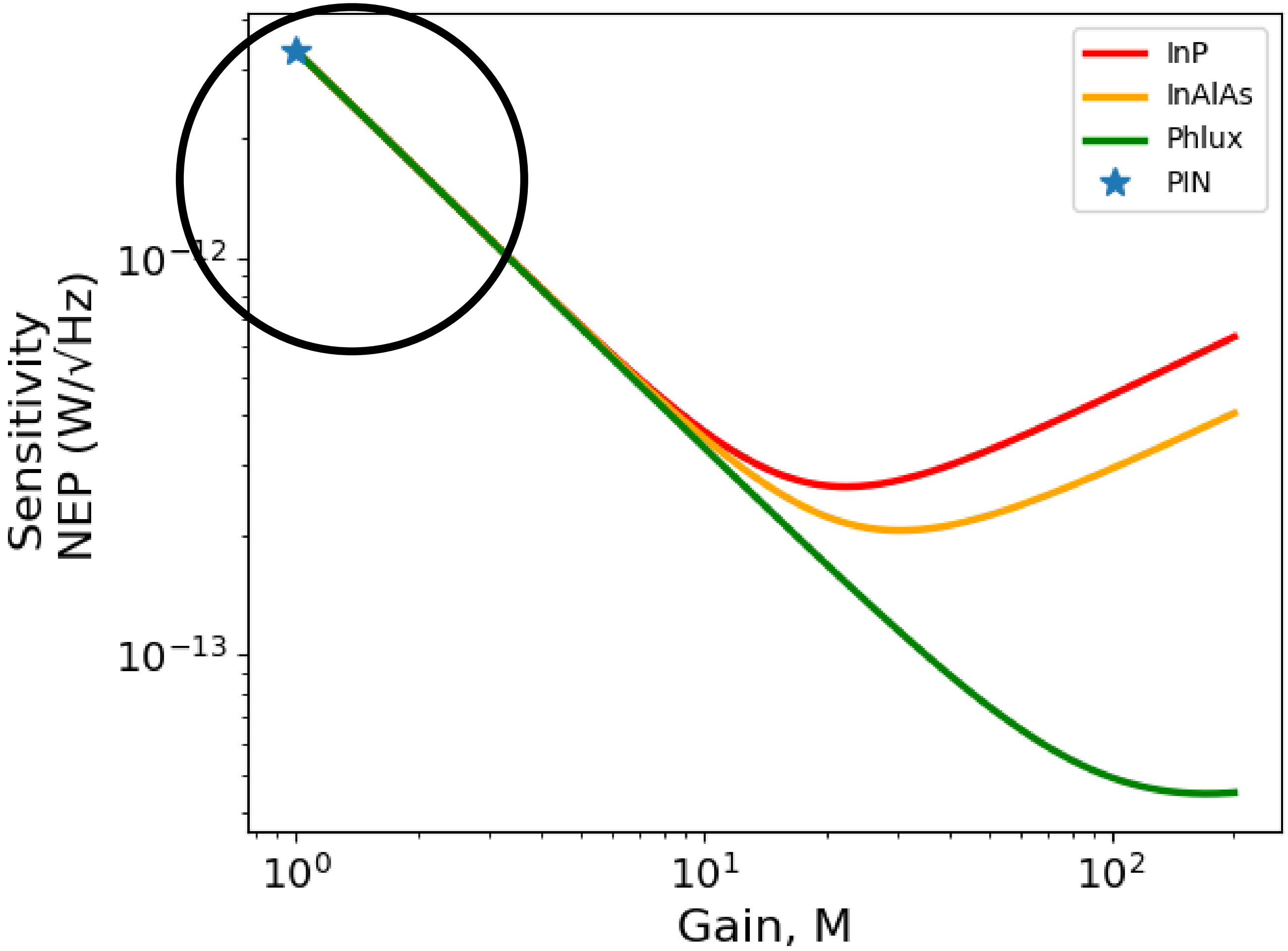
NEP vs Gain

- 1<M<10
- NEP dominated by amplifier.
- Increasing M improves the sensitivity

- $$\frac{1}{R_{M=1}}\left(\sqrt{2qI_{M=1}F(M)+{n_{amp}^2}/{M^2}}\right)$$



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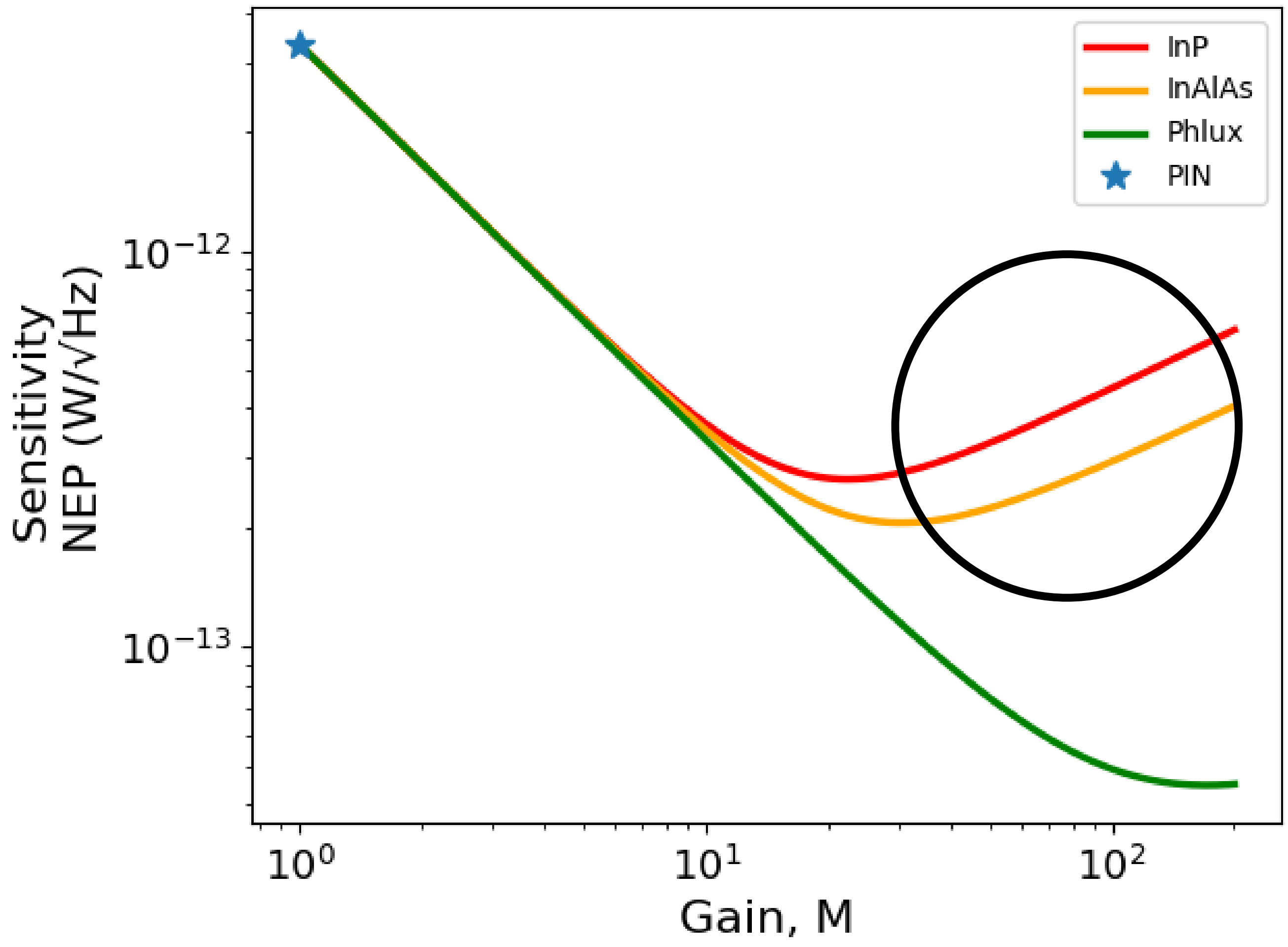
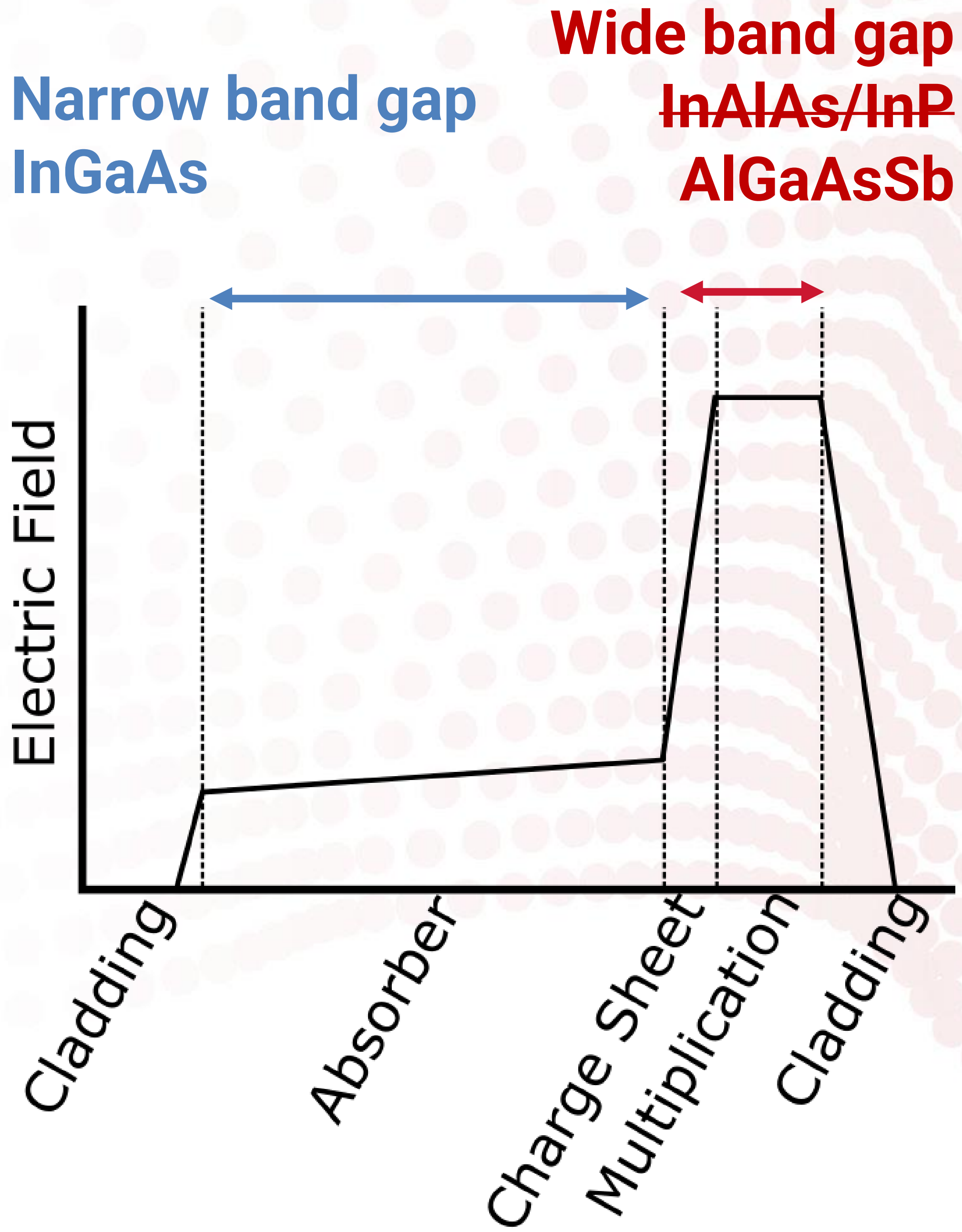


- M > 10
- F(M) is too high and APD noise dominates in InP and InAlAs

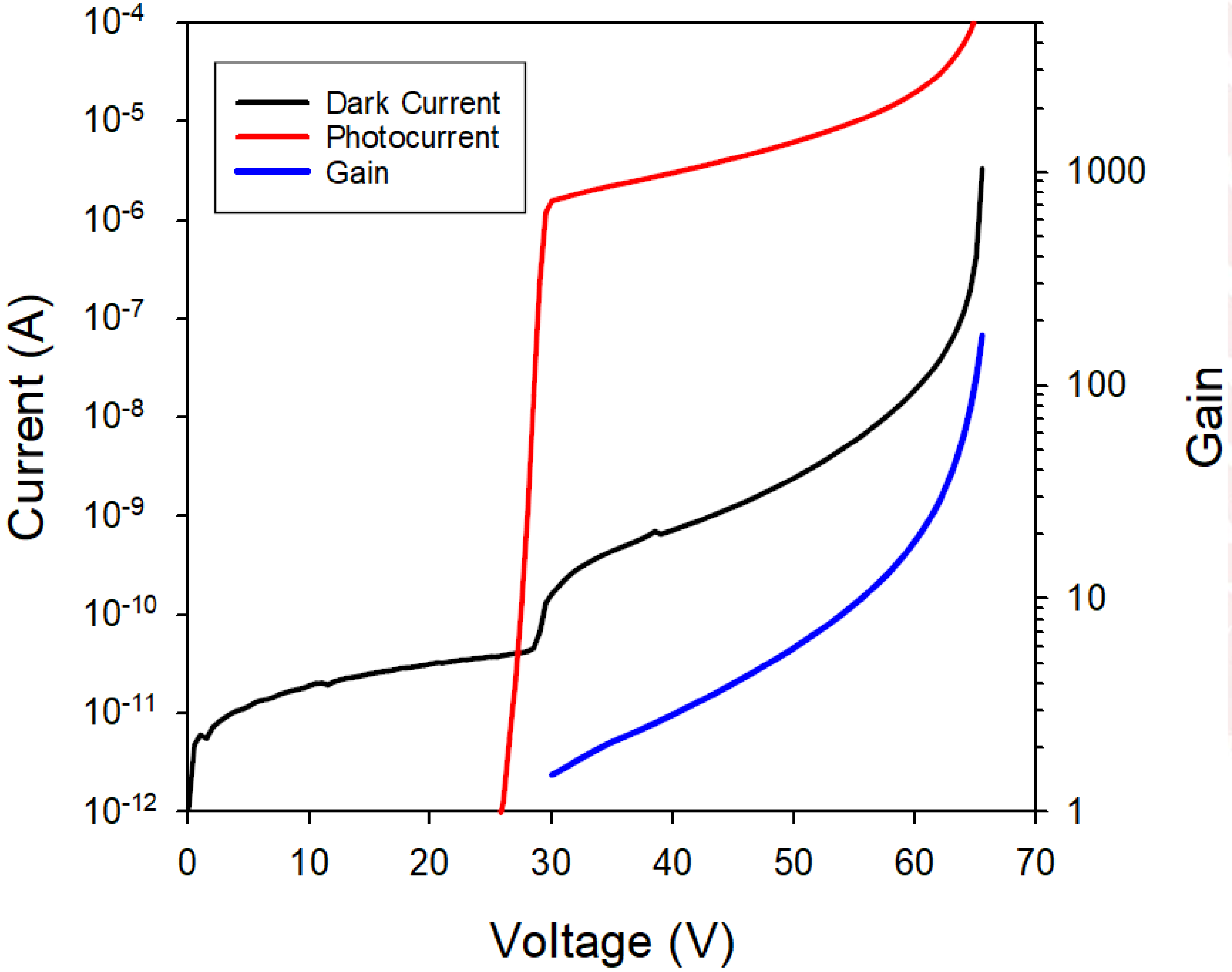
APD Structure

- No change to absorber or substrate.
- Change multiplication layer from InAlAs or InP to **AlGaAsSb**
  - Low excess noise factor
  - Low tunnelling (wide indirect band gap, 1.5 eV)
  - Temperature insensitive breakdown



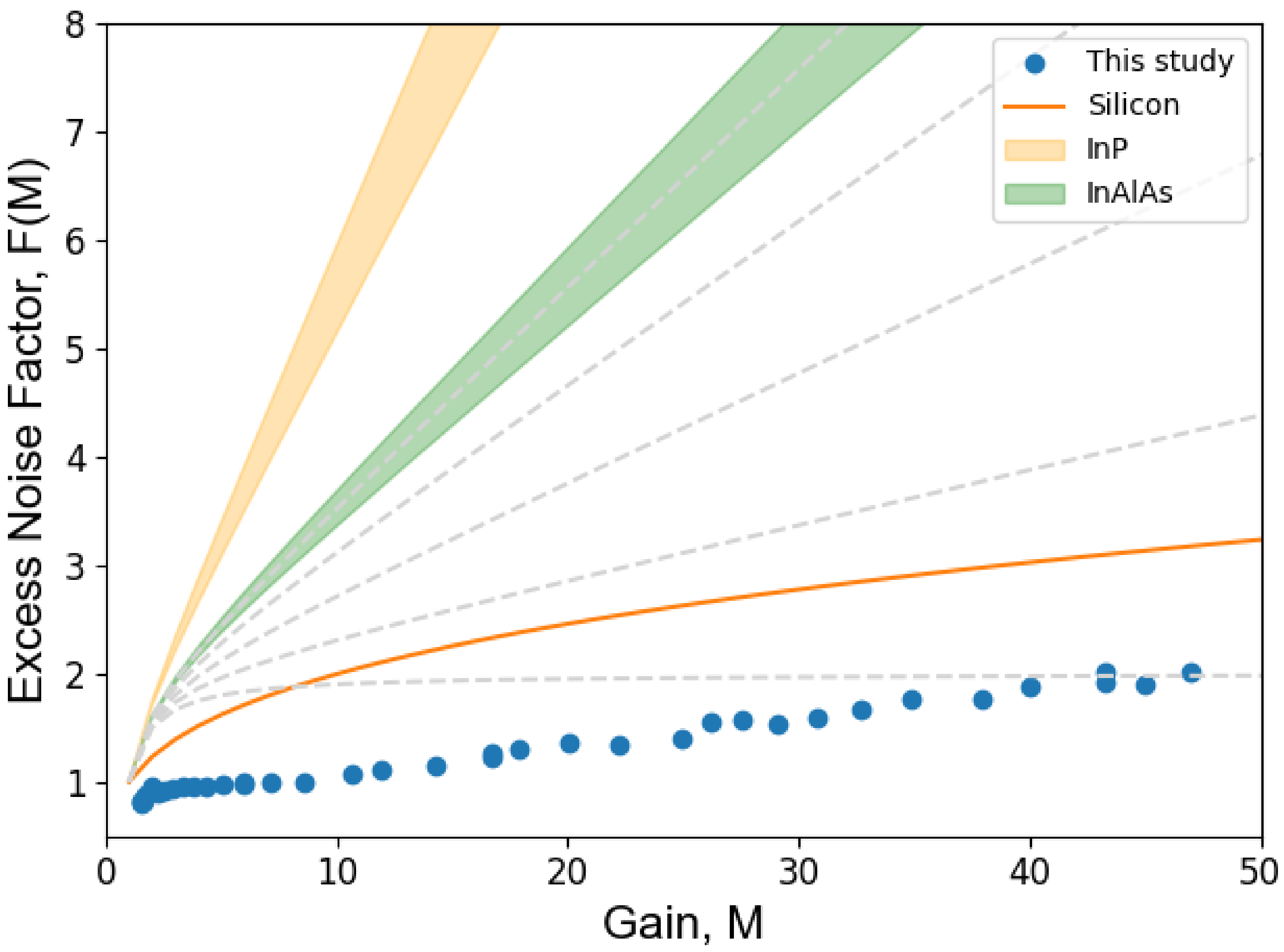
Wafer Characterisation

- Devices fabricated for wafer testing.
- Breakdown: 68V
- Punchthrough: 30V



Extremely Low Excess Noise

- Much lower than InP or InAlAs
- Comparable to Si



Device Performance

$$\frac{1}{R_{M=1}}\left(\sqrt{2qI_{M=1}F(M)+{n_{amp}^2}\big/{M^2}}\right)$$

APD (200 µm)	Responsivity M=1, (A/W)	Dark Current M=10, (A)	Excess noise M=10	Capacitance (pF)
Phlux	**0.97**	**7.0**	**1.0**	**2.8**
Laser Components	0.94	25	3.2	1.7
Hamamatsu	0.9	150*	5*	1.5
Excelitas	0.93	45	-	2.5

*Stated at 0.9*V_{br} rather than M=10

Device Performance

$$\frac{1}{R_{M=1}}\left(\sqrt{2qI_{M=1}F(M)+\frac{n_{amp}^{2}}{M^{2}}}\right)$$

- Slight improvement on responsivity

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$$\frac{1}{R_{M=1}}\left(\sqrt{2qI_{M=1}F(M)+{n_{amp}^{2}}/{M^{2}}}\right)$$

- **Major improvement on dark current**
- **Major improvement on excess noise**

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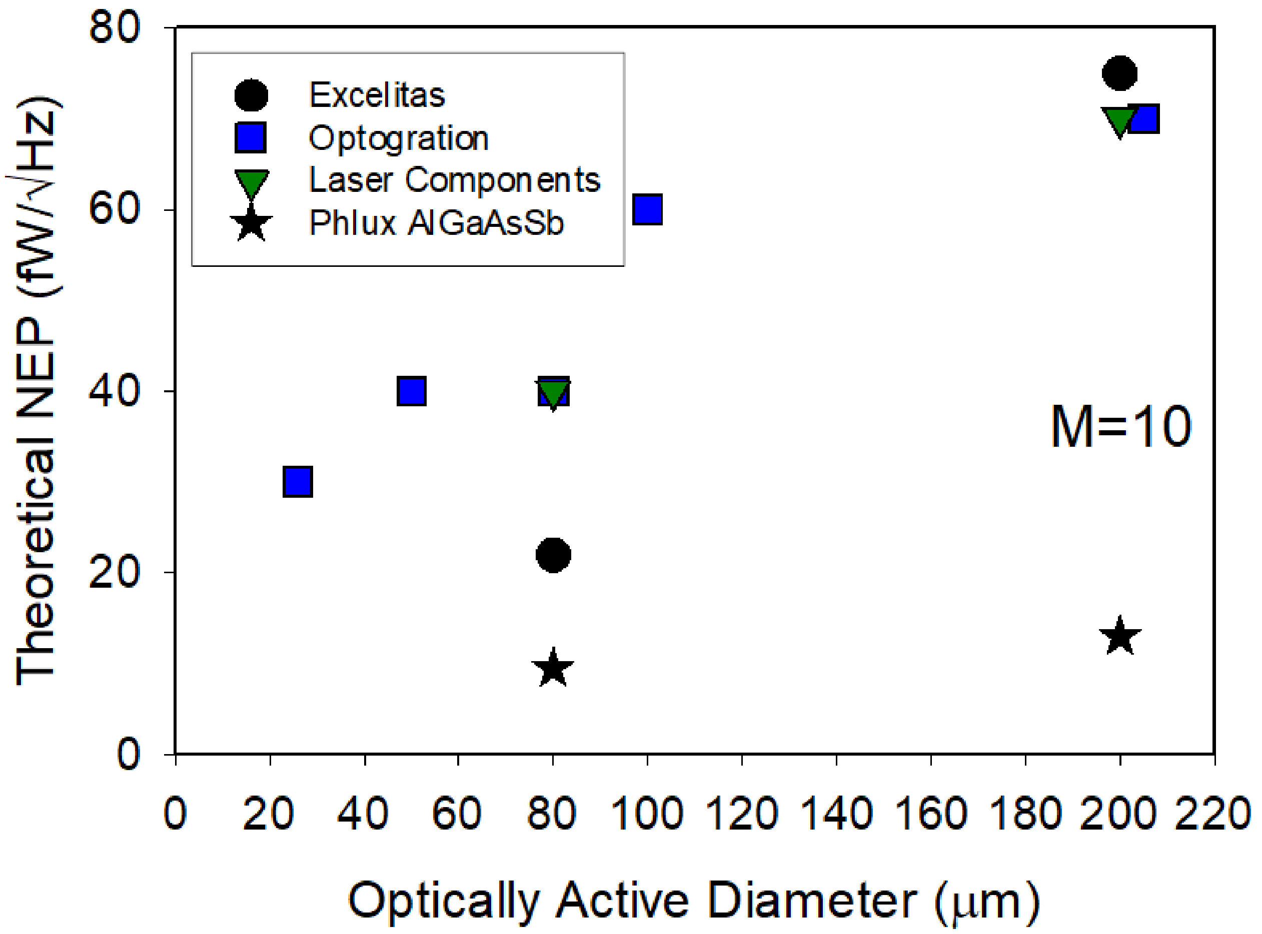
Calculated NEP

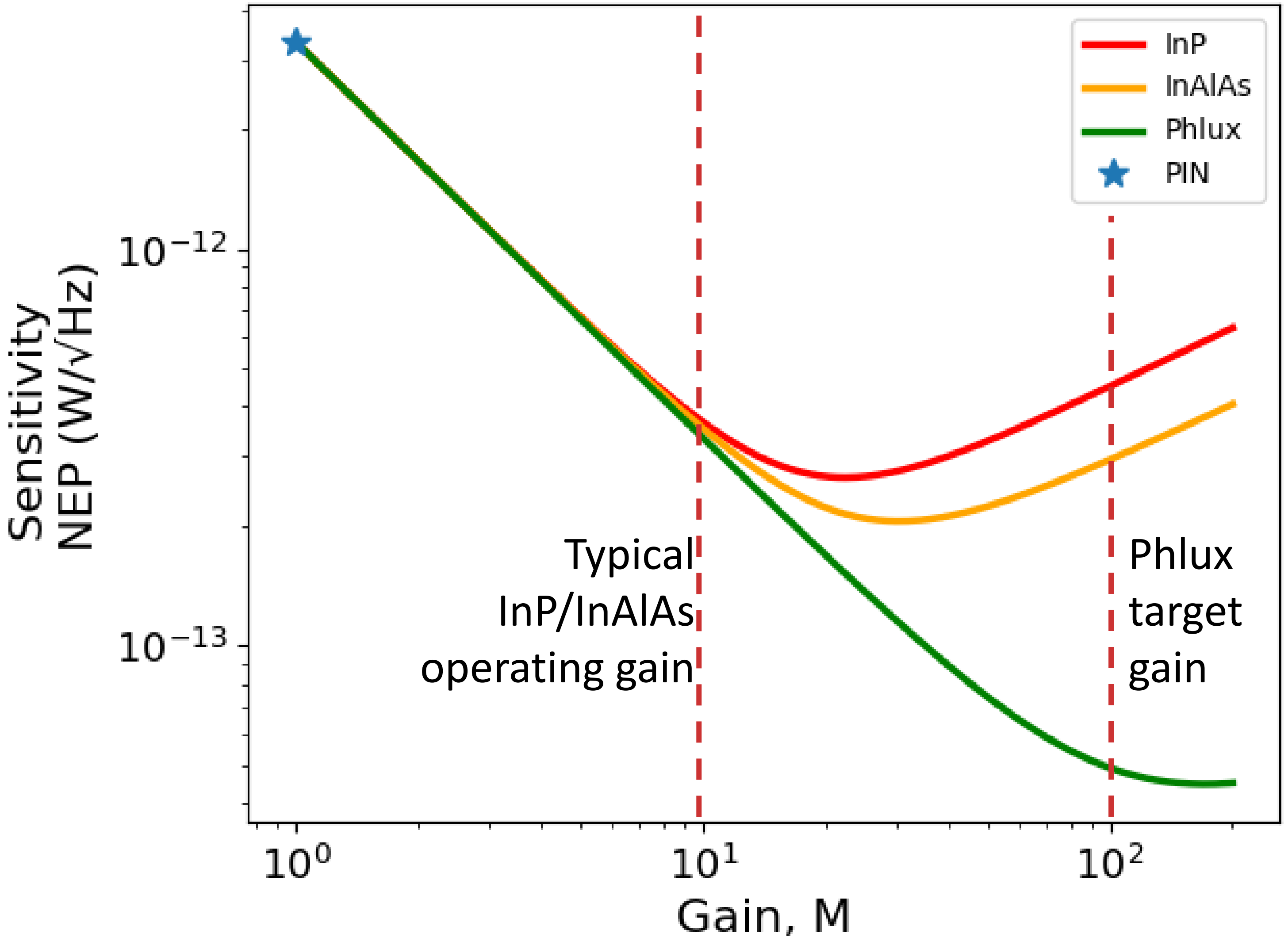
- Effect of the external amp removed.
- $NEP = \frac{1}{R_{M=1}}\sqrt{2qI_{M=1}F(M)}$
- Phlux APDs have a lower NEP than currently available APDs.

NEP (fW/√Hz)	Optically Active Window: 80 µm	200 µm
Phlux	**9.5**	**13**
Laser Components	40	70
Optogration	40	70
Excelitas	22	75



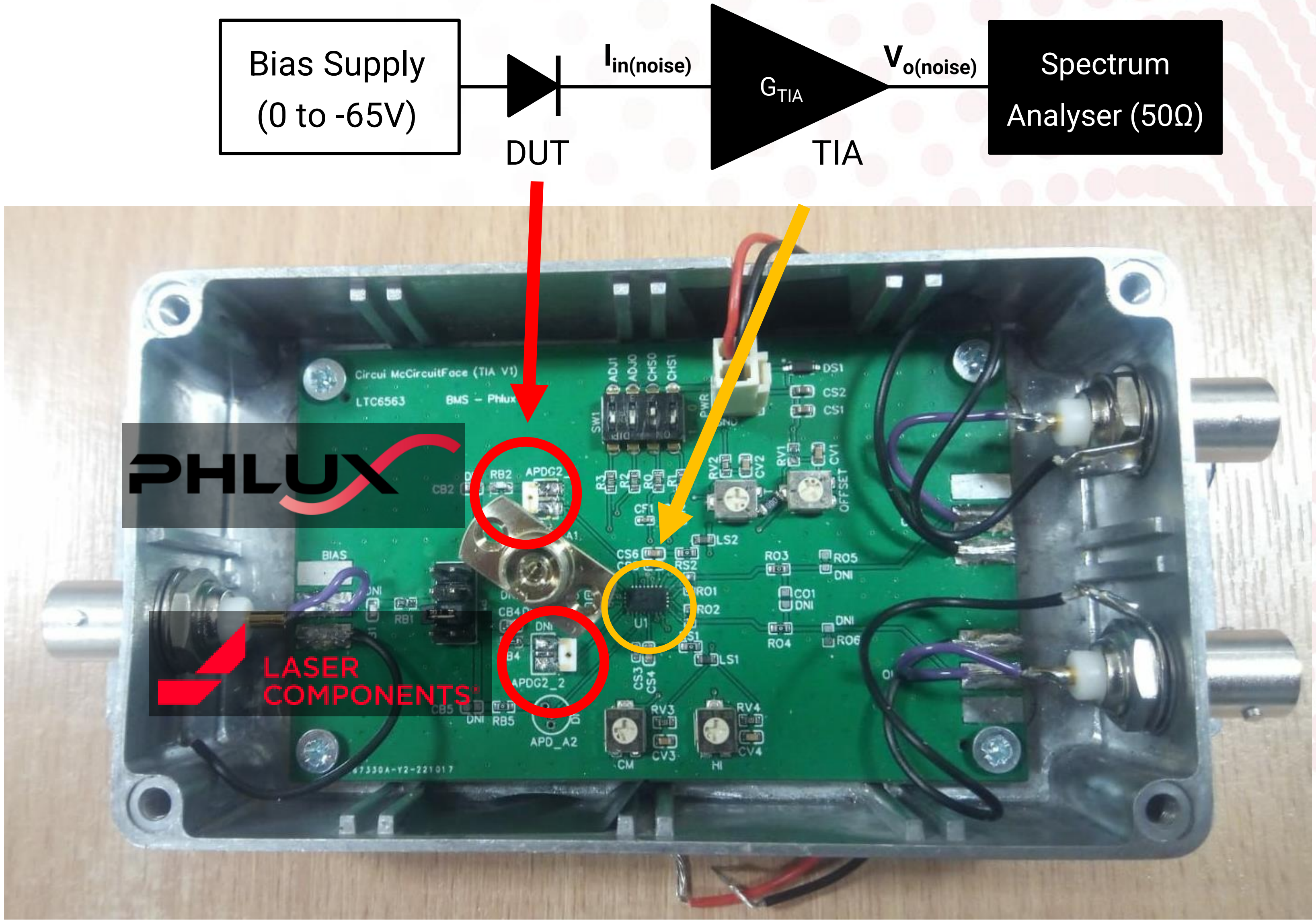
NEP vs Gain

- Noise at M=10 is dominated by the amplifier
- Phlux's APD could show excellent improvement at M=100



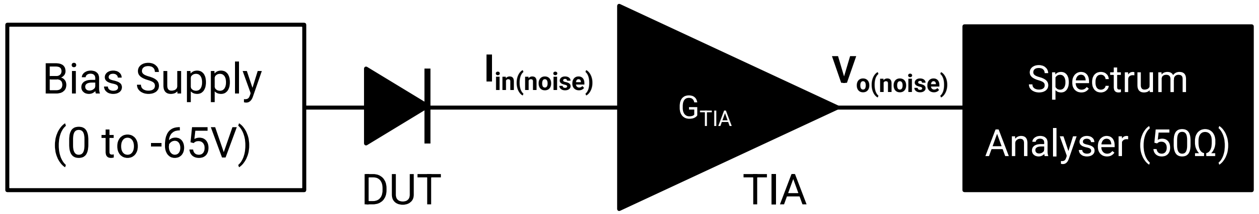
APD + TIA Evaluation Board

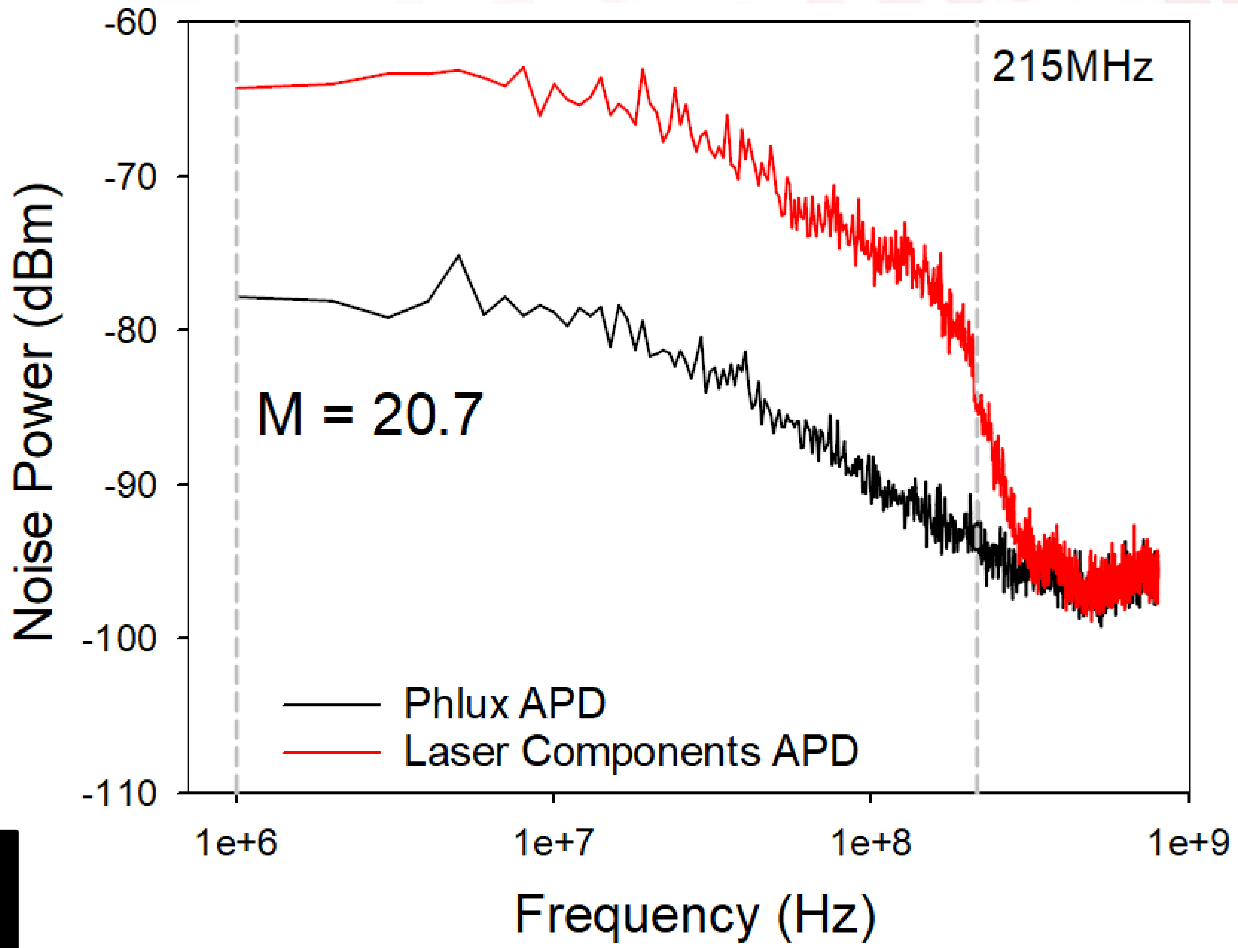
- This evaluation board allows us to test the NEP of 2 APDs:
  - Phlux
  - Laser Components (IAG 080X)



Experimental NEP

1. Measure dark output noise power density spectrum.
2. Convert to input noise current.
3. Calculate NEP = $I_{in(noise)}$ / R(M) over measurement bandwidth.

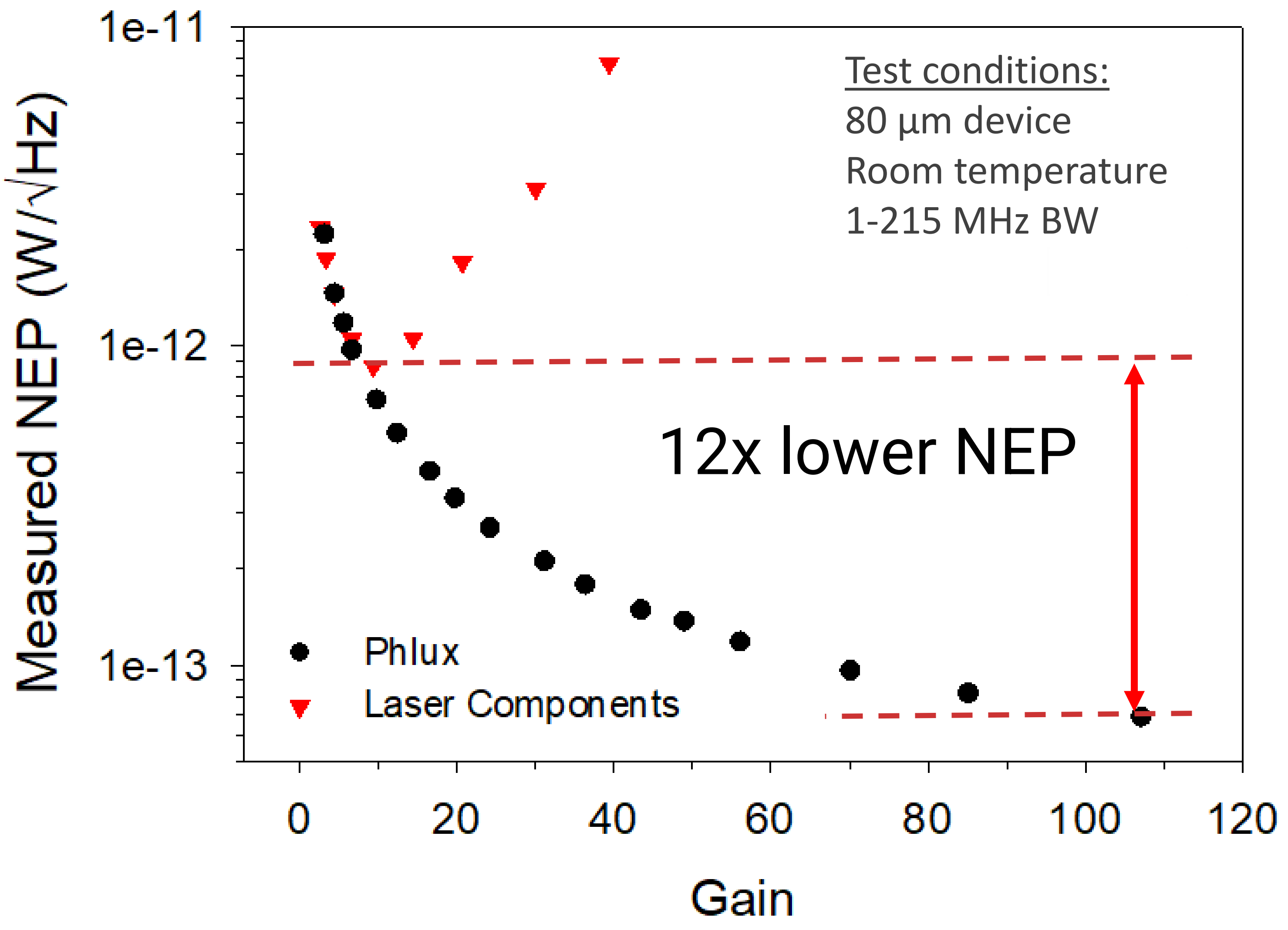




TIA: Analog Devices LTC6563

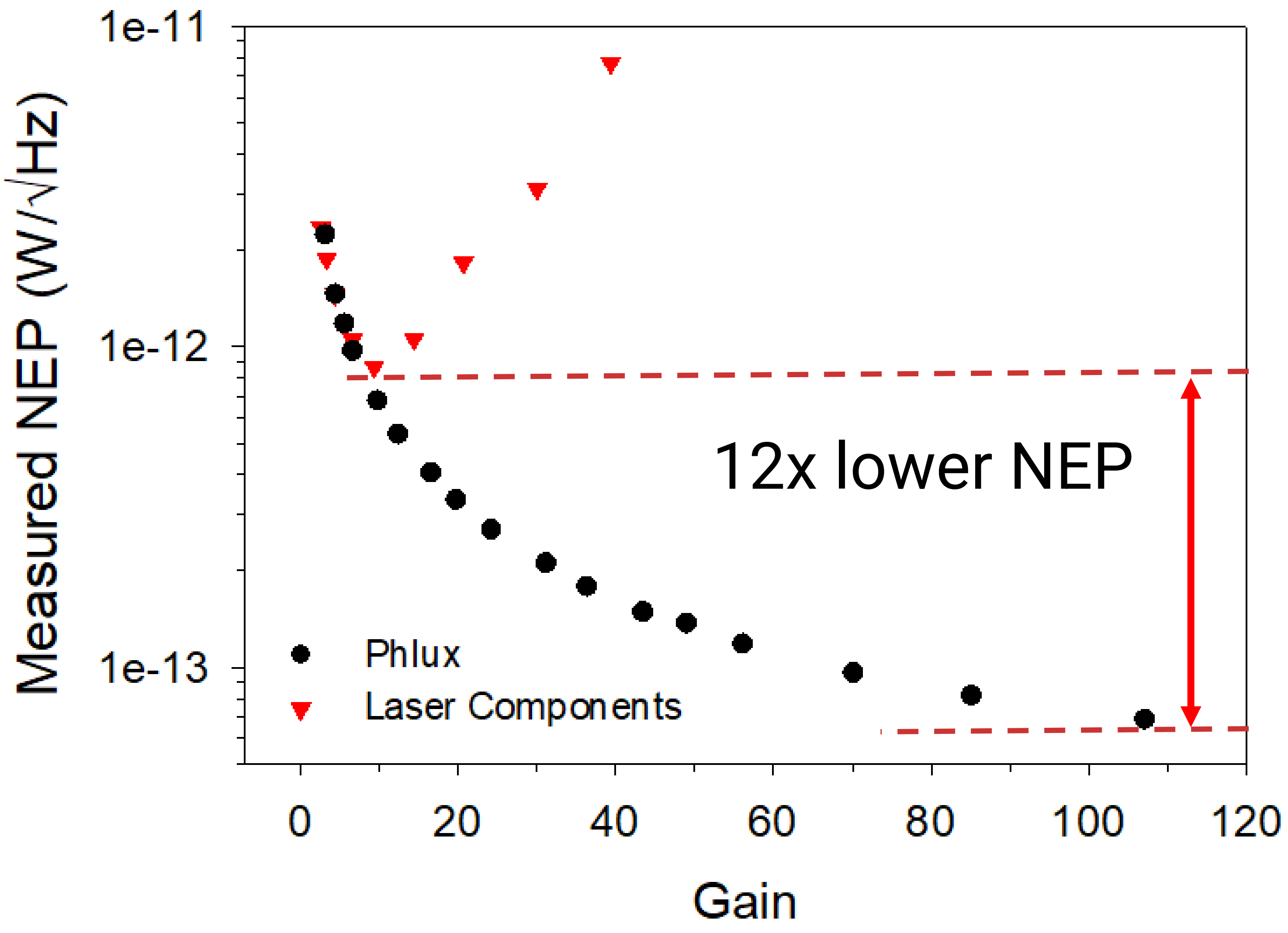
12x Lower Sensitivity!

- Phlux APD can be operated at APD gain > 100 with commercial TIA.
- **12X higher sensitivity** compared to a state of the art APD (Laser Components).



Conclusion

- Demonstrated low noise AlGaAsSb APDs for 1550 nm.
- **Low excess noise and dark current** allows for operation at **M = 100** allows for **12x improvement in sensitivity.**



Contact us

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