Alternative Calibration methods of radiometric detectors

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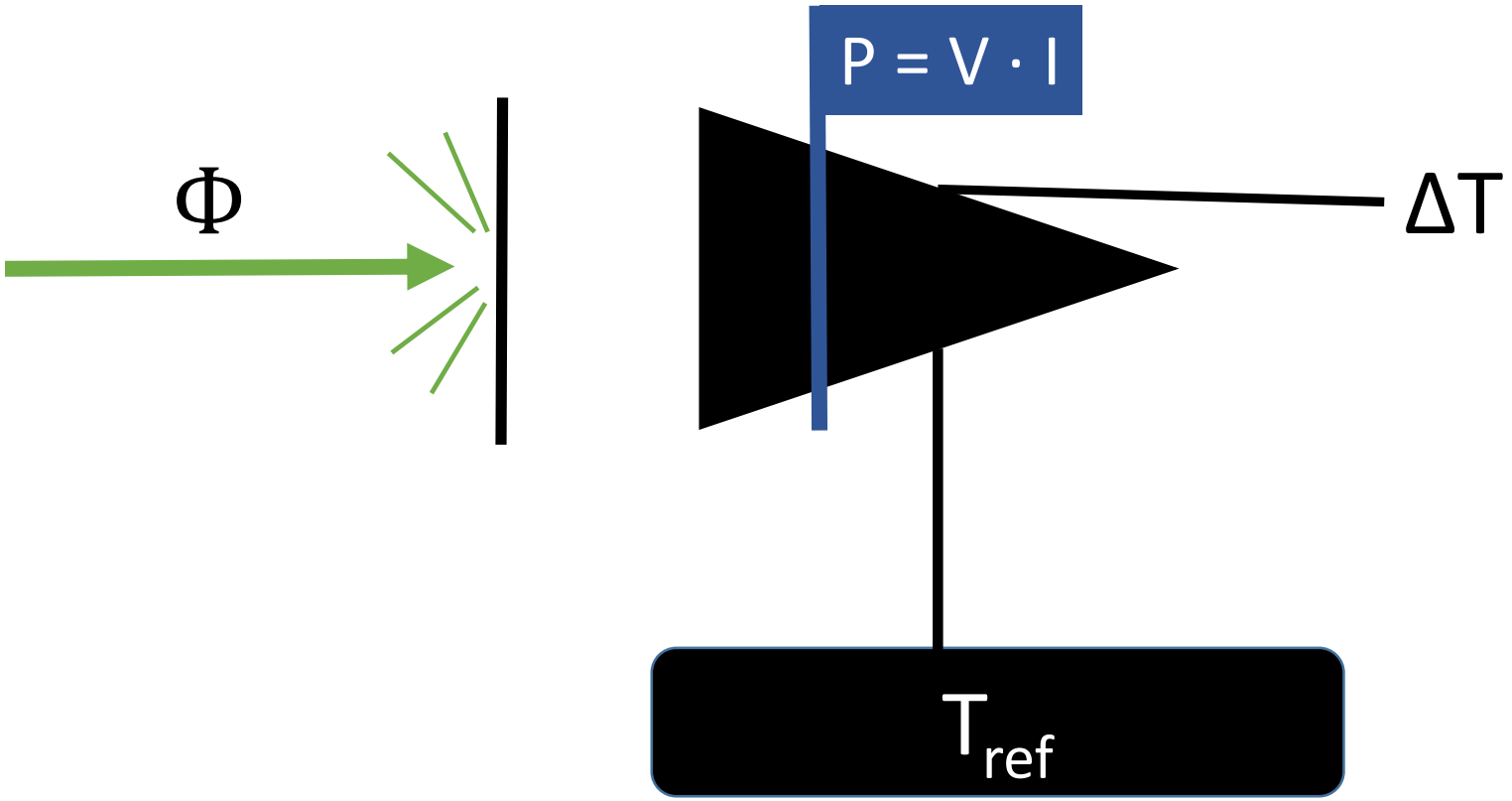
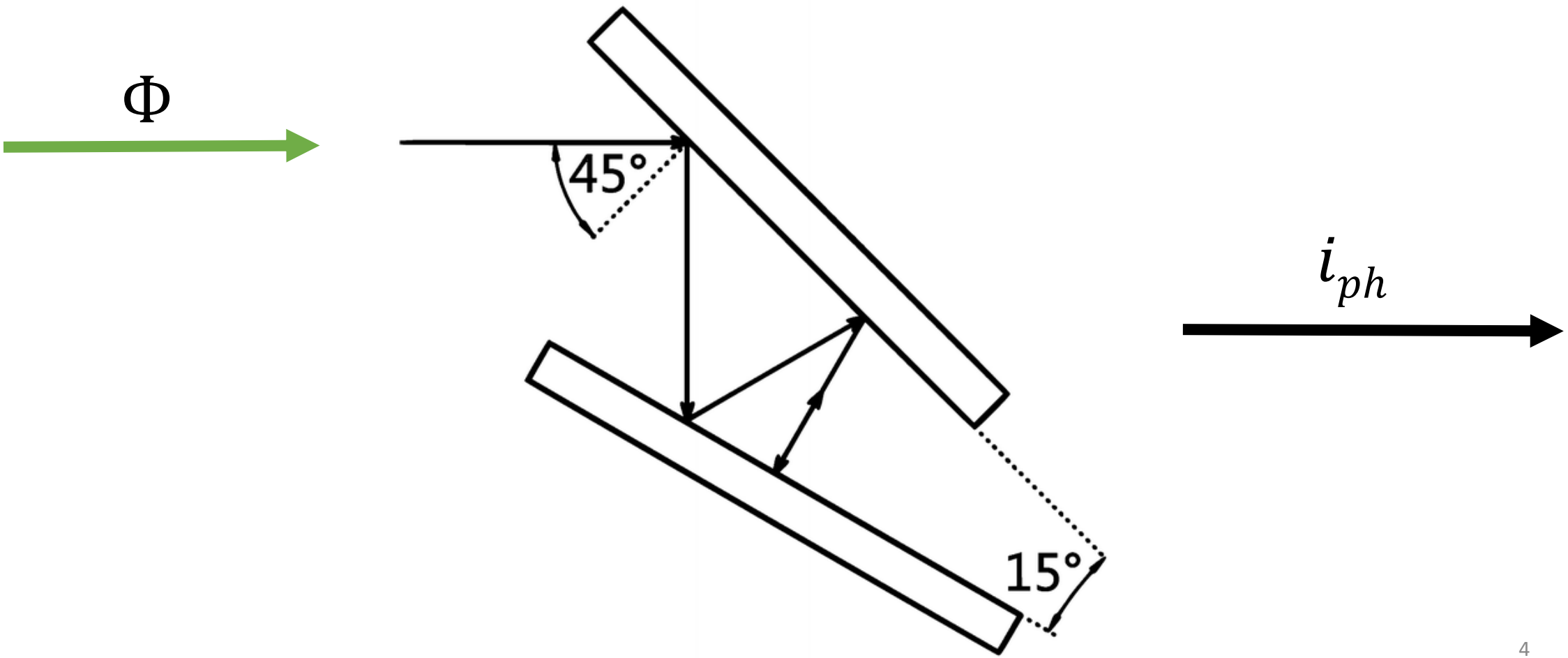
Existing calibration techniques



0.01 % Unc

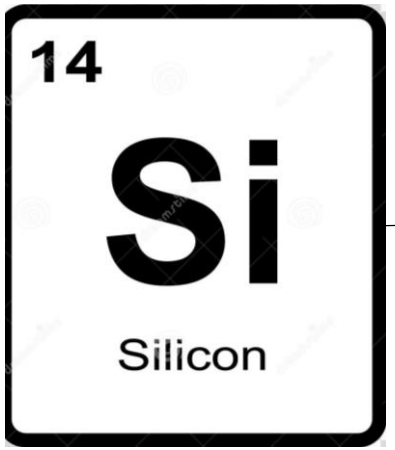
Existing calibration techniques



Existing calibration techniques

Why treat calibration object as a black box?

Mature Technology



Detection principle

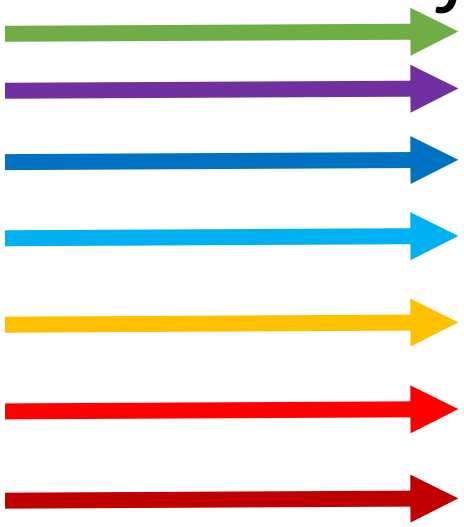
Charge transport

Measure current

Self-referenced embedded standard

A/W

$$\Phi = r \cdot h \cdot f$$



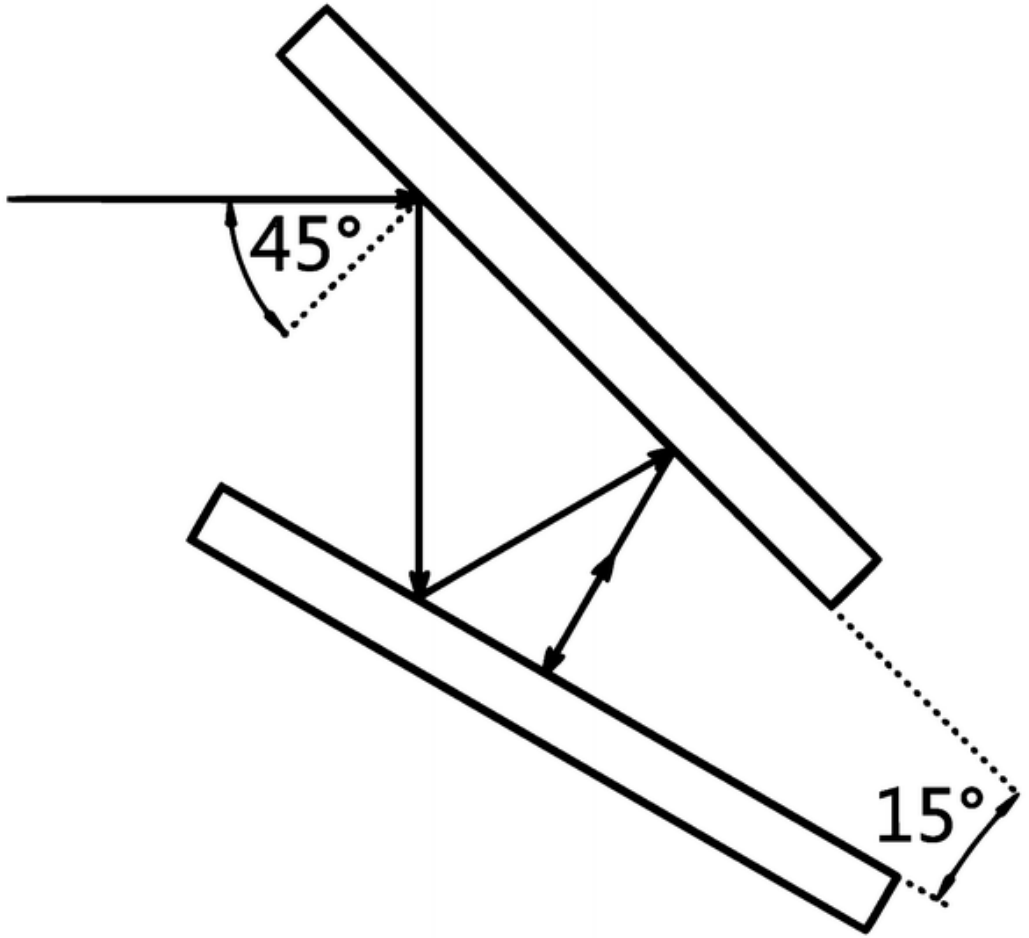
$$\frac{e}{hf} = \frac{e\lambda}{hc}$$

$$i_{ph} = r \cdot e$$

99.9 %

Self-referenced embedded standard

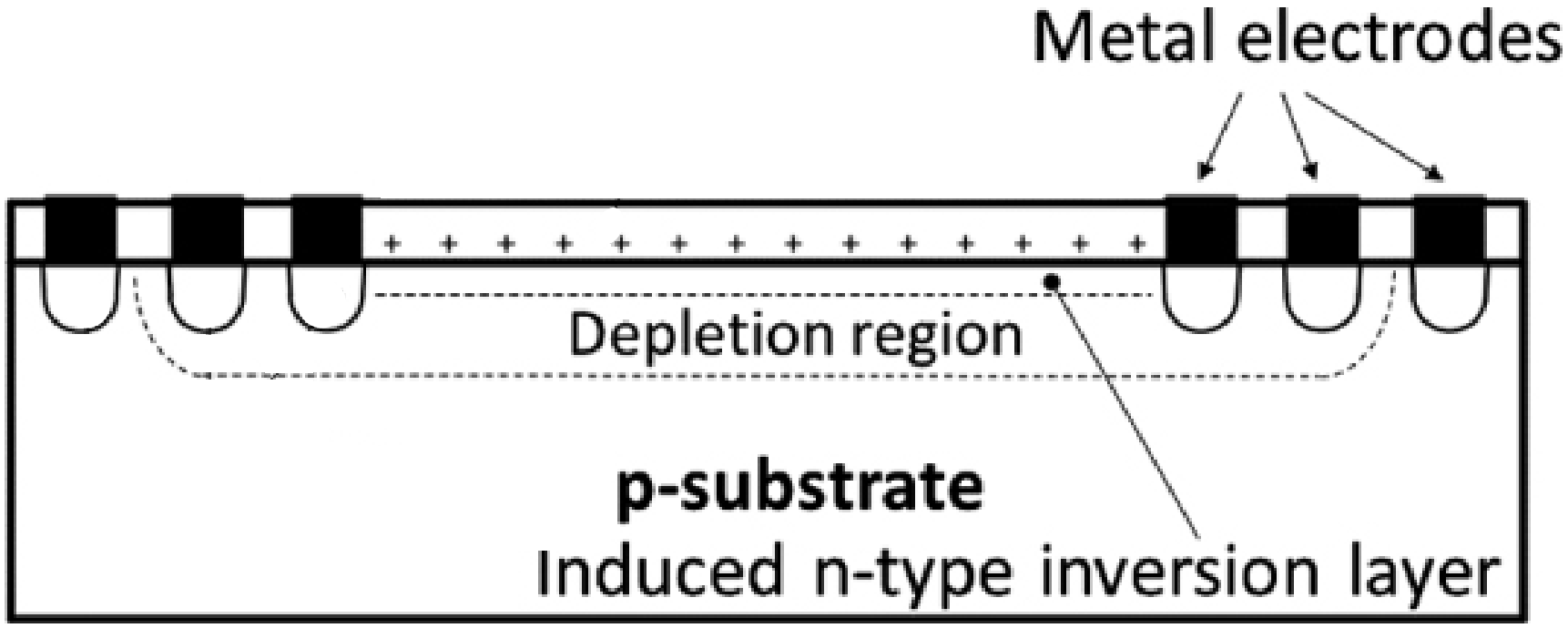
$$\Phi \rightarrow i_{ph} \cdot \frac{hc}{e\lambda(1-\delta)}$$



$$i_{ph}$$

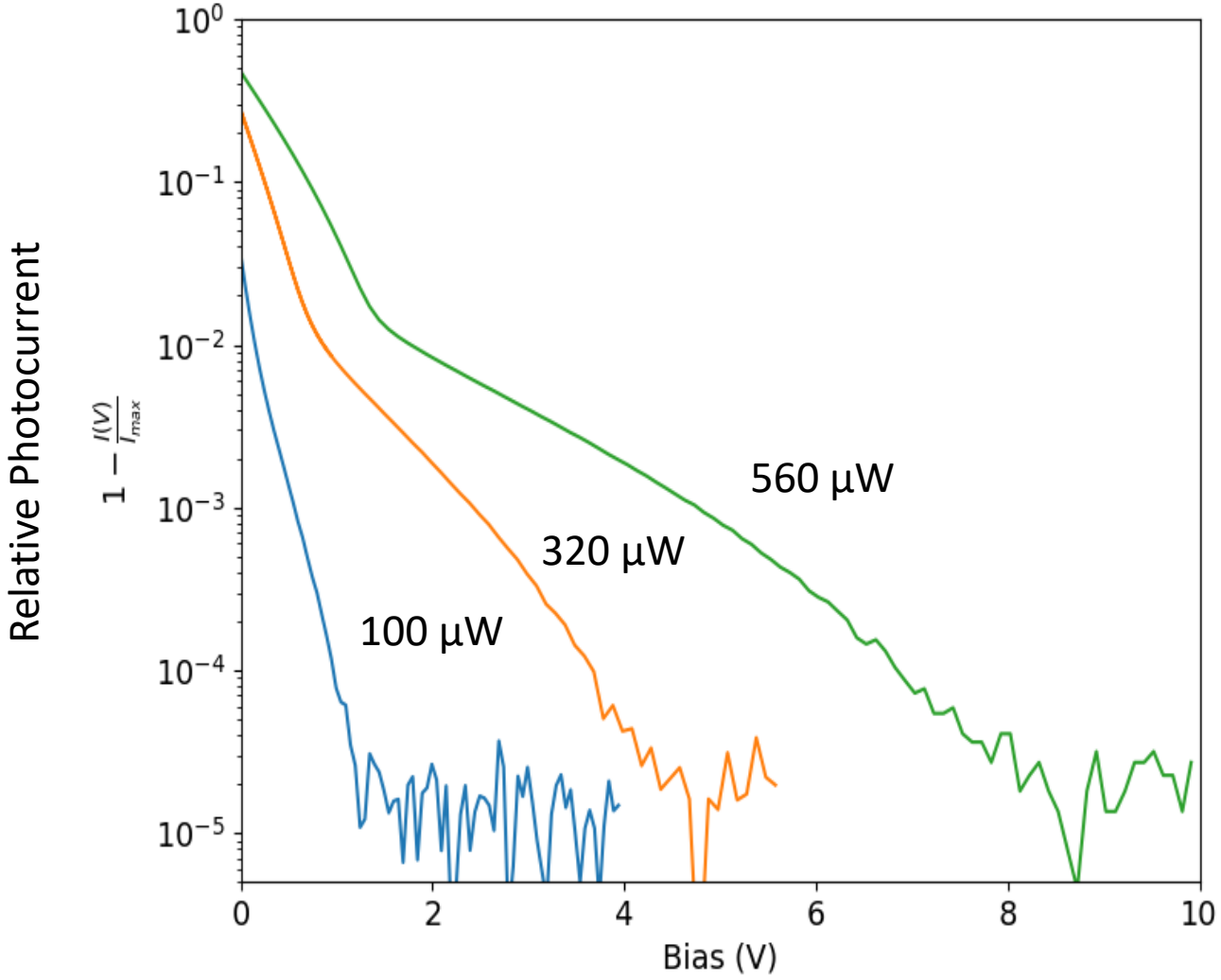
δ
- Eliminate
- Estimate

«Eliminate» δ – No doping diode



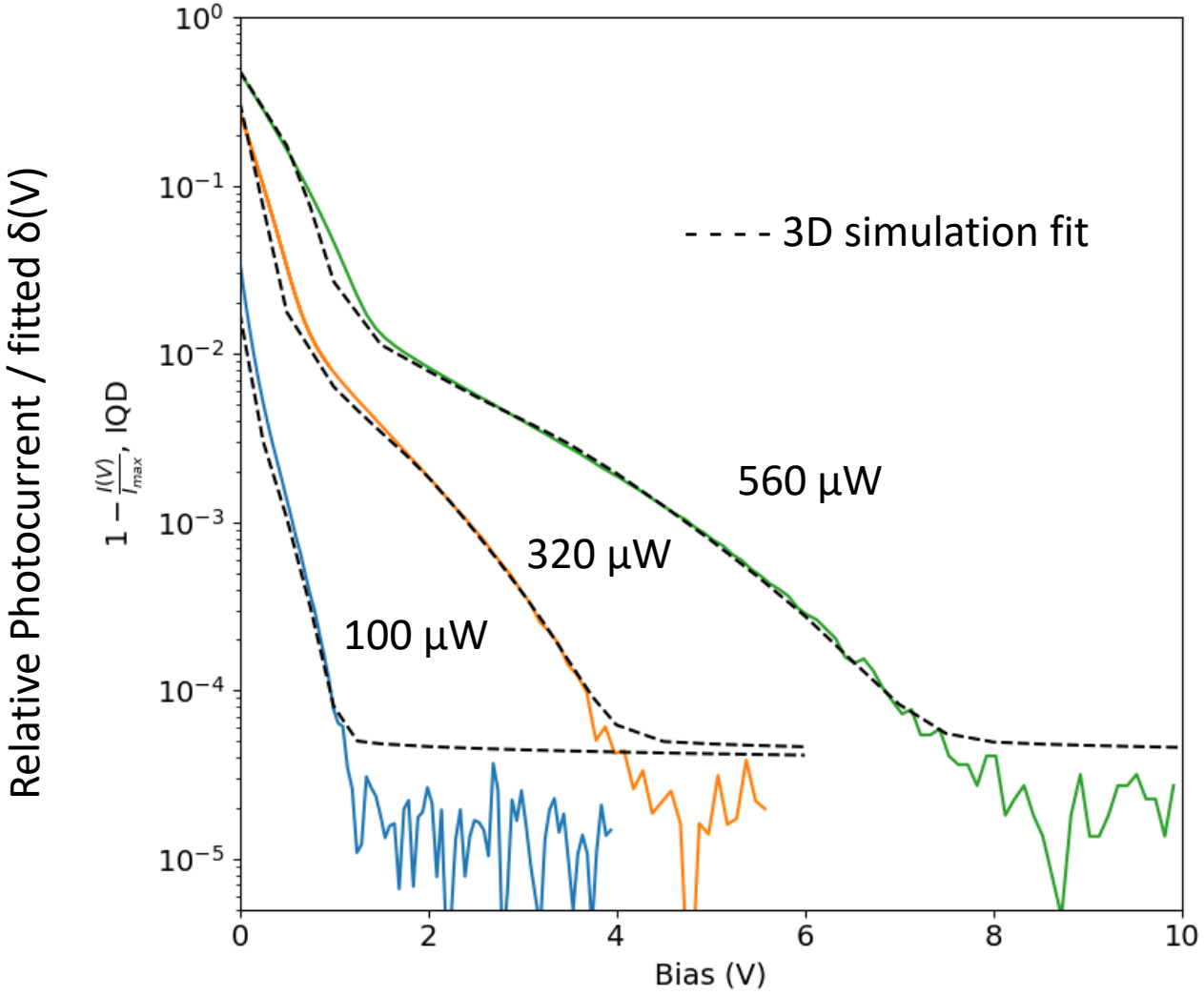
Confirmed internal losses around 100 ppm

Embedded predictable standard - Estimate δ



Measurements @ 488 nm by Aalto University

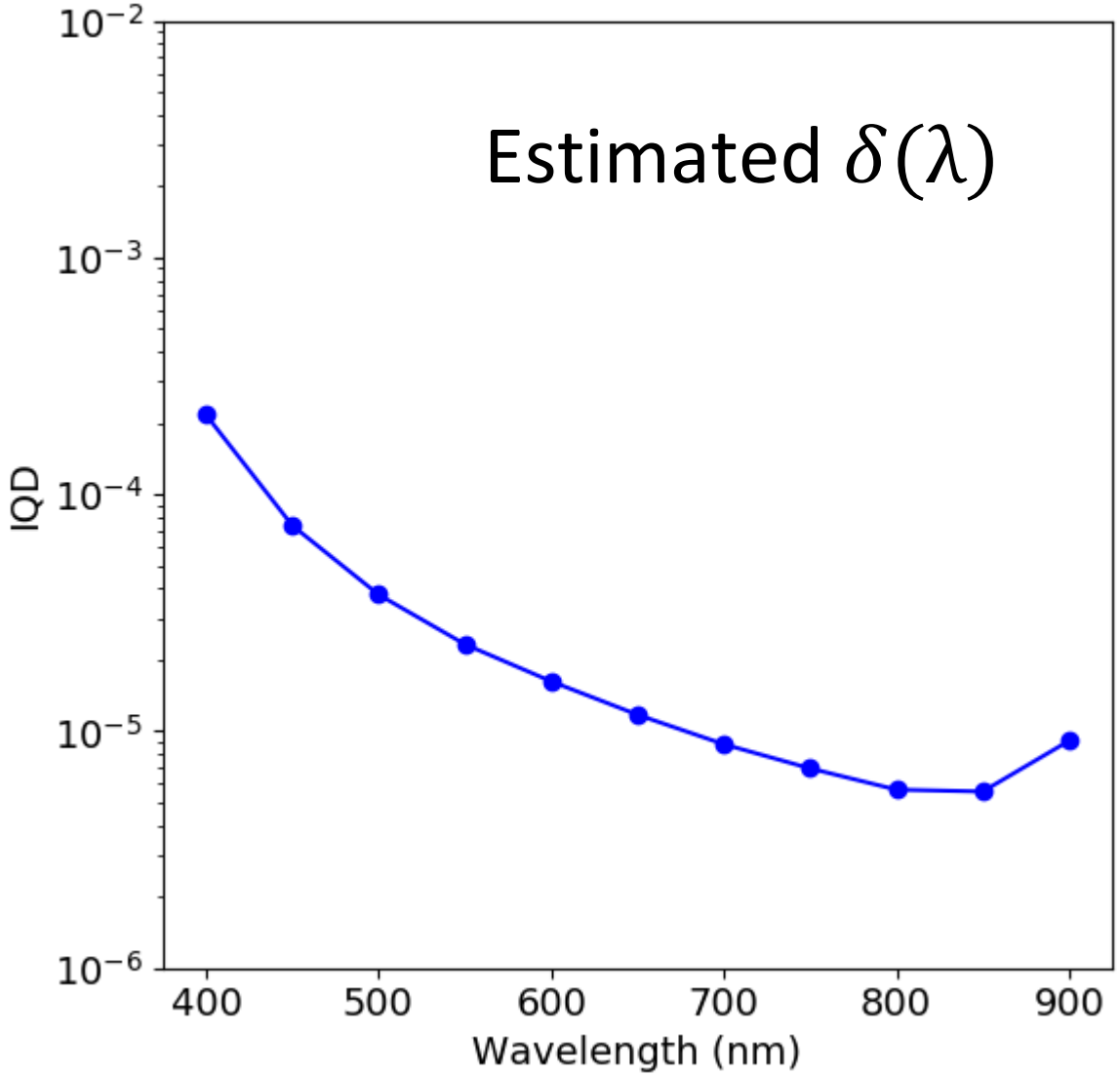
Embedded predictable standard - Estimate δ



Parameters	Fitted Values
Bulk Doping	1.4×10^{12} cm^{-3}
Qf	4×10^{11} cm^{-2}
Bulk lifetime	2.9ms
Surface recombination	8000 cm/s
Beam size	1007 µm×1290.2 µm Flat top

Intelligence into measurement system

Embedded predictable standard



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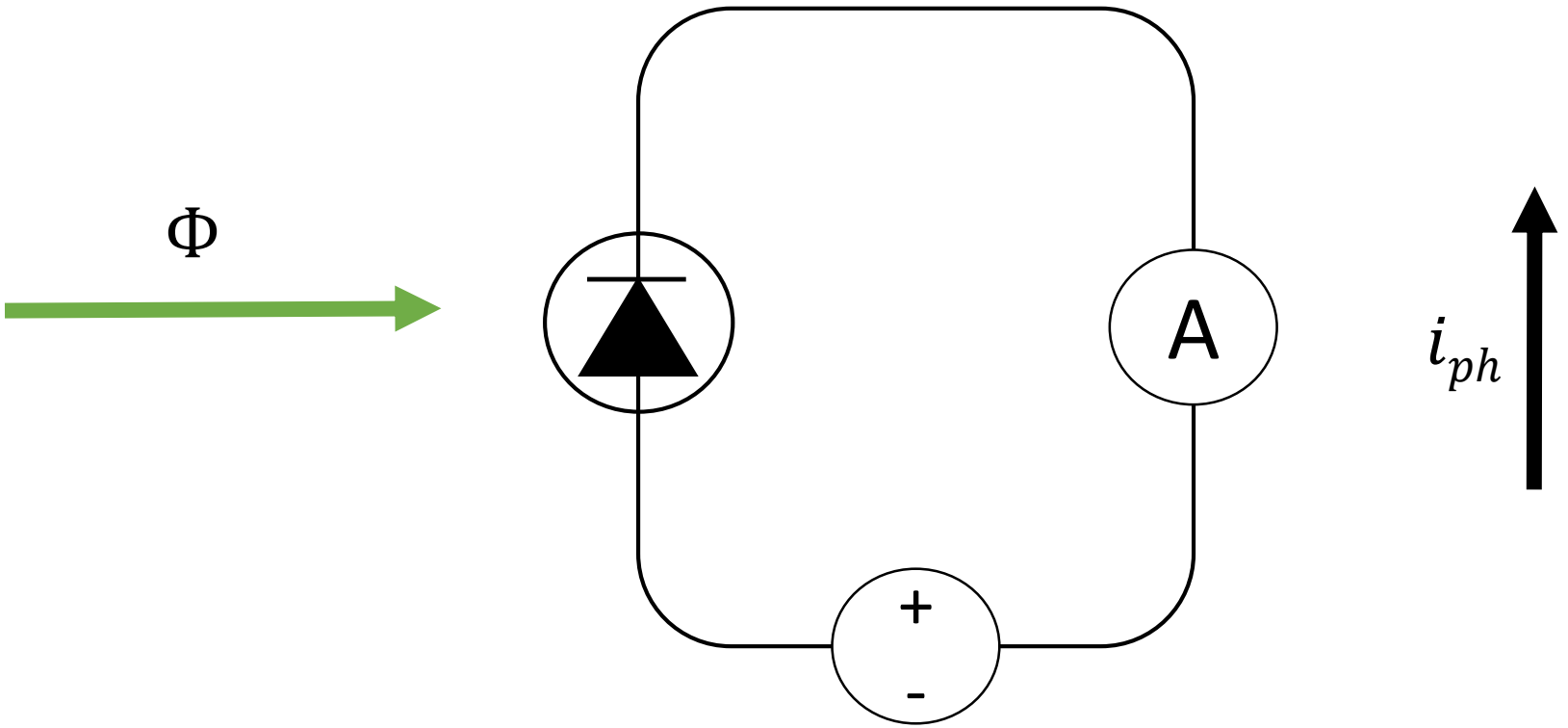
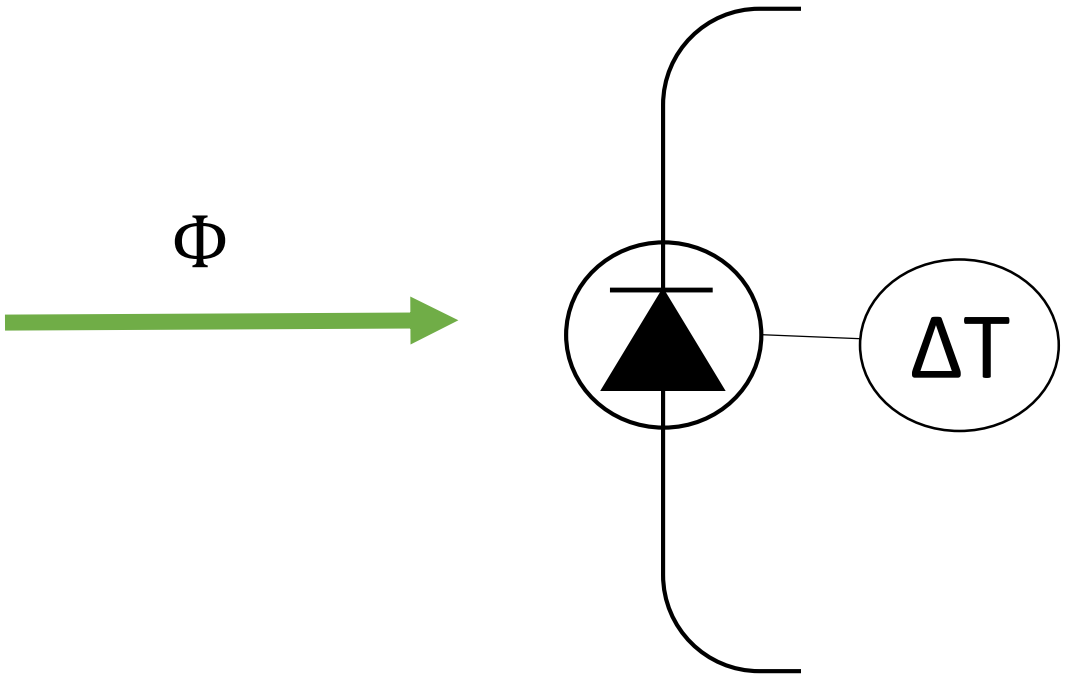
One wavelength measurement predicts full spectral range

Dual mode detector - photocurrent



Step I

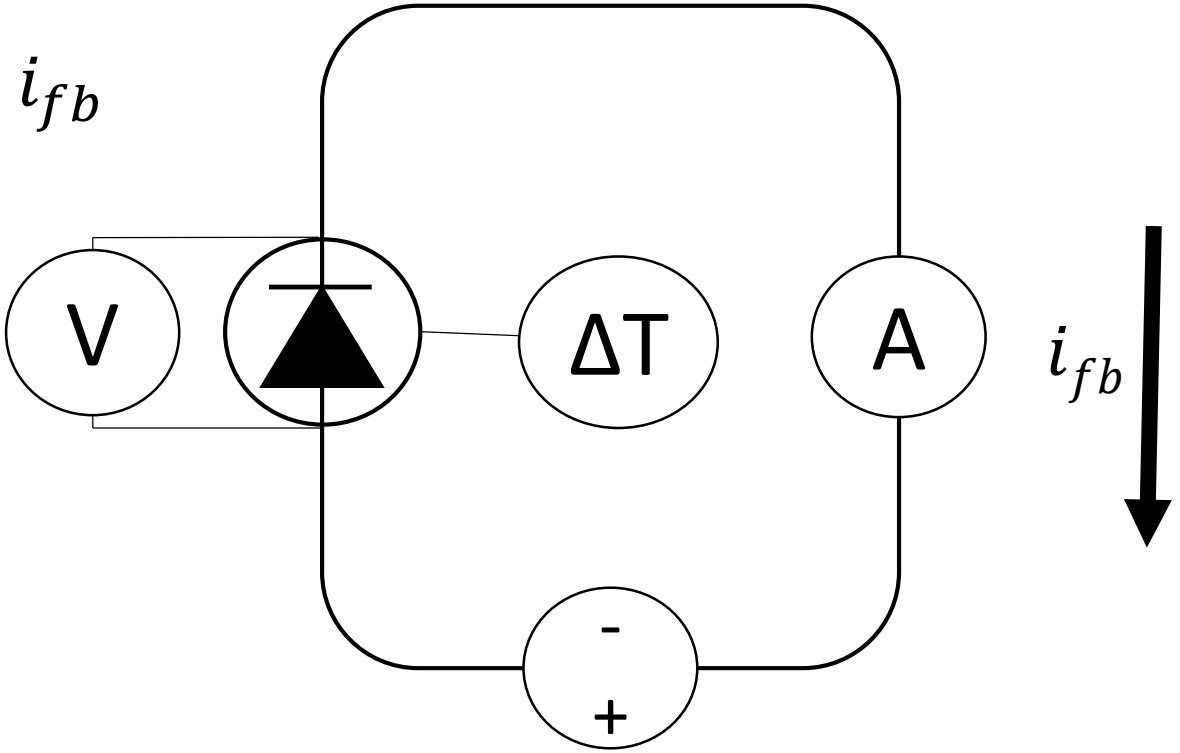
Dual mode detector – optical heat



Step II-a

Dual mode detector – electrical heat

$$\Phi = P = V \cdot i_{fb}$$

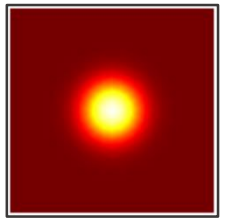


Step II-b

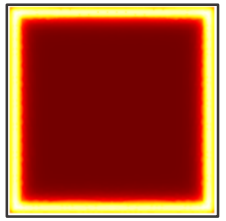
Experimental [A/W] - Same equipment, same absorber

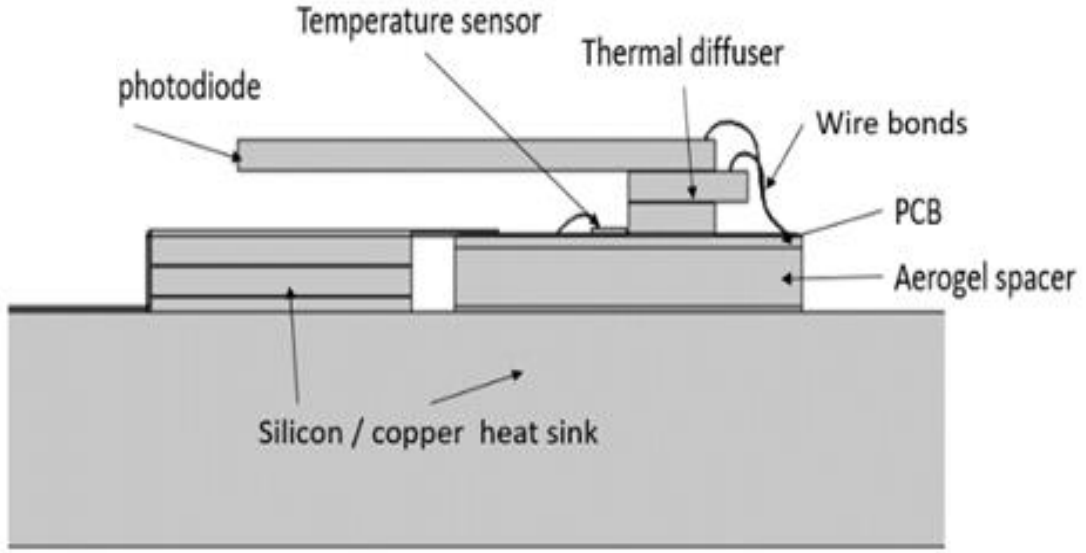
Dual mode detector – heat equivalence

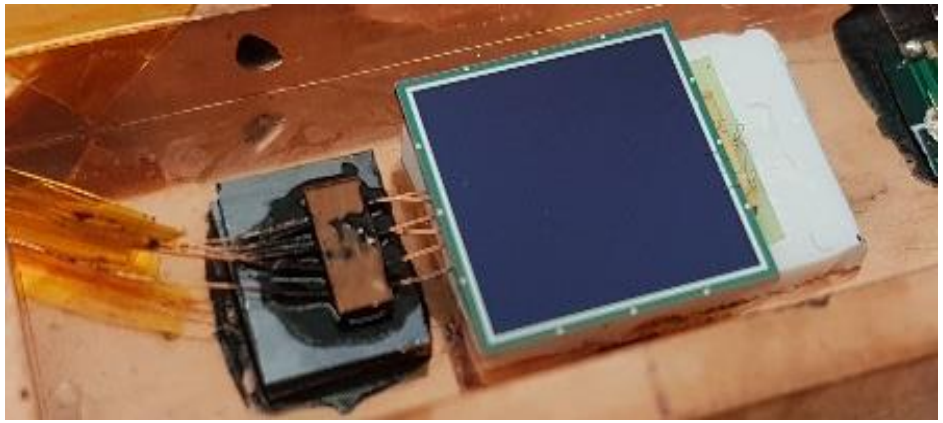
Optical heating



Electrical heating







Simulated heat nonequivalence:

< 500 ppm at 300 K
< 0.7 ppm at 60 K
< 0.2 ppm at 40 K

Measure e/h – equivalence between methods

Step I → $\frac{i_{ph}}{P} = \frac{e\lambda}{hc}(1 - \delta(\lambda))$ → 3D fit

Step II →

Dual mode

Embedded predictable

Conclusions

Off-the-shelf silicon photodiodes are self-referenced standards to 99.9%

Custom PQED photodiodes are self-referenced to 99.99 %

One wavelength measurement extracts full spectral responsivity

Self-calibrating detectors well suited in remote, unattended location capable of calibrating themselves and link to fundamental constants

Thank you!

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«It's not about taking instruments to the lab - it's about taking the lab to the instrument»

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