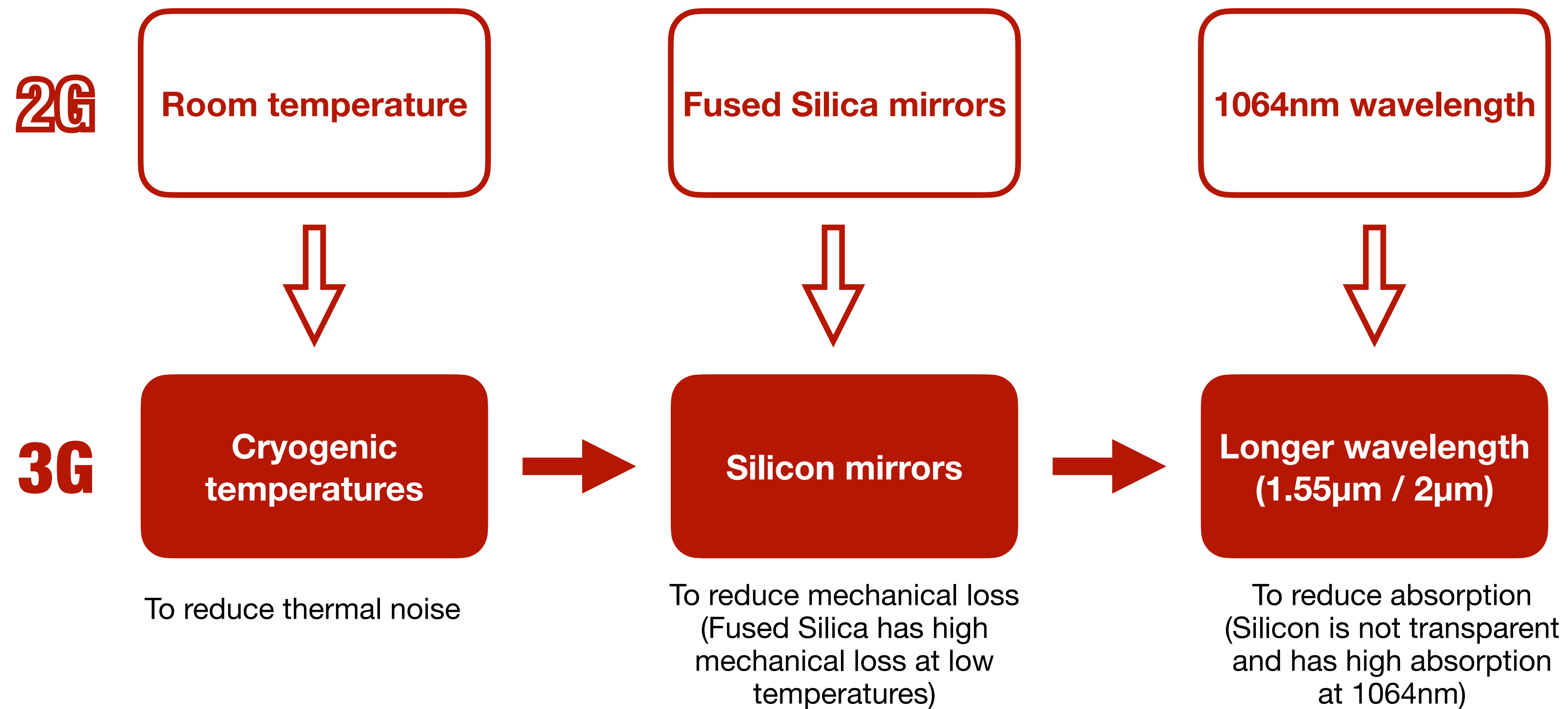


2 μ m Optical Lab

— status and projects —

Daniela Pascucci

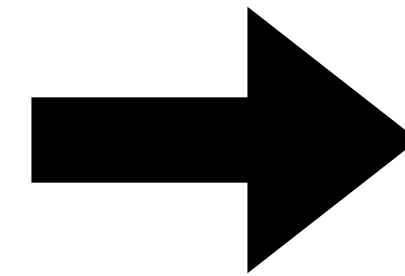
2μm optics



New wavelength for 3G detectors

Next-generation gravitational wave detectors will introduce new techniques to reduce fundamental noise sources. In particular the use of longer wavelengths is a challenge in terms of optical technologies that need to be developed.

The proposed laser wavelengths for next generation GW detectors are $1.55\mu\text{m}$ and $2\mu\text{m}$. While for the first most of the technologies have already been tested and developed, that is not true for $2\mu\text{m}$.



**The Ghent Gravity Group is
been setting up an optical lab
for $2\mu\text{m}$ characterisation.**

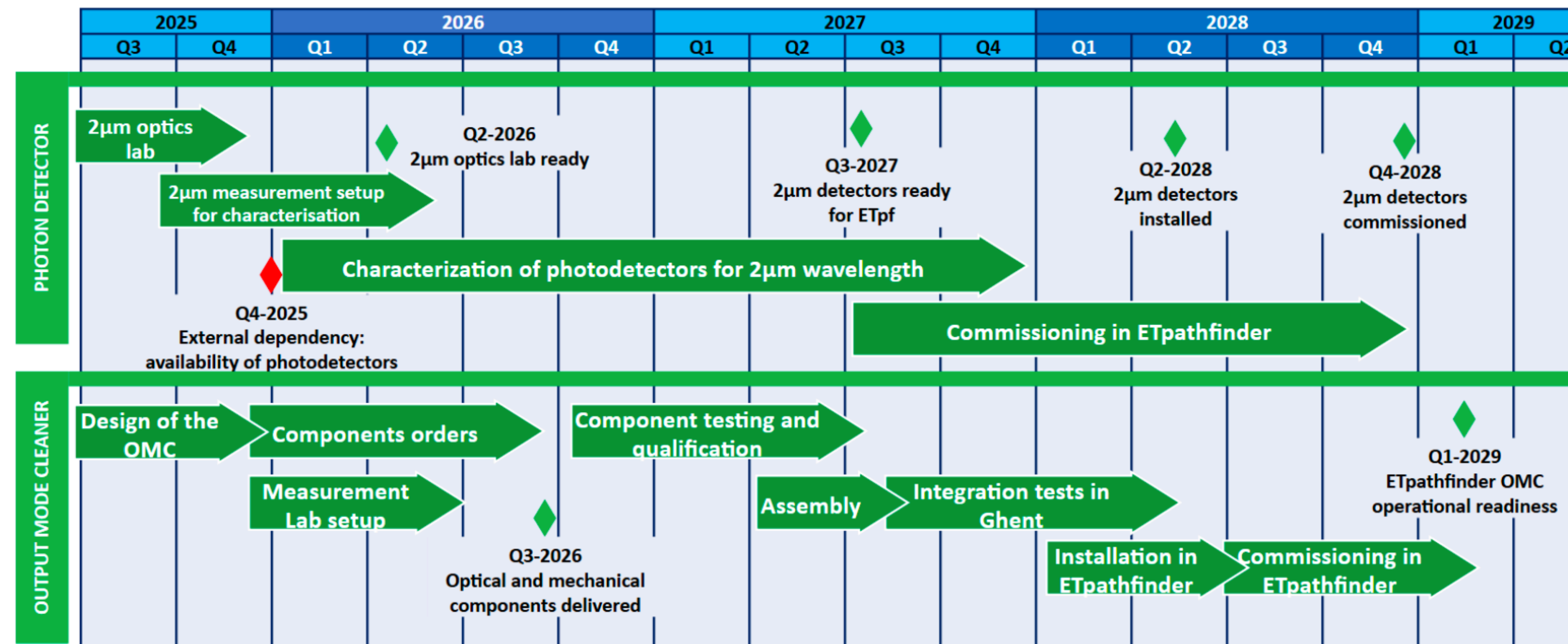
3GOL: Ghent Gravity Group Optical Lab

Lab for optical characterisation at 2 μ m wavelength.

- The optical lab is located at the Proeftuin Campus of Ghent University.
- A laminar flow enclosure with fan filter unit and air control monitor has been installed to ensure a clean environment. The clean area dimensions is approximately 2mx3m.
- The lab is provided with a very stable laser source and devices for optical measurements and characterisation.
- The lab has been recently upgraded the lab to **1064 nm optics**.



WP 2.1: 2μm light sources and photon detection sensors



KPI 1 - Q2/2026: Completion of measurement setup of 2μm wavelength optics lab in Ghent.

KPI 2 - Q3/2027: photodetector design quantum efficiency at 95% target.

KPI 3 - Q4/2027: Characterisation for the photodetectors for 2μm wavelength (in coordination with postdoc at UAntwerpen) completed for the optical and electronic components.

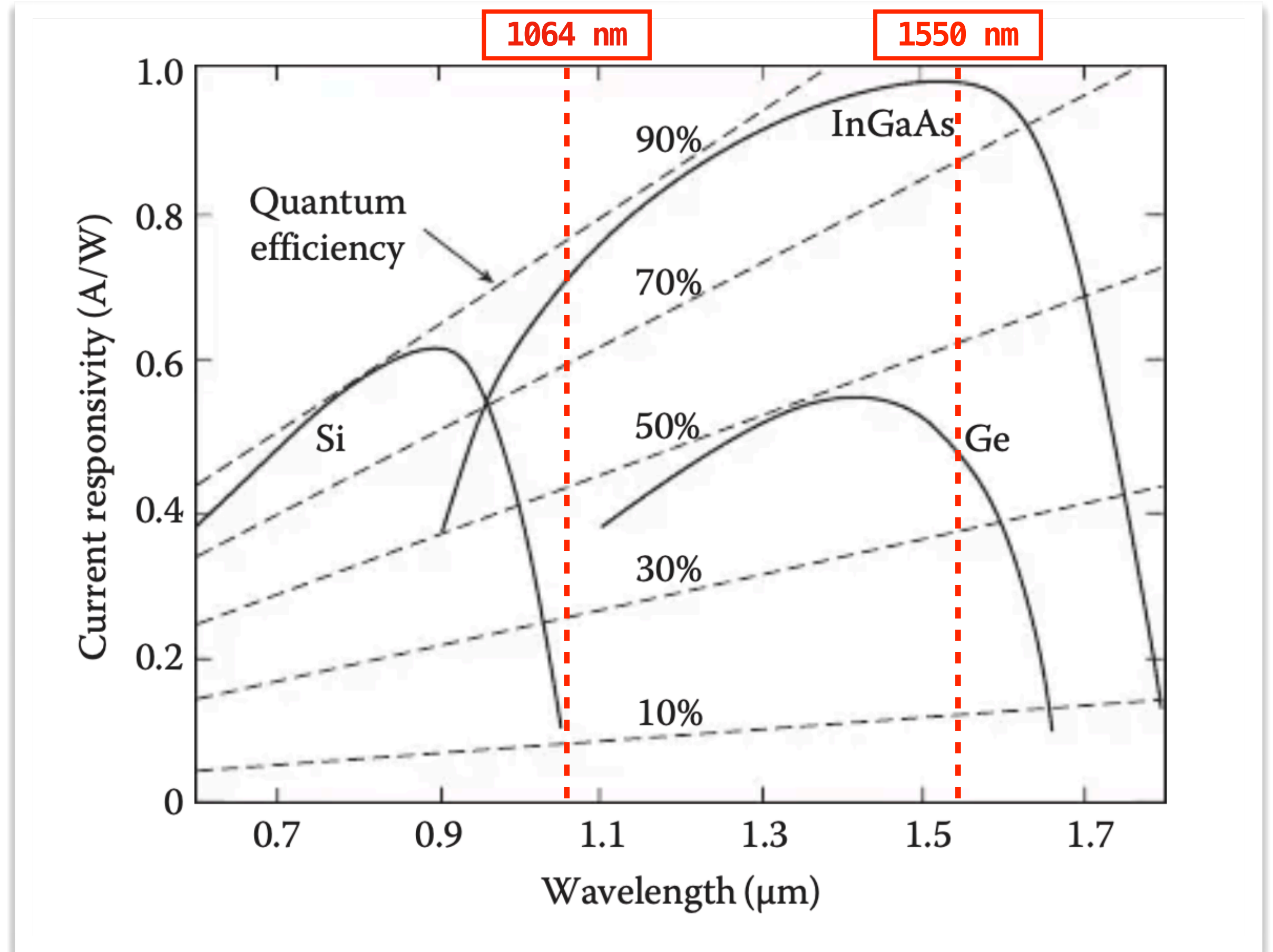
KPI 4 - Q3/2028: OMC total loss below 1.5% reached.

KPI 5 - Q3/2028: OMC mode matching of 95% or higher reached.

2 μm photodetectors

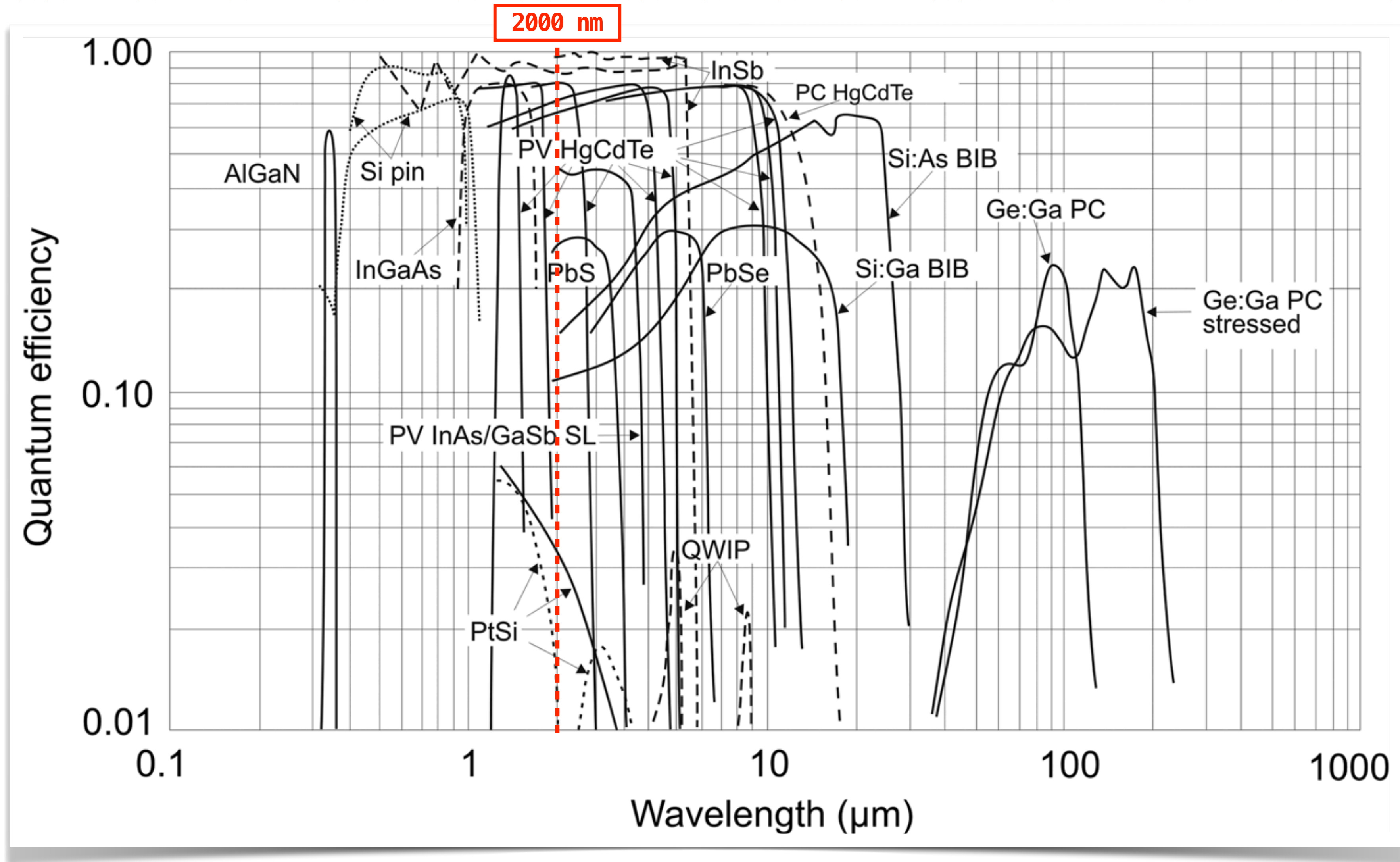
InGaAs photodiodes

- ▶ Current gravitational waves detectors use InGaAs photodiodes for 1064nm laser
- ▶ InGaAs photodiodes are still efficient for 1550 nm wavelength
- ▶ For 2 μm a new photodiode is needed



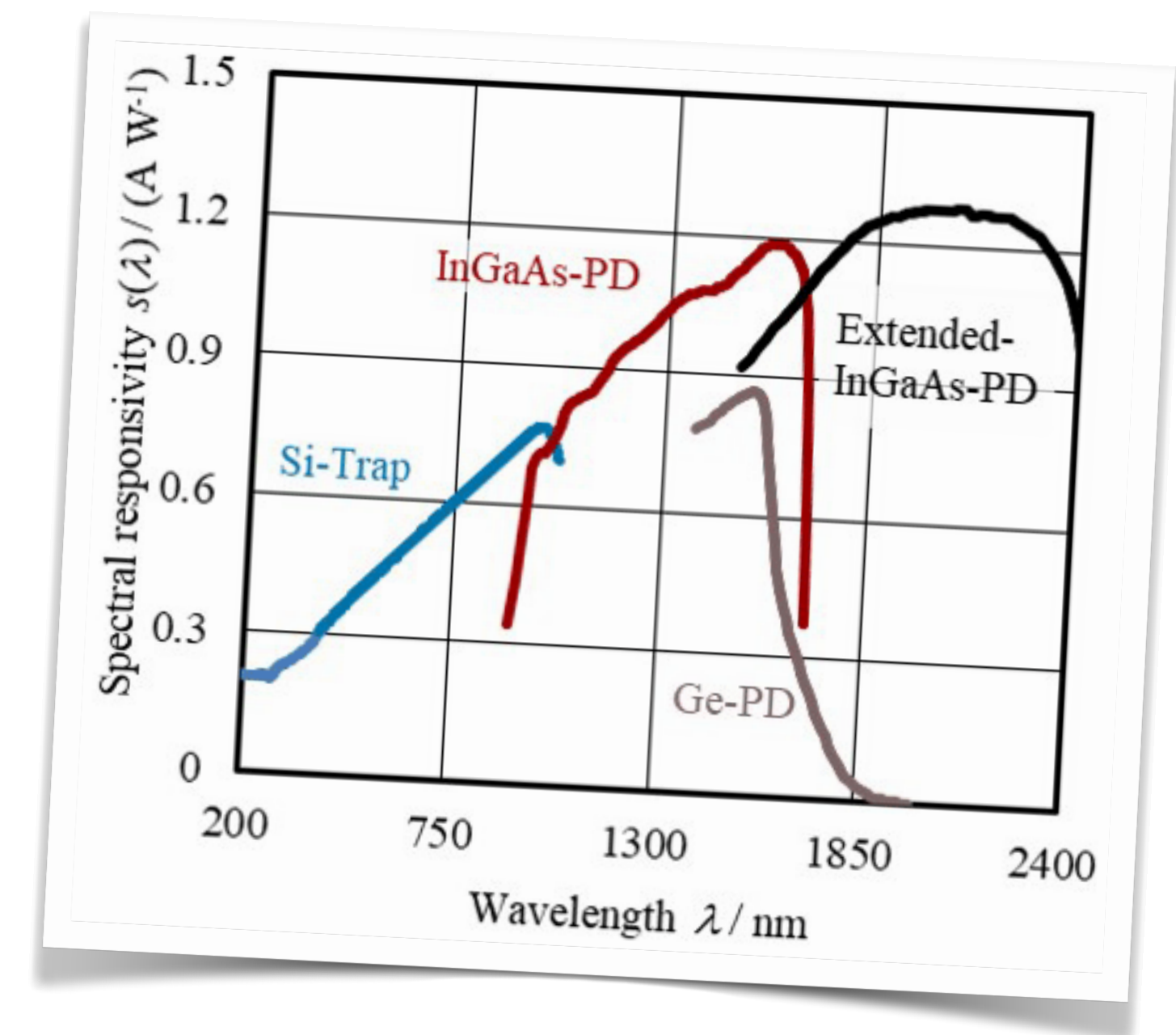
credits: A. Rogalski, Infrared Detectors, 2nd edition, CRC Press, Boca Raton, Florida (2010)

Alternatives



How to detect 2 μm

- Standard InGaAs photodiodes use **In_{53%}Ga_{47%}As**, which have a cutoff wavelength of $\sim 1.7\mu\text{m}$.
 - It is possible to increase the cutoff wavelength up to $2.6\mu\text{m}$ increasing the percentage of Indium to 82% (**extended InGaAs**)
- Other options require the use of a different material:
 - **HgCdTe** (MCT)
 - **InAsSb**



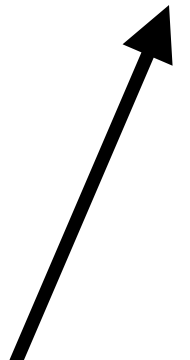
Photodiodes performance

Quantum efficiency

number of electron-hole pairs
generated per incident photon

$$QE = \frac{N_e}{N_\nu} = R \frac{hc}{\lambda e}$$

responsivity
(in A/W)



Dark noise

noise generated by the current
that exist in the photodiode
when no light is incident

Overview

type	wavelength range	comments
extended InGaAs	depending from the percentage of indium (max 2.6 μ m)	low noise implies low QE
HgCdTe	1.7 μ m - 30 μ m	high quantum efficiency (99%), but need cooling to reduce dark noise
InAsSb	2 μ m - 5 μ m	QE lower and dark noise higher than extended InGaAs

Characterisation of commercial photodiodes

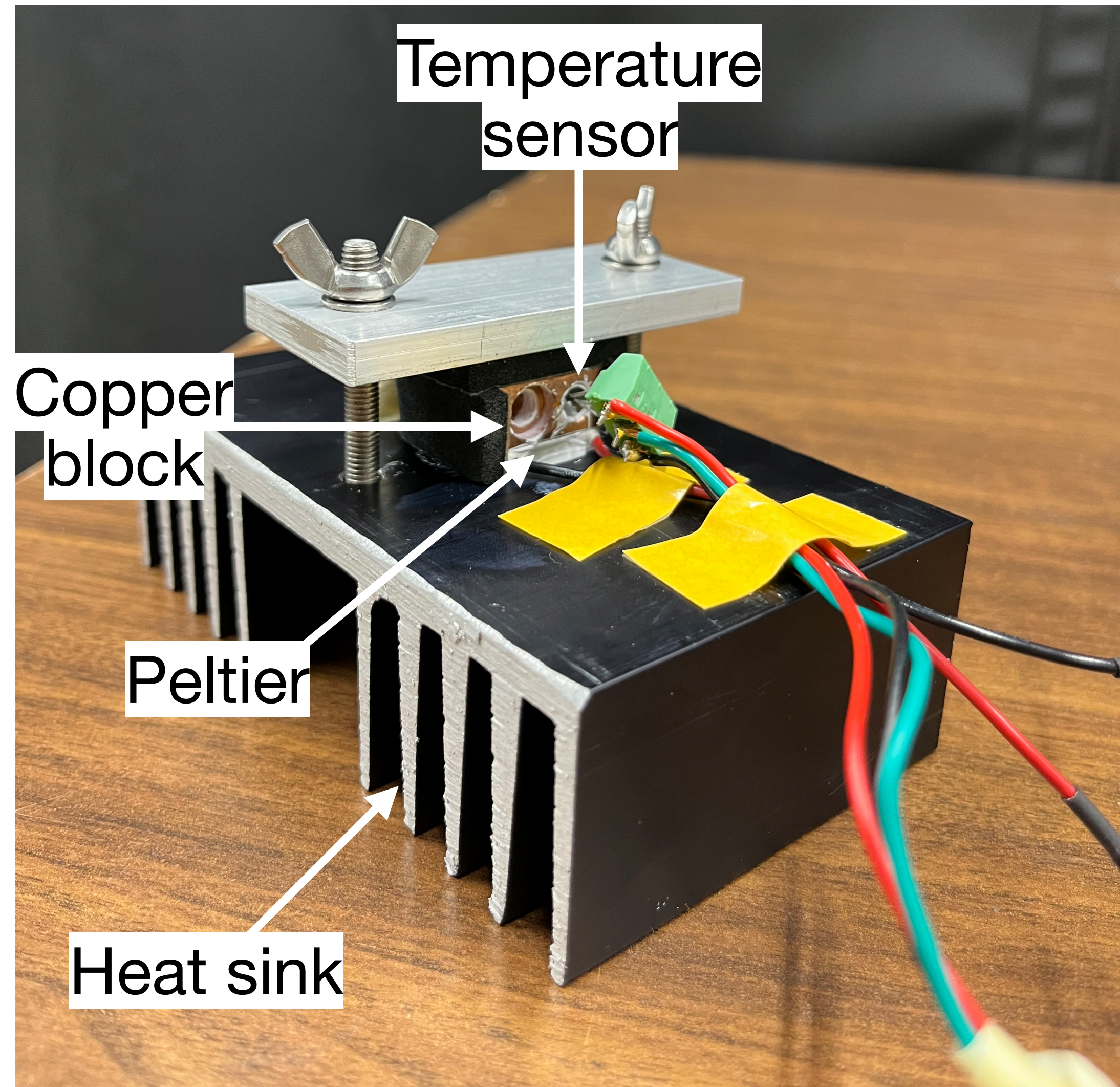
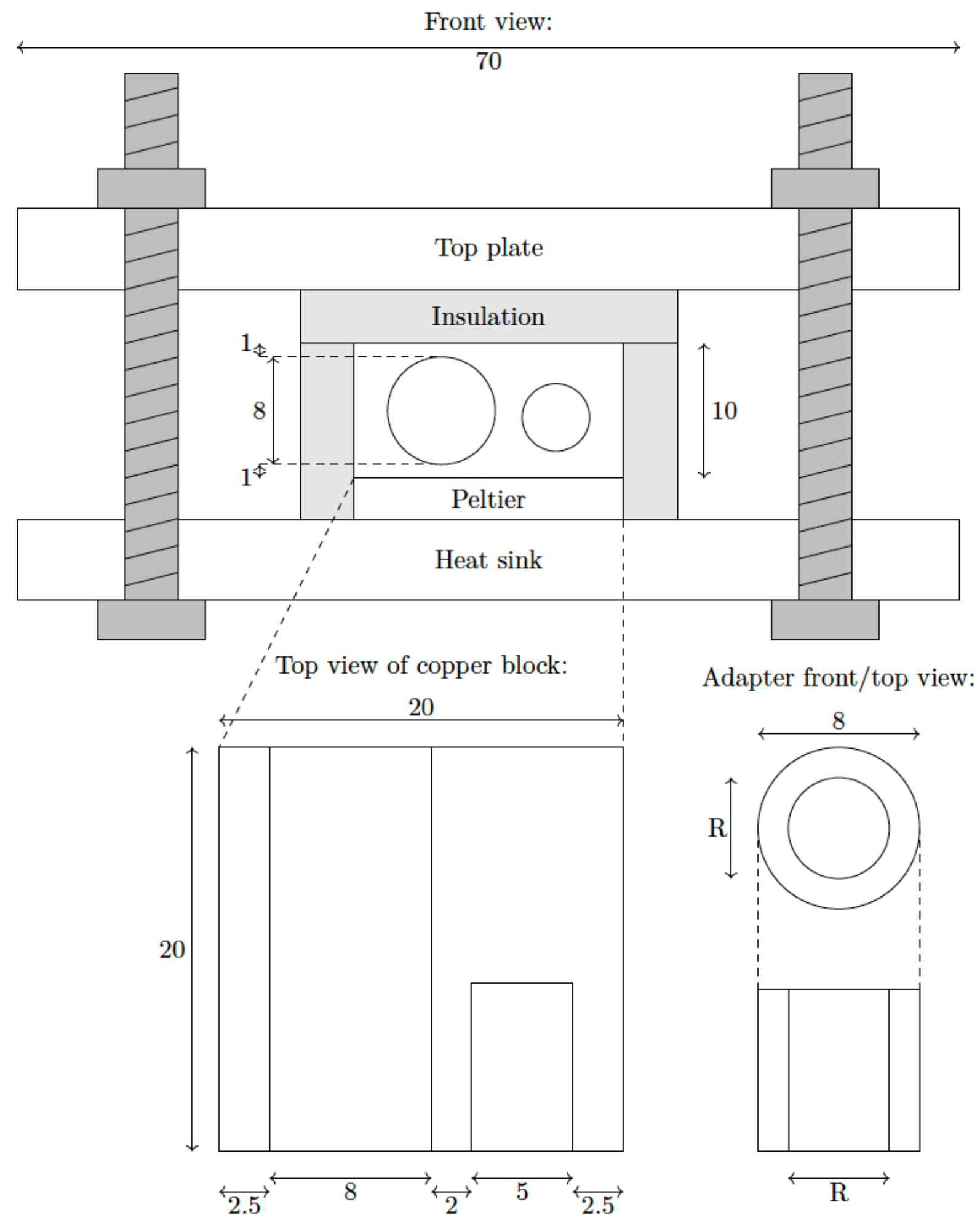
The work on characterisation of commercial photodiodes started on February.

The work has been carried out so far by Audric De Backer Rutger Dobbelaere Jorrit Vander Bracht (Masters students), with the supervision of Guy Janssens (electronic engineer).

A technical report has been written with the preliminary results.



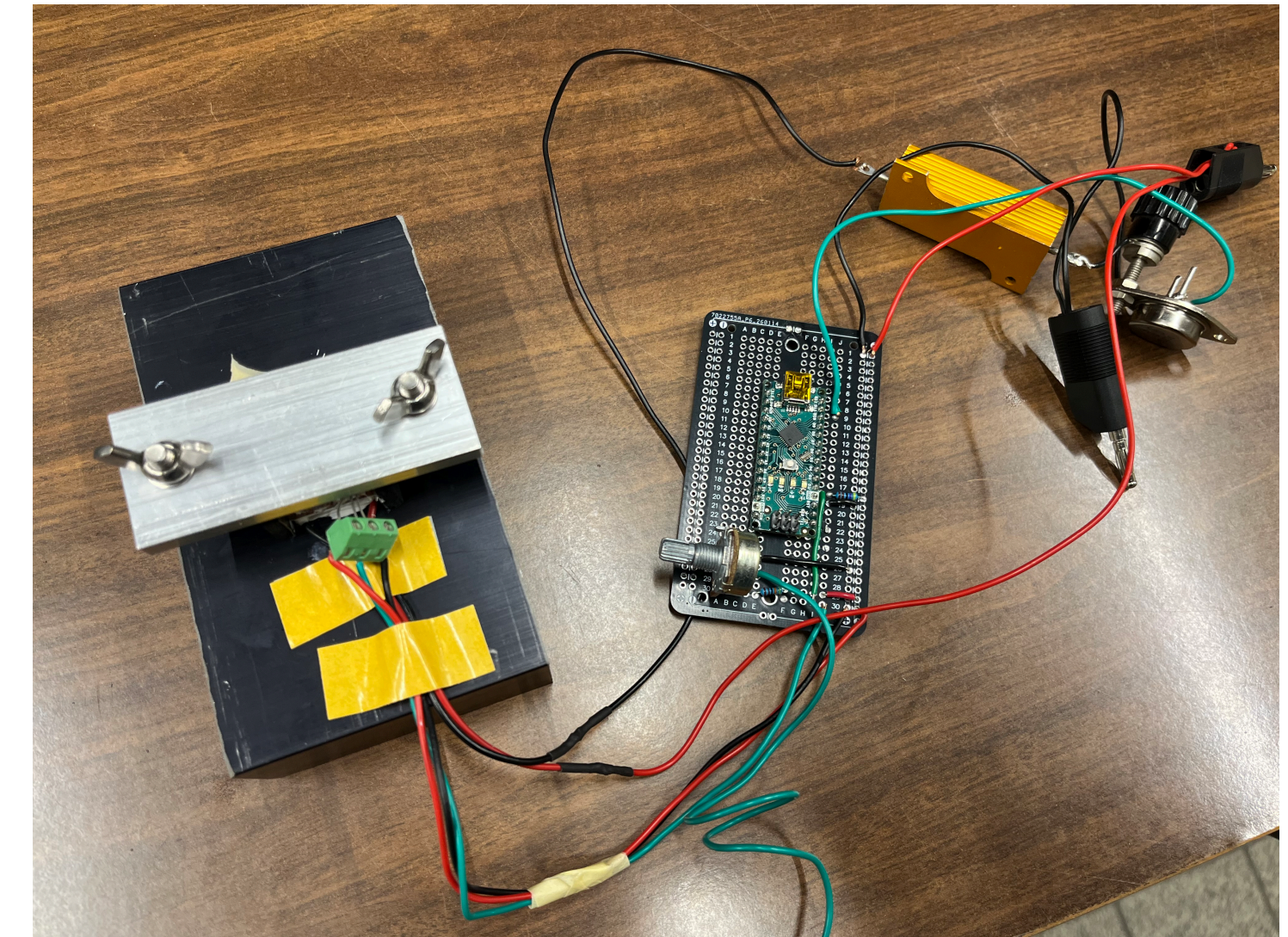
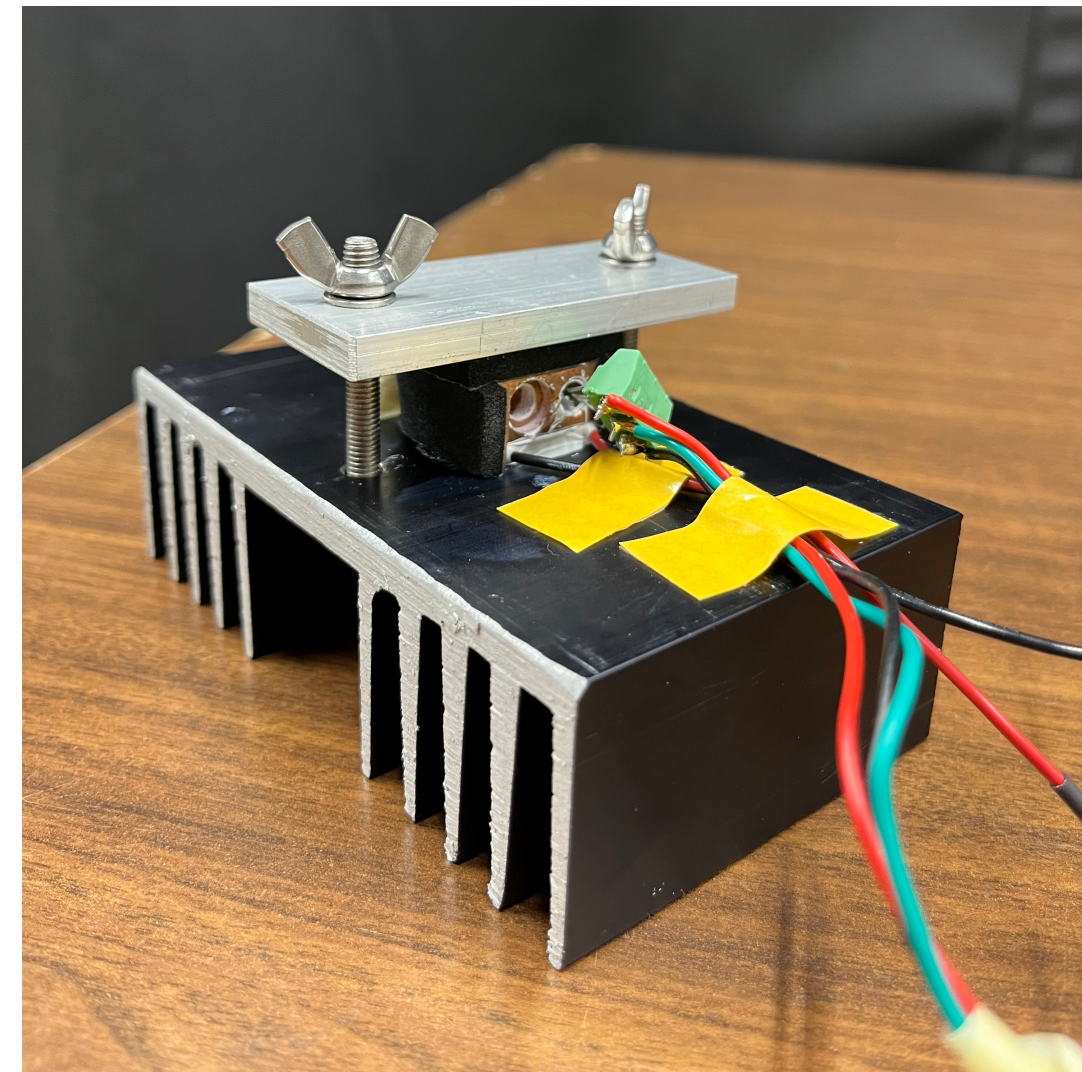
Measurements set-up



Temperature stabilisation system

The set-up will be used to measure the dark noise dependence to the temperature.

A temperature stabilisation system has been implemented using an Arduino and a PID circuit.

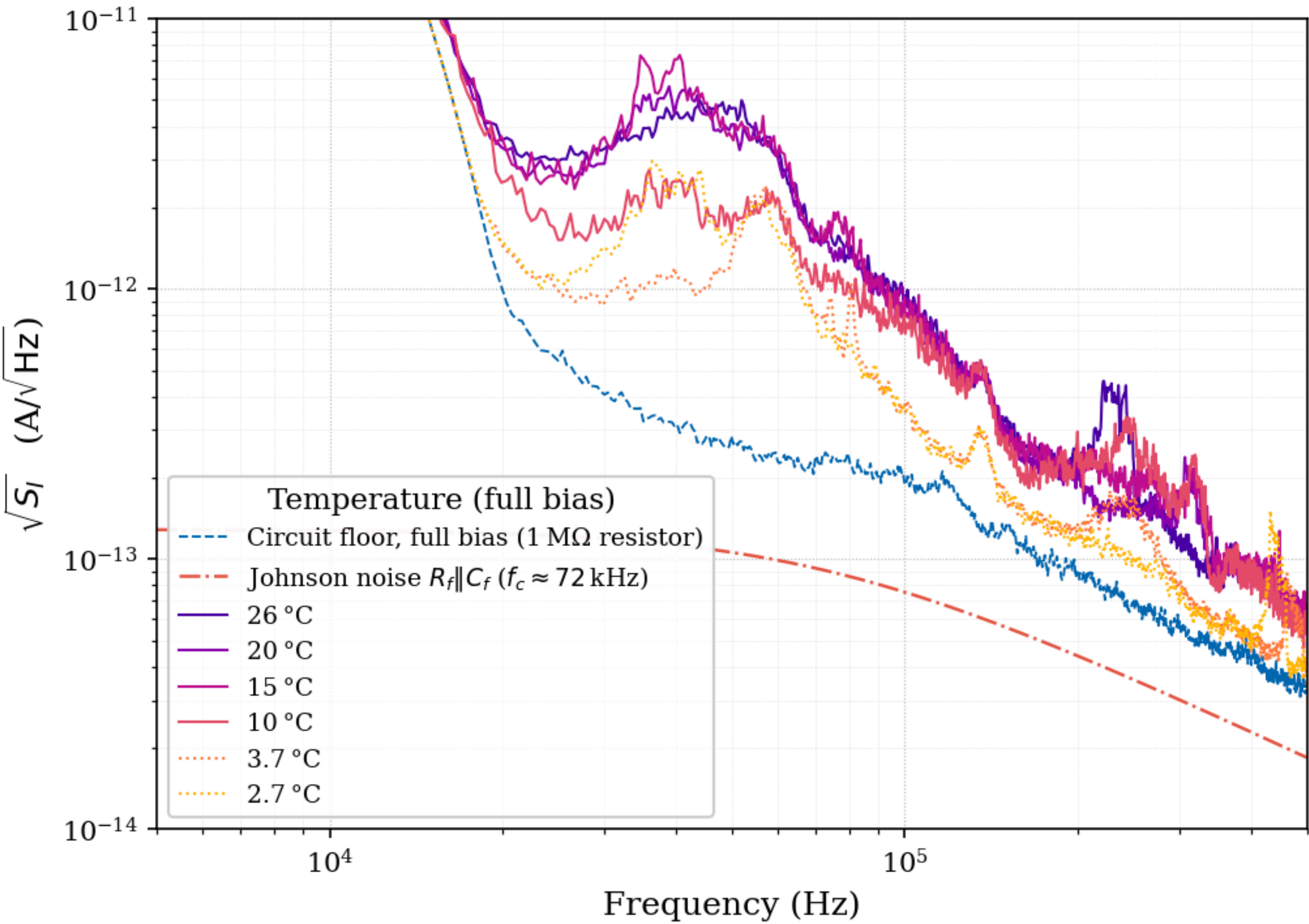
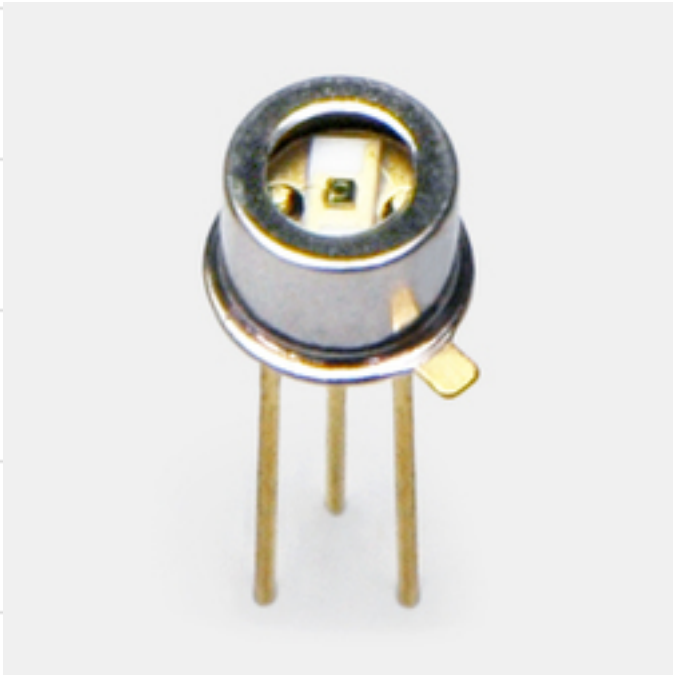


Dark current vs Temperature

Hamamatsu G12183-003K (extended InGaAs)

Specifications

Photosensitive area	φ0.3 mm
Number of elements	1
Package	Metal
Package Category	TO-18
Cooling	Non-cooled
Spectral response range	0.9 to 2.6 μm
Peak sensitivity wavelength (typ.)	2.3 μm
Photosensitivity (typ.)	1.3 A/W
Dark current (max.)	4000 nA

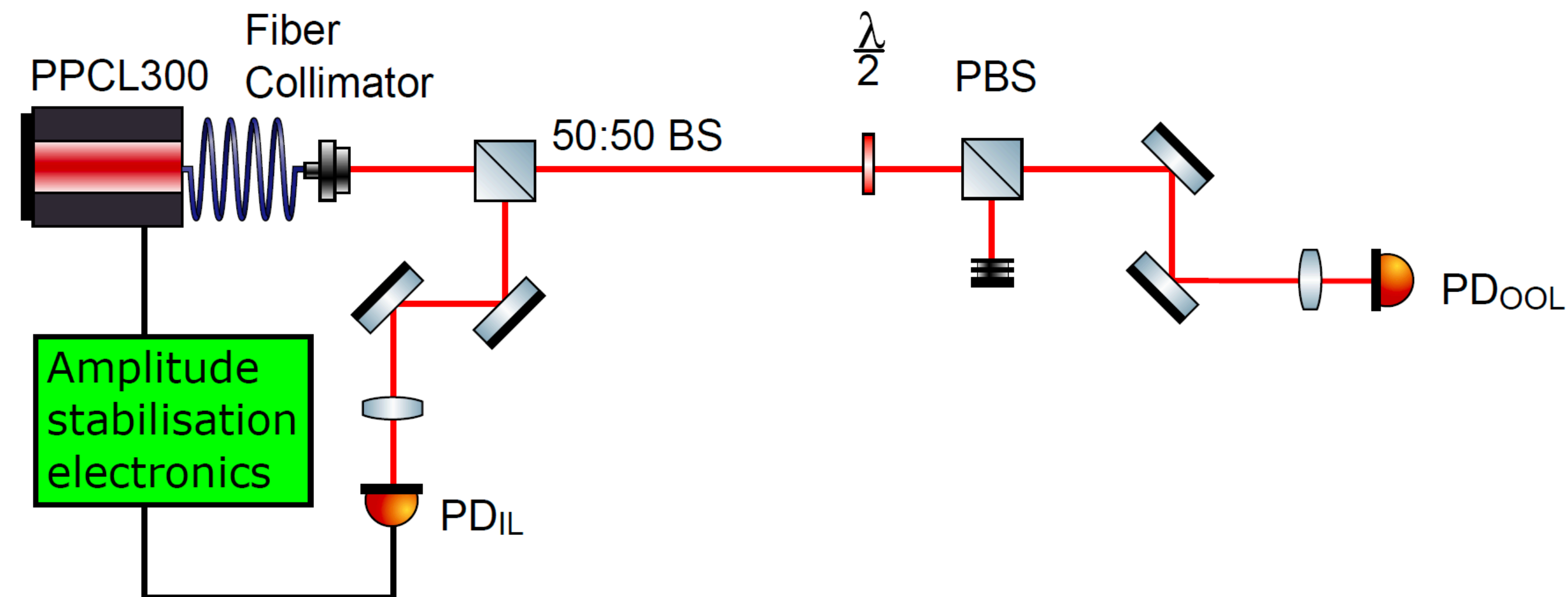


Quantum efficiency measurements

Next step will be the measurements of the quantum efficiency.

The electronics for the amplitude stabilisation system is ready.

Still need to implement the feedback control loop to the laser.



credits: Joseph Briggs, PhD Thesis, University of Glasgow (2021)

Conclusions

- 2 μ m optical lab ready
- The characterisation of commercial photodiodes started
 - Set-up almost ready
 - Preliminary results for dark noise vs temperature
 - Soon we will start with measurements of quantum efficiency
- OMC work will be resumed soon

