4K-MEMS

*Too small to see,*
*Too bright to go unnoticed.*

# Novel emitter technology and microlenses for novel NDIR schemes.

Ross Stanley

4K-MEMS

# 4K-MEMS SA - Introduction

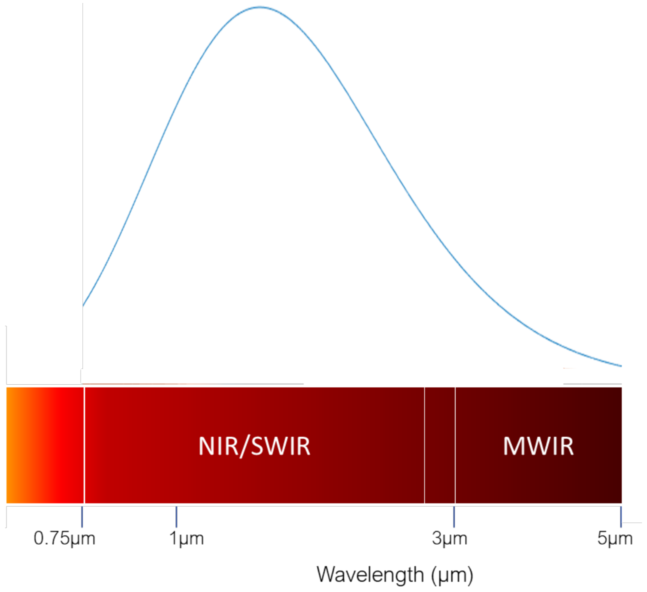


We are a fabless start-up based in Switzerland.

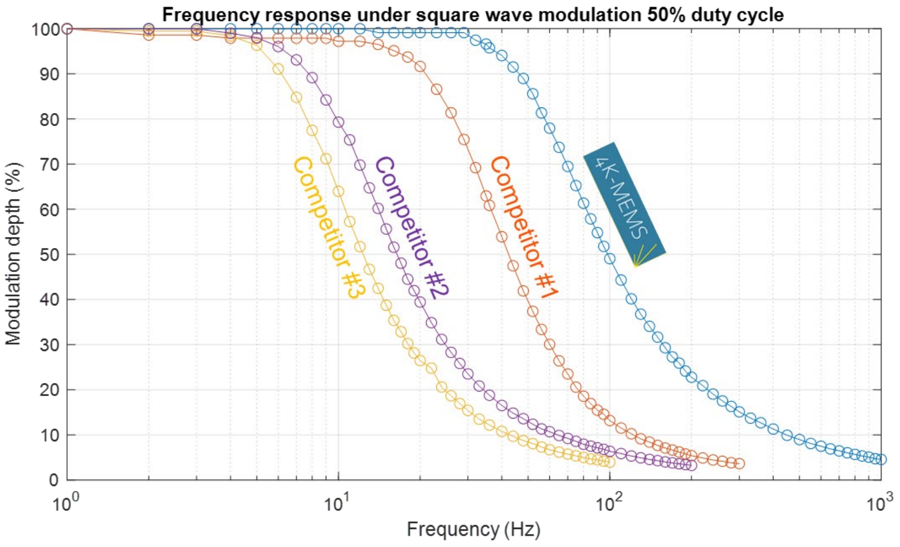
We have developed the smallest, hottest, fastest MEMS thermal emitter in the world.

Small ⇔ 1.4 x 1.4 mm


Hot ⇔ 2100 K




Fast >100 Hz




4K-MEMS is targeting embedded spectroscopy and consumer/automotive gas sensing markets.

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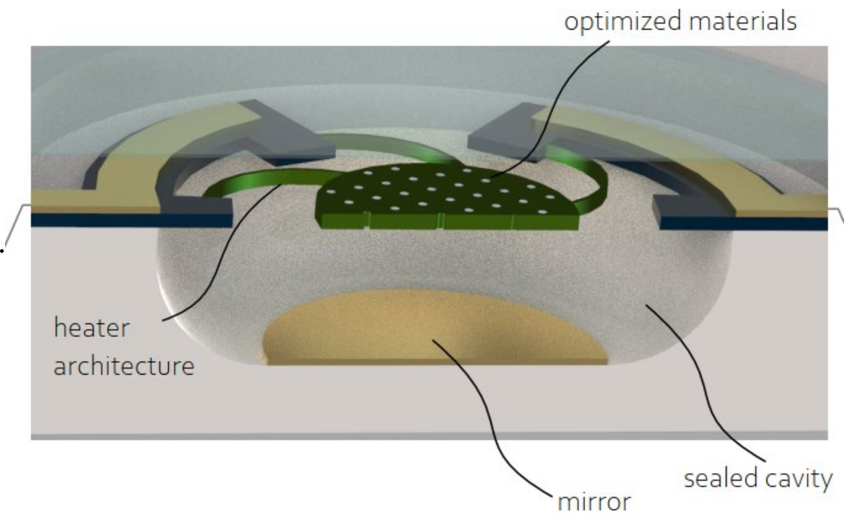
# 4K-MEMS SA - Introduction

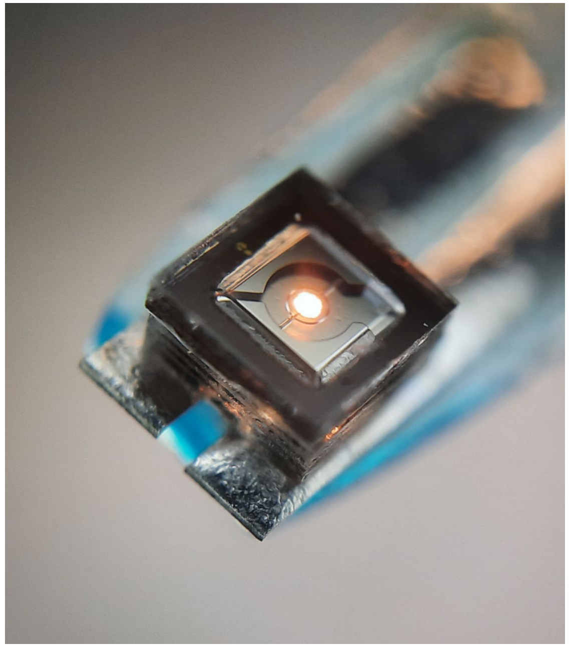


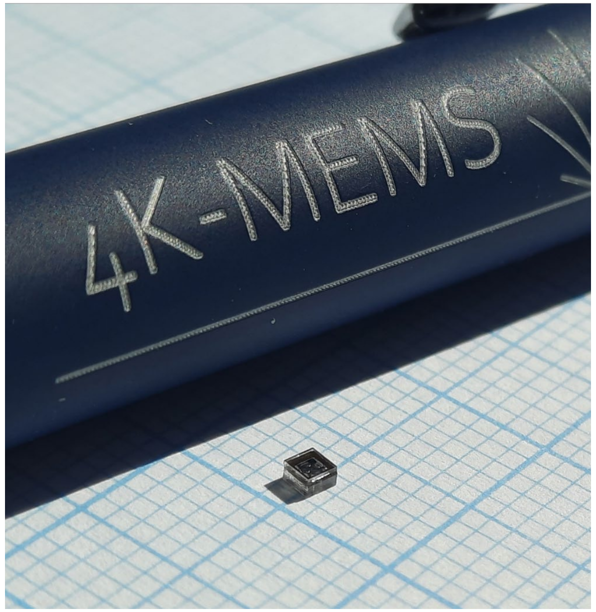



Key challenges had to be overcome:

- How to operate the device at 2100K without buckling.
- How to maintain a uniform temperature across the whole emitting area.
- How to make it using standard MEMS processes.
- How to make waferscale packaging
  so it can be made cheaply at high volumes.

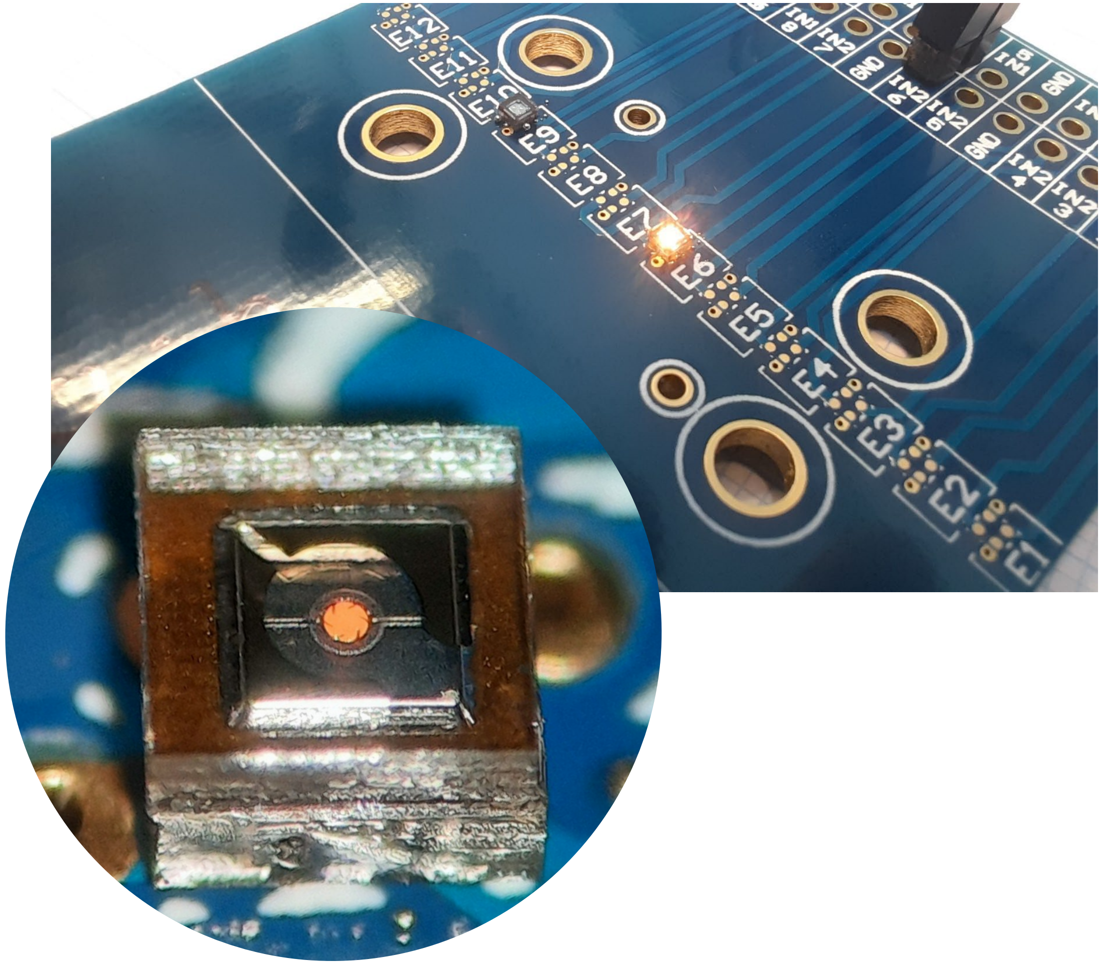
We call it a start on a chip…



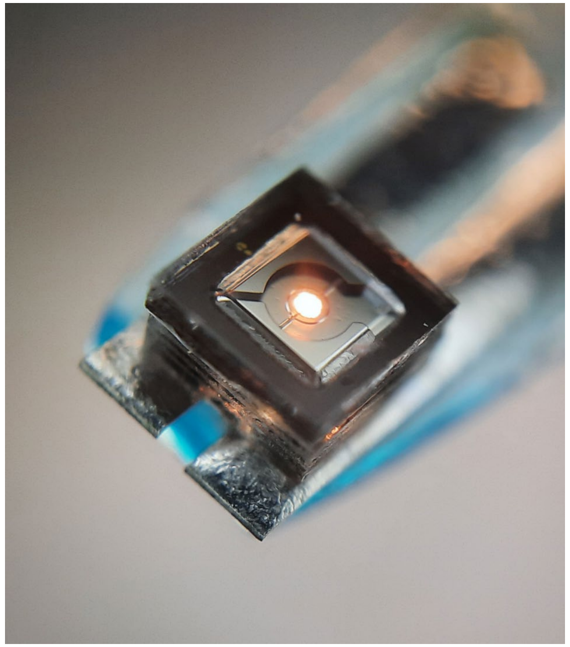


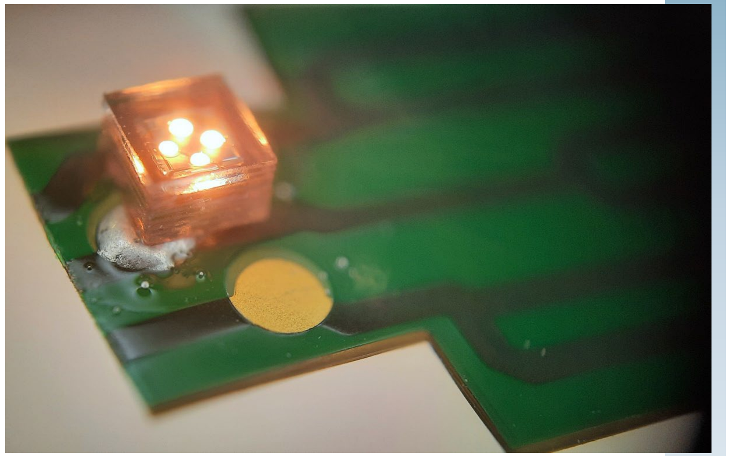
# From Dicing tape to PCB no further packaging steps needed.

Standard PCB




Flex PCB





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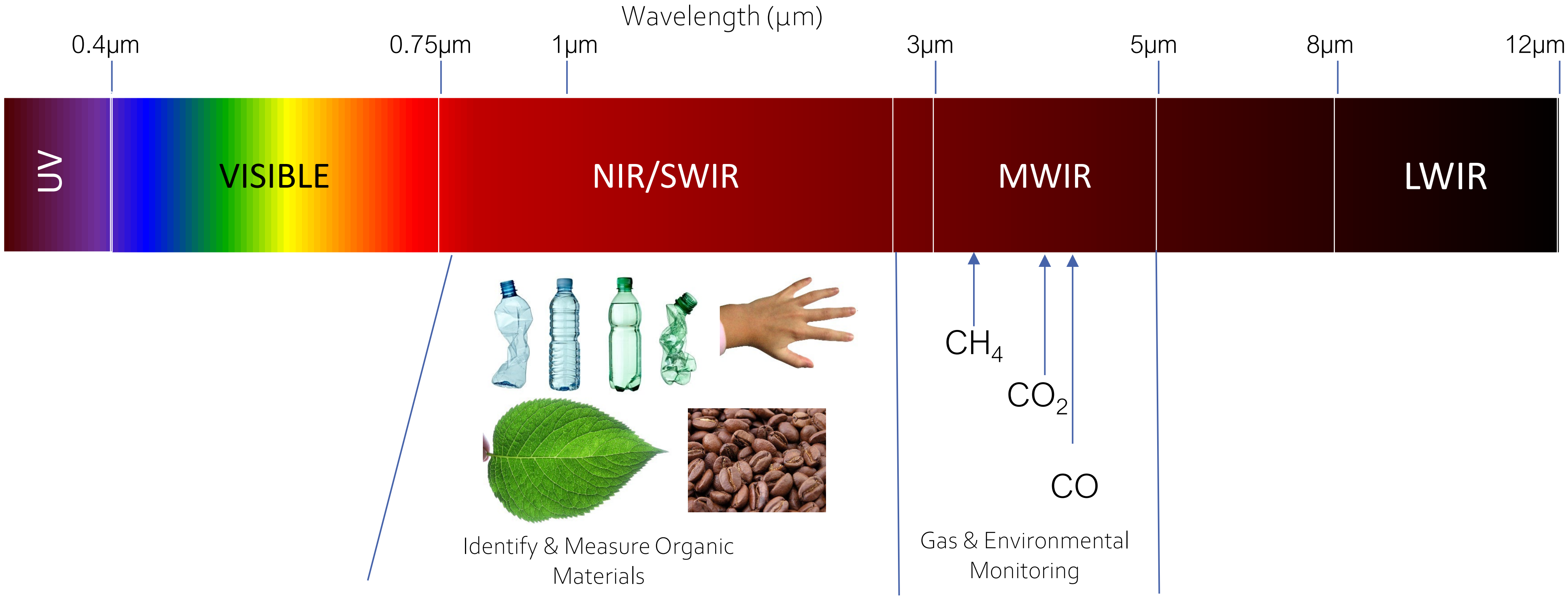
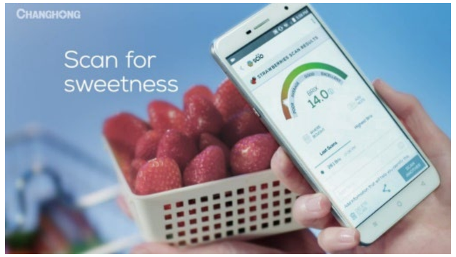
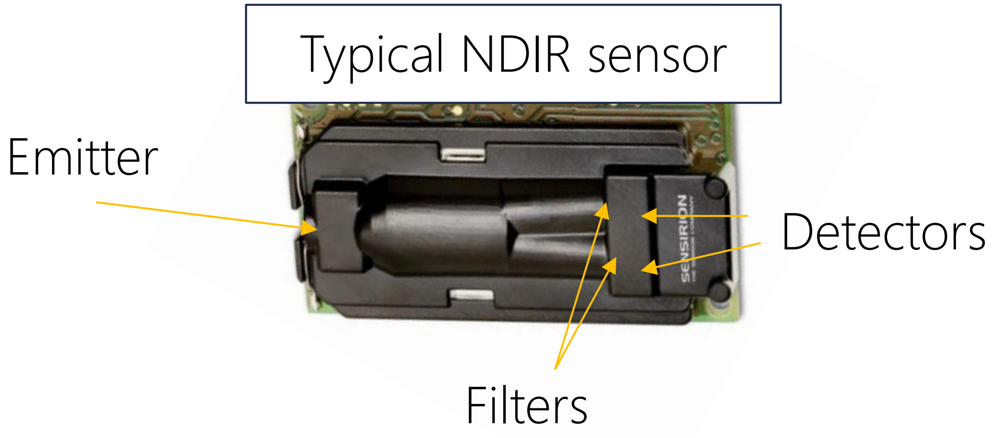
# High temperature (>2000K ) allows us to cover all wavelengths from NIR through SWIR to MWIR

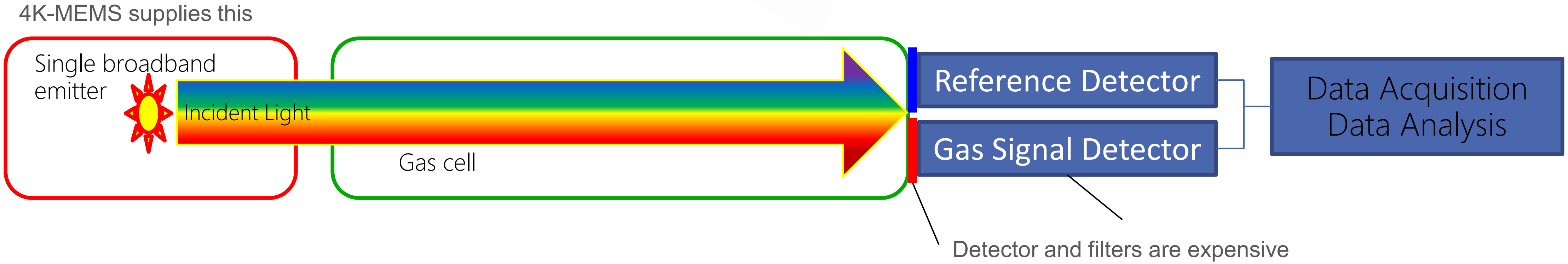



- Health, Diet & Wellness
- Personalized Cosmetics
- Coffee analysis
- Precision farming
- Effective recycling

# Non-dispersive optical gas sensing systems




The reference **detector** checks for changes in the **emitter and drift in the detector (assuming the detectors are very similar)**.
Assumes changes in detector are <u>less</u> than changes in emitter.

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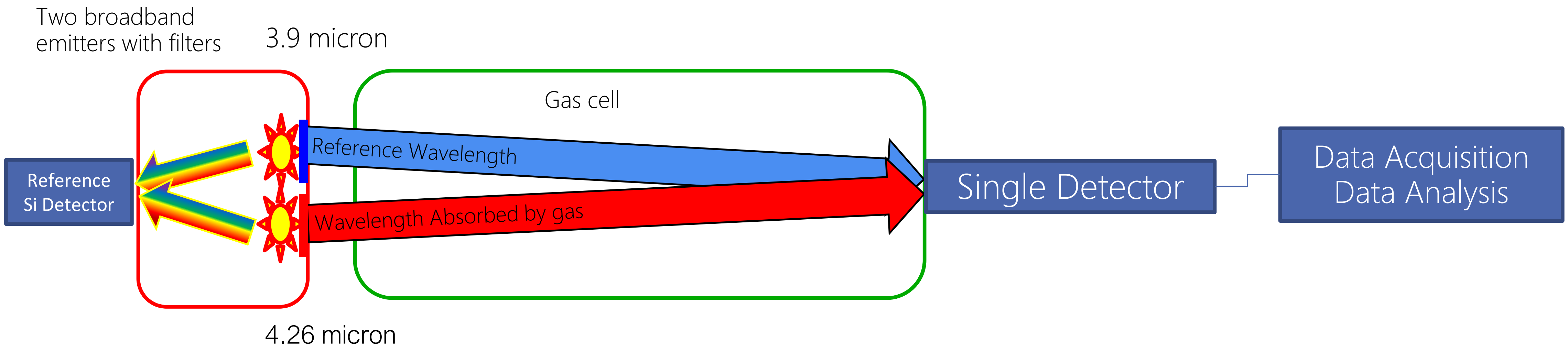
# Novel Geometry: Si-photodiode reference, 2 emitters, 2 filters, single IR detector






The silicon detector checks that the **signal** and **reference** emitter channels are stable and **locked** together.
Single detector so silicon detector drift is eliminated

The reference **emitter** checks for changes in the **detector**.

Single detector for emitter monitoring and single detector for gas monitoring with two channels **eliminates** drift mechanisms.

# Replace reference IR detector with Silicon – advantages

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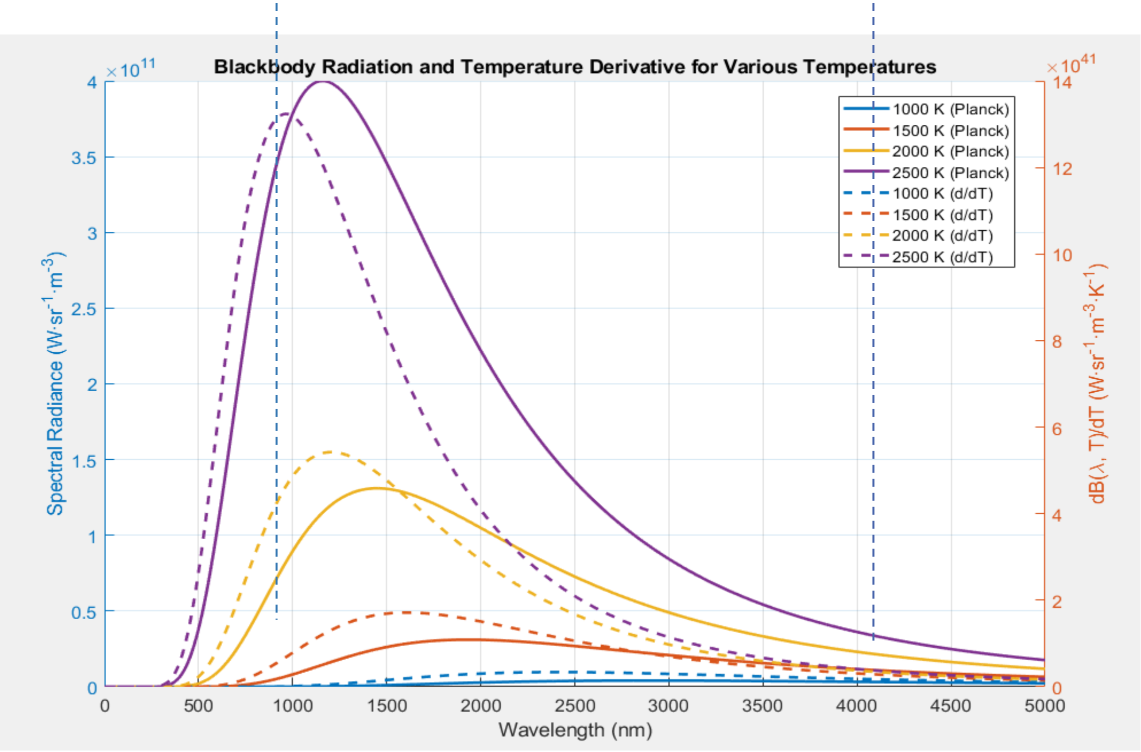
(1) Due to the shape blackbody spectrum at the operating temperature
the sensitivity of the Silicon detector to changes in emitter temperature is much higher than at the sensing wavelengths (3.9 and 4.2 microns).

(2) Silicon detectors are much cheaper than IR detectors

(3) The NEP is much higher so "stray light" can be used – no light wasted on a second detector

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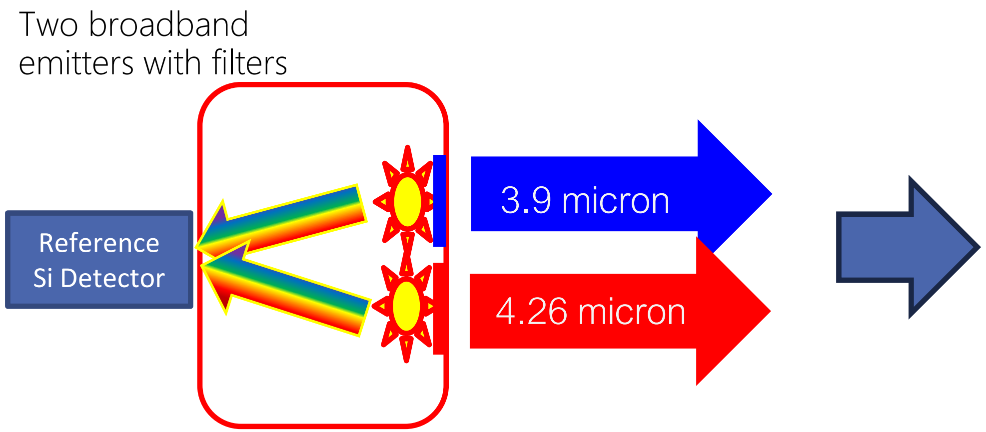
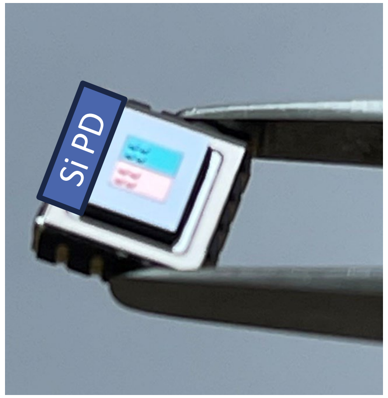
# How to implement it? (with the help of PHABULOuS)



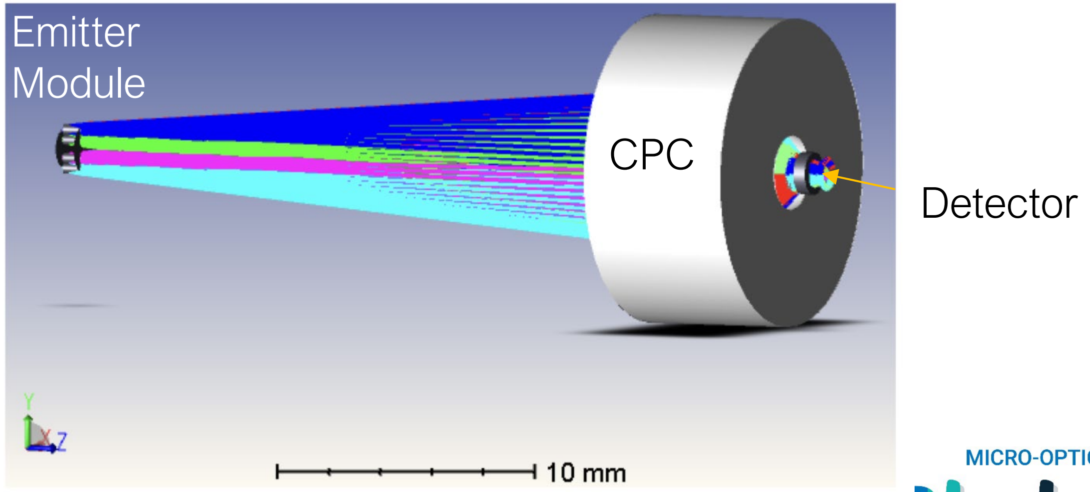



Module with
2 sets of 4 emitters.
2 sets of 4 microlenses
2 IR filters
Silicon Photodiode
(Phabulous Project)

System design:

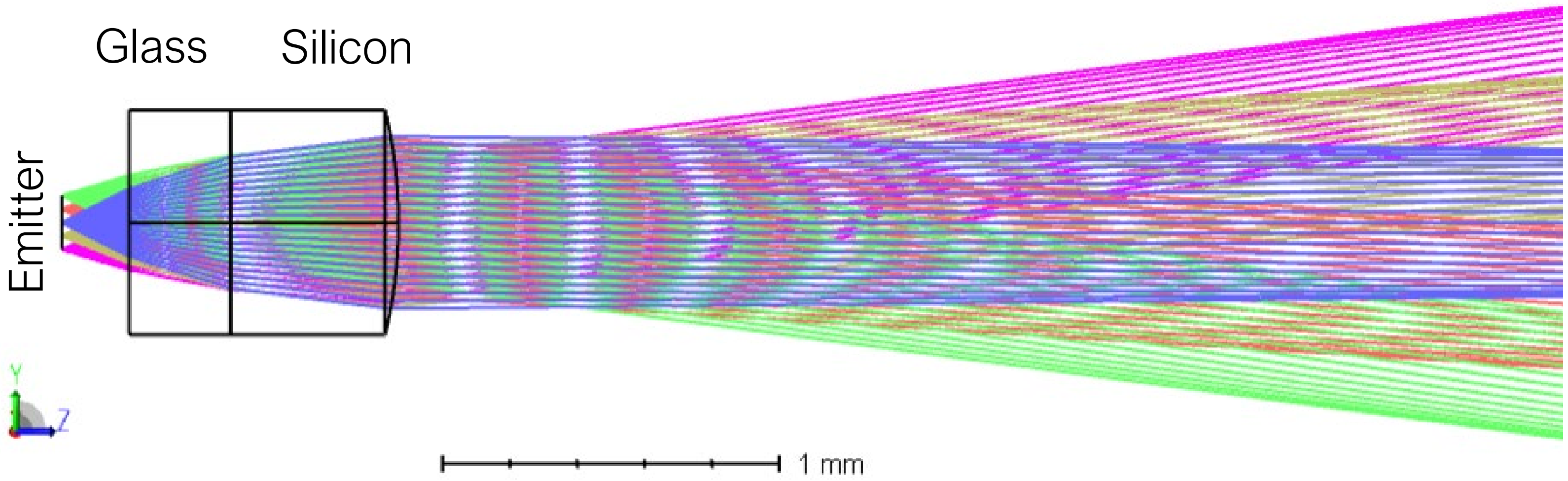
Light collimated by microlenses
Focused onto single detector using CPC



# Microlenses – to beam the light from emitters.



Microlens design diameter 400 microns,, radius of curvature 1.4mm,
EFL = 540 microns.
Divergence for 160 micron diameter emitter = 8°



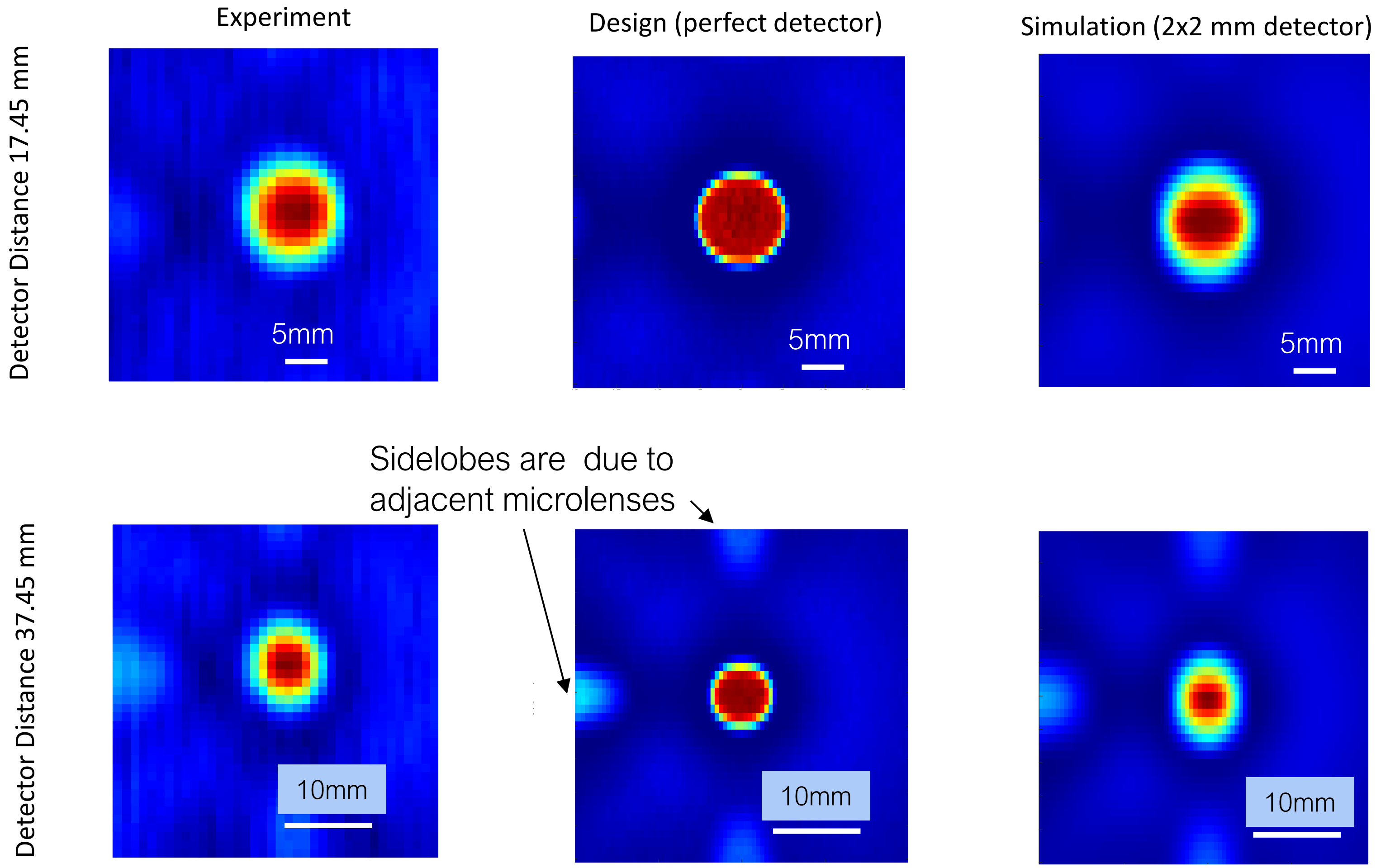

Lenses fabricated by Focuslight SA
Profile of fabricated lenses measured using Zygo white light interferometer ⬄ radius of curvature =1.40 +/- 0.03

# Microlenses – performance compared with design

Microlenses mounted on emitter packages – CSEM SA (Alpnach)

Beam profile measured – CSEM SA (Neuchatel)

Design – 4K-MEMS




Conclusion
Microlenses perform as designed.
Microlenses are well aligned with emitters

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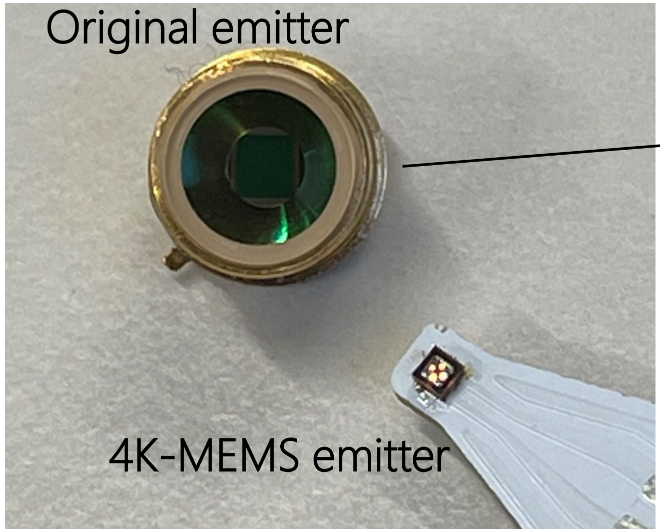
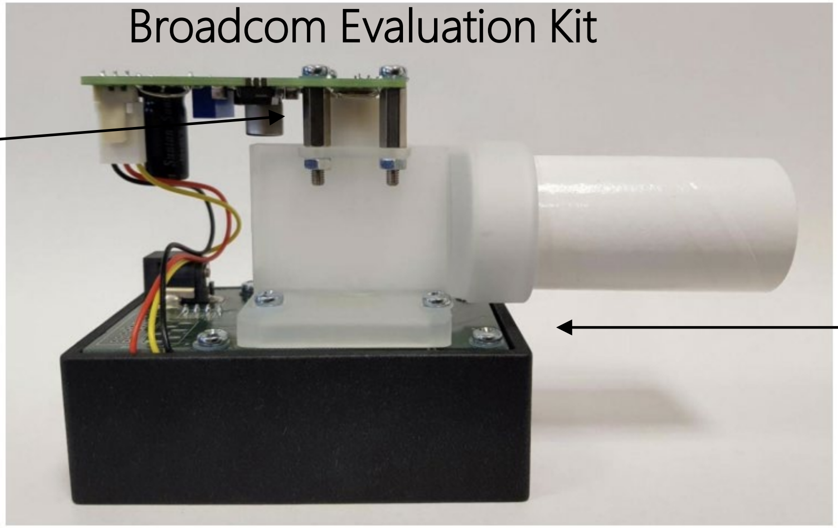
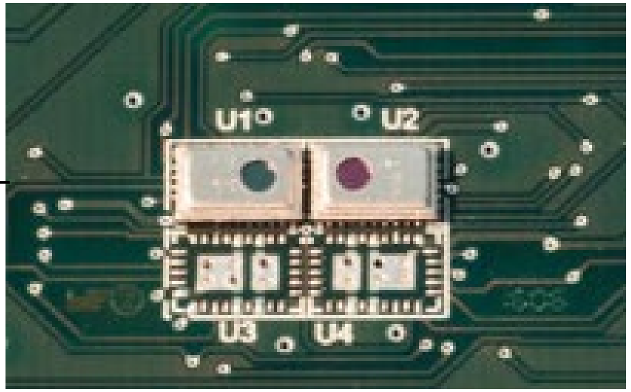
# Baseline : Broadcom evaluation kit.




Broadcom pyroelectric detectors.




The original emitter has an emitting area with a diameter of 3 mm.
4K-MEMS emitters have diameter of 0.16 mm

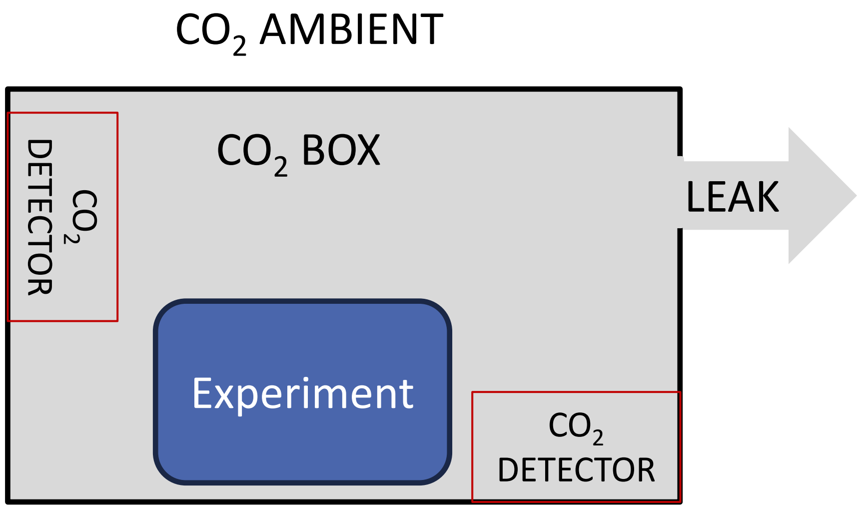
Can we achieve the same performance?

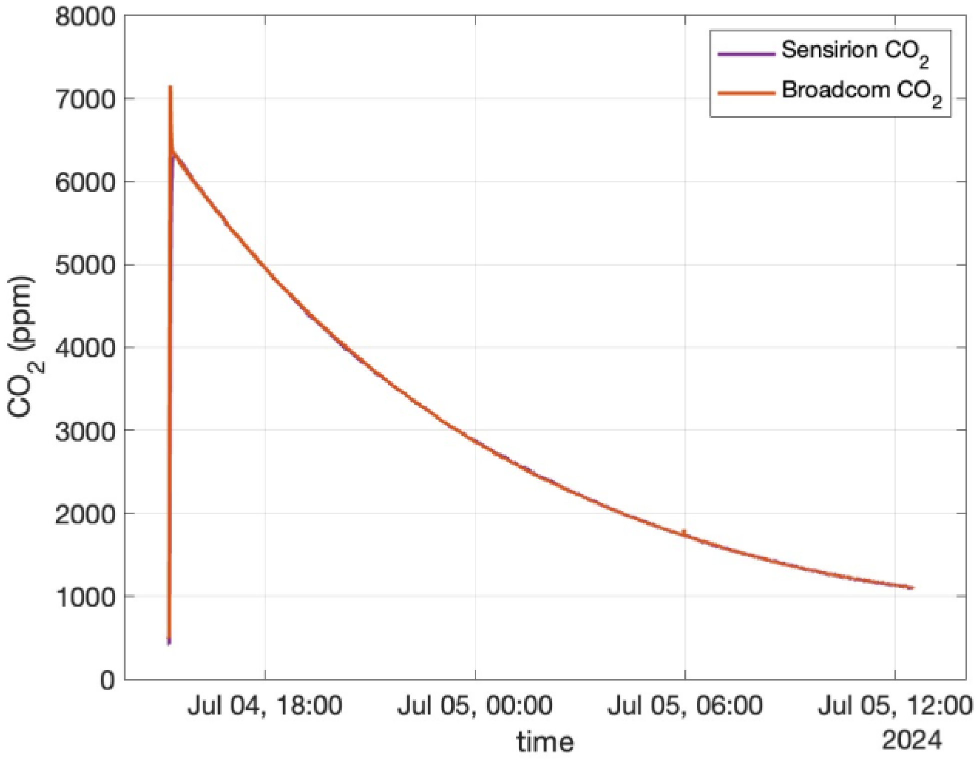
Yes – with intelligent optics and because our emitters are much hotter >2000 K

# Measurement Principle – Leaking box



- Measurement system in a box with a small leak.
- Introduce $CO_2$ and let the box come to equilibrium with the surroundings.
- Sensirion detectors are used to measure $CO_2$ level in box
- Exponential decay of $CO_2$ level to background level with time.

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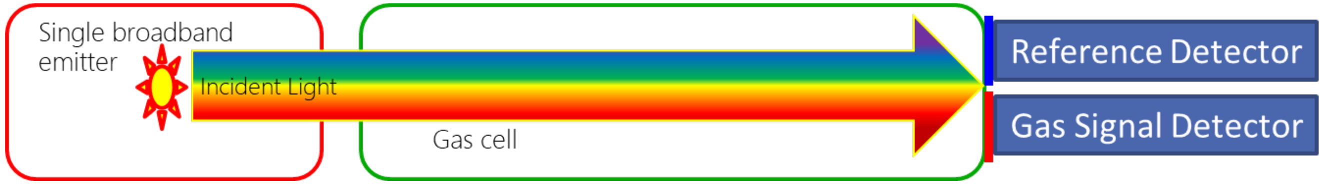
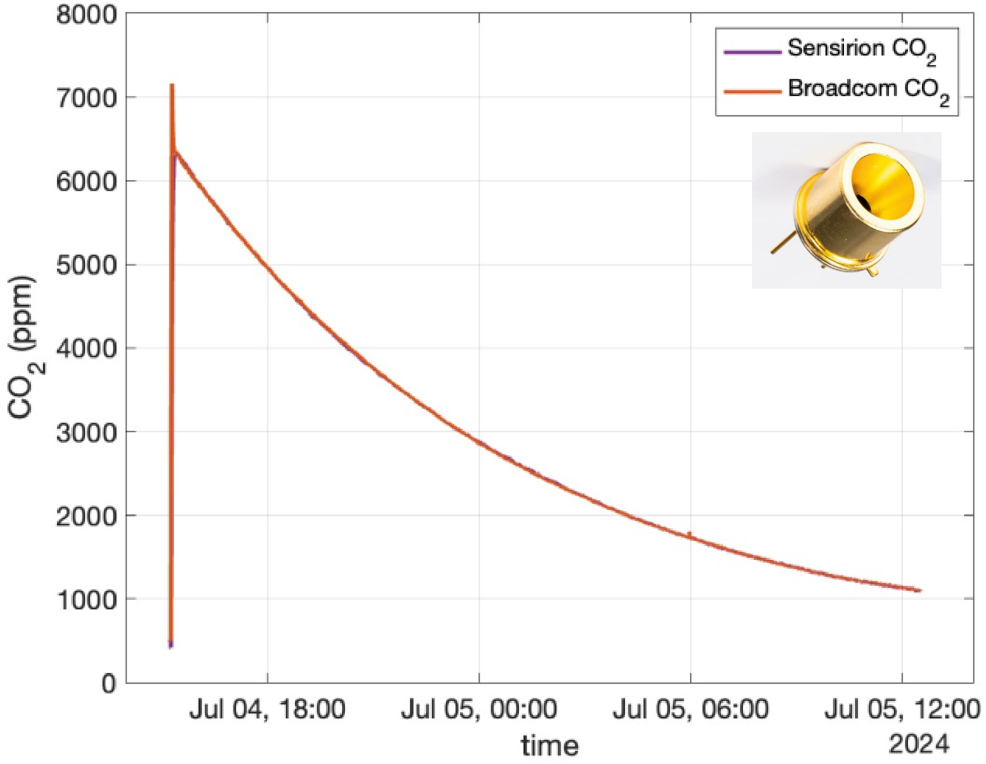
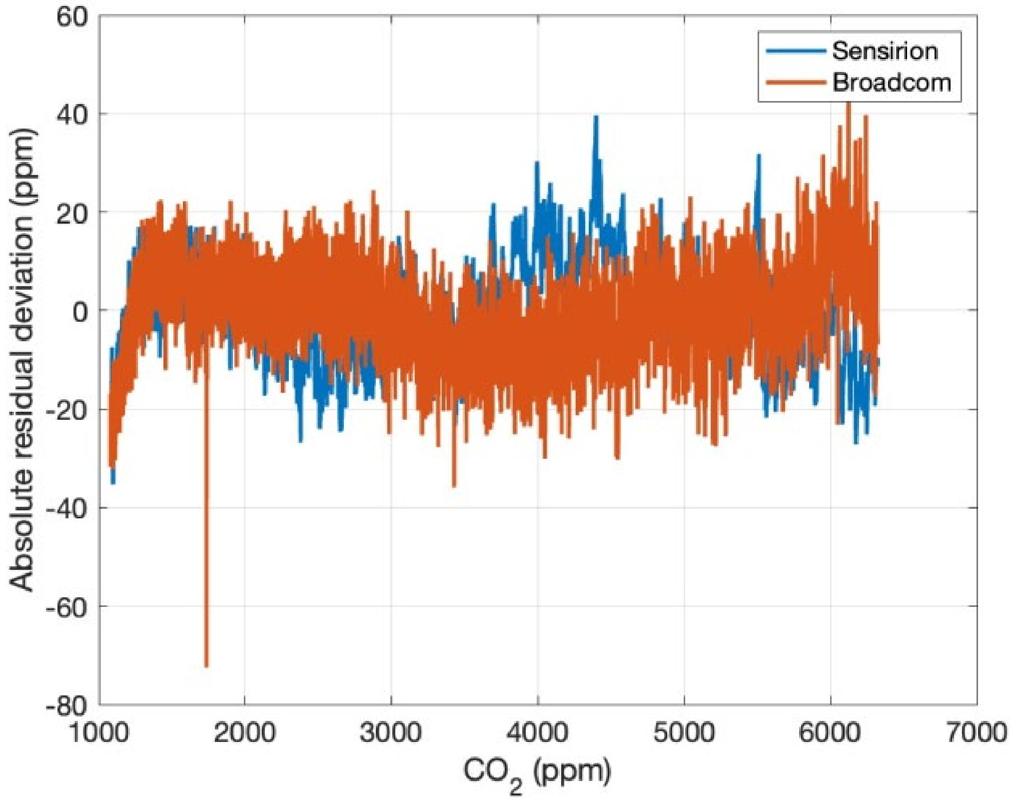
# Baseline – Broadcom System



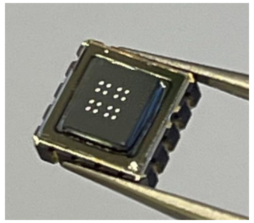


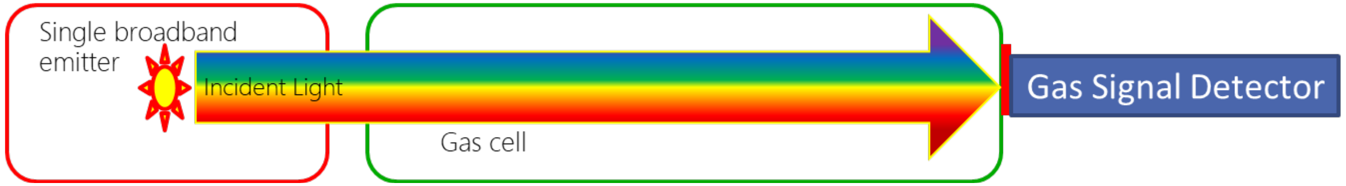



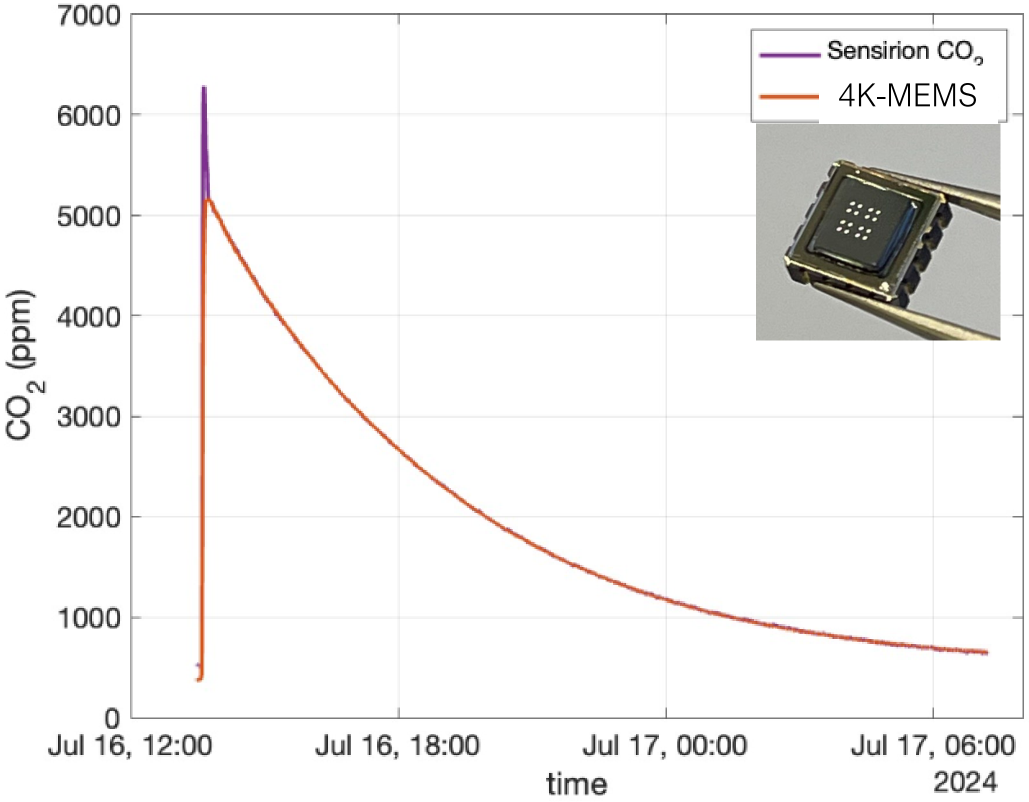



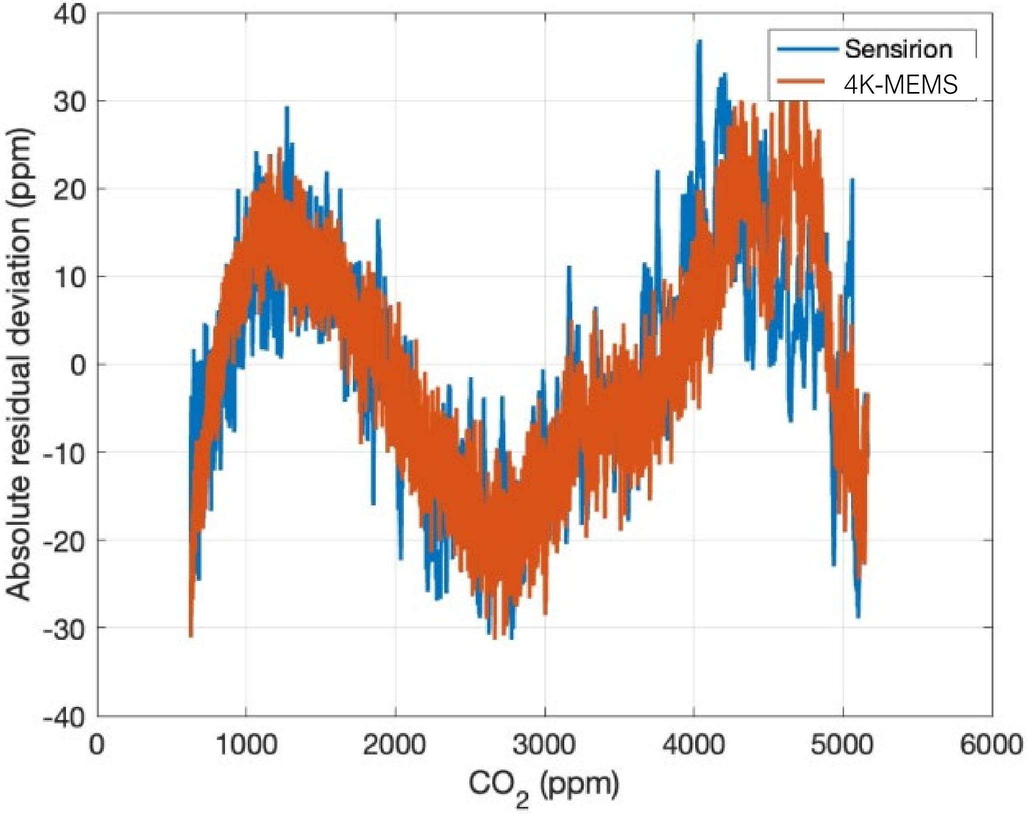
# Results with 4K-MEMS emitter and microlenses





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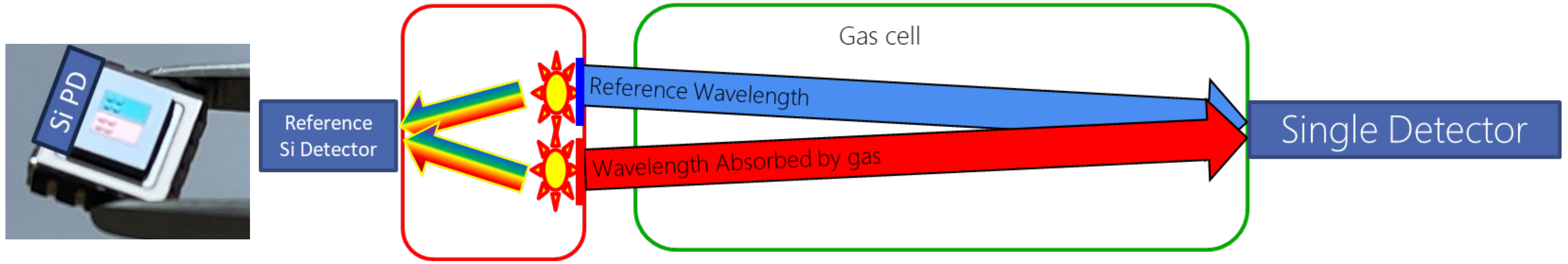
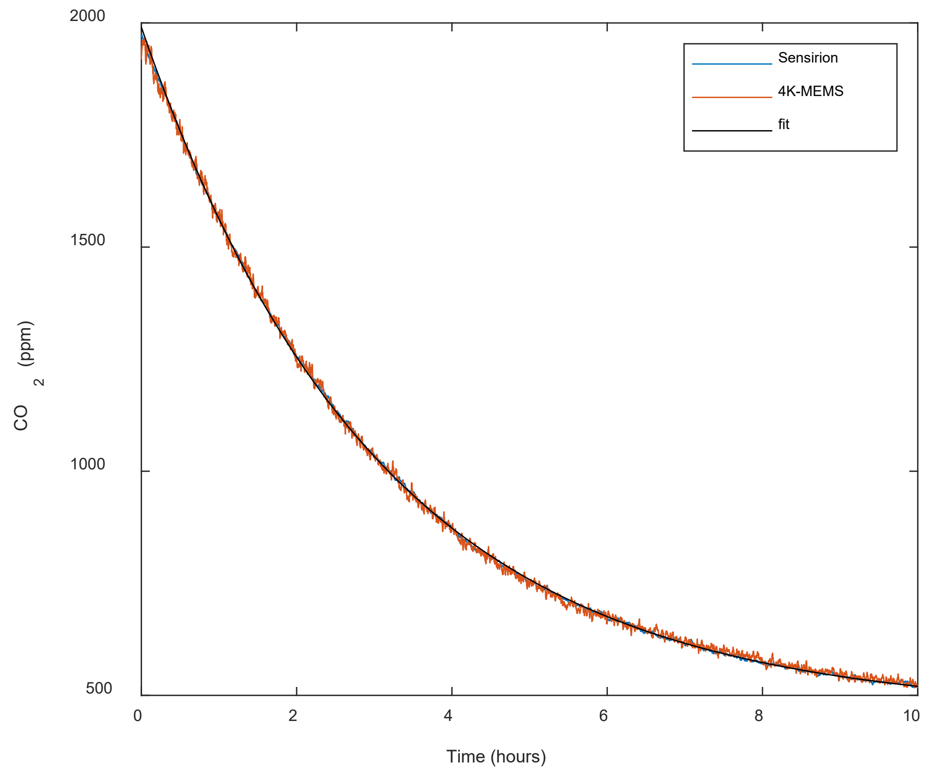
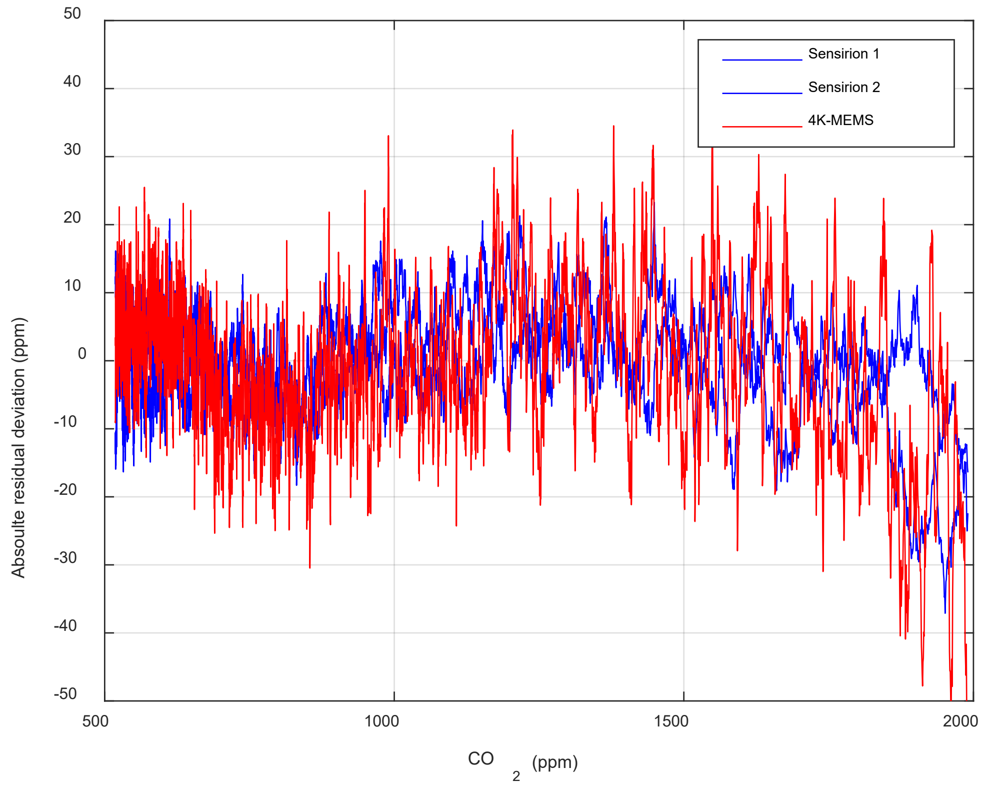
# Results with 4K-MEMS emitter module with microlenses and filters



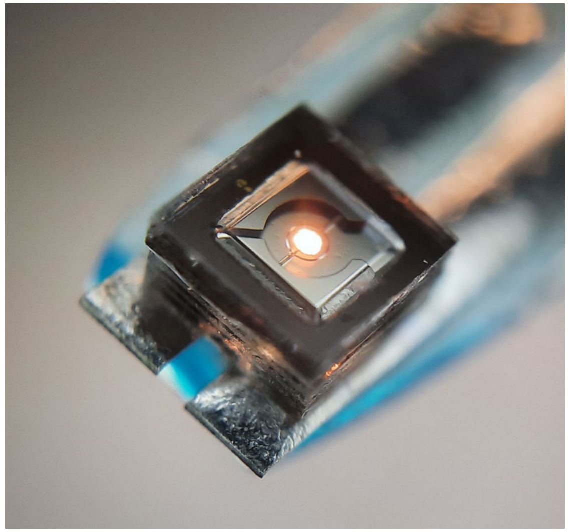

Standard deviation 10ppm

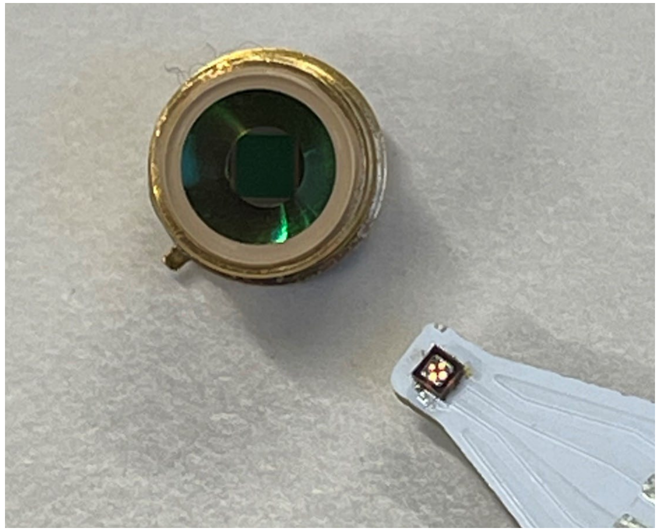
# Conclusion

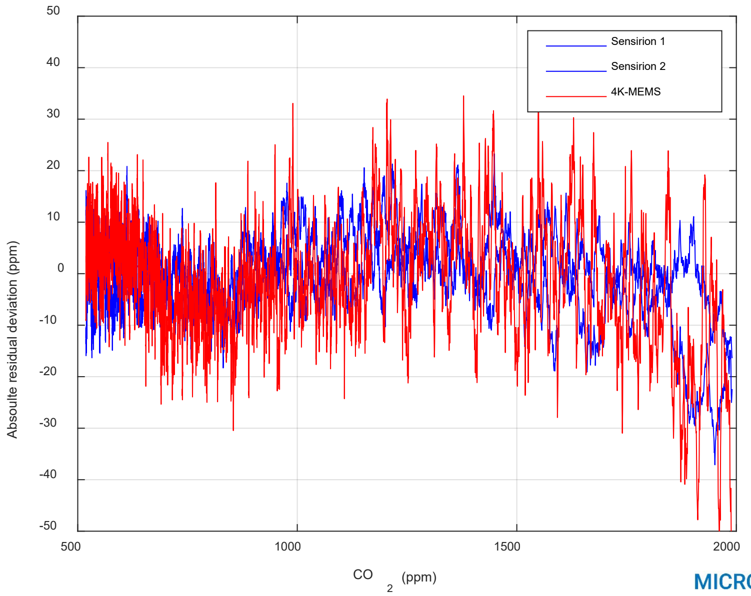


- Novel MEMS thermal emitter for 1-5 microns demonstrated.
- The device can be made wafer scale.
- Very small devices ⇔ allows miniaturization.

- Significant power for $CO_2$ sensing despite the small size.
- Novel NDIR scheme demonstrated by taking advantage of wafer scale manufacture of microlenses and filters.







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