

Senseair





CO₂ Sensors in Smart Phones

- THE ULISSES PROJECT



Live Webinar, Wednesday January 27th, 2021
 Presenters: Henrik Rödjegård and Kristinn Gylfason

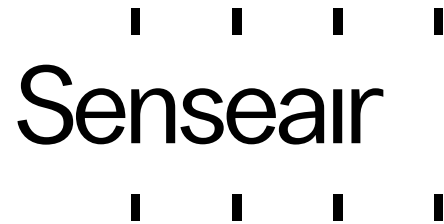


WEBINAR AGENDA

- 01 INTRODUCTION
- 02 WHY WE MEASURE CO₂
- 03 REAL-TIME AIR QUALITY MONITORING
- 04 SENSOR INTEGRATION AND DATA COMMUNICATION (IOT)
- 05 THE MOEMS (MICRO-OPTICS) TECHNOLOGY
- 06 TECHNICAL CHALLENGES
- 07 CURRENT ACHIEVEMENTS AND FUTURE POTENTIALS

 **AIR SENSORS
FOR EVERYONE,
EVERYWHERE**

This webinar is a co-production hosted by:



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825272 (ULISSES).





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MEET ULISSES



THE PROJECT



*Why do we want air sensors
everywhere and accessible to
everyone?*

*Discover the story behind
ULISSES.*



<https://www.ulisses-project.eu/>

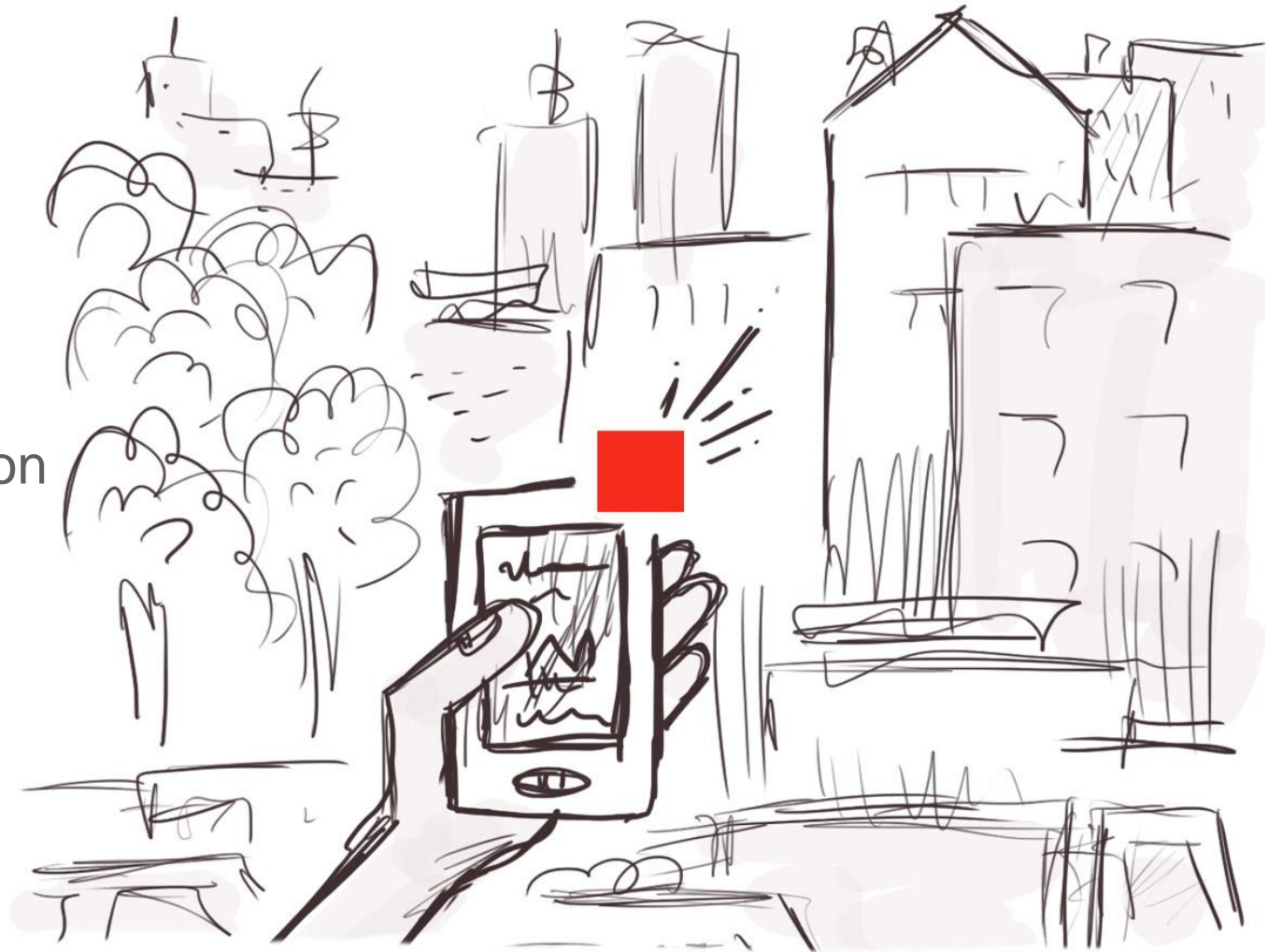
THE VISION

Develop:

- Technology
- Infra structure

for future mass implementation
of sensors for air quality
measurement

■ ■ ■ **AIR SENSORS**
■ ■ ■ **FOR EVERYONE,**
■ ■ ■ **EVERYWHERE**

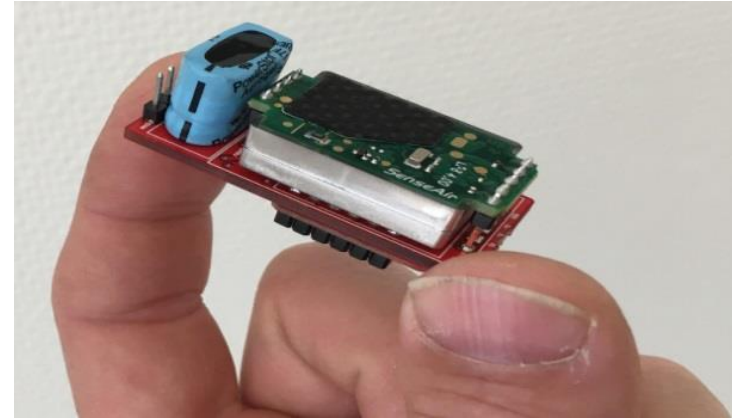


MARYNA RAZAKHATSKAYA



<https://www.creativetechnologist.london/mohair>

MARYNA RAZAKHATSKAYA

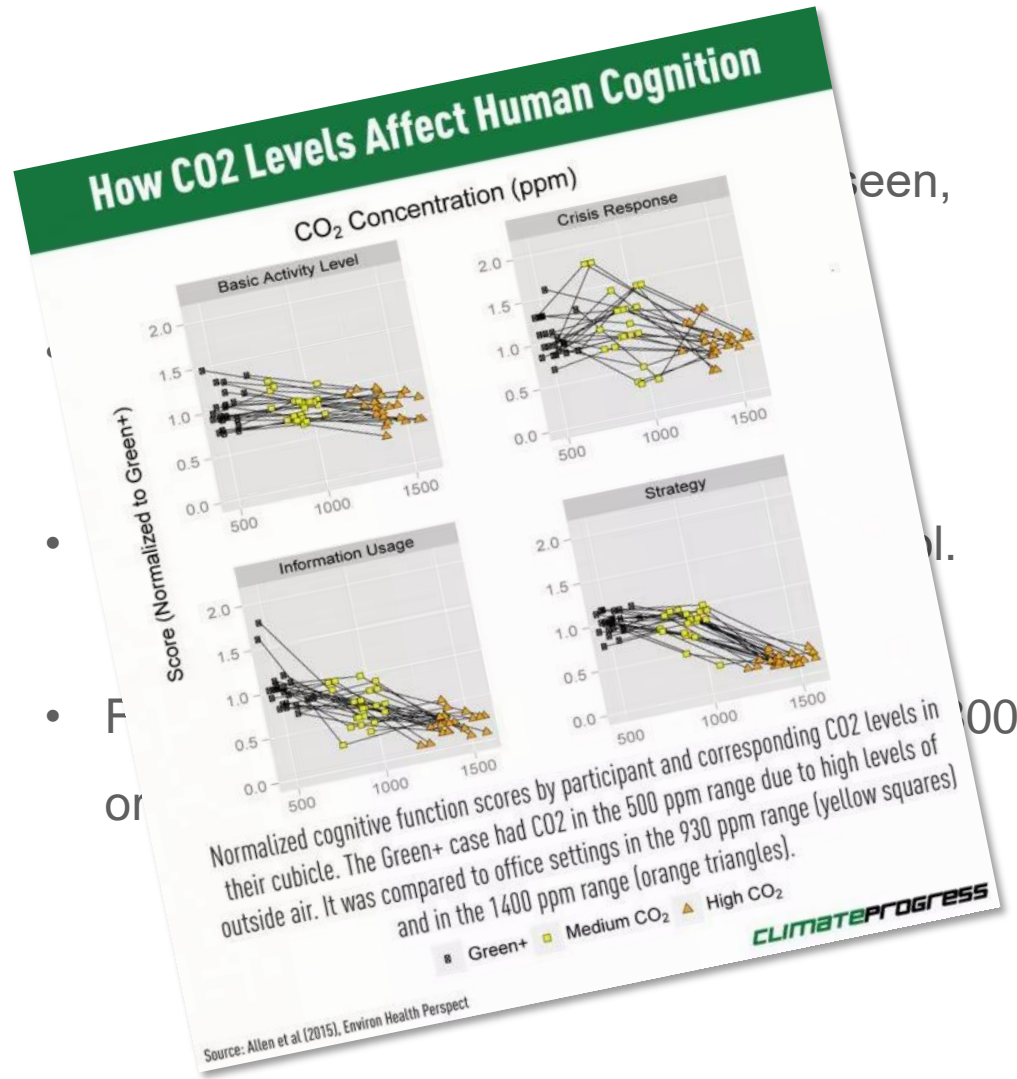


WHY WE MEASURE CO₂

- Many of the air pollutants can't be seen, smelled or sensed by humans.
- Poor Indoor Air Quality (IAQ) effects wellbeing, health and productivity.
- Perfect parameter for ventilation control.
- Fresh air is 400 ppm and indoors up to 800 or 1000 ppm is considered OK.



WHY WE MEASURE CO₂



WHY WE MEASURE CO₂

CO₂ Levels Affect Human Cognition

Journal of Exposure Science & Environmental Epidemiology
<https://doi.org/10.1038/s41370-018-0055-8>

ARTICLE

Airplane pilot flight performance on 21 maneuvers in a flight simulator under varying carbon dioxide concentrations

Joseph G. Allen¹ · Piers MacNaughton¹ · Jose Guillermo Cedeno-Laurent¹ · Xiaodong Cao¹ · Skye Flanigan¹ · Jose Vallarino¹ · Francisco Rueda² · Deborah Donnelly-McLay¹ · John D. Spengler¹

Received: 31 October 2017 / Revised: 14 May 2018 / Accepted: 15 June 2018
© Springer Nature America, Inc. 2018

Abstract

Background Recent studies suggest that carbon dioxide has an impact on cognitive function performance of office workers at concentrations previously thought to be benign (1000–2500 ppm). The only available data for CO₂ on the flight deck indicate that the average CO₂ concentrations are typically <1000 ppm, but the 95th percentile concentration can be as high as 1400 ppm, depending on airplane type.

Methods We recruited 30 active commercial airline pilots to fly three 3-h flight segments in an FAA-approved flight simulator with each segment at a different CO₂ concentration on the flight deck (700, 1500, 2500 ppm). CO₂ concentrations were modified by introducing ultra-pure CO₂ into the simulator; ventilation rates remained the same for each segment. The pilots performed a range of predefined maneuvers of varying difficulty without the aid of autopilot, and were assessed by a FAA Designated Pilot Examiner according to FAA Practical Test Standards. Pilots and the Examiner were blinded to test conditions and the order of exposures was randomized.

Results Compared to segments at a CO₂ concentration of 2500 ppm, the odds of passing a maneuver as rated by the Examiner in the simulator were 1.52 (95% CI: 1.02–2.25) times higher when pilots were exposed to 1500 ppm and 1.69 (95% CI: 1.11–2.55) times higher when exposed to 700 ppm, controlling for maneuver difficulty, Examiner and order of maneuvers.

Source: Allen et al (2018), Environ Health Perspect



WHY WE MEASURE CO₂

The collage features three main elements:

- Smartphone App Interface:** A mobile application titled "Aercast" showing various environmental metrics:
 - Senseair index: 8%
 - Carbon Dioxide: 1803 ppm
 - Temperature: 25,2 °C
 - Relative Humidity: 35%
 - Air pressure: 762 hPa
 - VOC
 - PM 2.5The bottom navigation bar includes "Dashboard", "Graphs", and "Settings".
- Scientific Article Snippet:** A snippet from the "Journal of Exposure and Health" titled "Airplane pilot simulator un...". The authors listed are Joseph G. Allen¹, Pie... and Jose Vallarino¹, Franc... The article was received on 31 October 2017. The abstract discusses recent studies on CO₂ concentrations in airplane simulators.
- Newspaper Clipping:** A clipping from "PROGRESS" discussing office workers and flight deck CO₂ levels, mentioning that concentrations can be as high as 1,690 ppm.



WHY WE MEASURE CO₂

nature sustainability

52 %

tion

REVIEW ARTICLE
<https://doi.org/10.1038/s41893-019-0323-1>

Journal of Experimental Psychology
<https://doi.org/>

ARTICLE

Direct human health risks of increased atmospheric carbon dioxide

Tyler A. Jacobson¹, Jasdeep S. Kler², Michael T. Hernke^{3,4*}, Rudolf K. Braun⁵, Keith C. Meyer⁶ and William E. Funk¹

Airplane simulation

Joseph G. Jose Vallab

Received: 31 October 2018
© Springer

Abstract

Recent data show an increasing trend in serum bicarbonate, indicative of CO₂ stored in the body, among the general US population¹. This increase—from 23.7 mmol l⁻¹ in 2000 to 25.2 mmol l⁻¹ in 2012—may reflect increased environmental exposure to CO₂ (refs. 1,2). Climate change is recognized as a substantial threat to human health^{3,4}. However, few studies have focused on the direct human health effects of increasing exposure to CO₂. The authors of a 2011 Institute of Medicine report acknowledged that studies investigating health risks of chronic or intermittent exposures to elevated CO₂ (below 5,000 ppm) are lacking for the young, the elderly, and the infirm⁵. Atmospheric CO₂ concentrations were therefore not be adapted to chronic or intermittent exposures to elevated CO₂. According to projections from the IPCC (Representative Concentration Pathways: RCPs), atmospheric CO₂ concentrations may increase from approximately 400 to 670 ppm (under RCP 6.0) or 936 ppm (under RCP 8.5) by the end of the century⁶. Mounting evidence suggests that human exposure to CO₂ is higher than previously realized, and that multiple factors are increasing this exposure. Health effects from CO₂ exposure are also being observed at concentrations lower than expected. The potential for these two trends to intersect is the purpose of this Review, providing two aims:

- To summarize the factors increasing human exposure to CO₂ and the frequency, duration and magnitude of possible adverse exposure.

Growing evidence suggests that environmentally relevant elevations in CO₂ (<5,000 ppm) may pose direct risks for human health. Increasing atmospheric CO₂ concentrations could make adverse exposures more frequent and prolonged through increases in indoor air concentrations and increased time spent indoors. We review preliminary evidence concerning the potential health risks of chronic exposure to environmentally relevant elevations in ambient CO₂, including inflammation, reductions in higher-level cognitive abilities, bone demineralization, kidney calcification, oxidative stress and endothelial dysfunction. This early evidence indicates potential health risks at CO₂ exposures as low as 1,000 ppm—a threshold that is already exceeded in many indoor environments with increased room occupancy and reduced building ventilation rates, and equivalent to some estimates for urban outdoor air concentrations before 2100. Continuous exposure to increased atmospheric CO₂ could be an overlooked stressor of the modern and/or future environment. Further research is needed to quantify the major sources of CO₂ exposure, to identify mitigation strategies to avoid adverse health effects and protect vulnerable populations, and to fully understand the potential health effects of chronic or intermittent exposure to indoor air with higher CO₂ concentrations.

design of adaptation and mitigation strategies to avoid potential adverse health effects.

We synthesize information from disparate fields such as physiology, immunology, cognitive psychology, environmental health and building engineering. Although there are few independent replicates of these findings, we highlight key patterns and gaps, and recommend promising avenues of future research. For our second aim, we systematically searched PubMed, the Web of Science and PsychINFO for studies that met predetermined inclusion criteria (Fig. 1). We screened the abstracts of all identified studies and read the full-text articles if appropriate. More articles were identified by reviewing the reference lists of relevant studies (see more details in the Supplementary Information). Key metrics were extracted from studies that met the inclusion criteria and are highlighted in the qualitative synthesis (Tables 2 and 3). To meet our inclusion criteria, model health effects of artificially raised ambient CO₂ at realistic CO₂ through statistical or methodological controls; or (3) employ animal models that used metabolically generated CO₂, if the authors implied that CO₂ had direct health effects.

Increased human exposure to CO₂

This section surveys the major sources of human exposure to CO₂ and the factors likely to increase it. Following studies that demonstrate direct effects of CO₂ on human cognitive performance and



WHY WE MEASURE CO₂

The collage features several overlapping elements:

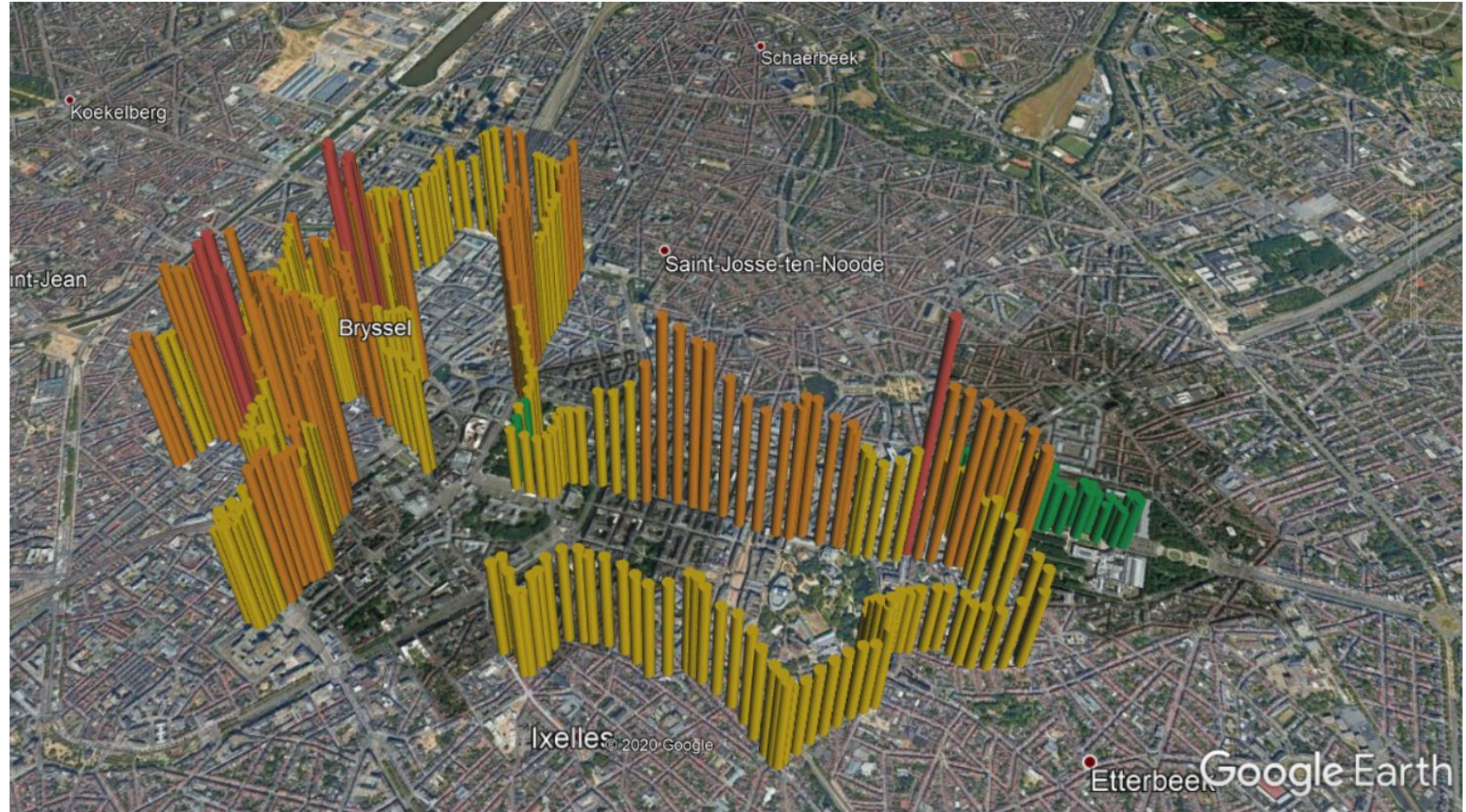
- Smartphone Dashboard:** A central smartphone screen displays a 'Senseair index' of 22%. Below it are six circular widgets: Carbon Dioxide (1460 ppm), Temperature (22 °C), Relative Humidity (42%), Air pressure (987 hPa), VOC, and PM 2.5. The bottom navigation bar includes 'Dashboard', 'Graphs', and 'Settings'.
- Scientific Article:** A 'REVIEW ARTICLE' snippet with a DOI link: <https://doi.org/10.1038/s41893-019-0323-1>. The authors listed are K. Braun⁵ and Keith C. Meyer⁶. The text discusses risks for human health related to CO₂ concentrations.
- Newspaper Clipping:** A snippet from the 'Journal of Experimental Psychology' titled 'Airplane simulator' by Joseph G. and Jose Valla. It discusses 'Growth in health' and 'increase in health' in the context of CO₂ exposure.
- Other Elements:** A 'nature sustainability' logo, a 'Discovery' logo, and a 'Aercast' logo are also visible.



BACK TO MARYNAs INVENTION



When you place outdoor CO₂-data on a map you get information with pollution from combustion engines.



REAL-TIME AIR QUALITY MONITORING

What if you could monitor AQ and make real-time decisions based on facts?

AQ Daily stats
Hourly PPM trend based on phone data and projections

7h	-6h	-5h	-4h	-3h	-2h	-1h	NOW	+1h
■	■	■	■	■	■	■	■	■

Air quality tutor

Activity **Running**

Go!

Floor 7 AQ Status

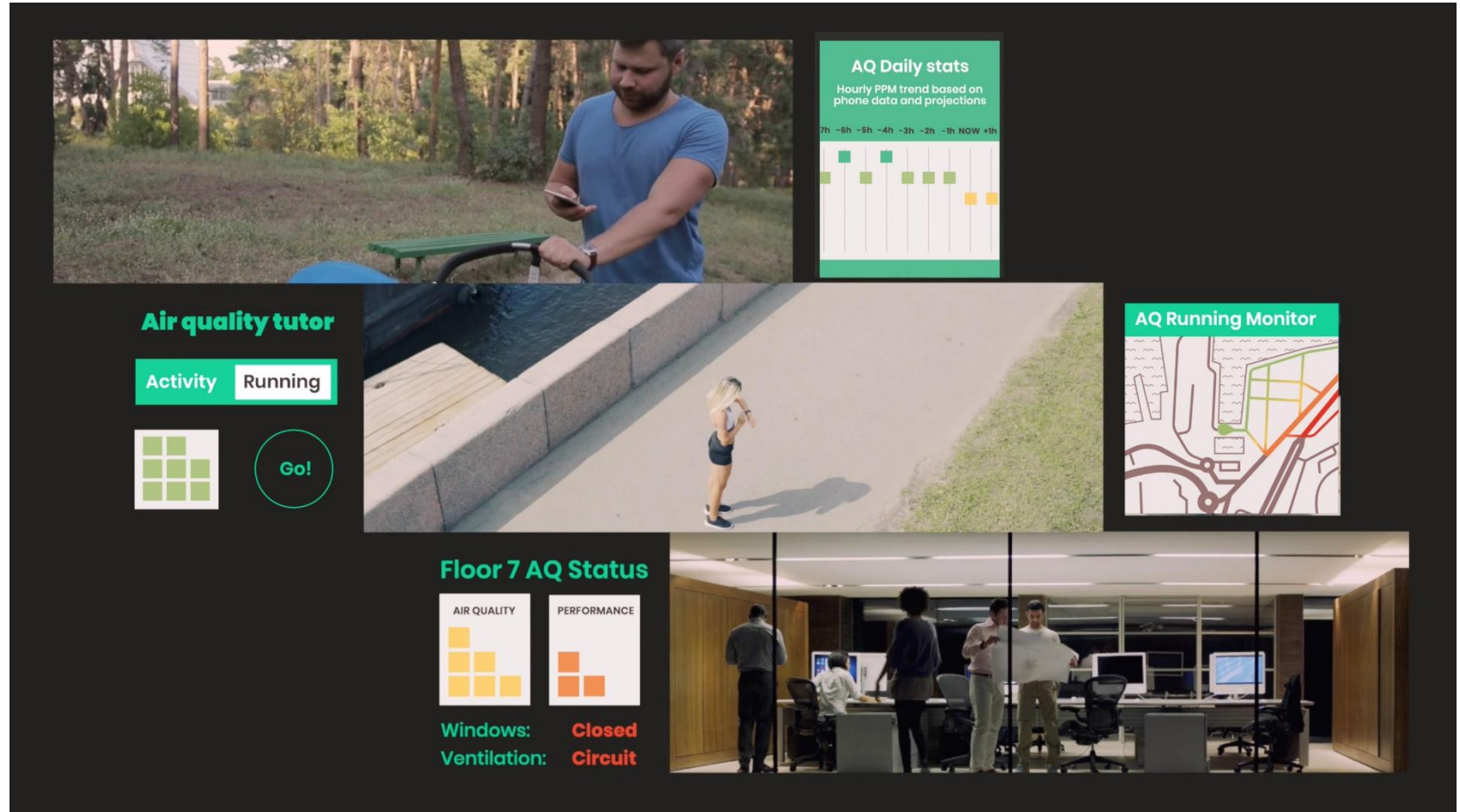
AIR QUALITY	PERFORMANCE
■ ■ ■ ■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■
Windows: Closed	Ventilation: Circuit



REAL-TIME AIR QUALITY MONITORING

What if you could monitor AQ and make real-time decisions based on facts?

What ideas do you have?



REAL-TIME AIR QUALITY MONITORING



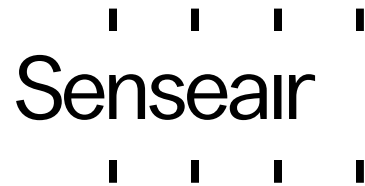
Scientific communication
and management



Smart sensor research
MOEMS research



Fabrication equipment business



Develop gas sensor technology and business



Material research



Physics modelling research

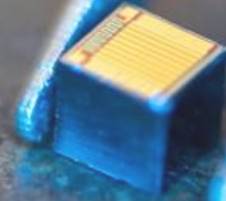
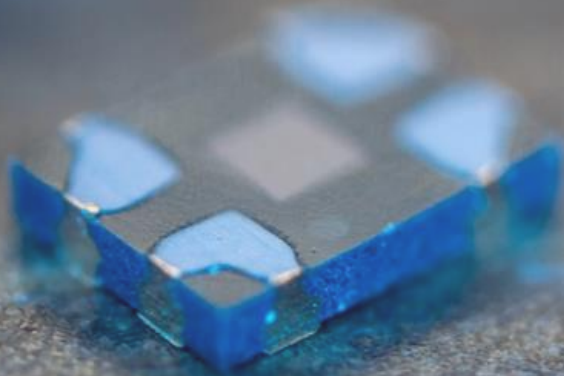


Graphene fabrication business



Opto-electrical
device research

NETWORKED SENSORS – Research in...



Fabrication and development of 2-D materials

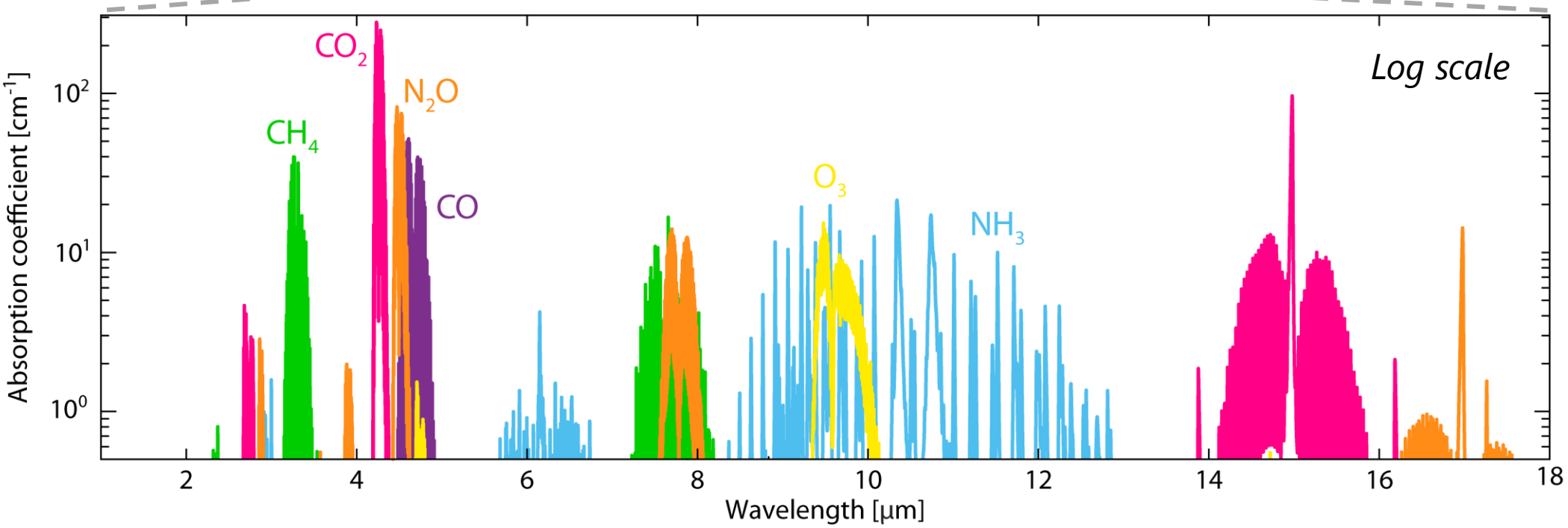
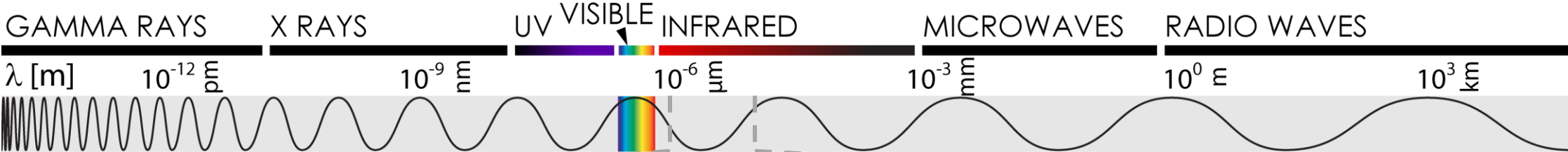
Micro structure integration

Component development

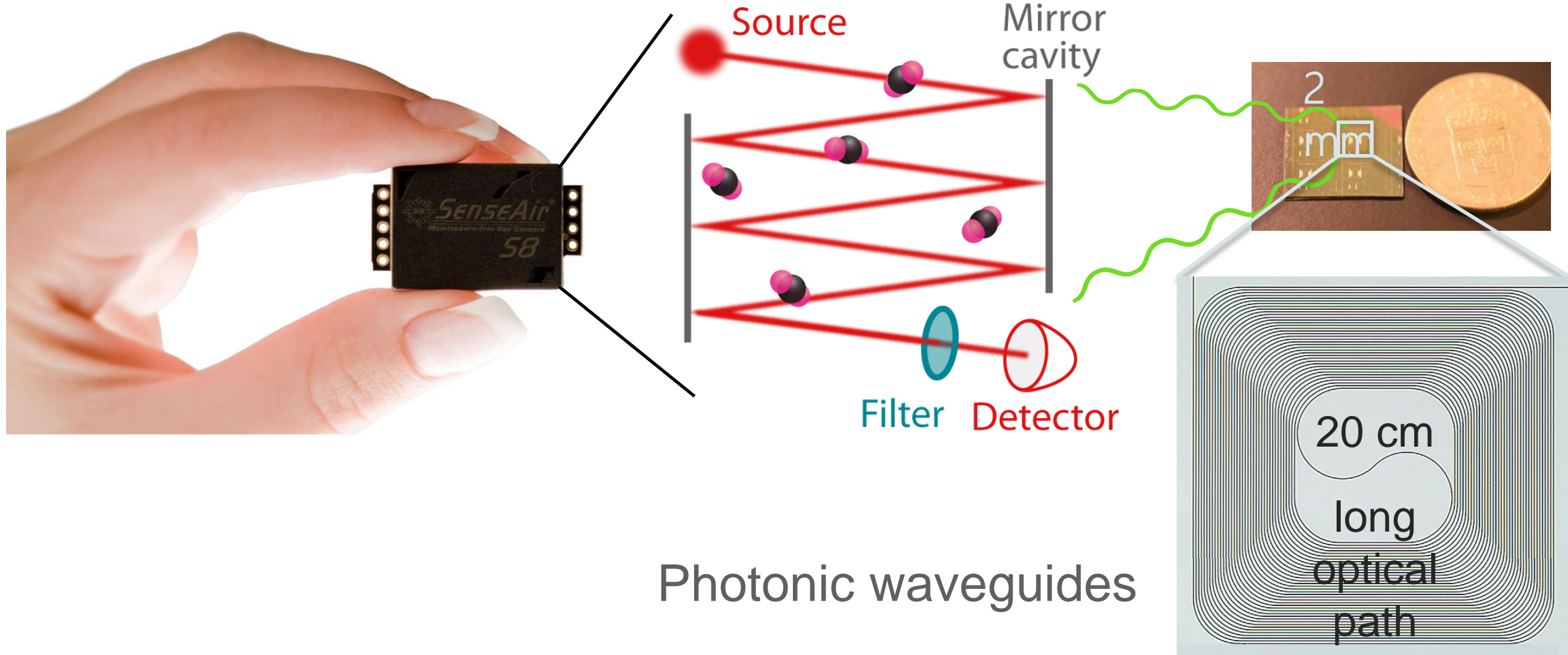
Sensor production and calibration techniques

Utilization of big data in the cloud

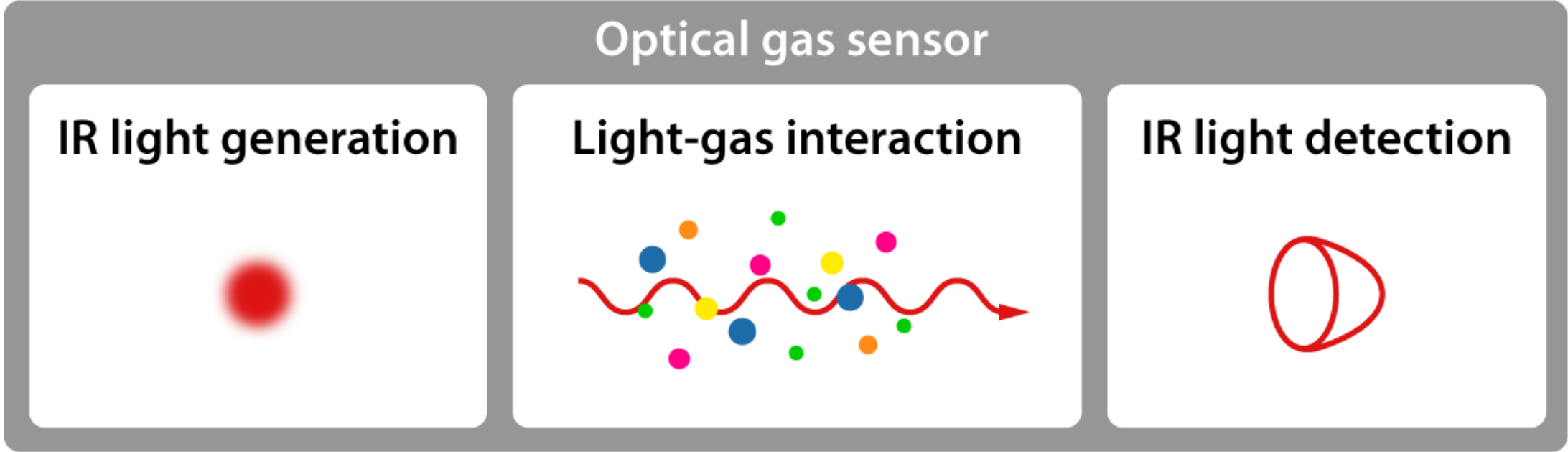
ABSORPTION SPECTRA: the mid-IR wavelength region



FIT A CM-LONG OPTICAL PATH IN MM



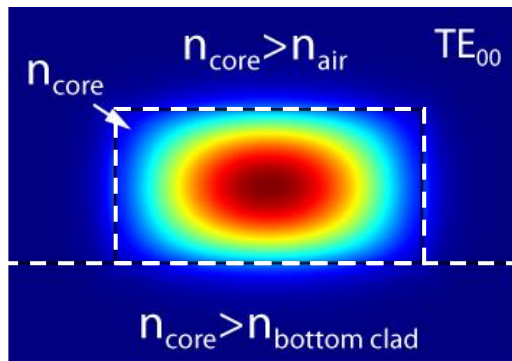
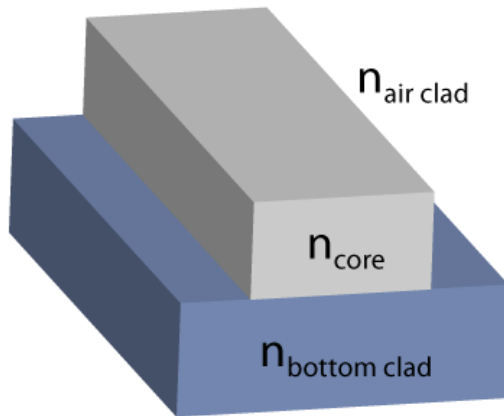
mid-IR TECHNOLOGIES: for miniaturized optical gas sensors



PHOTONIC WAVEGUIDES

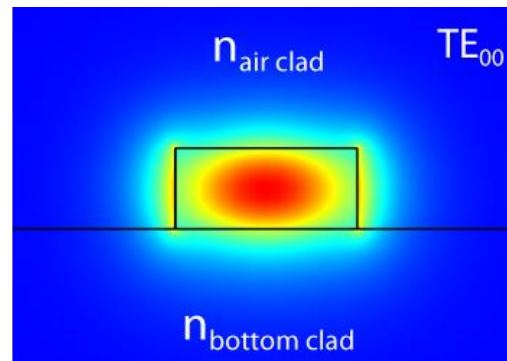
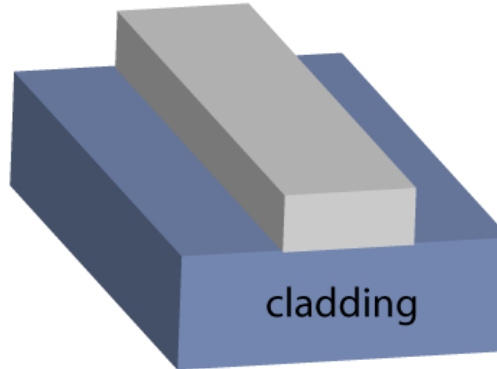
Strip waveguide

High confinement



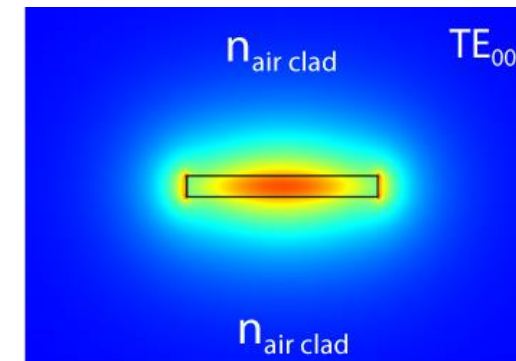
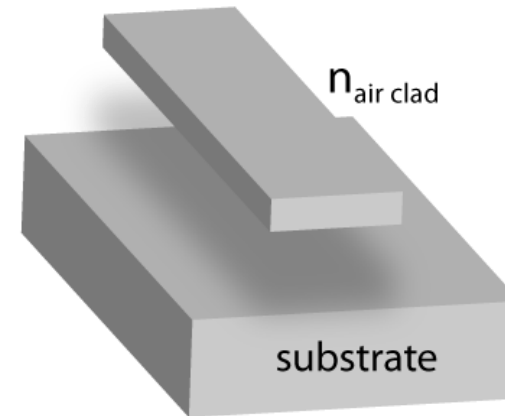
Strip waveguide

Low confinement

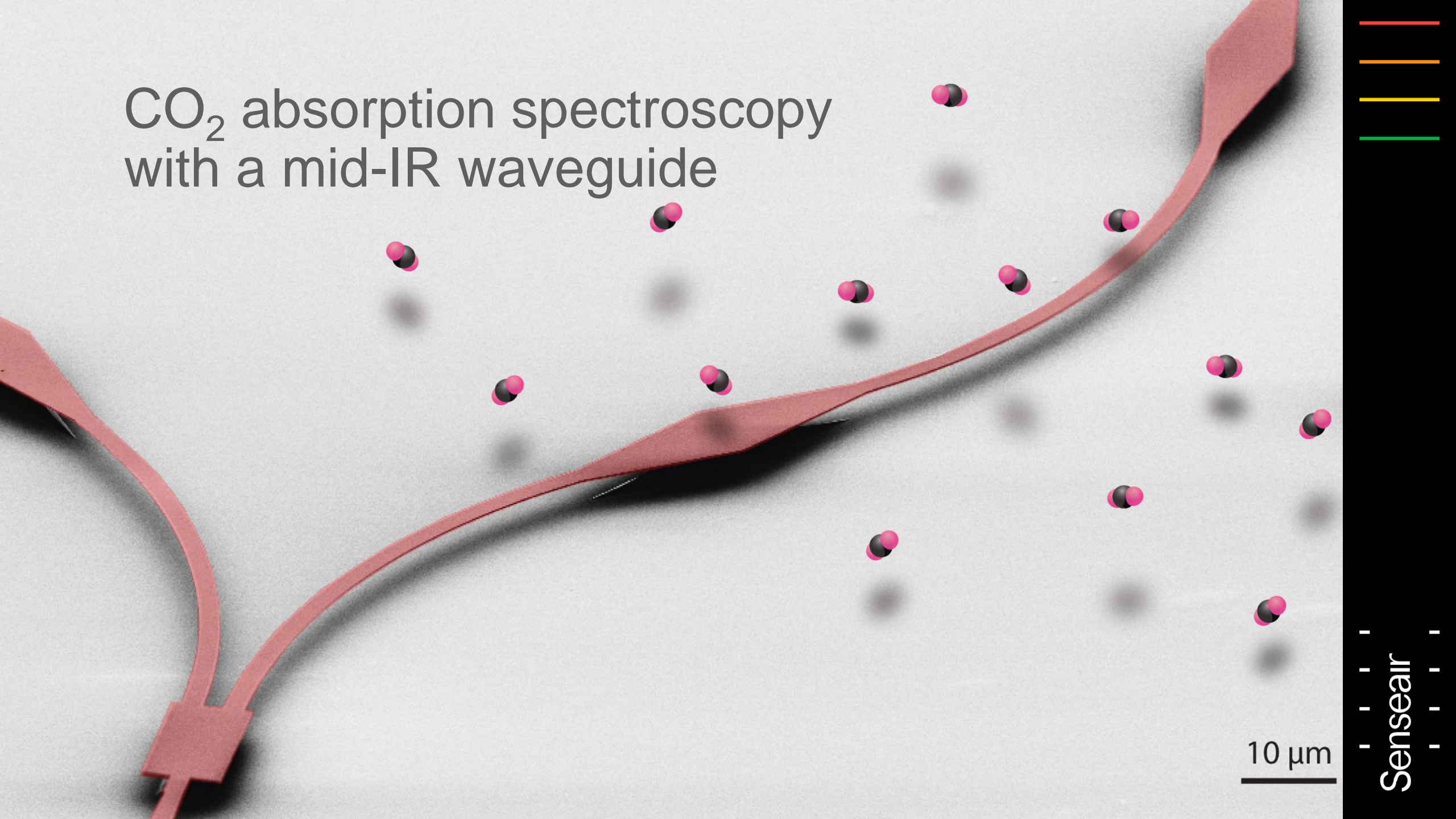


Suspended strip waveguide

Low confinement

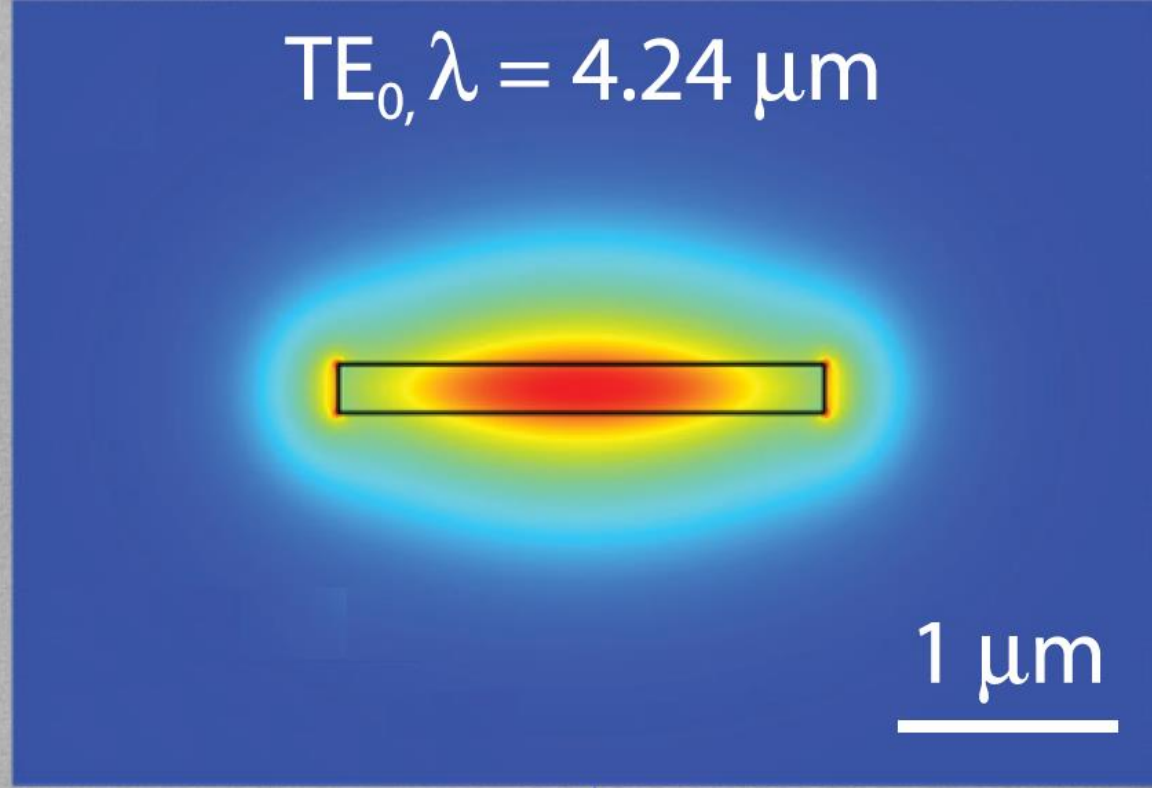


CO₂ absorption spectroscopy with a mid-IR waveguide



10 μm

$TE_0, \lambda = 4.24 \mu\text{m}$

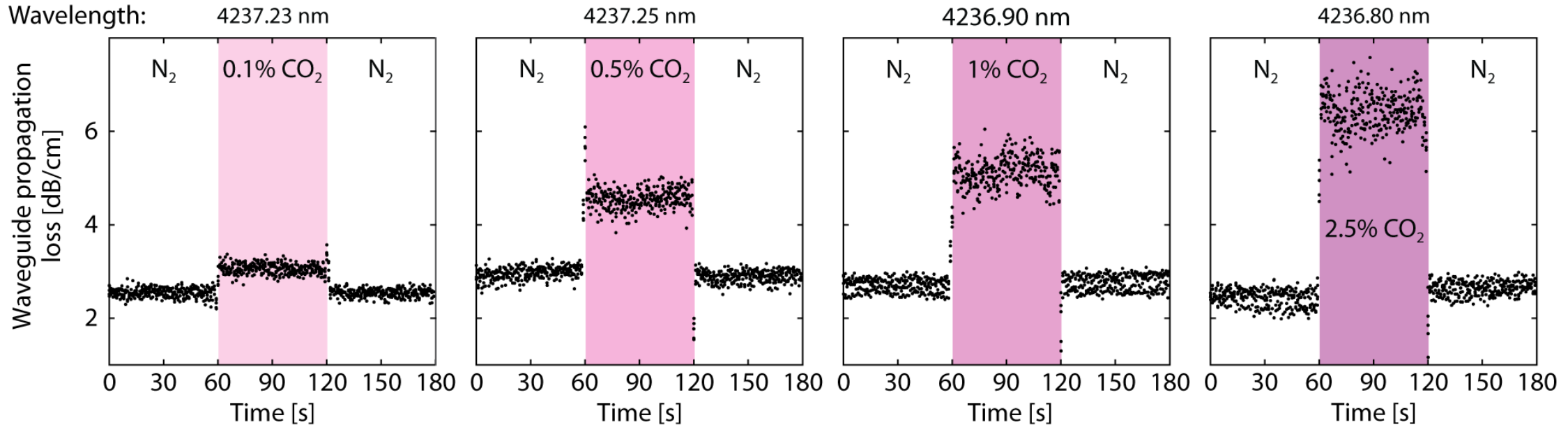


$1 \mu\text{m}$

CO_2 absorption sensing
with a mid-IR waveguide

$3 \mu\text{m}$

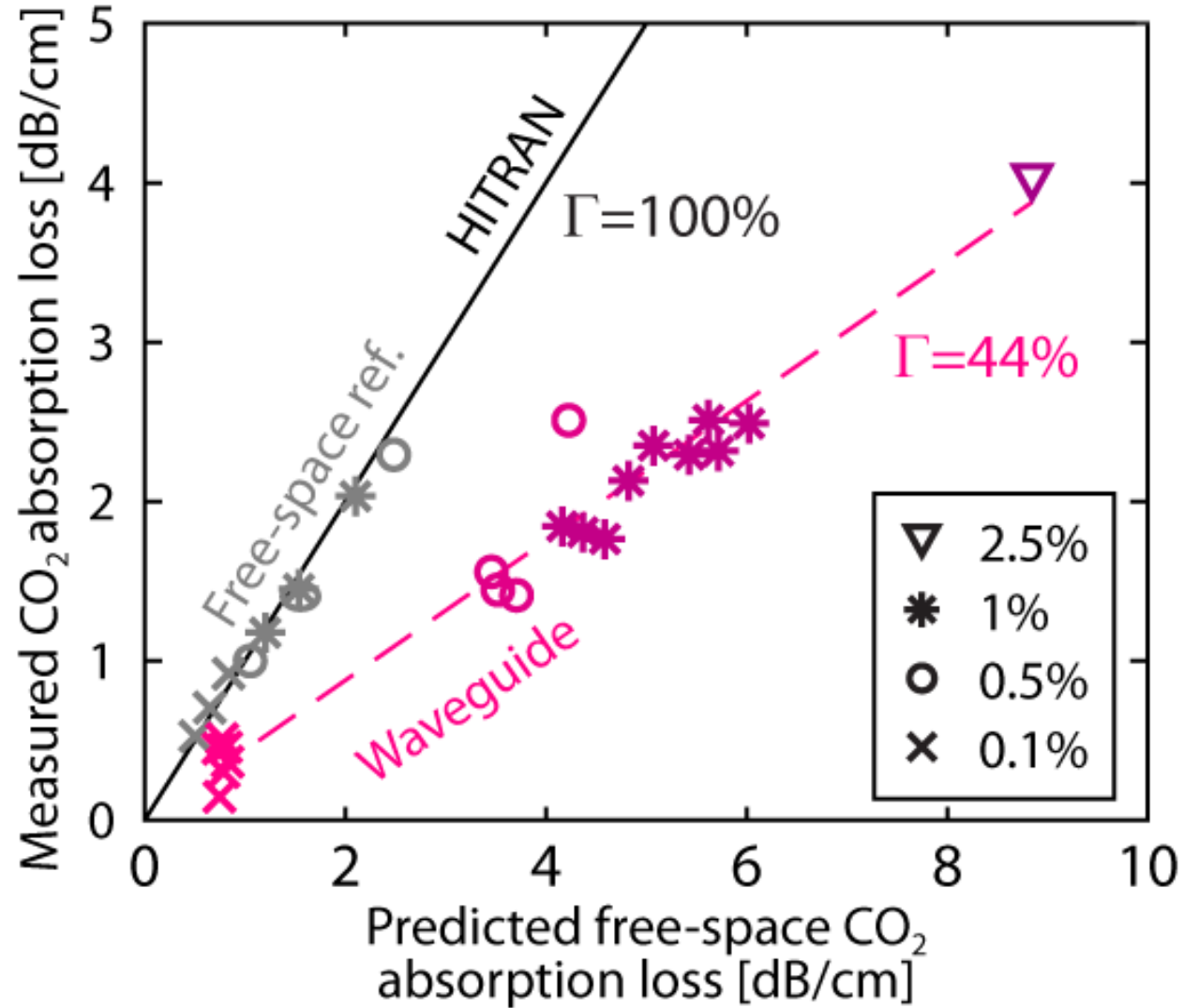
CO₂ MEASUREMENTS



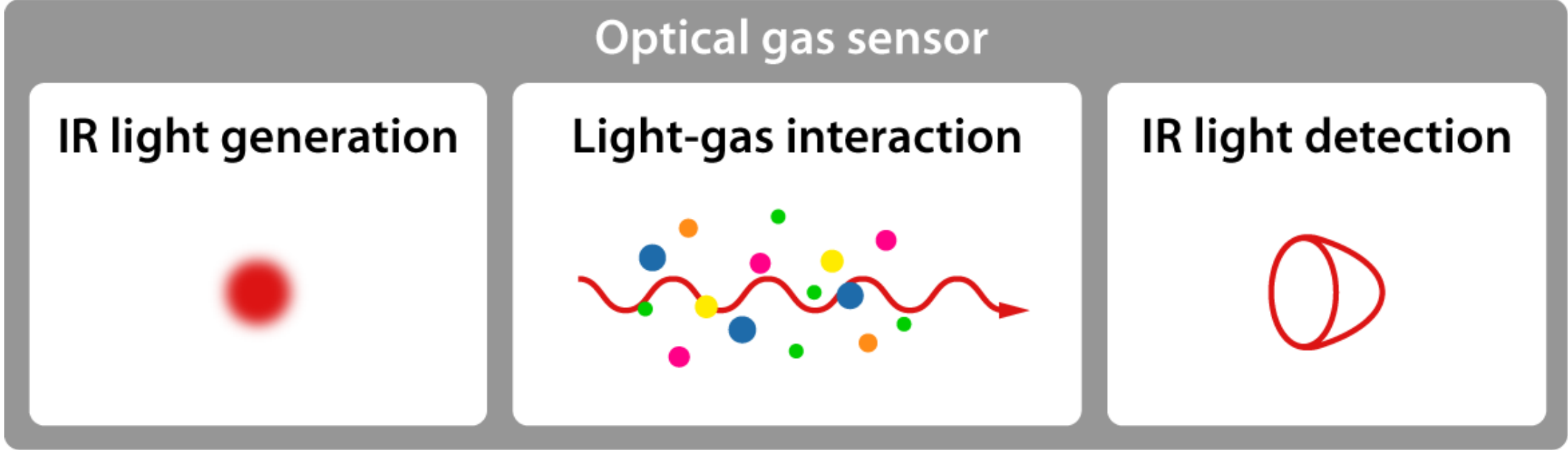
Waveguide CO₂ absorption loss



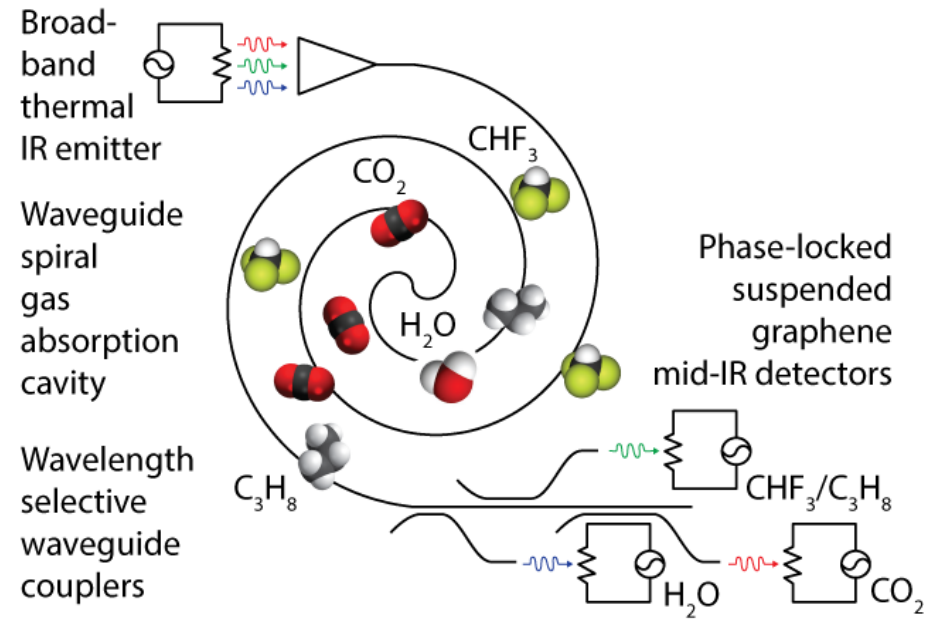
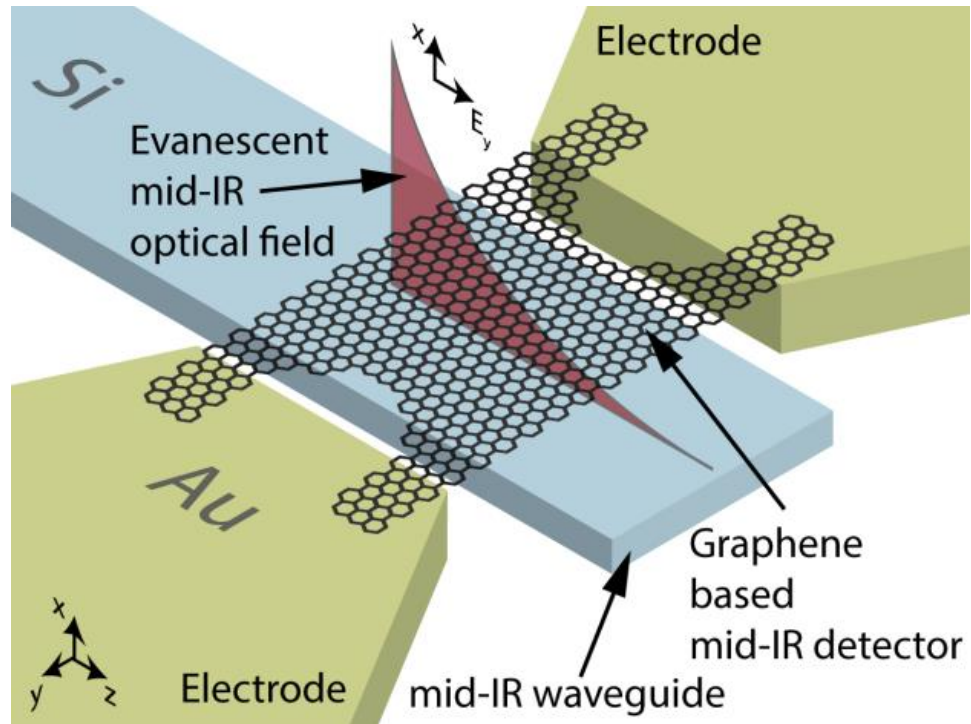
SENSING PERFORMANCE



mid-IR TECHNOLOGIES: for miniaturized optical gas sensors



Graphene as waveguide integrated mid-IR detector



SENSOR FUSION AND SELF-CALIBRATION



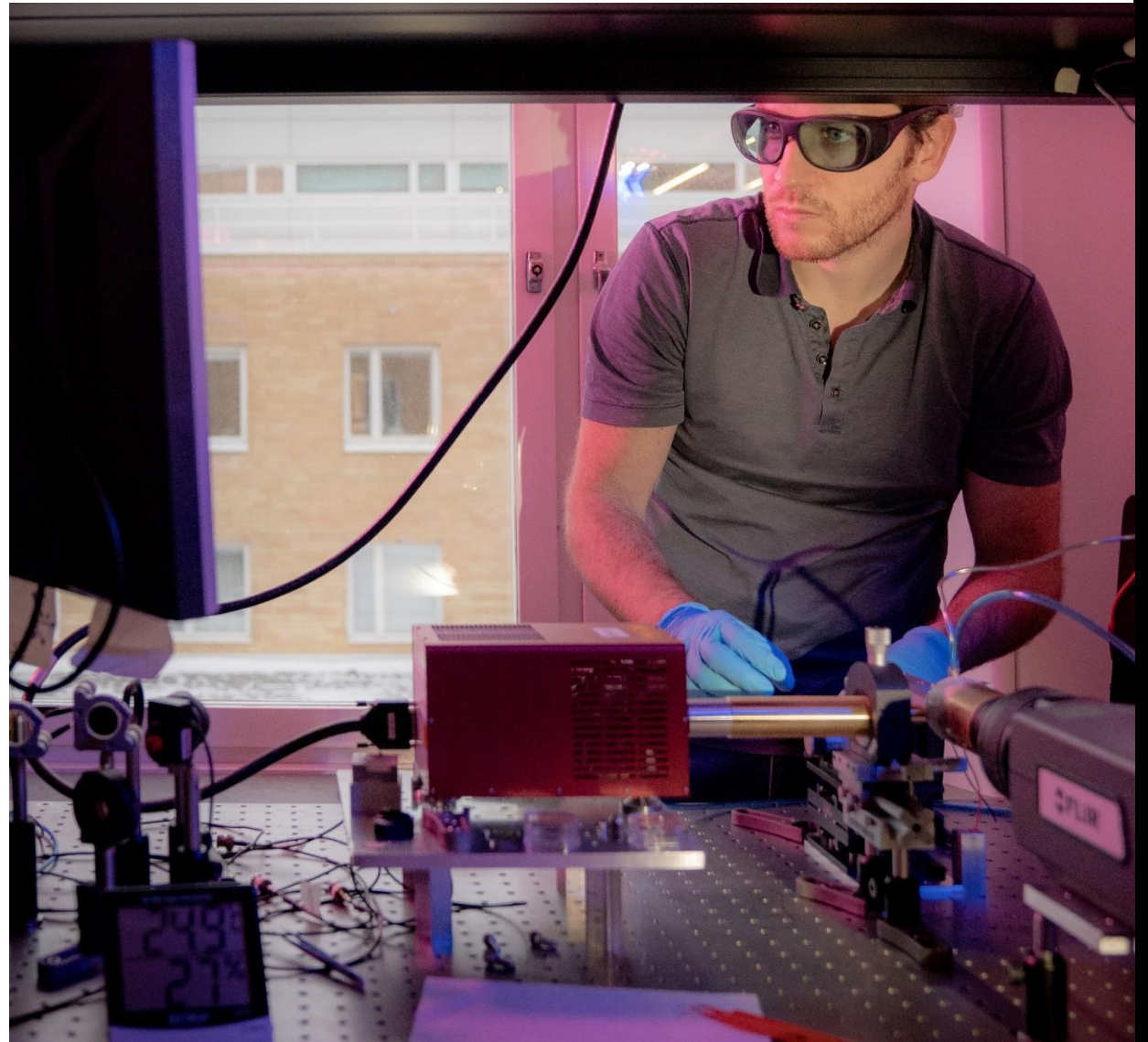
SENSOR FUSION AND SELF-CALIBRATION

- Use machine learning based on data uploaded to the cloud.
- Each sensor can learn from its history and self-estimate its reliability.
- The reported measurement is not just a single ppm-value, but a self-estimated belief function with a probability distribution over a range of ppm-values.
- Geometrical methods can be used to achieve more accurate data from several sensors in the same area. This is used for calibration, and improves the self-belief!



TECHNICAL CHALLENGES

- MOEMS chip integration
- 2D material fabrication
- Obtain proper signal-to-noise ratio
- Managing sensor drift and non-ideal behavior.



CURRENT ACHIEVEMENTS

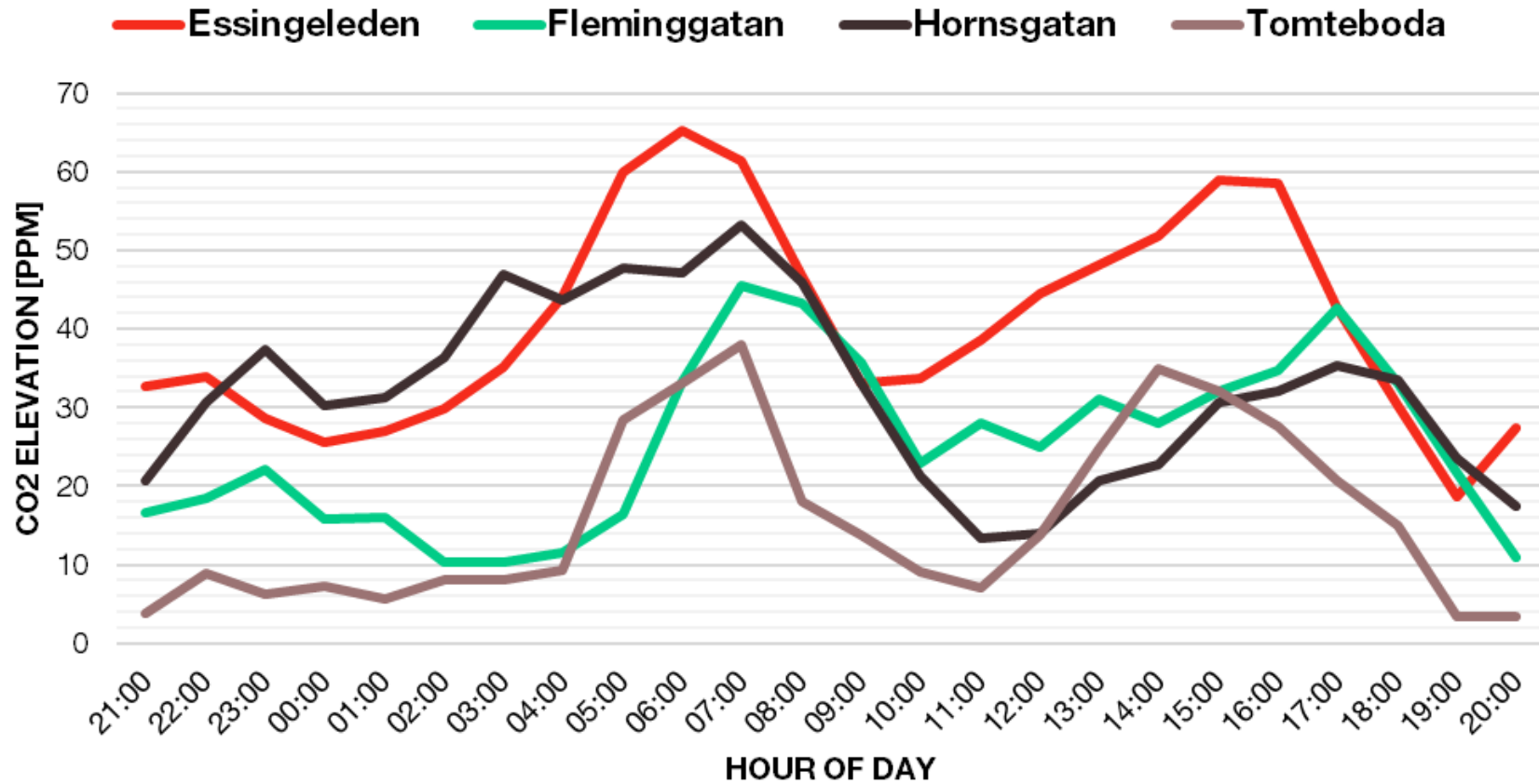
- Machine learning has been proven on large sets of real data.
- Chip based waveguide gas sensing has been proven to work in lab.
- A MOEMS architecture including 2D-materials has been proposed and the sub-components have been fabricated.
- A first test fleet with IoT sensors reporting to a cloud data is up and running 24-7.



CURRENT ACHIEVEMENTS

Stockholm Air Pollution

190515 21:00 to 190516 20:00



REAL-TIME AIR QUALITY MONITORING

What if you could monitor AQ and make real-time decisions based on facts?

What ideas do you have?

The collage features several key elements:

- AQ Daily stats:** A bar chart showing hourly PPM trends from 7h to 1h. The current status is 'NOW', with a yellow bar indicating a slight increase.
- Air quality tutor:** A control panel with 'Activity' set to 'Running', a 3x3 grid of green squares, and a 'Go!' button.
- AQ Running Monitor:** A map showing a running route in red and green.
- Floor 7 AQ Status:** A dashboard with two sections: 'AIR QUALITY' (a 3x3 grid of yellow squares) and 'PERFORMANCE' (a 3x3 grid of orange squares). Below are status indicators: 'Windows: Closed' and 'Ventilation: Circuit'.
- Office Interior:** A photograph of an office with several people working at desks.
- Man with Smartphone:** A man in a blue shirt looking at his phone outdoors.
- Woman Running:** A woman running on a paved path.



THANK YOU!

ANY QUESTIONS?

Please stay
for the Q&A
session

NEXT WEBINAR



The **FLAIR** Project

Thursday
February 18th

4pm – 5pm CET

The flying dog that can sniff and tell what gases there are in a specific place.

Learn more about the webinar at: www.senseair.com

Senseair

