cea

leti innovation for industry

ENOVA 2014

Les matinales de l'Embarqué - CAP'TRONIC

Nouvelles technologies pour l'analyse de composés chimiques : Solutions de monitoring bas coûts

Sylvie Joly

Display & Sensors Program Manager Département Optique et Photonique

sylvie-j.joly@cea.fr

MINATEC CAMPUS

All the air we breathe

- **Every human ….**

inhales

of air

drinks

of water

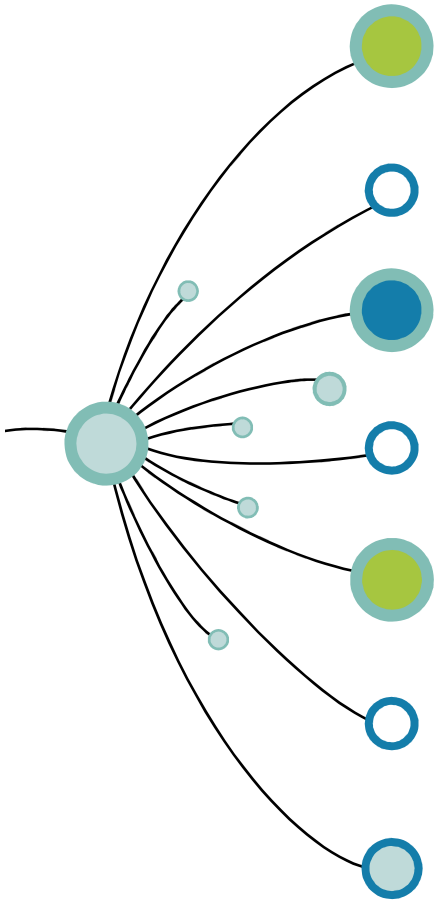
eats

of food

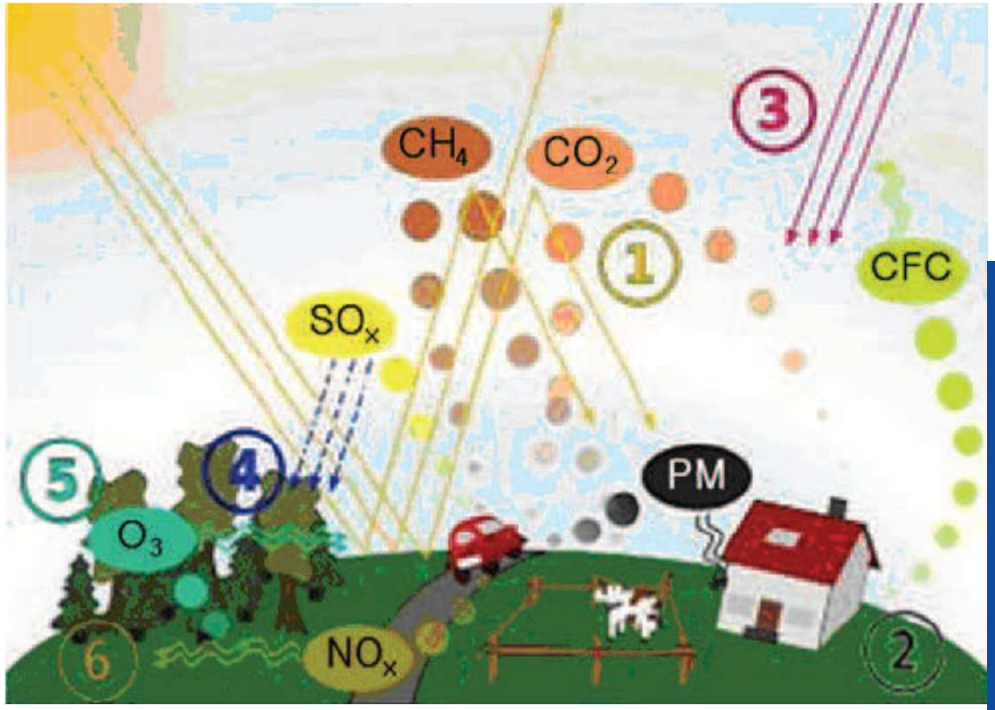
every day.

Air is therefore an essential element for life,
and a good quality of air is a fundamental need

Contents

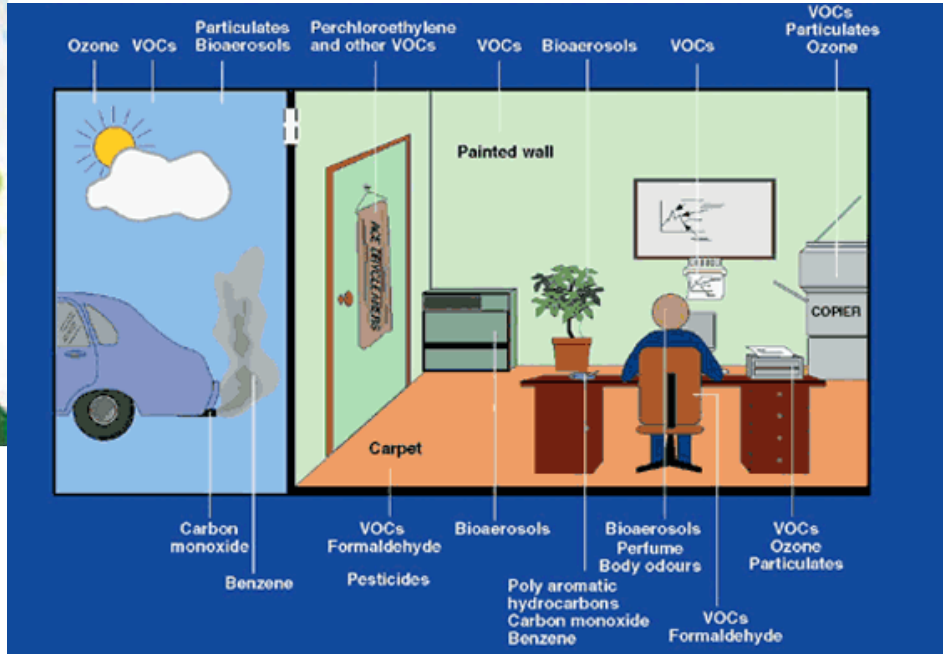


Sources of air pollution



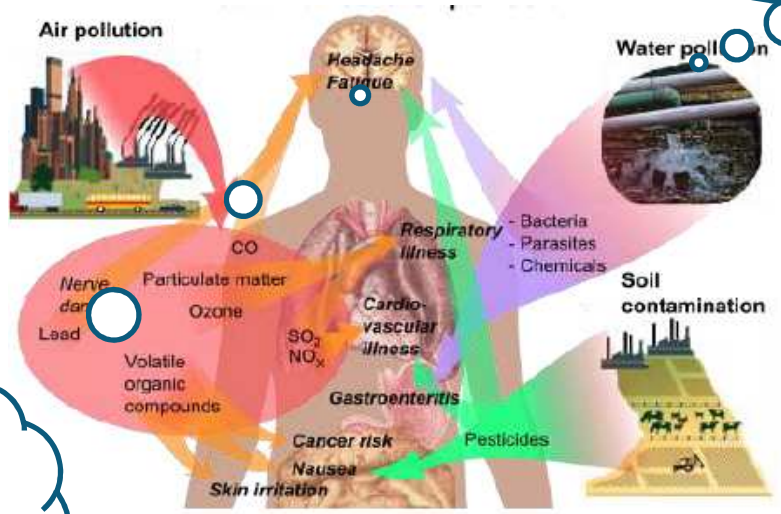
Outdoor air pollution

Indoor air pollution

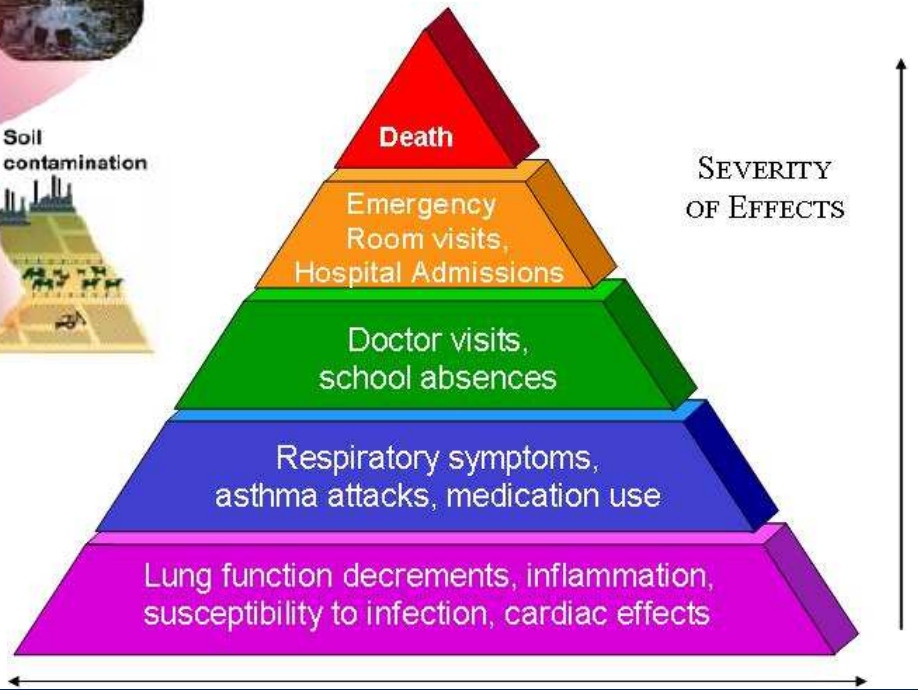


Health effects pollution

According to the Aphekom project, air pollution in Europe leads to a life expectancy reduction of around 8,6 months

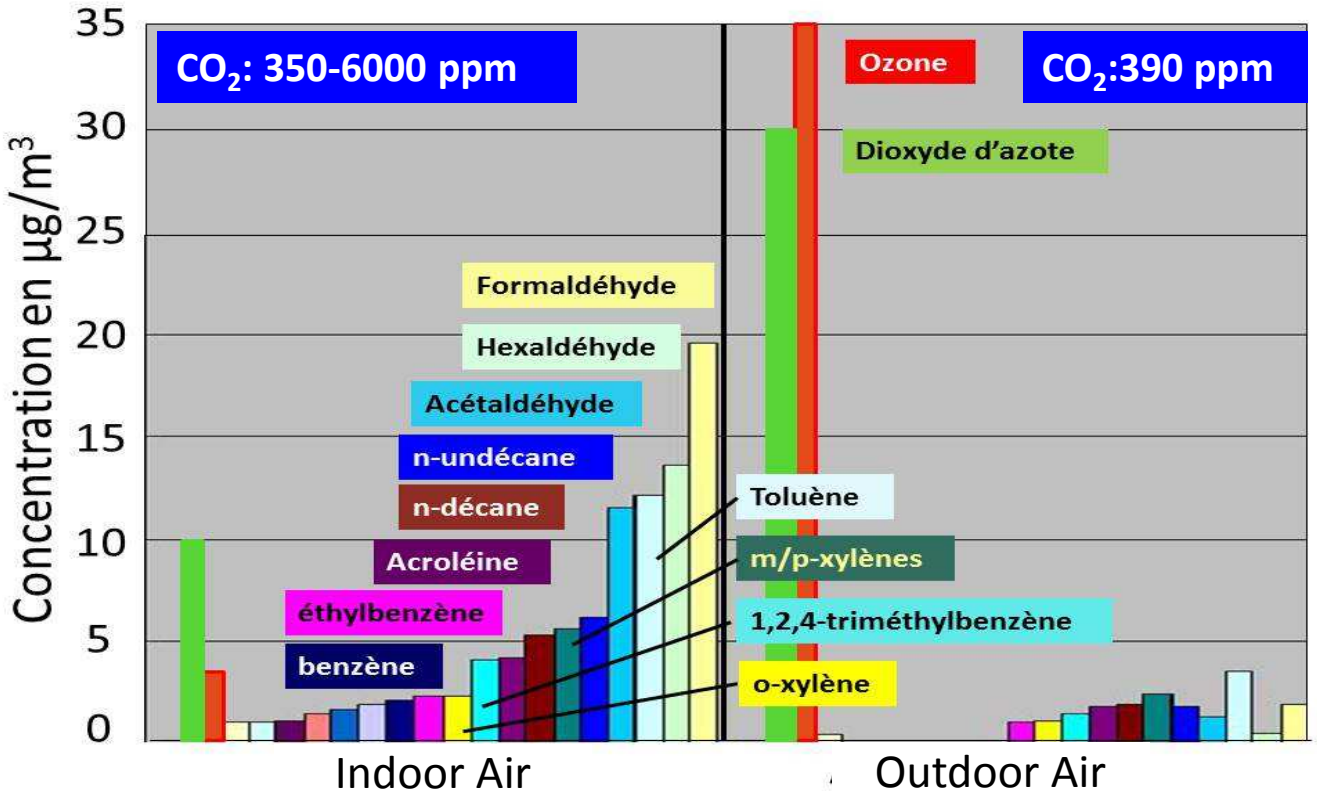


Almost one out of five Europeans says that they suffer from respiratory problems



It has long been understood that, under certain meteorological conditions, emissions of pollutants can have strong impacts on the environment, visibility, health and death rates

France: Indoor Air quality (IAQ) & outdoor (OAQ)



Values - ANSES
For long time exposure

Carcinogenic compounds
Formaldehyde (CH_2O)
Target value (2015) : 5µg.m^{-3}
Current: 10µg.m^{-3}

Benzene (B)
Target value (2015) : 5µg.m^{-3}
Current: 10µg.m^{-3})

Dioxide azote (NO_2)
Current: 20µg.m^{-3}

Particles PM2,5 and PM10
Currents: 10 µg.m^{-3} et 20 µg.m^{-3}

- Large number of pollutant gas to measure
- Very wide range of concentration (1 ppb benzene and formaldehyde to 500 ppm for CO_2

➔ Highly heterogeneous gas sensors : optic, electrochemical, sample and analyses

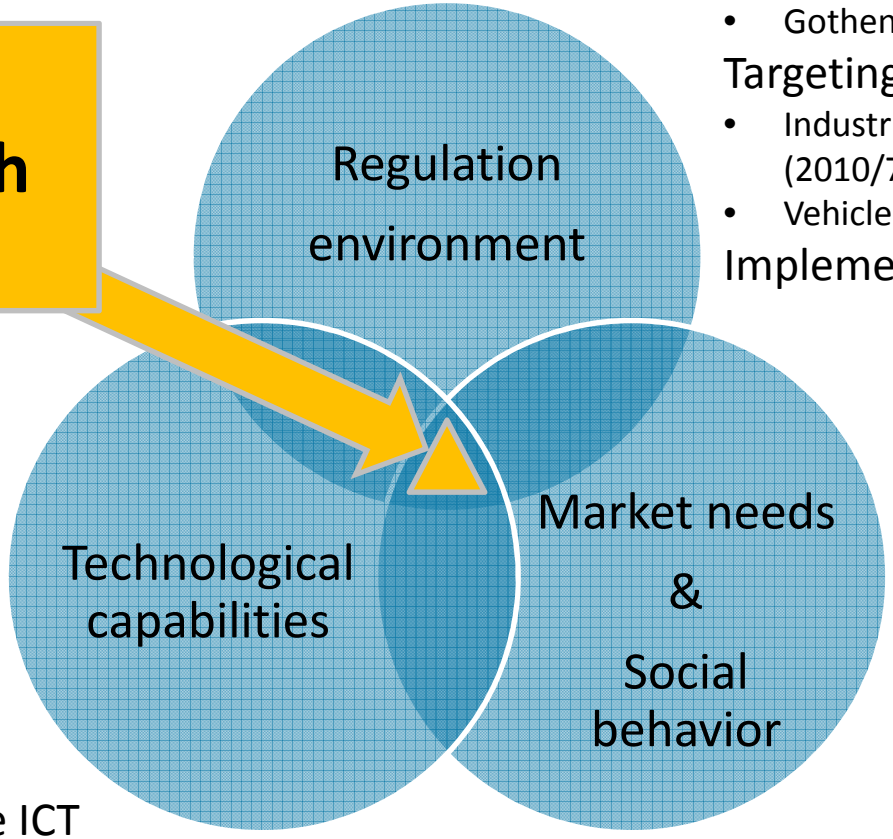
Trends

Targeting pollutants
- 2008 Directive on ambient air quality and clearer air for Europe
- National annual emissions limits
- Gothenenburg protocol

Targeting sectors
- Industrial emissions directive (2010/75/EU)
- Vehicle emission Euro 5 and 6

Implementation on the ground

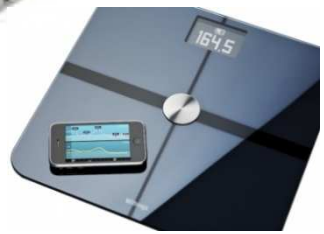
Market breakthrough products



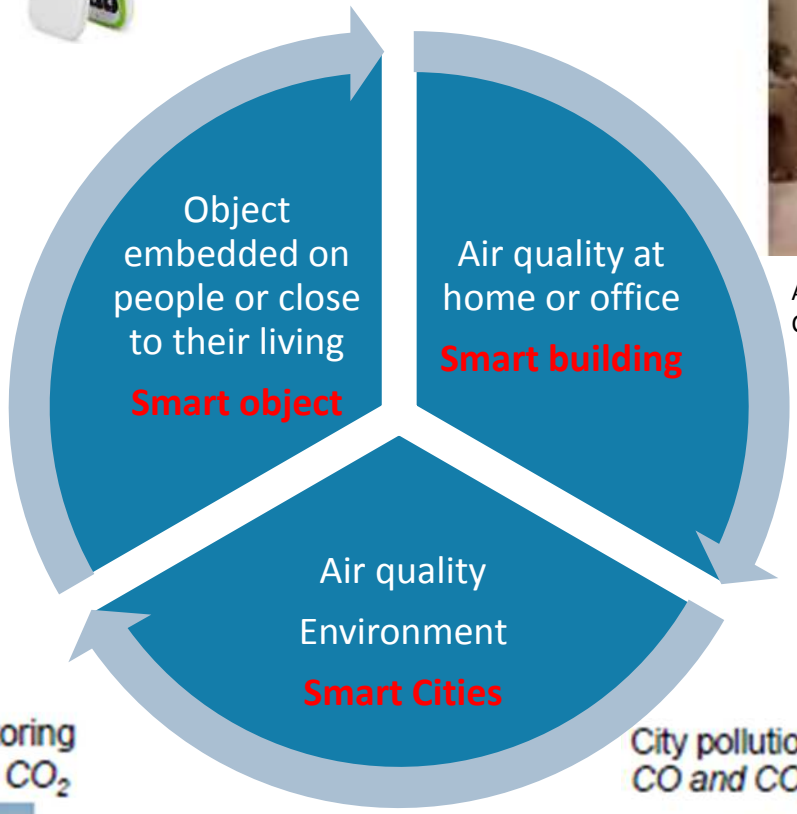
- Telecom Infrastructure ICT
- Anytime/anyplace devices – convenience
  mobile phone
- Sensors smaller, sensitive and low cost

Growing awareness of public
- Show in market survey
- IE: Cities hosting Olympic games

Applications for air quality monitoring



Breath analyzer (NTT Docomo, demo at MWC 2012)

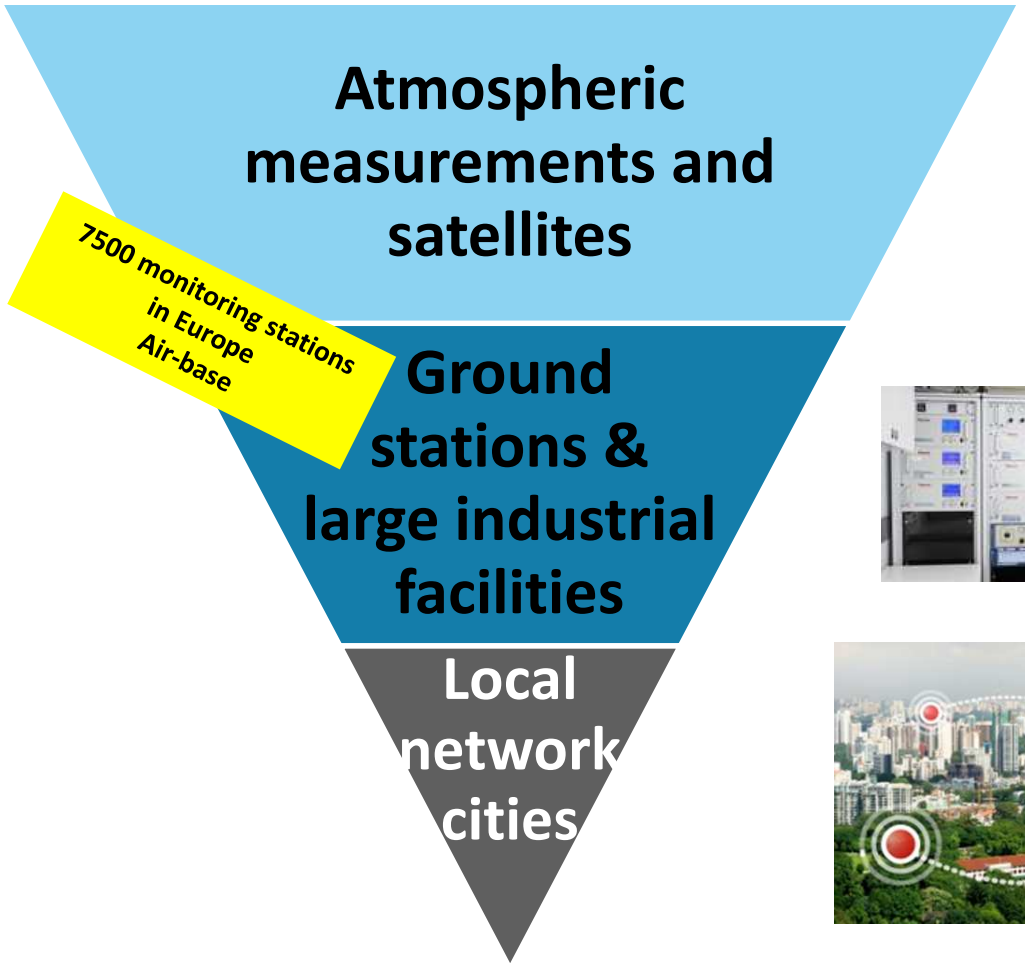


Air quality monitoring and indoor air quality Control

Global monitoring
Greenhouse CO_2

City pollution surveillance
CO and CO_2 monitoring

Products for today environmental monitoring towards “Smart cities”

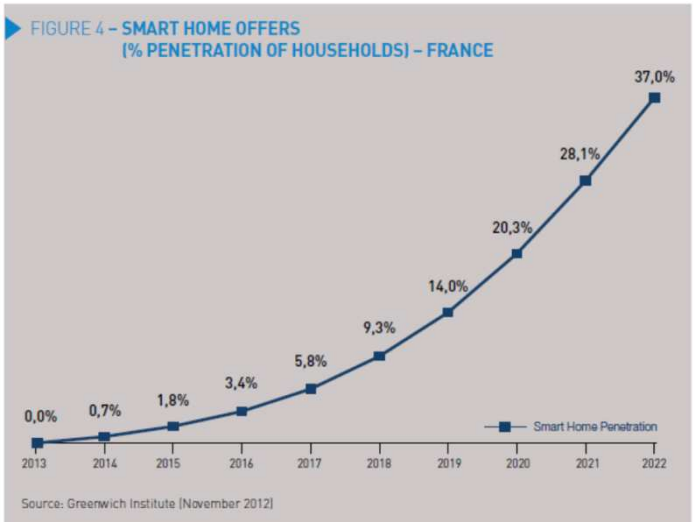


ATMO terminal

AirBase

Azimut Monitoring

Smart home Market



Smart home environment

Progressive influence on IP technology

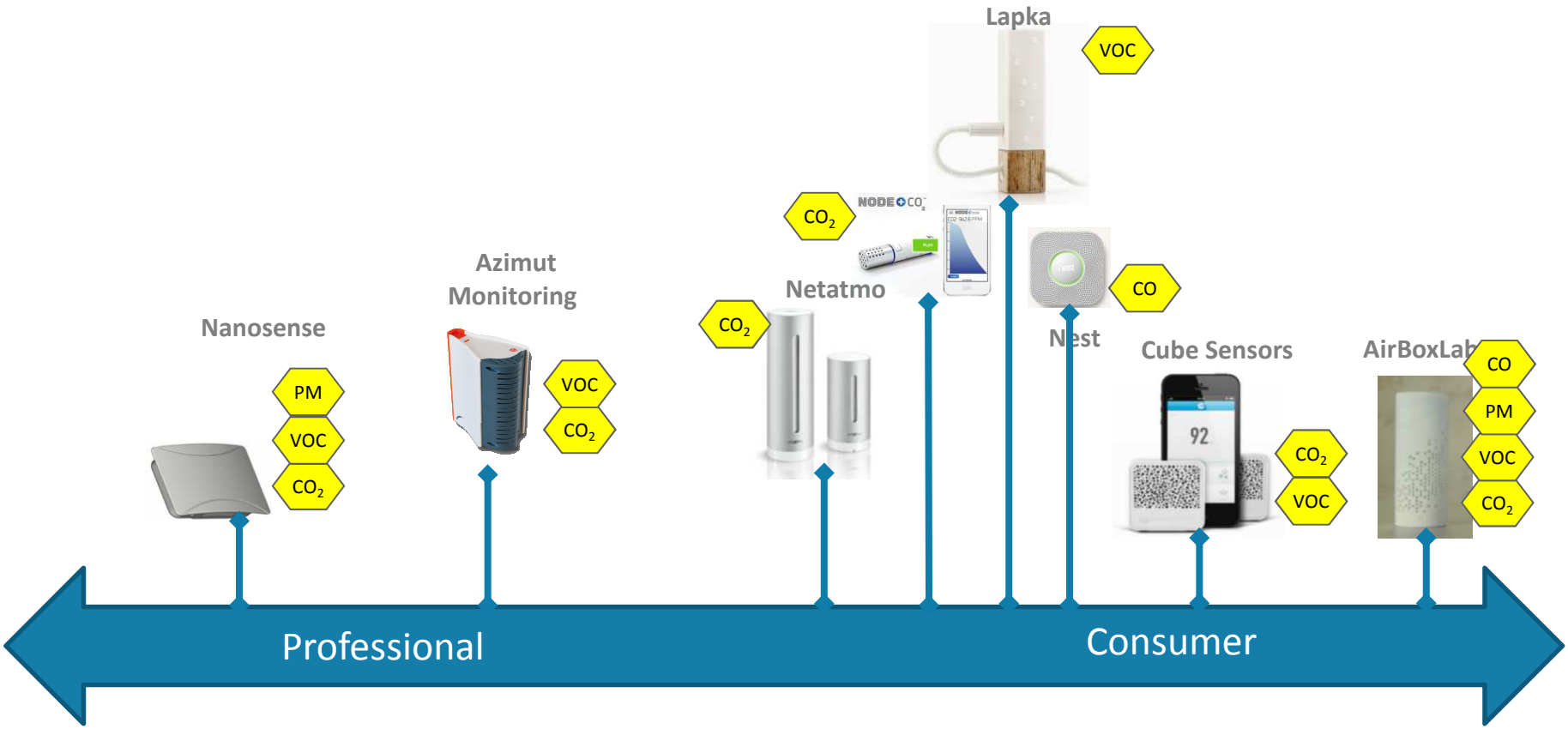
IP Access	Multimedia	Utilities	Safety, comfort, health
Telecom operators internet box with Wifi and Bluetooth	Entertainment usage performed by customer. TV VoD, Music	Management of water, waste, gas, electricity and HVAC	Standards for communication between sensors and the security and health centers

Smart sensors … gas sensors

A promising market with more than 90 millions home connected in 2017 according to ABI research
Everything is in place from the connection to the SW, smartphone, tablets … actors are frantically searching smart sensors

Existing solutions for smart home air quality

This market is still at its infancy …



Google + nest

$3.2 billion Google handed over to Nest

Smart objects … a starting for gas sensors?

- Environmental / bio sensors in handsets

Humidity sensors from Sensirion in handsets from Fujitsu and Chinese OEMs since 2010.
API available in Android

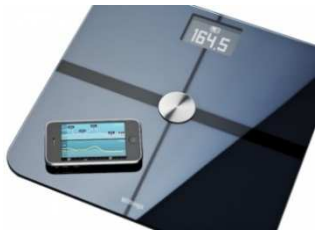
LG SD410, KP4100 and LP4100 with breath analyzer for alcohol (2004)

Breath analyzer (NTT Docomo, demo at MWC 2012)

Weather sensors (pressure, humidity, temperature, UV), NTT demo at MWC 2012

Sharp Pantone 5 with radiation sensor, July 2012

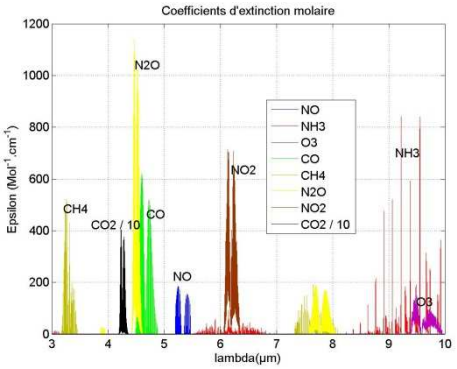
Gas sensor to monitor fat burning and hunger level (NTT docomo, March 2012)



Examples of smartphone

Examples of daily products

Need for new technologies for monitoring chemical exposure



Key Requirements:

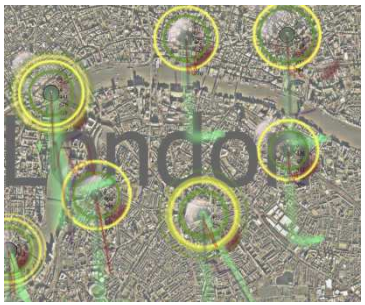
- **Sensitive and selective** basic requirements

- **Professional market**

  miniaturized, robust and low cost

  No maintenance

  Low-power



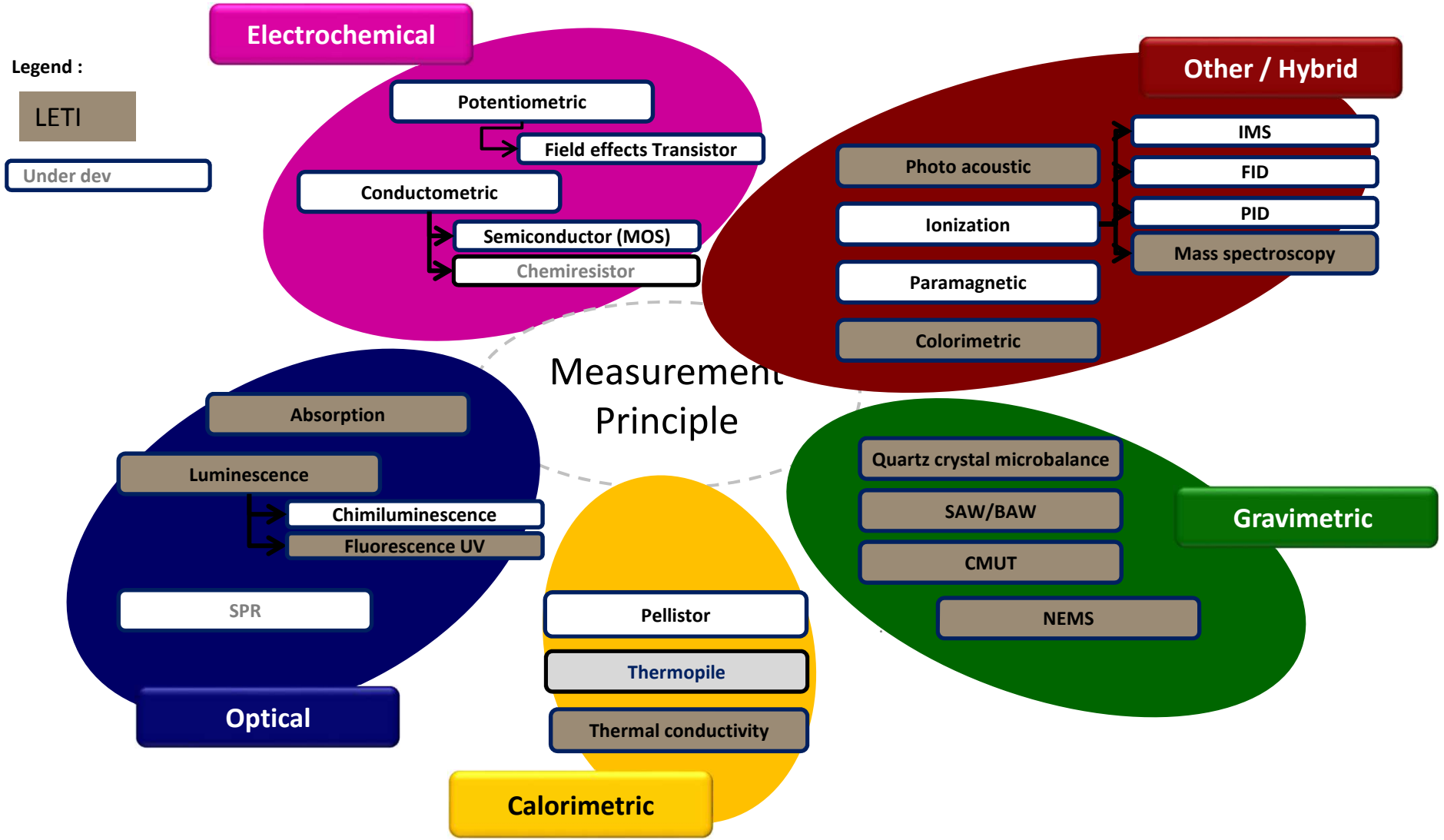
- **Consumer market**

  User friendly, miniaturized

  Ultra low cost

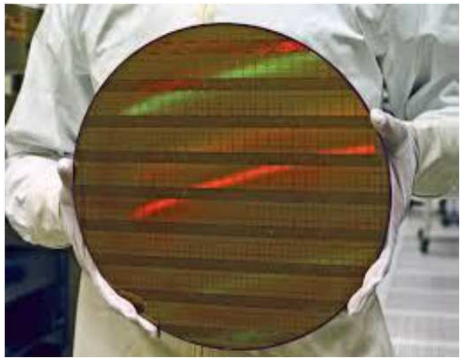
  Autonomous (ultra low-power)

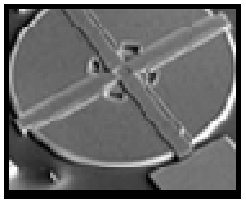
A lot of technologies available

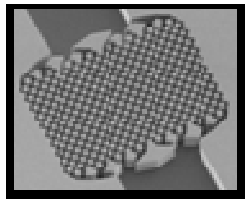


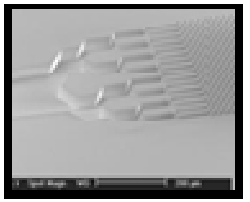
End-users requirements and technology trends

Technology trends	• Increasing miniaturization and integration • Increasing use of silicon MEMS • New standard NeSSI: New Sampling and Sensor Initiative from CPAC (Center for Process Analysis and Control) at the University of Washington.



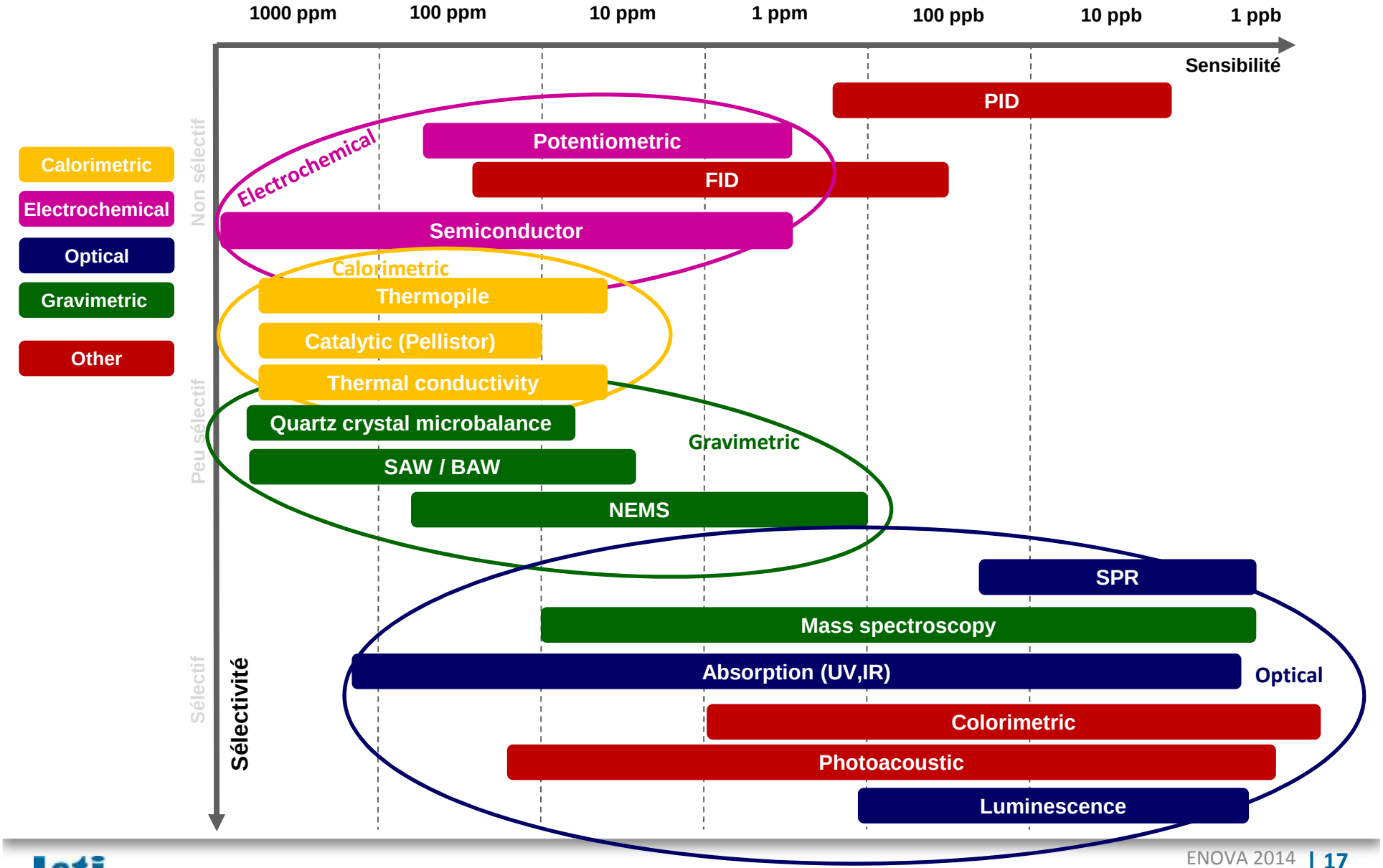




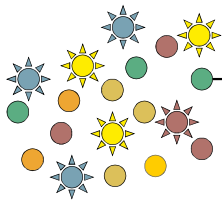


End-users requirements	• Low maintenance • High performance (accuracy, reliability) • Decrease of price

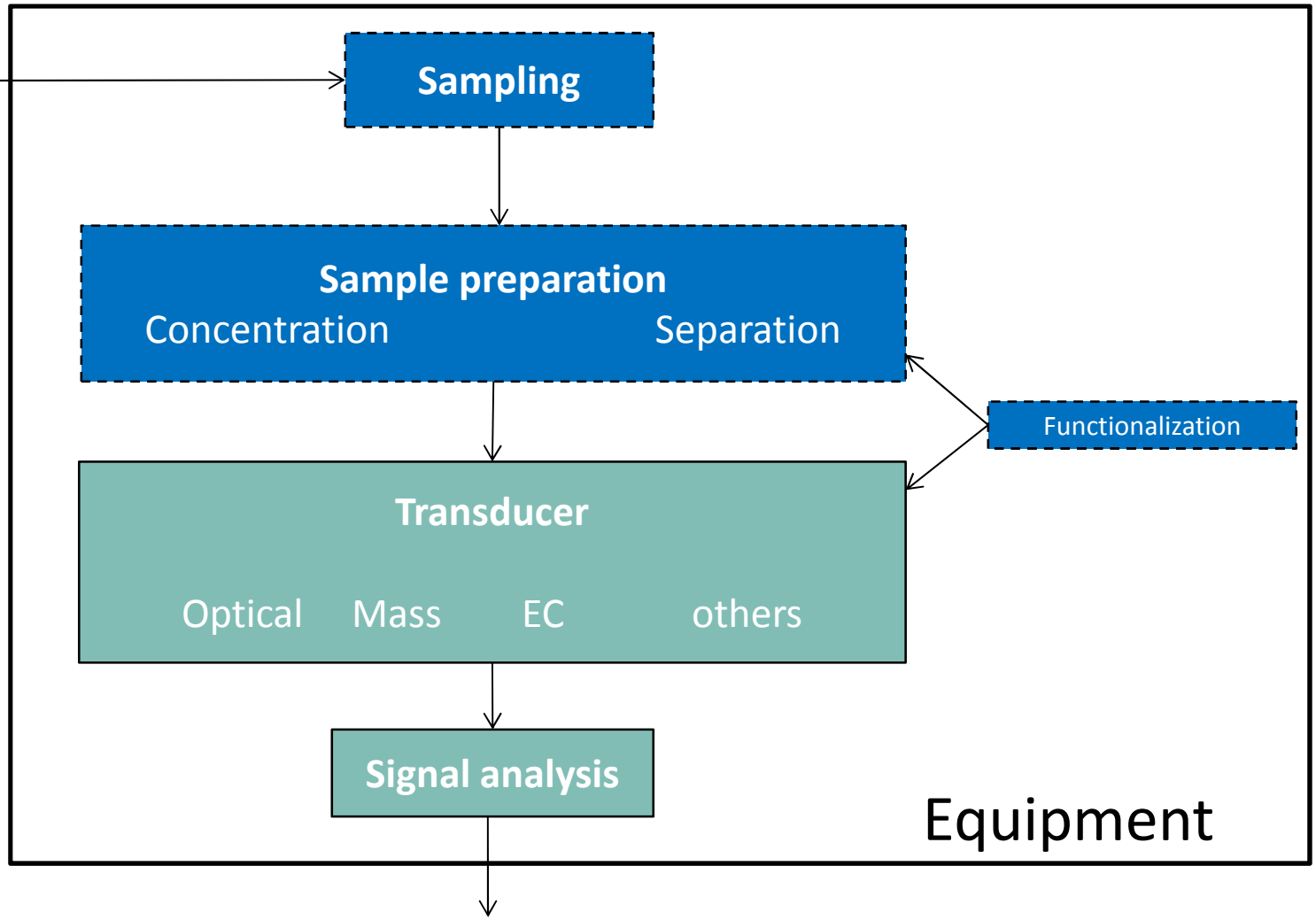
Technology positioning



Gas analyser or detector



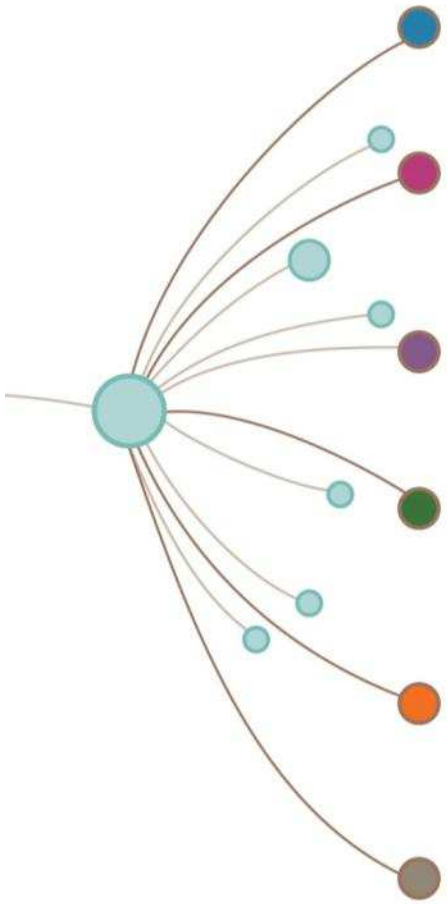
Gas



Optional steps

Interface : concentration of one or several components

Leti key figures



CEA Institute founded in 1967

Director : Dr Laurent Malier

1700 collaborators

1 150 permanent staff

200 PhD and post-doc, 40 nationalities

2200 patents

286 registered in 2012

40 % under licensing

Budget : 250 M€

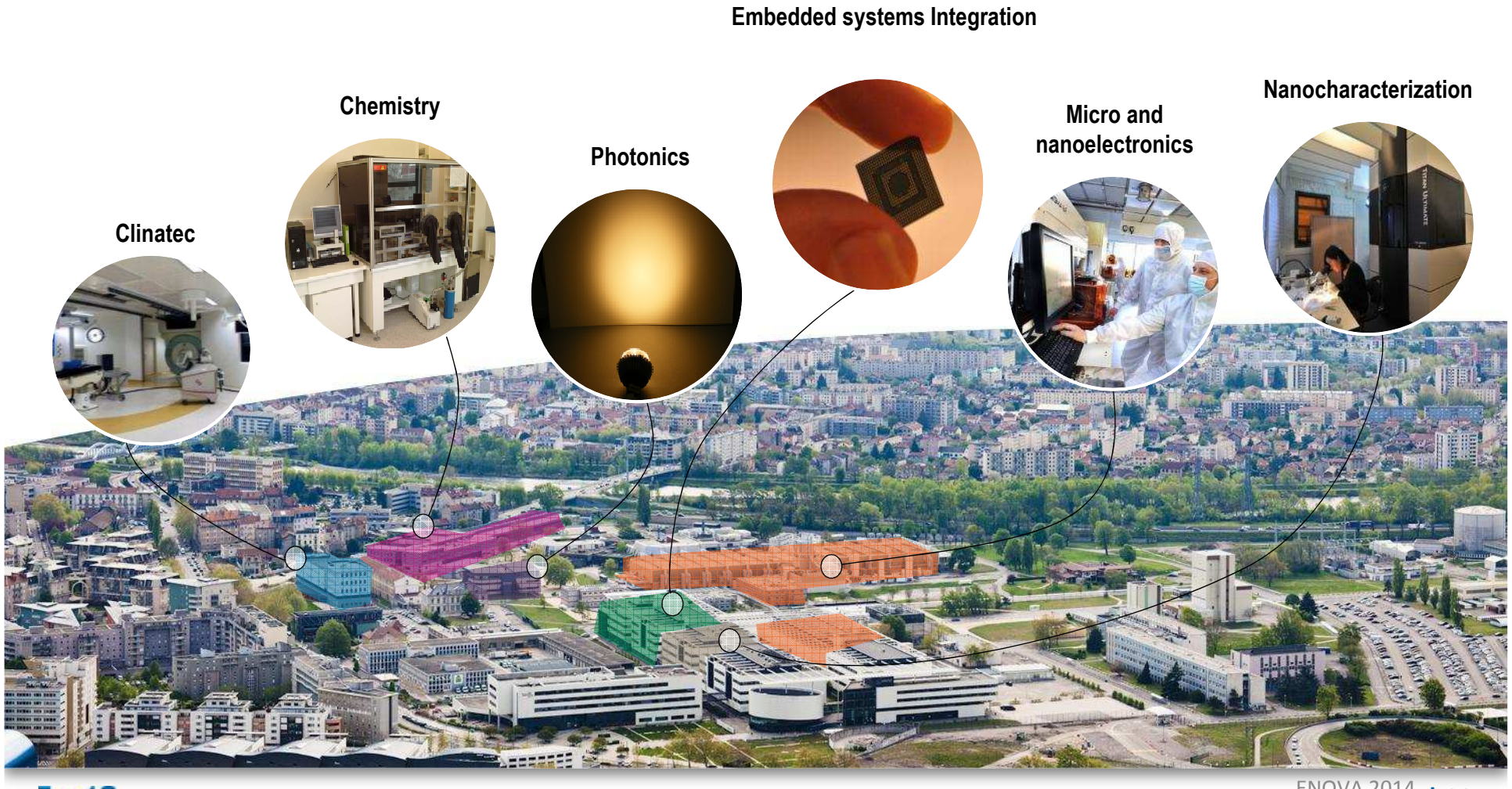
CapEx : 40M€

75% from external revenue

8 000m² clean rooms

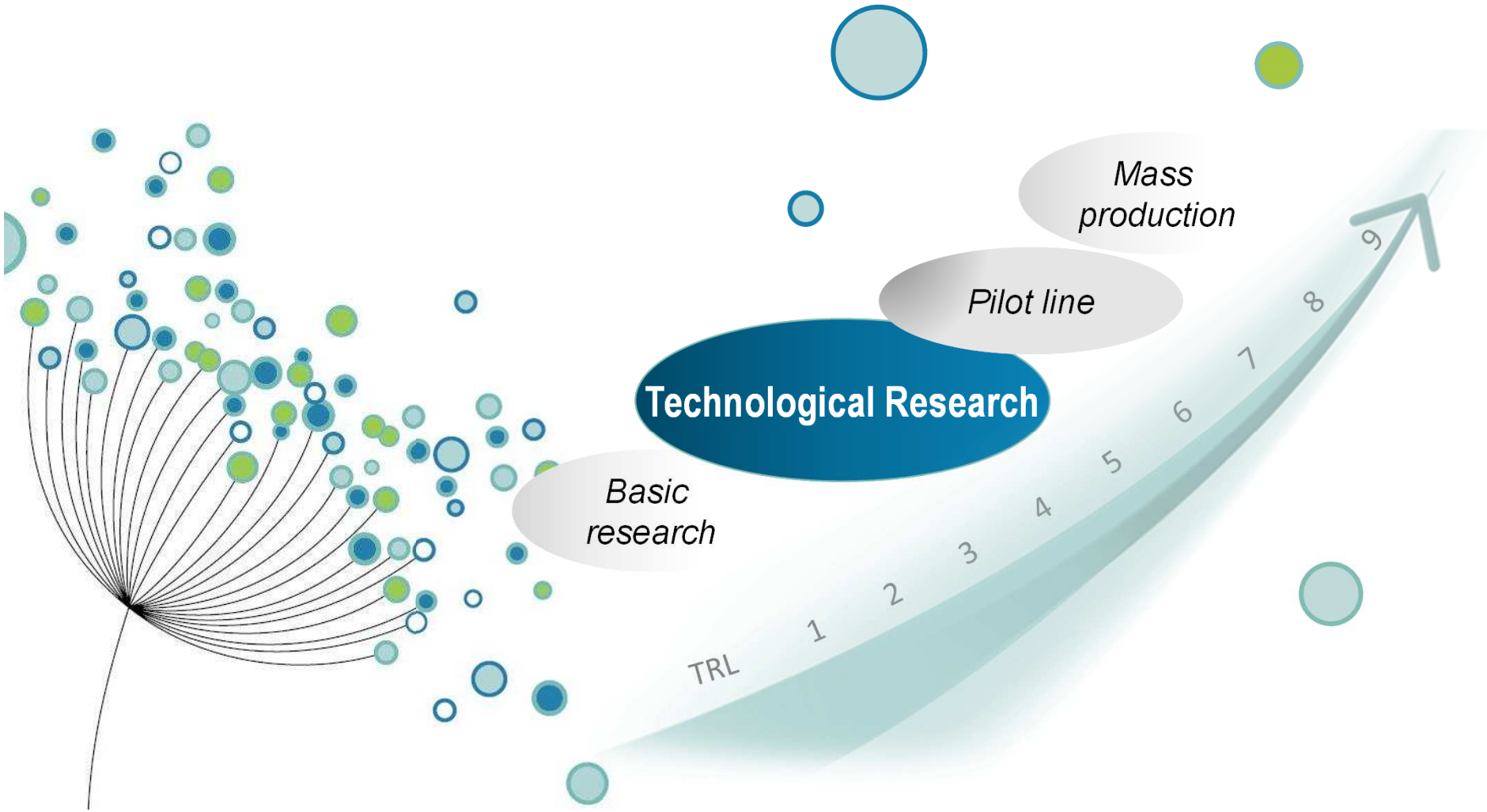
For 200 and 300mm wafer fab, operated 24/7

Our research platforms



A Business Model …

Create and transfer innovation to our industrial partners



Gas sensing @ Leti

System & Instrumentation

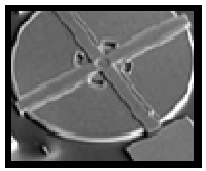
CO2 control in habitat

Miniaturized System for Real time & Multi-gas analysis

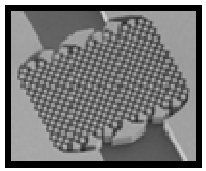
Continuous monitoring system for Explosives detection

Portable system for Formaldehyde analysis in Ambiant air

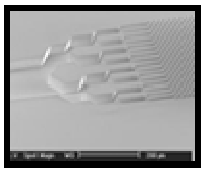
Pre-analytical bricks



sample



concentration



separating

Detection

Chemical Surface functionalization

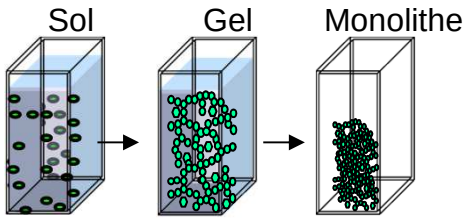
- Optical components
- Mems & Nems resonators
- Sol-gel
- Others…

Sol-gel porous materials for VOC detection

Consumer & Professional

Porous silica using sol-gel processes

- Porous silica with meso- and microporosity
- High ratio surface/volume (until 600m²/g)
- Detection of color/fluorescence- Specific detection
- Detection limit : ng/mL (depending on VOC)
- Thin layer (300nm), monolithic or defined shape



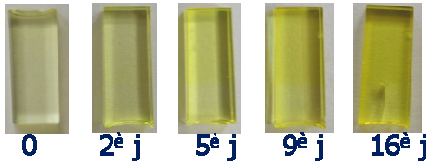
Main partners

ethera

Example of applications

1 Formaldehyde & total Aldehydes detection

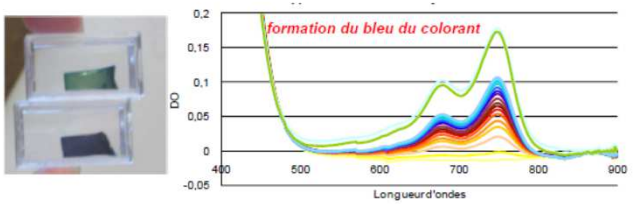
Formaldéhyde (cancérogène) : 18 ppb



Aldéhydes totaux (F:18ppb, Ac:17 ppb)

2 H_2S *detection* emitted by Salmonella

H_2S + specific probe → dye

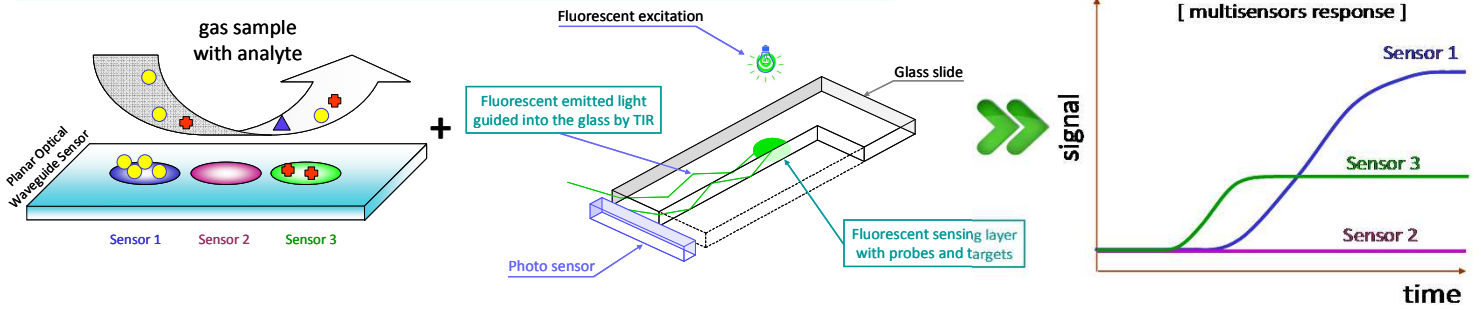


Specific probe is included in a transparent nanoporous matrix fabricated by sol-gel technology.
Reaction of H2S with the specific probe produce a product which absorbs in visible range.

Real-time air quality monitoring

Professional

Sol-gel & POW Sensor: principle



- Highly sensitive, selective sensor for **VOCs (formaldehyde,acetaldehyde, H2S, total aldehydes, BTEX…)**
- Low cost disposal sensor chip
- Optical detection

Main partners

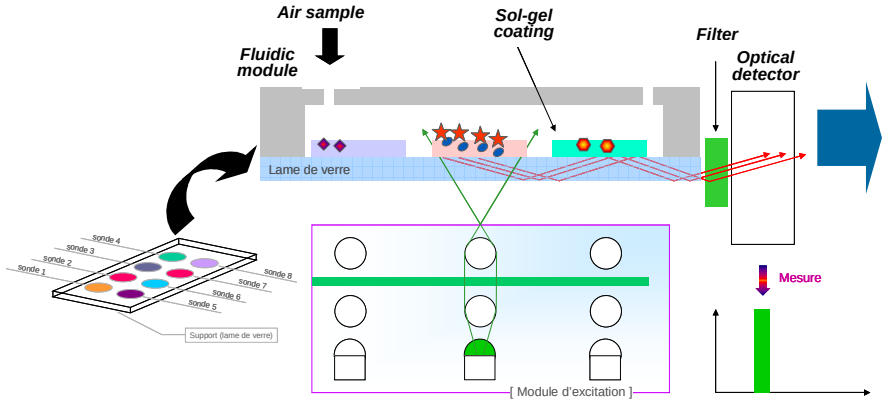
ethera

IRAMIS

BIOMERIEUX

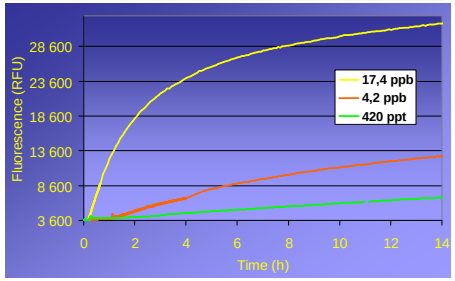
PleiadesTechnologies

Multi-gas portable system for on-site air quality control (fluorescence detection)



Stand alone portable

- Real time
- No sample preparation
- Multiplex : up to 10 targets



Ex: Quantification of formaldehyde

- 8 ppb in 3 minutes
- Detection limit: 400 ppt
- Temperature: 5 → 45°C

Multi-sensors for gas detection and identification

T-REX (Technology for the Recognition of Explosives)

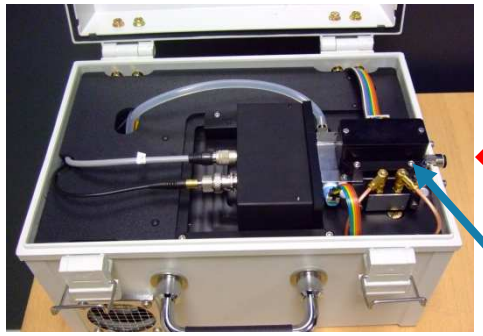
16 sensors:

4 fluorescent sensors

8 surface acoustic wave sensors

2 Quartz crystal microbalance sensors

Temperature and humidity sensors



Main partners

Collaboration
CEA Le Ripault ,
CEA List & CEA Leti

Electronic Nose

Advantages:

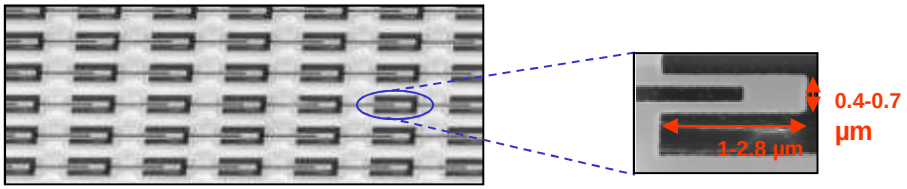
Good selectivity
Good sensitivity
Multicomponent analysis
Analyte recognition

NEMS for multi-gas analysis

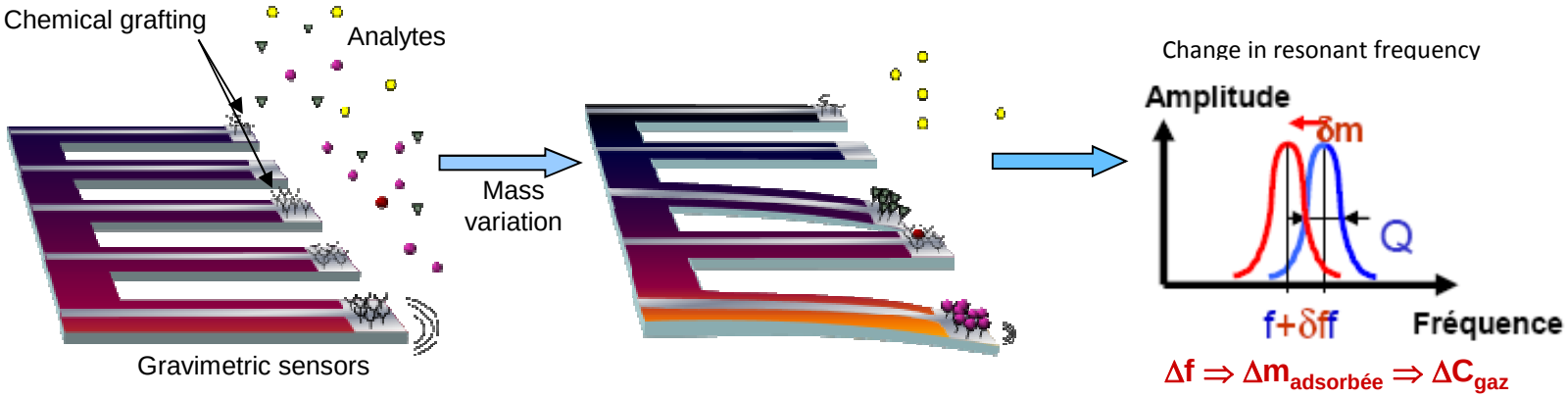
Partners

Objective

- Multi-gas analysis with nanostructures



Principle



Main features

- Enhancement of sensitivity and resolution, thanks to nanometric dimensions
- High selectivity, thanks to chemical functionalization

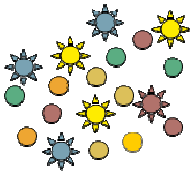
=> Specific and Sensitive Gas Analysis achieved with NEMS

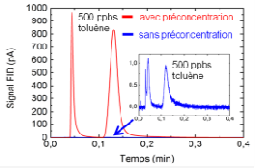
Lab-on-chip gas analysis systems
Revisiting gas analysis with new technologies

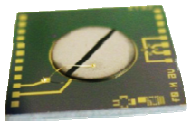
Professional

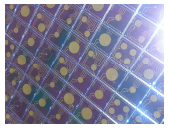
Gas chromatography principle

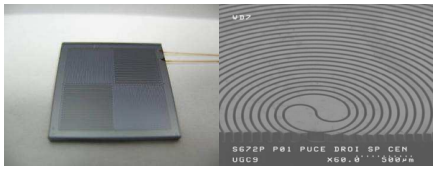
Gas mixture → Pre concentrator → Injector → Column → Detectors

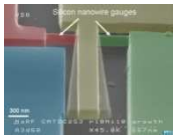


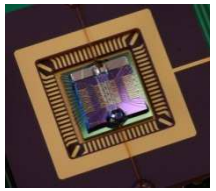












Main advantages: Wafer scale technology development

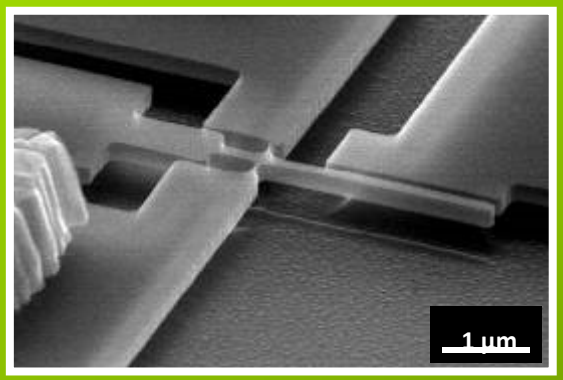
Miniaturization opens new product developement opportunities :

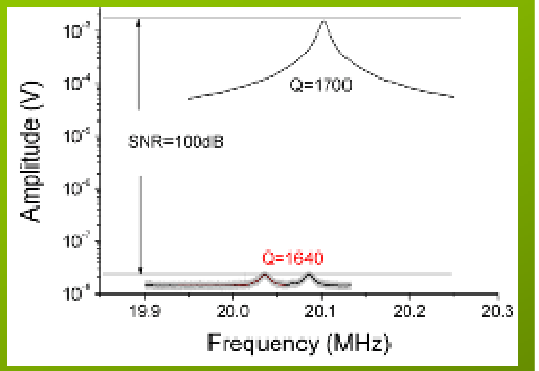
- Collective fabrication (MEMS technology)
- Lower power systems
- Faster analysis times
- Replace laboratory intrument by inline/field sensors

Integrated LOC system: µGC-NEMS for continuous monitoring

Professional

NEMS resonator





Very small characteristic length

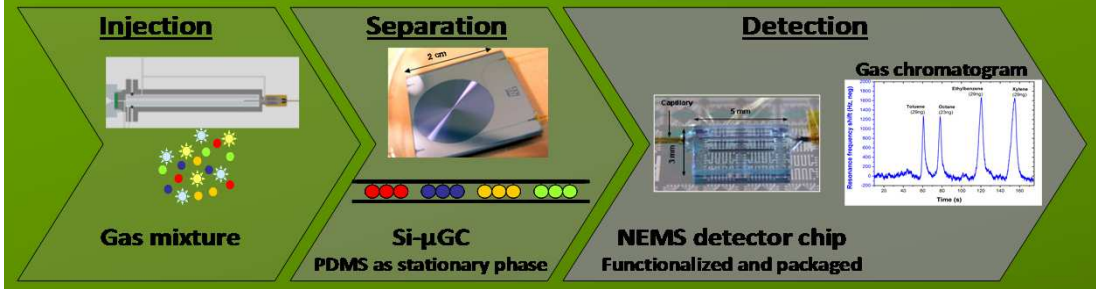
- High resolution: ato gram (10^{-18} g)
- Very short respond time
- High integration

Main partners

LETI/ CALTECH Alliance

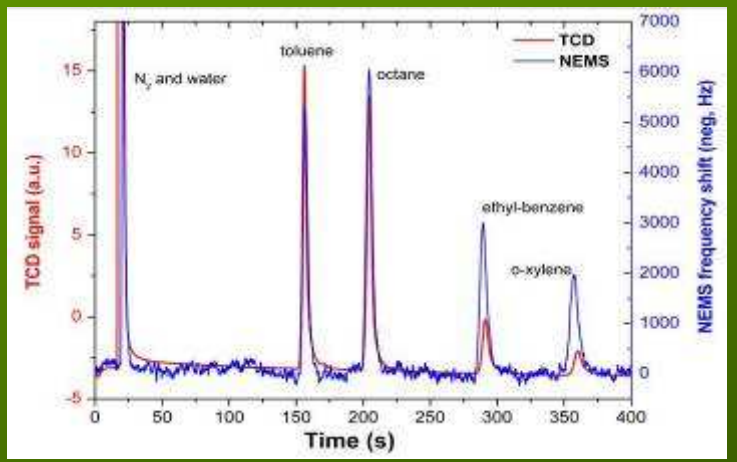
Startup establishment (2011) : APIX

Multi-gas analyzer for continous environment monitoring



Very high integration between µGC and NEMS

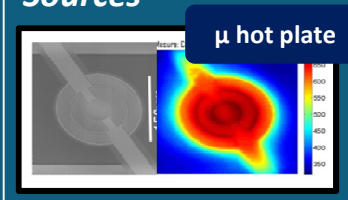
- Very reduced dead volumes
- Maintaining a good flow matching



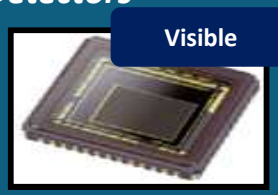
Optic for chemical sensing

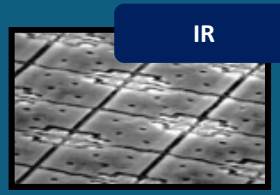
Optical components

Sources

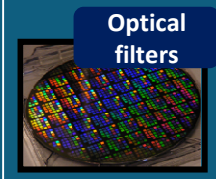


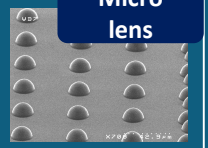
Detectors

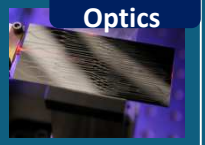




Integrated optics & nanophotonics







Partnership

III-V lab
ALCATEL-THALES

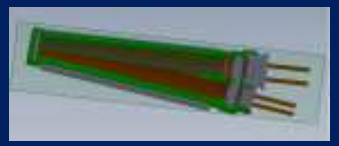
Schneider Electric

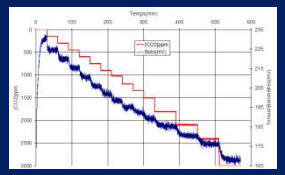
DELTA DORE

Low cost gas sensors

Non Dispersive infrared NDIR (CO_2)

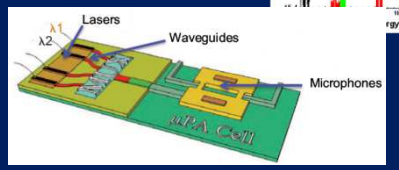
«black-body» Source → Optical cavity → Optical filters → µ-bolometers Detectors

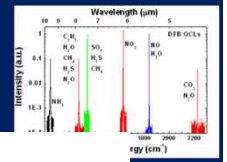




High-end gas sensors

QCL-Based µPhoto-Acoustic sensor

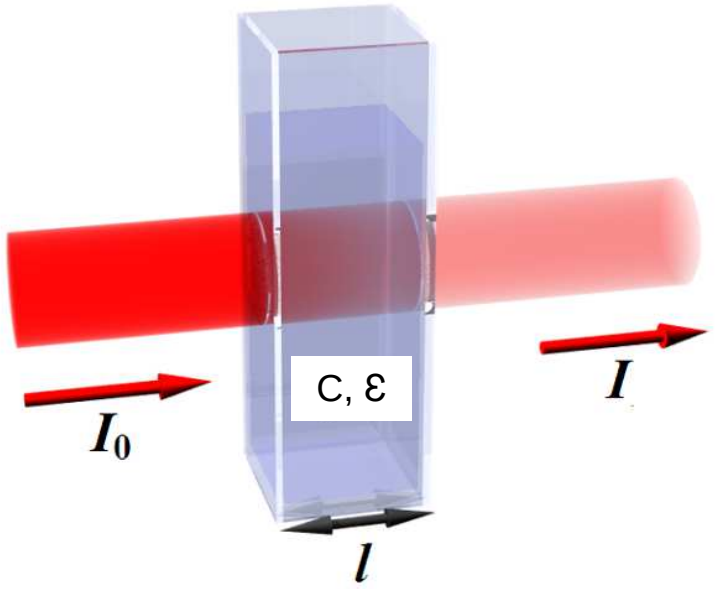




Our sensors combine optical detection strength values with miniaturization, multiple functions integration, power consumption reduction and cost effectiveness

Non Dispersive InfraRed sensor (NDIR) principle

- Non Dispersive IR detection:
  - Based on the light absorption measurement
  - Regulated by Beer-Lambert law
  - Used to measure gas concentration from hundred of ppm down to ppb



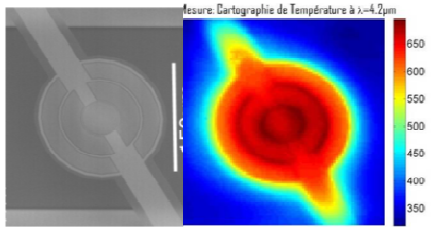
$$A = \log_{10} \frac{I_o}{I} = \varepsilon\, l\, c$$

I_0 = Intensity of the incident radiation
I = intensity of the radiation coming out of the sample
A = *absorbance* of the sample
Ɛ = molar absorptivity
L = Length of solution the light passes through
C = Concentration of solution

CO_2 sensor

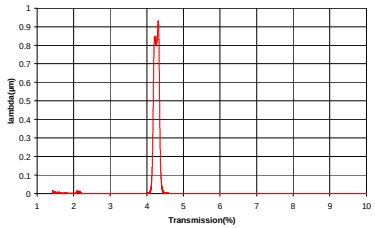
Consumer & Professional

Non Dispersive infrared NDIR : Principle



IR Source based on MEMS LETI technology

- Max Power op. 2 mW
- Lifetime > 10 Y @ 650 °C



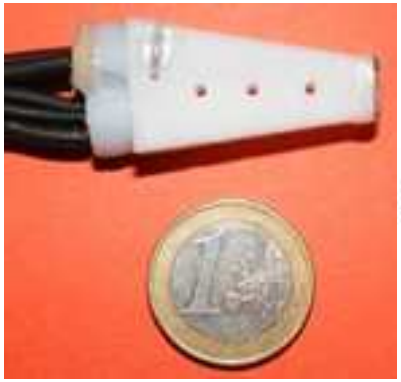
Commercial filter at 4,26µm

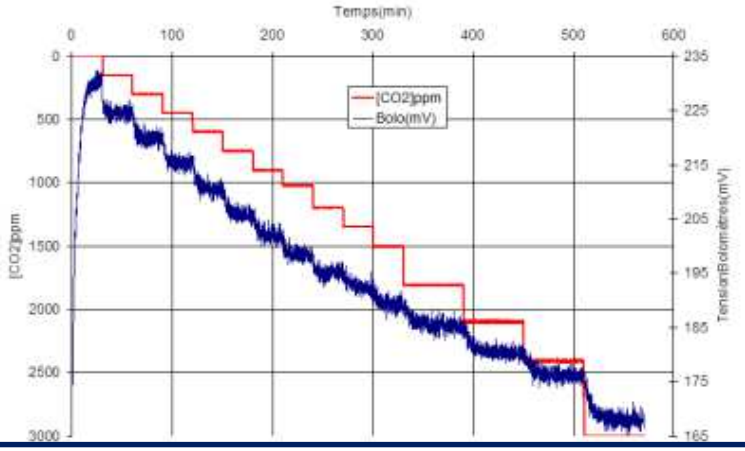
Commercial Infrared Detector Arrays based on thermopile technology

«black-body» Source → Optical path & WL lenses → Optical filters → Detectors

Key Results

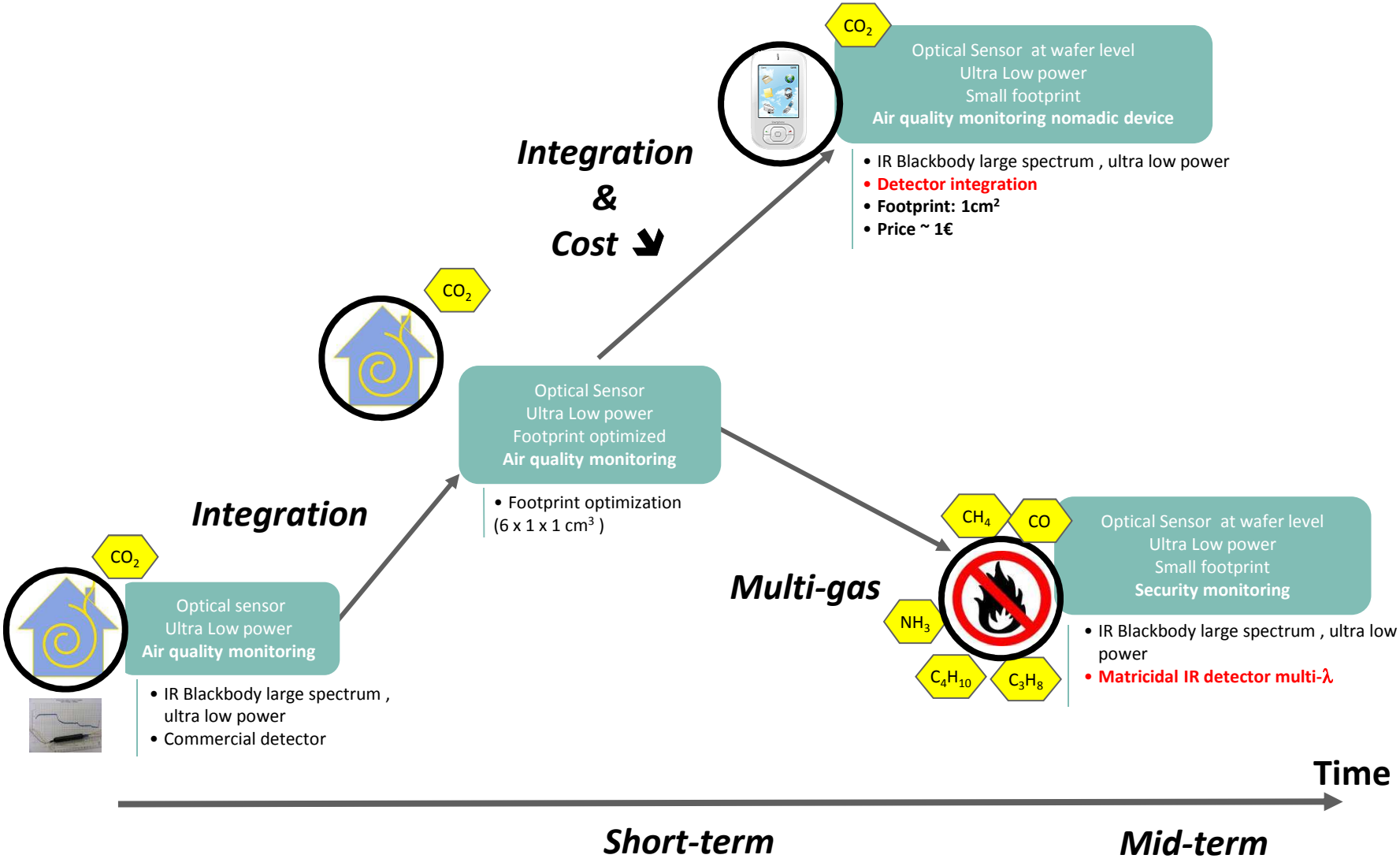
- Range: 100 – 3000 ppm
- Limit of detection: **40 ppm @ 1000 ppm**
- Lifetime: 10 Y
- Power max : ~**4,8 mW**
- Measured frequency: dependent on Apps
- ~ **0,15 mJ**/measure





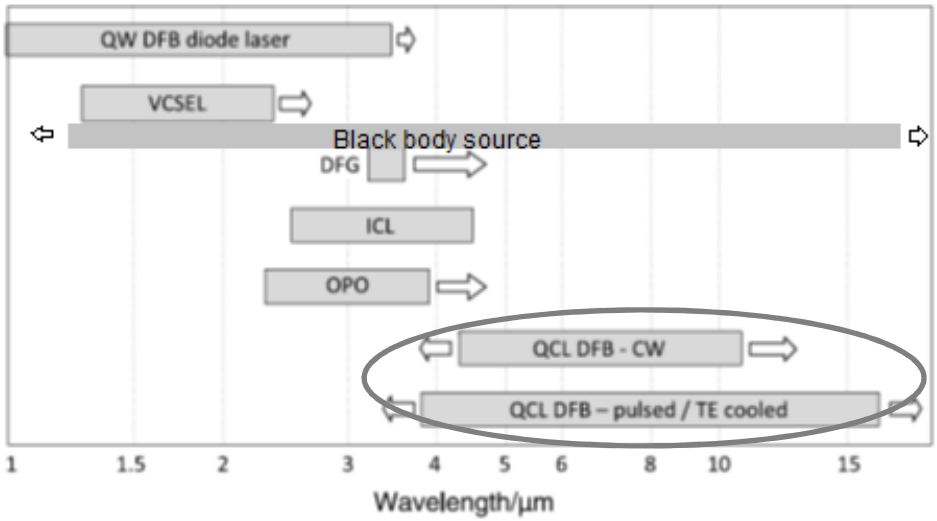
Roadmap to a low power, Embedded sensors

Consumer & Professional

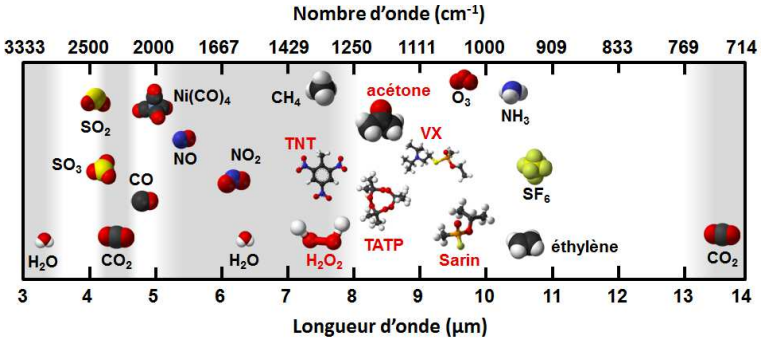


Quantum Cascade Laser (QCL) positioning

Emitting sources in Mid-IR wavelength



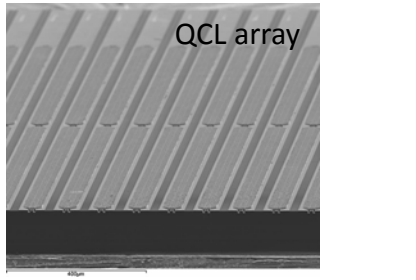
High absorption intensity
for
a larger number of components

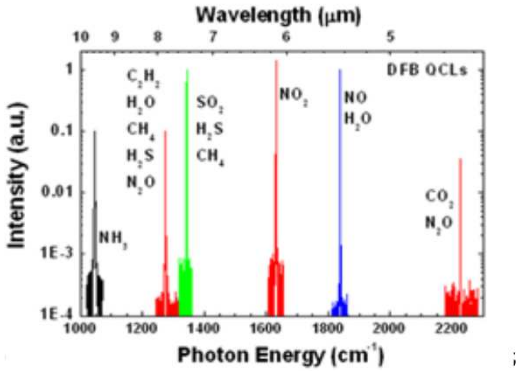


Quantum cascade laser is the most promising technology able to address the Mid-IR spectrum with high energy source and its is integration on a standard silicon wafers open new opportunities for affordable instrument.

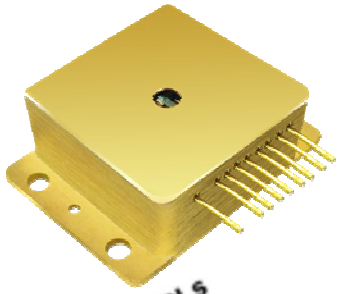
QCL-Based µPhoto-Acoustic sensor

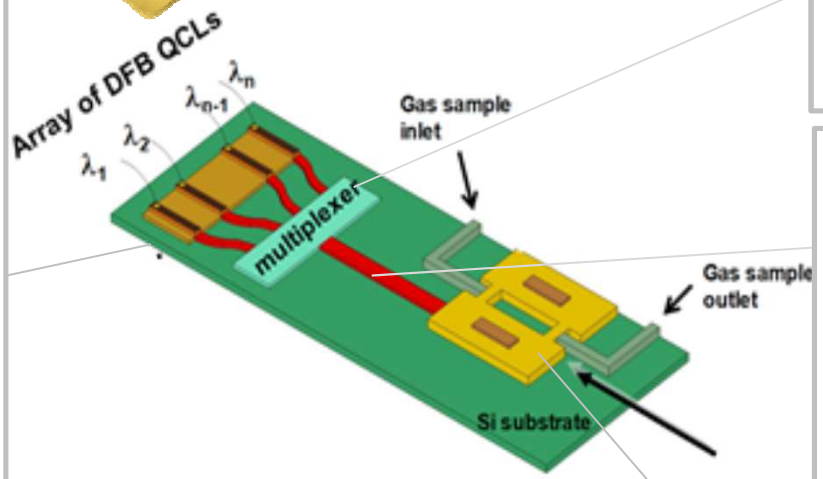
Professional

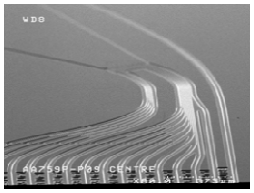




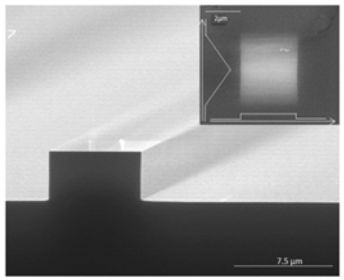
of interest



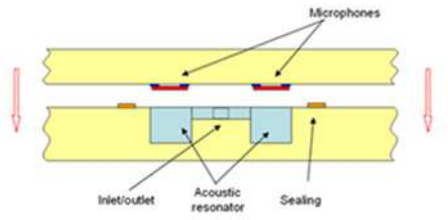




AWG multiplexer



Low Losses Waveguides working in the [4-8 µm] wavelength range



Ultra compact multi-gas spectroscopy system based on a MEMS PA cell

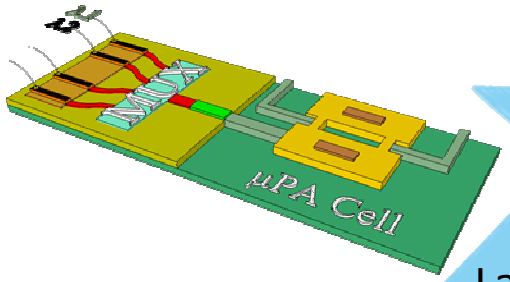
Lab on chip

Market opportunities

The system will enable a multigas measurement, with high selectivity and improved sensitivity (from ppm down to ppb levels)
Trace detection, chemical emission monitoring, process control applications

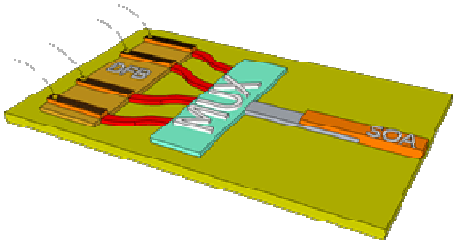
Roadmap QCL based sensing

Professional



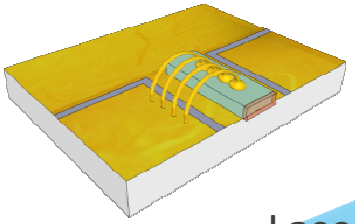
Lab on chip

2015



Multi-λ source
+ Micro PA cell

2014



Laser on submount

2013

Key differentiators

- Customizable solutions for multi gas sensing thanks to flexibility on QCL arrays (4 to 10 µm)
- Miniaturization
- Robustness
- Cost effective : IC/MEMS compatible fabrication chain
- High sensibility : high power laser sources
- High selectivity : Finely tunable narrow bandwidth

Conclusions and outlook

- LETI is positioning on sampling preparation to transducer and signal analyze to provide dedicated sensors to answer the different markets requirements “smart objects”, “smart homes”, “smart cities”
- It fulfills a direct need from the market, since consumers, citizen awareness, governments and agencies put more and more strict rules and guidelines to air quality.
- Leti’s commitment is to bring value to our society and to bring value to our partners thanks to research and innovation

Come and visit our showroom

Save the date now!

www.leti.fr

Leti Days

Grenoble • Paris • San Francisco • Tokyo

June 25-26, 2014 | MINATEC, **Grenoble**