OUTLINE

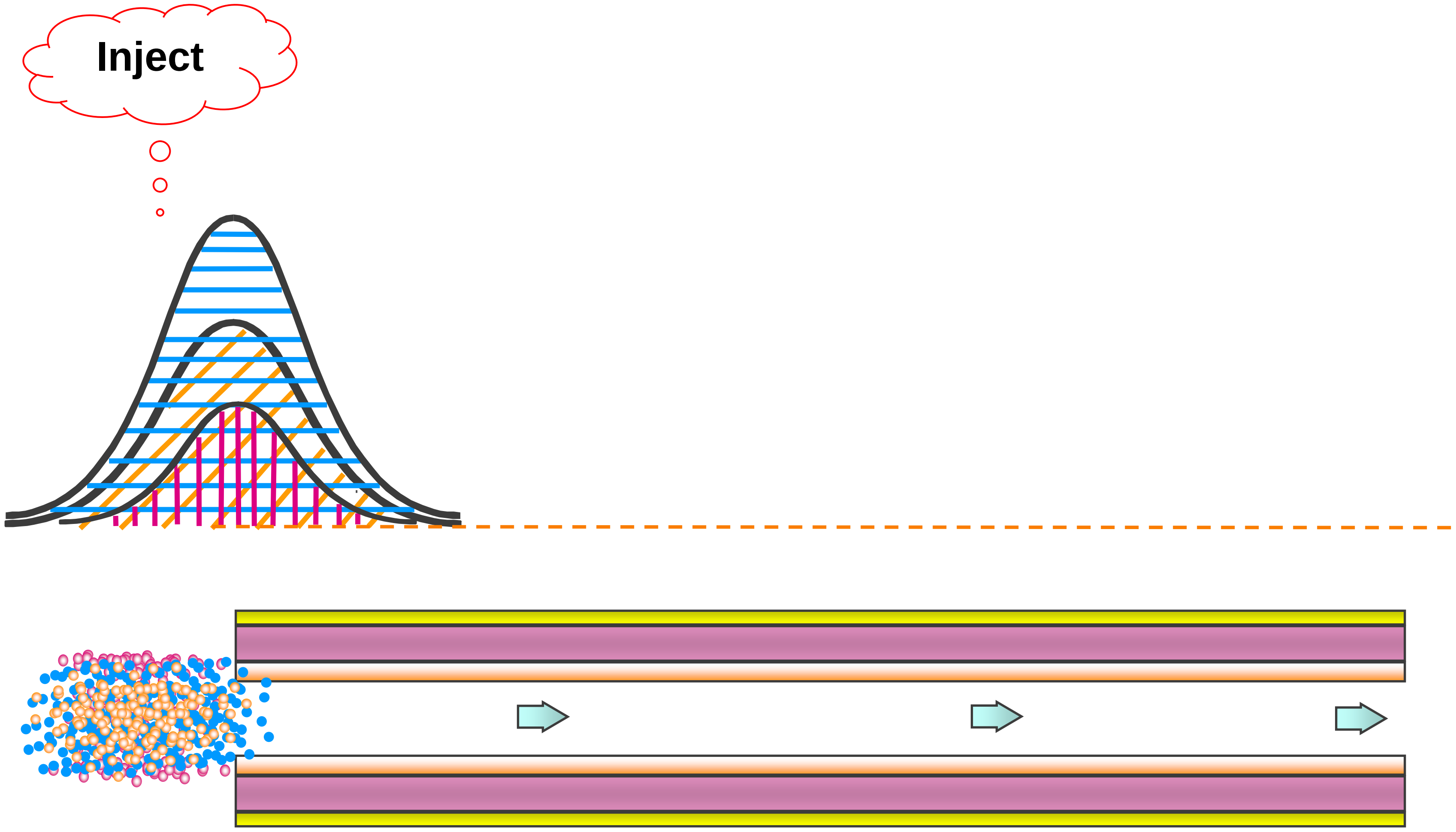
APIX ANALYTICS

- Gas Chromatography primer
- Applications
- APIX, a startup company experience

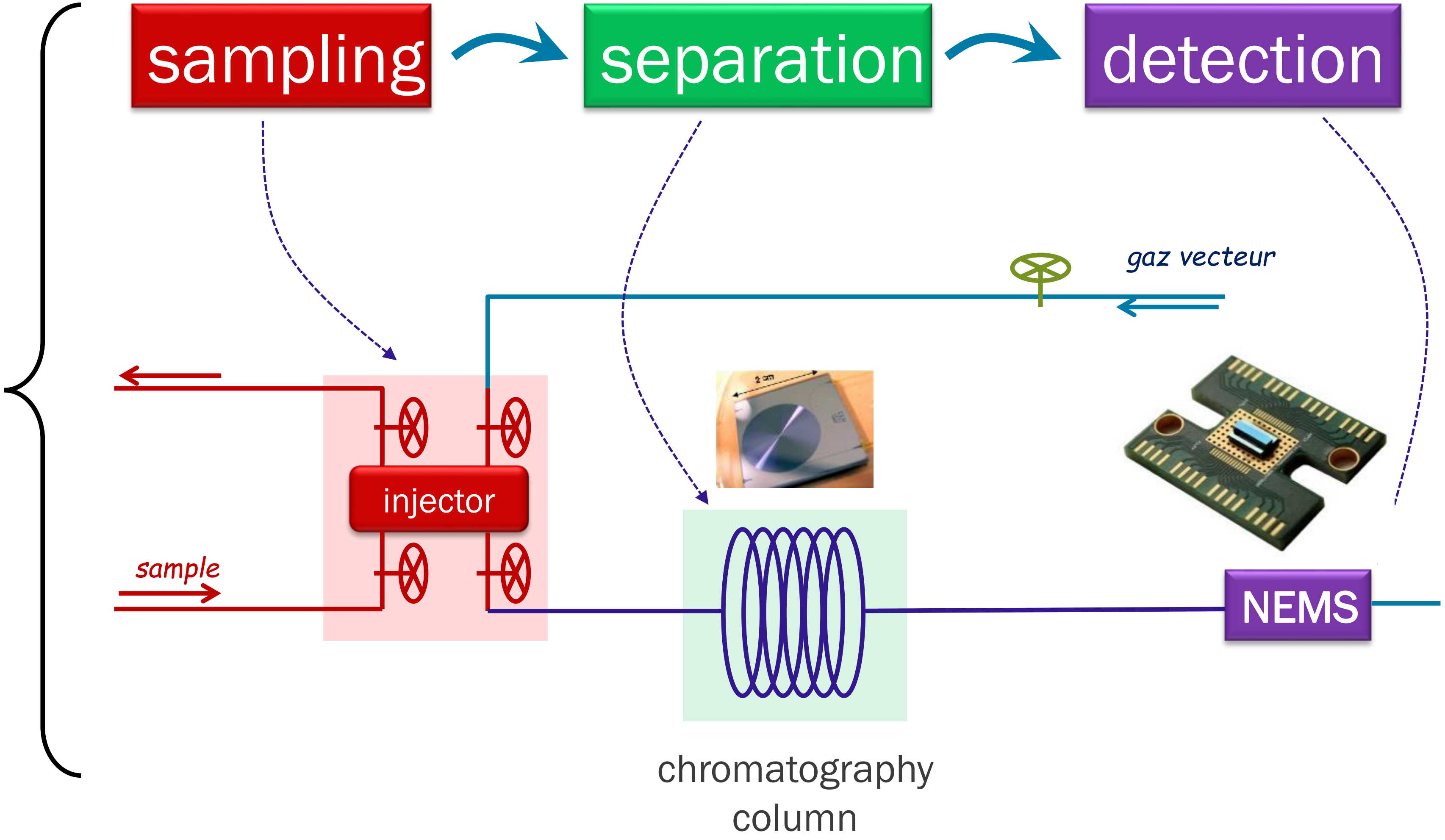
pierre.puget@m4x.org

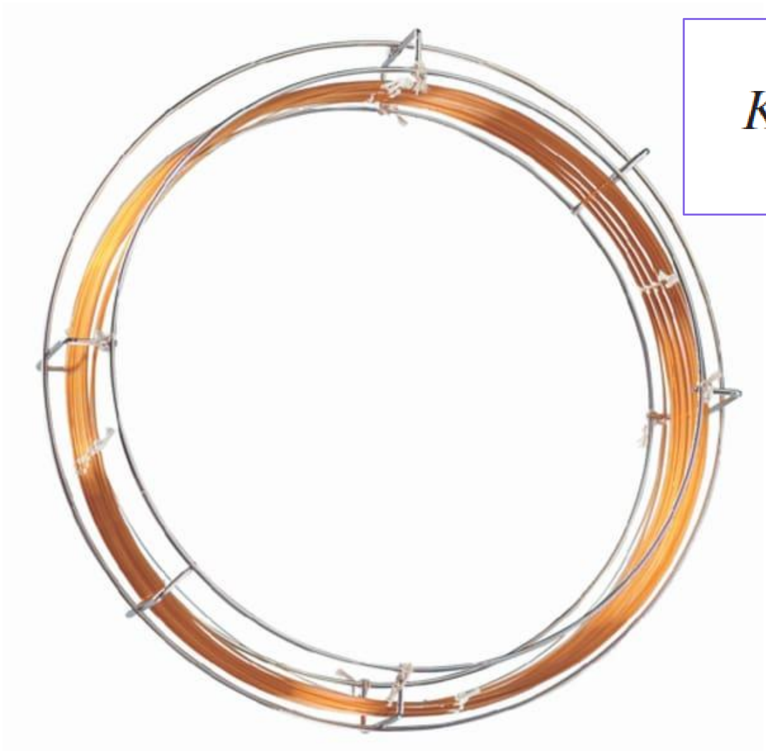
PRINCIPLES

PRINCIPLE OF GAS CHROMATOGRAPHY



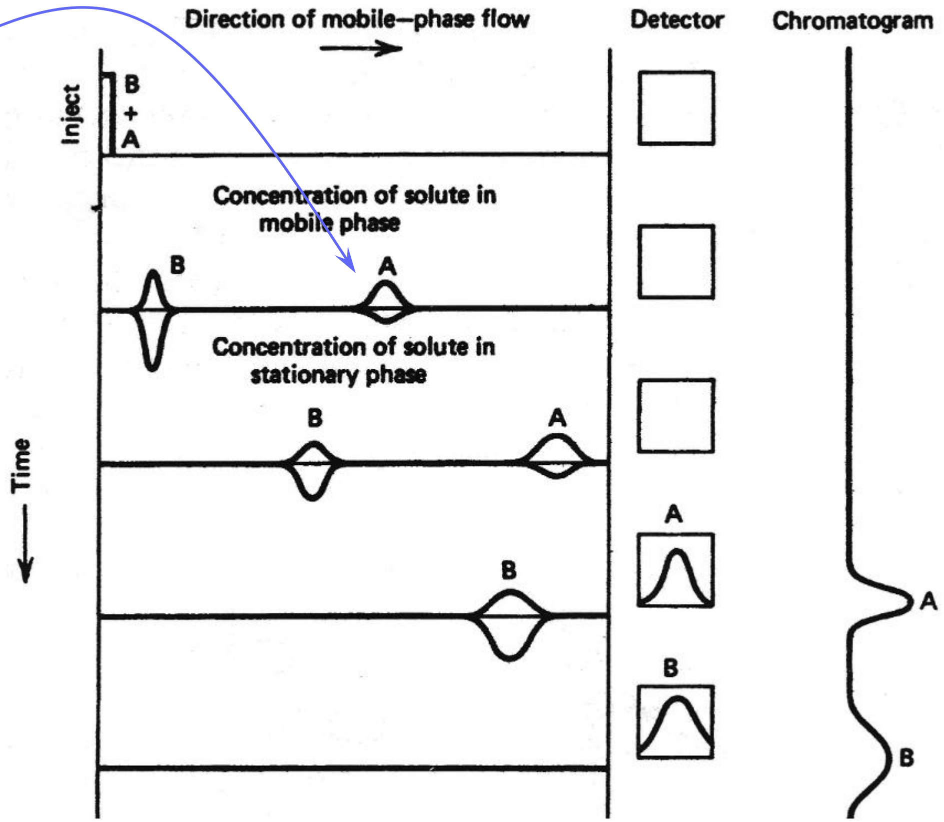
OUR PRODUCTS: PLUG & PLAY GC MODULE





length ~ a few to a few 10s meter range
diameter ~ 100 µm

$$K_c = \frac{[A]_S}{[A]_M}$$



Schematic representation of the chromatographic process. Adapted from Harold M. McNair, James M. Miller, *Basic Gas Chromatography*, John Wiley & Sons, New York,1998. Reproduced courtesy of John Wiley & Sons, Inc.
source: LibreTexts Chemistry, ch 3.1: Principles of Gas Chromatography

to remumber:

- control the flow (pressure) of carrier gas
- control the temperature of the column

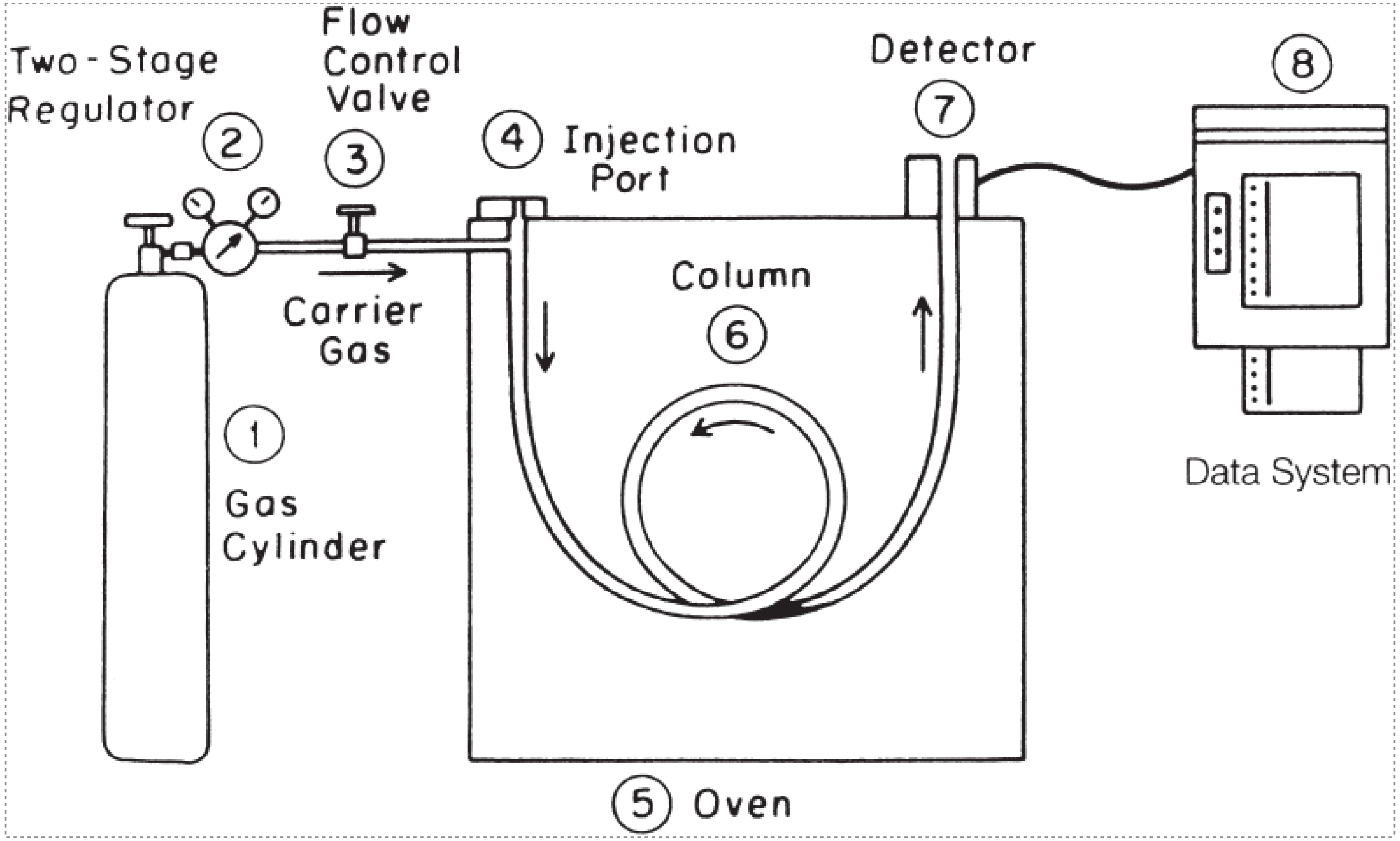
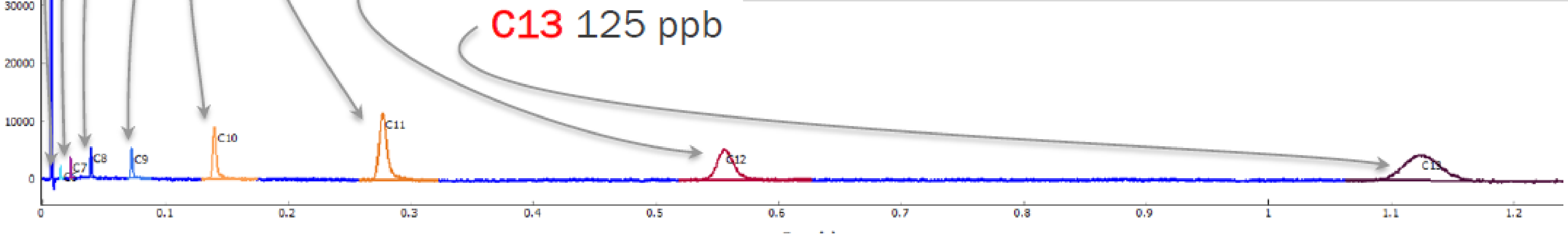
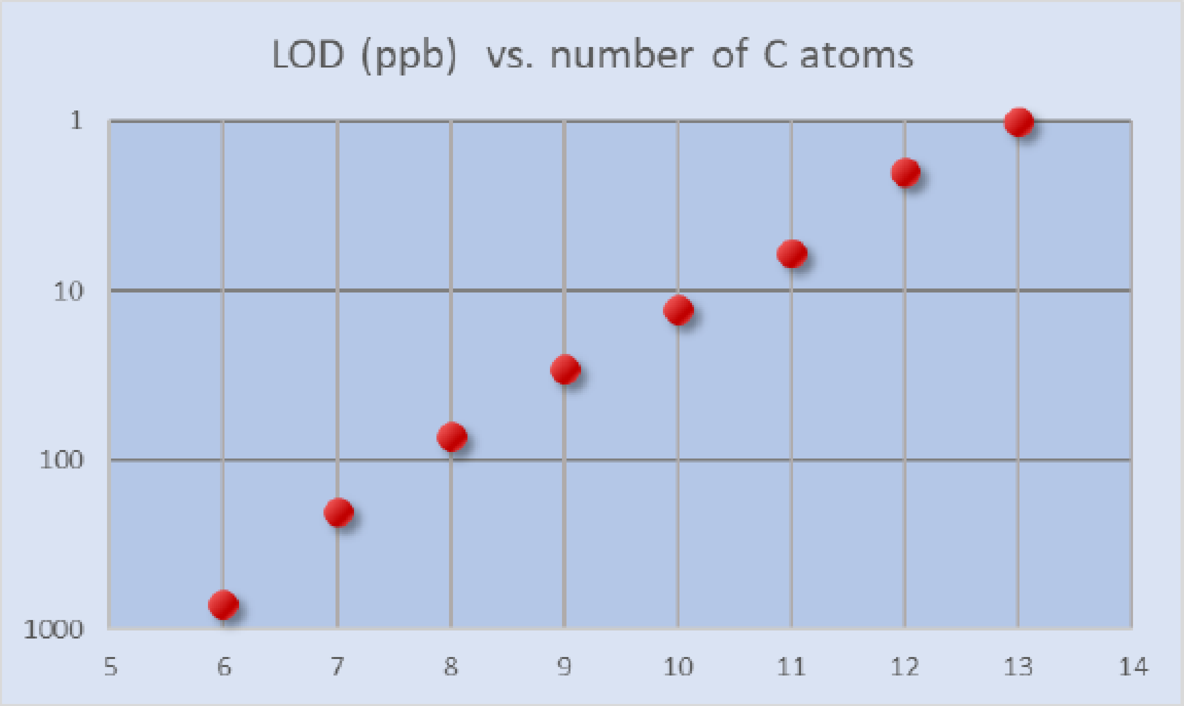


Fig. 1.8. Schematic of a typical gas chromatograph.

ANALYSIS OF ALKANES C6 TO C13 WITH NGD

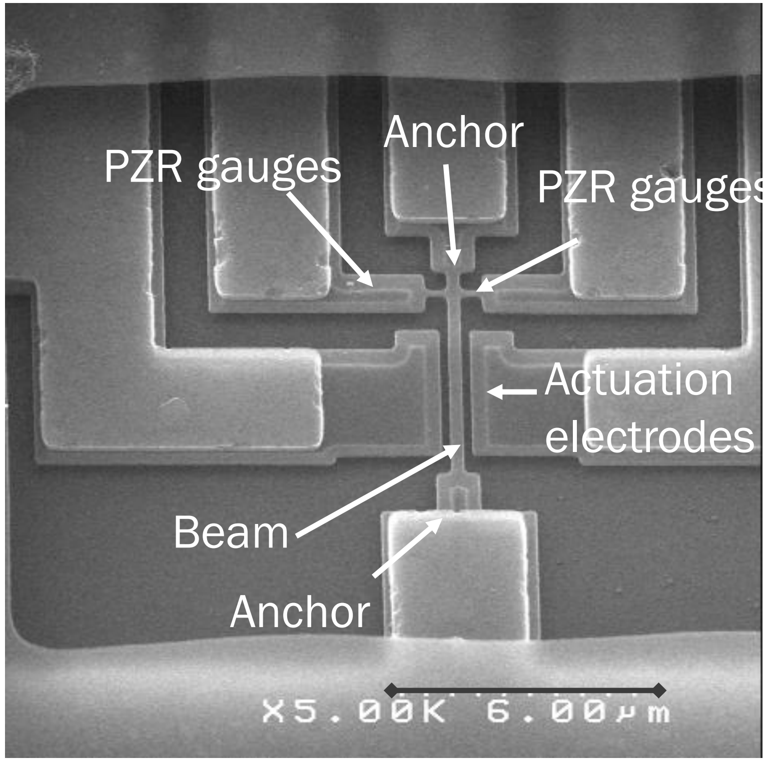




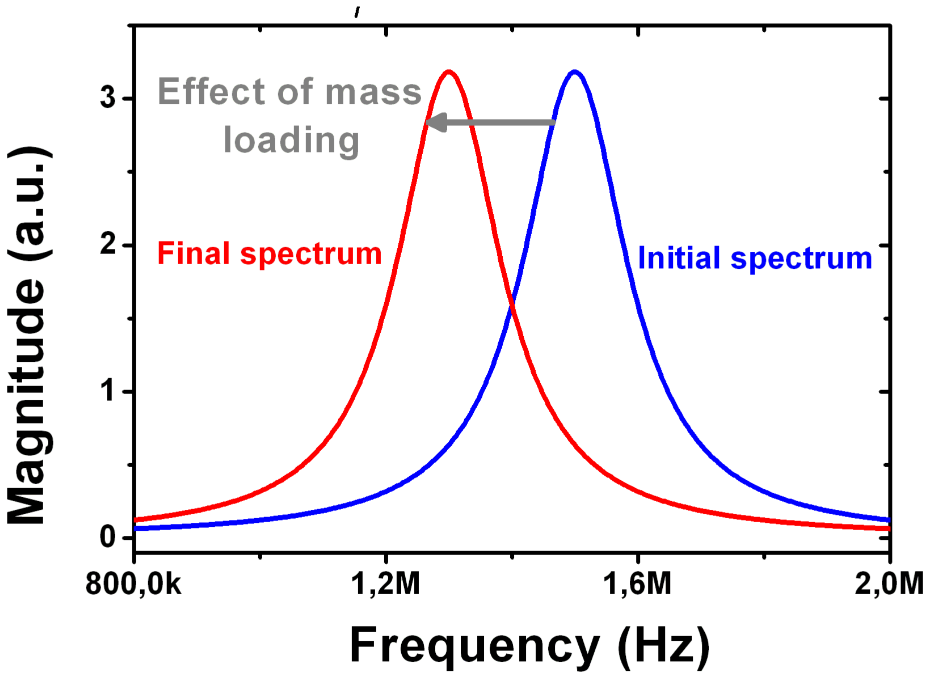
det

Our NEMS gravimetric detector
(a.k.a. NGD / Nano Gravimetric Detector)

1. resonating structure covered with a sensitive layer

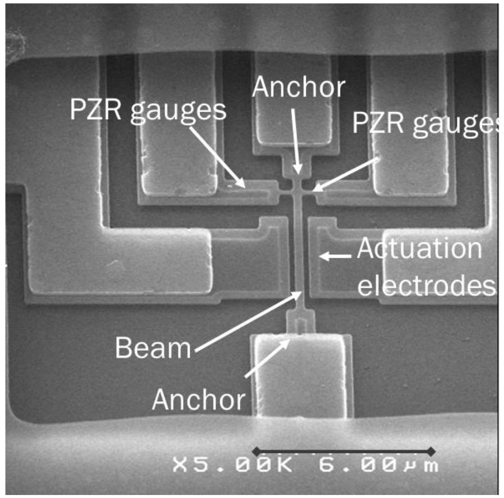


2. adsorption of compounds causes resonance frequency shift

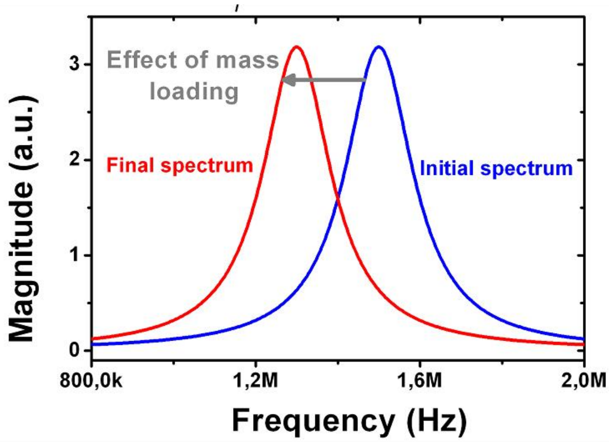


Our NEMS gravimetric detector (a.k.a. NGD / Nano Gravimetric Detector)

1. resonating structure covered with a sensitive layer



2. adsorption of compounds causes resonance frequency shift

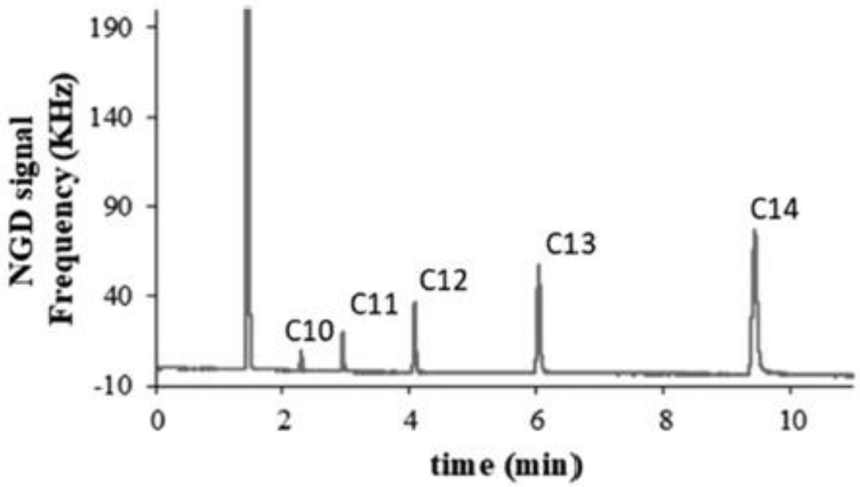


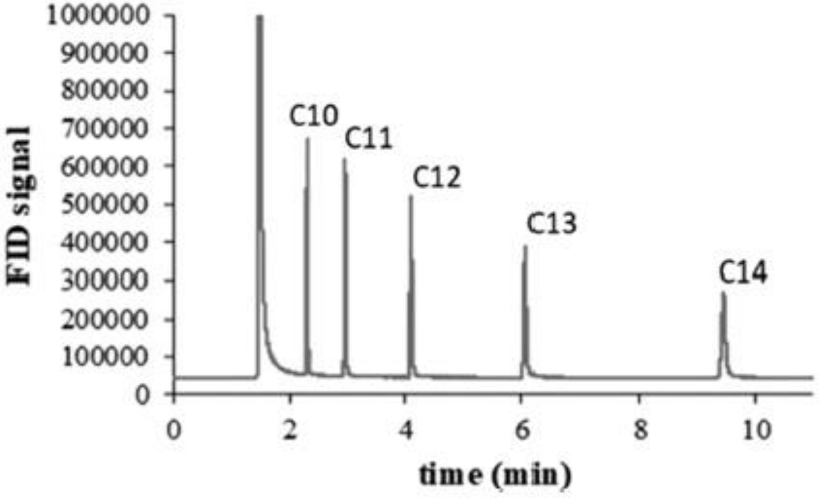
$$K_c = \frac{[A]_S}{[A]_M}$$

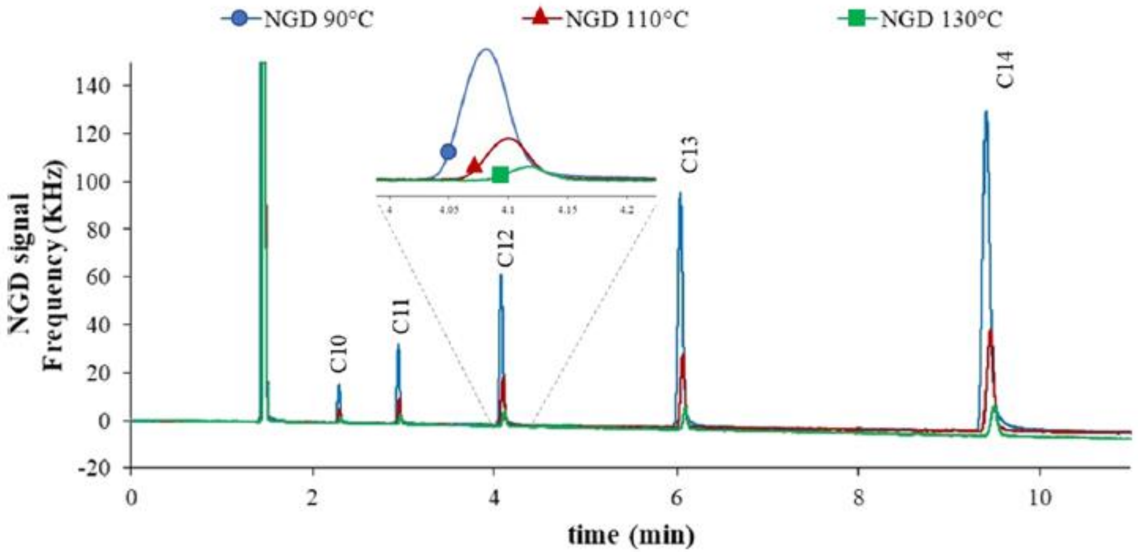
to remumber:

- freq. shift proportional to vapor concentration
- but sensitivity strongly depends on size of molecule (linear) and temperature (exponential)

EFFECT OF TEMPERATURE: COLUMN AND NGD ISOTHERMAL

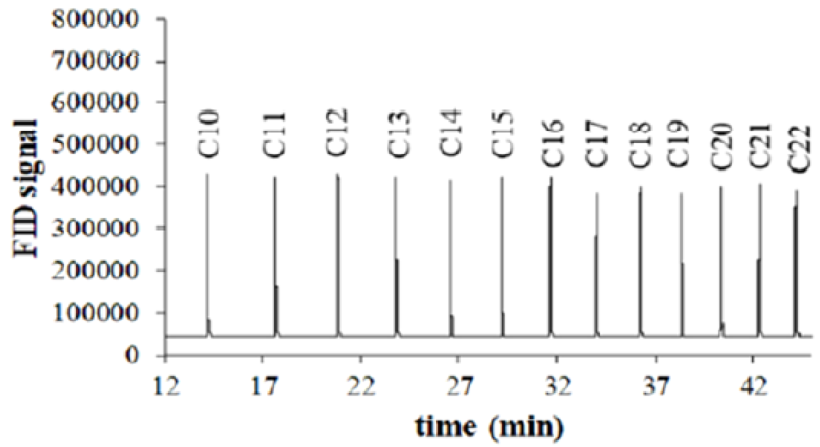




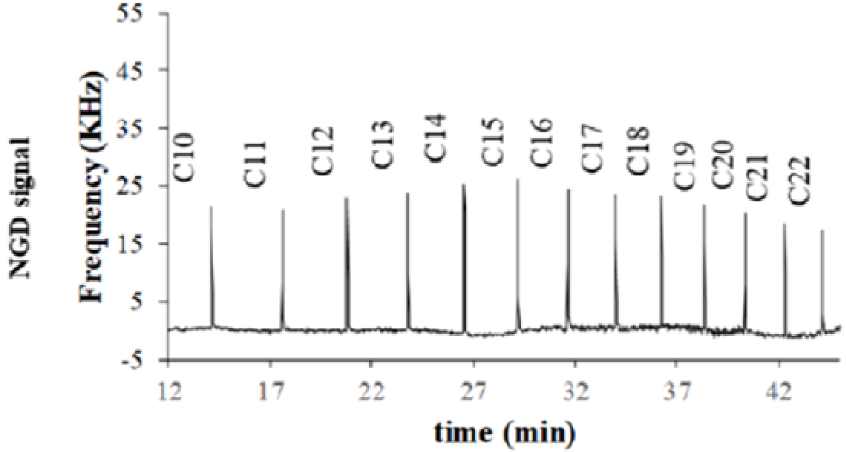


ref: L. Alonso Sobrado *et al.*, « Characterization of Nano-Gravimetric-Detector Response and Application to Petroleum Fluids up to C $_{34}$ », *Anal. Chem.*, vol. 92, nº 24, p. 15845-15853, déc. 2020, doi: 10.1021/acs.analchem.0c03157.

EFFECT OF TEMPERATURE: COLUMN AND NGD TEMPERATURE PROGRAMMING / RAMP



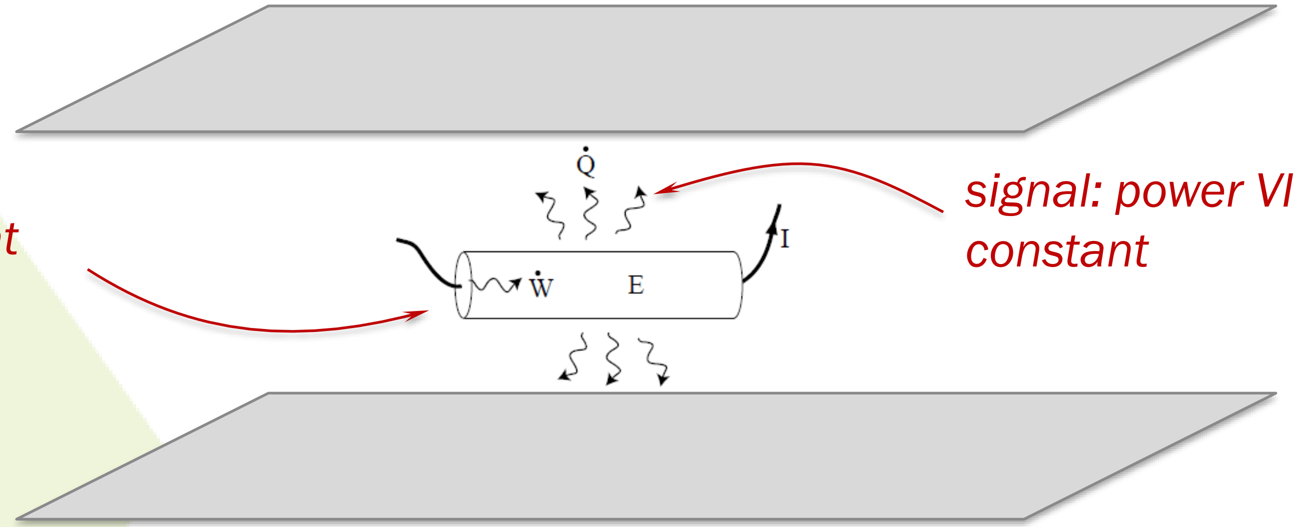
Observed NGD chromatogram



ref: L. Alonso Sobrado *et al.*, « Characterization of Nano-Gravimetric-Detector Response and Application to Petroleum Fluids up to C_{34} », *Anal. Chem.*, vol. 92, nº 24, p. 15845-15853, déc. 2020, doi: 10.1021/acs.analchem.0c03157.

THERMO CONDUCTIVITY DETECTOR

hot wire, controlled constant temperature (constant R)



signal: power VI delivered to keep V/I constant

puissance échangée avec l'écoulement de gaz:

- **conduction / diffusion dans le volume du gaz**
- **convection**

les deux termes dépendent des caractéristiques du gaz ambiant (gaz vecteur ou analyte)

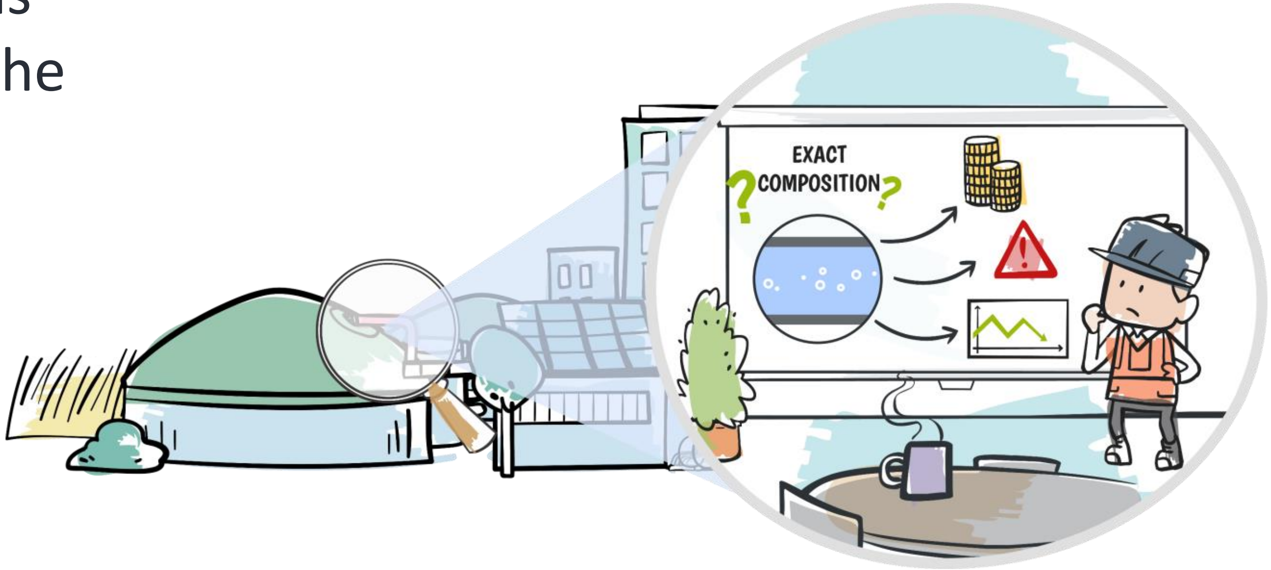
sources de bruit:

- **perturbations dans l'écoulement (variation de la pression d'entrée et/ou de sortie de l'écoulement)**
- **perturbations thermiques**
  - température du composant 'bulk' (contrôle commande de l'instrument)
  - température du filament (électronique de lecture du détecteur)

APPLICATIONS / MARKETS

WHY DO WE NEED TO MEASURE GAS COMPOSITIONS?

The **exact compositin of the gas** is critical for operators evolving in the field of **energy and environment**



- **Control** of productivity
- Improved **responsiveness**
- **Lower** costs
- **Reduce emission**

WHAT TECHNOLOGIES ARE AVAILABLE TO MEASURE GAS?

Low price & small size

Colorimetric tubes

Handheld single g detectors

CO_2 sensors

Analyzers

- ✓ Lab tools
- ✓ Expensive
- ✓ Sample transportation issues
- ✓ Time of analysis
- ✓ Utilities – Carrier gas & consumption

Micro GC tools

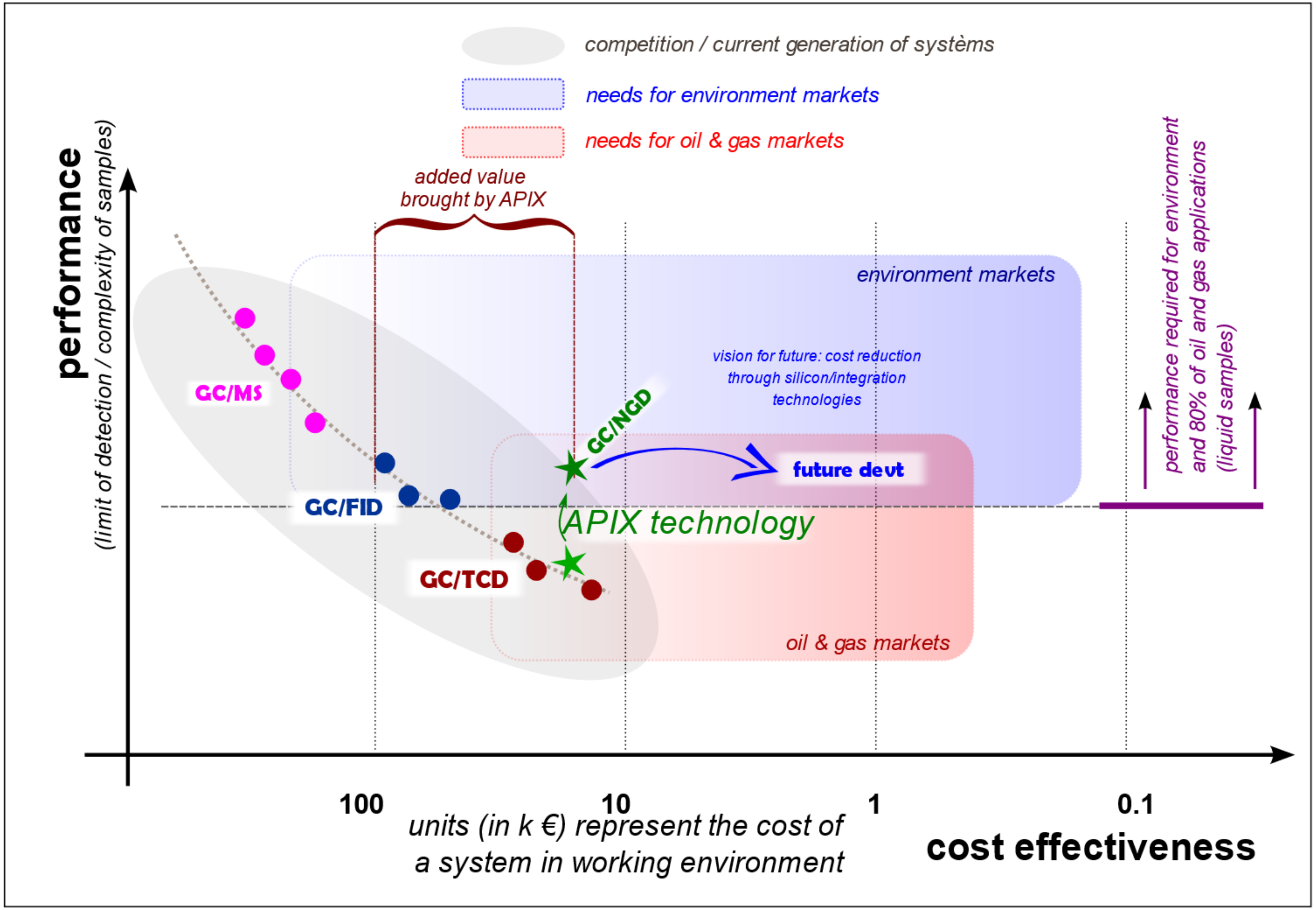
Specialized analyzers

Detectors

- ✓ Single gas
- ✓ Suited for simple apps.

Bench-top GC/MS or GC/XX systems

Multigas & high performances


competition / current generation of systèms
needs for environment markets
needs for oil & gas markets
added value brought by APIX
performance
(limit of detection / complexity of samples)
environment markets
vision for future: cost reduction through silicon/integration technologies
GC/MS
GC/NGD
future devt
GC/FID
APIX technology
GC/TCD
oil & gas markets
performance required for environment and 80% of oil and gas applications (liquid samples)
100
10
1
0.1
units (in k €) represent the cost of a system in working environment
cost effectiveness

NUMEROUS KEY APPLICATIONS

HYDROGENE

Production & process control
Purity
Quality

REFINERY GASES

Fuel gas composition
Flare gas monitoring
CO_2 emission

BIOMETHANE

Methanisation process
Energy content
Injection to the distribution grid
Odorization control
Control of impurities (sulfur compounds)

NATURAL GAS (ASTM D1945)

Quality
Energy content
Custody transfer
Odorization control

INDUSTRIAL EMISSIONS AND VOCS

Outdoor air quality
Indoor air quality
VOCS
BTEX

INDUSTRIAL AND SPECIALTY GASES

Purity
Quality

OUR BENEFITS

All-in-One analyzer for process

Capability to analyze all parameters of interest in a single system (4 modules)

>50% CAPEX Reduction

Reduced OPEX

Low carrier gas consumption

Carrier gas can be Air for the NEMS

No need of services from a GC expert

Small footprint

Measurement in situ, right at the sampling point with limited infrastructure and space requirements

Reduced Infrastructure costs

Measurement in situ, right at the sampling point with limited infrastructure and space requirements

Faster Measurements

Shorter measurement cycle times for faster decisions thanks to miniaturization

Cycle time <1 min vs 10+ min

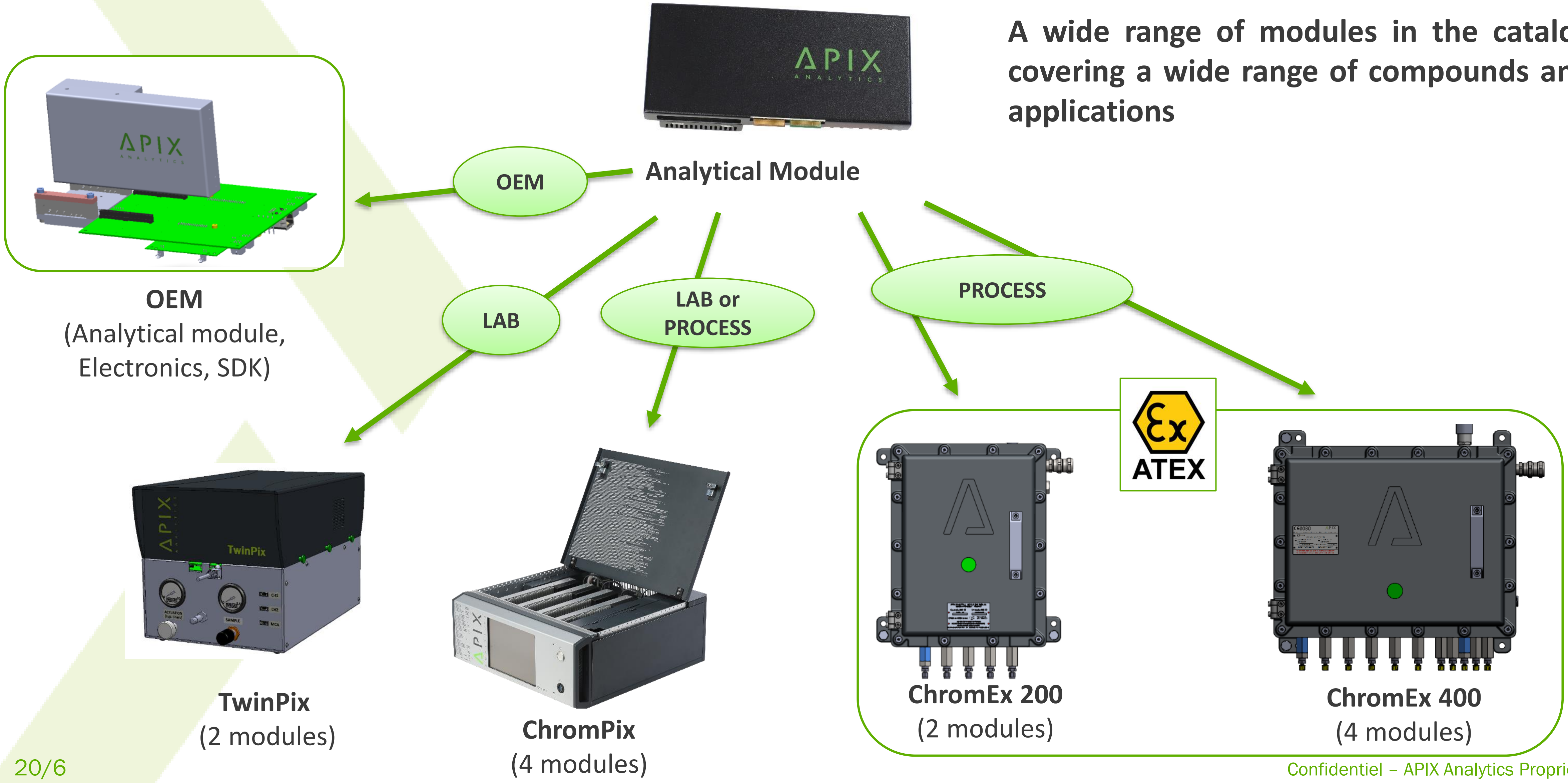
Wide range of detection

Intrinsically safe detector (No flame, no H2)
Wider detection spectrum with the combination of micro TCD and NEMS

PRODUCTS CURRENT GENERATION

MODULAR ARCHITECTURE

A wide range of modules in the catalog covering a wide range of compounds and applications



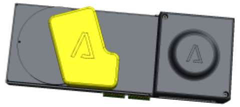
TECHNOLOGICAL ROAD-MAP

2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024

MODULES

V1 Modules
First generation of analytical modules

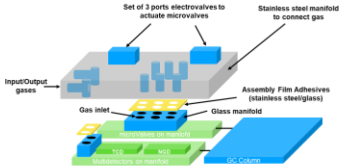
MI100G
Second generation of modules (isothermal)



MI100G-R2
Optimized module with regeneration function

ML
Module for liquid analysis

MRT100G
New module with temperature ramp function



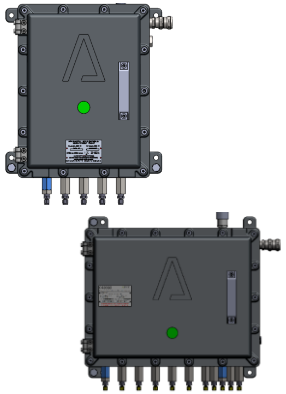
GREENPIX
Integrated module on manifold

SYSTEMS

ChromPix® V1
Product launch

MaxONE® V1
Product launch

ChromPix® V2
Product launch



ChromEx® 200/400
Product launch

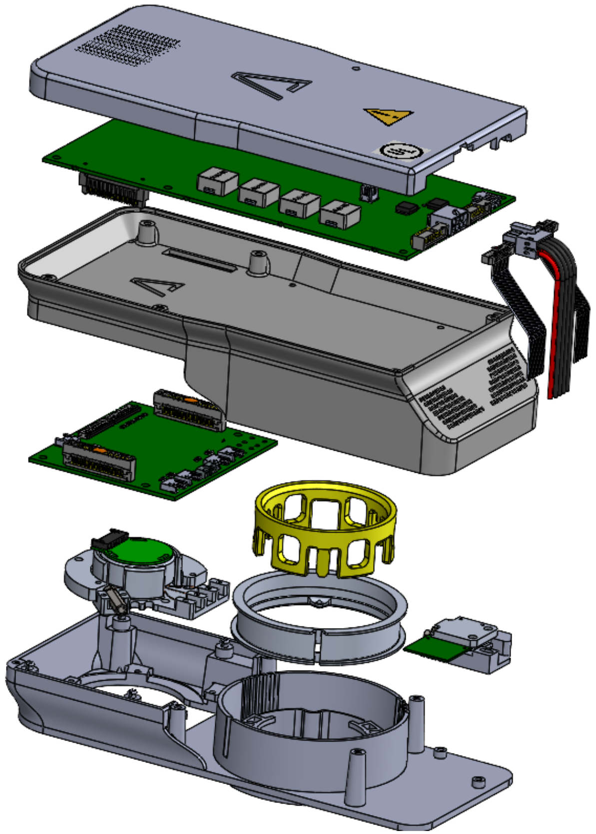
NanoPix®
Product launch

AlphaPix®
Product launch

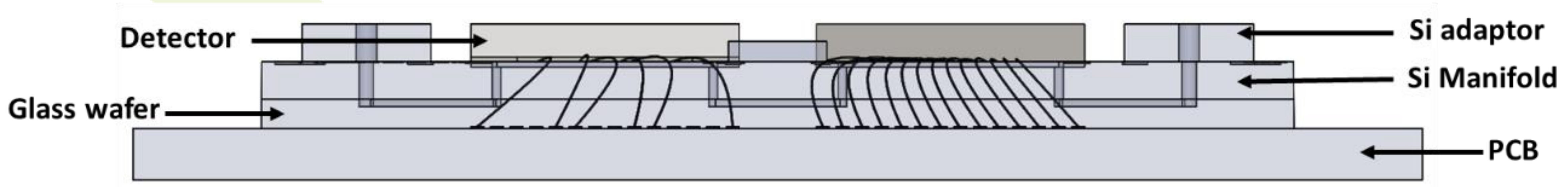
GREENPIX SYSTEM
All-in-one system

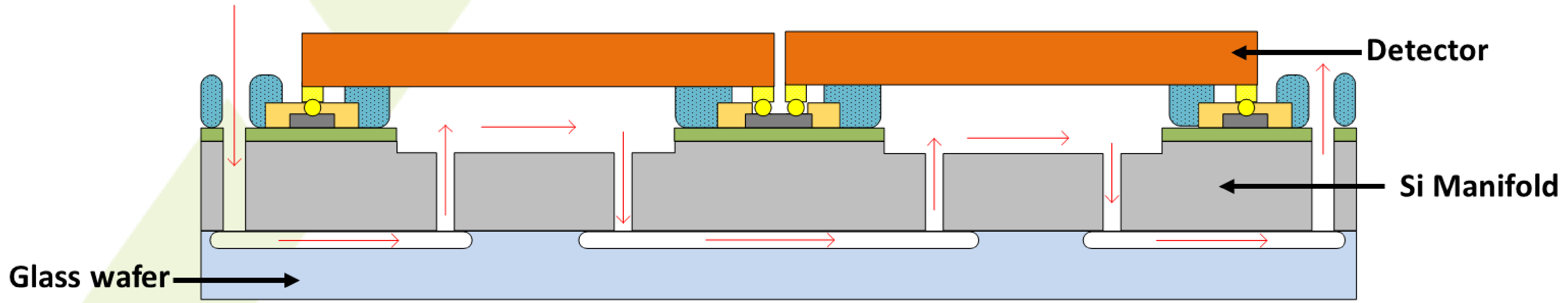
GREENPIX: A NEW GENERATION

FROM 'SPIDER' MICROFLUIDICS TO 'INTEGRATED' MICROFLUIDICS

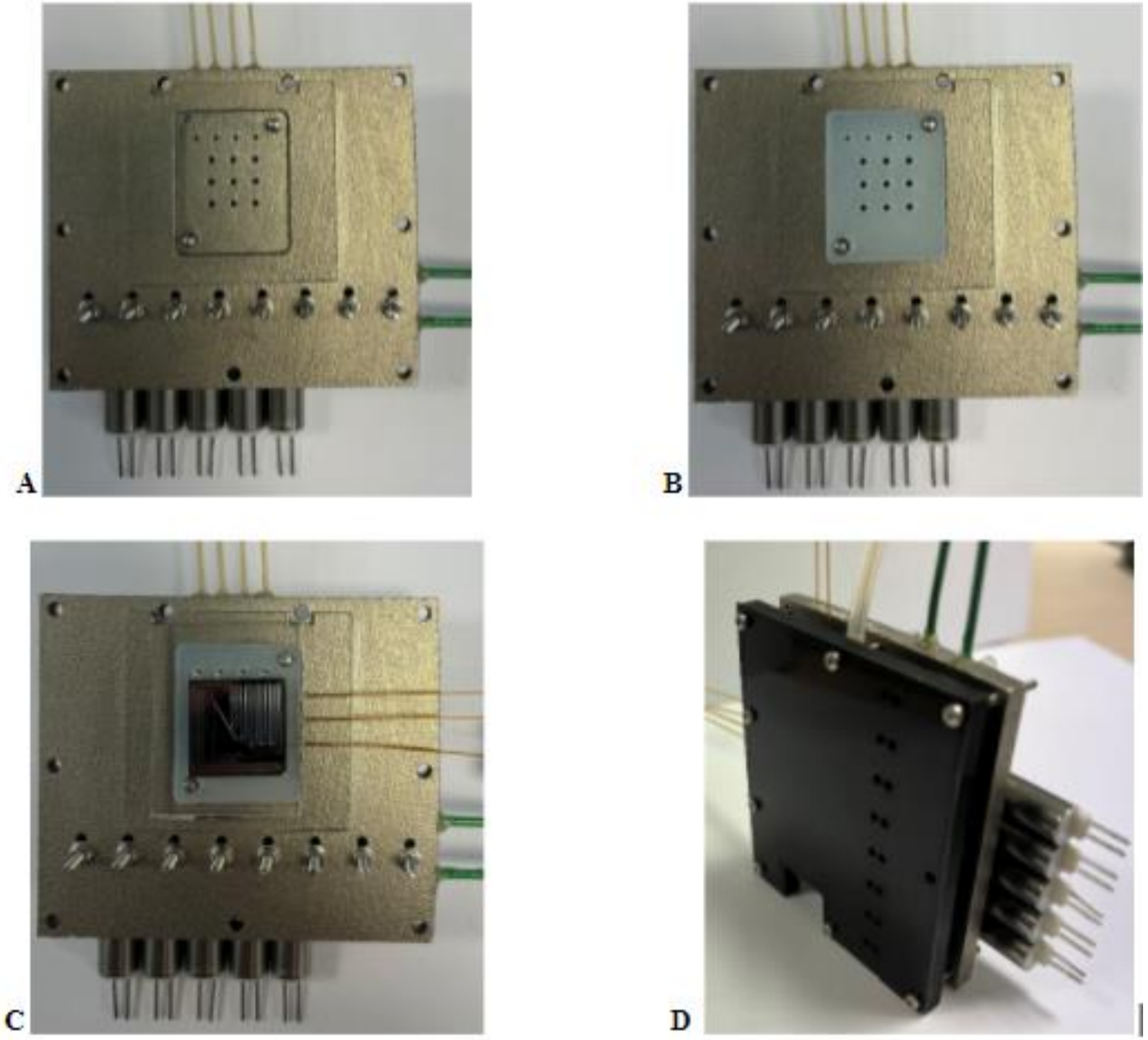


MULTIDETECTOR FABRICATION PROCESS

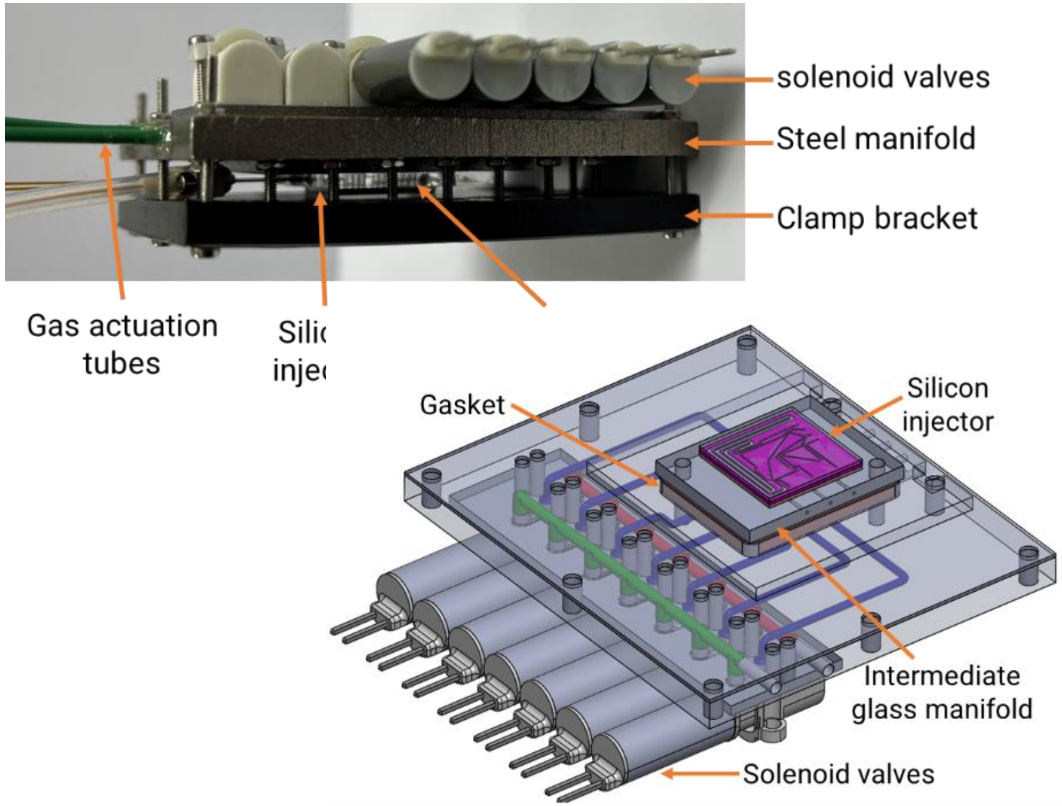




MICRO INJECTOR ASSEMBLY



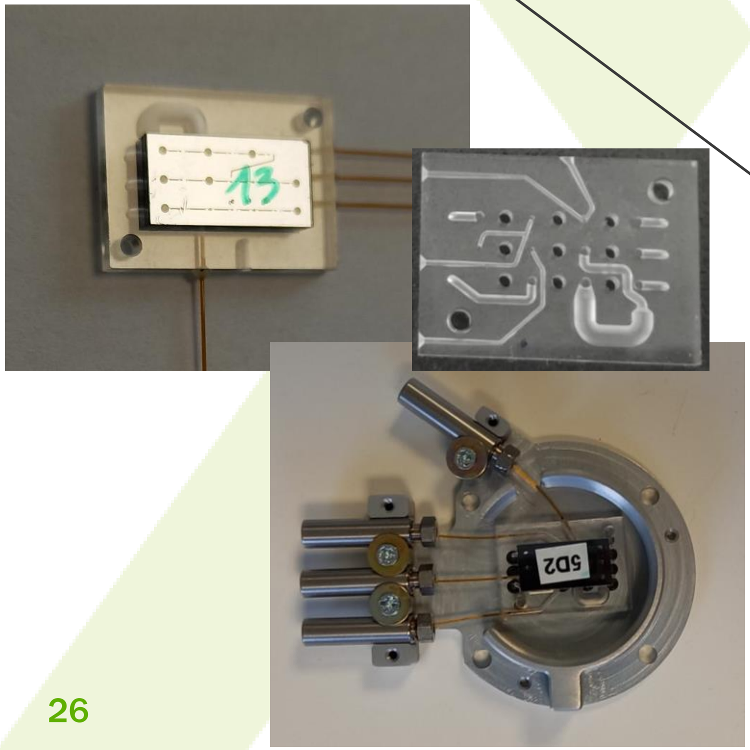
Assembly of silicon injector with intermediate glass manifold on the steel manifold using a gasket.
(A) Lower view of the steel manifold. (B) Steel manifold with the gasket placed in the dedicated area. (C) Silicon injector with intermediate glass manifold placed on the gasket. (D) Clamp bracket in contact with the lower side of the silicon injector and is fixed to the steel manifold.

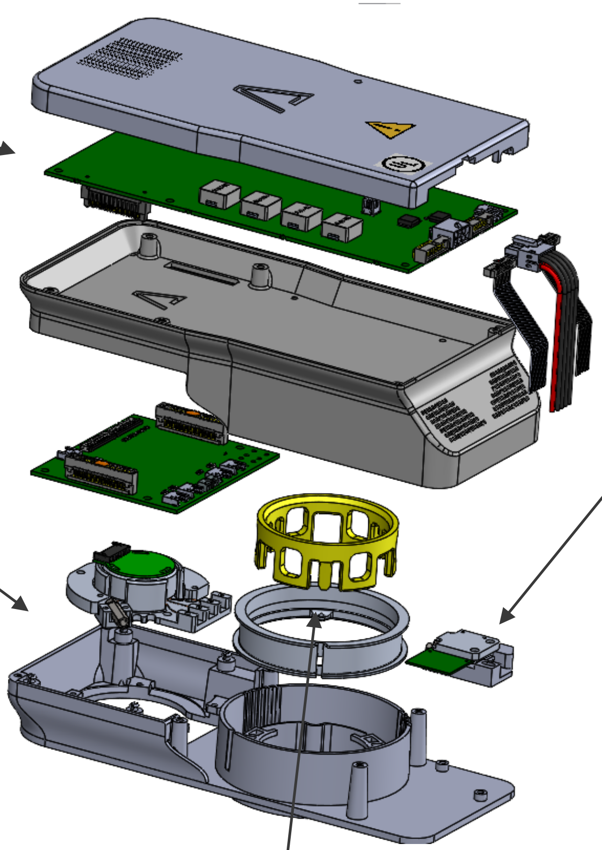


INSIDE THE GREENPIX MODULE

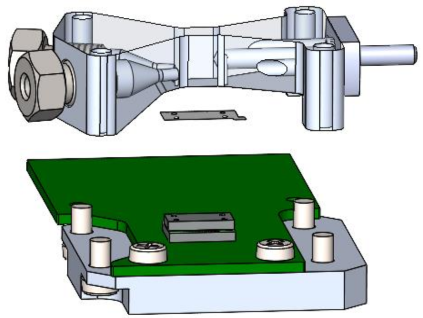
Electronic board

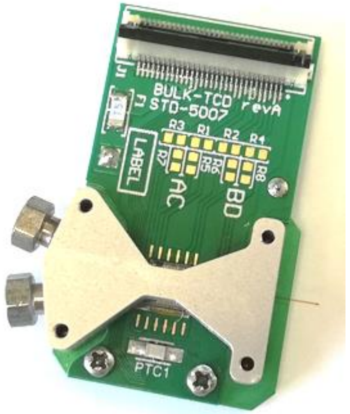
Fully encapsulated silicon injector





Fully encapsulated detector with no capillaries

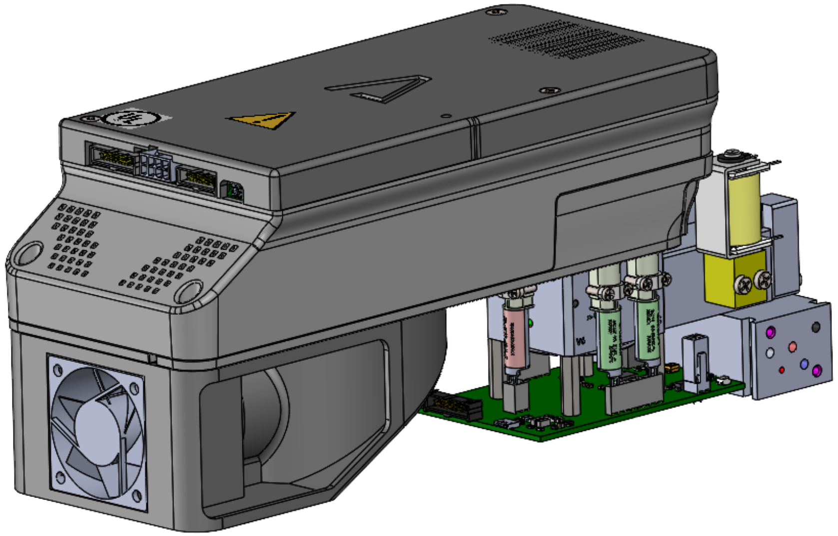


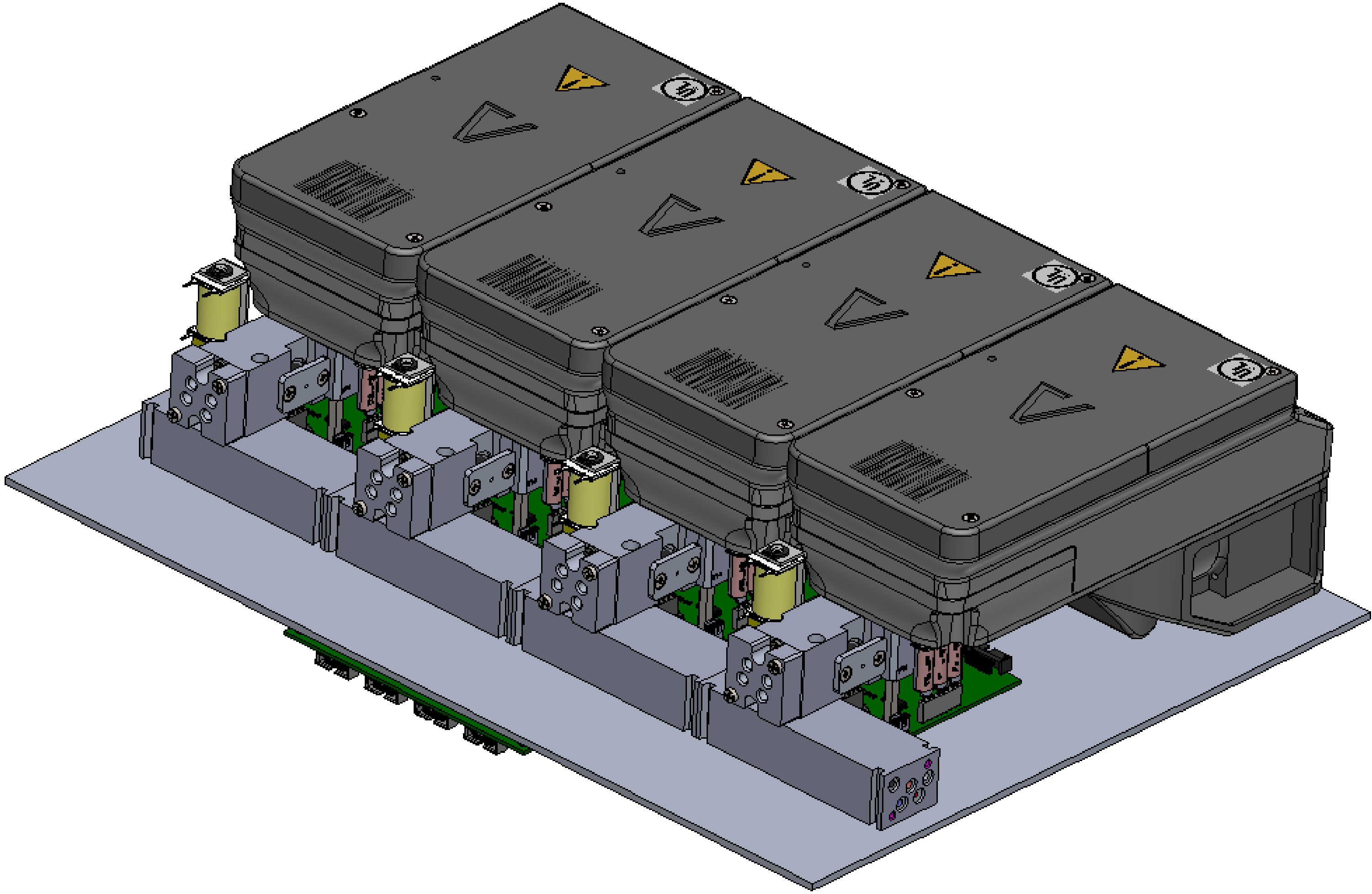


GC capillary column

Double detection TCD/NGD chips

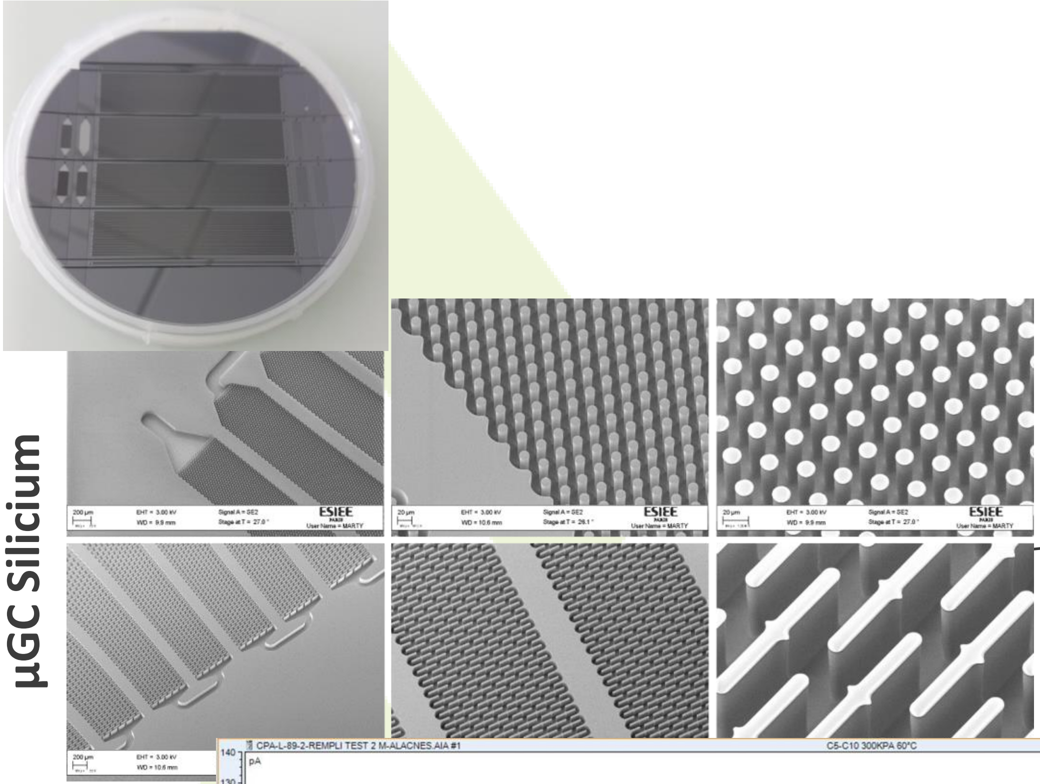
CONNECTION OF MULTIPLE ANALYTICAL MODULE IS MADE EASY IN A VERY COMPACT FORM FACTOR

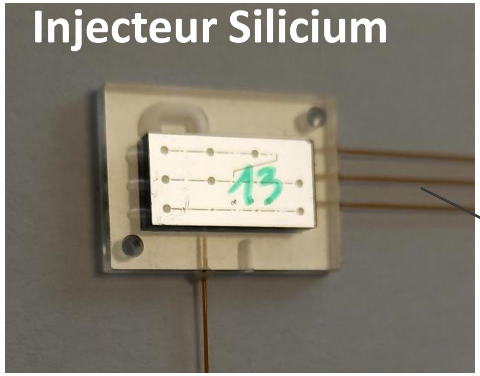


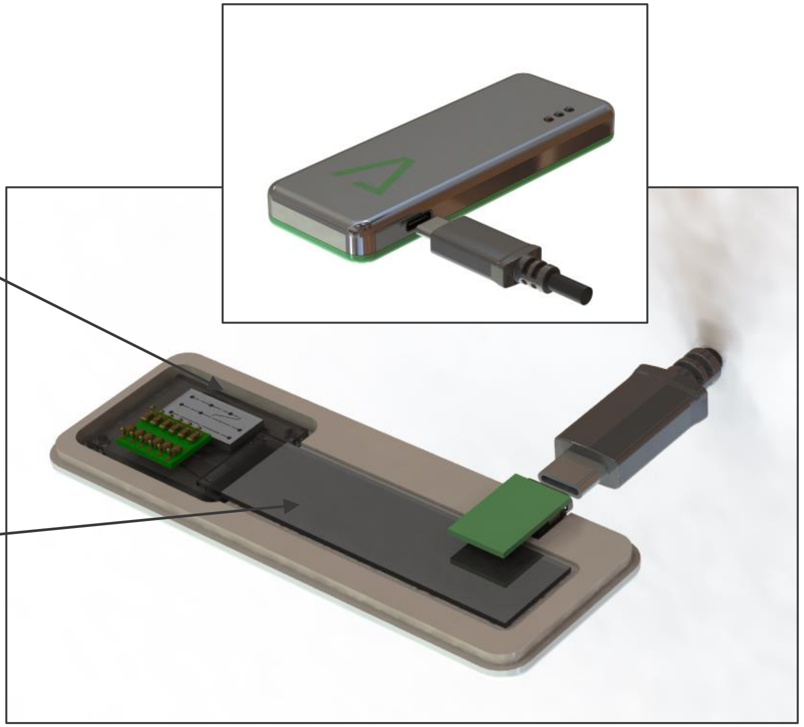


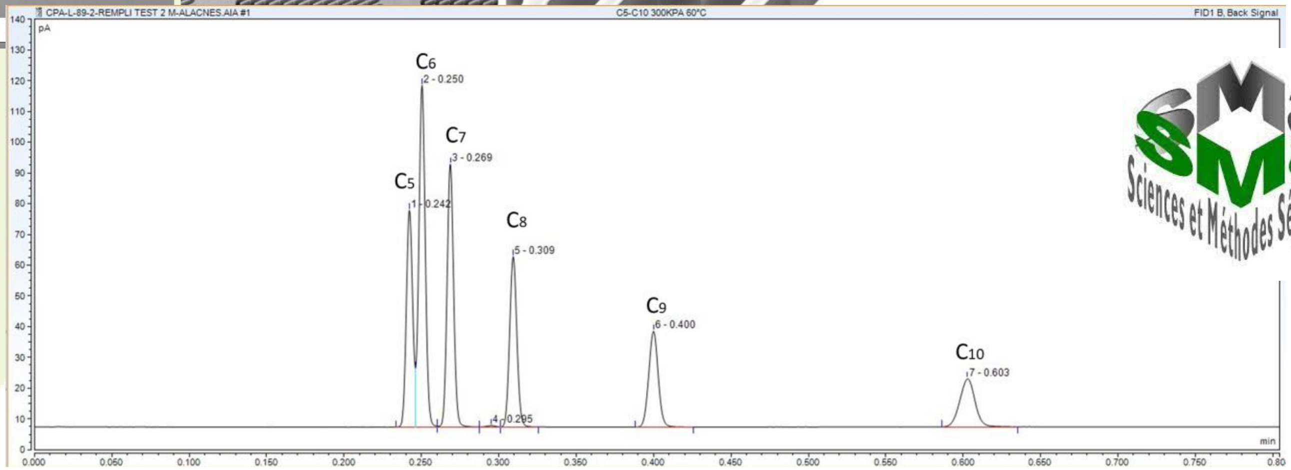
TOWARD A FULL SILICON GC!

µGC Silicium









Collaboration SMS (et ISA) pour fonctionnalisation µGC Silicium

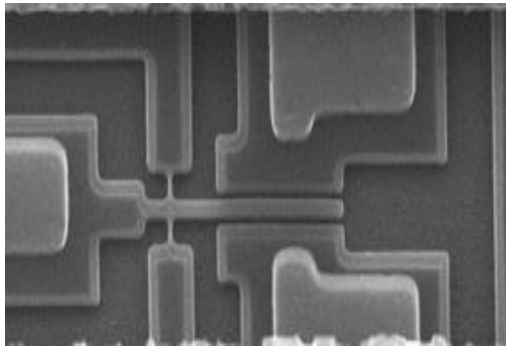
APIX COMPANY

Our company in a few words

30 Collaborators :

- R&D, Sales, Admin **Grenoble : 18 people (4 PhDs, 8 Master degree)**
- Manufacturing in **Pau : 8 people**
- Subsidiary in **Beijing : 2 people**

Based on 8 years of Joint R&D
with CEA (France) and CALTECH (USA)
20 patents that protect the technology



5 rounds of Investment for a total of 25 M€ raised

Industrial Partnerships
with Leading Oil and Gas Players

Our history

- 2006-2011 : collaboration between CEA-LETI (Grenoble) and Pr. Roukes from Caltech (USA) on NEMS technology for gas sensing application.
- 2011 : Apix incorporated in December 2011
- 2013 : first demonstration of a miniaturized GC analyzer using a NGD detector
- 2014 : first generation of products is launched
- 2015 : first round of funding
- 2016 : Chrompix V1 is OIML R140 Certified to measure the calorific value
- 2017 : Apix acquires nCx to reinforce its production capacity. Second round of funding to expand our development
- 2018-2019 : development of the second generation of products
- 2019 : Customers located in Europe, China, North America. Turnover 1M€.
- 2020 : development of third generation of products to measure gas and liquid Turnover 1.8M€
- 2021 : selected by the EIC accelerator to develop new generation of instruments to address the green energy market (H2, biogas, biomethane, CO2,)
- 2024 : Turnover 3.5M€

ADDITIONAL REFERENCE

- Bringing a hardware product to market: navigating the wild ride from concept to mass production, Elaine Chen (MIT)

- pierre.puget@m4x.org