Interreg France-Wallonie-Vlaanderen
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SAFESIDE project presentation

SAFESIDE Workshop, Dunkirk, 19th September 2019

AVEC LE SOUTIEN DU FONDS EUROPÉEN DE DÉVELOPPEMENT RÉGIONAL
MET STEUN VAN HET EUROPEES FONDS VOOR REGIONALE ONTWIKKELING

Project SAFESIDE overview:
- Consortium
- Technologies involved
- Role of partners

Recent developments:
- Integrated NIR laser sources
- Spectroscopy measurments with a multipass cell
- Development of a tunable synchronously pumped OPO
- Spectroscopy measurments

Next steps:
- Free space outdoor tests.

Project SAFESIDE overview:

- Consortium
- Technologies involved
- Role of partners

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Project SAFESIDE

Système d'Analyse de Feux et Emanations par Spectroscopie Infrarouge à Distance et Embarquée / Analysesysteem voor branden en gaslekken op basis van infrarood spectroscopie

Started on 1 January 2017.

End on 30 June 2021.

Funding : 882 689,34 €

Total cost : 1 765 378,71 €

Avec le soutien de la

Aim of the project

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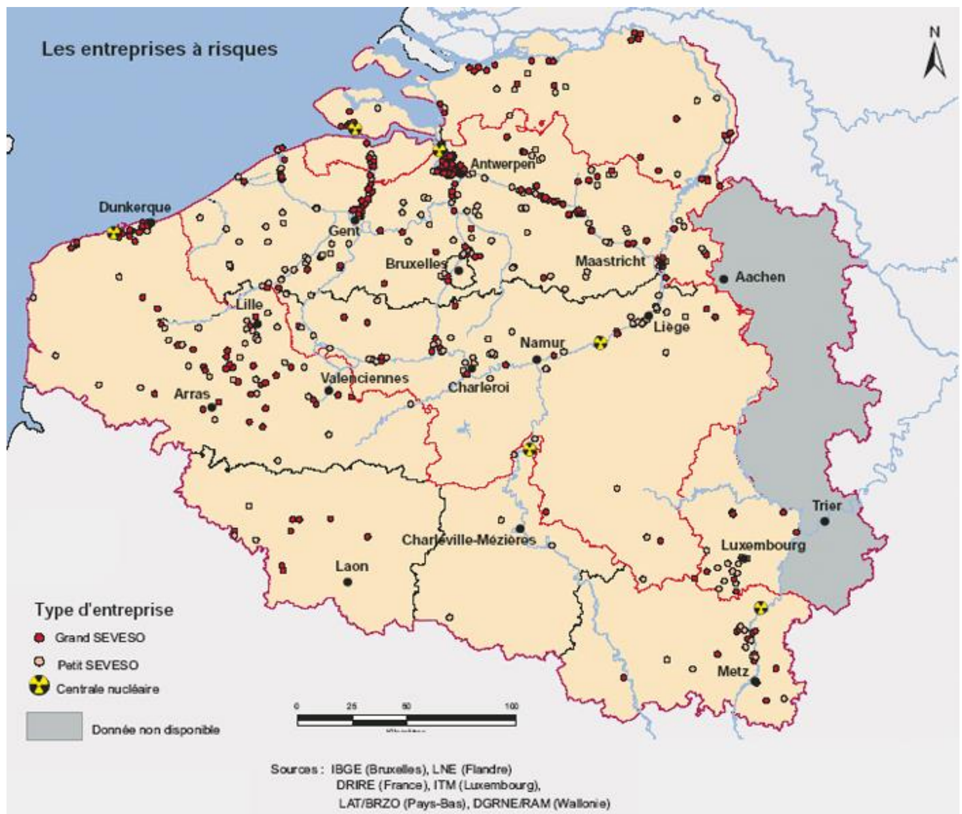
Realization of portable and transportable diagnostic tools for:

- identification of chemicals present in fumes or gas leaks with concentration measurements,
- prediction of gas dispersion in air.



Target gases and concentrations

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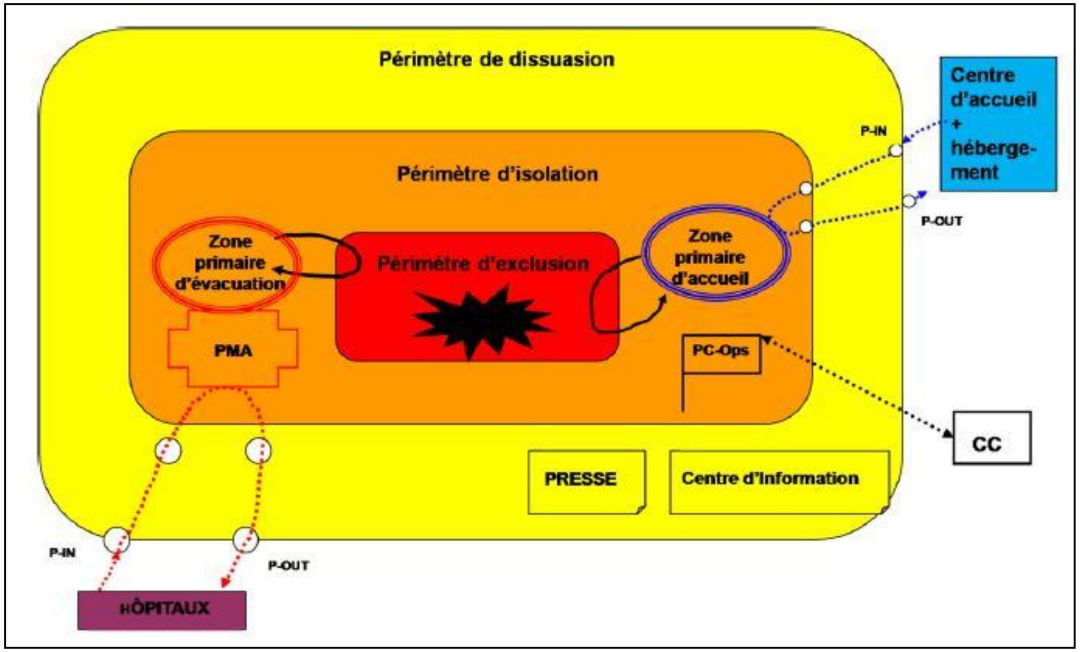
(ppm)	HCl	NH3	HCN	NO	NO2	SO2	CO	CO2
ERPG1	3	29	5	1	1	1	86	-
ERPG2	33	142	9	8	5	4	430	27309
ERPG3	132	706	45	40	27	76	859	54618

ERPG : Emergency Response Planification Guidelines



Consortium

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Lasers developments

Multitel INNOVATION CENTRE

ULCO Université du Littoral Côte d'Opale

Multipass cells

Université de Reims Champagne-Ardenne

Photo-acoustic detection

UMONS Université de Mons

Field tests and dispersion models

ULCO Université du Littoral Côte d'Opale

Intercomparaison with conventional techniques

Technologies involved

- NIR Semiconductor laser sources:
  - Indium Phosphide lasers coupled onto silicon integrated photonic circuits.

- Compact multi-pass cells:
  - Handheld multi-pass cell.

- Mid-IR optical parametric oscillators:
  - Fibre laser pumped optical parametric oscillator with broadband operation and fast tuning.

- Photo-acoustic sensors:
  - High sensitivity photo-acoustic module.

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Multitel INNOVATION CENTRE
UNIVERSITÉ DE REIMS CHAMPAGNE-ARDENNE

Recent developments:

- Integrated NIR laser sources
- Spectroscopy measurments with a multipass cell
- Development of a tunable synchronously pumped OPO
- Spectroscopy measurments

Integrated NIR laser sources

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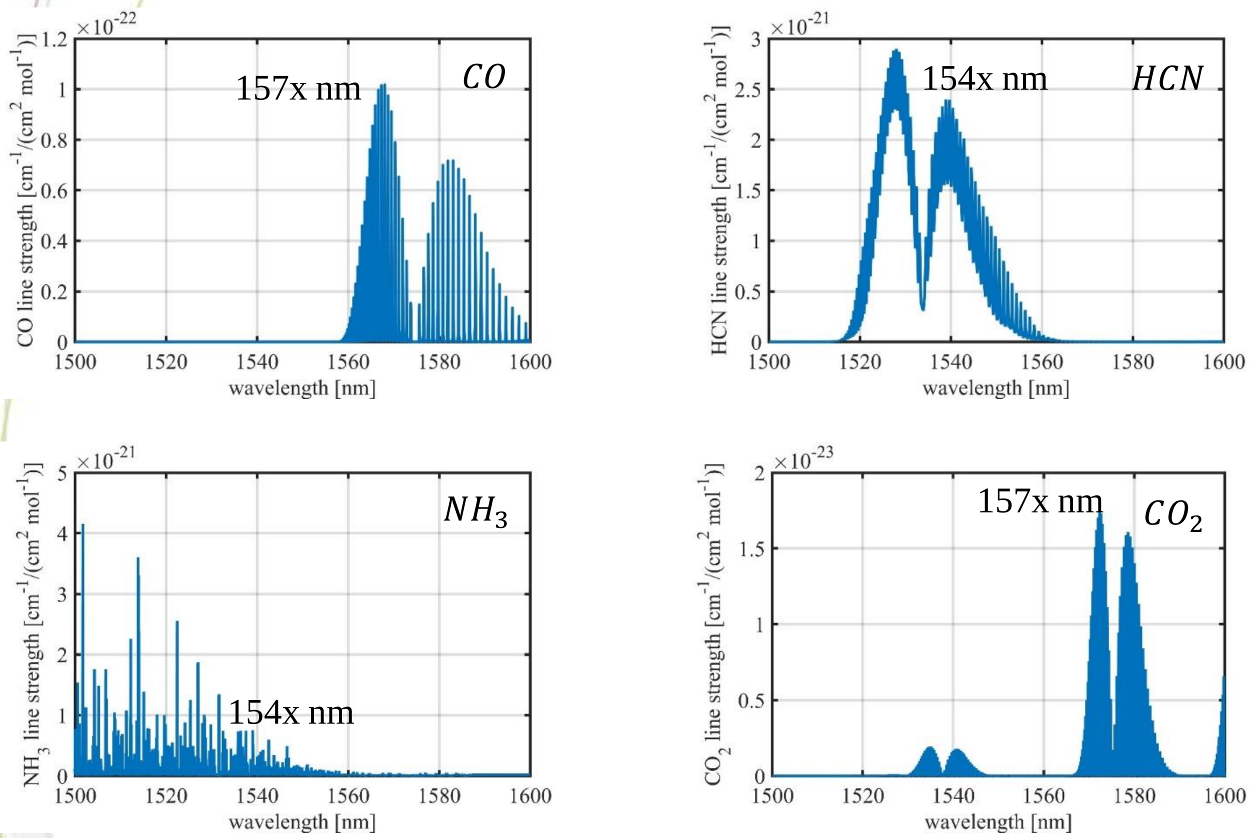
Spectral lines and targeted wavelengths:



Integrated NIR laser sources

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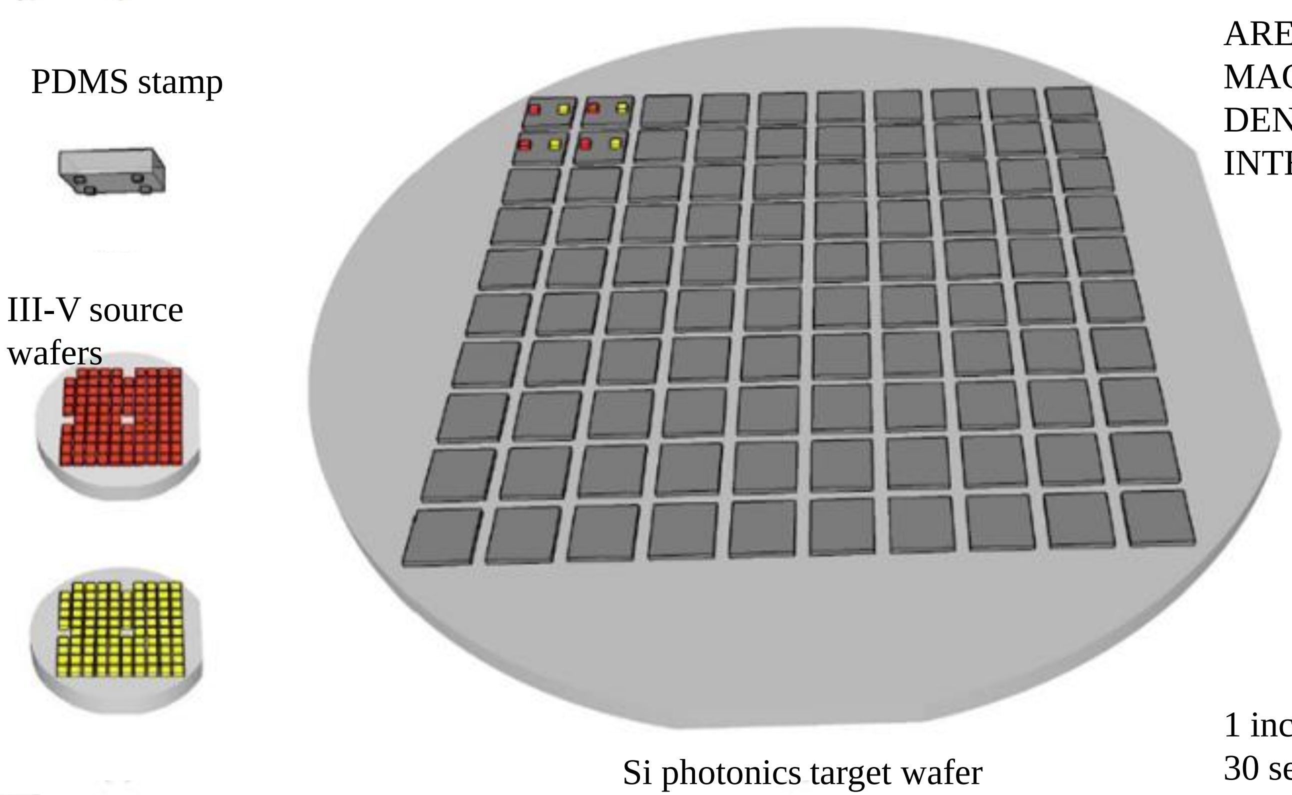
Transfer printing: Enabling technology for heterogeneous integration



AREA MAGNIFICATION
DENSE INTEGRATION

1 inch stamp size
30 sec per print cycle

A. De Groote et al. Optics Express, 24(13), p.13754-13762 (2016)

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Integrated NIR laser sources

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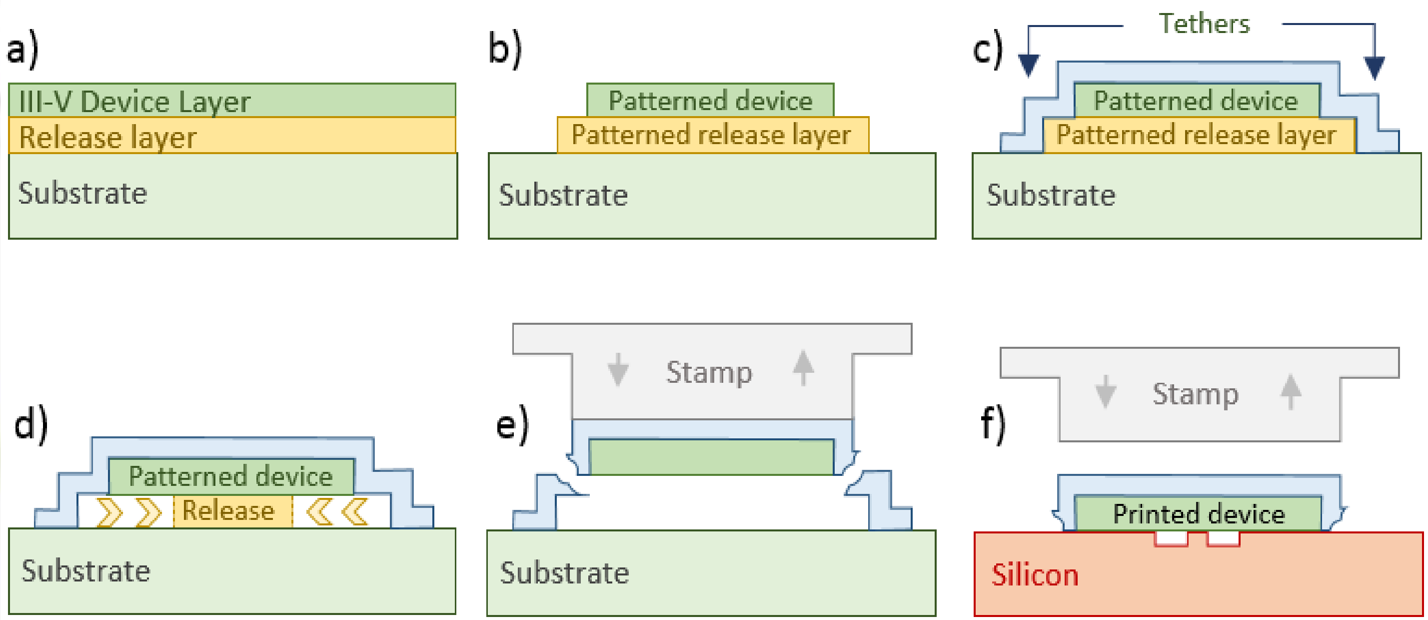
Transfer printing principle:



Transfer of **micro-scale** III-V coupons/devices
to a silicon target wafer

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Integrated NIR laser sources

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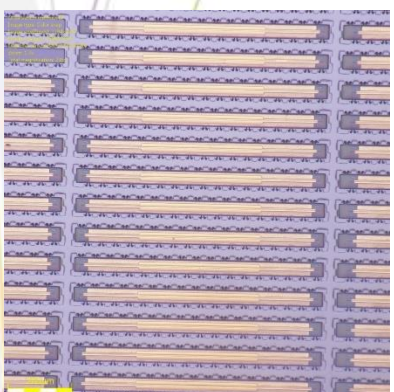
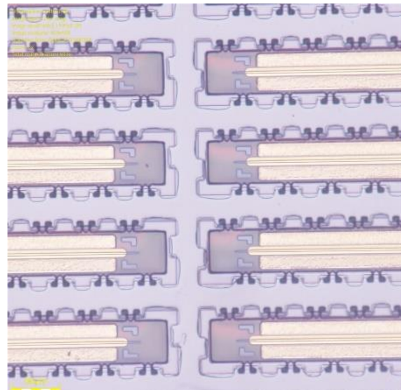
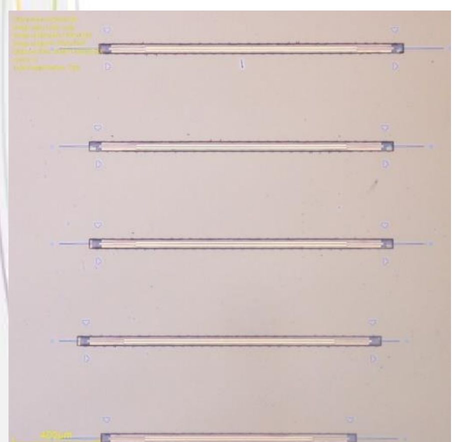
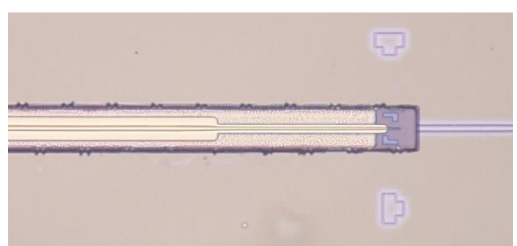
SOA coupons processed on Inp substrate:

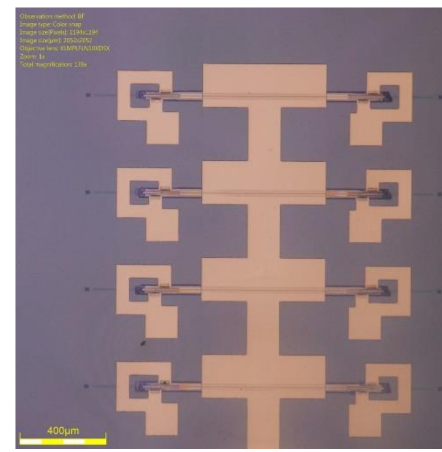




Printing on 400nm SOI and processing







Final metallization

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Multi-pass cell

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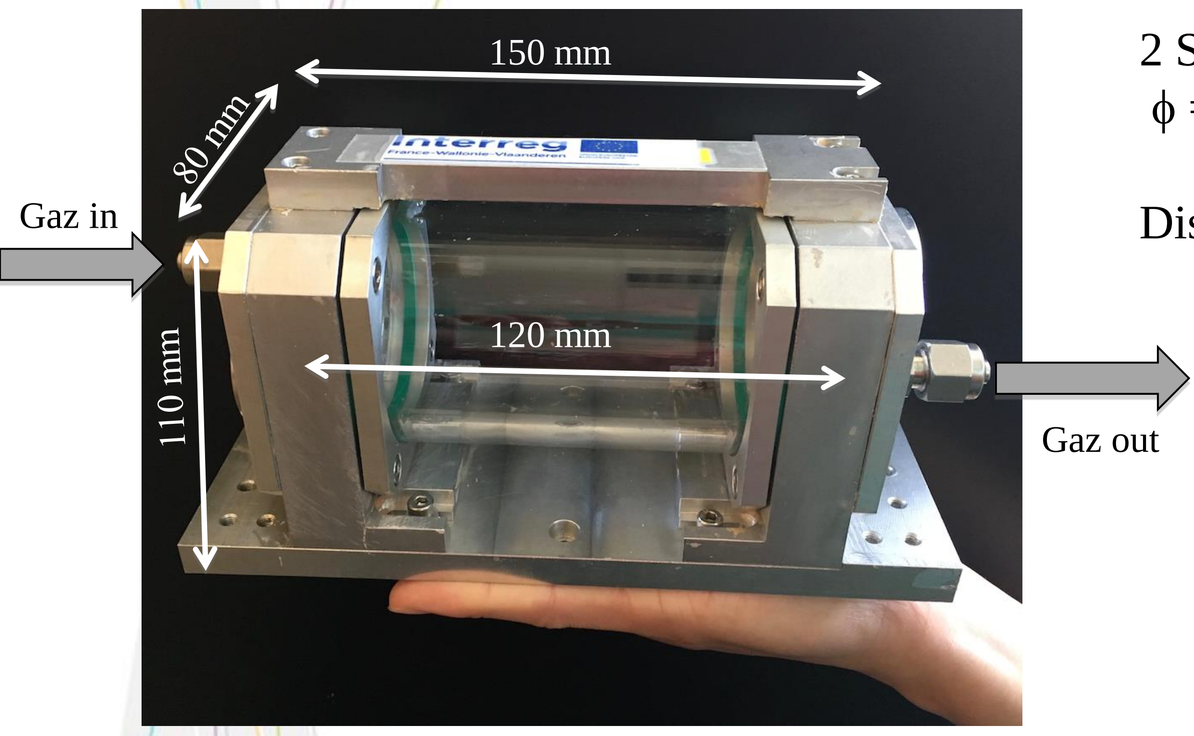
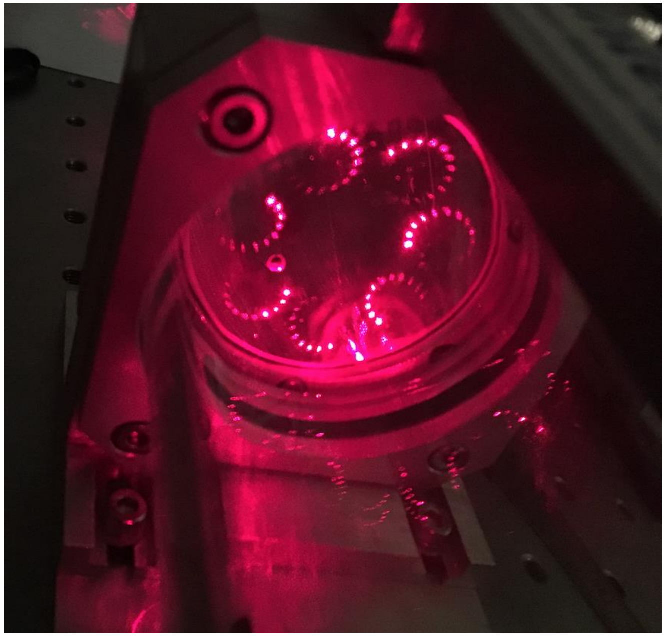
Design of a miniaturized multi-pass sensor:



2 Silver coated concaves mirrors
ϕ = 50,8 mm, R = 100 mm

Distance between Mirrors : 120 mm



N = number of spots in a ring
L= total lenght (m)

L= 0,12*(14N+1) = 25,32 m

With a carefull alignement we obtained 7 rings with 15 spots each.

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Gas sensing

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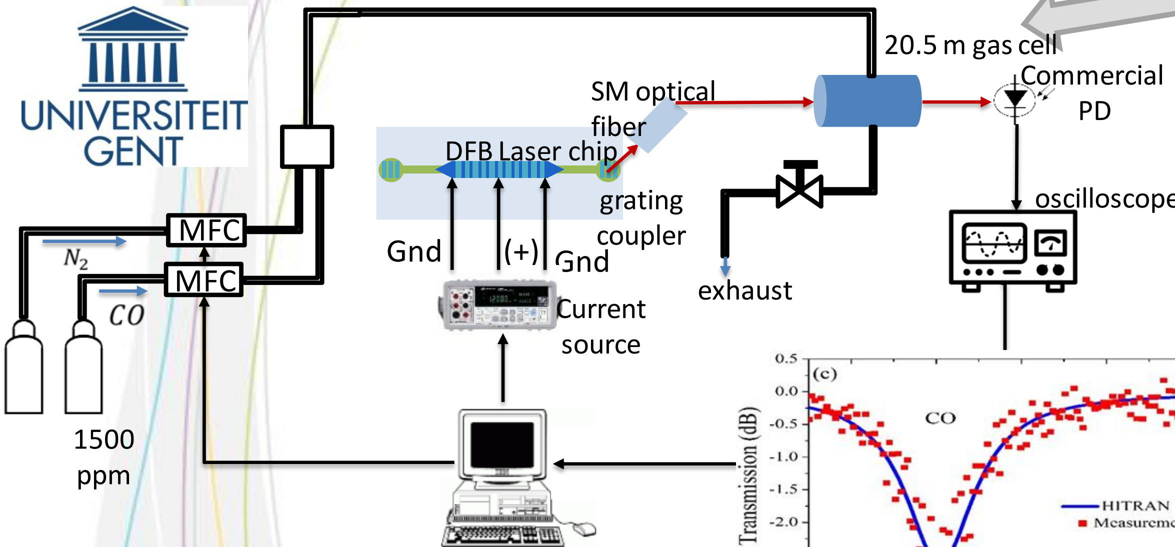
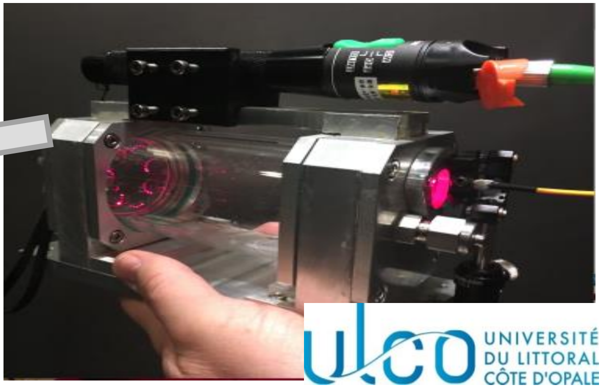
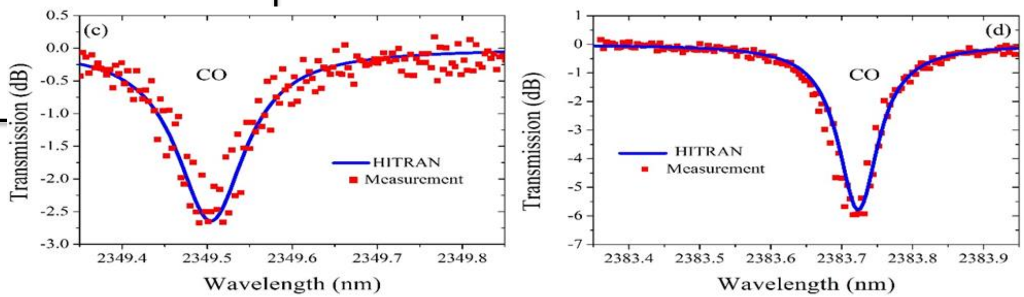
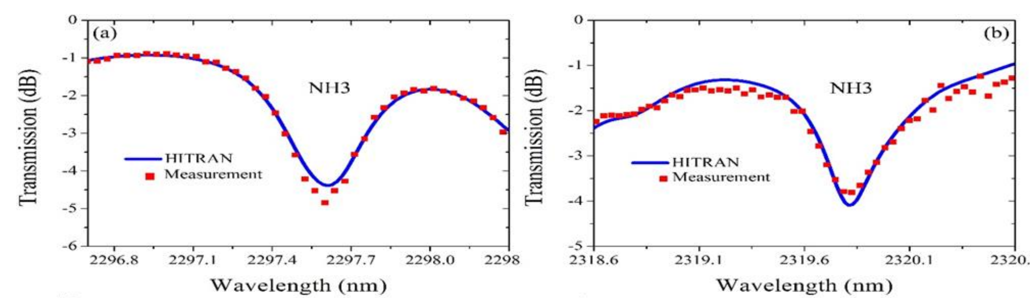






Tests on CO



Tests on NH_3

Development of a tunable synchronously pumped OPO

Targeted wavelengths:

Gas	ERPG2 (ppm)	Best spectral region (cm-1)	Reduced spectral region due to interferences (cm-1)	Wavelength (nm)	Possible technology
HCL	33	2600-3100	2673-3046	3 283-3 741	OPO
NH3	142	1100-1200 (1500-1700)	1100-1200		QCL
		5 094, 4 367, 4 348	4 348	2 300	OPO
CO	430	2000-2250	2 027-2 038 ; 2 093-2 140 ; 2 145-2 210	~ 4 580	OPO
CO2	27 309		4835-5124	1 951-2 068	OPO
SO2	4	1300-1400	1347		QCL
HCN	*10*	3200-3400	3 268, 3 290, 3 305, 3 331, 3345	3 059, 3 039, 3 025, 3 002, 2 989	OPO
NO	*10*	1750-1950	Interferences		Impossible: low absorption and interferences with H_2O
NO2	*10*	1560-1660	1 596-1 600		QCL

Tunable synchronously pumped OPO

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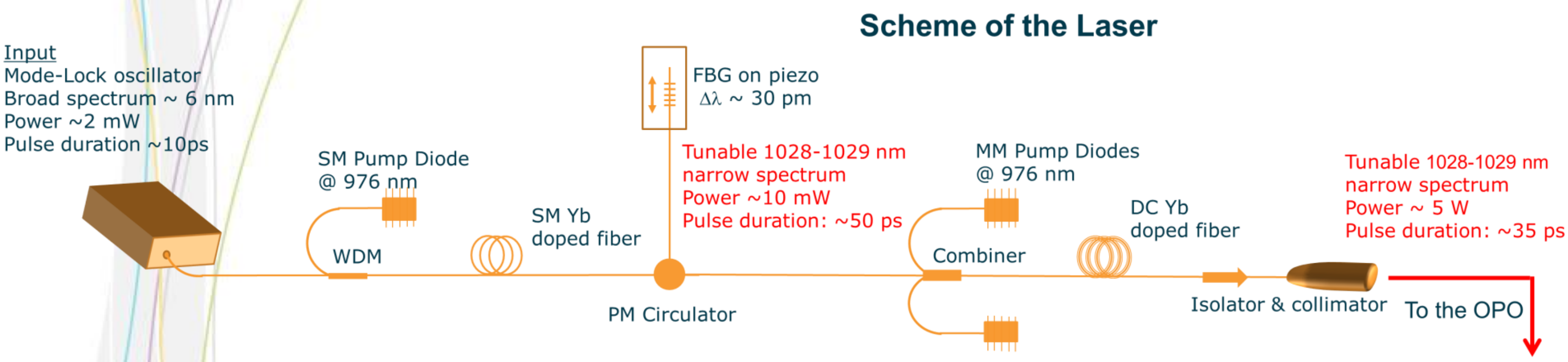
Fiber laser pump source:



Fibre laser pump characteristics	Wavelength	Spectral linewidth	Pulse duration	Rep.rate	Average Power
	1028-1029 nm	40 pm	30 ps	40 MHz	5 W

OPO characteristics	Coarse tunability range	Spectral linewidth	Piezo Modulation	Fast tunability range	Average Power
	3 - 3.5 µm (2,5 – 4 µm)	0.4 cm^{-1}	600 Hz (Up to 1 kHz)	7 cm^{-1}	700 mW

Tunable synchronously pumped OPO

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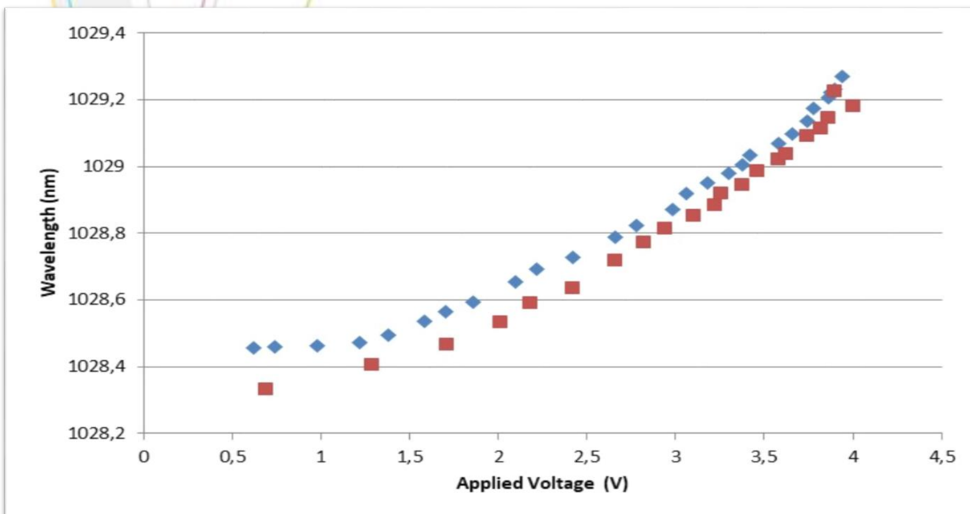
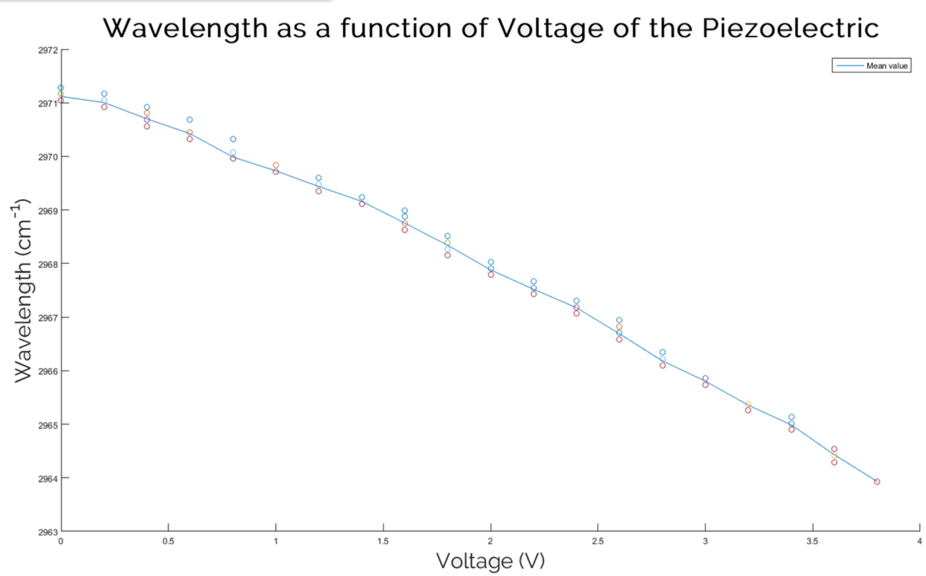
Fast wavelength modulation



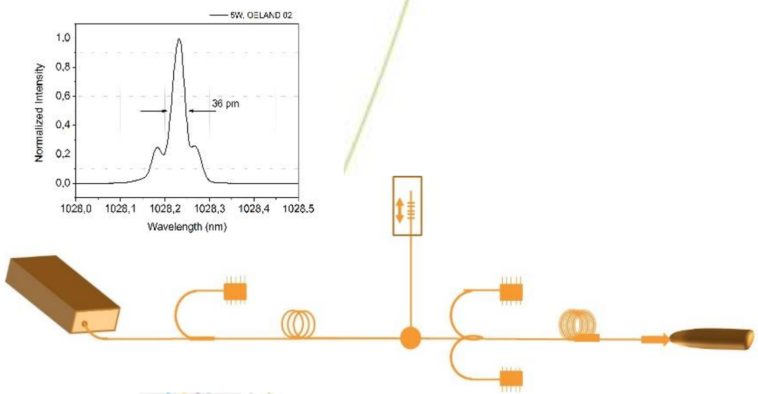
➔ Wavelength modulation out of the laser

Wavelength variation out of the OPO ➔

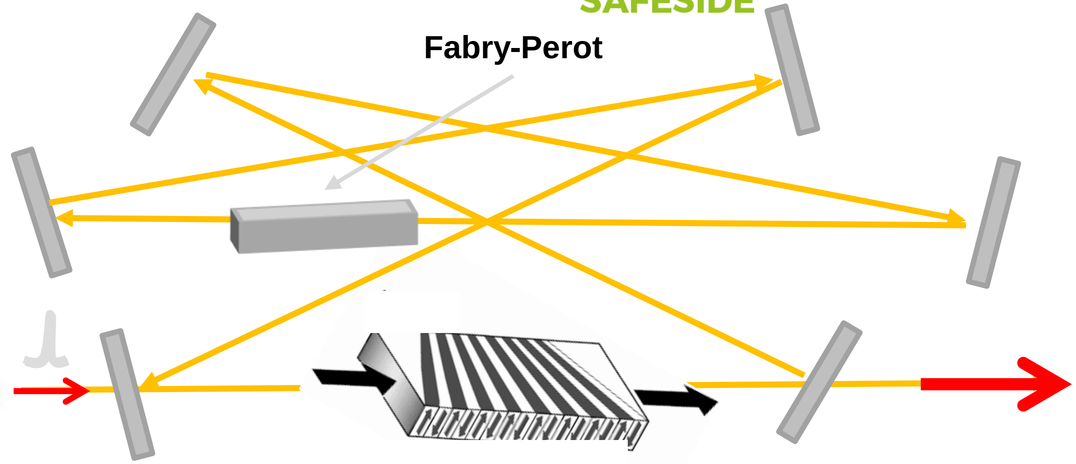


Tunable synchronously pumped OPO

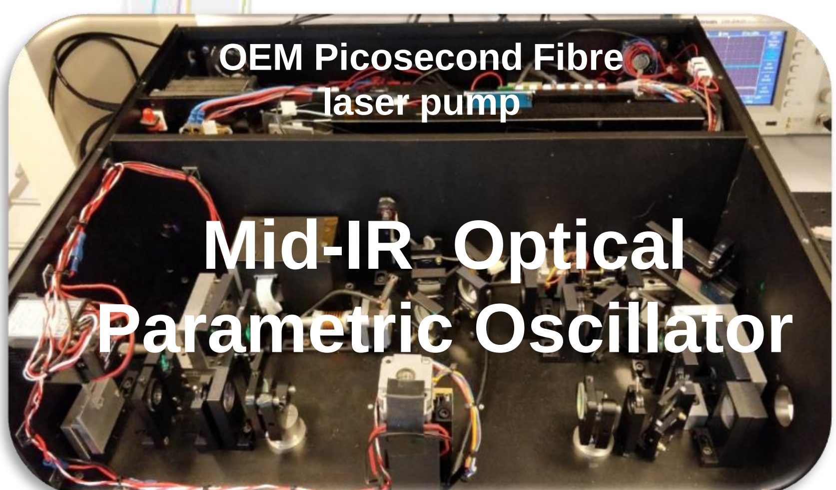
Narrow linewidth, fastly tunable picosecond Fibre laser

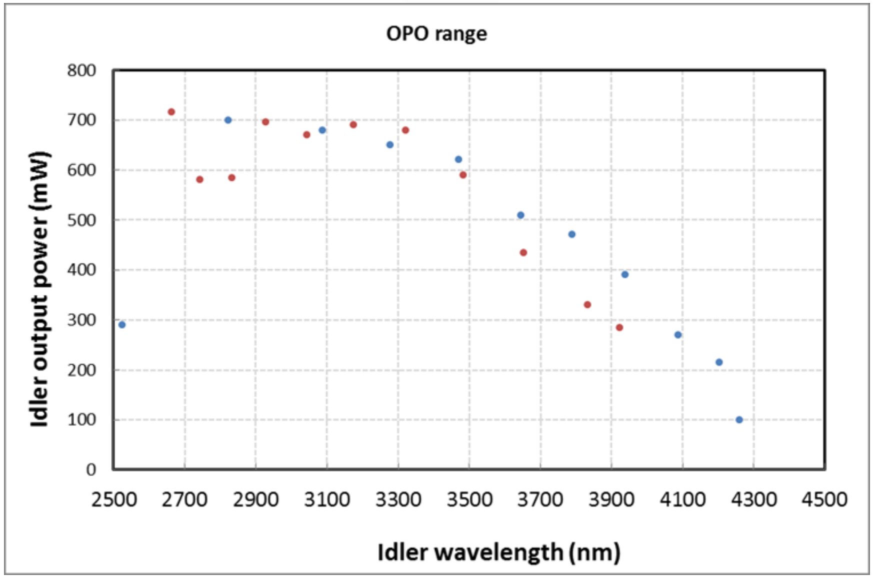


& SP-OPO cavity



Fan-out PPLN





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Low speed broadband scanning

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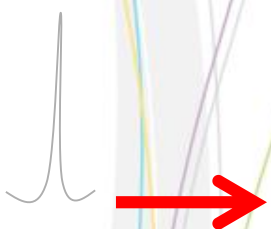
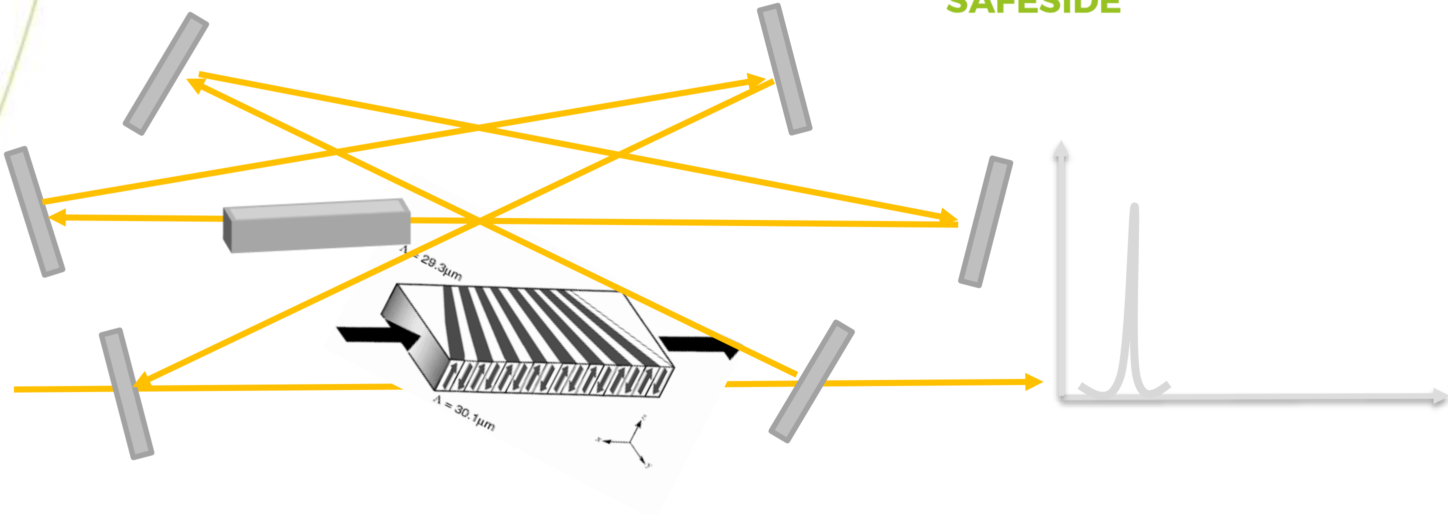
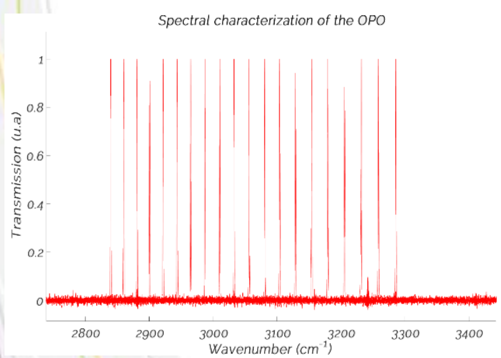
Fixed pump wavelength



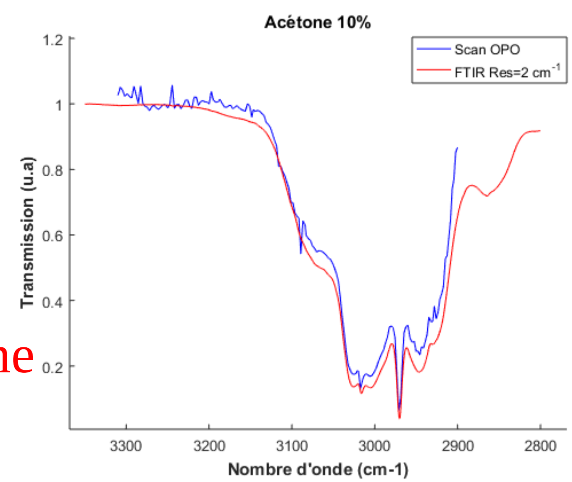


Translation of the OPO crystal

Tunable over hundreds of wavenumbers



Ex. of acetone detection



High speed narrow band scanning

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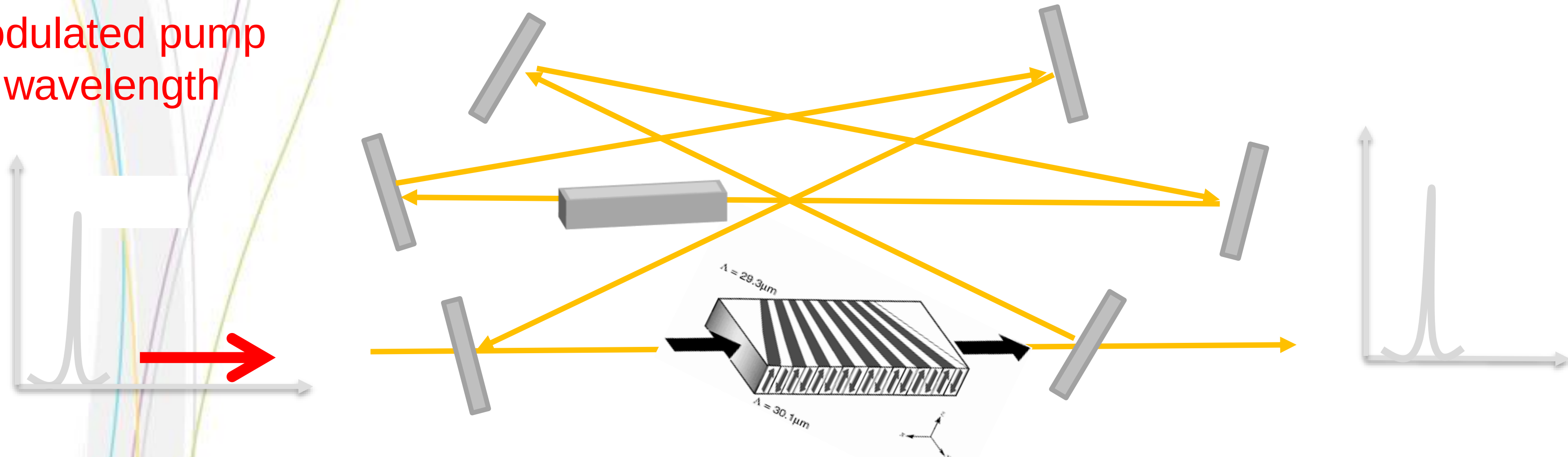
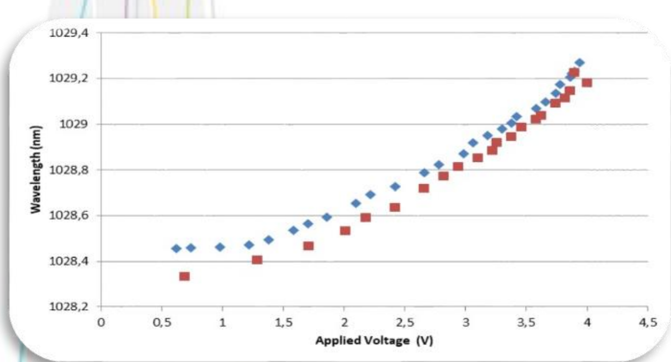
Modulated pump wavelength

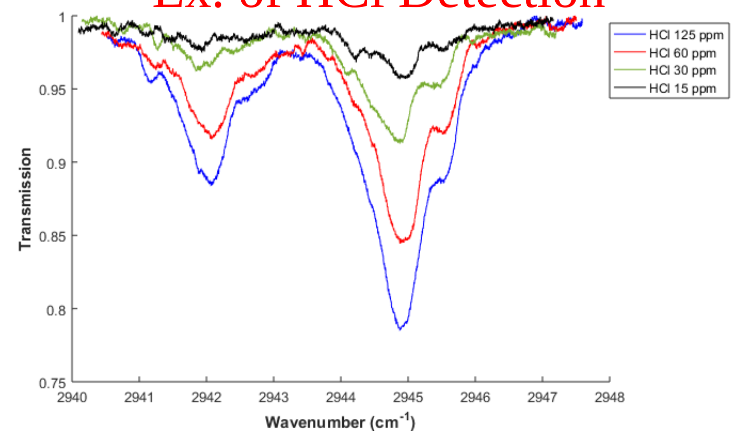


Fixed position of the OPO crystal

Tunable over 10 cm-1



Ex. of HCl Detection



Wavelength modulation spectroscopy

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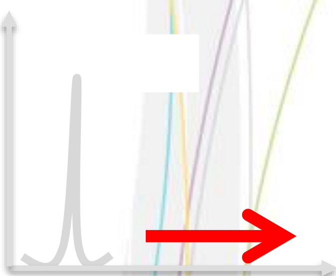
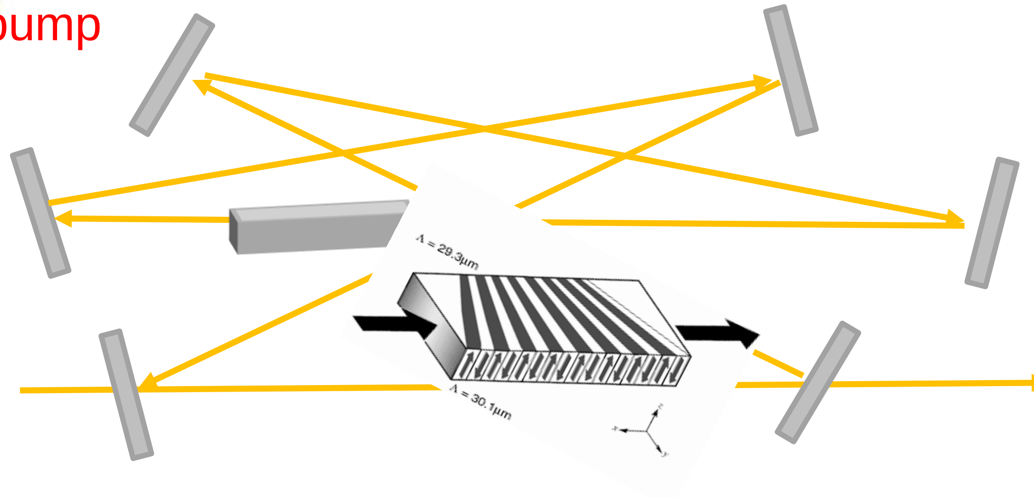
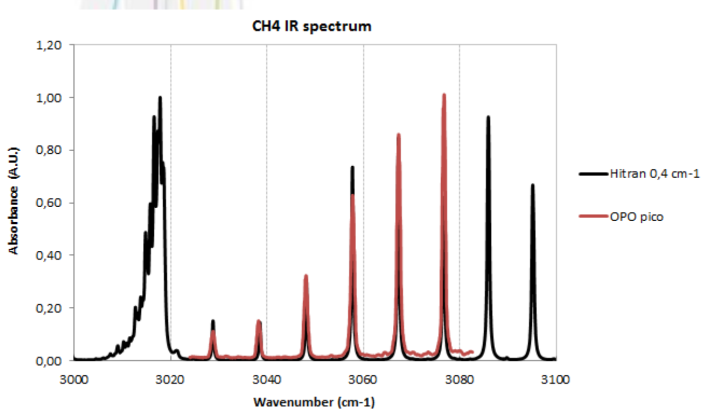
Modulation of the pump wavelength



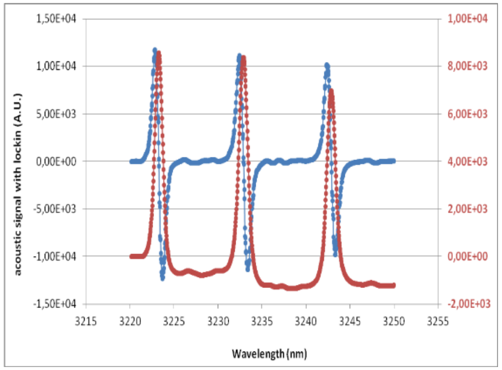


Output

& translation of the OPO crystal



Ex. of Methane detection



Photoacoustic cell

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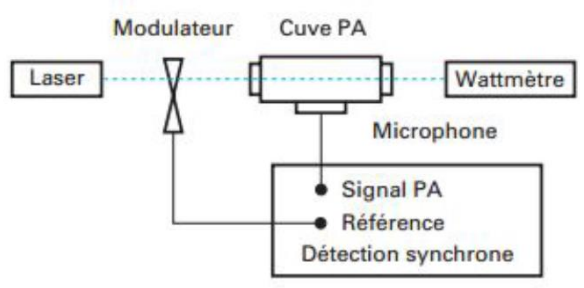
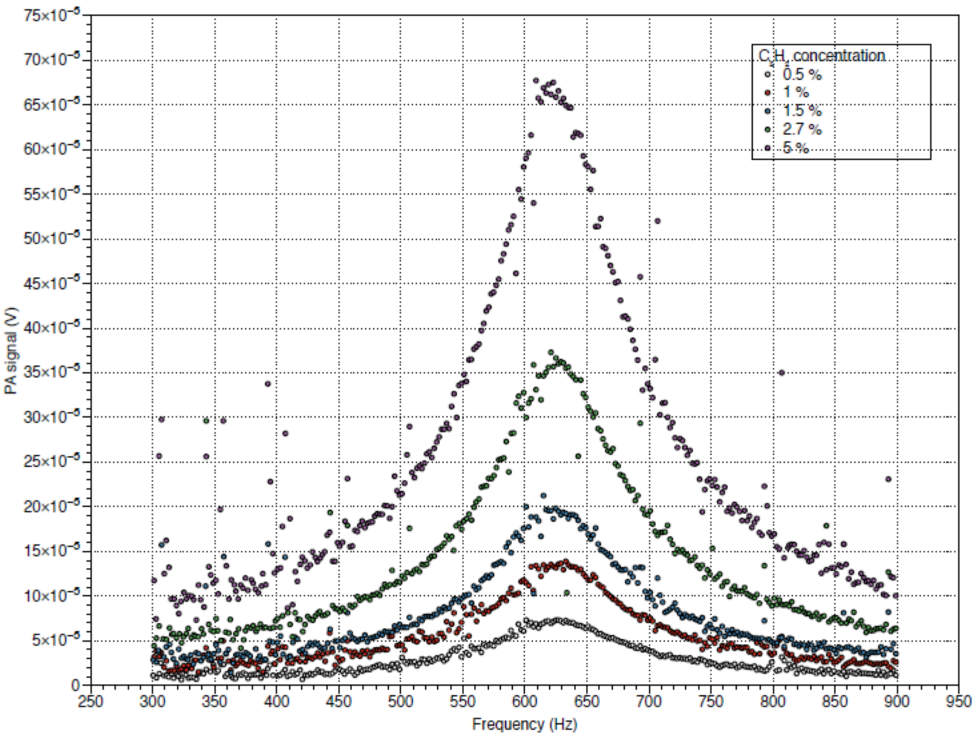
Validation of the PA cell with Acethylene





Photoacoustic cell

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Estimated sensitivity with the OPO + PA system

Molecule and (ERPG2)	Spectral Region	Laser technology	Laser power (mW)	Absorption coefficient (cm^{-1})	Minimum concentration (ppm)
HCl (33ppm)					
	1.7472µm / 5723.4cm^{-1}	DFB	1	1.2	7500
	3.3 µm / 3030 cm^{-1}	OPO	100	30	3
CO (430ppm)					
	1.568µm	DFB	1	2.50E-03	-
	2.3µm	OPO	100	0.45	200
	4.58 µm	OPO	100	60	1.5
HCN (10ppm)					
	1.54µm	DFB	1	0.5	18000
	3.0µm	OPO	100	22	4
NH_3 (142ppm)					
	1.9631µm	DFB /OPO	1/100	1.1	8000/80
	2.29µm	OPO	100	0.7	130
CO_2 (27000ppm)					
	1.6µm	DFB	1	0.01	-
	2.004 µm	OPO	100	0.14	650

Next steps:

- Prototyping
- Free space outdoor tests.

NIR laser source + Multipass cell

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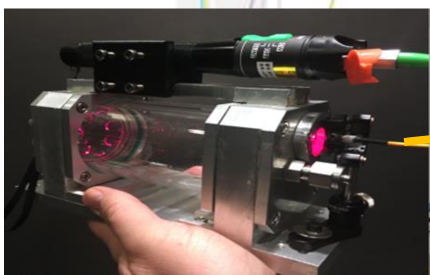
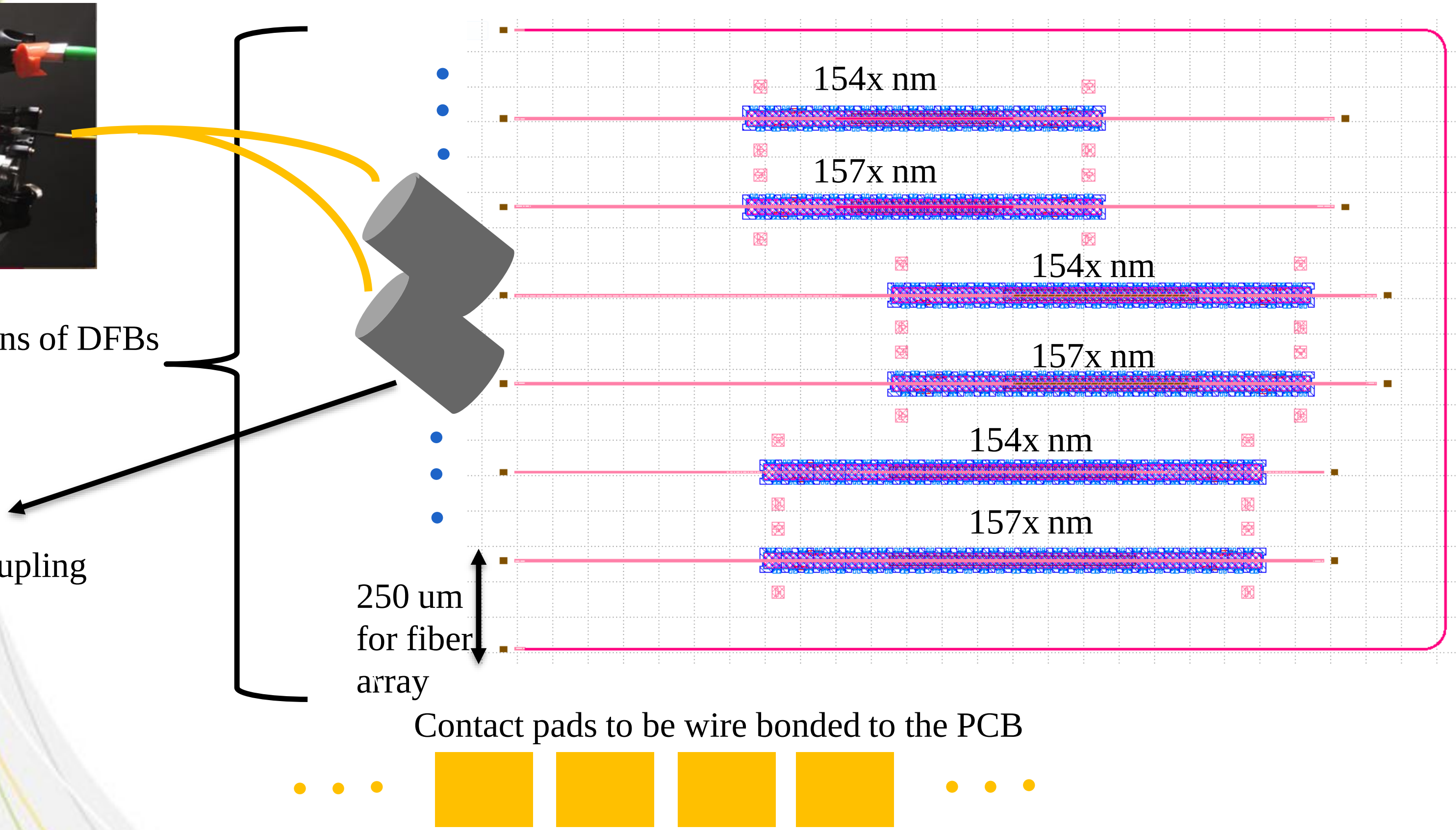
- Field tests are expected in 2020 with two type of devices / methods:

Multiple DFB chip for gas sensing experiment





MIR laser source + Photo-acoustic sensor

- Field tests are expected in 2020 with two type of devices / methods: