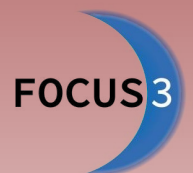


MILENE: Development of the interferometric test bench for mid infrared photonic integrated circuits characterisation

Louis Gemmerlé^{1*}, Manon Lallement¹, Jean-Philippe Berger¹, Guillermo Martin¹, Pierre Labeye², Laurence Gluck¹, Stéphane Curaba¹

¹Univ. Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France. ²Commissariat à l'Energie Atomique (CEA), LETI, 38000 Grenoble, France.



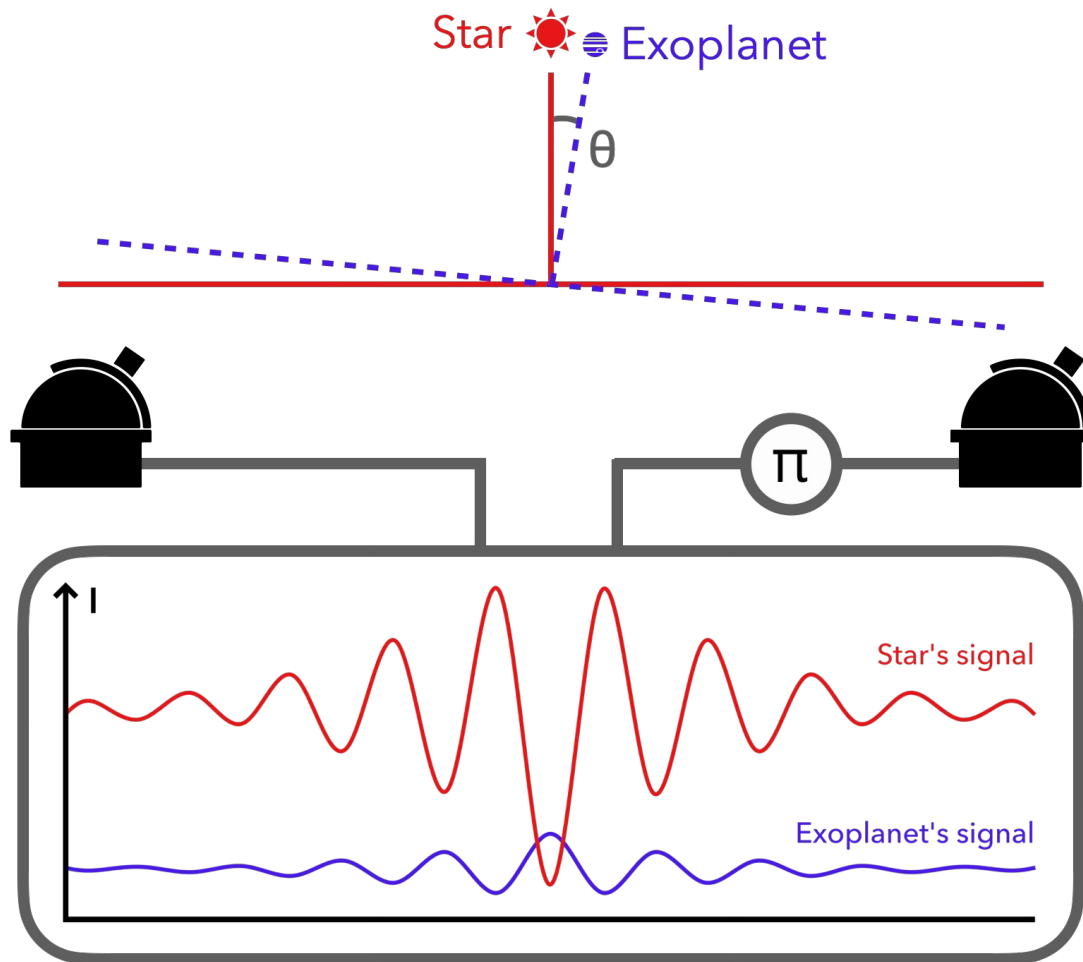
This work received government funding administered by the French National Research Agency (ANR) under the France 2030 programme, reference number ANR-22-EXOR-0005

MILENE : **M**ID **I**NFRARED **L**AB **E**QUIPMENT FOR **N**ULLING **E**XPERIMENTS

Summary

- I. Nulling interferometry
- II. MILENE test bench
- III. Perspectives and opportunities

I. Nulling interferometry



Long-base interferometer
telescopes separated by B

$$\theta_{lim} \sim \frac{\lambda}{B}$$

Flux ratio of an exo-earth
around a sun-like star

$\sim 10^{-10}$ in **visible**

$\sim 10^{-6}$ in **mid-IR**

Null depth

$$N = \frac{I_{min}}{I_{max}}$$

I. Nulling interferometry

Asgard/NOTT (VLTI)

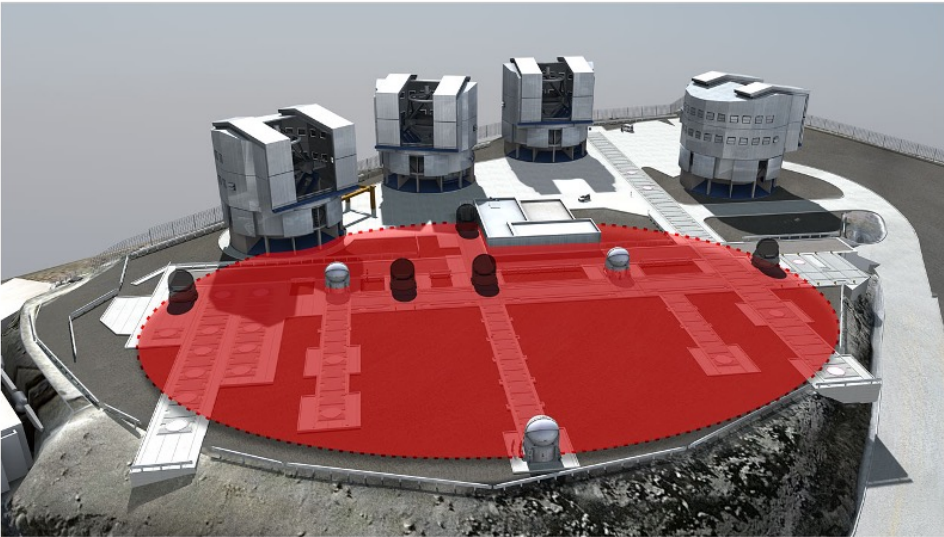


Image credit: ESO

3.5 - 4.0 μm

raw N $\leq 10^{-3}$

Hot jupiters
Exozodiacal dust
Protoplanetary disks

LIFE

Large Interferometer For Exoplanets



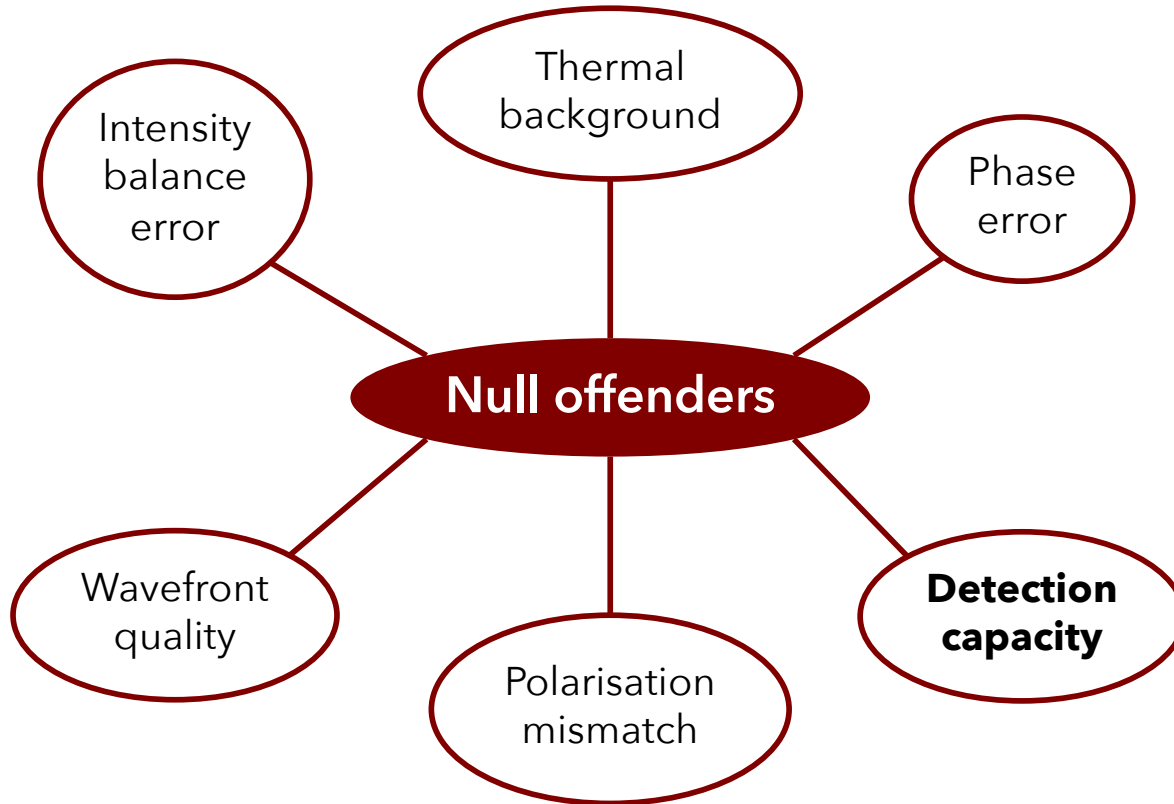
<https://life-space-mission.com/learn/>

4.0 - 18 μm

raw N $\leq 10^{-5}$

Athmospheric characterisation
of telluric planets
(Atmospheric biosignatures)

I. Nulling interferometry



Integrated photonics

- Stability
- Compacity
- Modal filtering
- Self-alignment
- Cooling

II. MILENE test bench

Integrated photonics

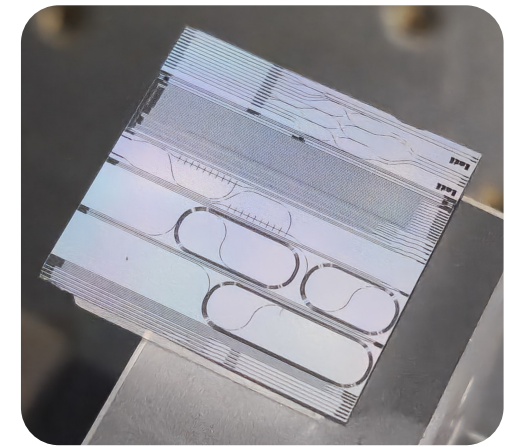
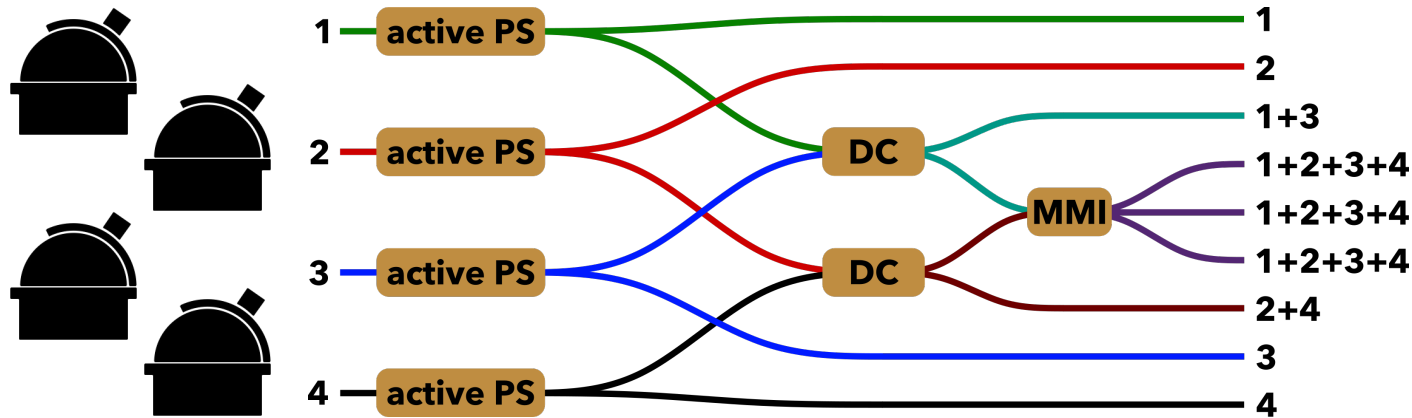
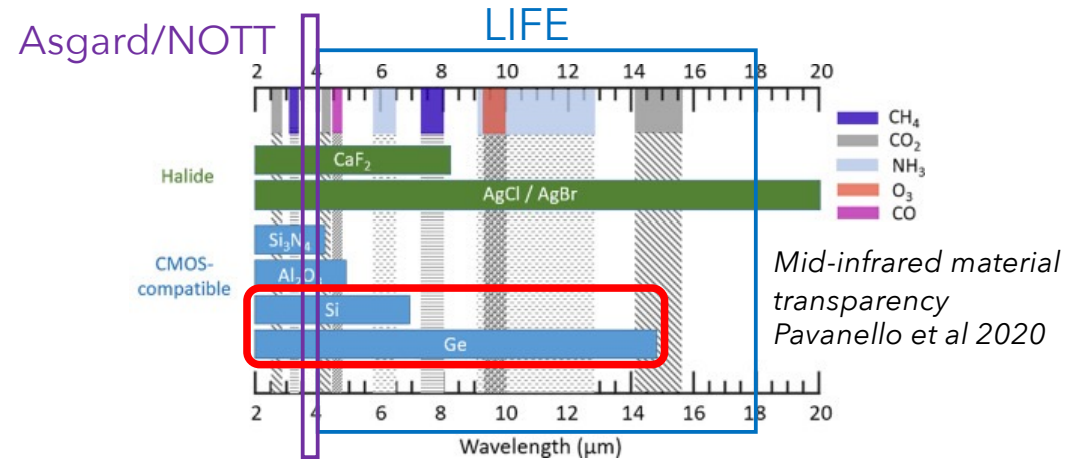
SiGe technology from the CEA-Leti



- Up to **11 μm**
- **Active** phase shifters!

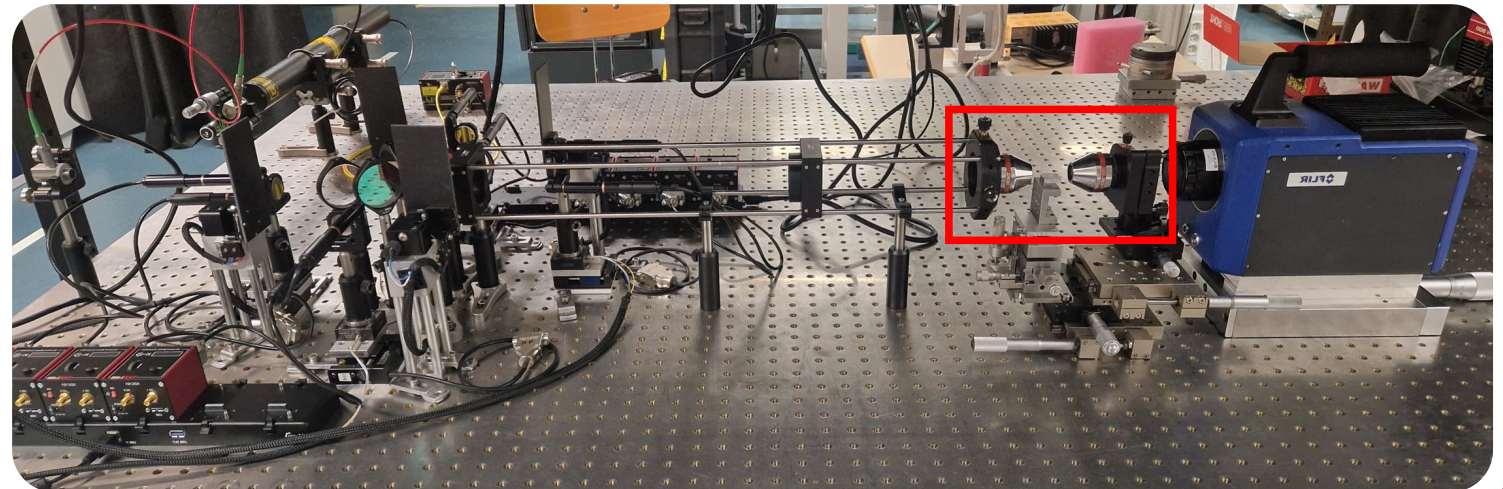
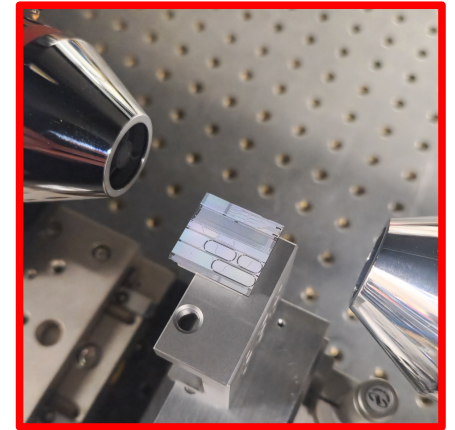
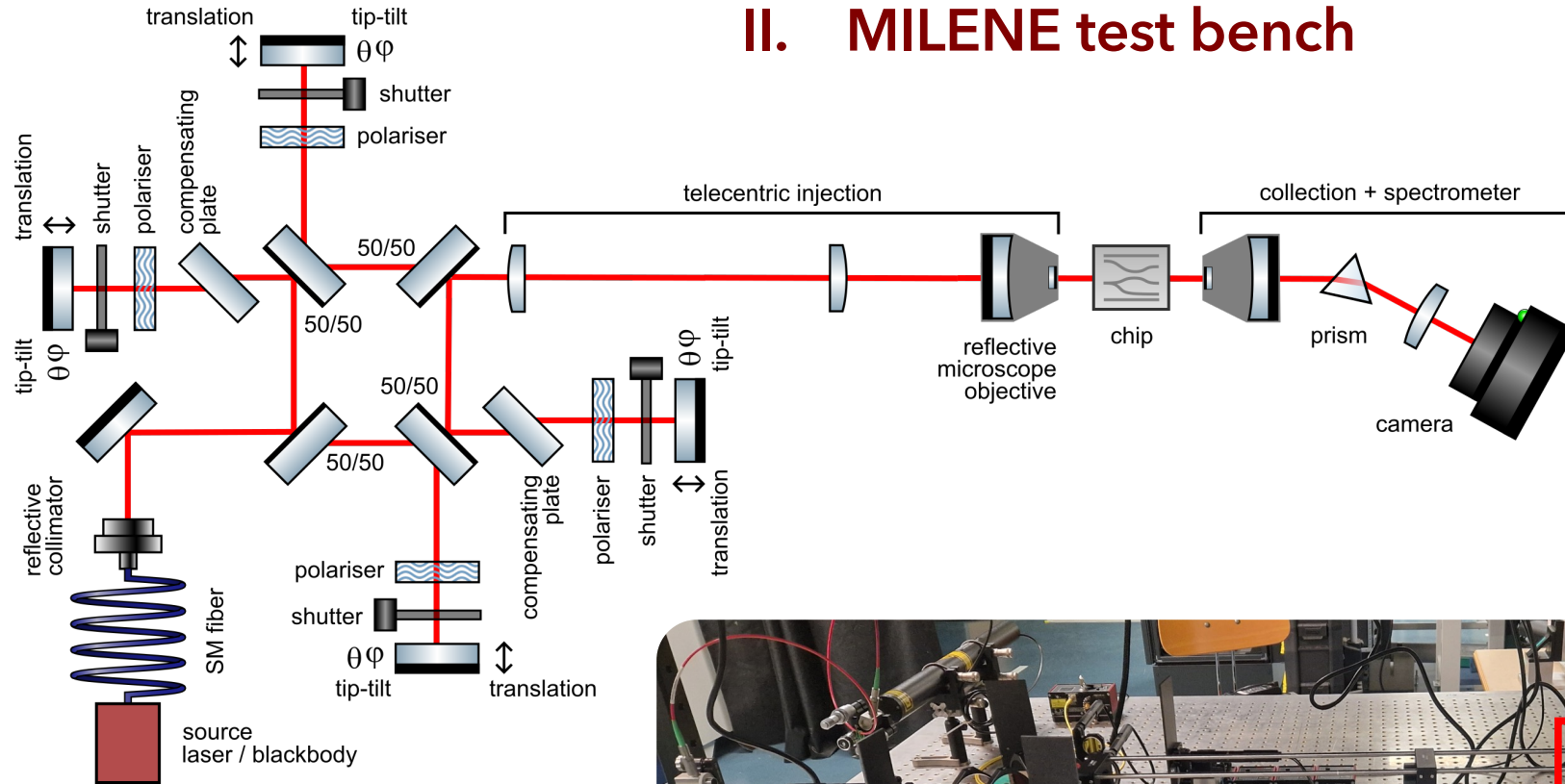
Actual chip optimised for **L band** (3.25 - 3.75 μm)

$N \leq 10^{-3}$ goal over the L band



Designed by Pierre Labeye

II. MILENE test bench



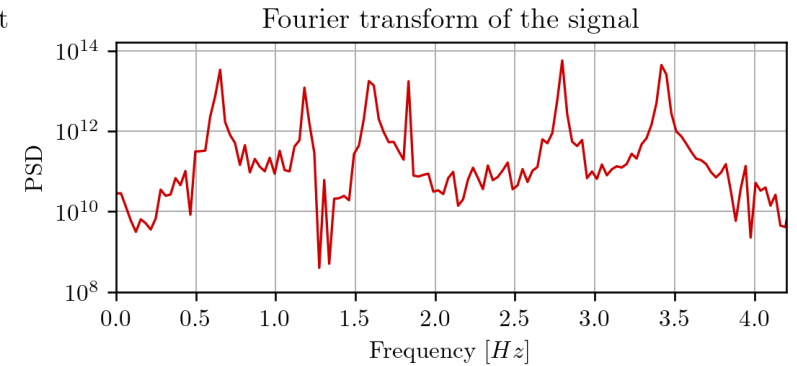
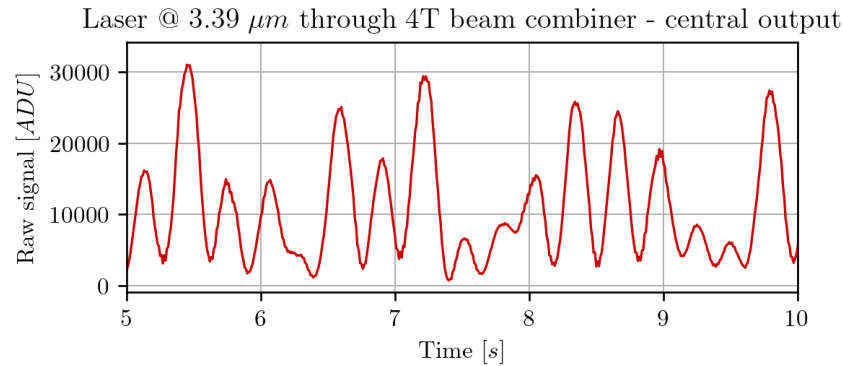
Control of:

- **Flux** balance
- **Polarisation**
- **Phase**

II. MILENE test bench

First results

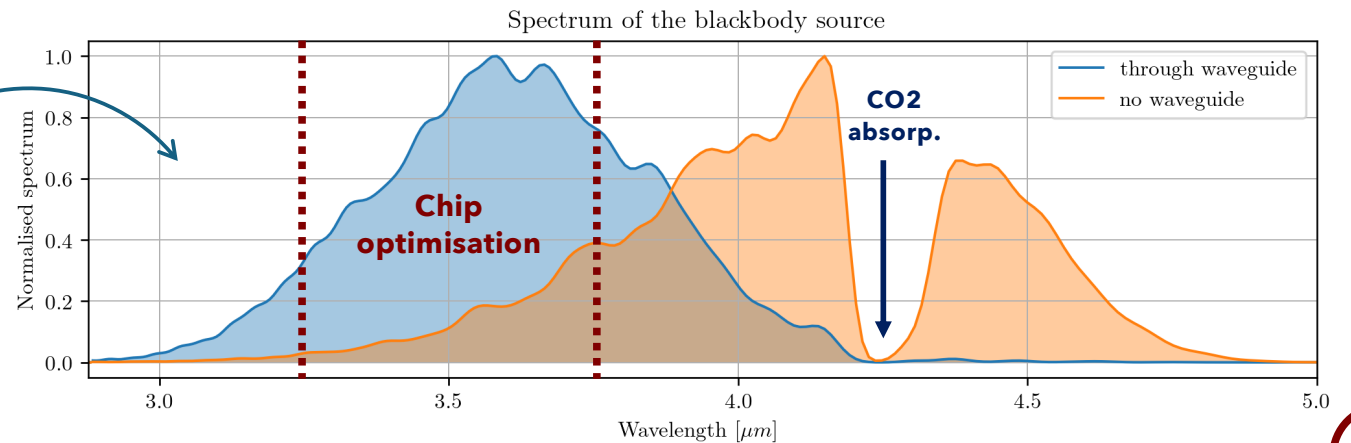
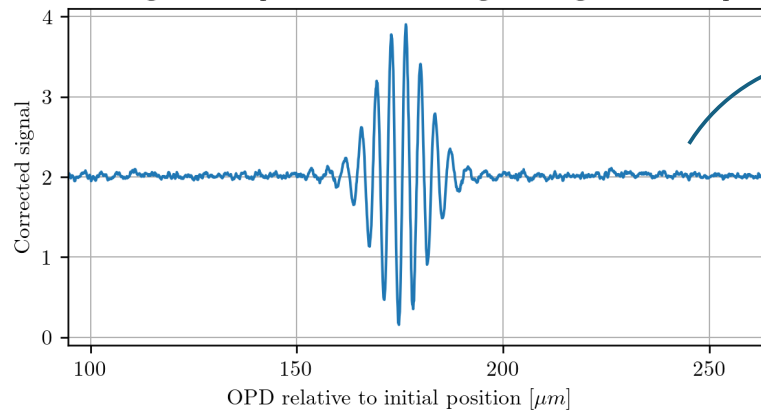
4-channel 3.39 μm laser
injection inside the 4T
Integrated combiner



6 peaks for 6 bases

2-channel polychromatic injection inside a single straight waveguide

Corrected signal from photometries - straight waveguide with tapers



III. Perspectives and opportunities

This bench can also be used to **test detector** technologies in a **precision interferometry** context and demonstrate their suitability for **nulling in broadband** light conditions

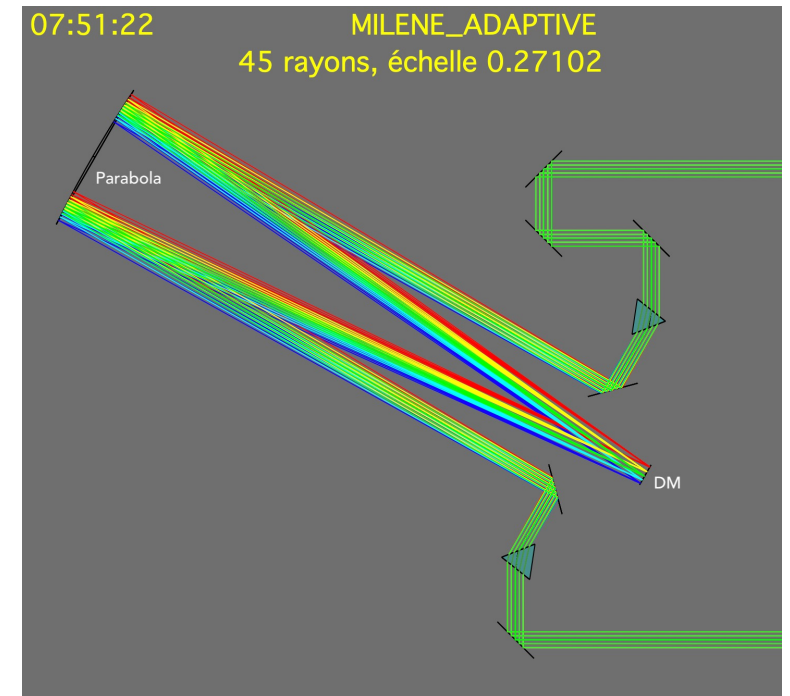
Needs

Very few photons from the planet → really low noise
Ultrawide wavelength bandwidth (4 - 18 μm for LIFE)

Current beamsplitters designed between 2 - 8 μm
Could change them to **include the H band**
Test detectors in this range (avalanche photodiodes?)

III. Perspectives and opportunities

- Implementation of **closed loop operations** for phase initialisation, flux balance and chromatic injection optimisation
- Addition of an electronic system to **control the integrated active phase shifters**
- **Full characterisation** of first generation SiGe 2T and 4T integrated combiners, both in mono- and in polychromatic conditions
- Characterisation of **other PIC technologies**, such as Lithium Niobate, Si on SiO₂ (VTT), ...
- Conception and construction of an **object simulator**
- Study of the interest of building **adaptive arms** for MILENE



Key takeaways

Nulling interferometry introduces big **challenges** we want to explore with the MILENE test bench

Use of **integrated photonics** to gain in : compacity / stability / modal filtering / cooling possibilities

Collaboration with the **CEA-Leti** for **SiGe** integrated photonics technology

Built of the **MILENE** bench to characterise the photonics technologies: **$N \leq 10^{-3}$** goal over the **L band**

Detectors are a key challenge to handle

The MILENE bench can be used to **test** them in **broadband nulling conditions**



MILENE : **M**ID **I**NFRARED **L**AB **E**QUIPMENT FOR **N**ULLING **E**XPERIMENTS