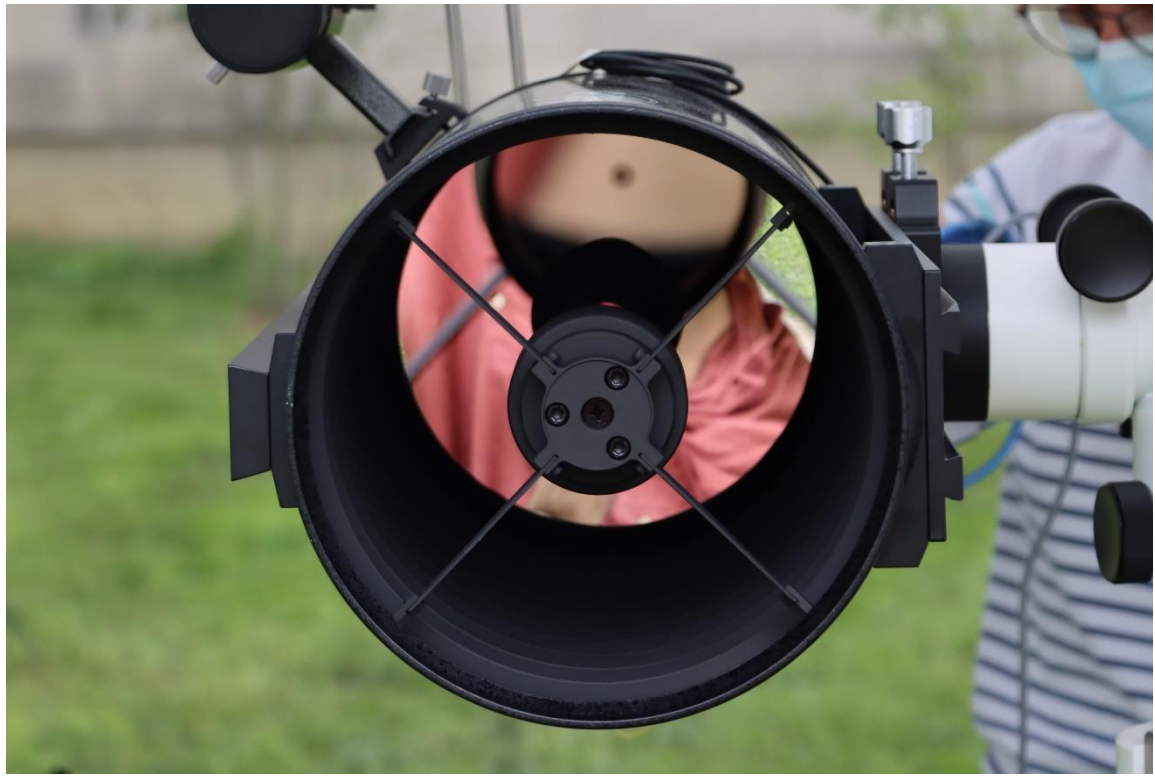
TILBA
BY CAILABS

High-throughput laser communication without adaptive optics

Experimental demonstrations and roadmap



Jean-François Morizur, CEO

Cailabs: is a deeptech company in photonic
With a core specialty around light shape manipulations

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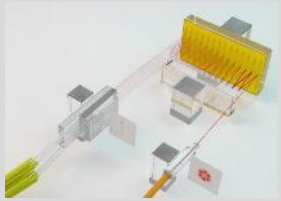
Unique MPLC technology



- Derived from quantum optics at **Kastler Brossel Lab** (Paris)
- Complex beam shaping through a succession of **spatial phase profiles**
- Passive **optical beam shaping** with **no intrinsic loss** and **no moving parts**

Declined into mature product lines

CANUNDA BY CAILABS

Improve laser machining processes with high-power beam shaping

AROONA BY CAILABS

Future-proof multimode fiber infrastructure of LANs

PROTEUS BY CAILABS

Invent the optical networks of the future with space division multiplexing

TILBA BY CAILABS

Deliver high-capacity & long distance free space optical communication

CUSTOM

Enable tailored optical solutions for emerging applications

Cailabs key figures

Created in **2013**

22 patent families

62 employees

70% export

We are based in Rennes, in a brand new building

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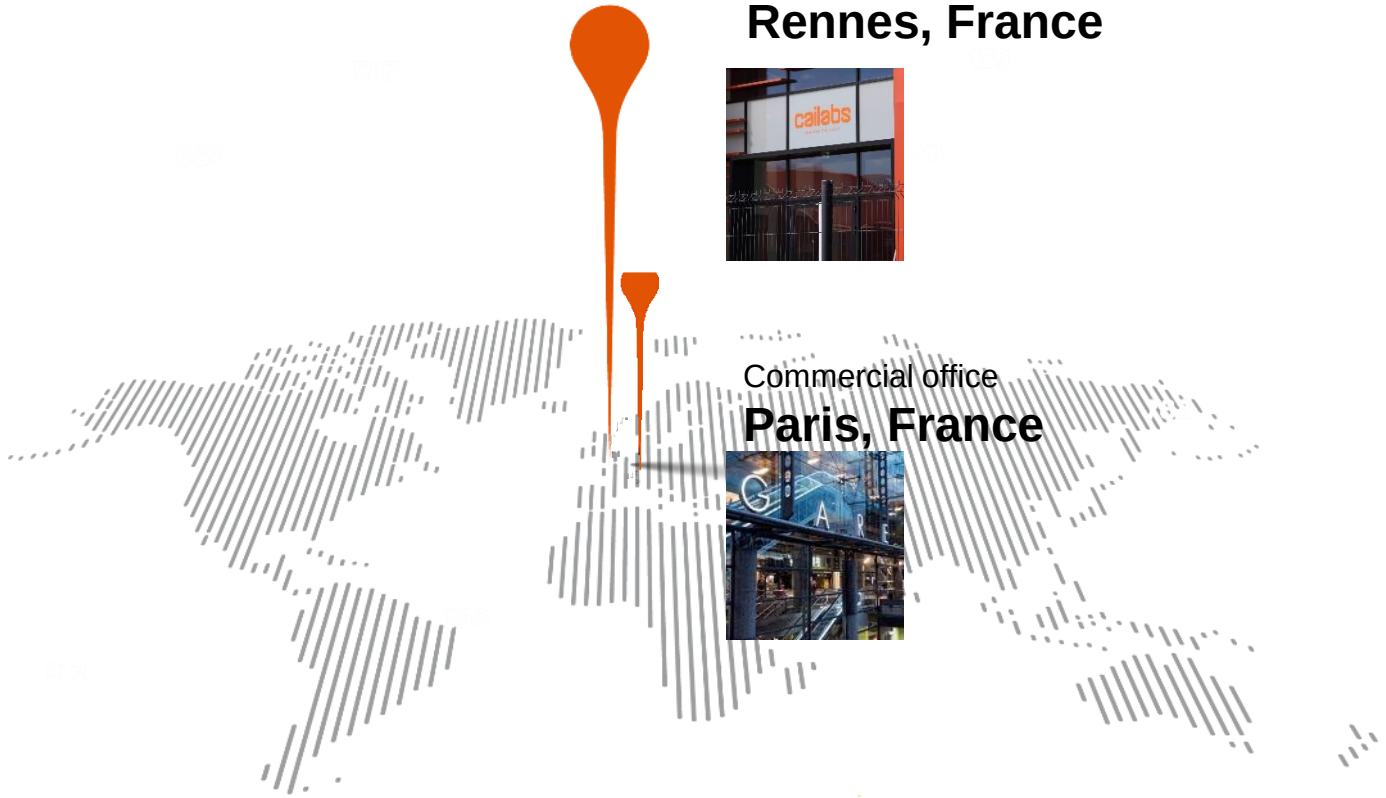

Headquarters:
Rennes, France

Commercial office
Paris, France

In the last 2 years, we have dedicated considerable resources to optical ground station projects

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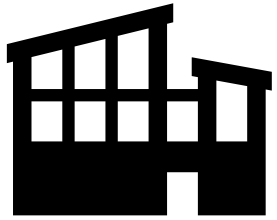
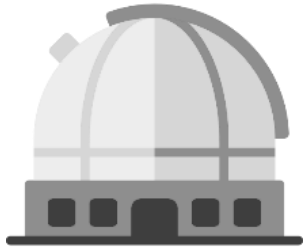
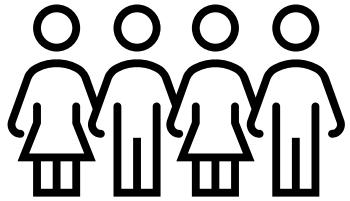


New facilities in
2022

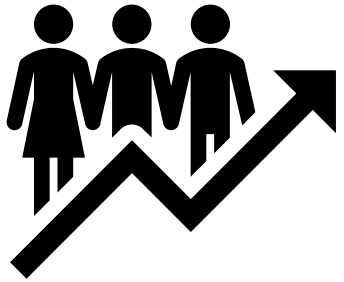


… with a dedicated
Optical Ground Station

and an in-house
production line
audited by B$ companies



15 PhDs currently working on lasercom projects



A team scaling up with recruitments planned in
2022 & 2023

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Laser communication

Overcome communication limitation

Radio satcom suffers from technical limitations
And laser communication is the only credible alternative

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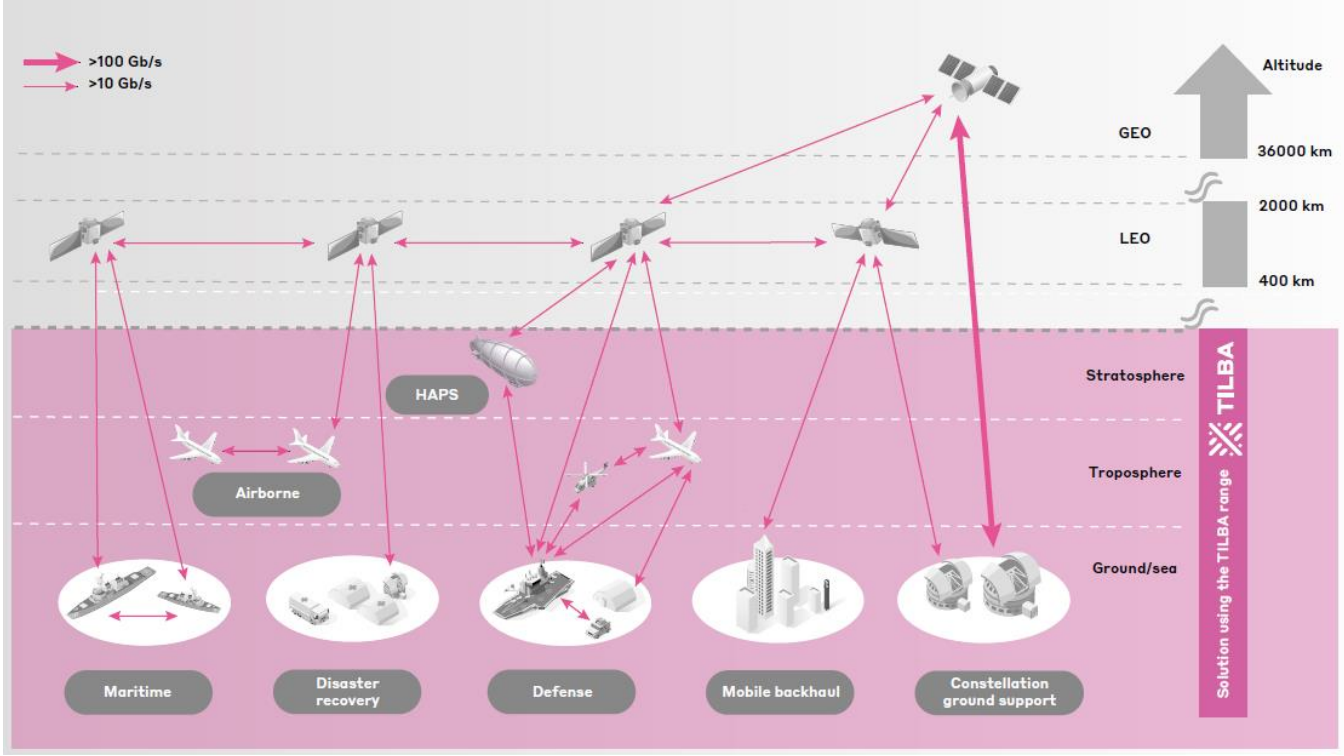
Lasercom overcomes RF limitations and enables

- Ultrafast up- and downlink (100Gbps+ !)
- An unlicensed communication spectrum
- Highly secure links (directional and non-jammable)

Essential for operational use cases:

- Latest generation Earth Observation satellites generate Tb of data per day
- Sovereign communication requires secure satcom links
- Telecom constellations rely on ultra-broadband feeder uplinks



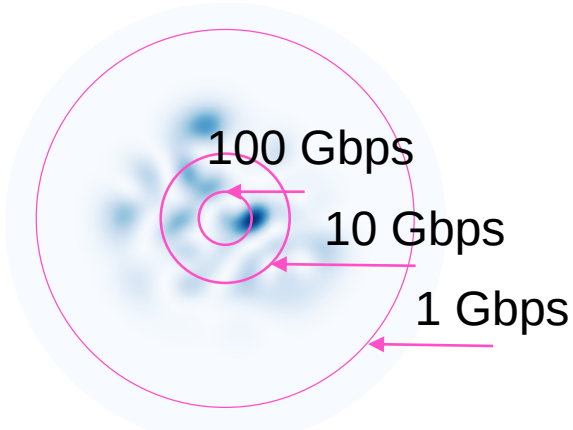
Turbulence makes it difficult to couple into the required detector for high capacity links

Laser communication is competitive with RF at high throughput (> 10 Gbps) which requires small detectors

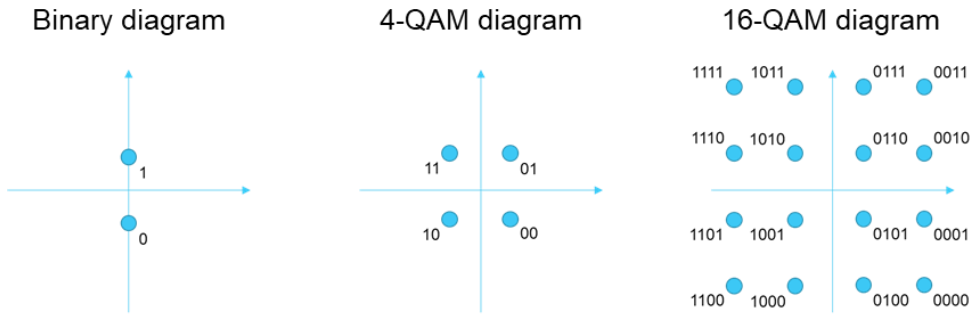
- 10x more data rate means 10x more sensitivity
- Small detectors feature less noise for higher sensitivity

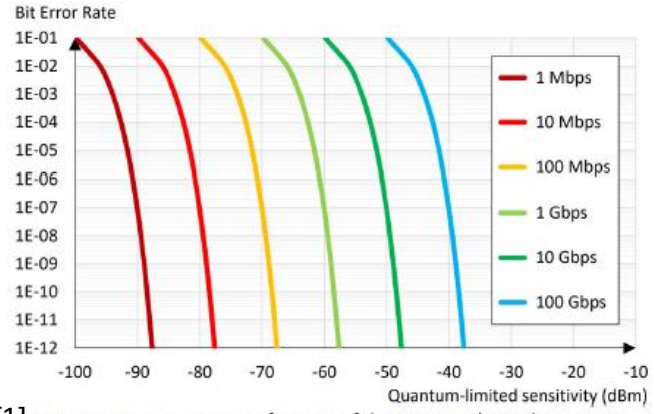
To benefit from efficient telecommunication equipment, coupling inside single-mode fiber becomes compulsory

- Enabling coherent detection for > 10Gbps
- Unlocking the use of EDFAs to amplify the signal



Detector size depending on throughput and turbulent beam





[1] Fig. 8.10. Bit Error Rate as a function of the quantum-limited sensitivity.

[1] Carrasco-Casado, A. & Mata-Calvo, R., Free-space optical links for space communication networks, 2020

We mitigate turbulence, but not in the “usual” way

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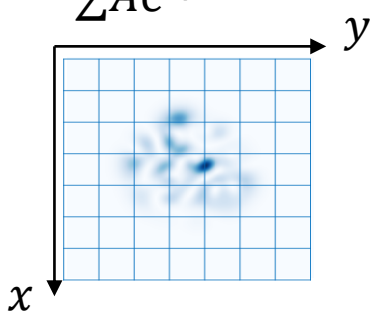
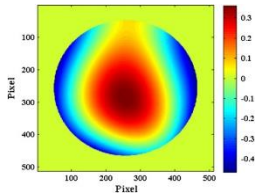
ADAPTIVE OPTICS

Zernike decomposition of the **phase** and cartesian **phase** compensation

$$\sum A e^{i\psi(x,y)}$$



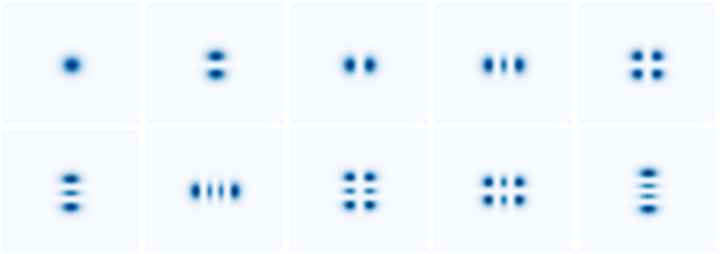


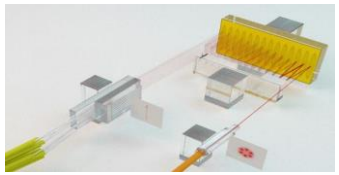
Wavefront sensor + Deformable mirror

SPATIAL DEMUX

Mode basis of the **field**

$$\sum \alpha_{n,m} \mathrm{HG}_{n,m} e^{i\psi_{n,m}}$$





MPLC + Recombiner

The concept is packaged into TILBA-ATMO, a turnkey solution

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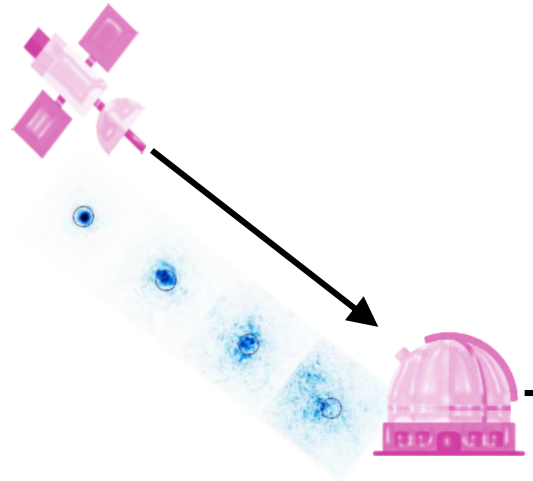


Tip/Tilt mirror

TILBA ATMO

MPLC DEMUX

φ_1 φ_2 φ_3

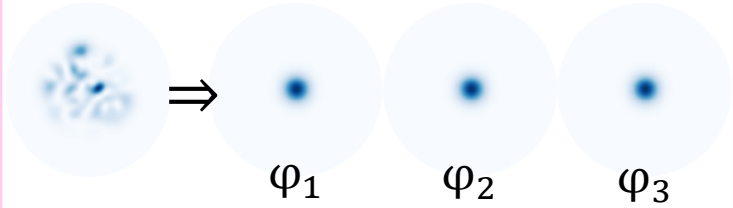
SMFs

Electronics controller

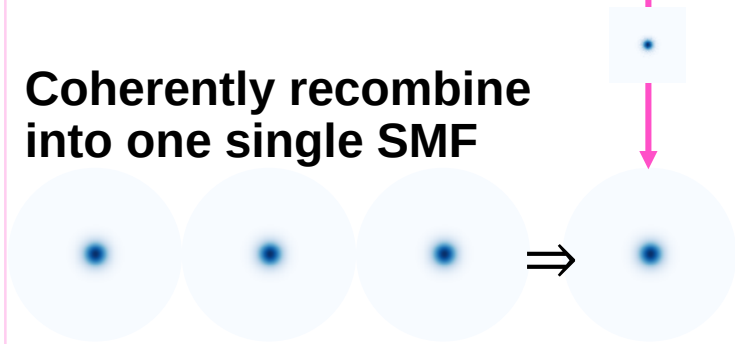
All optical recombiner

Decompose light on modes

Demultiplex into SMFs



Coherently recombine into one single SMF



To implement it, TILBA-ATMO leverages state-of-the-art technology

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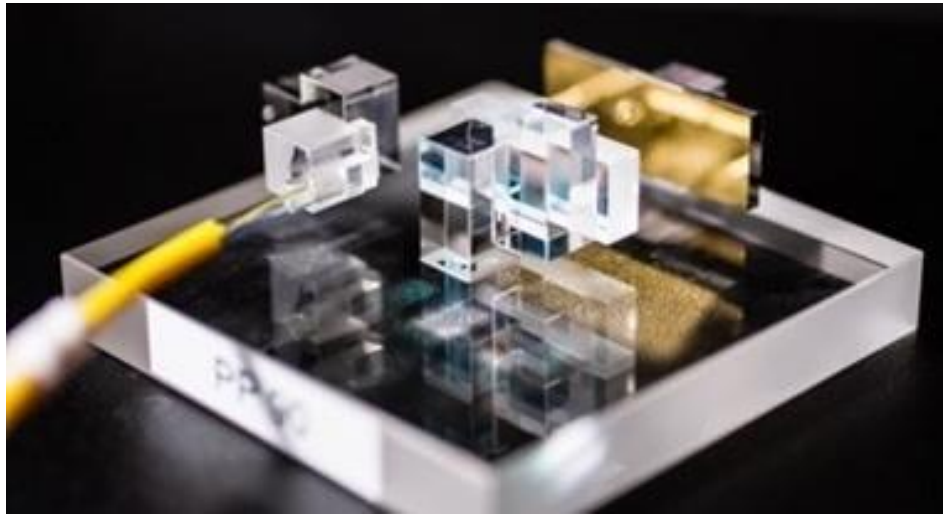
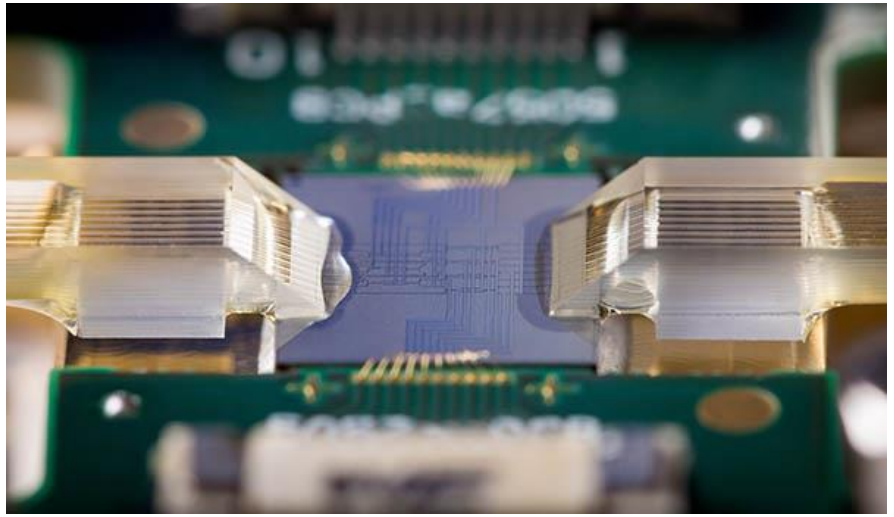
Multi-Plane Light Conversion



Integrated Photonics Chip



Beyond core turbulence mitigation, Cailabs provides up to the full ground-station

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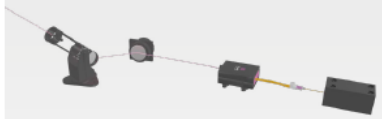
TILBA-ATMO

Component

Optical system

Subsystem



OGS

Entire station

Infrastructure		
Communication module	Optical system	
OGS Command and control	TILBA ATMO	
Environment monitoring and metrology		

Infrastructure		
Communication module	Optical system	
OGS Command and control	TILBA ATMO	
Environment monitoring and metrology		

Infrastructure		
Communication module	Optical system	
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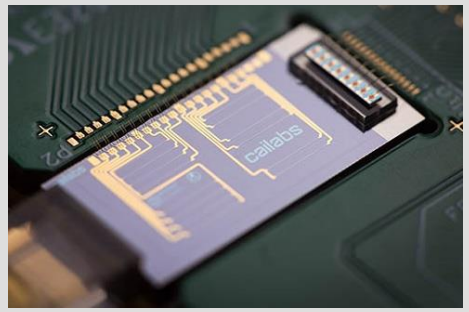

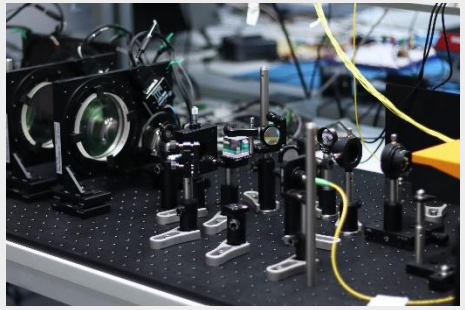

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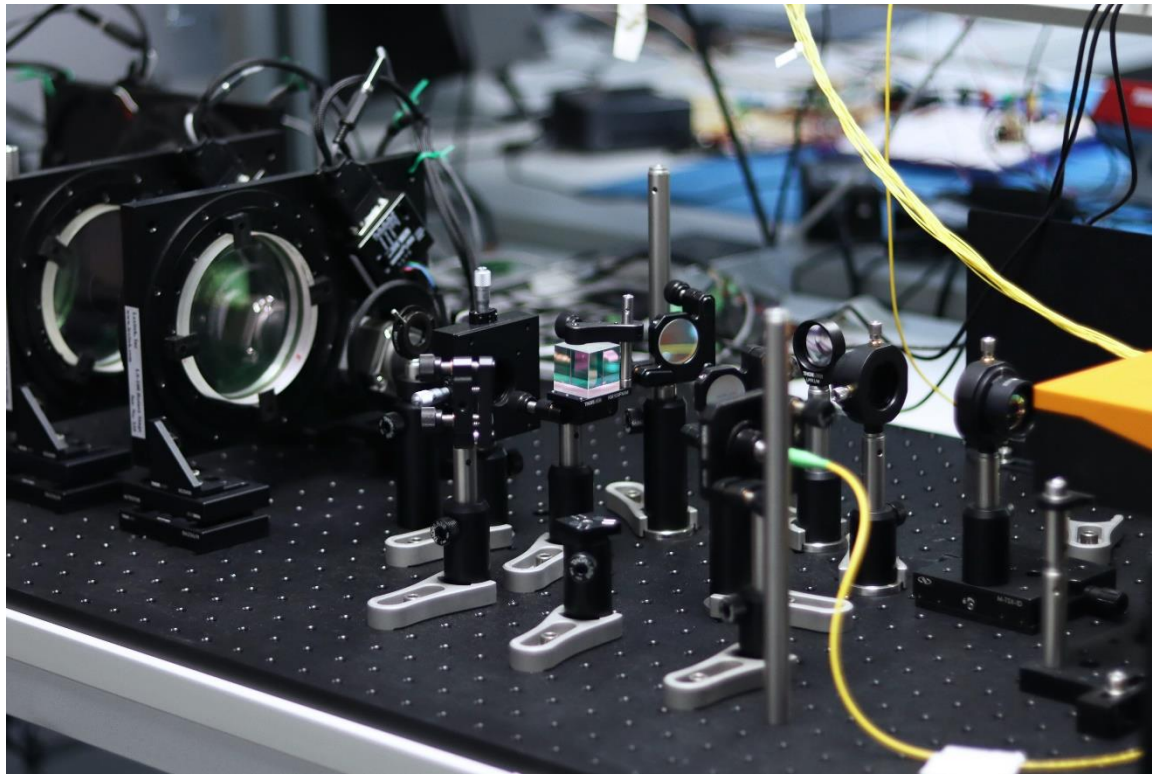
Results and going-forward

From link budget calculation to full OGS operation



Resource
Autonomous and peer-validated turbulence and link budget modelling

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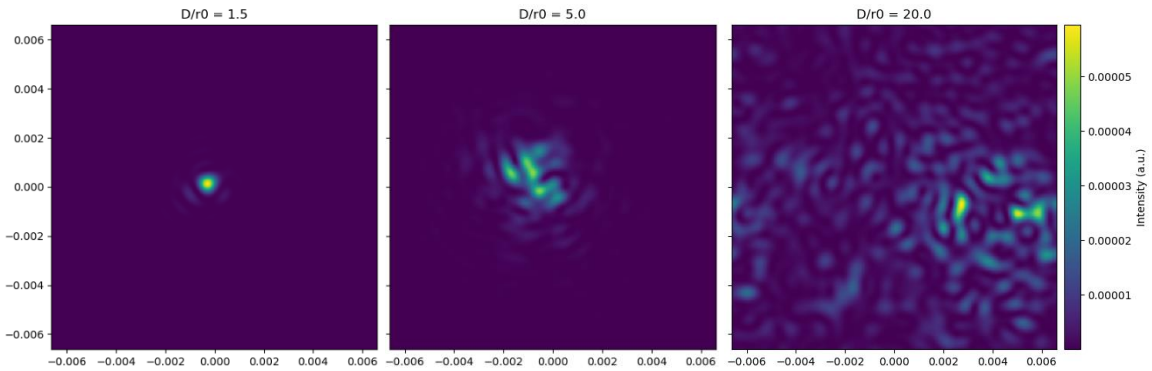
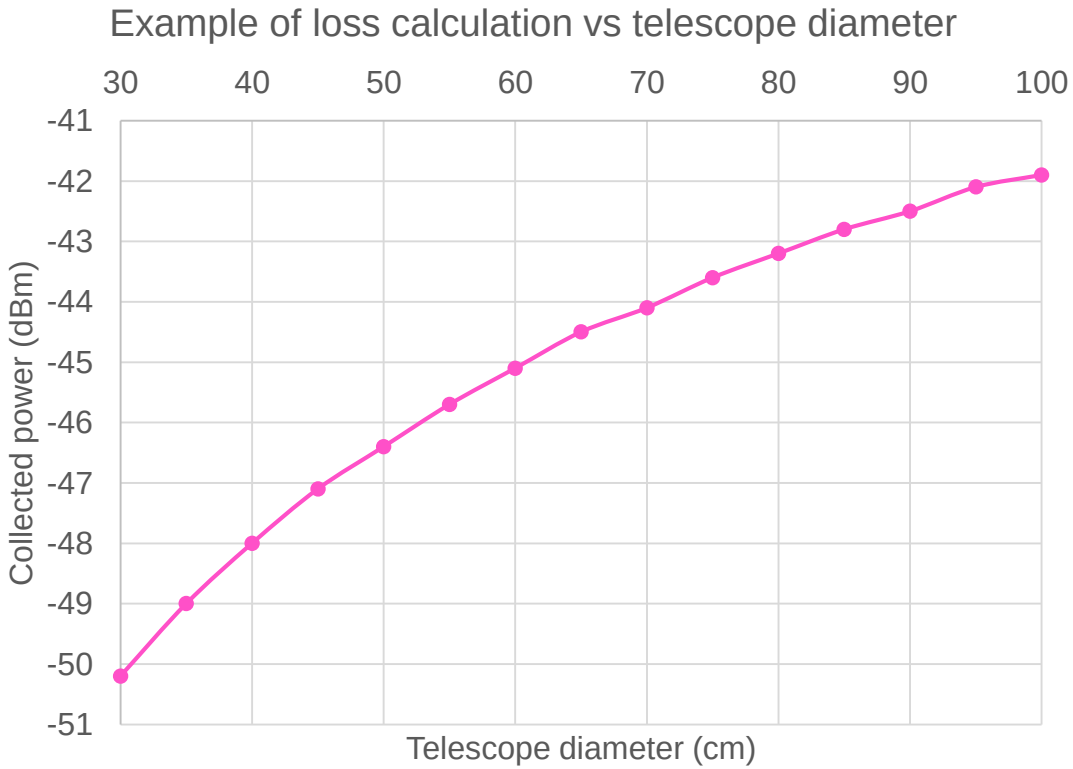
Turbulence simulation tools



Simulated turbulent wavefront profil

Optical budget calculation



Resource
State-of-the-art dynamic turbulence optical bench

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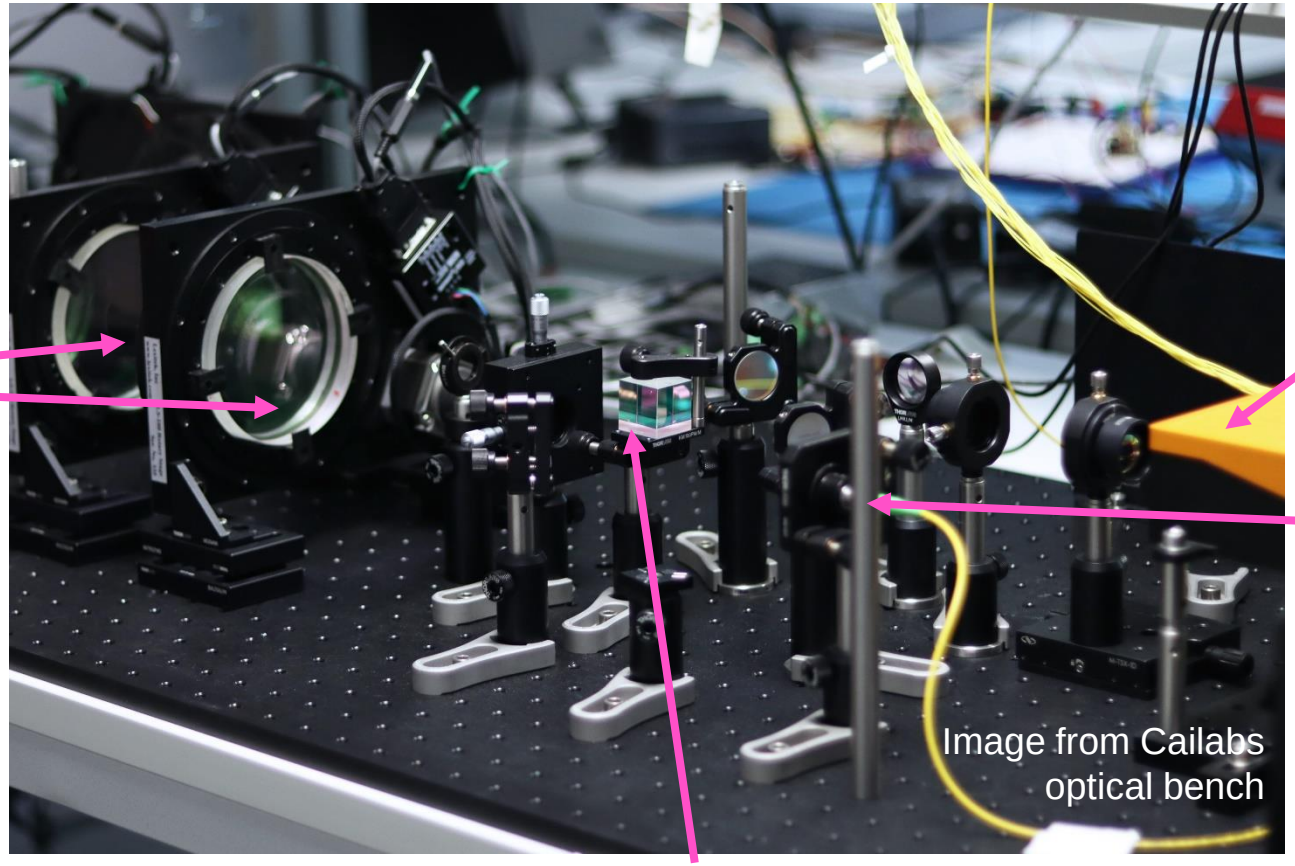
Up to three turbulence phase plates.
We can adjust :

- Speed ➔ Greenwood frequency
- Distances ➔ Scintillation index
- Input beam size ➔ D/r0



MPLC at receiving end

SMF output

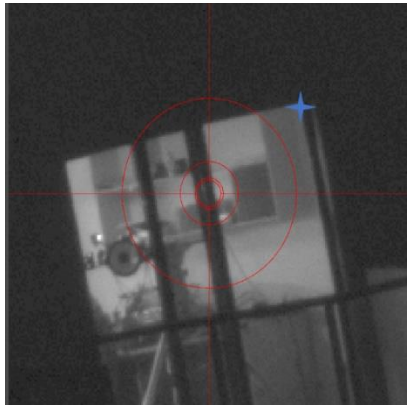
Beam splitter

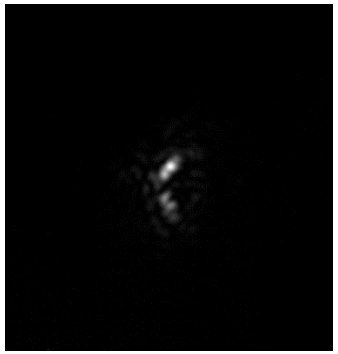
Resource
Short distance link (200m)

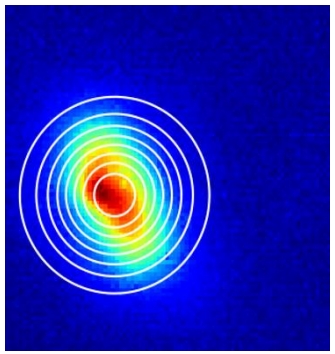
TILBA BY CAILABS

Two telescopes facing each other, one emitting and one receiving the signal

Resource
Medium distance link (1km)







Turbulent wavefront

Resource
Proprietary Optical Ground Station and prototypes at Cailabs

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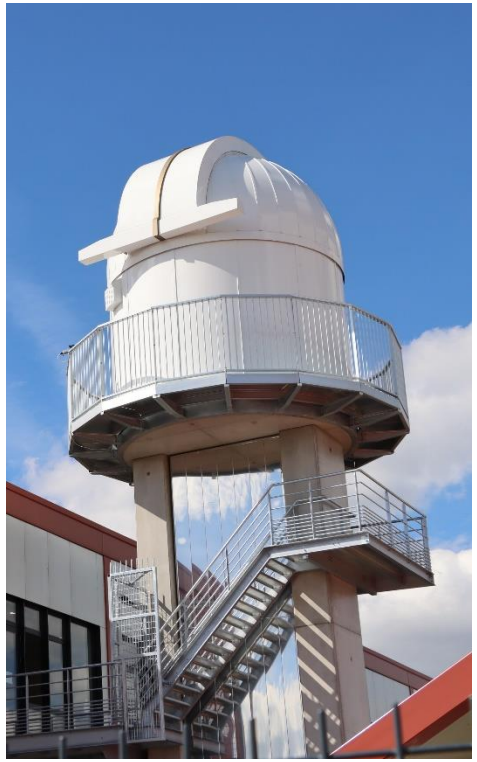
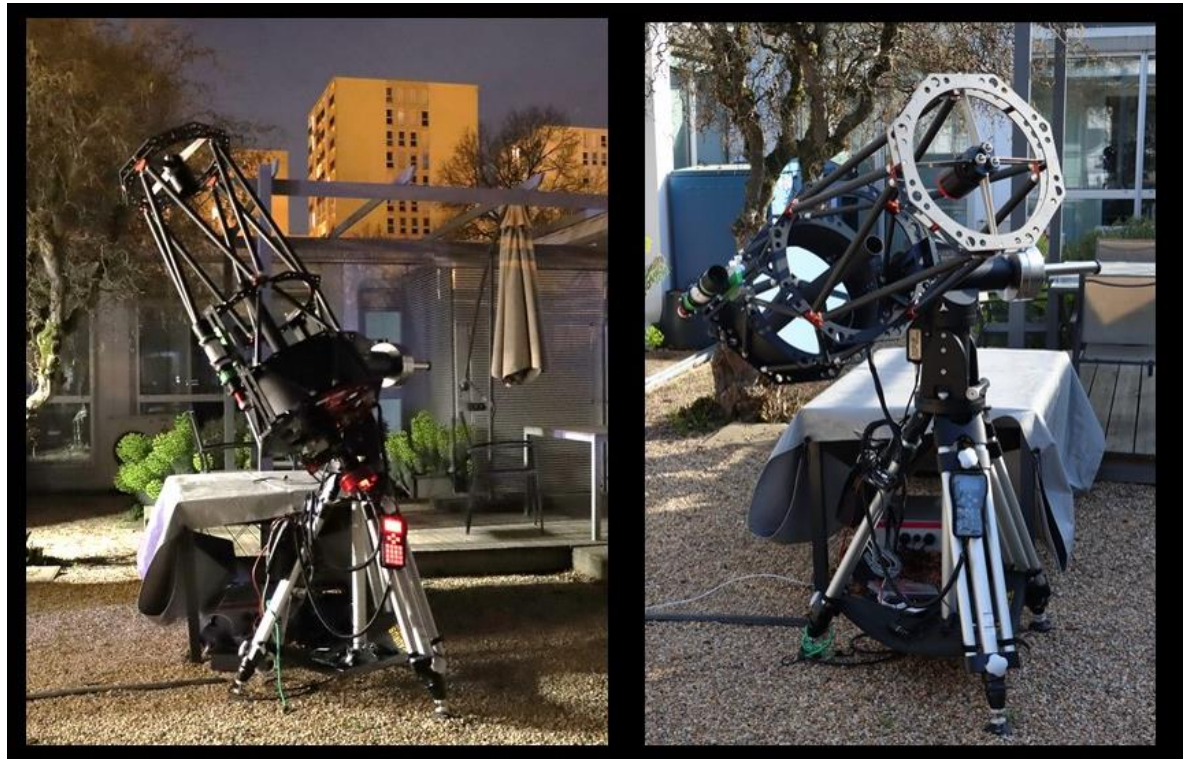
Operational optical Ground station



Example of telescope – 80 cm

Example of telescope – 35 cm



Resource
Partnerships : Example of tests at DLR (10 km)

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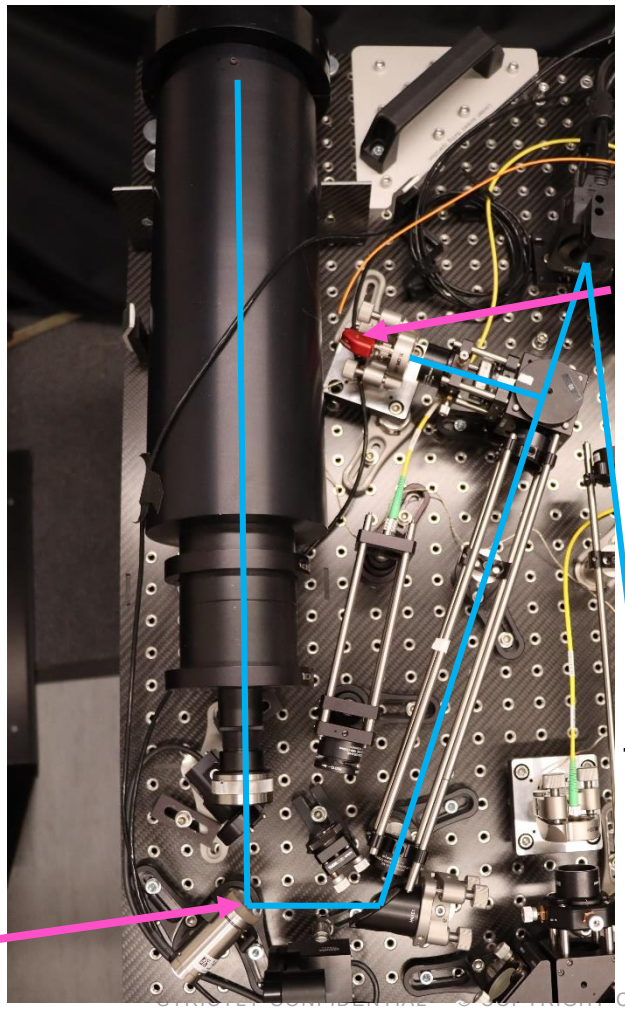
DLR’s optical link around Weilhem in Germany



Leveraging these resources enabled us to perform a series of validations – more details at www.cailabs.com

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Coherent and high data-rate link
- 100 Gbps DQ-QPSK demonstration
- 50 Gbps NRZ demonstrated on recombining unit
- 10 Gbps DPSK

Ground-to-ground demonstration
- 200 m – 10 Gbps link in Cailabs
- 1 km – 10 Gbps link in Cailabs
- 10 km CW power link in partnership with the DLR

Telescope and optical ground station qualification
- Qualification of telescope from 20 cm to 80 cm
- LEO satellite tracking
- Optical sub-system qualification: mount, tracking, beacon, tip-tilt, modem,…

What to expect in the next 12 months?

TILBA
BY CAILABS

Next campaign with partner on turbulence mitigation TILBA-ATMO – late 2022 and early 2023

Next version of turbulence mitigation TILBA-ATMO – early 2023

LEO-to-Ground communication link validation – early 2023

Delivery of automated and industrial ground station to clients – mid 2023

We are pushing an ambitious roadmap to support lasercom deployment

TILBA BY CAILABS

2019-2021

Turbulence mitigation validation

Telecom sub-system tests and production (TILBA-ATMO)

cnes ONERA THE FRENCH AEROSPACE LAB

Field tests

DLR

2022

Demonstrate broadband and ground-to-ground field tests

Higher than RF data rate (> 10 Gbps) and comparison with alternative technologies (AO)

First in house optical ground station and sat-to-ground experiments

2023

First deliveries of client optical ground station

Optical ground station pre-series for commercial use

First optical terminals for on-board applications (e.g. naval)

2024-2025

Industrializing of new on-board terminals

Ramp-up of optical ground stations and new terminals

What do we need from the EPIC & ESA community?

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We need always better PICs

- Low-loss
- Fast phase modulation
- Delivered on time, and within specs
- => we run 1-2 dedicated runs per year

We need some specialty fibers / components

We need partners for relevant context requirements and to support demos

- Sat-ground on-going (French DoD, EU)
- Ship-Ship is just starting (French DoD, major OEM)
- Aircraft / Drone in discussion
- Others ? TBD