



Robust laser **communications** through **atmospheric** turbulence

A fully integrated module for space-to-earth laser communication, free-space optical networks and inter-satellite links

Improved reliability in the presence of atmospheric turbulence

Easy to integrate and plug-and-play component

Compatible with standard telecommunication components

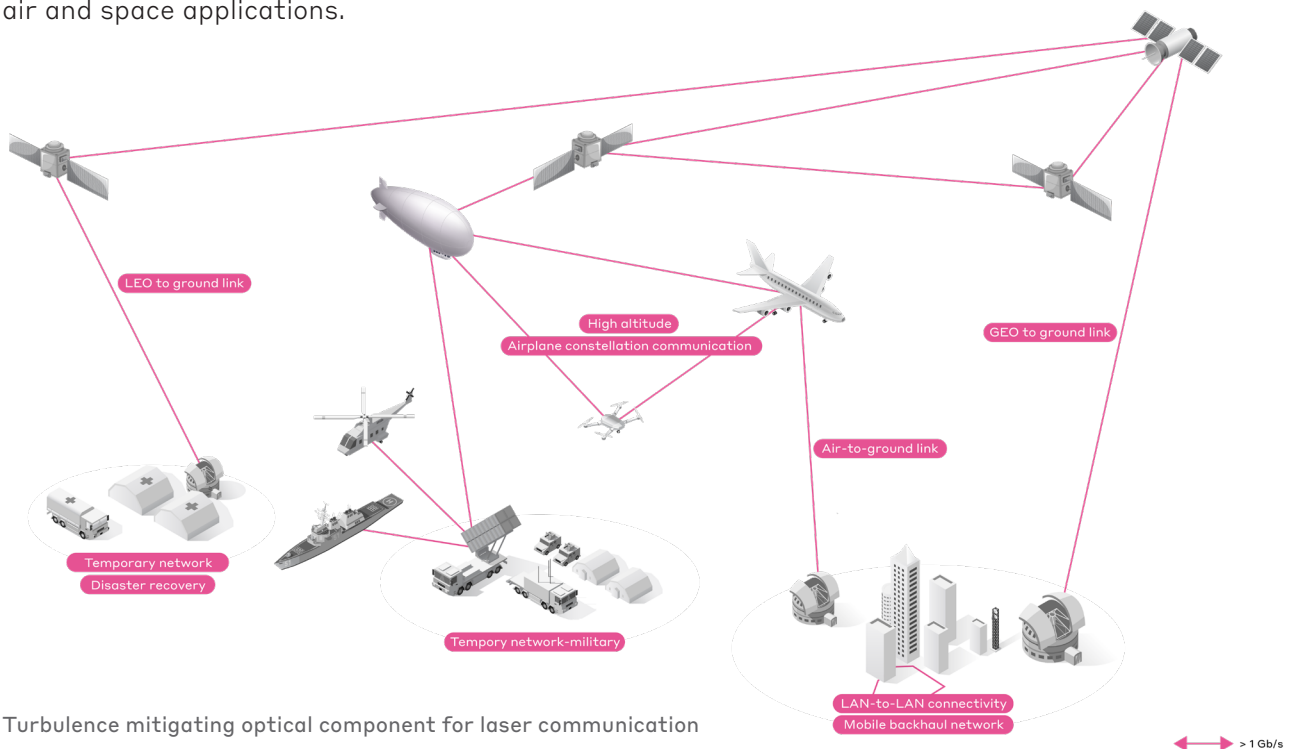


TILBA-ATMO is a state-of-the-art atmospheric turbulence mitigation module dedicated to laser communication links. By coupling a perturbed laser beam into a standard single-mode fiber, TILBA-ATMO improves the reliability of free space optical links for all turbulence conditions.



Laser communications are the next generation of free space transmissions. Additionally to radio frequency communications, optics guarantee very high speed, secure and low latency links without the need for a license.

With TILBA-ATMO, we want to facilitate the deployment of optical communications in land, naval, air and space applications.



Turbulence mitigating optical component for laser communication

TILBA-ATMO main features:

● Atmospheric turbulence mitigation

Collecting and spatially demultiplexing a perturbed beam enables mitigating turbulence with an adaptive optics-free module.

● Free-space to single-mode fiber receiver

With its all optical recombiner, TILBA-ATMO can send all the collected signals to a unique SMF output.

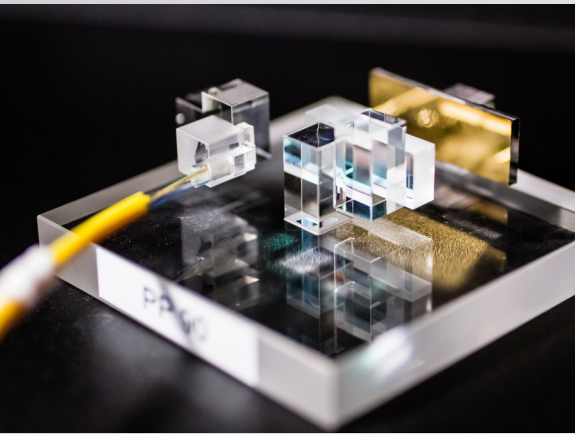
● Plug-and-play and easy to integrate

With a large area input, a unique SMF output and an integrated electronic and algorithm control, TILBA-ATMO can be installed easily in any optical ground station.

● No moving parts

TILBA-ATMO is mechanically passive.

Perturbed beam collection



Based on the MPLC technology

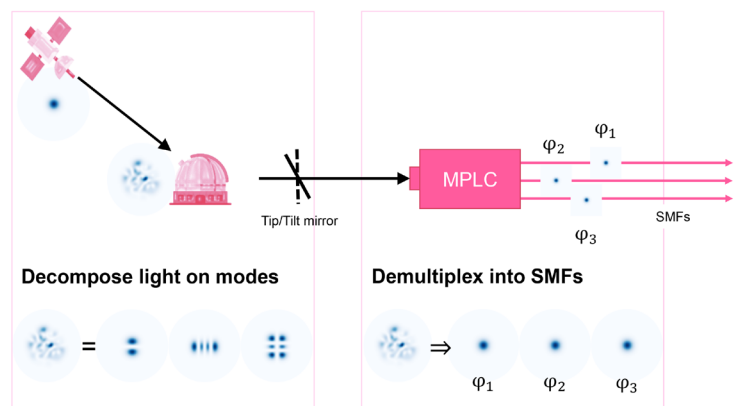
The TILBA-ATMO module is based on Cailabs' Multi-Plane Light Conversion (MPLC) technology. Using a succession of reflections on phase plates, the MPLC can perform any spatial transformation, single-mode or multimode.

The advantage of the MPLC for laser communication relies on its **state-of-the-art multimode spatial demultiplexing capabilities**.

Demultiplexing modes to collect them

After propagation through the atmosphere, light displays a perturbed wavefront profile which **can be decomposed on a limited number of spatial modes**.

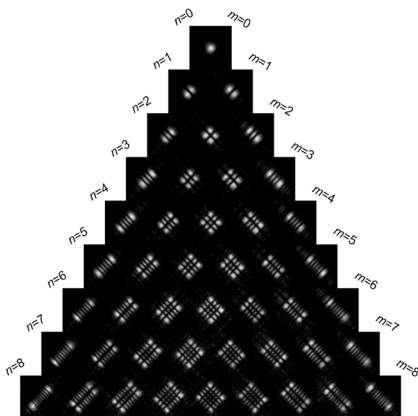
The MPLC spatial demultiplexer decomposes these modes that are subsequently coupled to **single-mode fiber**.

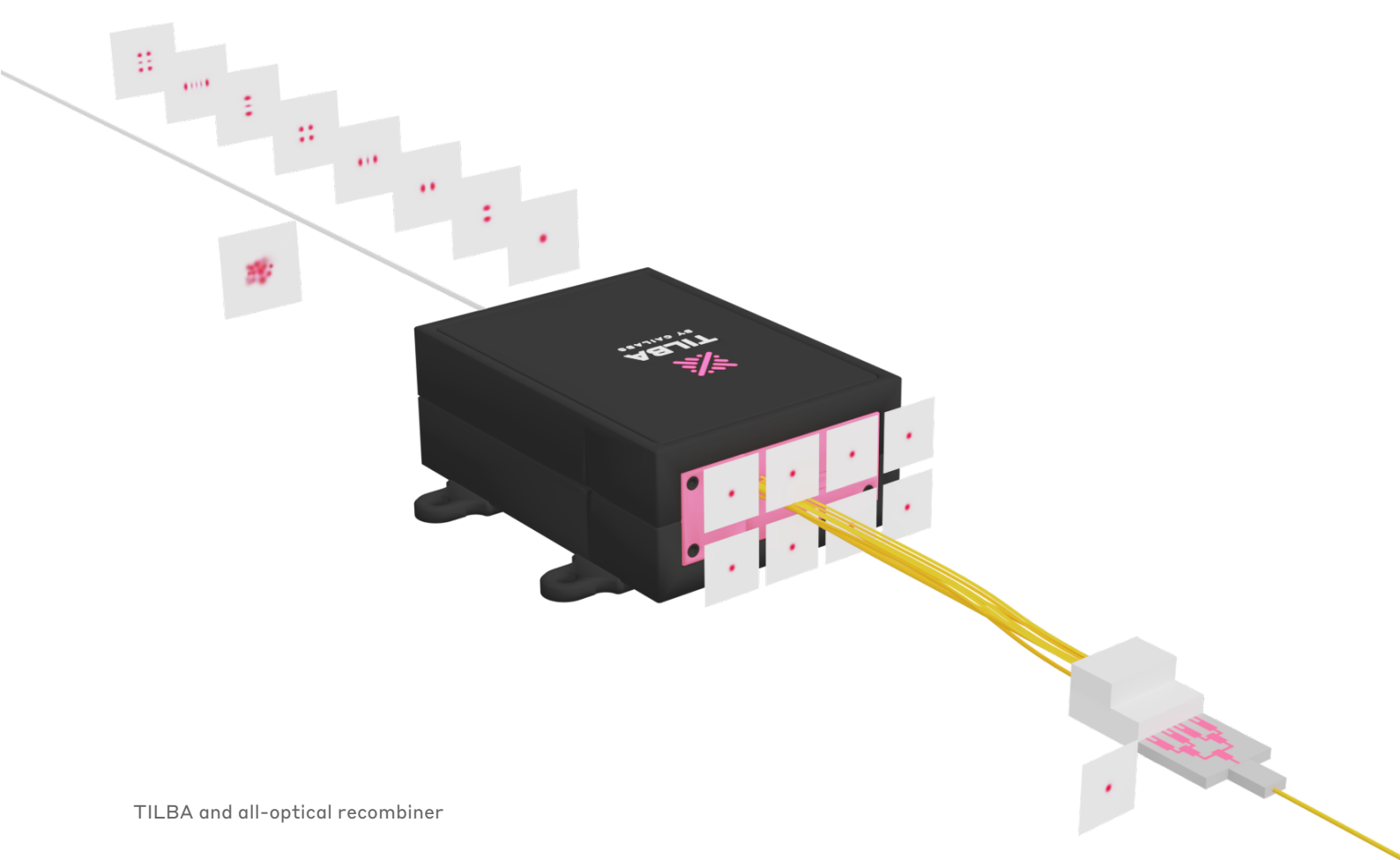


MPLC options

A **Hermite-Gaussian spatial mode** basis is used as a standard. It is well adapted both to the decomposition of the turbulence and to the design of the MPLC.

The TILBA product line is customizable in terms of the number of modes and spatial mode basis that can be adapted to the client's specific needs.





TILBA and all-optical recombiner

Rephasing modes with a photonic coherent combiner

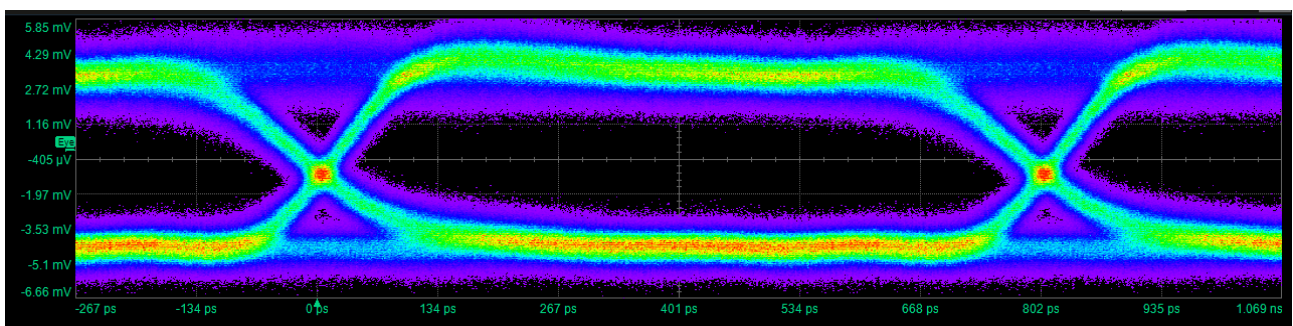
To ensure **easy, plug-and-play integration**, Cailabs provides a **photonic recombiner**.

Signals inside single-mode fibers are out of phase after the demultiplexer. Thanks to active phase and intensity control, the module ensures the **coherent all-optical recombining** of the MPLC's outputs directly to a unique single-mode fiber.

With >kHz modulators, **TILBA-ATMO compensates high-speed turbulence effects without any moving elements.**

Phase lock loop

Real-time compensation of turbulence effects requires a fast and efficient phase-lock loop. Electronics and software for the photonic recombiner control are included in TILBA-ATMO to provide a plug-and-play, all-in-one turbulence mitigation system.



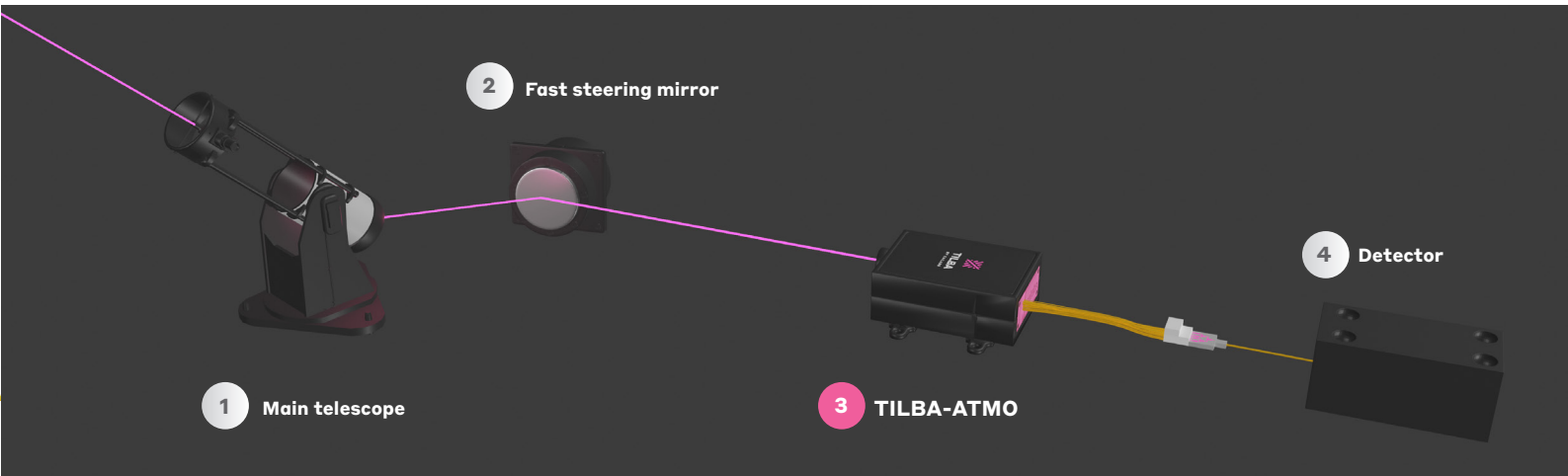
Eye diagram after 8 modes recombining.

System integration

TILBA-ATMO takes place between the telescope or the fine pointing mirror, if one is needed, and the fibered optical communication block.

The main advantage of this architecture is that it is **compatible with all single-mode components** like small diameter high-speed detectors or optical amplifiers.

With a net gain in the optical budget and single-mode compatibility, TILBA-ATMO releases constraints for medium throughput and simply enables high throughput communication.



TILBA-ATMO should be installed directly at the output of the telescope, or after a fine steering mirror. Its standard SMF output enables single mode component compatibility.

Case study

Comparison of *TILBA* vs. *Adaptive Optics* to compensate for atmospheric turbulence

DLR (Deutsches Zentrum für Luft- und Raumfahrt) is the German space research center and a world reference in optical satellite communications.

MPLC spatial demultiplexer was tested by the DLR team on a 10 km link at the Weilhem site.

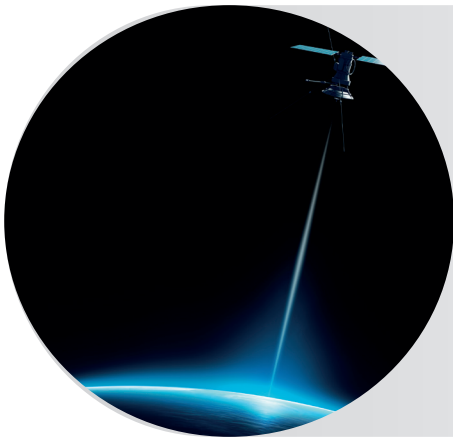
- The spatial demultiplexer was installed in parallel with an adaptive optics (AO) unit to compare the two technologies in real time.
- Link stability (scintillation) was equivalent to that of the AO unit in low and medium turbulence and more effective in high turbulence.
- The passive component, with a connectorized multimode input, allowed for quick and easy installation.



General technical specifications

Parameters	Unit	Value	Comment
Function	-	Perturbed beam to single-mode fiber converter	-
Operating Wavelength	nm	1550	Functional over C-band
Input	μm	300 μm free space collimated input	
Output	-	1 SMF	FC/APC connector
Phase shifters cut off frequency	kHz	> 1	-
Phase shift control	rad	$> 3\pi$	

TILBA-ATMO main applications



Earth-space laser communication

Thanks to its **beam shaping technology**, TILBA-ATMO **improves the reliability of free-space optical links between the earth and satellites** by:

- Increasing the range and robustness of laser communication in atmospheric turbulent environments.
- Using passive components, which are therefore not limited in bandwidth.
- Being compatible with standard telecom systems such as detectors and amplifiers.

Naval communication bubbles

TILBA-ATMO **boosts the stealth and capability of naval communications** and offers:

- Improved link robustness by compensating for atmospheric turbulence at reception using standard, off-the-shelf on-board components.
- Increased transmission range of links, by coherently combining several laser sources.
- Compatibility with standard telecommunication architectures.



Designed, manufactured and assembled in Rennes, France

TILBA-ATMO is made in France.

The design, manufacturing and assembly are performed in the Cailabs' headquarters in Rennes, France. This ensures the quality and the control of the critical components.

The MPLC is a patented technology used in multiple applications, from laser manufacturing and local area networks to aircraft cabling.

For this last application, Cailabs develops, in partnership with Safran, an airborne version of the MPLC demonstrating the robustness of this technology.



In addition, **find out** about our **TILBA-EMIT** solution



TILBA is the Cailabs' product range dedicated to free-space laser communication. Where TILBA-ATMO mitigates turbulence at reception, **TILBA-EMIT coherently combines multiple sources to increase power during emission.**

TILBA-EMIT main features:

- Optimum beam combining
- High power handling
- Large number of sources (>10)





Founded in 2013, **Cailabs** is a French deep tech company which designs, manufactures and distributes innovative photonic products for telecommunications, free space transmission, industrial lasers, and LANs. A global leader in complex light shaping, its technology is currently protected by 19 patent families. Its innovative optical components are used in a variety of sectors and have contributed to several world records (notably the optical fiber bandwidth record achieved by the Japanese operator KDDI).

Ordering information

- Standard TILBA-ATMO includes an 8-mode recombiner, compatible with medium to high atmospheric turbulence compensation.
- Custom versions with a higher number of modes are available on demand.
- For research purposes, TILBA-ATMO is also available in its recombiner-free version. This can be used as a spatial demultiplexer to collect perturbed light and output them on individual single mode fibers.
- Specific applications requiring additional customization can be considered on a case-by-case basis.

Customized systems are available on demand, contact us to get a quotation!

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