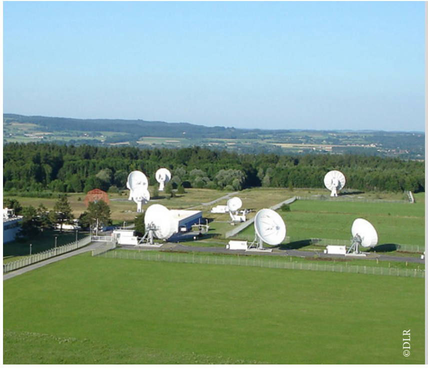
TILBA

CASE STUDY

TILBA improves laser communication through atmospheric turbulence



The partner's issue

DLR (Deutsches Zentrum für Luft- und Raumfahrt) is the German space research center. It is a world reference in optical satellite communications networks. DLR's Advanced Optical Technologies Group holds the world record for laser data transmission with a link throughput of 13.65 Tbps. However, atmospheric turbulence limits laser communication. Therefore the group is researching technologies that can compensate for this turbulence.

The TILBA-R solution

TILBA-R is an optical device designed to improve the reliability of free space optical links in the presence of atmospheric turbulence. It uses a unique passive light shaping technology, replacing the need for active devices such as adaptive optics to compensate for atmospheric turbulence.

The advantages of the solution

- TILBA-R was installed in **parallel with an adaptive optics (AO) unit, without modifying the initial bench setup**, in order 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**.

COMPARISON OF TILBA VS. ADAPTIVE OPTICS USING AN EXPERIMENTAL DEMONSTRATION OF A GEO LINK

Using standard telecommunication components: the challenge of laser communications.

To create a high-throughput link, it is essential to use standard telecom equipment which is available mainly on single-mode optical fibers. These components, which benefit from the technological maturity of fiber-optic networks, are the only ones that meet the performance requirements while remaining economically competitive.

Unfortunately, atmospheric turbulence deteriorates coupling efficiency in the optical fiber and degrades the telecommunications link. To achieve high throughput rates, a turbulence compensation system is therefore required.

In the article co-published by DLR and Cailabs, two technologies are compared: a standard adaptive optics system (AO) and the first version of Cailabs' TILBA-R, without optical recombination.

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Two technologies with the same functionality

The two techniques have the same objective, but use a different approach. While the AO unit actively reforms the disturbed wavefront, TILBA's MPLC technology collects all the light and demultiplexes it into single-mode fibers. The dynamics of turbulence then result in variations in phase and intensity in the single-mode fibers.

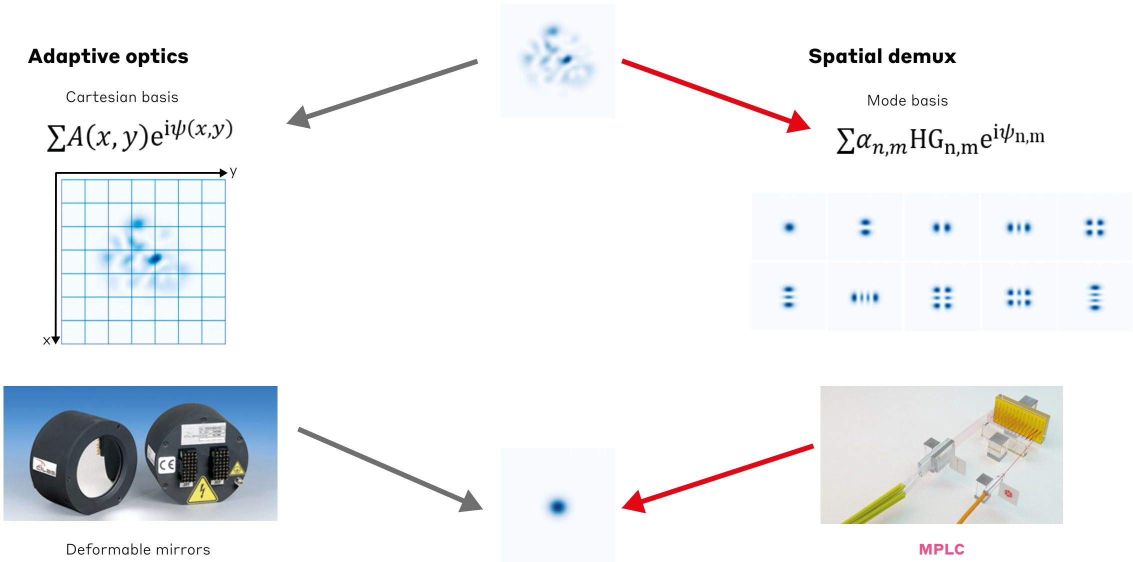


Figure 1 : Comparison of AO and MPLC functionality. AO directly influences the wavefront to reform a Gaussian beam. The MPLC approach passively collects light in the form of modes, which are demultiplexed into single-mode fibers.

Similar performance to adaptive optics, and even better in high turbulence conditions.

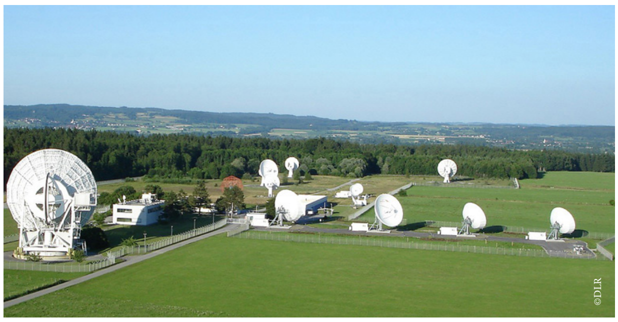
The experiment took place between the station in Weilhem, acting as the ground station, and a terminal, representing the satellite, located at the weather station in Hohenpeißenberg. This site, which is frequently used by DLR, has turbulence characteristics that are representative of a GEO-ground link.

The test bench consists of a 10 cm diameter telescope followed by a pointing mirror. The signal is then separated into two equal fractions, one of which is sent to the MPLC and the other to the Adaptive Optics unit.

The **TILBA-R** includes a 10-mode fiber input demultiplexed to 10 single-mode fibers (SMF). Each SMF is connected to a photodiode whose signal is oversampled. The signals are then summed digitally to obtain a single digital signal: the compensated signal.

The **AO** unit comprises a deformable mirror (DM) with 97 actuators which couple the beam into a single-mode fiber connected to a photodiode. A Shack-Hartmann wavefront sensor measures a fraction of the signal to control the DM and estimate the Fried parameter. A wide-angle camera is used to measure the signal intensity in the focal plane.

Hohenpeißenberg Meteorological Observatory



DLR Weilhem

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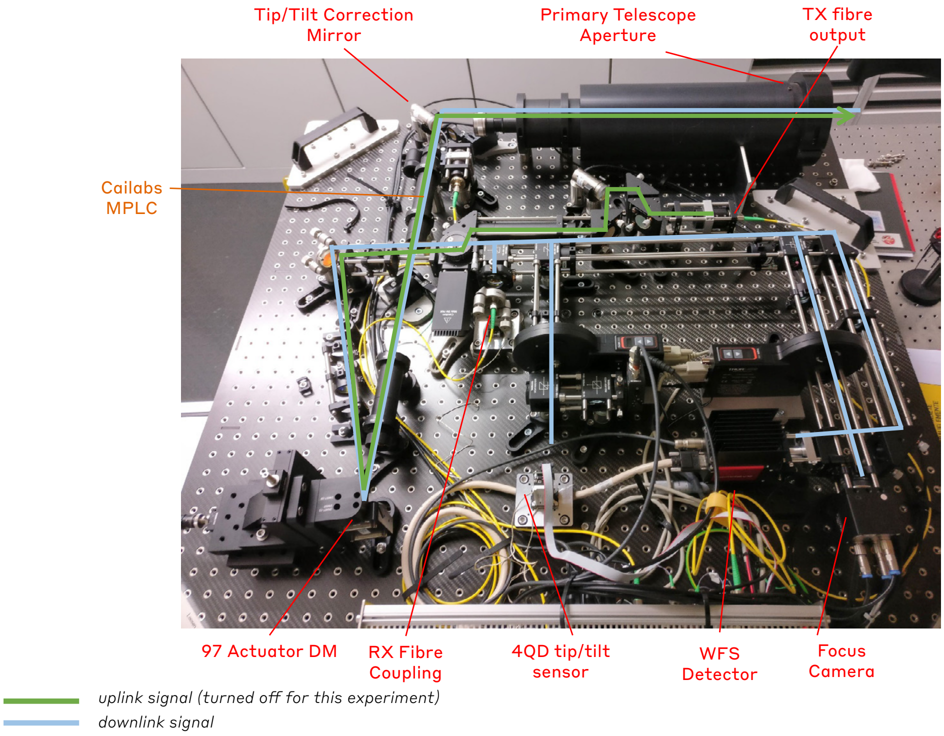

Test bench for measuring turbulence compensation.

AO and TILBA-R were compared in three turbulence conditions corresponding to three types of scintillation in the focal plane σ_I^2: low for $\sigma_I^2 < 0.1$, medium for $0.1 < \sigma_I^2 < 0.3$ and high for $0.3 < \sigma_I^2$. In each case, the scintillation after correction was measured. The lower the scintillation, the more effective the correction and therefore the better the performance.

The results obtained show an equivalent performance for TILBA-R and AO in cases of low and medium turbulence. However, in cases of high turbulence resulting in link interruptions, TILBA-R achieves a better performance than adaptive optics.

This experiment is the first real-time comparison of the performance of an AO unit with that of an MPLC in turbulent conditions representative of a GEO link. However, these measurements show the relevance of a passive modal approach to provide an off-the-shelf atmospheric turbulence compensation system.

> *"By comparing the coupled signal fluctuations using the two techniques, we can see that the two systems have a similar performance. However, the MPLC behaves more robustly under high scintillation conditions, where the AO performance is limited, mainly due to the dynamics of the wavefront sensor."*

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Cailabs: beam shaping made easy

Cailabs designs and manufactures innovative solutions to enhance the performance of laser systems for many applications, such as research, optical telecommunications and materials processing. With its TILBA product range, Cailabs offers high-performance, easy-to-integrate beam shaping components that improve the quality of free space optical links. The TILBA range aims to make laser communication technologies widely accessible for applications such as increasing the power of feeder links, mitigating turbulence at reception and correcting pointing errors in inter-satellite links.