Setup of a 150-meter Optical Link through Atmospheric Turbulence

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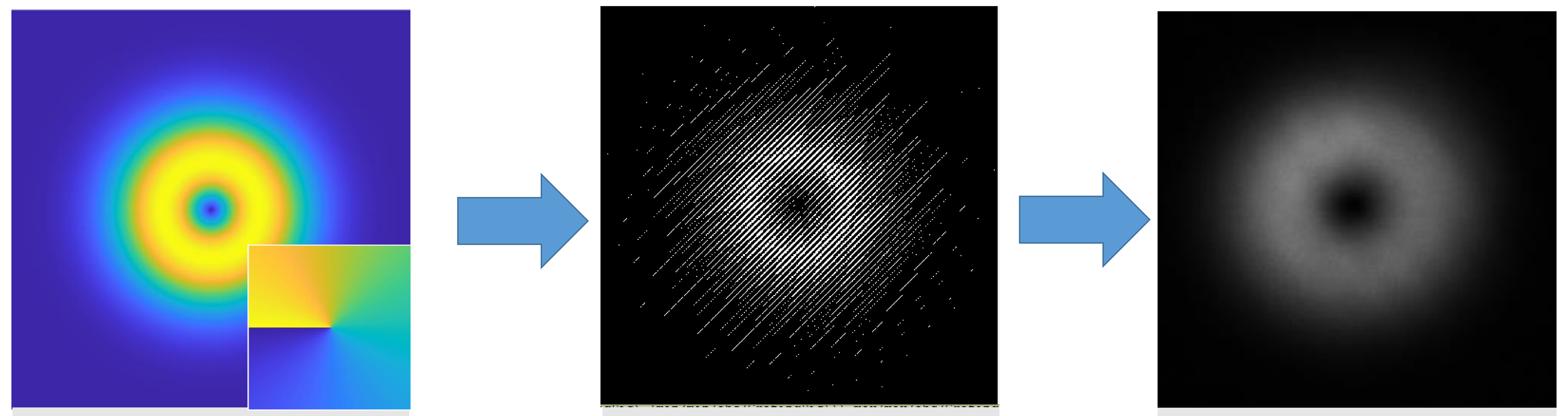
Background

One of the largest problems faced in free space optical communication is the influence of atmospheric turbulence on a beam's structure. Thus, investigating the effects of turbulence on beams has become a major research area in recent years. Experiments within this research area have mainly been performed by generating turbulence within a laboratory setting using, for example, phase screens on a spatial light modulator. Few experiments have made use of real atmospheric turbulence generated naturally outdoors. Therefore, we describe in this poster a semi-permanent setup built for use in experiments requiring outdoor turbulence.

The Transmitter and Beam Generation

We generate the required beam and magnify it at the transmitter to ensure that the beam can be sent across the link. The beam is generated as shown below:



Desired Beam (inset phase) — Binary Hologram on the DMD — Resulting Beam

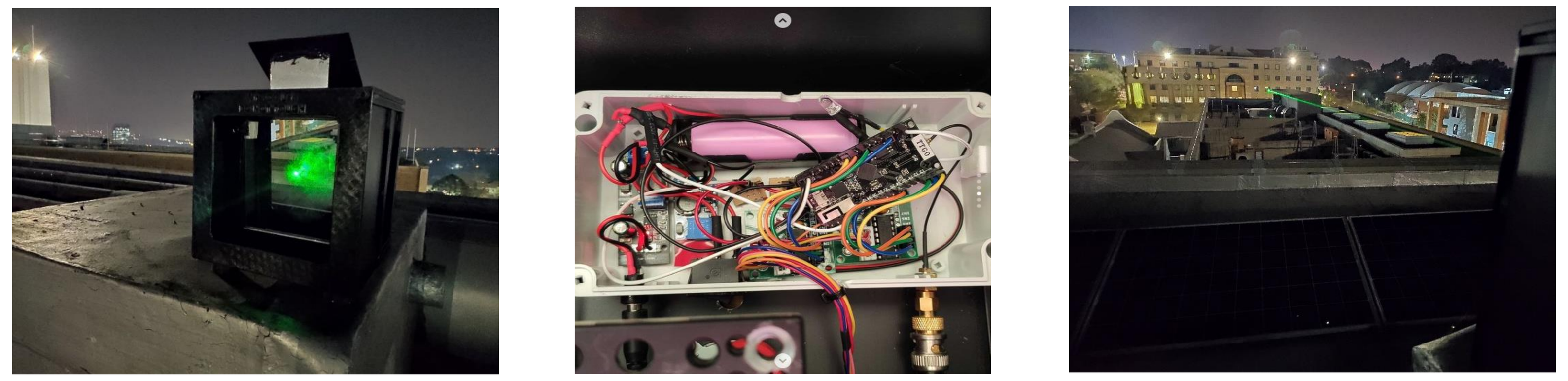
Magnification of the Beam

When magnifying the beam, we consider the following limitations to the beam size:

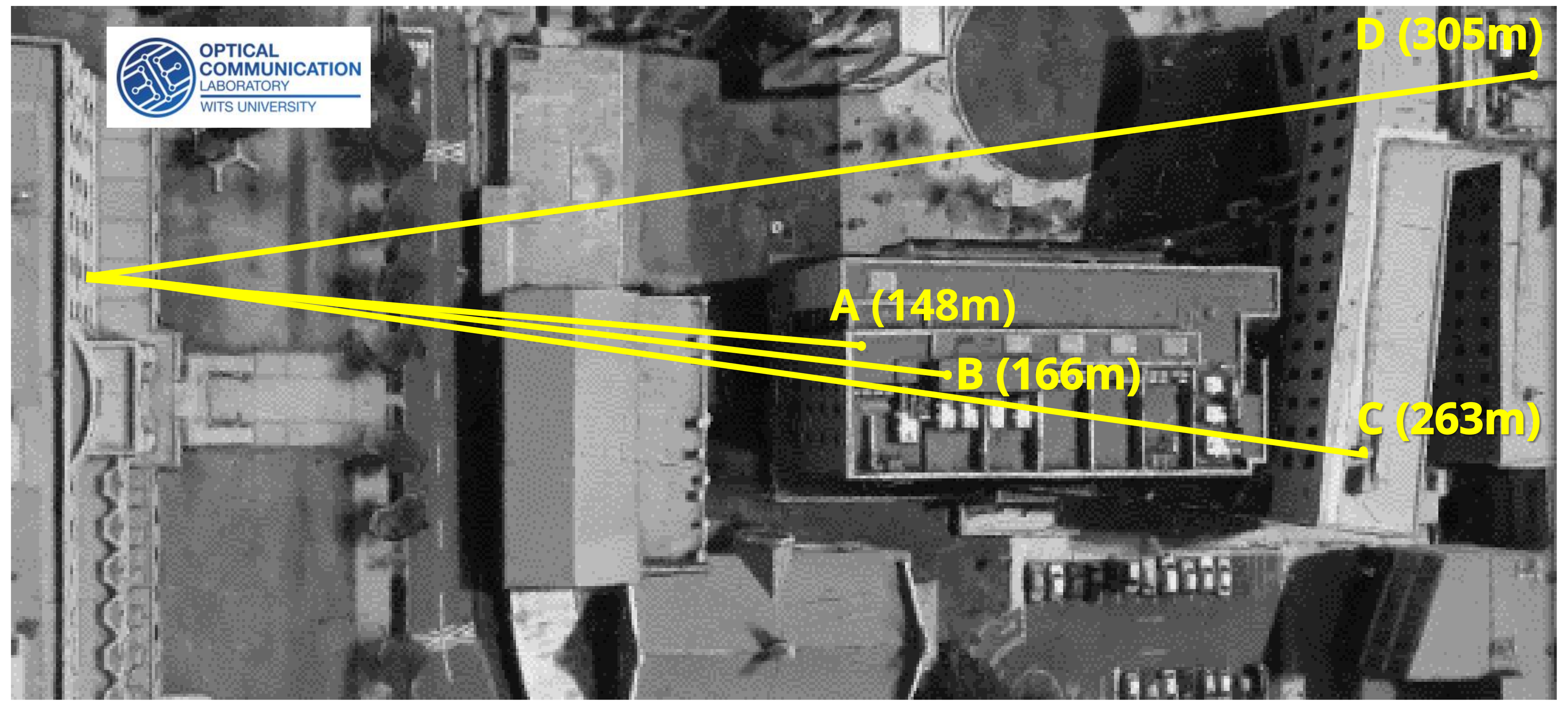
- Available lenses for magnification
- Size of the receiving aperture due to the divergence of the beam
- Mode sets as aperture sizes may restrict which modes sets can be efficiently used (aperture size should be three times larger than the beam size) [1]
- Maximum mode order of the beam due to the increase in the size and divergence of the beam as the mode order increases

The Optical Link and the Remote-Controlled Mirror

We send the beam across an optical link through real atmospheric turbulence. A remote-controlled mirror placed at any four distances away from the lab is used to direct the beam back to the lab.



The remote-controlled mirror which can be used to direct the beam back to the lab and the electronics required to control the motor



The four possible placements of the mirror each with different distances and, therefore, turbulence strengths

The Receiver

We decrease the size of the beam and perform modal decomposition at the receiver to determine the mode crosstalk. The strength of the turbulence is measured using the Scintillation index by sending a Gaussian beam through the system and using the following equation (the higher the value the stronger the turbulence) [2]:

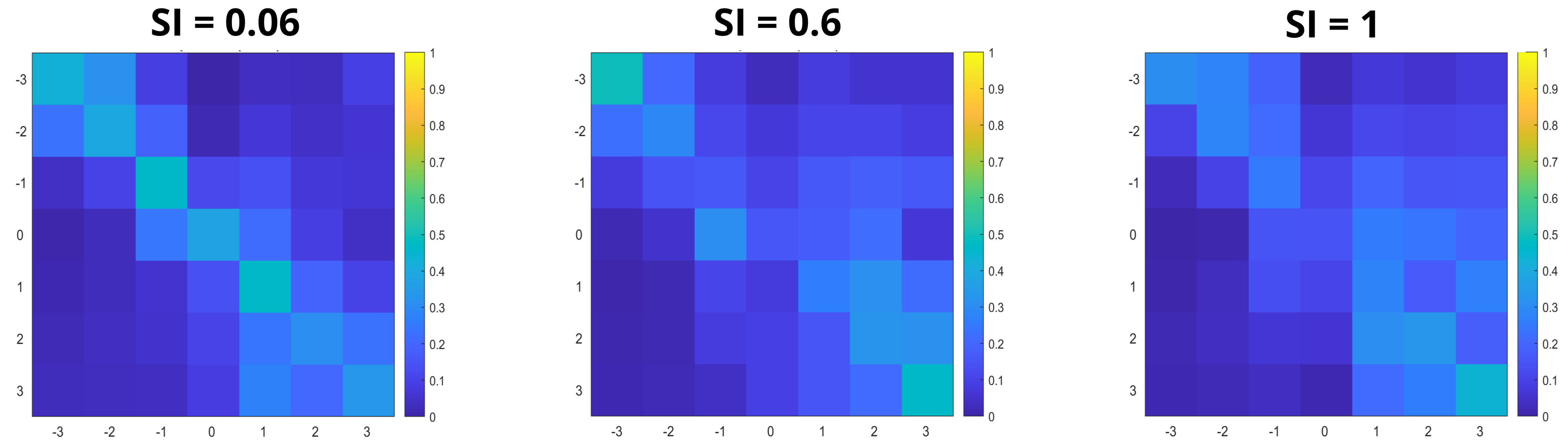
$$\sigma_I^2 = \frac{\langle I^2(0)\rangle - \langle I(0)\rangle^2}{\langle I(0)\rangle^2}$$

← **Average on axis intensity**

OAM Modal Crosstalk Testing

We generated crosstalk matrices at different turbulence strengths using OAM modes with $l = -3$ to $l = 3$. These are shown below.

The crosstalk seems severe for lower scintillation indices even though the turbulence is supposed to be low. Due to this we believe that the setup needs to be optimised further. Through optimisation of the setup, we hope to create a facility that others can use.



References

[1] S. Restuccia, D. Giovannini, G. Gibson, and M. Padgett, "Comparing the information capacity of Laguerre-Gaussian and Hermite-Gaussian modal sets in a finite-aperture system," Opt. Express, vol. 24, no. 24, pp. 27127–27136, Nov. 2016.

[2] Cox, M., Mphuthi, N., Nape, I., Mashaba, N., Cheng, L. and Forbes, A., 2021. Structured Light in Turbulence. *IEEE Journal of Selected Topics in Quantum Electronics*, 27(2), pp.1-21.