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Coherent Free-Space Optical Communications with Concurrent Turbulence Characterization in a Terrestrial Urban Link

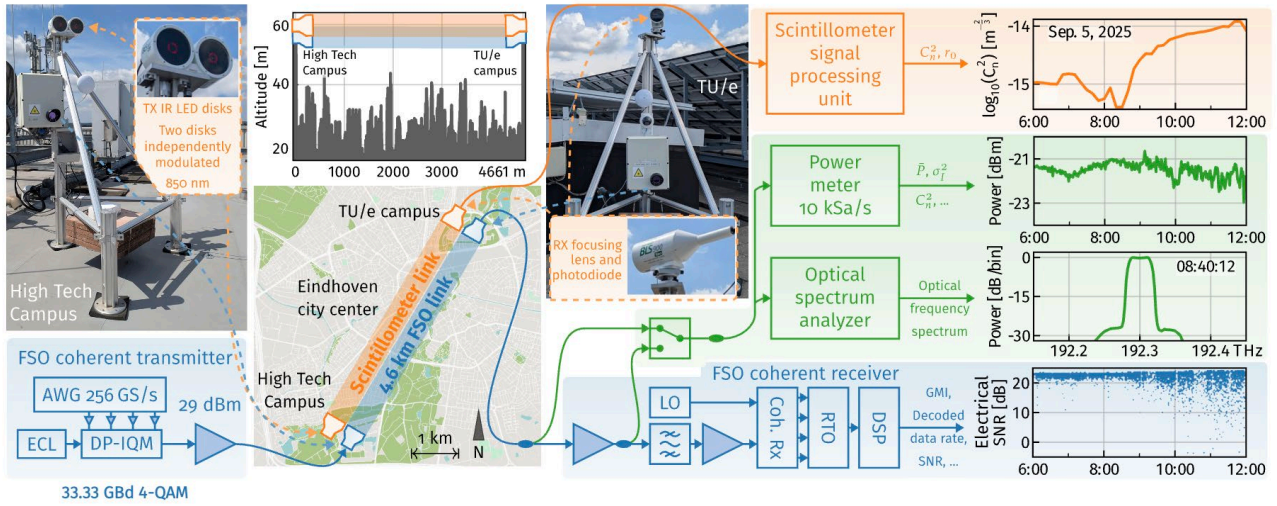
Free-space optical (FSO) communication can deliver optical-fibre-like capacity over urban links without the cost and disruption of cable deployment. In the terrestrial atmosphere, however, temperature gradients and wind shear generate optical turbulence where pockets of air with randomly varying refractive index distort the propagating wavefront and limit link availability. Quantifying this turbulence is therefore essential to the design of reliable urban FSO systems [4].

We report the joint characterization of optical turbulence and coherent transmission performance over a 4.6 km urban free-space optical channel in Eindhoven, the Netherlands. The link, part of the Reid Photonloop testbed [1], connects the TU/e Flux building to Building 37 on the High Tech Campus using Aircision Blackbird optical antennas with automatic pointing and tracking, fibre coupling, and bi-directional operation. A fibre-coupled coherent system transmitting 33.33 GBd 4-QAM carries the data [2], while a co-located scintillometer concurrently characterizes the atmosphere, retrieving the refractive-index structure parameter C_n^2 and the Fried parameter r_0 with 10-minute averaging.

Continuous measurements reveal a clear daily trend in turbulence strength and show that scintillometer-indicated turbulence coincides with the deep fades and outages observed on the communication link [3]. The resulting statistics relate atmospheric conditions to the achievable code rates, demonstrating that optical turbulence induces substantial variability in link performance and that optimal operation requires adaptive link management. This growing dataset of urban optical turbulence will support the validation and further development of theoretical urban FSO channel models and guide future availability-focused FSO system design.

References

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- [2] V. van Vliet, M. van den Hout, K. Gümüş, E. Tangdiongga, and C. Okonkwo, "5.7 Tb/s Transmission Over a 4.6 km Field-Deployed Free-Space Optical Link in Urban Environment," *Optical Fiber Communication Conf. (OFC) 2025*, paper M2J.7.
- [3] V. van Vliet, M. van den Hout, K. Gümüş, E. Tangdiongga, and C. Okonkwo, "Experimental Investigation of Availability in a 4.6 km Terrestrial Urban Coherent Free-Space Optical Communications Link," *European Conf. Optical Communication (ECOC) 2025*.
- [4] V. van Vliet, S. van der Heide, M. van den Hout, and C. Okonkwo, "Turbulence Characterisation for Free-Space Optical Communication Using Off-Axis Digital Holography," *OSA Technical Digest (SPCom) 2022*, paper SpTu3G.1.



Experimental setup between Eindhoven University of Technology and High Tech Campus, Eindhoven, including FSO terminals and newly installed Scintillation index measurement capabilities.