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Quantum Communications along Optical Links with Strong Turbulence

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Abstract content
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The free space propagation of photonic qubits is one of the most intriguing and novel subjects, in which Quantum Physics provides the paradigm for a leap forward in Communications. However, quantum protocols as teleportation, quantum-key-distribution and entanglement swapping along free-space and satellite links are entwined with beam degradation due to turbulence [1–3], seriously hampering the quantum-bit-rates and the immunity from background noise. For instance, in QKD the quantum state that is prepared and sent at the transmitter side experiences a transformation in the spatial spectrum in addition to the vacuum diffraction, that requires strategies to be compensated.

We report in a series of experiments in which the turbulence is probed and the possible countermeasures, including the use of Adaptive Optics, is investigated. The longest link was chosen between the Optical Ground Station (OGS)of the European Space Agency (ESA), in Tenerife and the Jakobus Kapteyn Telescope (JKT) in La Palma, at the The Canary archipelago, separated by about 143 km, both at the altitude of about 2400 m above the Atlantic Ocean. The level of losses is in the range of what expected in the Space-to-ground links, while the effects of turbulence are
supposedly larger.

We have realized the link using a optimized refracting transmitter, whose key component is a singlet aspheric lens of 23 cm diameter with f/10 aperture [4]. The choice of the lens aims to minimize the spot size at OGS compared to the telescope primary mirror according to our observations and consequently a greater power transfer between the two sites. A near infrared (808 nm) laser coupled into single mode fiber and suitably attenuated was used as source. The receiver at OGS uses a telescope with 1m primary mirror diameter equipped with single photon detector and suitable electronics.

We analyzed the overall losses of the free-space channel and temporal scintillation of the intensity at the receiver as a function of the atmospheric conditions. The intensity has been collected during many nights. From its analysis we infer that for this scale length the distribution follows the lognormal distribution [4], extending by more than a decade the observations of Ref. [5]. The scintillation index and the possible use of Adaptive Optics are discussed.

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