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Adaptive Optics for Quantum Key Distribution between an Earth station and a Satellite

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Global-scale distances for Quantum Key Distribution (QKD) can be achieved by utilizing an orbiting satellite acting as an intermediate node between two or more ground stations as has been recently demonstrated with the Chinese satellite Micius and there are further missions to follow from various countries including Canada (QEYSSat). Each of these missions have different methods to implement QKD, but the desired effect of global distances is the same. With QKD states encoded in photon polarization, the total number of photons collected (or equivalently, the total received optical power) is the limiting factor to the secure key generation rate. In this study we analyze an optical uplink, and how atmospheric turbulence affects the signal strength. Atmospheric turbulence mixes air of different temperatures and, hence, possessing different refractive indices along the beam path, inducing phase errors in the propagating beam. These phase errors have negligible impact on the beam in the near field, but their evolution creates temporal intensity fluctuations (scintillation), beam wander, and beam broadening along the path to the satellite which all negatively affect the secure key generation rate. Here we investigate the use of adaptive optics to mitigate the effects of the atmosphere on the collected power of an uplink to a satellite-based receiver for QKD. We model four representative scenarios of atmospheric conditions using the Hufnagel-Valley generalized turbulence model which relate to prospective ground station location turbulence strengths, and determine the impact of using an adaptive optics on the successful key generation rate. We also model low-Earth-orbit vs. geostationary orbits as well as laser guide stars to determine if they can further improve the total secure key generation rate.

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