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Quantum light in atmospheric turbulence

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Quantum communication is a rapidly developing field focused on enhancing the security of communication protocols and new methods of information exchange. These techniques use quantum light propagating through glass fibers or free space as the information carrier. While the free-space channels are useful in many practical scenarios, they face challenging problems due to fluctuations in the refractive index caused by atmospheric turbulence.

We have tailored a numerical method from classical optics to study the effect of atmospheric turbulence on the quantum states of light [1]. This method employs the phase screen approach with the sparse spectrum model to simulate the complex propagation dynamics. Our method enabled us to validate existing analytical models of atmospheric quantum channels and to highlight limitations in the standard interpretation of their applicability. In particular, we showed that turbulence strength alone is not sufficient to determine model applicability, such that receiver aperture size must also be considered as a primary factor. In addition, we proposed a new heuristic analytical model based on the Beta distribution. This model showed better agreement with numerical simulations in almost the entire range of channel parameters. We also studied the time correlations [2], which provided insight into the preservation of continuous and discrete variable entanglement between two pulses in turbulent conditions, and estimated the possibility of preserving nonclassicality of quantum states with the method of adaptive selections.

[1] M. Klen and A. A. Semenov, PRA 108, 033718 (2023).

[2] M. Klen, D. Vasylyev, W. Vogel, A. A. Semenov, PRA 109, 033712 (2024).

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