# Phase compensation for free-space continuous-variable quantum key distribution

**Shiyu Wang, Peng Huang*, Miaomiao Liu, Tao Wang, Ping Wang, and Guihua Zeng**

*State Key Laboratory of Advanced Optical Communication Systems and Networks, Center of Quantum Sensing and Information Processing, Shanghai Jiao Tong University, Shanghai 200240, China*

## Motivation

Linear relationship between transmitted and received signals should be recovered, therefore phase compensation is required. This becomes challenging in the presence of **channel fading**.

## Compensation scheme

The **Gaussian-modulated** quantum signal and the local oscillator (LO) are **co-transmitted**. The **correlation** between the transmitted signal $X_A$ and the received signal $X_B$ can be given by

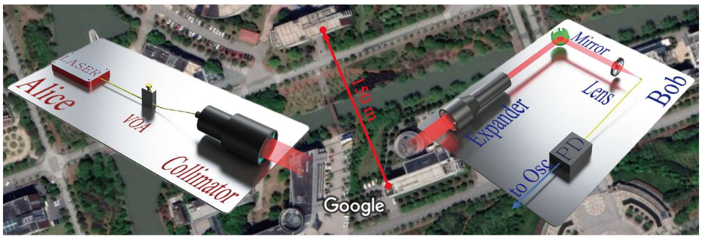
$$\langle X_A X_B \rangle = \sqrt{\eta}\langle\sqrt{T}\rangle V_A \cos(\Delta\theta - \Delta\varphi),$$

where $\eta$ is the detection efficiency, $T$ is the channel transmittance, $V_A$ is the modulation variance, $\Delta\theta$ is the phase drift (due to free-space transmission), and $\Delta\varphi$ is the phase shift that introduced to Alice's data.

Interestingly, the **fluctuating characteristic of $T$ vanishes** in this equation. Therefore, Alice can scan $\Delta\varphi$ and obtain the estimated value of $\Delta\theta$, $\widetilde{\Delta\theta}$ when $\langle X_A X_B \rangle$ reaches its maximum.

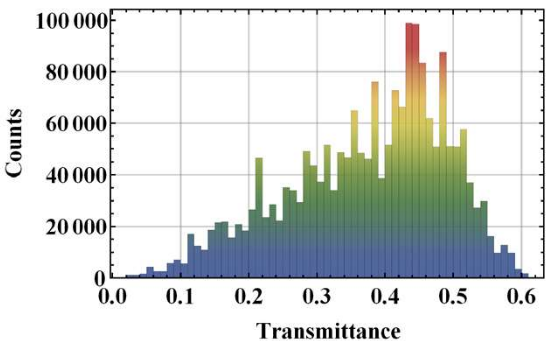
## Demonstration

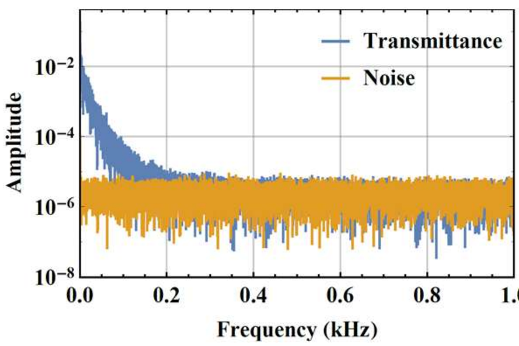
A 150-m free-space fading channel is established on the Minhang campus of Shanghai Jiao Tong University in an urban environment.




Imagery ©2019 CNES / Airbus, Maxar Technologies, Map data ©2019

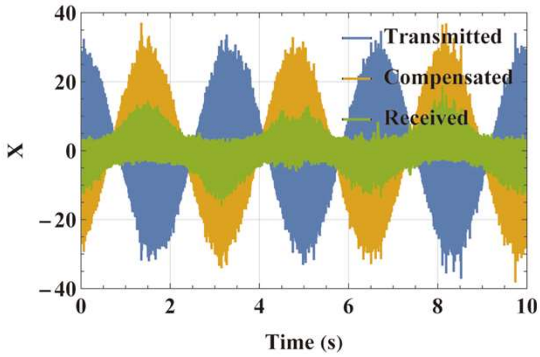
Real fading channel transmittance data are acquired by performing direct detection at the receiver. The transmittance distribution and spectrum are shown below.



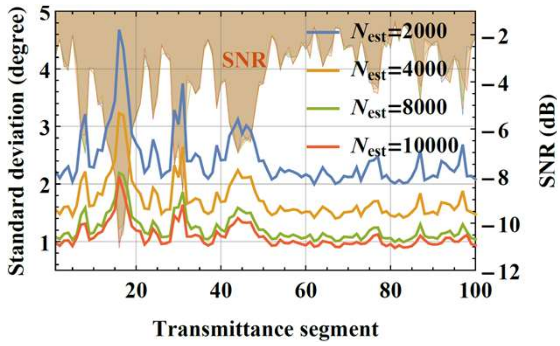

* huang.peng@sjtu.edu.cn

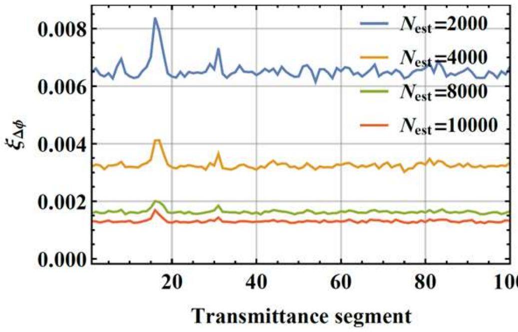
It is obvious that low-frequency components dominate the transmittance spectrum, and the transmittance fluctuation is basically below 0.2 kHz. The phase compensation scheme is simulated according to the transmittance data.




## Performance Analysis

The uncertainty of $\Delta\theta$, i.e., $\Delta\phi = \widetilde{\Delta\theta} - \Delta\theta$ and excess noise caused by the imperfect compensation depend on the signal-to-noise ratio (SNR) and the block size of data used.




The key rate degradation is further estimated.