Correction of quantum phase errors with integrated photonic circuits

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In quantum technologies, management of possible errors is of key importance [1]. For quantum optical systems, the phase errors accumulated by the photons in their propagation channels such as optical fibers or free-space are very common [2]. In this work, we propose a protocol to detect and correct quantum phase errors in a transmission system, where the quantum state is encoded in multiple channels, see Fig. 1. The sender expands the input state to a larger number of channels, which then allows the detection of possible errors at the receiver using specially designed coupled waveguide arrays (CWAs) that can be implemented in integrated photonic circuits. When an unknown multi-photon state with the density matrix of ρ_{in} enters the system from the sender side, the output photon counts distributions ($\mathbf{I} = [I_1, I_2, I_3, I_4]$) are related to the phase errors and also depend on the applied phase shifts at the receiver $[\delta\varphi_i]$.

We demonstrate that by performing measurements using several optimized phase-shifter configurations, with the reduced single-photon density matrix ρ_{in} averaged over the measurement time having the form of a fully mixed state, one can ensure the uniqueness of the output for any unknown phase errors. Then, we train an artificial neural network to efficiently reconstruct the phase errors, which can then be corrected by the phase shifters. We anticipate that the scheme will find applications in quantum communications.

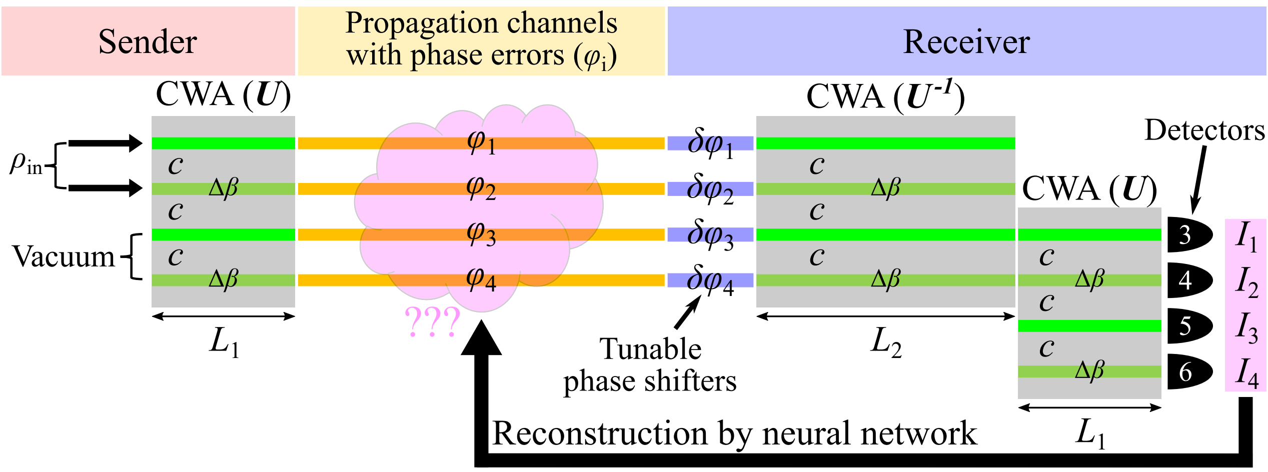

Figure 1: Suggested scheme for the detection and correction of quantum phase errors in propagation channels using specially designed coupled waveguide arrays (CWAs) at the sender and receiver sides. The phase errors are uniquely reconstructured from the photon counts $[I_1, I_2, I_3, I_4]^T$ at several optimized phase-shifter configurations $[\delta\varphi_1, \delta\varphi_2, \delta\varphi_3, \delta\varphi_4]^T$ and then corrected by the same phase shifters.

[1] S. J. Devitt, W. J. Munro, and K. Nemoto, Rep. Prog. Phys. **76**, 076001 (2013).

[2] P. Zhang, K. Aungskunsiri, E. Martin-Lopez, *et al.*, Phys. Rev. Lett. **112**, 130501 (2014).