Harnessing Higher-Order Polarization Mode Dispersion for Enhanced Fidelity in Broadband Quantum Communications

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Polarization mode dispersion (PMD) in optical fibers presents a significant challenge to maintaining the fidelity of quantum states in fiber-based quantum communication systems. This issue is particularly pronounced in broadband entanglement-based quantum key distribution (QKD) due to the stochastic nature of PMD. In this study, we investigate the impact of PMD on broadband entangled photons by examining the wavelength-dependent rotation of polarization states on the Poincaré sphere. We derive and experimentally validate a straightforward formula that connects the measurement error probability with the differential group delay (DGD) over a finite signal bandwidth. Our recent findings suggest that higher-order PMD can, under specific conditions, mitigate the deleterious effects of first-order PMD by averaging out polarization distortions across the spectrum. This result opens new avenues for passive PMD mitigation strategies in deployed fiber networks, potentially enhancing the robustness and reliability of practical QKD systems.

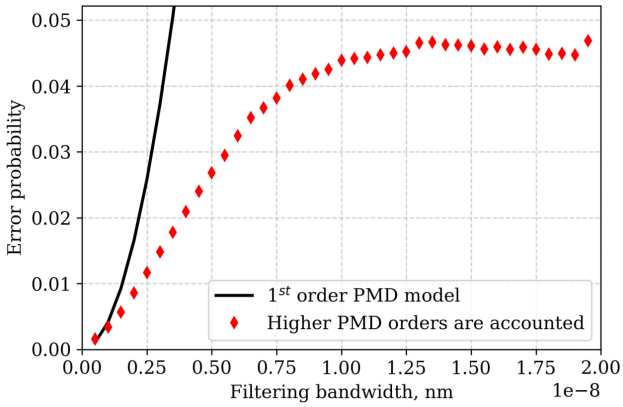

Figure 1: Probability of quantum measurement error (infidelity) as a function of filtering bandwidth for a broadband biphoton spectrum centered at 1310 nm. The curves correspond to two models: the parabolic behavior predicted by first-order PMD (solid line) and a saturating trend observed when higher-order PMD is included (dots). Experimental data for the modeling were obtained using a 50 km deployed fiber channel