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Decoherence-assisted quantum key distribution

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In the development of quantum technologies, the interaction between a quantum system and its environment, that leads to decoherence, is traditionally viewed as a fundamental obstacle. In Quantum Key Distribution (QKD) protocols like BB84, environmental noise inevitably degrades state purity, increases the Quantum Bit Error Rate (QBER), and ultimately compromises the security of the communication channel.

In this talk, we challenge this standard paradigm by presenting a theoretical and experimental study of a controllable decoherence-assisted QKD scheme [1]. Rather than attempting to isolate the quantum system from environmental noise, we demonstrate how decoherence can be actively harnessed as a tool to enhance security against specific eavesdropping strategies, such as the entangling probe attack.

We will discuss our method of introducing tunable decoherence to polarization qubits by coupling them to the spatial degree of freedom of light. By treating the transverse
momentum of the light as a controllable environment, the sender and receiver (Alice and Bob) can dynamically coordinate and vary the induced dephasing during transmission. When incorporated into a modified key reconciliation stage, this shared, controlled decoherence effectively limits the amount of information an eavesdropper
can extract.

Finally, we will share the results of our experimental implementation, demonstrating that Alice and Bob can cancel out the dephasing effects to recover a low QBER of approximately 7.38%. Ultimately, this work adds to the effort of a different perspective on open quantum systems: proving that system-environment interactions can be strategically managed to our advantage rather than merely mitigated.

[1] Sci. Rep. 15, 31258 (2025).

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