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Self-Referenced Continuous-Variable Quantum Key Distribution

Sandia National Laboratories

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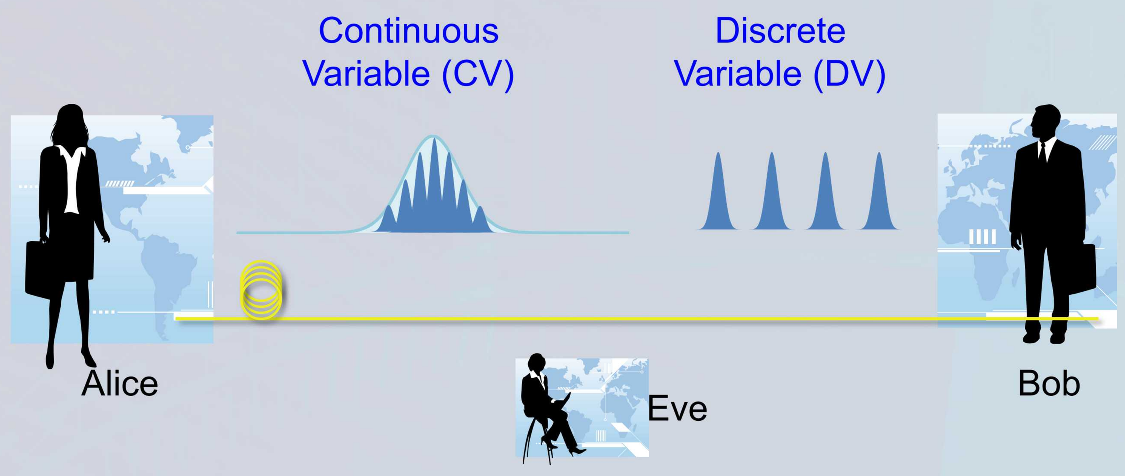
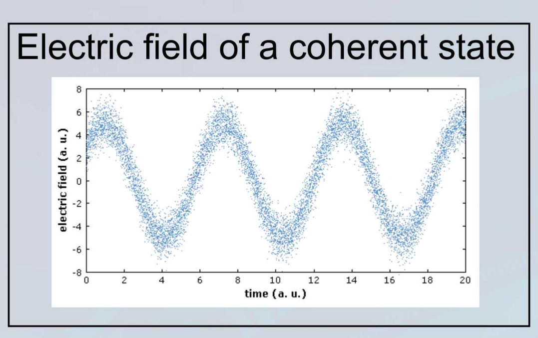
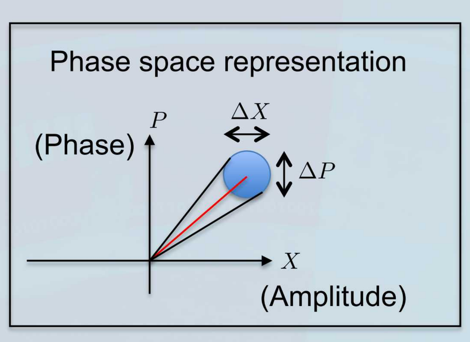
Problem

- This work is a part of the SECANT-QKD Grand Challenge LDRD project.
- Quantum key distribution (QKD) aims to distribute secret keys (one-time pads) that can be utilized for unconditionally secure communication.
- The main goal of the project is to put a QKD system on a photonic chip.
- Two approaches to QKD: CV and DV:



- CV-QKD approach is based on measuring two conjugate quantum observables: amplitude and phase of the optical field:

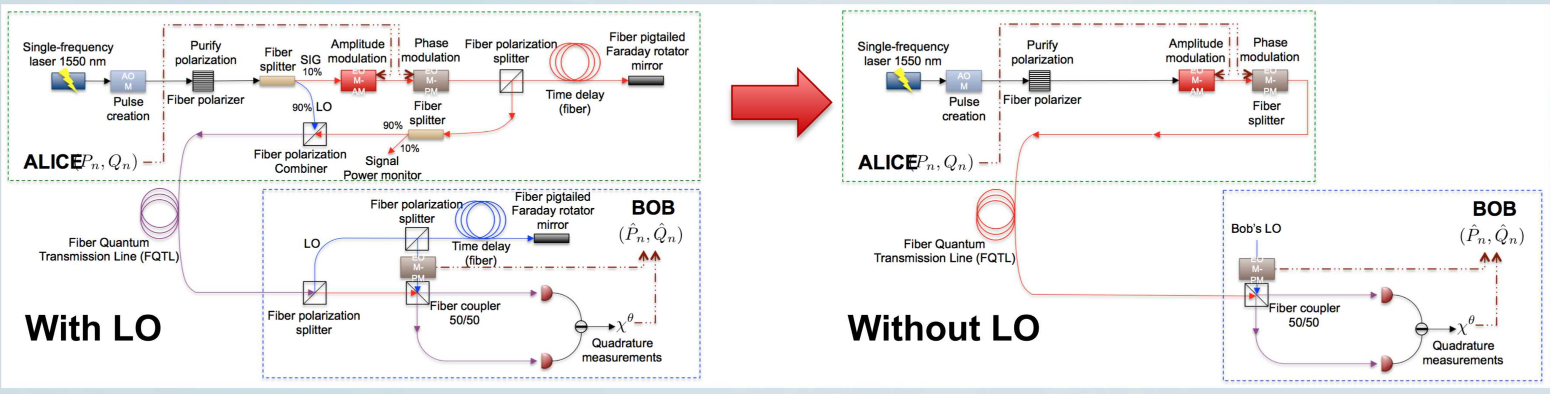




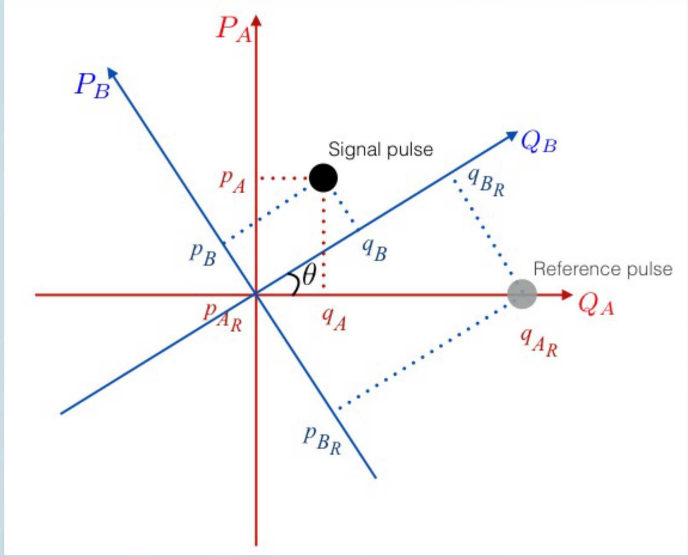
- A major problem of CV-QKD: it requires transmission of a high-intensity coherent pulse, called local oscillator (LO).

Approach

- We have developed a new CV-QKD protocol that eliminates the transmission of an LO.
- Instead of transmitting an LO, Alice sends regularly spaced reference pulses whose quadratures are measured by Bob to estimate Alice's phase reference.
- This new protocol, which we call self-referenced CV-QKD (SR-CV-QKD), greatly simplifies the hardware requirements at Alice's and Bob's since it enables them both to employ independent (truly local) LOs.



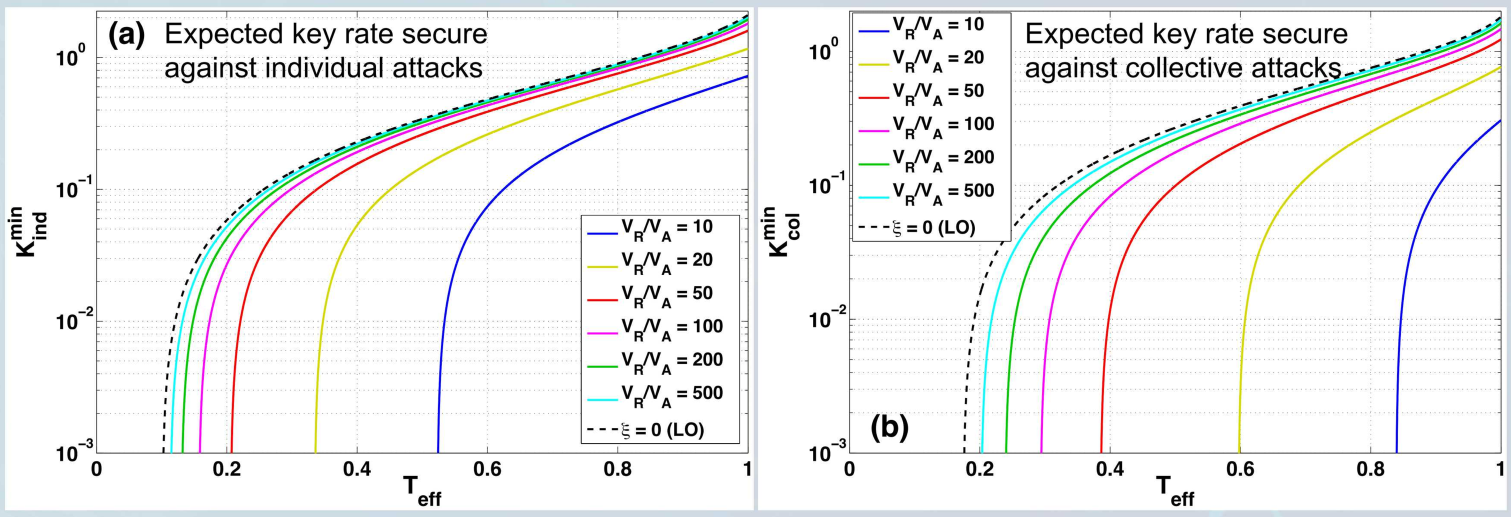
- In a physical implementation of the SR-CV-QKD protocol, Alice chooses two independent Gaussian random variables (q_A, p_A), both normally distributed with zero mean and a fixed variance V_A, and sends Bob a coherent-state signal pulse with amplitude $q_A + i\,p_A$.
- She also sends a coherent-state reference pulse with publicly known fixed amplitude $V_R^{1/2}$, which is much smaller than that of a typical LO.



- In each round, Bob performs homodyne measurement of one of the quadratures of the received signal pulse.
- He also performs heterodyne measurement of both quadratures of the received reference pulse.
- The key operation is the estimation of the phase difference θ between Alice's and Bob's frames.

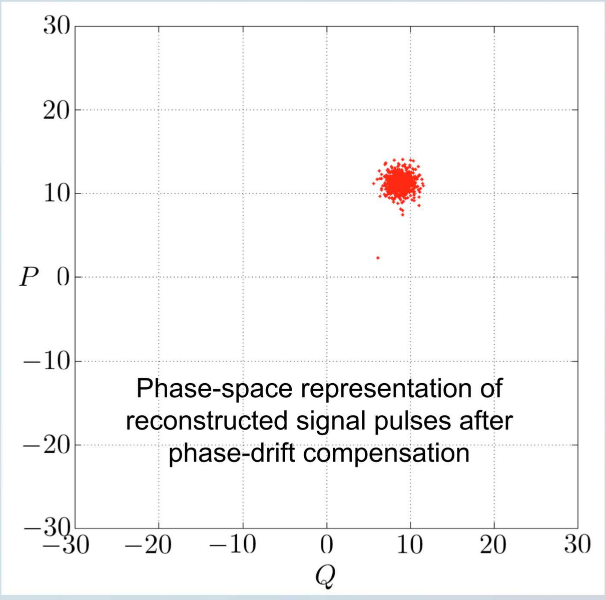
Results

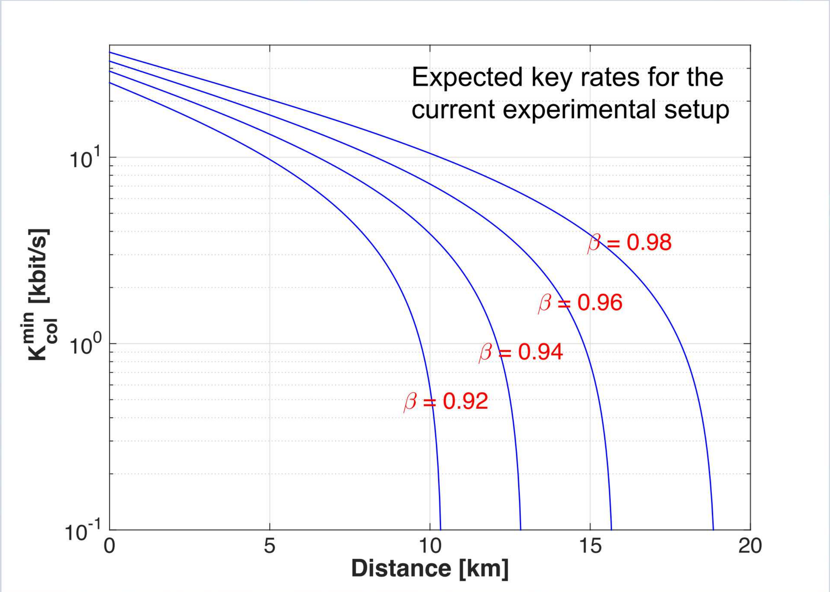
- Our theoretical analysis focused on obtaining expected asymptotic key rates, secure against individual and collective attacks.
- A principal feature of our security analysis is the incorporation of the inherent quantum uncertainty of reference pulses.



- Our experimental work focused on:

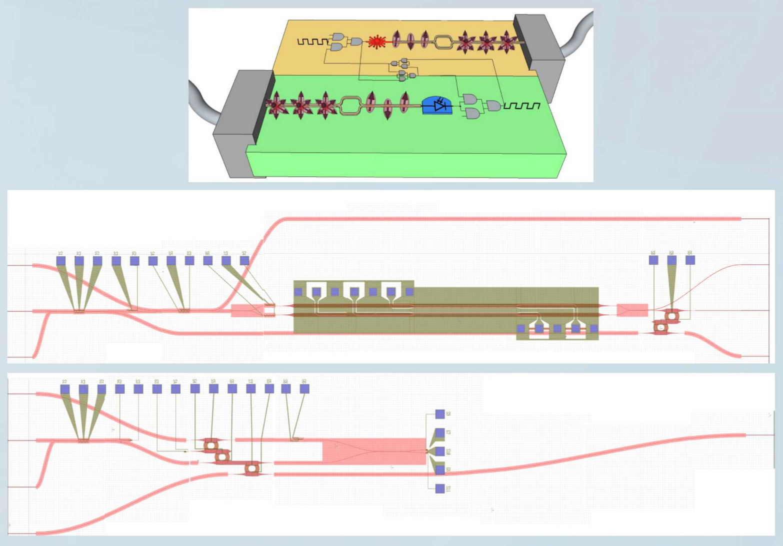
1. Characterizing the performance of the central element of SR-CV-QKD – signal reconstruction through compensation of the drifting phase;
2. Performing a proof-of-principle demonstration of key distribution using the new protocol.





Significance

- SR-CV-QKD obviates a key assumption of most CV-QKD security proofs – namely that the LO is trusted – and thus provides a more secure implementation of CV-QKD.
- SR-CV-QKD is manifestly compatible with chip-scale implementation since it only requires classical optical communication components. This enables miniaturization of CV-QKD hardware:



Transmitter design

Receiver design

- Our results [1], along with demonstrations by other groups [2, 3], establish SR-CV-QKD as a practical protocol with significant benefits in terms of hardware simplification and compatibility with integrated photonics.

References

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