UNIVERSITÀ DEGLI STUDI FIRENZE

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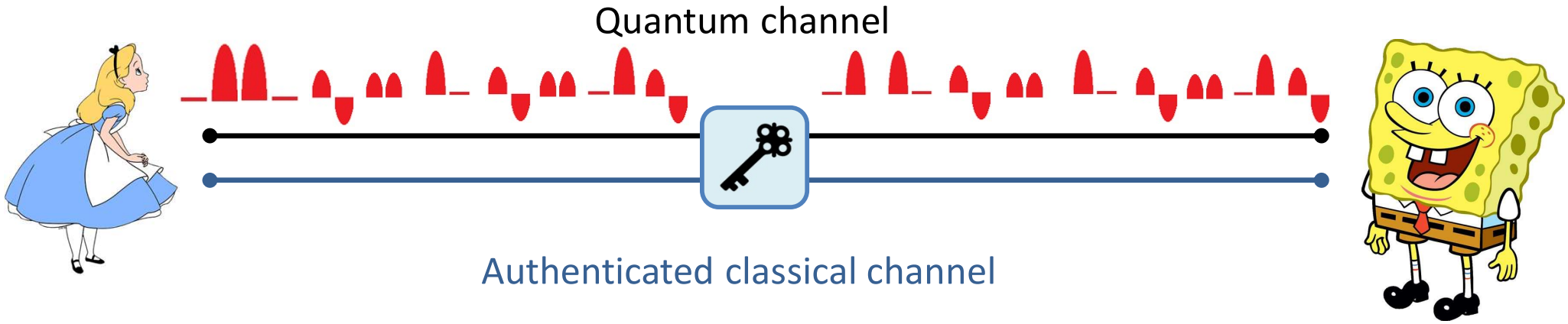
Decoy-state quantum key distribution over long-distance optical fiber

Giulia Guarda

Quantum Key Distribution

The BB84 protocol



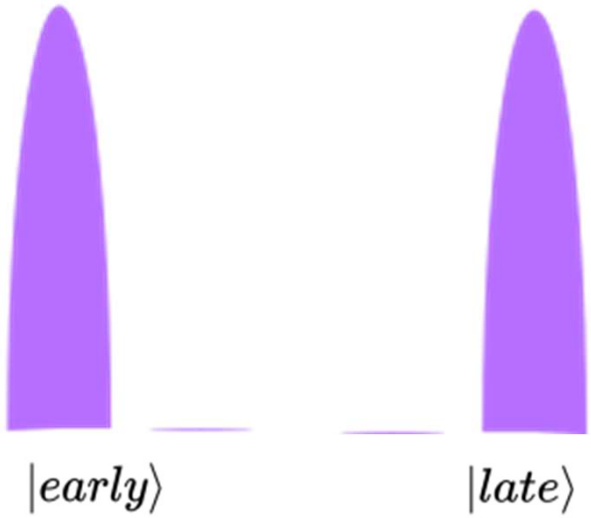
- Disturbance introduced by eavesdropper
- Unconditionally secure key

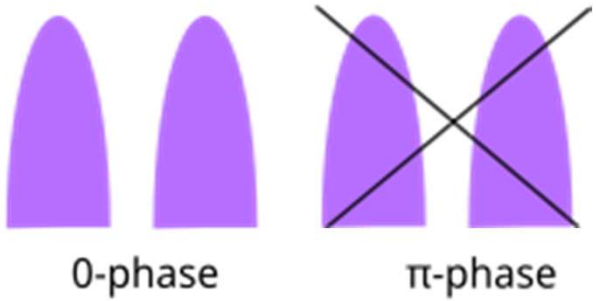
Motivation

- Long distance links using low-loss optical fibers
- Main limitation: photon absorption
- Solutions: protocols, higher rates, **better detection systems**
- State-of-the-art: 421km at 2.5GHz rep. rate

Boaron, Alberto, et al. "Secure quantum key distribution over 421 km of optical fiber." *Physical review letters* (2018)

Efficient three-states time-bin encoding





Z-basis: arrival time

X-basis: relative phase

Rusca, Davide, et al. "Security proof for a simplified Bennett-Brassard 1984 quantum-key-distribution protocol." *Physical Review A* 98.5 (2018)

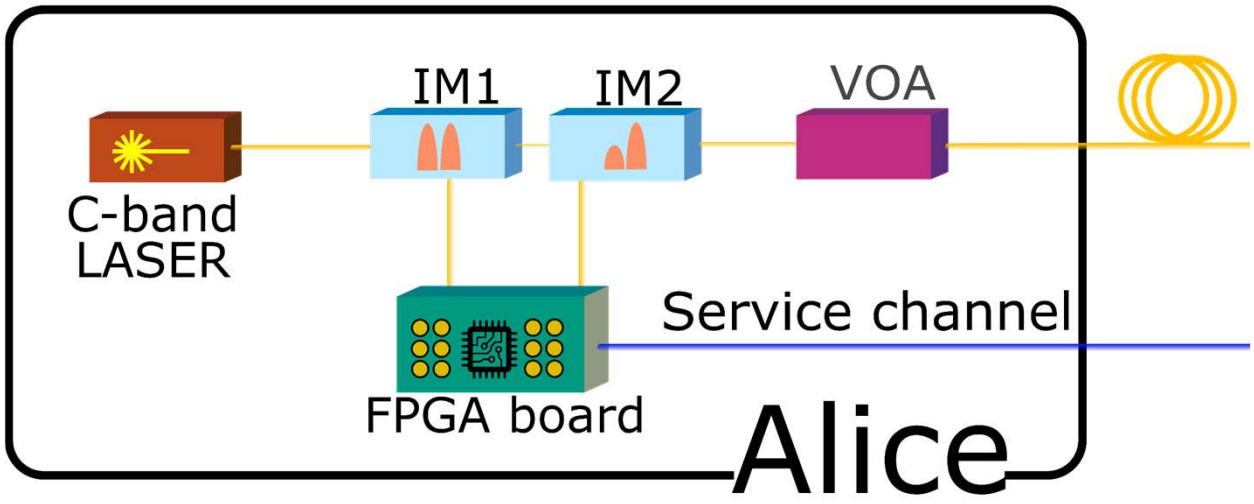
Decoy method

Attenuated laser source -> photon number splitting attack

Experimental realization: three level signal

Pirandola, Stefano, et al. "Advances in quantum cryptography." *Advances in optics and photonics* 12.4 (2020)

Transmitter



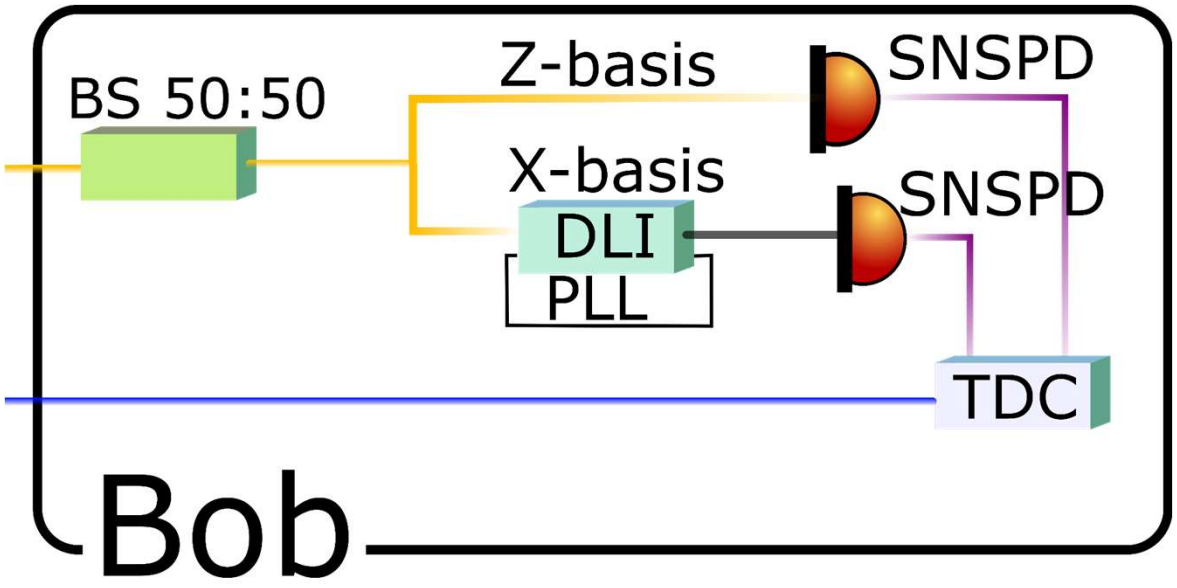
595MHz rep. rate

IM1: laser carving

IM2: decoy states generation

Ribezzo, Domenico, et al. Deploying an Inter-European Quantum Network. *Advanced Quantum Technologies*, 2023.

Receiver



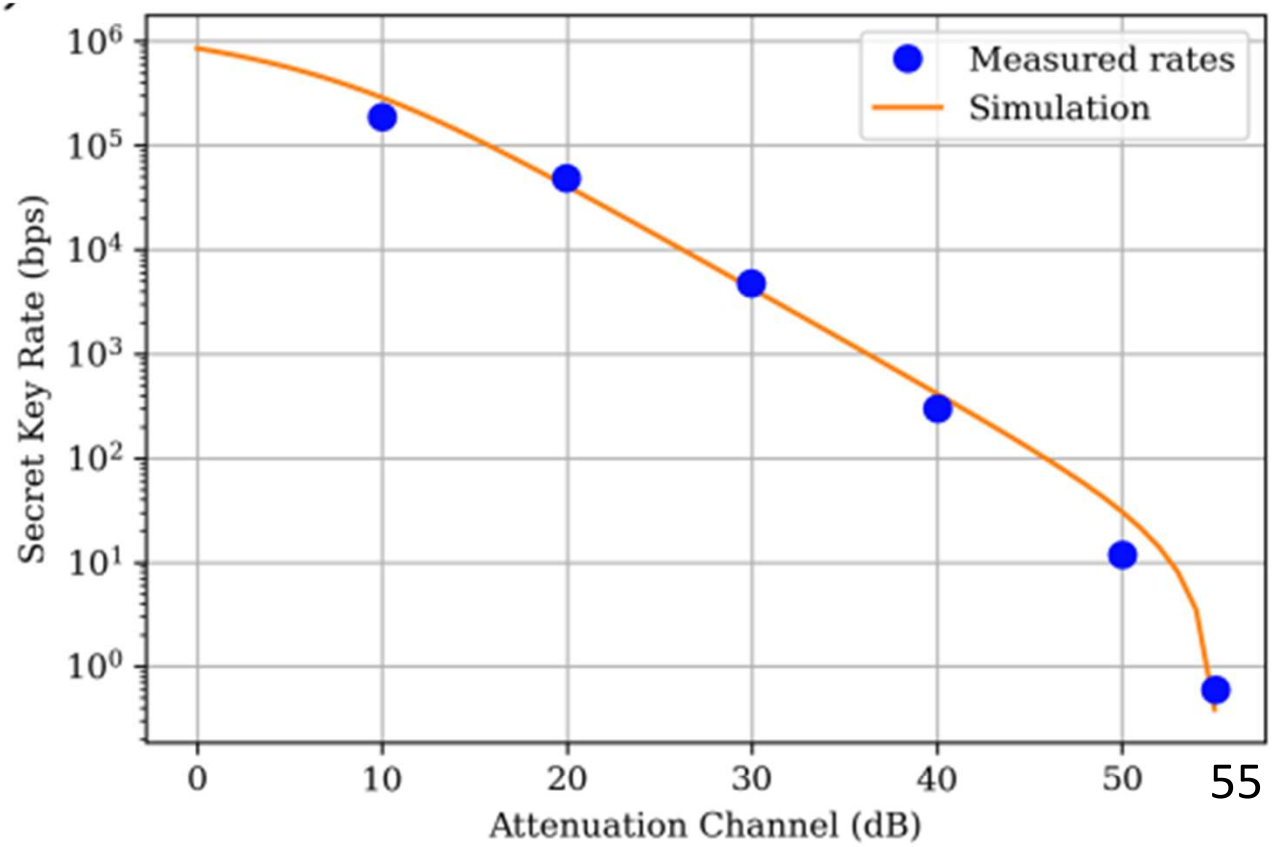
Detection system: high efficiency (≈ 90%) and low dark count rate (< 1 Hz)

DLI: delay line interferometer

PLL: phase locked loop

TDC: time to digit converter

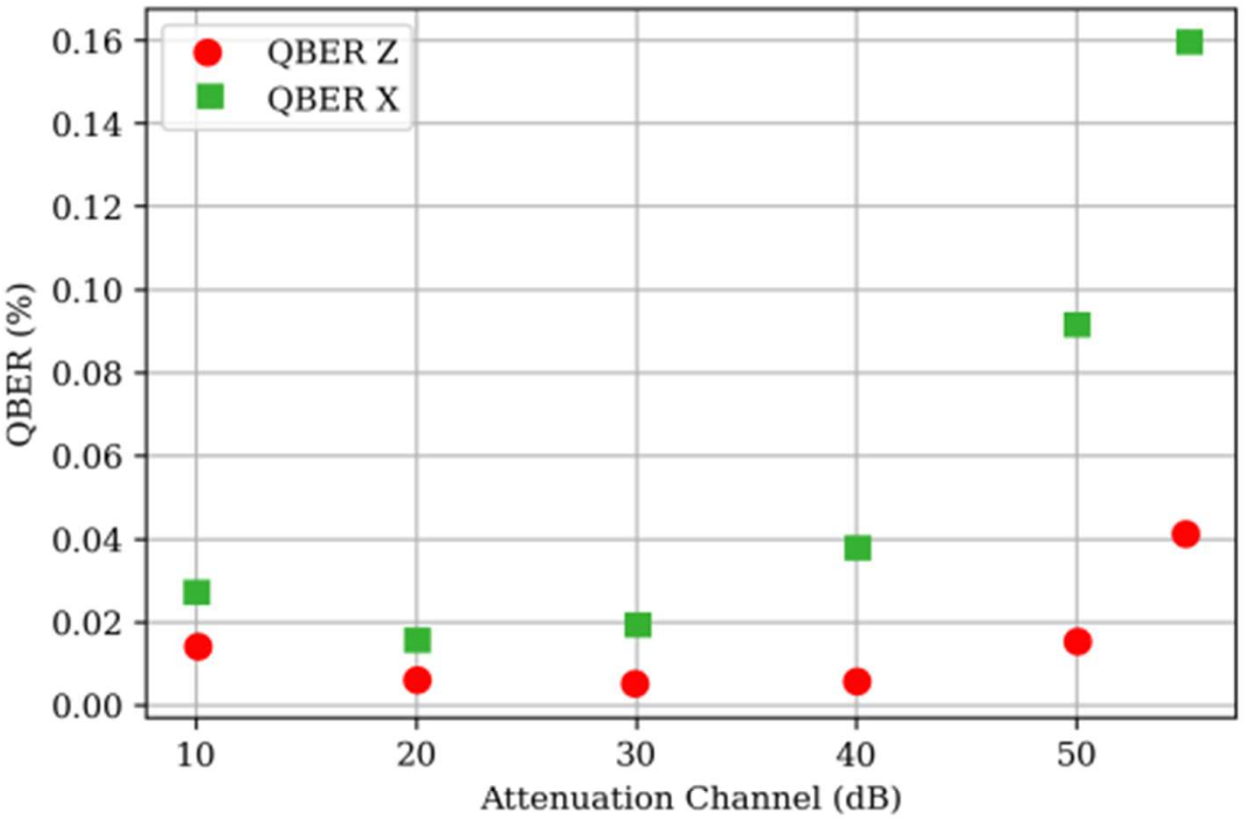
Secure key rate



55 dB = 340 km

10dB: due to ttag instability, the mean photon number has been set lower than the optimal value (from simulations)

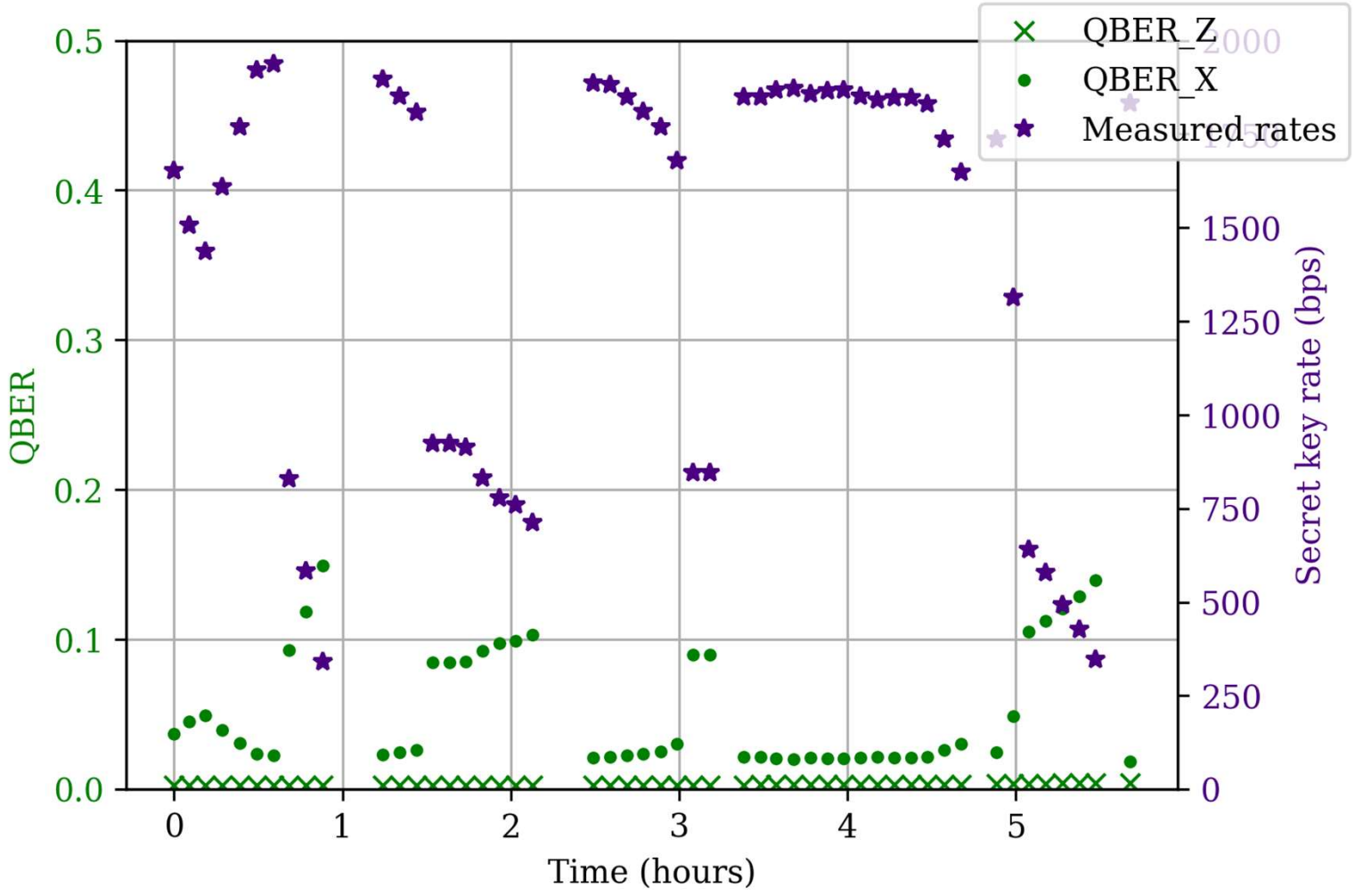
Quantum bit error rate



X basis: more noisy due to the PLL loop

Ttag instability: higher error rate at 10dB

Long acquisition 30 dB



Conclusions

- State-of-the-art SNSPD with **high efficiency (≈ 90%)** and **low dark count rate (< 1 Hz)**
- Enabled QKD for **55dB** channel losses, equivalent to **340km** in ultra low-loss optical fiber
- Future improvements: better interferometer's stability, higher rep. rates

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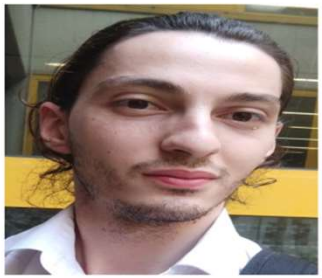
TEAM

Giulia Guarda
LENS, CNR INO

Domenico Ribezzo
CNR INO, Uni Napoli

Daniela Salvoni
Photec



Ciro Bruscino
Uni Napoli

Pasquale Ercolano
Uni Napoli

Mikkel Ejrnaes
CNR

Loredana Parlato
Uni Napoli, CNR

C. Zhang
SIMIT

H. Li
Photec

L. You
Photec

Claudia De Lazzari
QTI

Ilaria Vagniluca
QTI

Tommaso Occhipinti
QTI

Giovanni Piero Pepe
Uni Napoli

Alessandro Zavatta
CNR, QTI

Davide Bacco
Uni Firenze, QTI

Università degli Studi di Napoli Federico II

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