A resource-effective QKD field-trial in Padua with the iPOGNAC encoder

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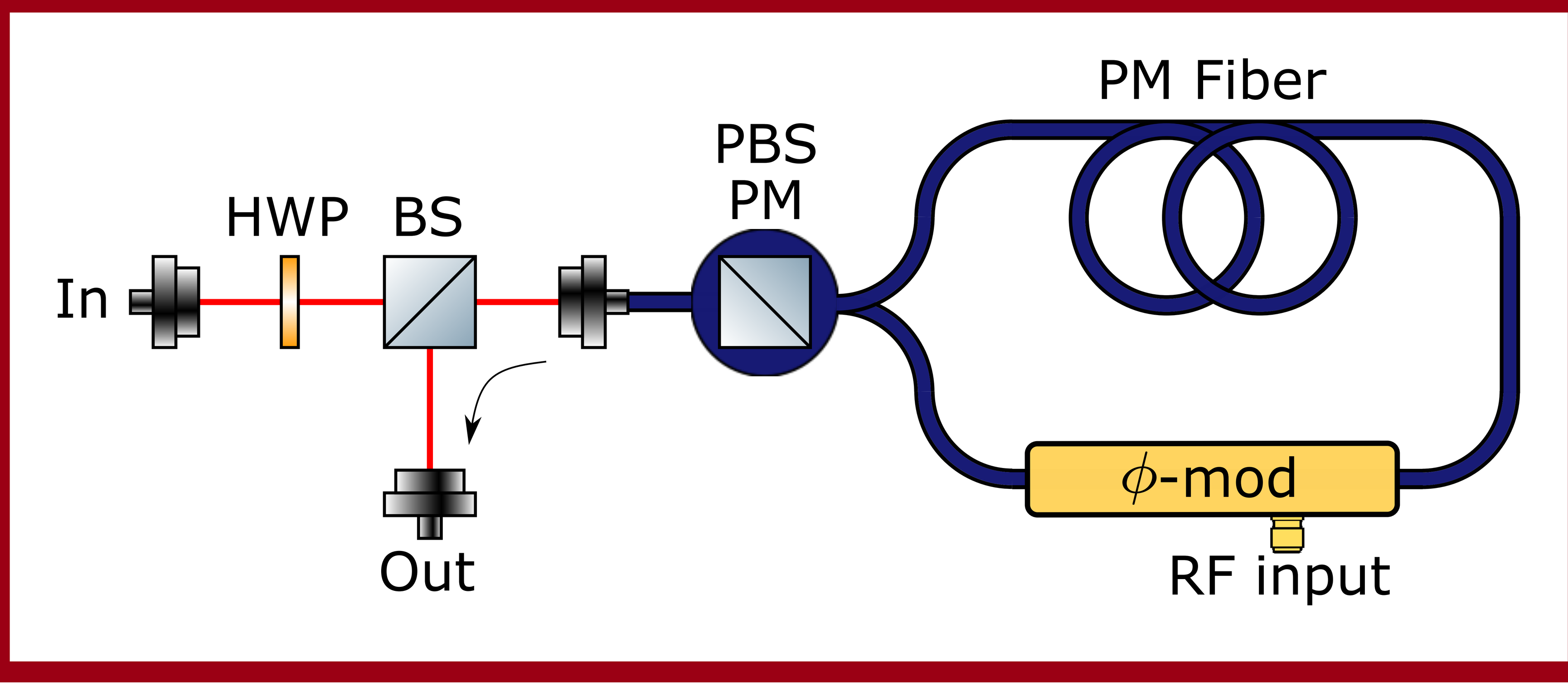
Outline

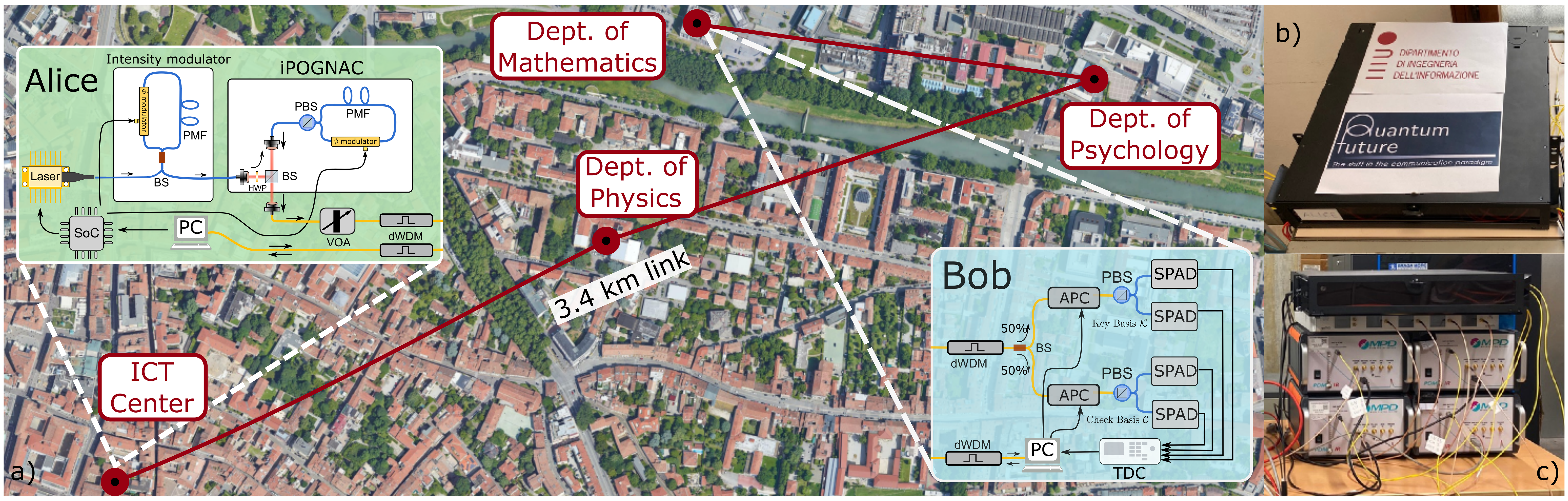
We test a QKD system based on the iPOGNAC encoder on the deployed urban fiber network in Padua. This new encoder guarantees stability and ease of alignment.

The iPOGNAC

- A polarization encoder based on a **Sagnac interferometer** on a **polarization-maintaining** (PM) fiber [1].
- Light enters the fiber in a **balanced** (w.r.t. the axes) polarization state, set by a half-waveplate (HWP) in free-space.
- In the fiber, the two components are separated by a polarization beam splitter (PBS) and travel in opposite directions, both on the slow axis.
- They encounter a **phase modulator** which sets the relative phase.
- They are mixed again at the PBS and directed to the output by a free-space beam splitter (BS).
- PM components guarantee **stability** and offer a **definite polarization reference**.

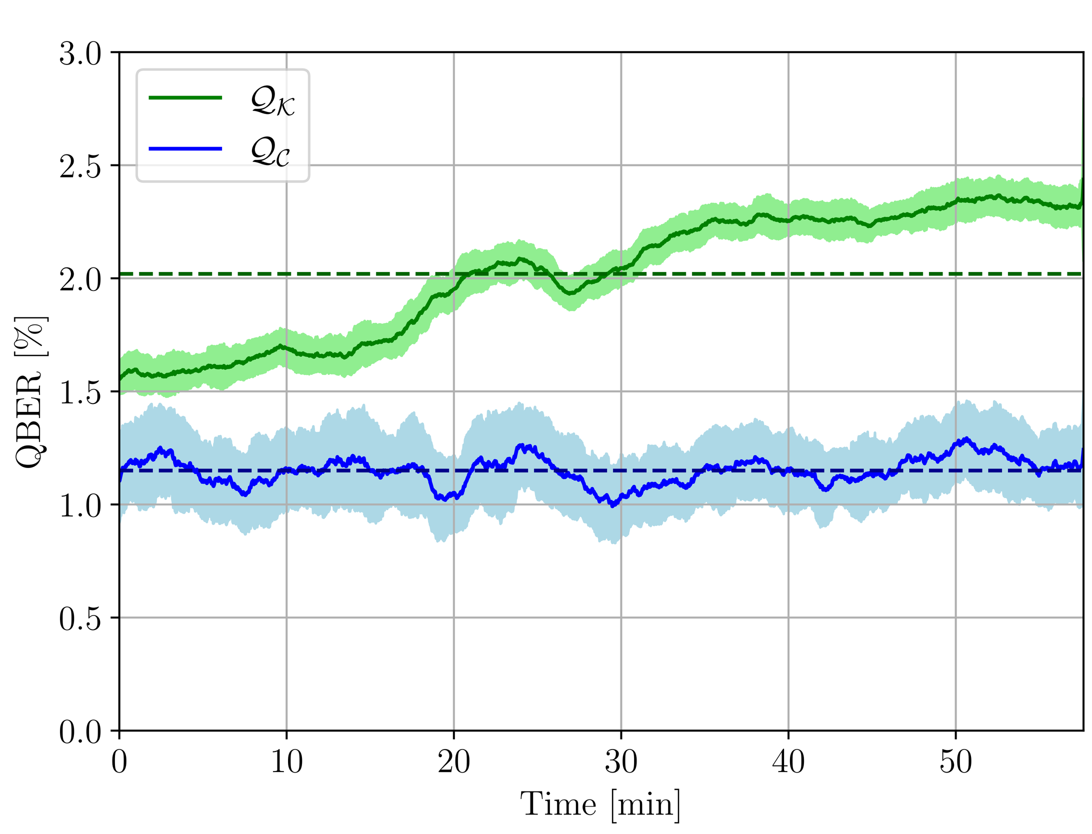


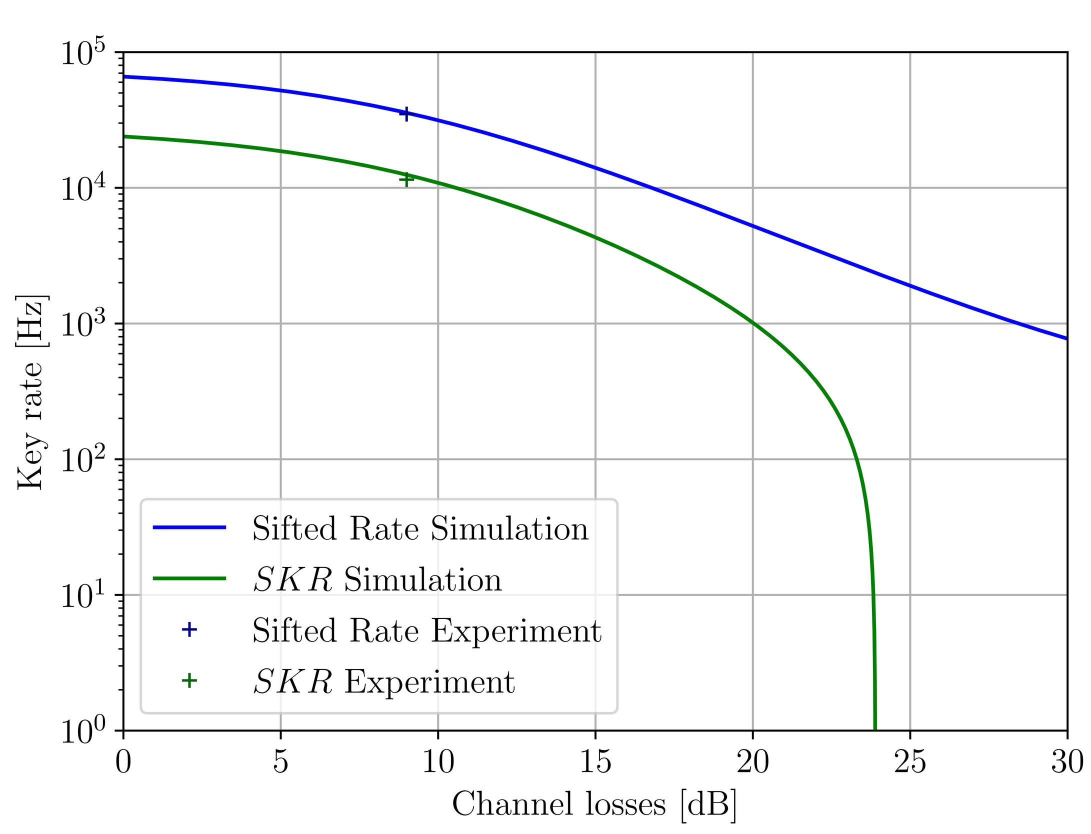
The field trial



This is the first test of the iPOGNAC outside of the laboratory [2]. We implement the **efficient BB84 protocol** with three transmitted states and two intensity levels [3]. The two terminals are connected via **two 3.4 km-long deployed urban fibers**: the qubits travel on one, whereas the other is for the classical post-processing. The transmitter includes a distributed feedback laser source at 1550 nm and 50 MHz of repetition rate, an intensity encoder for the decoy-states method, the iPOGNAC and various attenuation stages. At the receiver, a polarization decoder based on BSs and PBSs sends the qubits, separated in polarization, to four InGaAs single-photon avalanche diodes (SPADs) whose output is temporized by a time-tagger. The alignment of the measurement bases uses a **pre-shared qubit sequence** sent at the beginning of the acquisition, without additional optical signals. The **Qubit4Sync** algorithm synchronizes the two terminals without additional hardware, using only the expected times of arrival of the qubits. All components are **commercial and off-the-shelf** and we could fit the optical sections of both transmitter and receiver into portable 2U rack enclosures.

Results





During a one-hour long QKD run, we accumulated $2.7 \cdot 10^8$ qubits. The average error rates (QBERs) in the key ($\mathcal{K}$) and control ($\mathcal{C}$) bases were 2.0% and 1.1% respectively. We attribute the change in QBER shown on the left to minor temperature variations at the receiver. After the post-processing, we measured a **secret key rate (SKR) of 11.5 kbps**. Using parameters extracted from the experiment, we simulated the performance that the system would have with different channel losses, and concluded that we would obtain a positive SKR with up to **23 dB attenuation**, as shown on the right.

Conclusions

- We deployed our QKD system on the **urban fiber network** in Padua.
- We tested for the first time outside the laboratory the polarization encoder **iPOGNAC**.
- This encoder guarantees stability, ease of installation, and a **fixed polarization reference**.
- Our simple system **does not use additional optical signals** for polarization alignment nor for synchronization.
- We measured a QBER of 2.0% and 1.1% in the two bases and a **SKR of 11.5 kbps**.
- This field trial represents a step towards the **deployment of resource-effective and practical QKD systems** in urban fiber networks.

References

[1] M. Avesani, *et al.*, Opt. Lett. 45, 4706-4709 (2020).
[2] M. Avesani, *et al.*, Opt. Lett. 46, 2848-2851 (2021). (This work).
[3] D. Rusca, *et al.*, Appl. Phys. Lett. 112, 171104 (2018).

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