A simplified receiver for 32 channel wavelength-division multiplexing QKD

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INTRODUCTION

Quantum key distribution (QKD) systems based on time-phase coding typically consist of one delay line interferometer (DLI) on the transmitter side and one DLI-on the receiver side. Simply multiplexing (e.g. by wavelength) *n* quantum channels would require 2*n* DLIs.

The “colorless” interferometric technique [1] reduces the number of DLIs to only one at sender and receiver, respectively. This approach requires to precisely tune the phase of every quantum channel independently.
➔ *n – 1* additional high frequency phase modulators required

We demonstrate a simplified receiver with only one DLI for all quantum channels. By tuning each wavelength, a high visibility for all channels is possible simultaneously without additional high frequency phase modulation.

DESIGN

Our proposed receiver design is shown in Fig. 1. We only use one tunable DLI for all quantum channels.

The sender side uses dense wavelength-division multiplexing (DWDM) to multiplex all wavelengths into one fiber. We omit the DLI to eliminate the need for high-frequency phase modulation. Our experiments are representative for QKD protocols where no DLIs are needed on sender side, e.g. for the coherent one-way protocol [2] or BB84.

Inaccuracies of the free spectral range of the DLI and channel spacing still lead to a wavelength-dependent phase-mismatch, which we compensate by fine-tuning each wavelength.

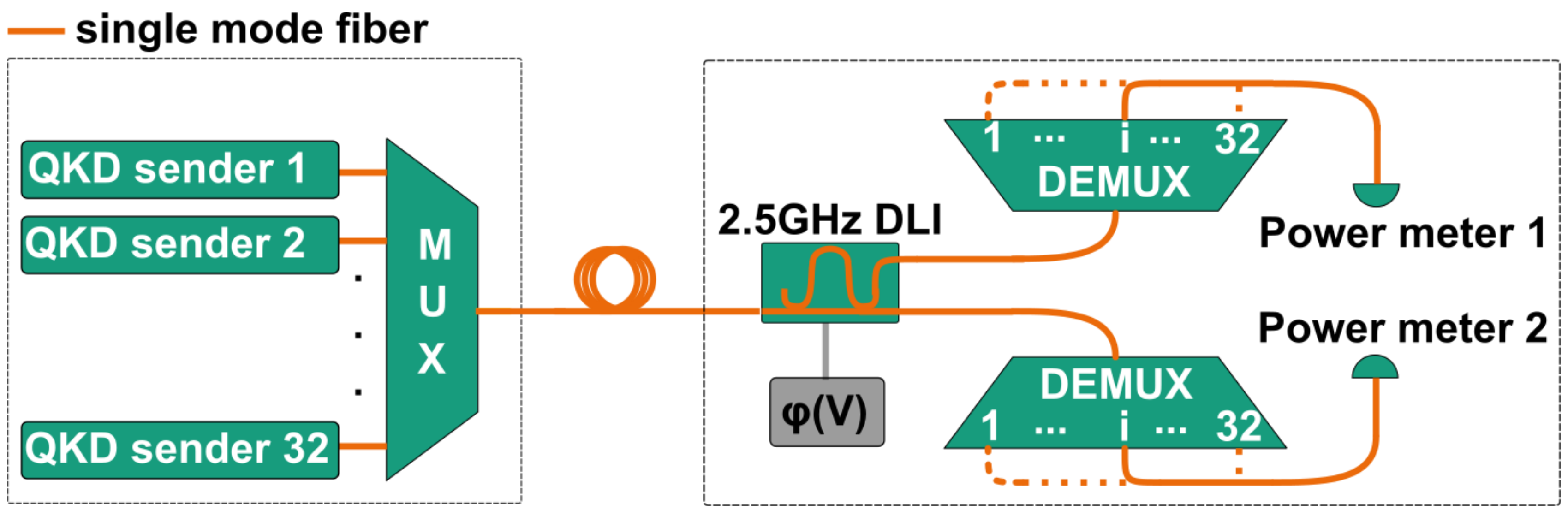

Figure 1: *Simplified multi-channel setup. For our experiments, we substitute each QKD sender with a distributed feedback laser in continuous wave mode. All channels are multiplexed (MUX) into a single-mode fiber. On the receiver side, only one delay line interferometer (DLI) is deployed before demultiplexing (DEMUX).*

EXPERIMENTS

Our QKD senders are represented by 32 commercial off-the-shelf distributed feedback lasers (Thorlabs LS5000 DWDM laser modules) in continuous wave mode on the 100GHz ITU grid.

We connect both output ports of the receiver DLI to a demultiplexer (DEMUX) and measure the power of each wavelength channel using standard power meters as shown in Fig. 1. The resulting visibility for each channel is shown in Fig. 2.

To measure the total visibility, we connect both power meters directly to the DLI output. We reached an initial total visibility of **V_{tot} = 0.995 ± 0.003**. Over time, V_{tot} decreases slowly but stays well above 0.98 for more than three hours as shown in Fig. 3. **We are able to restore the total visibility of V_{tot} = 0.994 ± 0.003 by simply adjusting the interferometer phase φ.**

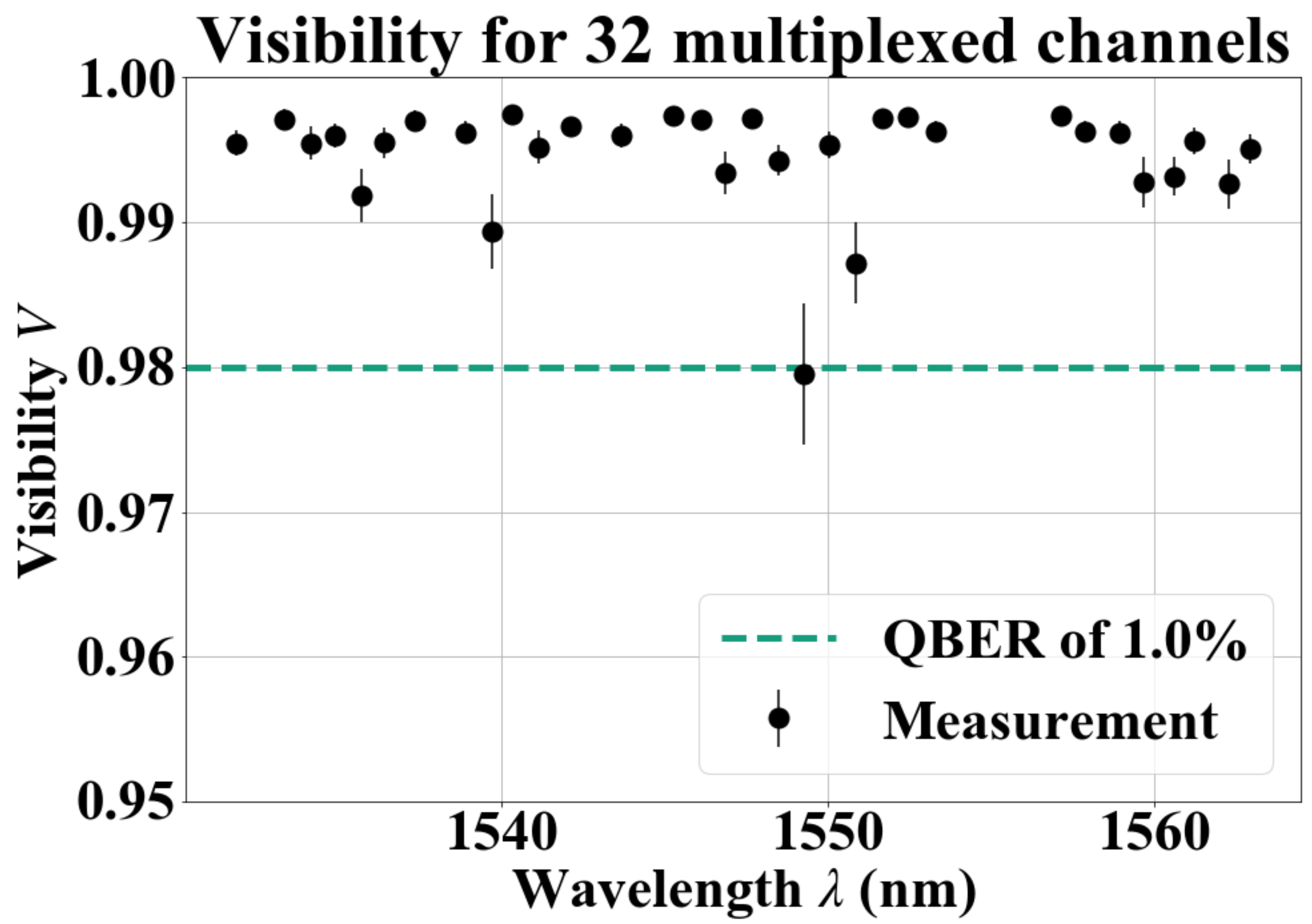

Figure 2: *Visibility for all channels. Within the calculated measurement uncertainty all channels have a visibility above 0.98 corresponding to a QBER of less than 1.0 %.*

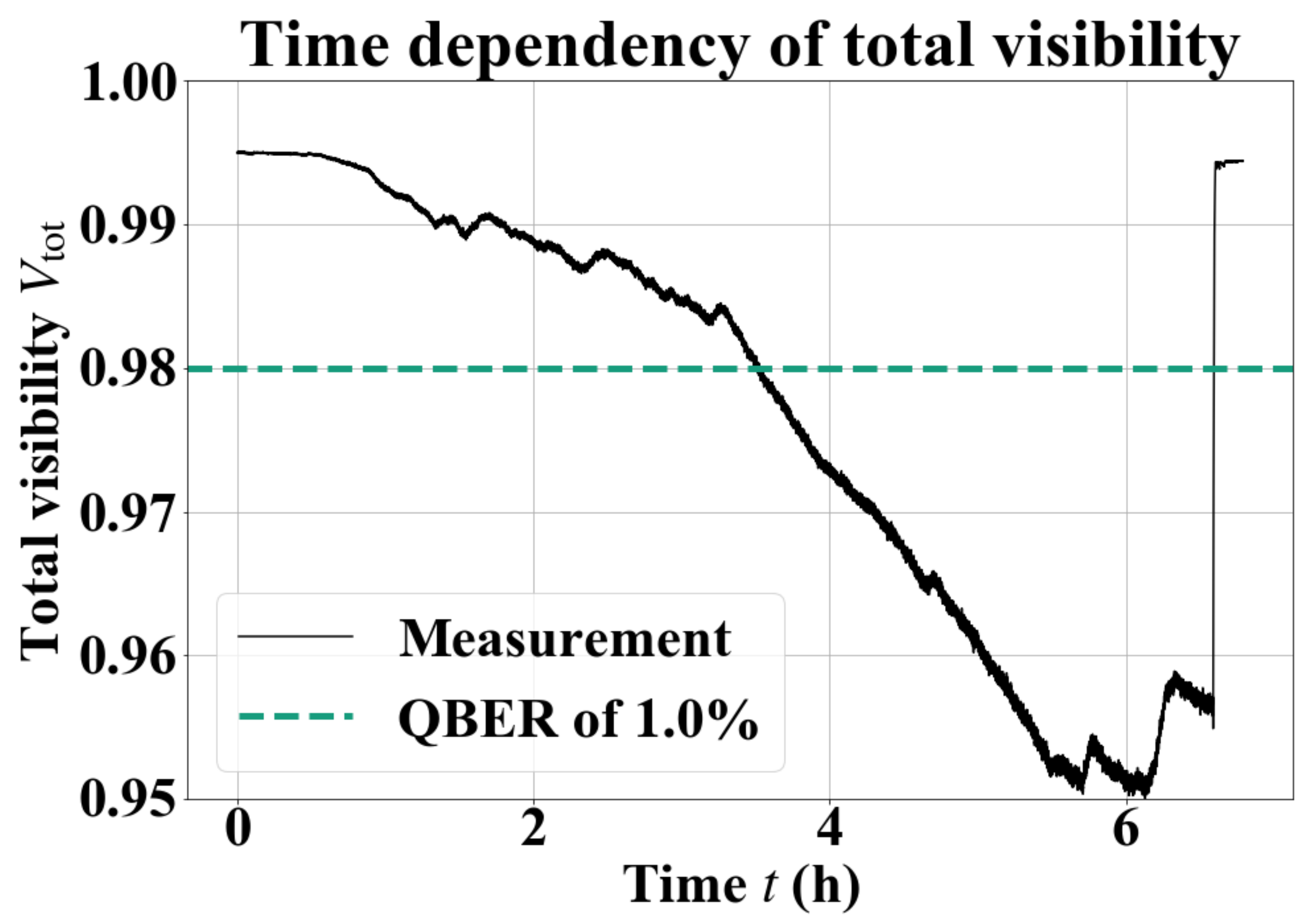

Figure 3: *Time dependency of the total visibility.*

RESULTS

We present a simplified receiver with one DLI for all channels. Fine-tuning the wavelength without additional high-frequency modulation reduces cost and complexity resulting in a simple to implement receiver for WDM QKD.

An initial fine-tuning of the wavelength of each quantum channel is enough to maintain a visibility well above 0.98. The slow visibility change over time allows a simple stabilization mechanism.

REFERENCES

[1] A. Tanaka et al., *2009 35th European Conference on Optical Communication*, Vienna, 2009, pp. 1-2.

[2] D. Stucki et al., In Proc. SPIE 6583, Photon Counting Applications, Quantum Optics, and Quantum Cryptography, 65830L, 2007; https://doi.org/10.1117/12.722952

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https://www.photonikforschung.de/projekte/quantentechnologien/projekt/qupad.html

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