Progress towards a portable polarization-entangled photon source & receiver toolset for quantum network metrology

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Abstract: The aim of this work is to develop low-cost, portable/rack-mounted, robust, and reliable tools for a quantum network testbed. We report our progress on the development of well-characterized prototypes of single-photon sources and receivers.

1. Introduction

A quantum network will consist of many physically separated nodes connected by quantum communication channels that distribute entanglement between them [1]. Such nodes will require mechanisms for the generation, routing and measurement of quantum states in order to fulfill a communication protocol between any two quantum nodes. Producing entangled states using photons at the telecom C-band wavelengths near 1550 nm enables implementing relatively long-distance quantum links, thanks to the low-loss transmission in optical fibers and the high-performance of standard telecom components. The aim of this work is to develop low-cost, portable/rack-mounted, robust, and reliable tools for a quantum network testbed. The prototypes are, by-design, integrated into a standard 19-inch rack to allow for the easy deployment into anywhere with standard networking infrastructure. These prototype source and receiver systems will serve as benchmarking devices for the implementation of metrology protocols in quantum network testbeds.

2. Source

The Entangled Photon Source (EPS, figure 1), designed and built to fit within a portable rack-mountable box, generates polarization entangled photons at 1554 nm via Spontaneous Parametric Down-Conversion (SPDC) in a periodically-polled potassium titanyl phosphate (PPKTP) waveguide using type II phasematching. The SPDC process is pumped by a narrowband continuous wave (cw) laser at 777 nm. The signal and idler photons are coupled into a birefringent polarization maintaining fiber (PMF) oriented such that the fiber fast axis is rotated by 90° compared to that of the waveguide in order to compensate for the temporal walk-off between the $|H\rangle$ and $|V\rangle$ photons that is due to the waveguide birefringence [2]. The correct compensation length of the PMF is 1.18 m, measured by using a two-photon interference experiment based on the Hong, Ou and Mandel (HOM) interference setup [3]. Then we employ a 32 channel DWDM with a 100 GHz channel separation to filter the photons into the ITU-47 and ITU53 channels, respectively, to create a polarization entangled state.

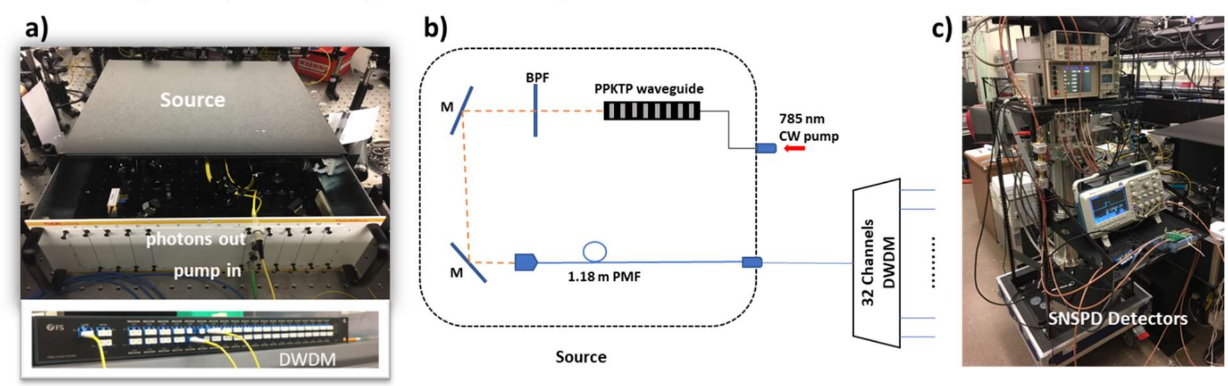

Figure 1: Portable Entangled Photon Source and SNSPD detectors for quantum network applications, **a)** photo of the portable source and DWDM, **b)** schematic of the Portable Entangled Photon Source connected to DWDM; M: Mirror, PMF: Polarization-Maintaining Fiber, BPF: Band Pass F, **c)** photo of the portable SNSPD detectors.

3. Receiver

We also built a set of relatively low-cost, portable, and rack-mountable receivers' boxes, as shown in figure 2a, with two simple polarization-entanglement analyzers. The analyzers in the polarization-entanglement receivers used for measuring polarization correlations between the nodes are based on Bell-state analyzers. In addition, a portable single photons detector, as shown in figure 1c, based on superconducting nanowire single photon detectors (SNSPDs) has been built in-house. Each of the analyzers' setup shown in figure 2b include a motorized quarter-wave plate (QWP), motorized half-wave plate (HWP), and a polarization beam-splitter (PBS). A fiber polarization controller is used to set the input polarization and phase. The analyzer outputs are connected to the SNSPD to measure the coincidences of the entangled photon pairs. A Python program was developed to control and manage the measurement between the automated receivers' systems.

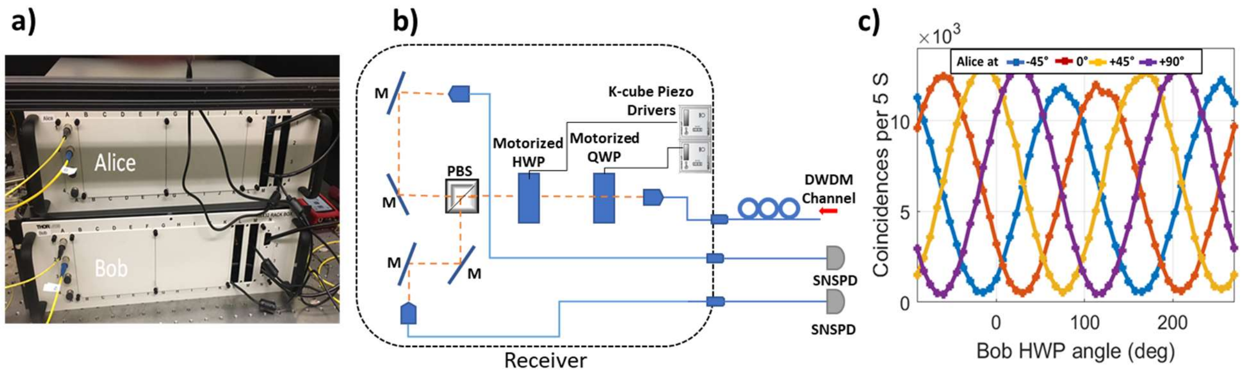

Figure 2: Portable polarization-entanglement analyzers (receivers), **a)** photo of two receivers boxes, Alice and Bob **b)** Setup schematic of the receiver, QWP: quarter-wave plate, HWP: half-wave plate; PBS: polarizing beam splitter. **c)** Polarization entanglement fringes as measured in different bases.

As shown in figure 2c, we obtained preliminary testbed results of the Bell- Clauser, Horne, Shimony and Holt (B-CHSH [4]) inequalities using two receivers and one source. We have reached a coincidences rate of approximately 4000 s^{-1} for a waveguide coupled pump power of 0.7 mW. The S parameter for the CHSH inequality is S = 2.65, the visibility is 93%, and the overall efficiency and signal-to-background (coincidence to accidental) ratio is approximately 330.

Our sources and receivers' toolset are relatively low-cost compared to more efficient receivers. With this low-cost and portable design, many of such well characterized toolsets can be deployed into a multi-node quantum network testbed for metrology purposes.

4. References:

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