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Free-Space Quantum Key Distribution With a High Generation Rate KTP Waveguide Photon-Pair Source

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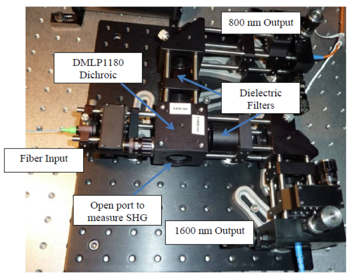
INTRODUCTION

NASA awarded Small Business Innovative Research (SBIR) contracts to AdvR, Inc to develop a high generation rate source of entangled photons that could be used to explore quantum key distribution (QKD) protocols. The final product, a photon pair source using a dual-element periodically-poled potassium titanyl phosphate (KTP) waveguide, was delivered to NASA Glenn Research Center in June of 2015. This paper describes the source, its characterization, and its performance in a B92 (Bennett, 1992) protocol QKD experiment.

PHOTON-PAIR SOURCE

AdvR, Inc designed and built a photon-pair source as part of a NASA SBIR Phase III effort. The system integrates a 1064-nm diode laser with a dual-element frequency conversion device in which the photons are up-converted to 532 nm in the first section of the waveguide, then down-converted in the second section of the waveguide, where each 532-nm photon has an approximately one in one billion chance of converting into a pair of Type 1 polarized entangled pair of 800-nm and 1600-nm photons. A photo of the source is shown below.

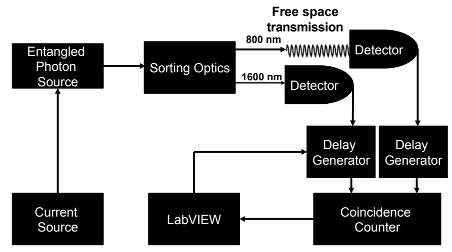
PHOTON SORTING OPTICS



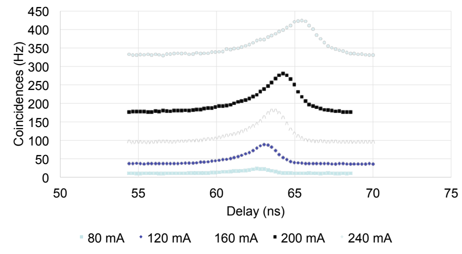
SOURCE CHARACTERIZATION

After the 800-nm and 1600-nm photons are separated by the sorting optics assembly, the 1600-nm photons travel via fiber to an InGaAs detector, and the 800-nm photons travel through free space to a Si APD. Then each set of photons pass through a delay generator and then to a coincidence counter. The counter tags each count and determines if they occur within 243 picoseconds of each other. The experimental setup for coincidence counts is shown below.

COINCIDENCE COUNTING



COINCIDENCE RESULTS



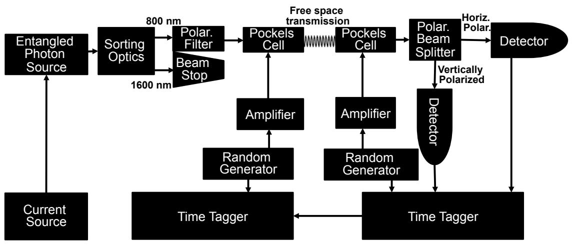
The coincidence curve peaks above correspond to the delay at which signals from the two photons are arriving at the same time. The nonzero level of coincidences far from the peak indicates accidental coincidences. The summation of a coincidence curve, with the floor of accidental coincidences subtracted away, yields the total number of true coincidences detected. The nonzero width of the coincidence peaks are due to jitter in the detectors and the delay generators. At 240 mA, the true coincidence rate is 1450 per second. From this measurement and the independently measured 800- and 1600-nm detection rates, we can estimate the source photon-pair generation rate as 880 MHz.

B92 QKD PROTOCOL

We demonstrated QKD with the B92 (Bennett, 1992) protocol which requires only the 800-nm photons and measured 31.6 key bits/sec. The key is distributed between Alice and Bob in the manner described in the following table:

Alice's Bit/Basis	Bob's Bit/Basis	Bob's Measurement	Bob's Bit
0 / l0°>	0 / l45°>	Yes/No	0 / -
0 / l0°>	1 / l90°>	No	-
1 / l-45°>	0 / l45°>	No	-
1 / l-45°>	1 / l90°>	Yes/No	1 / -

B92 QKD SETUP



CONCLUSIONS

- Measurements indicate that the periodically-poled KTP waveguide source developed by AdvR, Inc generates polarization-entangled photon pairs at a rate of 880 MHz, orders of magnitude higher than BBO crystals.
- B92 QKD demonstrated at 31.6 kbits/second.
- QKD rate is not limited by source, but by switching speed of amplifiers and data transfer rate from coincidence counter. With equipment improvements, we estimate our setup could generate secure key at 1 MHz.

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