Airborne Demonstration of a Quantum Key Distribution Receiver Payload

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Abstract: We demonstrate the viability of components of a quantum receiver satellite payload by successfully performing quantum key distribution in an uplink configuration to an airplane. Each component has a clear path to flight for future satellite integration.

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1. Introduction

Demonstrations of quantum key distribution (QKD) [1] with moving platforms are important to prove the viability of future satellite implementations. Thus far, however, demonstrations of QKD to aircraft have operated exclusively in the downlink configuration [2, 3], where the quantum source and transmitter are placed on the airborne platform. While this approach ultimately has the potential for higher key rate, it is more complex and is not as flexible as an uplink configuration, which places the quantum receiver on the airborne platform while keeping the quantum source at the ground station [4]. Here we present the first successful demonstration of QKD to a receiver on a moving aircraft.

2. Apparatus and Methods

The apparatuses for our demonstration consist of a QKD source and transmitter located at a ground station at Smiths Falls-Montague Airport, and a QKD receiver located on a Twin Otter research aircraft from the National Research Council of Canada. Optical links were established using strong beacon lasers (at a wavelength different from the quantum signal), an imaging camera, and tracking feedback to 2-axis motors at each of the two sites. Once at the aircraft, the QKD signals were recorded for later processing to complete the QKD protocol and secure extract key.

Our weak coherent pulse source implements polarization-encoded BB84 with decoy states [5] at a rate of 400 MHz. These signals are characterized at the source with an automated polarization compensation system to compensate for drifts due to the optical fiber portion of the transmission to the transmitting telescope.

During our airborne trials, the QKD source optics and electronics, as well as computers for data recording and pointing feedback, were located inside of a trailer to maintain thermal and humidity stability. The transmitter pointing stages, polarization characterization optics, and telescope were located just outside the trailer, with cabling running through a small window. Equipped with an electric generator, our ground station is relocatable and self sufficient.

The signal is coupled from the receiver telescope into a custom fine pointing unit which guides both the quantum and beacon signals with a fast-steering mirror. Inside the fine-pointing system, a dichroic mirror separates the quantum and beacon signals—the beacon is reflected towards a quad-cell photo-sensor, providing position feedback to guide the fast-steering mirror in a closed loop [6].

The quantum signal then passes into a custom integrated optical assembly, containing a passive-basis-choice polarization analysis module with a 50:50 beam splitter and polarizing beam splitters, resulting in four beams corresponding to the four BB84 measurement states. These four modes are then coupled into multimode fibers and guided to Silicon avalanche photo diodes detectors operating in Geiger mode with passive quenching. The detectors trigger low-voltage differential signalling pulses which are measured at a control and data processing unit based on Xiphos' Q7 processor card, which has recently flown on the GHGSat [7], with a custom daughter board.

The airplane flew two path types: circular arcs around the ground station, and lines past the ground station. The distances for each type of pass varied from 3 km to 10 km. The flight paths were prepared in advance of the flight and integrated with the flight software.

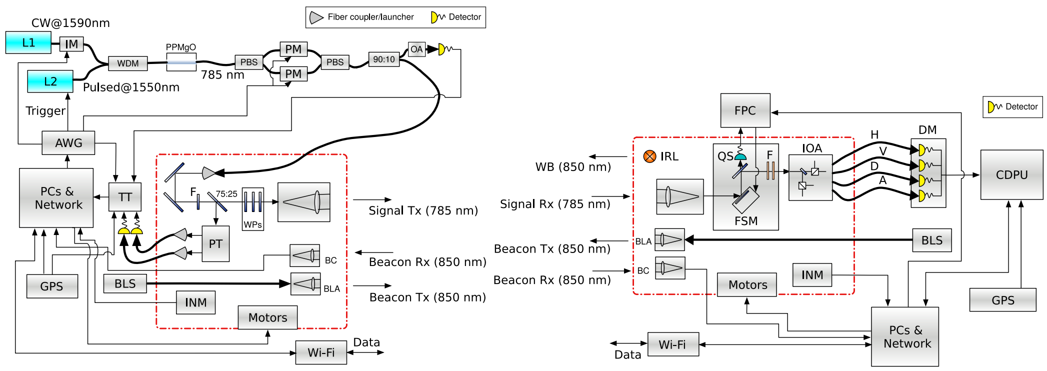

Fig. 1: Schematic diagrams of (a) the transmitter and (b) the receiver. Most receiver subsystems are custom designed and have clear path to flight.

3. Results and Conclusions

In total, we had successful quantum links in seven of 14 passes of the airplane over the ground station, generating asymptotic key in one pass and finite-size secure key in 5 passes, with one showing over 800 kb. The loss in the various passes ranged from 34.4 dB to 51.1 dB. The circular passes allowed the demonstration of longer link times, whereas the line passes were more representative of a satellite pass over a ground station. Angular speeds (at the transmitter) between 0.4 °/s and 1.28 °/s were achieved.

We have demonstrated the viability of components of a quantum receiver satellite payload by successfully performing quantum key distribution in an uplink configuration to an airplane. The major components in the receiver payload (fine pointing unit, integrated optics assembly, detector modules, control and data processing unit) have a clear path to flight for future satellite integration.

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