# Simple Integration of Quantum and Beam Tracking Channels for Free-space Quantum Key Distribution

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## Abstract

- Free-space quantum key distribution (QKD) systems require integration of quantum and beam tracking channels accompanied by issues such as beam path alignment, mode matching, single mode operation and small volume etc.
- We report applying fiber-based wavelength division multiplexing (WDM) filter as a simple and effective solution for integrating these channels, removing free-space beam alignment within QKD transmitter.
- QKD performance was measured with sifted key rate of 1074 kbps and QBER of 1.1 %, showing similar performance results.

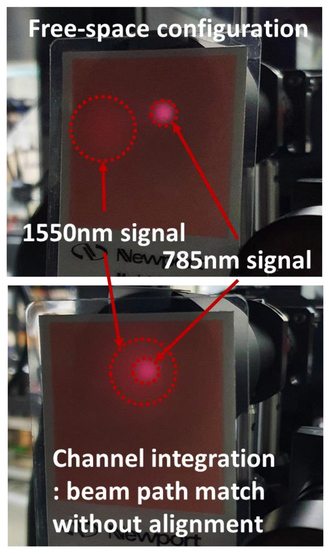
## Introduction

- Free-space QKD has received an increasing attention for its inherent secure communication capability between two systems.
- Free-space QKD systems require integration of various signals such as quantum and beam tracking signals, which is usually performed through dichroic mirrors with free-space alignment.
- However, free-space alignment requires a large volume space, much alignment effort and is easily affected by mechanical shock.
- We report alignment-free operation within transmitter by applying fiber WDM filter for channel integration and chip based 1 x 4 polarization beam combiner.

## Experimental results

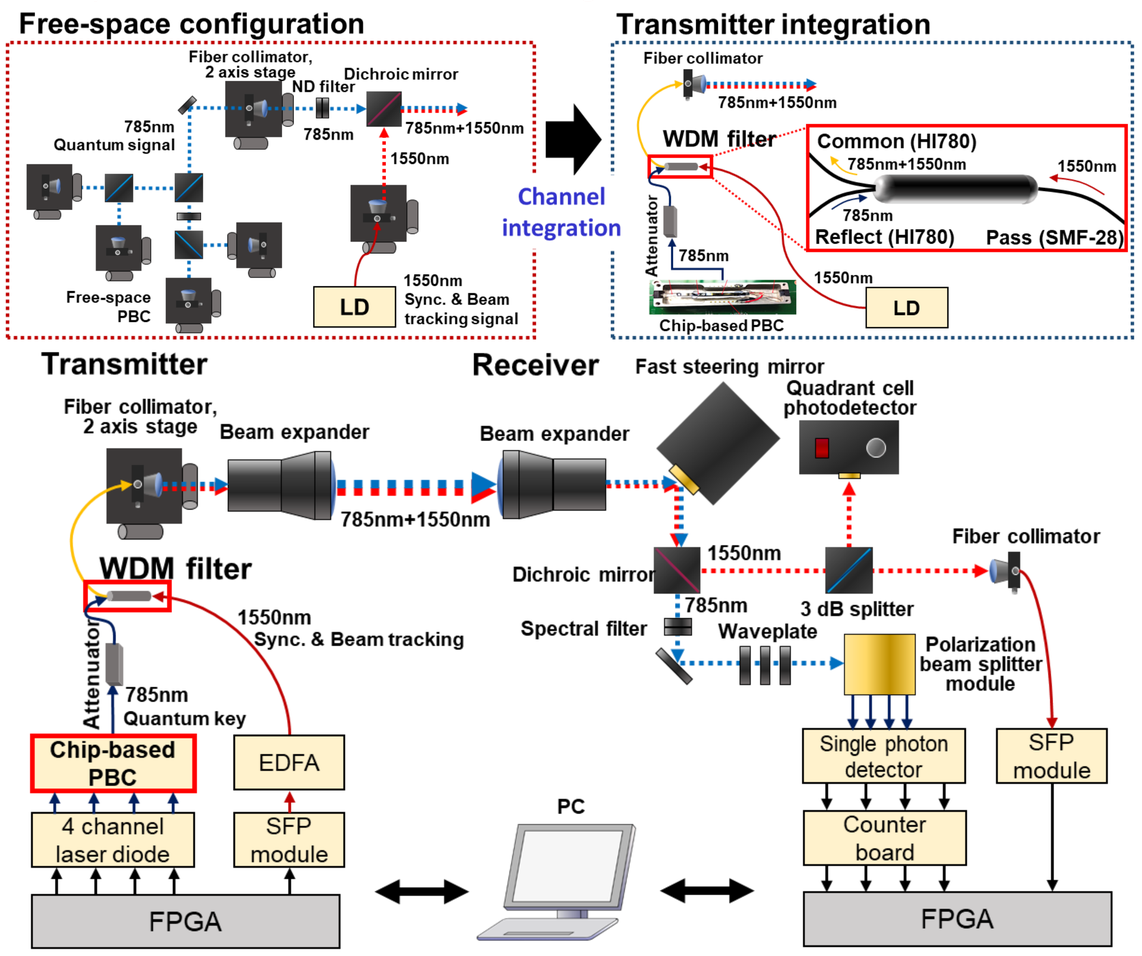
### Channel integration issues in free-space QKD

- Free-space configuration
  - Beam path alignment required
  - Vulnerable to mechanical shock
  - Large space required
- Solution: channel integration
  - Alignment-free operation
  - Robust to shock
  - Small space

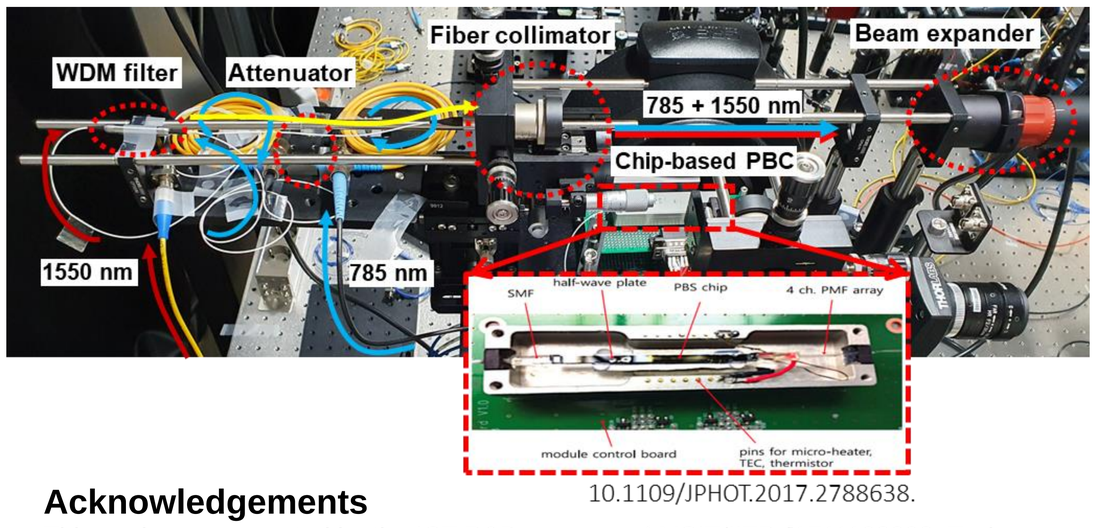



### Proposed free-space QKD system

- Free-space QKD using polarization encoding BB84 protocol
- Waveguide and fiber-based signal integration in transmitter
  1) Chip-based polarization beam combiner (PBC)
  2) WDM filter based channel integration

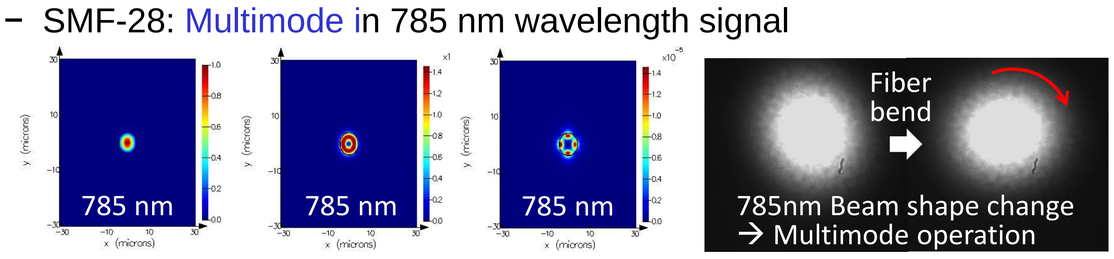



- Implemented transmitter system

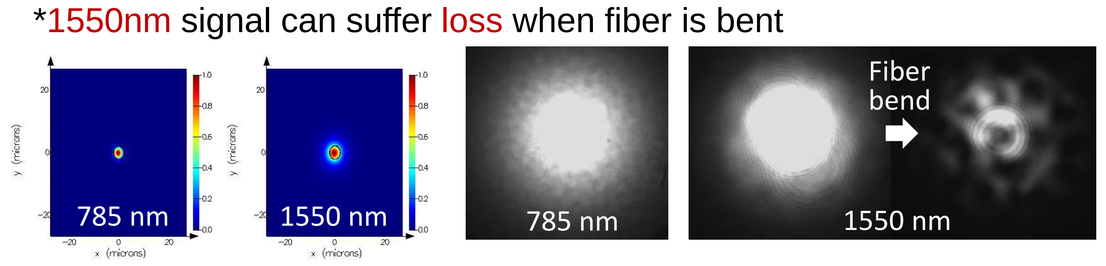



### Device measurement

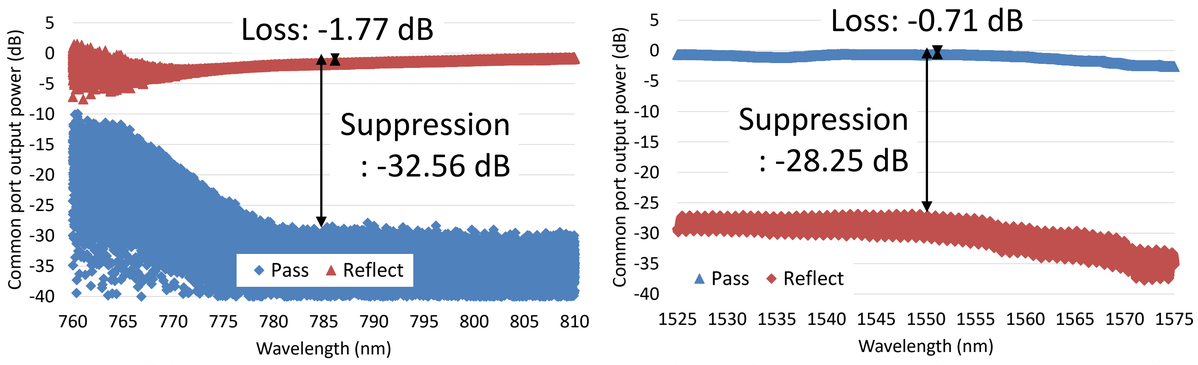
- Common output port fiber of WDM filter
  - SMF-28: Multimode in 785 nm wavelength signal




  - HI780: Single mode in both 785 nm & 1550 nm wavelength signal
    *1550nm signal can suffer loss when fiber is bent



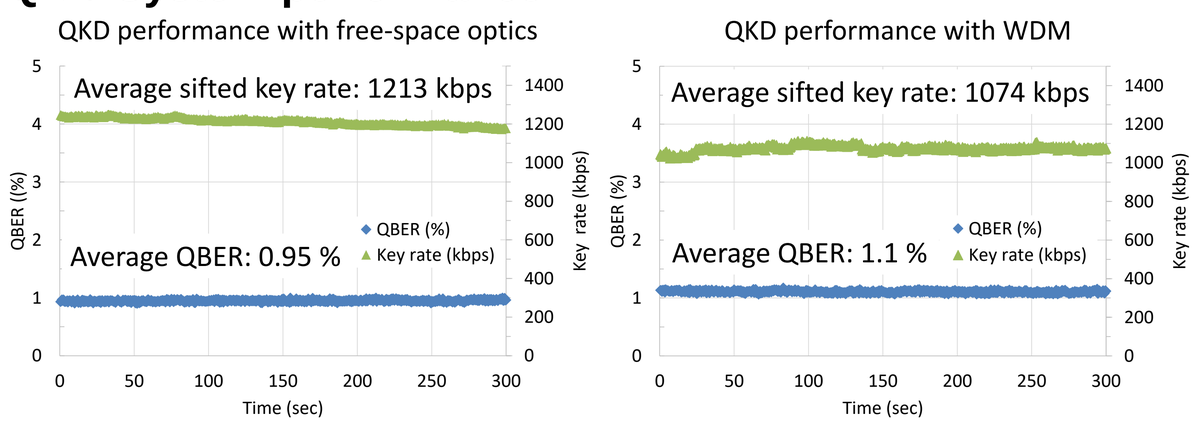

- Spectral response of reflect and pass ports




  - Small insertion loss and good suppression of other wavelength channels
- Polarization orthogonality: maintained within measurement error

➢ **High performance WDM filter with short HI780 fiber**
→ **Good mode matching, single mode operation and small volume**

### QKD System performance




- Repetition rate : 100 MHz
- Mean photon number : 0.1
- QBER : ~1.1 %, Sifted key rate : ~1074 kbps
  ✓ Similar performance with a free-space optics system, but small difference was caused by incomplete waveplate alignment at the receiver.

### Conclusions & Future works

- WDM filter applied for channel integration in free-space QKD system
  - Alignment-free operation within QKD transmitter achieved
  - robust to shock, small space
- QKD performance: (QBER: 1.1%, Sifted key rate: 1074 kbps)
- Future: Single chip integration of transmitter and receiver components
  ➔ Minimizing size, free-space alignment issues, polarization issues

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