1550-nm Free-Space Reference Frame Independent (RFI) Quantum Key Distribution System

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Free-Space Quantum Key Distribution (QKD)

- **A promising solution for secure communication between two remote parties through free space**
  - **Unconditional security** based on no-cloning theorem
  - **No requirement of physical connection** between two remote parties
  - Applicable to **moving terminals** with the characteristics such as **moving position**, **outside operation**, and **limited internal space**

Moving Position

- **Conventional BB84 protocol assumes a shared reference, i.e., polarization reference**
  - Requires **active compensation**
- **Solution**
  - **Reference Frame Independent (RFI) QKD**
  - Removal of active compensation

Outside Operation

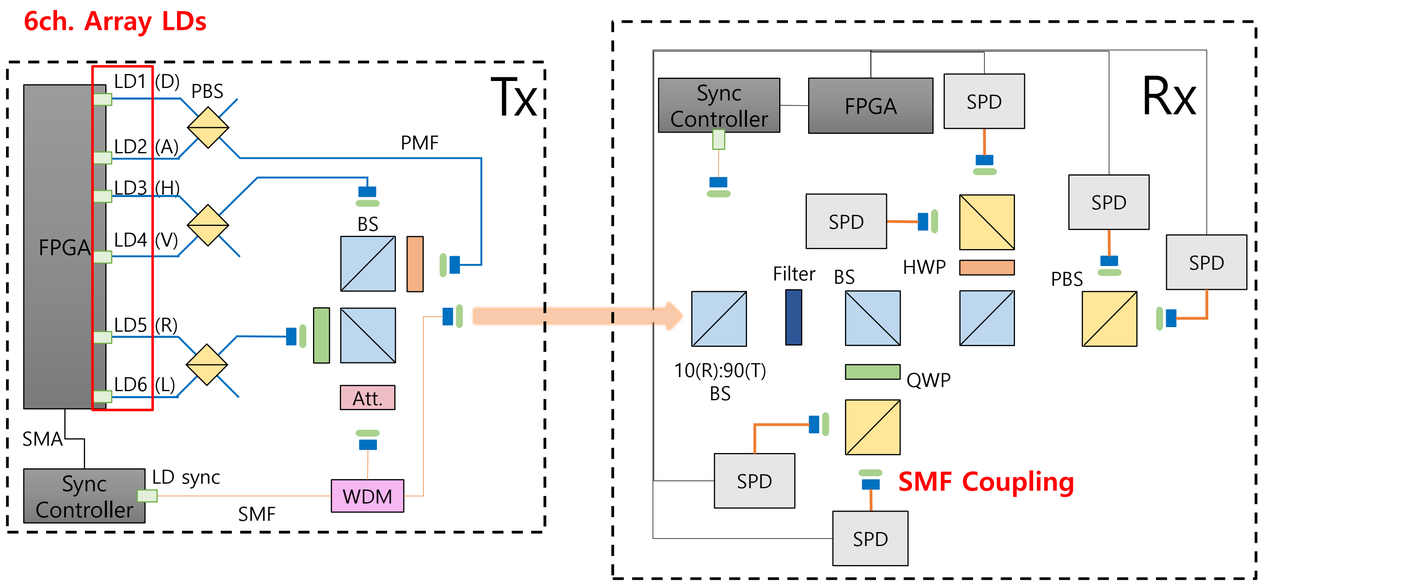
- **Intensive noise issue by sun light**
  - **Significant degradation** of the performance
- **Solution**
  - The use of **1550-nm wavelength**
  - **Single mode fiber (SMF) coupling** for spatial filtering

Limited Transmitter/Receiver Size

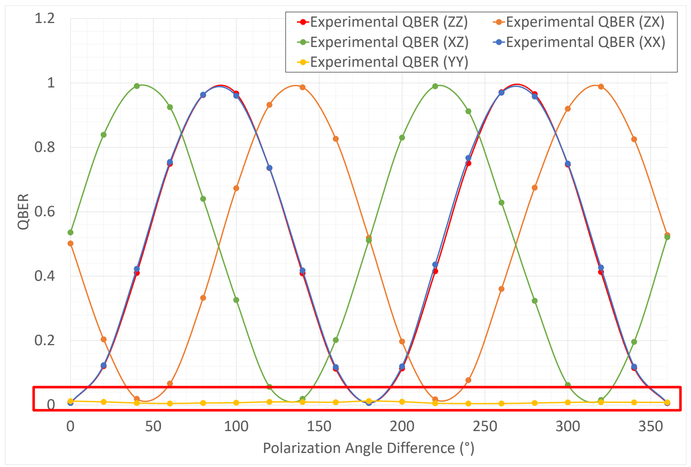
- **Moving terminals usually has limited space**
  - **Bulk optics based implementation** is not suitable
- **Solution**
  - **Chip scale implementation**
  - **Comparability** with chips in fiber based QKD

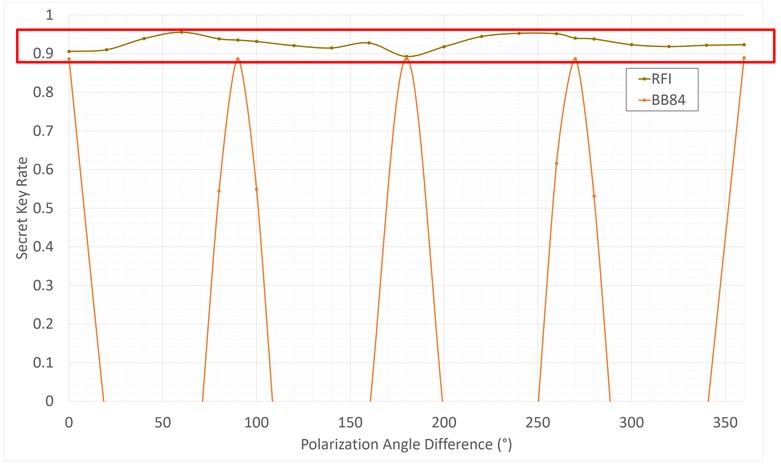
1550-nm Free-Space RFI Quantum Key Distribution System & Performances

- **1550-nm free-space QKD system**
  - **RFI** QKD protocol
  - Generation of **1550-nm** quantum signal
  - **100 MHz** repetition rate
  - 0.1 mean photon number
  - Implementation with **passive optical components**
  - **Fully controlled** by FPGA
  - 1560-nm sync signal for control of FPGA
  - InGaAs SPDs
    with 10% DE, 1 ns gate width, 0 dead time

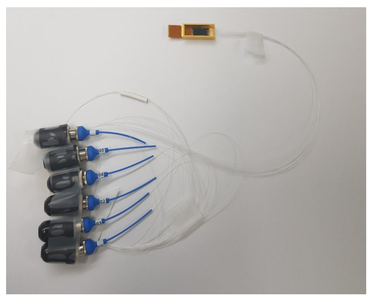


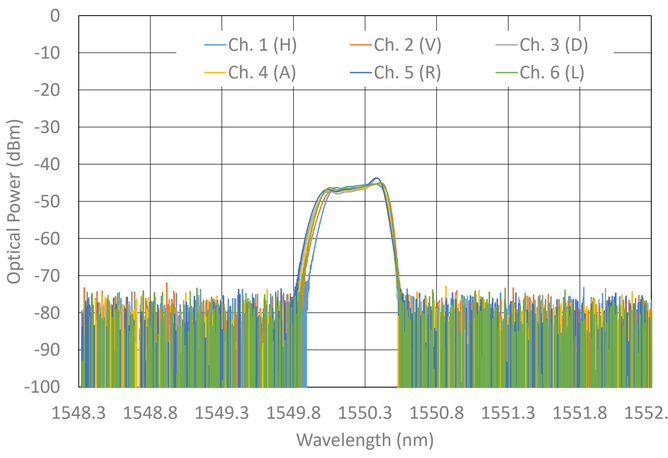
- **SMF coupling in Rx**
  - Each SPD is **coupled with SMF** (9 μm)
  - Coupling loss **< 2 dB**
  - **Robust to the noise** from external light
  - Low quantum bit error rate (QBER) at circular polarization **(~ 0.8%)**

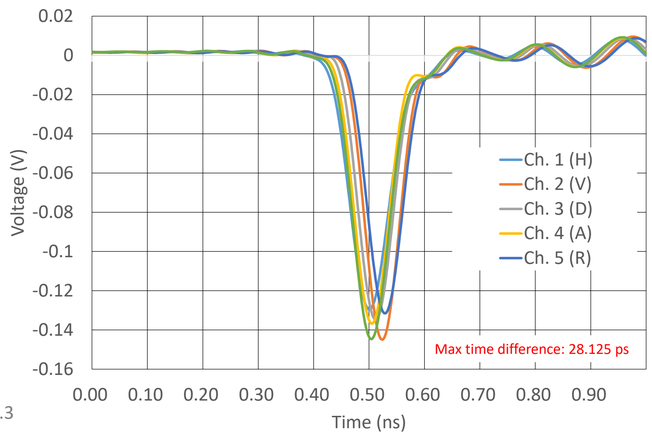




- **6-channel array laser diode**
  - Dimension: **31 mm x 8 mm x 6 mm**
  - Gain switching operation for **phase randomization**
  - 100 MHz pulse operation with 200 ps pulse width
  - **Controllability of temperature of individual channel**
  - Polarization maintaining fiber (PMF) pigtail







Conclusion

- **Free-space RFI QKD implementation**
  - QKD performance **independent to reference frame**
- **1550-nm optics implementation and SMF coupling in Rx**
  - **Robust operation** to external light
- **6-channel array laser diode**
  - **Chip scale implementation** of laser source

Future Works

- **Fully chip scale implementation**
  - Polarization encoder and decoder
  - Single photon detector
  - Related electronics and integration of the chips
- SMF coupling with beam tracking
  - Stable coupling under moving terminals