Resource-efficient quantum key distribution with using integrated silicon photonics

merged with

Fully chip-based decoder for polarization-encoding quantum key distribution

Photon. Res. 11, 1364 (2023), Chip, 2, 100039 (2023)

Kejin Wei

Xiao Hu, Yongqiang Du, Xin Hua, Zhengeng Zhao, Ye Chen, Chunfeng Huang, and Xi Xiao

School of Physical Science and Technology

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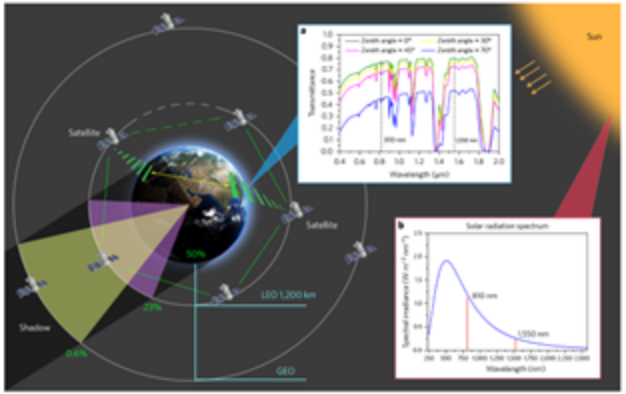
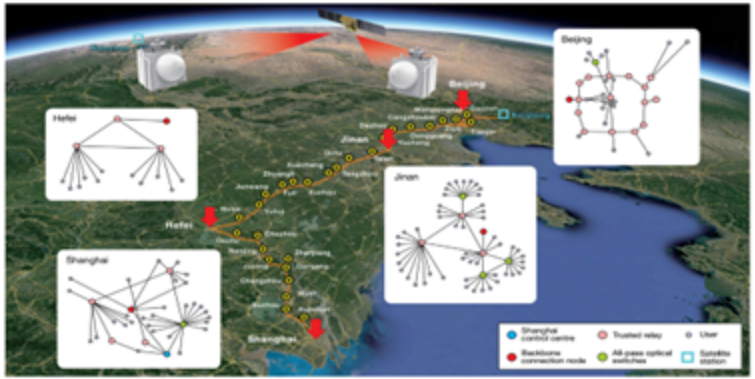
QKD Achievements

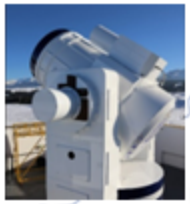


- Global quantum networks based on satellites [Nature Photon. 11, 509-513 (2017)]



- Space-to-ground quantum network[Nature 589, 214 (2021)]

Micius satellite



Urumqi quantum metropolitan network

Beijing quantum metropolitan network

Naning quantum network

Chip-based QKD

Si

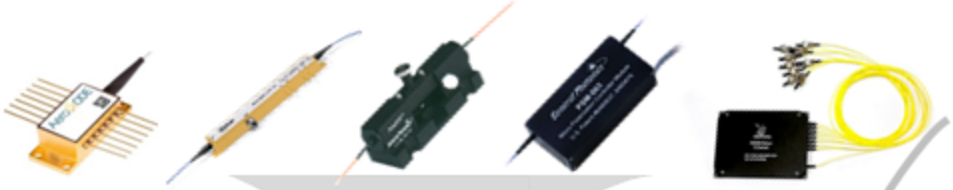
- C. Ma et al., Optica 3, 1274 (2016) (**BB84**)
- P. Sibson et al., Optica 4, 172 (2017) (**COW, BB84**)
- D. Bunandar et al., PRX 8, 021009 (2018) (**BB84 field test**)
- G. Zhang et al., Nat. Photon. 13, 839 (2019) (**CV-QKD**)
- G. Zhang et al J. Lightwave. Technol. 40, 2052-2059 (2022)
- C.-X. Zhu et al Phys. Rev. Appl. 17, 064034 (2022)
- R. Sax, et al Photon. Res. 11, 1007-1014 (2023)

InP

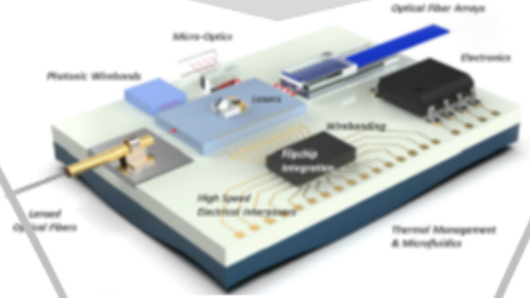
- P. Sibson et al., Nat. Commun. 8, 13984 (2017) (**COW, BB84, DPS**)
- H. Semenenko et al, Optica 7, 238-242 (2020)
- T. K. Paraïso, et al, Nature
  850-856 (2021) **(BB84 F**

QKD with silicon photonics

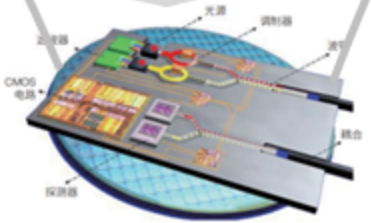
Classical QKD devices



Silicon Photonics (Current)

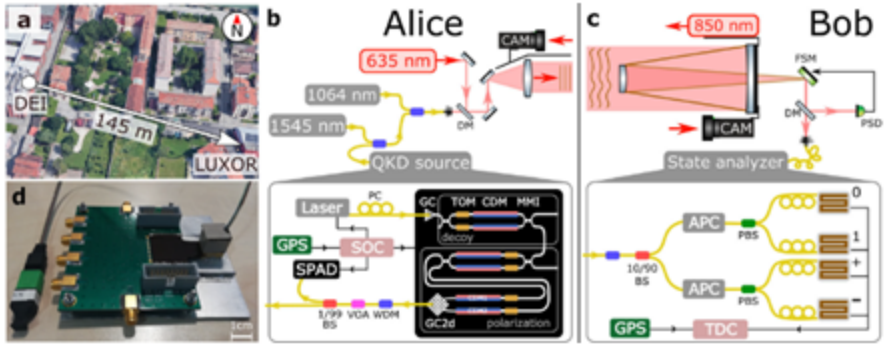


Silicon Photonics (Future)

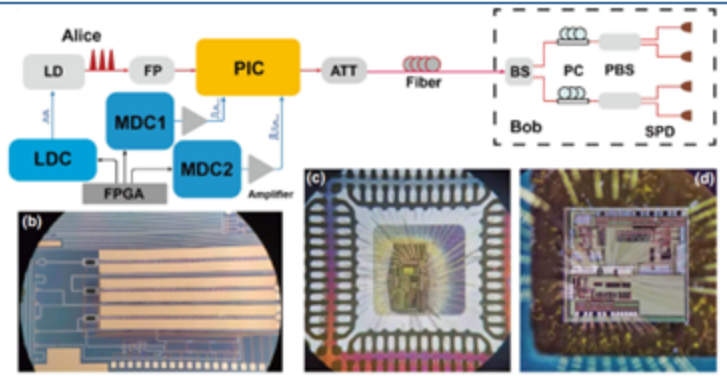


- ✓ Large-scale integration
- ✓ Mature fabrication
- ✓ CMOS Comparability

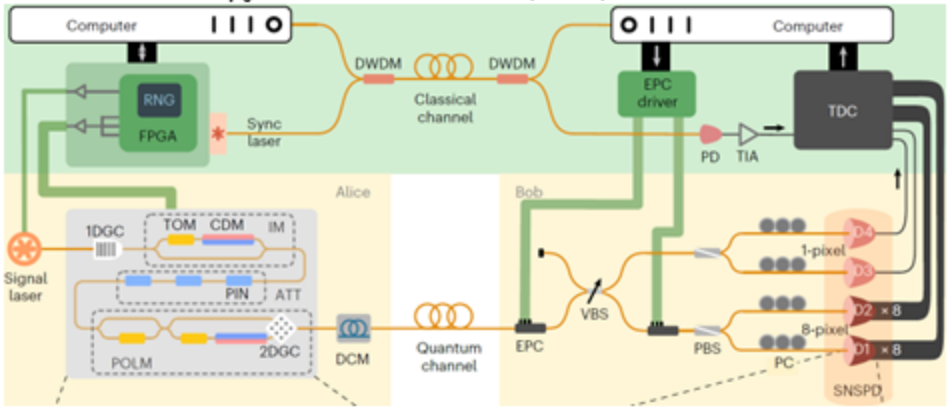
Silicon-based polarization-encoding QKD



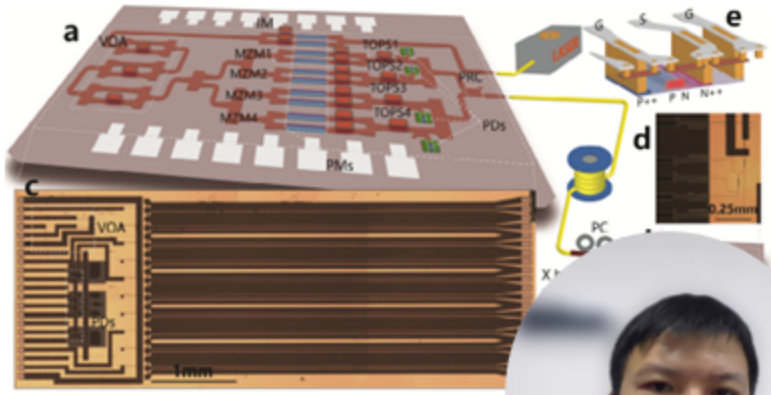
npj Quantum Inf. 7, 93 (2021)



Phys. Rev. Applied 17, 064034 (2022)



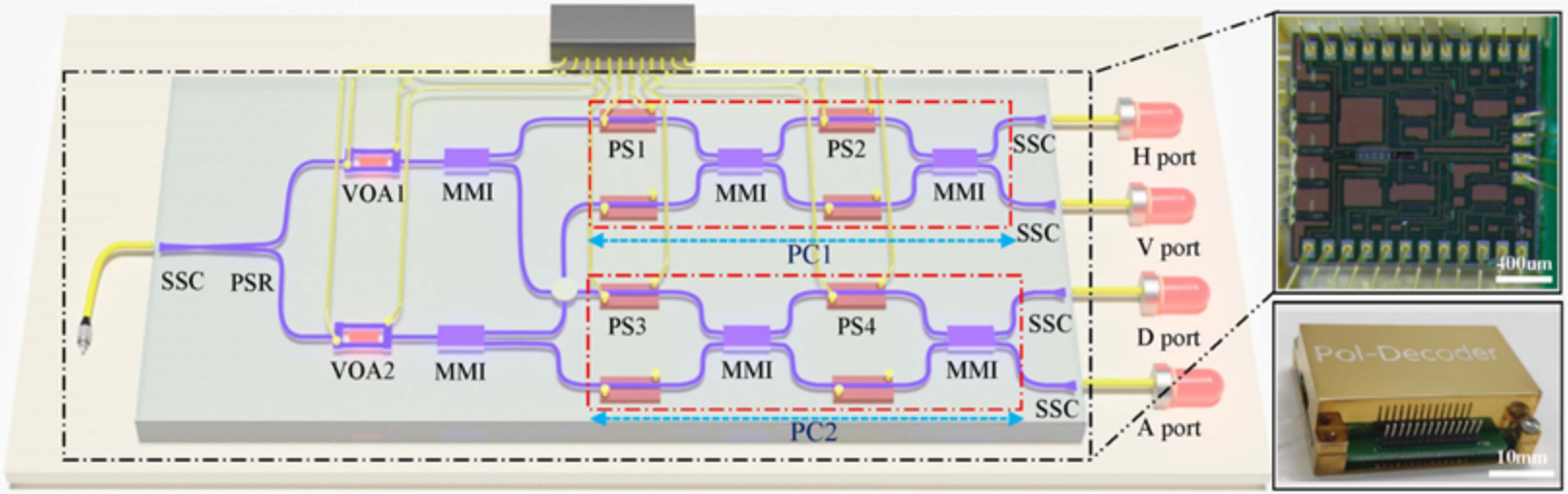
Nat. Photon. 17, 416–421 (2023)



J. Lightwave Technol. 40, 2052

A silicon-based fully integrated decoder have no yet reported!

Polarization QKD receiver

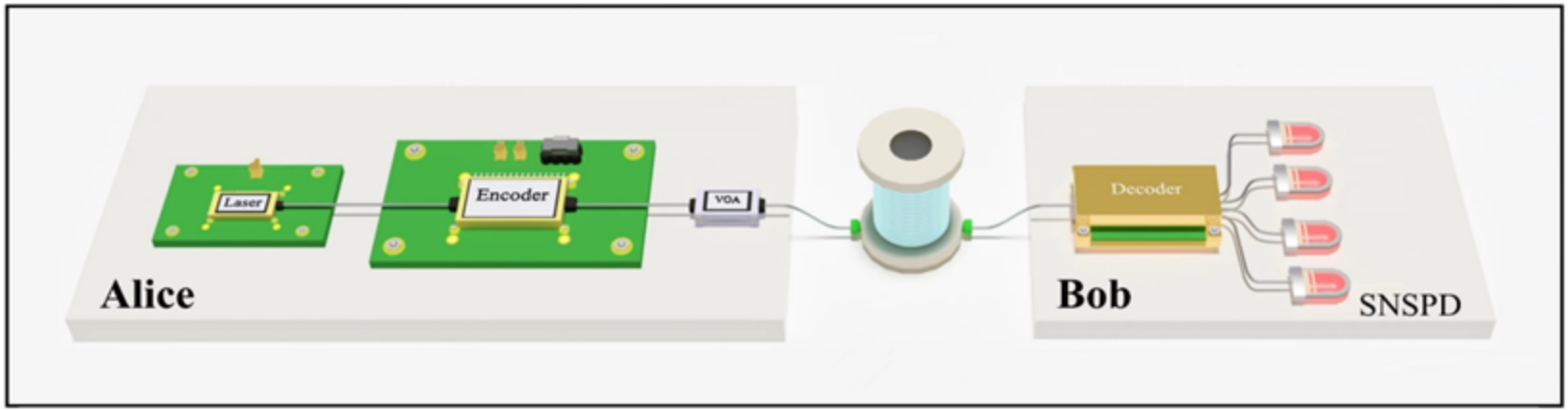


- ✓ **Size of the chip:** 1.6mm × 1.7mm
- ✓ **Size of the packaged device:** 40mm × 22mm × 9mm
- ✓ **Rate of Polarization compensation:** 3kHz
- ✓ **Extinction ratio:** 28dB
- ✓ **Insertion loss:** ~4.6dB

- ➢ Performance is comparable with the state-of-the-art bulk devices
- ➢ Active compensation of th polarization drift using chip

Y. Du(#), X. Zhu(#), X. Xiao(*), and **K. Wei(*)**, Chip, 2, 100039 (2023), Featured

Resource-efficient QKD with integrated chips



- ✓ Transmitter: Pulsed laser, intensity and polarization modulation
- ✓ Receiver: Polarization decoder
- ✓ Electronic control: PCB
- ✓ Detector: Free-running SNSPD, InGaAs, Ge-Si
- ✓ Auxiliary tasks: Synchronization, polarization compensation

Laser chip

Thorlabs Semiconductor Manufacturing

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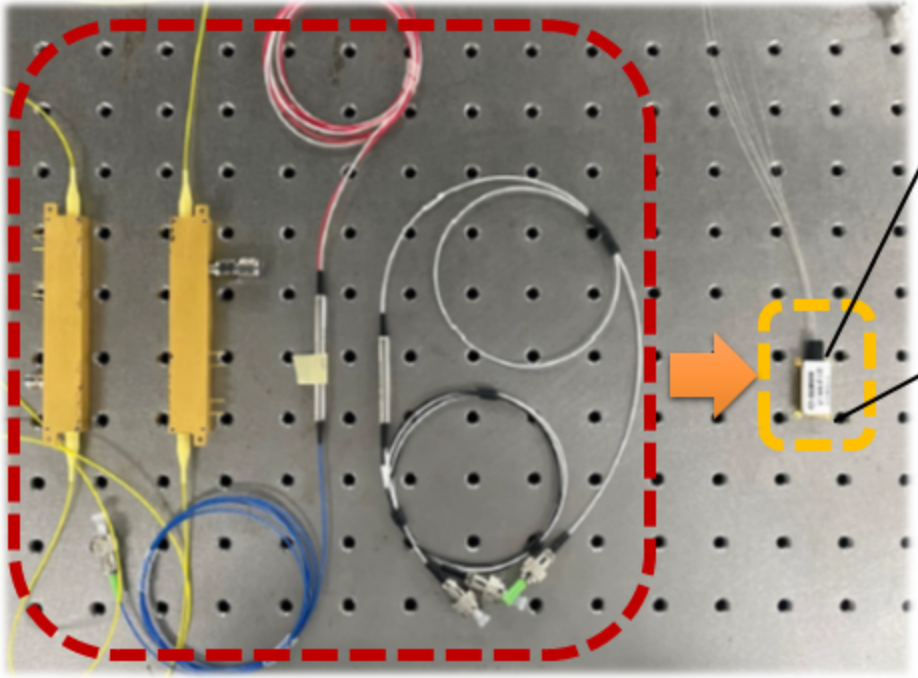
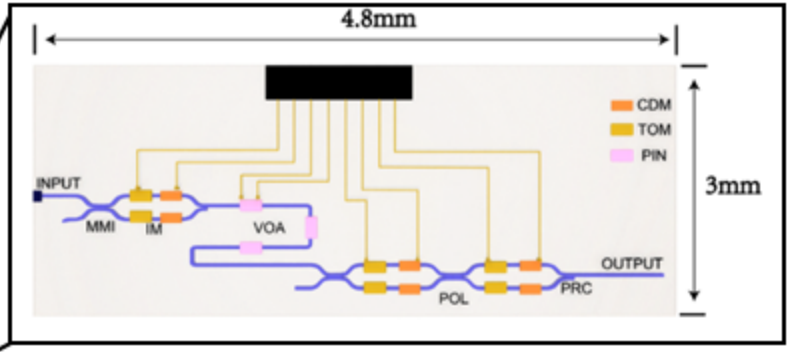
Single-Frequency Lasers chip is commercially available

Polarization-encoding encoder



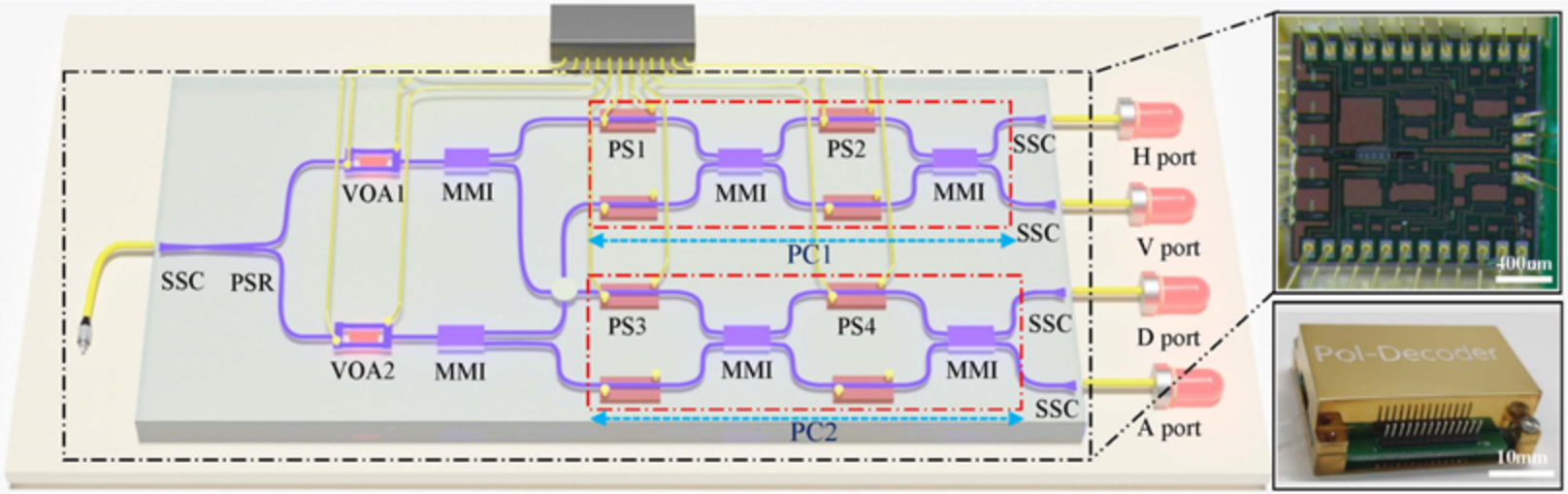


- ✓ **Size of the chip:** 4.8mm × 3mm
- ✓ **Size of the packaged device:** 24mm × 15mm × 5mm
- ✓ **Intensity modulator ER:** static 30dB, dynamic 20dB@1.25GHz
- ✓ **Polarization ER:** 23dB@1.2

Performance is comparable to the state-of-the-art bulk devices

K. Wei(#), W. Li(#), F. Xu(*), and J.-W. Pan(*), Phys. Rev. X 10, 031030 (2

Polarization QKD receiver



- ✓ **Size of the chip:** 1.6mm × 1.7mm
- ✓ **Size of the packaged device:** 40mm × 22mm × 9mm
- ✓ **Rate of Polarization compensation:** 3kHz
- ✓ **Extinction ratio:** 28dB
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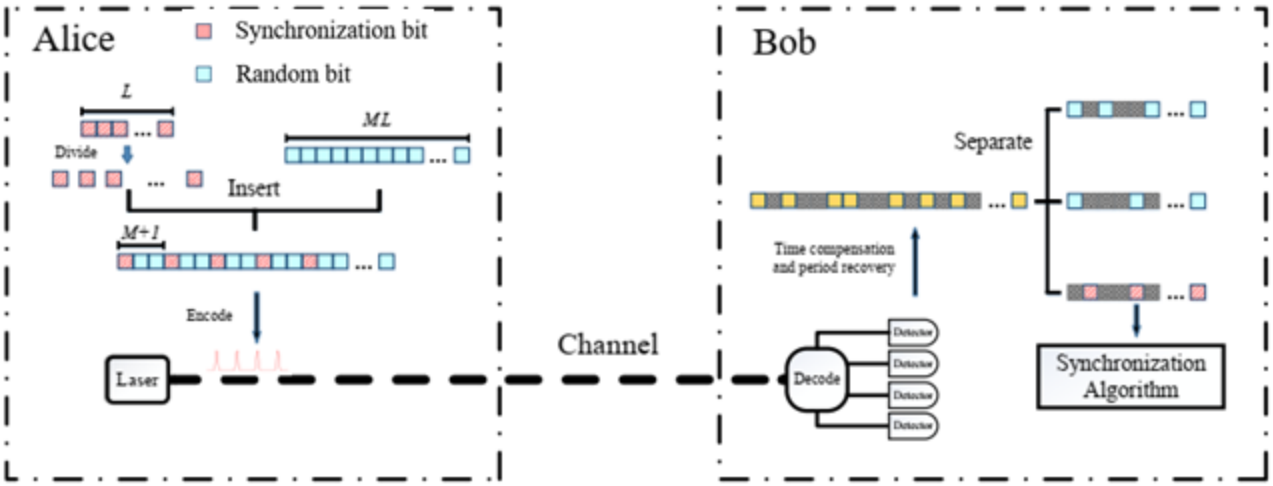
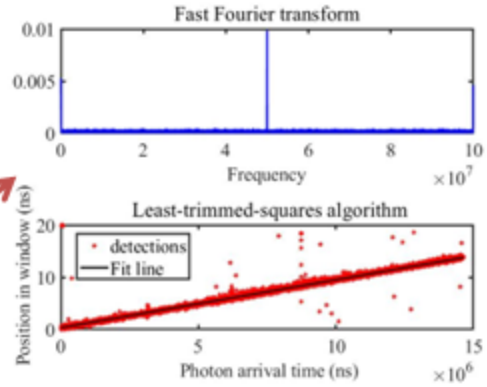
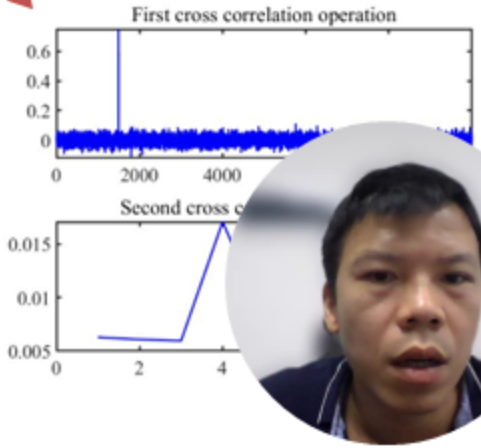
Y. Du(#), X. Zhu(#), X. Xiao(*), and **K. Wei(*)**, Chip, 2, 100039 (2023), Featured

Qubit-based frame distributed synchronization



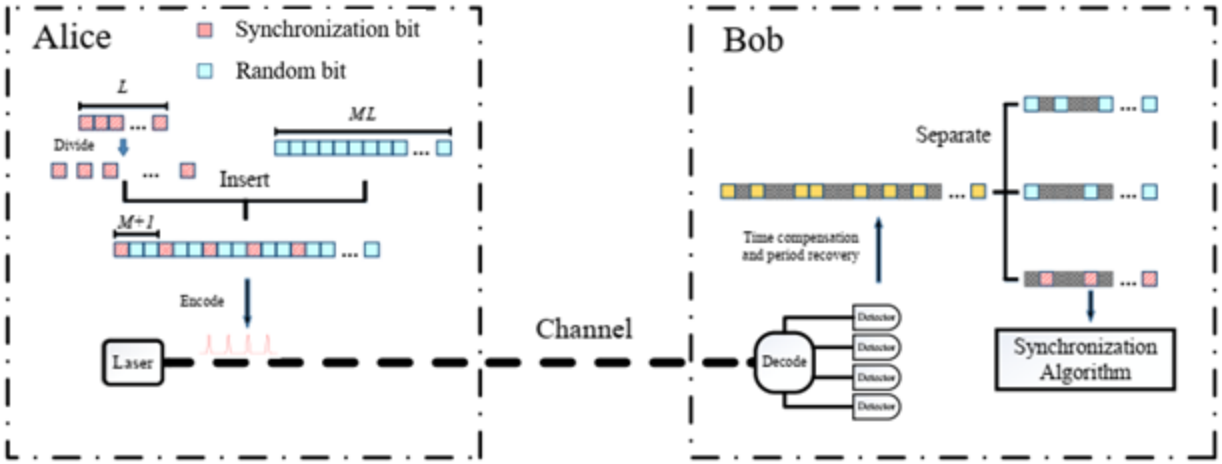


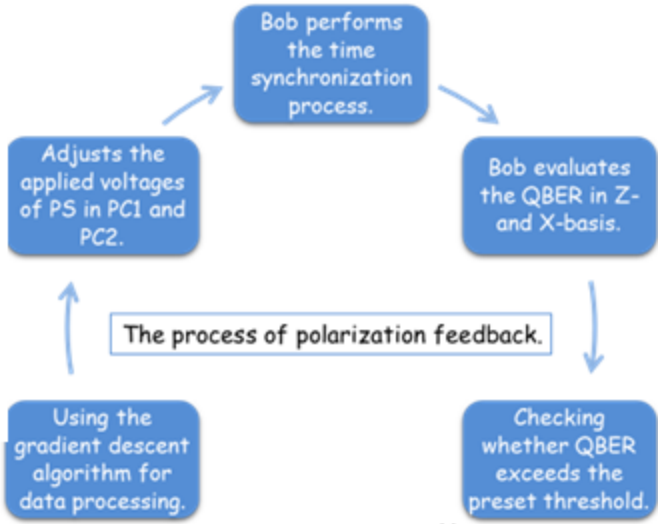


- ✓ Without additional synchronization subsystem.
- ✓ Improvement of integration level of chip QKD system.
- ✓ Rapid synchronization by recycling the public periodic-correlation code over long distances.

L. Calderaro, et al Phys. Rev. Appl. 13, 054041 (2020)

Qubit-based synchronization





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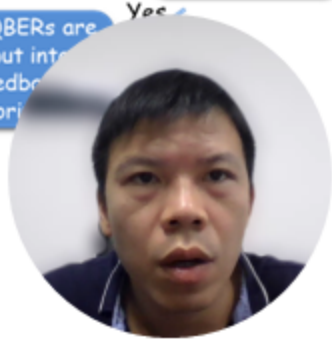
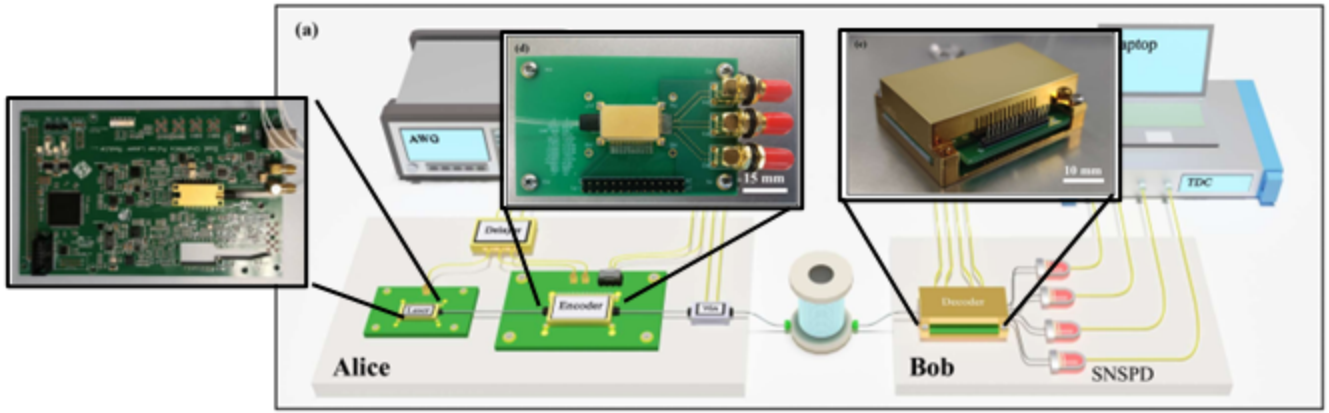
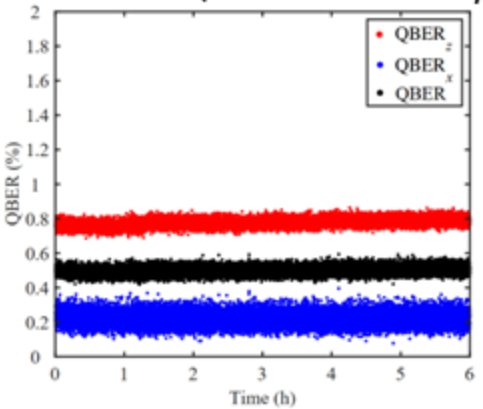


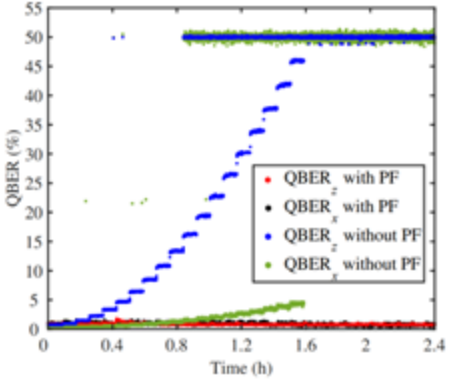
Resource-efficient BB84 QKD with integrated Chips



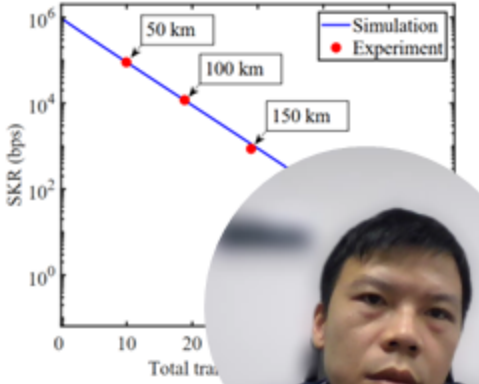
Intrinsic QBER and stability



Polarization compensation



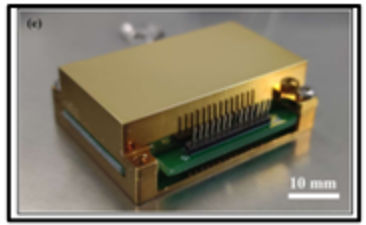
Secure key distribution

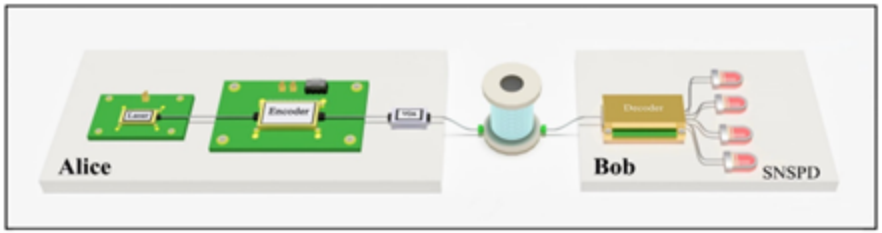


K. Wei*, X. Hu, Y. Du, X. Xiao* et al, arXiv:2212.12980 (2022), Photon. Res. 11, 1364 (

Summary

- Chip-based QKD devices
  - Encoder [Phys. Rev. X 10, 031030 (2020)]: intensity and polarization modulation
  - Decoder [Chip, 2, 100039 (2023)]: polarization demodulation and drift compensation





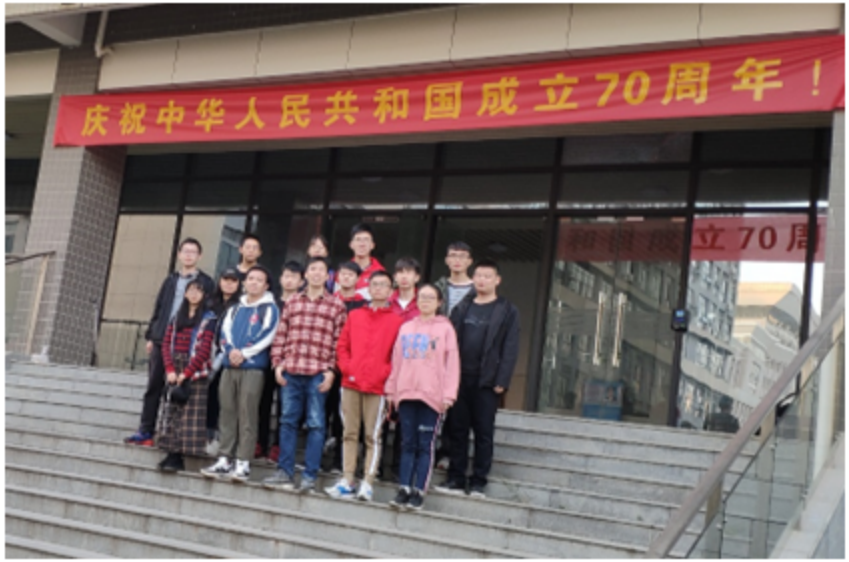
- QKD demonstrations using SIP
  - BB84-QKD [Photon. Res. 11, 1

Thanks for your attention

Jian-Wei Pan

Feihu Xu

Xi Xiao



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Technology,USTC, Shanghai, China
National Information Optoelectronics Inn
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