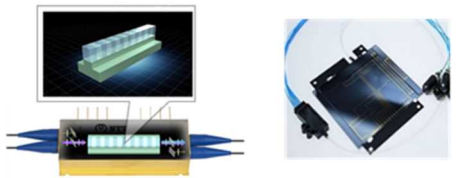
R&D Theme

R&D of waveguide optical parametric amplifiers and optical quantum waveguide circuits

Progress until FY2022

1. Outline of the project

This R&D theme is on quantum teleportation on a chip. This chip technology will contribute to Goal 6 and the goal of this project, which are to achieve a large-scale fault-tolerant universal optical quantum computer as an elemental technology that provides high-quality quantum states and quantum information processing. In this theme, we will apply waveguide-type periodically poled lithium niobate (PPLN) and planar lightwave circuit (PLC) technologies, which were developed for optical communications, to quantum information processing (Fig. 1). With these technologies, we aim to achieve teleportation with 10-dB squeeze light and 8.3 fidelity.

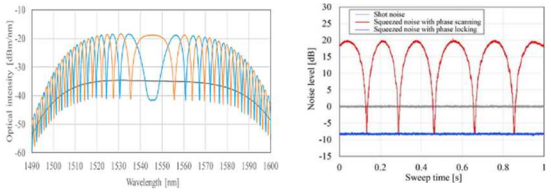


(a)Waveguide-type PPLN (b)Planar lightwave circuit

Fig.1 Device technologies for optical quantum computing

2. Outcome so far

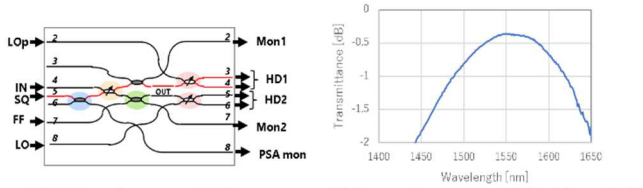
(1) By squeezing with only a PPLN waveguide with reduced loss, the world's first 10-THz bandwidth was achieved without the resonator structure causing band limitation, and the squeezing level exceeded 8 dB (Fig. 2).



(a) Squeezing band width over 6.3dB at 12 THz on both sides of the band (b) Noise characteristics with squeezing levels of 8dB

Fig 2. Quantum noise intensity of squeezed light of waveguide -type PPLN squeezer

(2) Using a PLC-type universal squeezer circuit that can be scaled up to a quantum teleportation circuit, we have thoroughly reduced the loss and confirmed that it can be kept to around 0.5 dB (Fig. 3).



(a) Universal squeezer PLC (b) Transmittance of path(Red line of(a))

Fig. 3 Universal squeezer by PLC and its transmittance

(3) In quadrature phase amplitude detection, which is the basis of projection measurements, we demonstrated for the first time quantum measurements in the 43-GHz band using a PPLN-waveguide phase-sensitive amplifier as a pre-amplifier, rather than a bandwidth-limiting, late-stage electrical amplifier (Fig. 4).

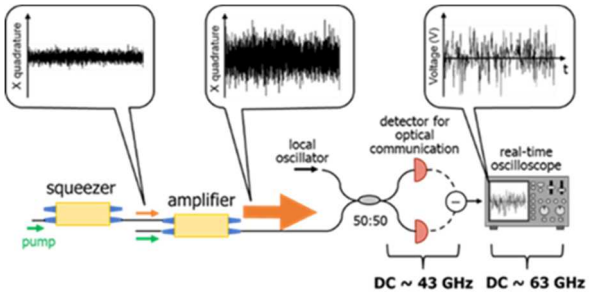


Fig. 4 Quadrature phase amplitude measurement system with waveguide-type PPLN phase sensitive pre-amplifier

3. Future plans

We aim to further develop the device technology to achieve the target characteristics. From the viewpoint of demonstrating quantum computing as quickly as possible, we will combine waveguide-type PPLN modules with spatial optics and optical fiber systems and collaborate with other R&D themes in the project to demonstrate optical quantum computing.

References

1) T. Kashiwazaki, et al., Appl. Phys. Lett. 119, 251104 (2021)
2) T. Kashiwazaki, et al., Appl. Phys. Lett. 122, 234003 (2023)
3) A. Inoue, et al., Appl. Phys. Lett. 122, 104001 (2023).