Quantum Key Distribution toward Scalable Quantum Communication Networks and Photonic Integrated Systems

Sang-Wook Han[1,2,3]

[1]*Center for Quantum Technology, Korea Institute of Science and Technology (KIST), Seoul*
[2]*Division of Quantum Information, KIST School, Korea University of Science and Technology, Seoul*
[3]*KU-KIST Graduate School of Converging Science and Technology, Korea University, Seoul*

Abstract:

Quantum Key Distribution (QKD) is the most mature quantum technology and is expected to play a key role in securing future communication infrastructures against quantum-computing attacks. Despite remarkable progress over the past two decades, practical deployment of QKD still requires significant advances in network scalability, long-distance transmission, and system miniaturization.

Over the past decade, our research group at the Korea Institute of Science and Technology (KIST) has focused on addressing these challenges through system-level innovation and photonic integration. We have developed practical QKD network architectures based on wavelength- and polarization-division multiplexing, enabling efficient one-to-many quantum key distribution over field-deployed optical fiber networks while maintaining stable quantum bit error rates in real communication environments.

To further improve scalability and reduce system size, our recent research has concentrated on photonic integrated QKD systems using thin-film lithium niobate (TFLN). By integrating passive and active optical components on a monolithic photonic chip, we demonstrated on-chip BB84 QKD over a 32-km field-deployed fiber network. The identical transmitter and receiver chip architecture provides a practical route toward compact, robust, and mass-producible quantum communication systems suitable for future quantum networks.

Building upon these achievements, our current research is focused on next-generation Twin-Field QKD (TF-QKD), which has the potential to overcome the fundamental distance limitation of conventional QKD without quantum repeaters. In particular, we are investigating high-precision phase estimation, pure phase error analysis, and experimental implementation of TF-QKD for ultra-long-distance secure communication. We are also extending integrated lithium-niobate photonic technologies toward chip-scale TF-QKD platforms.

This presentation will review the evolution of our QKD research from practical quantum communication networks to integrated photonic quantum systems and discuss future directions toward scalable quantum internet technologies.

References

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