

QUANTUM COMMUNICATION – SCIENCE & TECHNOLOGY

NEWS: **India** has successfully demonstrated **quantum secure communication using quantum entanglement** over free space by the DRDO-Industry-Academia Centre of Excellence (DIA-CoE), IIT Delhi.

- This marks a **significant milestone in India's quantum technology roadmap**.

WHAT'S IN THE NEWS?

Technology Used: Entanglement-Based Free-Space Quantum Key Distribution (QKD)

- **Experiment Location and Setup:**
Conducted at IIT Delhi, this experiment involved establishing a **free-space optical link** over **1 km distance**, without using fiber cables.
- **Secure Key Rate Achieved:**
A **secure key generation rate** of approximately **240 bits per second** was achieved using entangled photons.
- **Quantum Bit Error Rate (QBER):**
The experiment maintained a **QBER of less than 7%**, indicating high accuracy in photon-based quantum key transmission.

What is Quantum Communication?

- **Definition:**
Quantum communication leverages principles of **quantum mechanics**, especially **quantum entanglement**, to create ultra-secure communication channels.
- **Purpose:**
The main goal is to **ensure leak-proof communication** — any unauthorized attempt to access the data alters the quantum state, immediately revealing the intrusion.
- **Entangled Photons Principle:**
When two photons are entangled, measuring one instantly determines the state of the other, regardless of the distance between them. This is the foundation for secure key exchange.

What is Quantum Key Distribution (QKD)?

- **Definition:**
QKD is a method to **securely share cryptographic keys** between two parties using quantum properties of photons.
- **Mechanism:**
It employs **light particles (photons)** to carry information, and any disturbance or observation during transmission **changes their quantum state**, thus revealing hacking attempts.

Advantages of Entanglement-Based QKD

- **Enhanced Security:**
Even if the communication devices are compromised or imperfect, **entanglement-based QKD maintains high security**.
- **Eavesdropping Detection:**
Any external attempt to measure or intercept the signal introduces measurable disturbances in the quantum system, **instantly alerting users**.
- **Superior to Prepare-and-Measure Methods:**
Unlike traditional QKD methods (e.g., BB84 protocol), entanglement-based QKD is **more robust** and resistant to side-channel attacks.

Applications of Quantum Communication and QKD

- **Defence Sector:**
Used in **military communications** where high-level security is essential to protect strategic information.
- **Banking and Telecom:**
Quantum-secured communication is vital for **financial transactions and telecom networks** to prevent data breaches and cyber threats.
- **Strategic Sector Protection:**
Helps in **safeguarding sensitive national infrastructure and government networks**.
- **Cost-Efficient Deployment:**
Free-space QKD is ideal in geographies where laying fiber-optic cables is **technically or financially unfeasible**, such as mountainous or remote areas.

Why Use Free-Space Communication?

- **Long-Distance Communication Without Cables:**
Free-space or satellite-based QKD allows secure communication over **hundreds or even thousands of kilometers** without the need for physical cables.
- **Avoids Fiber Optic Costs:**
Installing fiber optic cables is **expensive and impractical** across long distances or challenging terrain. Free-space channels offer a scalable alternative.

Global Comparison and India's Position

- **China's Leadership:**
China established a **4,600 km long quantum network** by 2021 and successfully demonstrated **satellite-based quantum communication** almost a decade earlier.
- **Early Initiatives by Western Countries:**
Since **2005**, **Europe, Canada, and the USA** have conducted free-space QKD demonstrations over **100 km** distances, highlighting their early investment in the field.
- **India's Late Start:**
India began significant efforts in **quantum communication only in the 2020s**, implying a need for accelerated progress to catch up with global benchmarks.

Challenges Faced by India

- **Multidisciplinary Skill Requirement:**
Development of quantum technologies requires **expertise in physics, engineering, photonics, and computer science**, demanding large, well-coordinated teams.
- **Atmospheric Interference:**
Free-space communication is **vulnerable to weather conditions, air turbulence, and environmental factors**, leading to higher error rates compared to fiber-based systems.
- **Need for Infrastructure and Funding:**
Large-scale QKD development demands **significant funding**, research infrastructure, and policy-level prioritization.
- **Stability in Fiber vs Free-Space:**
While fiber optic cables offer **stable and consistent quantum channels**, free-space links are subject to **signal degradation and loss**.

Future Plans Under the National Quantum Mission (NQM)

- **Focus on Satellite-Based QKD:**
India is aiming to develop **satellite-based long-distance quantum communication** as part of its broader National Quantum Mission.
- **Support for Start-ups and Indigenous Technology:**
The mission encourages **quantum start-ups, indigenous manufacturing, and lab-to-market translation** of innovations.
- **National Quantum Network in 5–10 Years:**
India aspires to build a **domestically developed quantum communication network**, including satellite links and secure terrestrial QKD infrastructure, within the next decade.

Source: <https://www.thehindu.com/sci-tech/science/with-money-and-manpower-india-could-achieve-quantum-satellite-communication-by-2030-says-expert/article69724357.ece#:~:text=India%20could%20be%20technologically%20capable,farthest%20such%20transmission%20in%20India%2C>

