

India's Quantum Leap: IIT-Delhi Achieve Secure 1 km Free-Space Quantum Communication

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Quantum Communication Latest News

- Recently, the Ministry of Defence announced that IIT-Delhi and DRDO scientists successfully demonstrated quantum communication over a distance of more than 1 km in free space, marking a major breakthrough in quantum cybersecurity.

Understanding Quantum Communication

- **About Quantum Communication**
 - Quantum communication uses principles of quantum physics—especially quantum entanglement—to create highly secure communication channels.
 - It ensures that any attempt to intercept the communication is immediately detected.
- **The Role of Quantum Entanglement**

- Quantum entanglement is a phenomenon where two particles become so closely linked that a change in one instantly affects the other, regardless of the distance between them.
- When two photons are entangled, measuring one instantly determines the state of the other, regardless of distance.
- This makes quantum communication highly resistant to eavesdropping.

- **Applications in Defence**

- Due to its leak-proof nature, quantum communication is especially valuable in military and national security settings.

- **Key Method: Quantum Key Distribution (QKD)**

- QKD is a major technique within quantum communication that enables two parties to share encryption keys securely, with any interception attempts being detectable.

Working of Quantum Key Distribution (QKD)

- **Purpose of QKD**

- QKD enables two parties to securely share a secret encryption key.
- This key is later used to encrypt and decrypt messages using traditional algorithms (e.g., AES).

- **QKD Is Not Encryption**

- QKD does not encrypt the message itself.
- It only ensures that both parties receive an identical key in a way that cannot be intercepted without detection.
- Just like a letterbox is publicly known but accessible only with a private key, QKD ensures that while the communication channel is known, the key remains private and secure between the sender and receiver.

- **Types of QKD**

- **Prepare-and-Measure QKD**

- One person prepares photons in specific quantum states and sends them to another, who measures them to establish a key.

- **Entanglement-Based QKD**

- A source produces entangled photon pairs—one sent to the first person, the other to the second person.
- The correlated measurements help them derive the same key securely.

- **Security Advantage**

- Any attempt to intercept the photons in transit disturbs their quantum state, immediately alerting the parties and ensuring tamper detection.

IIT-Delhi's Quantum Communication Achievement

- **Latest Breakthrough: 1 km Free-Space QKD**

- The IIT-Delhi team successfully demonstrated entanglement-based Quantum Key Distribution (QKD) over 1 km through open air on the IIT campus.
- This marks progress beyond fibre-based transmission.

- The photons travel through open air, not through cables or fibres.
- This is useful for communicating over long distances, even between buildings or from the ground to satellites.
- **Towards Satellite-Based QKD**
 - The experiment aims to lay the groundwork for ground-to-satellite QKD, where satellites could beam encryption keys securely to any location across India via atmospheric transmission.
- **Performance Metrics**
 - Secure key rate: ~240 bits per second
 - Quantum bit error rate (QBER): Less than 7%
 - This low error rate is acceptable and shows the system's viability despite challenges like air turbulence, detector noise, and ambient light.
- **How It Works**
 - Entangled photons were sent to two receivers.
 - When both receivers measured their respective photons, results matched over 93% of the time—validating entanglement and secure key distribution.
- **Past Milestones by IIT-Delhi Team**
 - 2022: Quantum link between Vindhyachal and Prayagraj
 - 2023: 380 km QKD using telecom fibre (QBER: 1.48%)
 - 2024: QKD over 100+ km optical fibre link
 - These progressive steps showcase India's growing capability in quantum-secure communication infrastructure.

What Lies Ahead for Quantum Communication in India

- **Building a Quantum Communication Network**
 - The next step is to establish a multi-node quantum network, enabling secure communication across various locations.
 - India aims to join global leaders like China, which already has a 4,600 km hybrid quantum network combining satellite and optical links.
- **Civilian Applications**
 - Quantum communication also holds promise for banking, telecom, and data security—where ultra-secure channels are vital to protect sensitive information.
- **Towards a Quantum Internet**
 - A future quantum internet could revolutionise:
 - Distributed quantum computing
 - Precision sensing
 - Secure time synchronisation
 - Highly encrypted communication networks
 - The U.S. is targeting such a network by the mid-2030s.
- **Government Support: National Quantum Mission**
 - To accelerate progress, the Indian government launched the National Quantum Mission in 2023, allocating Rs 6,000 crore for the 2023–2031 period to support research and infrastructure

development in quantum technologies.

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