Satellite-Ground Integrated Quantum Network Construction and Applications

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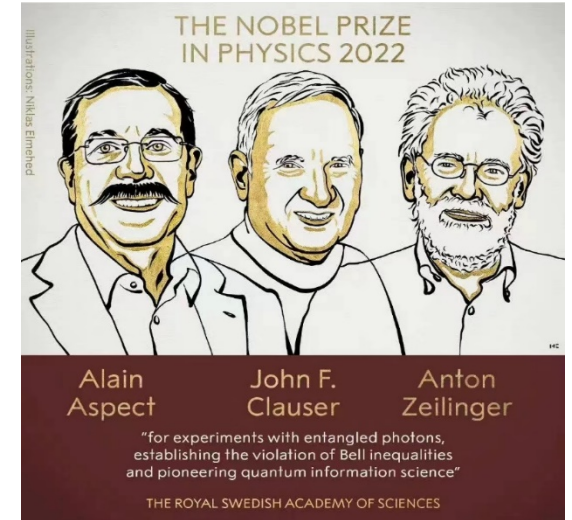
25 July, 2023

The era of quantum information is coming

2022 Nobel Prize in Physics[1]

- **For their pioneering work in the field of quantum information science, clearing the way for new technologies based on quantum information**

- **Intense research and development are underway to utilise the special properties of individual particle systems to construct quantum computers, improve measurements, build quantum networks and establish secure quantum encrypted communication.**

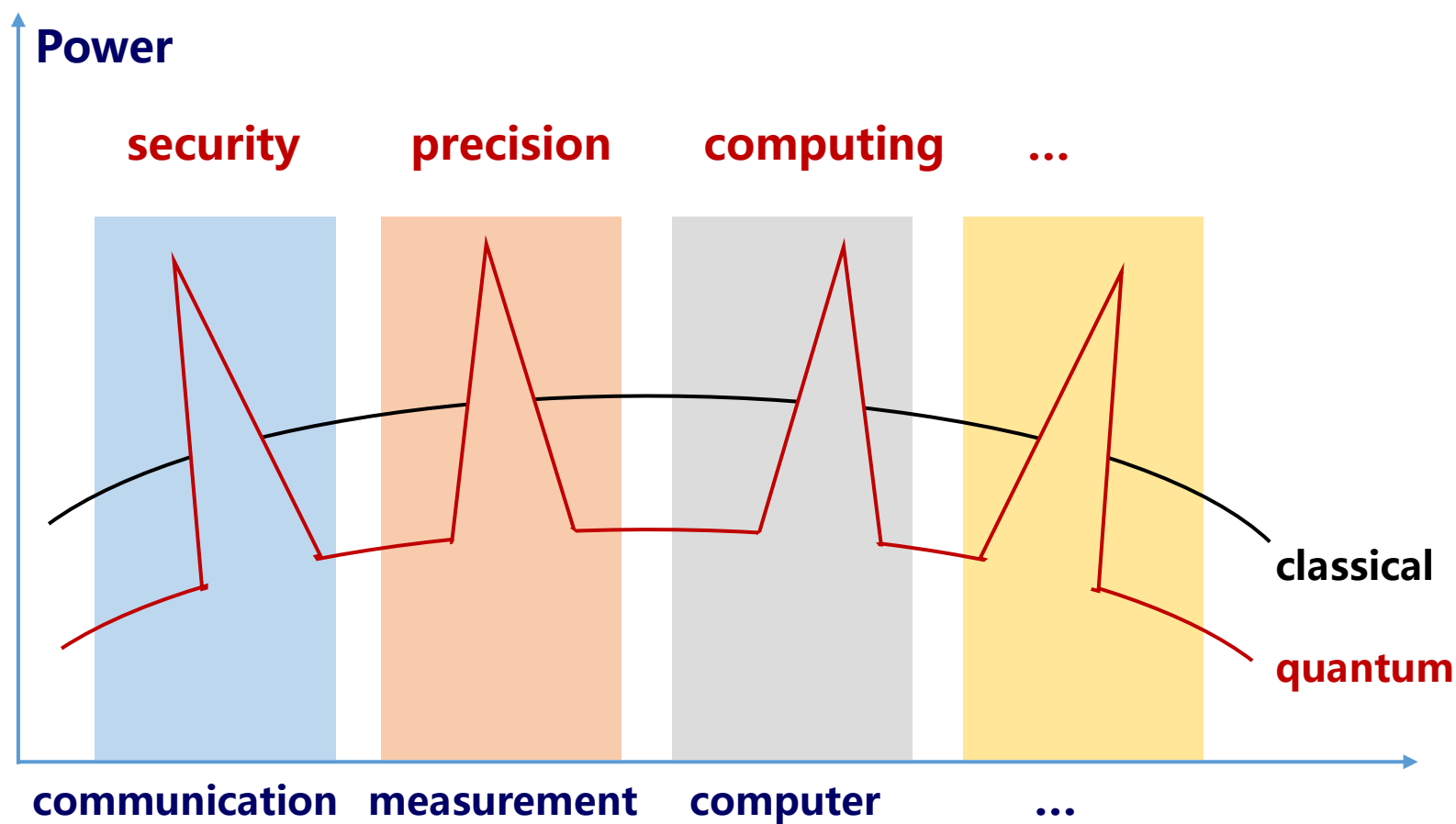   **——THE NOBEL PRIZE IN PHYSICS 2022 POPULAR SCIENCE BACKGROUND**

THE NOBEL PRIZE IN PHYSICS 2022

Alain Aspect   John F. Clauser   Anton Zeilinger

"for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science"

THE ROYAL SWEDISH ACADEMY OF SCIENCES

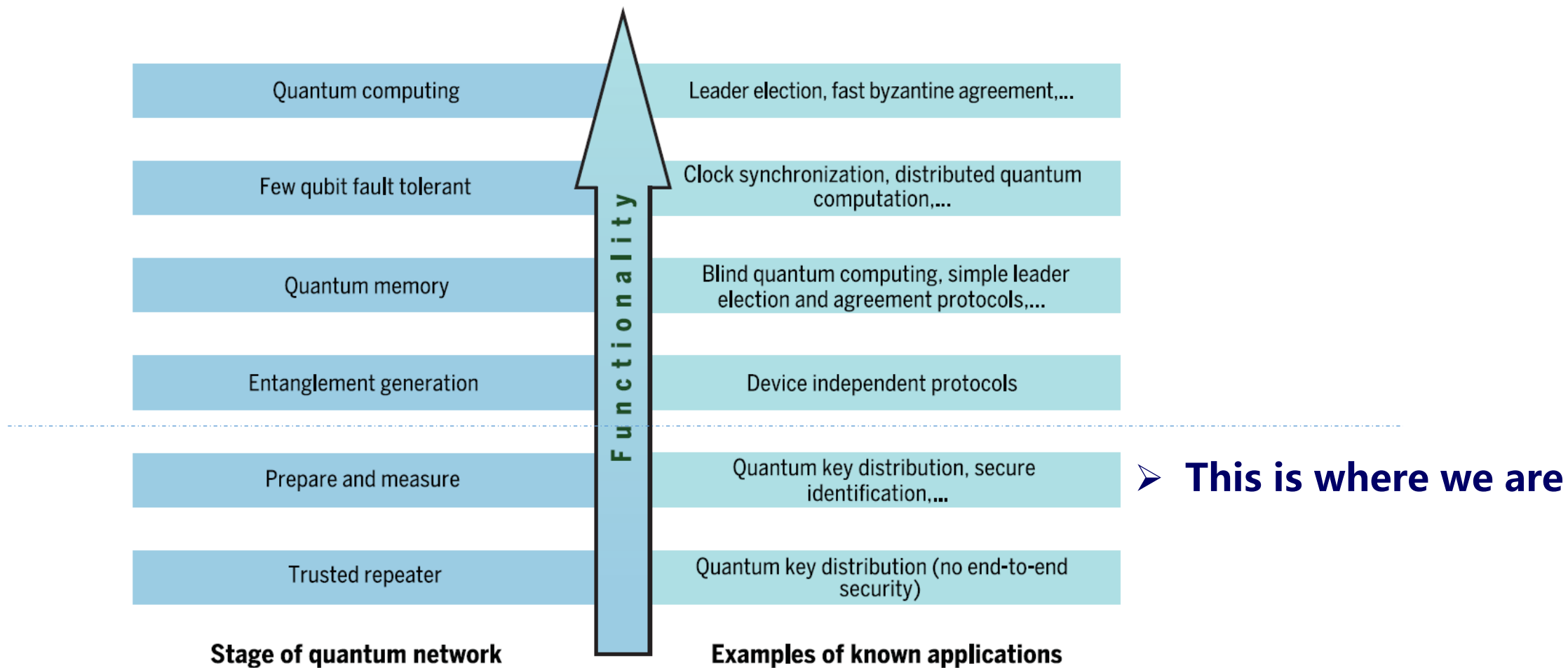1、 https://www.nobelprize.org/prizes/physics/2022/press-release/

Quantum information and classical information are complementary

QKD network is the primary form of quantum Internet

Stage of quantum network	Examples of known applications
Quantum computing	Leader election, fast byzantine agreement,...
Few qubit fault tolerant	Clock synchronization, distributed quantum computation,...
Quantum memory	Blind quantum computing, simple leader election and agreement protocols,...
Entanglement generation	Device independent protocols
Prepare and measure	Quantum key distribution, secure identification,...
Trusted repeater	Quantum key distribution (no end-to-end security)

Functionality

➢ **This is where we are**

Quantum network based on fiber

From experimental to commercial

Beijing-Shanghai QKD backbone network (2013-2017) → **National wide-area quantum secure communication network (2018-2022)**

Feature

- Exceeds 10,000 kilometers (6,214 miles) in length
- Commercial services have been provided in Beijing, Shanghai, Guangzhou, etc.
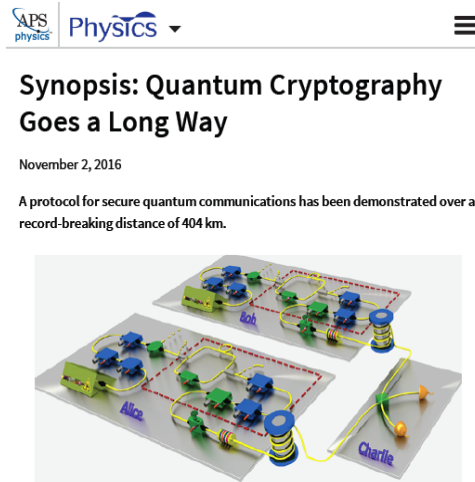
Upgrade quantum network based on fiber

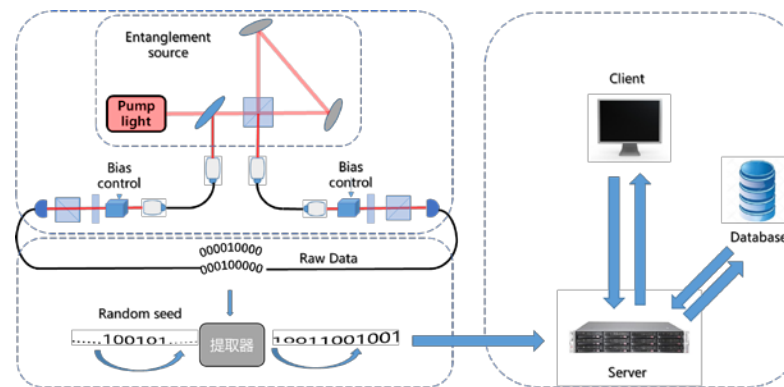Upgrade the present fiber network in China
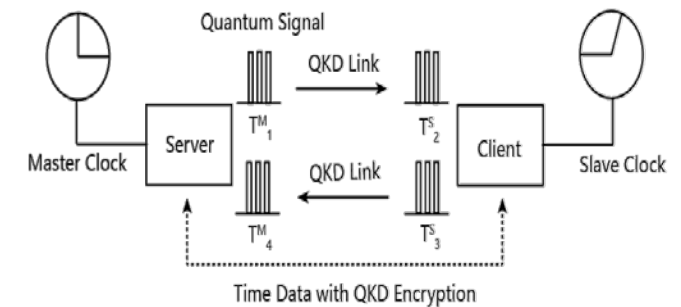
MDI/TF QKD

DIQRNG in quantum network

Integration of QKD and time-frequency transmission
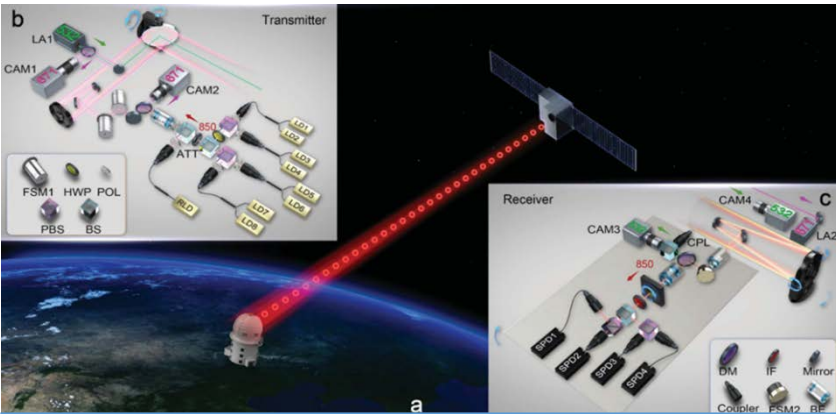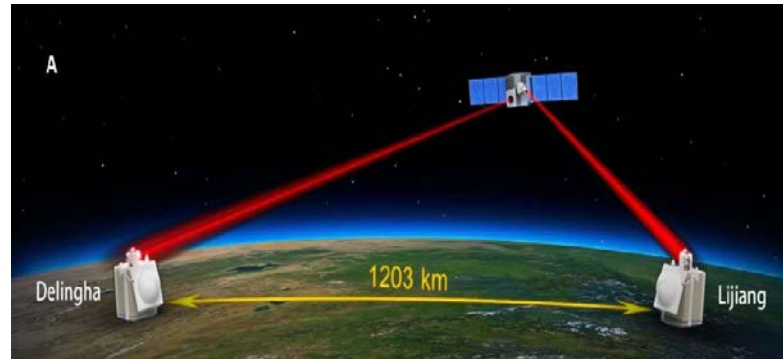

PRL 117, 190501 (2016)

http://sjs.qilushop.cn/web/#/
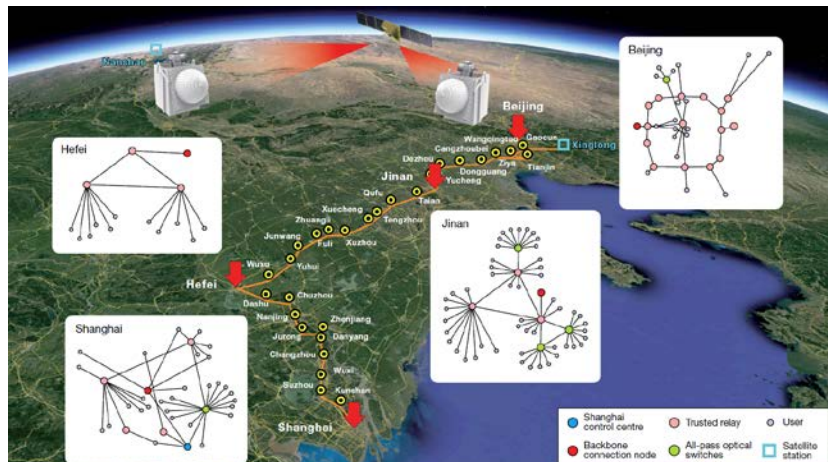
Nature Physics, 16, 848–852 (2020)
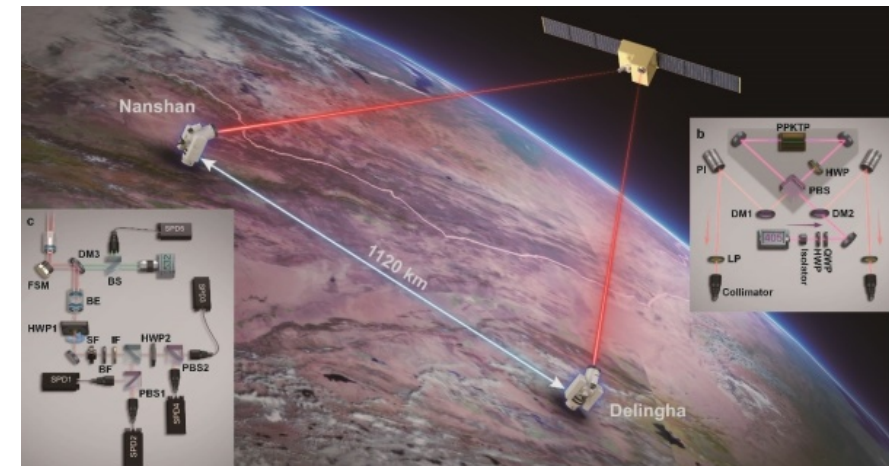
Satellite-to-Ground
Quantum Key Distribution

Satellite-to-Ground
quantum entanglement
distribution
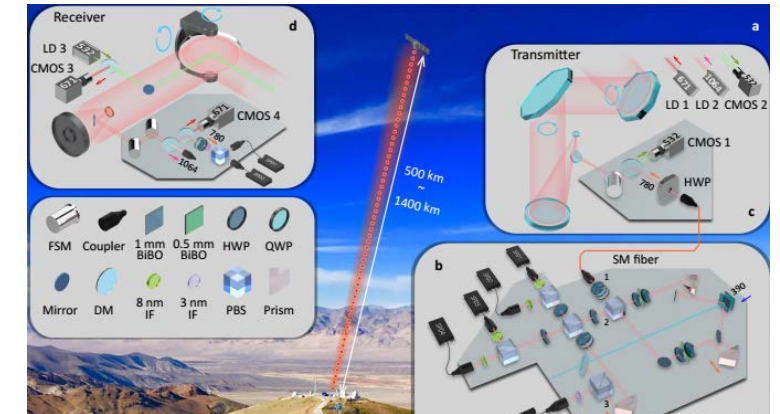
Ground-to-Satellite
Quantum Teleportation

Intercontinental QKD

Satellite-to-Ground QKD
based on entanglement

Upgrade quantum network based on satellite

July 2022: "Jinan-1" was launched

- Real-time satellite-to-ground quantum key distribution between micro-nano satellites and miniaturized ground stations.
- Lay the foundation for the construction of a low-cost, practical space-earth integrated wide-area quantum secure communication network.

The differences between "Jinan-1" and "Micius"

- Lighter weight: only 23 kg, 1/5 of the "Micius "
- The frequency of the light source: 6 times higher
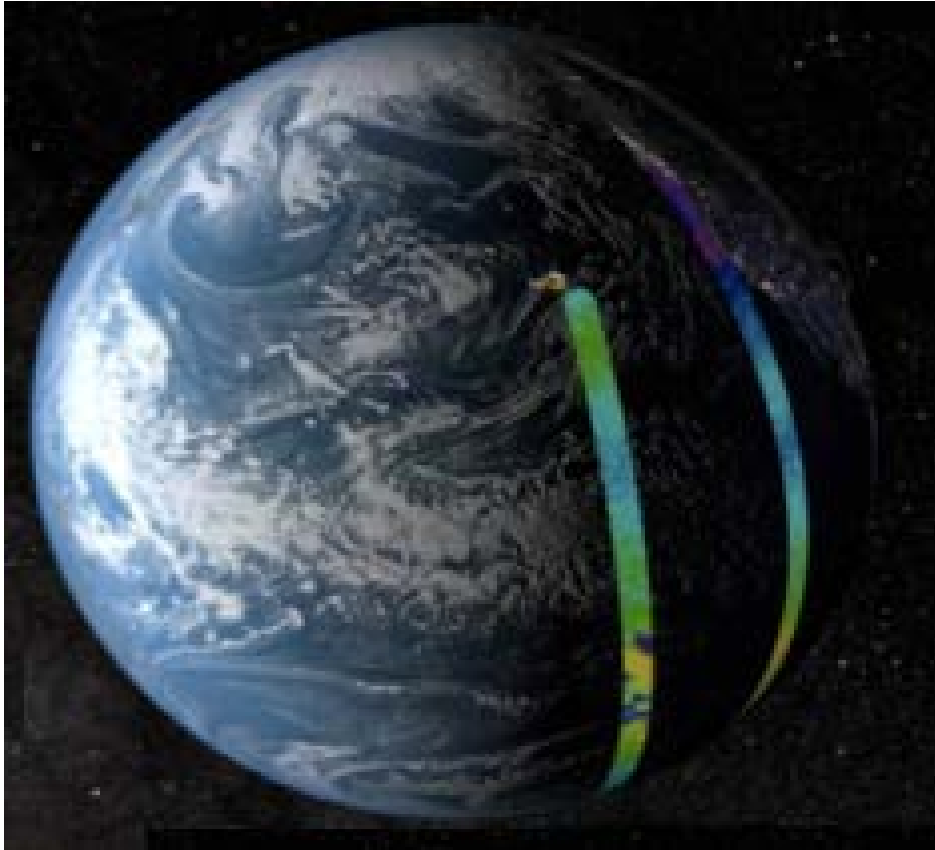- Key generation: 2-3 orders of magnitude higher

Smaller

more economics

more practical

Upgrade quantum network based on satellite

**Take Micius as an example**

limitations of Micius

- Experiment time is ~ 6 minutes for each pass
- Coverage range is about 500km (Radius)
- Have to be in the shadow of earth
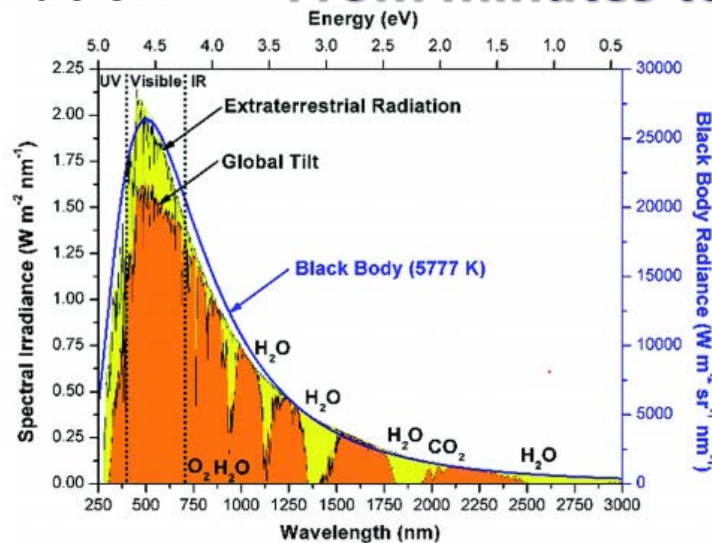- The ground station is expensive to maintain, and it must be re-coated every year

Solutions

- ☑ Quantum constellation with LEO satellites
- ☑ The MEO-to-GEO quantum satellite
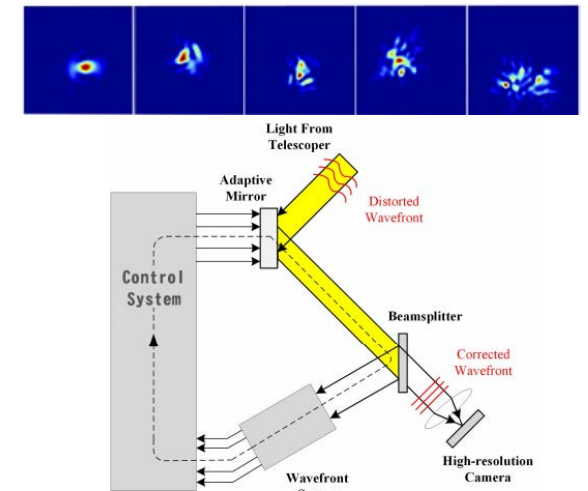- ☑ Development of a portable ground station

☑ **Wide area coverage.**

☑ **Breakthrough earth shadow limit.**

☑ **Longer experiment duration——From minutes to hours.**
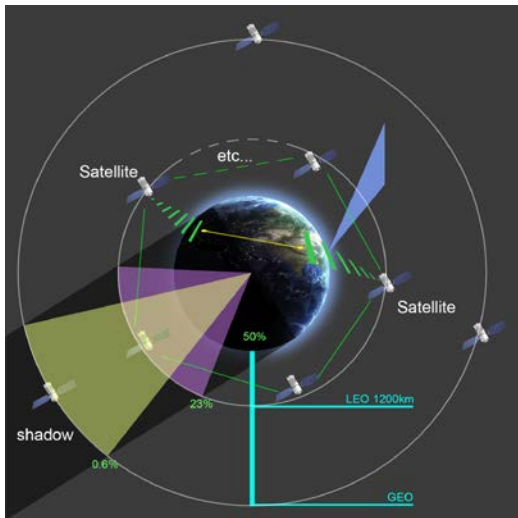
Ultra-high optical loss

Bright background sunlight

Terrible optical mode

A large number of technological breakthroughs are required for these goals. A good optical system design is required to reduce the ultra-high channel loss caused by long-distance links. Good optical filtering is needed to overcome the influence of the sun's background light. It is necessary to use advanced technologies such as adaptive optics to optimize the spatial pattern of optical signals.

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Development of a portable ground station

Micius Ground Station

- Weight: ~10 Tons
- Power: ~60kW
- Need a special dome observation building needs to be built
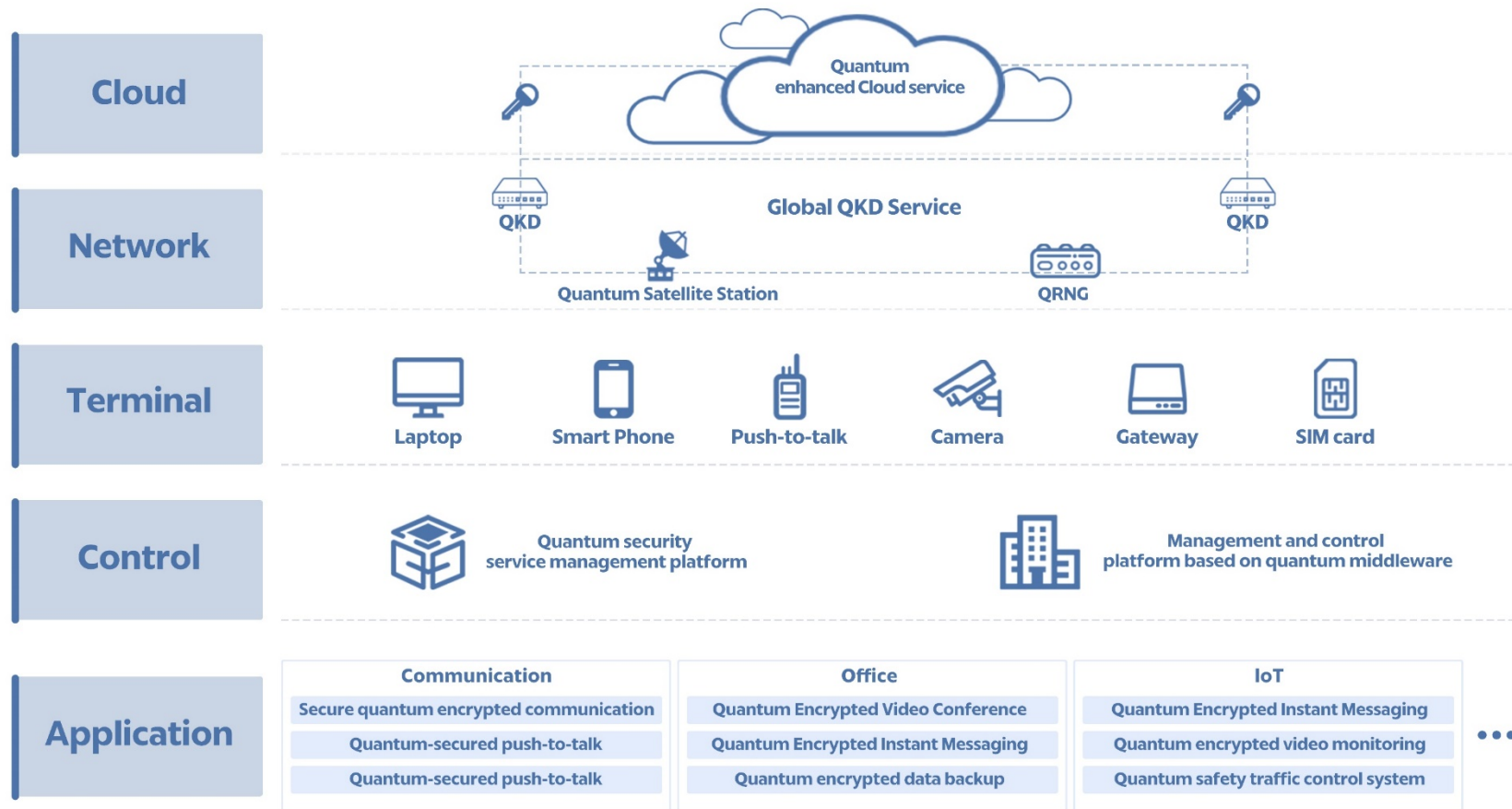- High maintenance cost, re-coating every year

Portable Ground Station

- Weight: ~500kg/100kg
- Power: ~300W
- Can be quickly deployed, temporarily erected before use
- High degree of automation and easy operation
- Modular design, quick replacement in case of faults

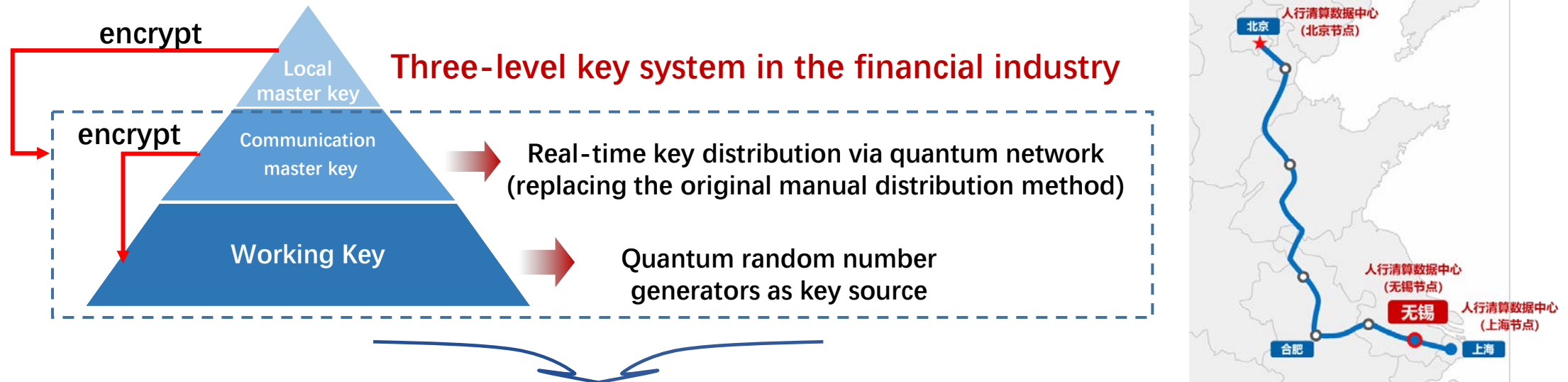## Product system

https://qtict.com/english

Applications: Quantum-enhanced financial services

The People's Bank of China Clearing and Payment System

Key generation, distribution and update between bank clearing data center nodes based on quantum technologies

encrypt

encrypt

Local master key

Communication master key

Working Key

Three-level key system in the financial industry

Real-time key distribution via quantum network (replacing the original manual distribution method)

Quantum random number generators as key source

- **Security improvement:** root key security guaranteed, high-frequency large-scale key distribution enabled
- **Cost reduction:** All sub-service systems can share the common quantum-based security infrastructure via flexible APIs, needless for separate development

Commercial quantum secure applications for mobile telecom terminals were carried out in practice
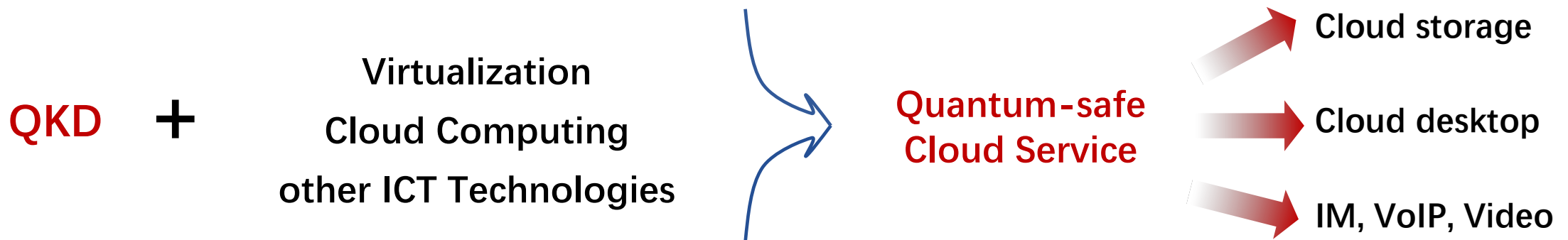

- End-to-end encryption with keys extracted from QKD network
- Achieve one-session-one-key for each call

May 17th, 2022 (World Telecommunication and Information Society Day)
China Mobile released
Quantum Encryption Call Service (VoLTE version)

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Quantum-safe Cloud Service (QCS) is to embed quantum security services into the basic components of ICT cloud platforms, where quantum secure communication plays an essential role of its overall ICT architecture, to provide generic cryptographic services based on unified quantum key generation and management capabilities

QKD **+**

Virtualization

Cloud Computing

other ICT Technologies

Quantum-safe Cloud Service

Cloud storage

Cloud desktop

IM, VoIP, Video

- QCS can provide quantum-security-enhanced computing, storage, network and other digital resources through the flexible quantum key management and control mechanisms

- QCS is adopted as an important security solution for the "east-data-west-computing project"

Call for cooperation

Like climate change and public health, information security is a global issue.
After a three-year delay caused by the pandemic, we call for more international communication and cooperation

the international cooperation
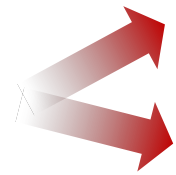
Standardization   ETSI, ITU, etc.

Industrialization   Infrastructure and Applications

Thanks