Quantum communication in Russia: status and perspective

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Quantum communication as a strategic technological priority
Government programs and investment
Major QKD research groups in Russia
Development directions and status
QKD standardization policy
Our view of quantum-secure future

“Point-to-point QKD technology in Russia is characterized by a high degree of completeness (with a notable exception of certification procedures) and has been included into National Technology Initiative as well as industrial investment programs”.

From the roadmap “Data Economy: Quantum technologies”, 2019
Data Economy government program (2019-2024)

Continuation of National Technology Initiative (NTI) program (launched in 2014), that focused on forming hi-tech markets. See https://asi.ru/eng/nti/

Aims:
1. Adapting laws, regulations and standards
2. Research and development
3. Education
4. Information infrastructure
5. Information security (for people and state)

Program amount: $7.5 bil. (government funding), plus comparable amount of industrial investment. $0.7 bil. for Quantum Technologies

Main instruments:
1. Creation of Leading Research Centers
2. Co-funding of R&D supported by industry
3. Technological start-up funding
4. Regional project support
5. Industry digital platforms support
Data Economy: “Quantum technologies”. Main directions (2019-2024)

Quantum computing and simulation:

Subtechnologies:
1. Superconducting
2. Neutral atoms
3. Ion traps
4. Photonic circuits
5. Polariton condensers

R&D directions:
1. Quantum computers and simulators
2. Quantum error correction codes
3. Quantum algorithms
4. Cloud platform for quantum computing

Quantum communication:

1. Point-to-point QKD
2. CV QKD
3. Quantum networking
4. Quantum and classical channel multiplexing
5. Trusted repeater network
6. QKD on-chip
7. MDI QKD
8. Quantum memory
9. Quantum repeaters
10. Free-space QKD
11. Satellite QKD
12. QKD for IoT
13. Single photon detectors
14. Quantum IoT

Quantum sensing and metrology:

1. Quantum clock
2. Gyroscopes
3. Accelerometers and gravitometers
4. Temperature, electric and magnetic field sensors
5. Spintronic sensors
6. Plasmonic 2D materials
7. Solid state photomultipliers
8. Electronic nose

Source: roadmap draft “Data Economy: Quantum technologies”, 2019
ITU Workshop on Quantum Information Technology for Networks
Shanghai, China, 5-7 June 2019

QKD in Russia as an industry-ready technology

QKD research centers
- ITMO UNIVERSITY
- RQC
- KQC
- Kazan Quantum Center

QKD manufacturers
- SMARTELECOM
- infotechs
- ORATE

Network device manufacturers
- CNB
- s·terra
- АМИКОН

Telecom operators and IT
- СМАРТС
- ТАТТЕЛЕКОМ
- open code

International companies
- Rostelecom
- SBERBANK
- GAZPROMBANK
- ПСД
Quantum network testbeds in Russia

Saint Petersburg: Backbone QKD networks

Kazan: QKD networks with trusted and quantum repeaters

Samara: Software-defined quantum networking

Moscow: Secure banking and regional networks
Dr. Artur Gleim, head of quantum information lab, ITMO University. Director general, Quanttelecom LLC.

QKD research groups:
ITMO University (St. Petersburg)

Main development directions:

- Subcarrier wave QKD
- CV QKD
- Quantum hacking
- QKD protocols
- Single photon detectors
- Quantum RNGs
- SDN QKD networking
- Quantum networking

Subcarrier wave QKD scheme
2011 – R&D, experimental demonstration of quantum channel formation and communication using the subcarrier wave QKD method;

2012-2013 – Working prototype created, successful laboratory tests of technical parameters

2014 – **Metropolitan area quantum link launched at ITMO**

2014-2015 – Finalization of separate system modules for optimizing their characteristics

2015-2016 – Quantum Communications LLC launches sales with a 340 000 EUR contract

2016 – ITMO & KRNTU-KAI launch the **first Russian multimode quantum network** in Kazan

2017 – ITMO and OpenCode launched the **first software defined quantum network**

2018 – ITMO and SMARTh are developing **quantum-secure distributed data center**

2019 – ITMO and KRNTU-KAI launched **160 km intercity quantum channel** over a deployed fiber
Field-test of intercity QKD link (160 km), 2019

Year: 2019 (to be published)
QKD protocol: phase subcarrier wave [1,2]
Wavelength: 1550.12 nm
Mean photon number: 0.2
Clock frequency: 100 MHz
Bob loss: 6.4 dB
Quantum channel loss: 45 dB
Detector: SNSPD (Scontel, Russia)
Quantum efficiency: 50%
Dark counts: 0.5 Hz

Node 1: Kazan Quantum Center, KRNTU-KAI, Kazan
Node 2: Tattelecom PJSC building, Chistopol town

Quantum channel length: 160 km (45 dB)

ITU Workshop on Quantum Information Technology for Networks
Shanghai, China, 5-7 June 2019

Dr. Yury Kurochkin, leader of quantum communication group, RQC. Technical director, Qrate LLC.

**QKD research groups:**
Russian quantum center (Moscow)

**Main development directions:**

- Fiber and free-space QKD
- Error correction algorithms
- Quantum hacking
- QKD protocols
- Single photon detectors
- Quantum RNGs
- Quantum-secured blockchain
- Quantum networking
ITU Workshop on Quantum Information Technology for Networks
Shanghai, China, 5-7 June 2019

QKD research groups:
Russian quantum center (Moscow)

- 2015 – R&D, experimental demonstration of quantum channel electronic subsystem
- 2015 – QKD project funded by Ministry of Education and science
- 2016 – Developed software platform for quantum key processing
- 2017 – Launched a metropolitan area QKD network in Moscow connecting Gazprombank offices
- 2017 – Developed high-speed (300 MHz) QKD operation electronics
- 2017 – Launched a quantum link between Sberbank offices
- 2017 – Gazprombank infrastructure was used to test quantum key distribution on a blockchain in real-life conditions
- 2018 – Started serial production of QKD systems

Sources: goqrate.com, https://www.ethnews.com
Prof. Sergei Kulik, head of quantum optics lab, NTI center for quantum technology, Moscow State University

Main development directions:

- Fiber and free-space QKD
- Single photon sources
- Single photon detectors
- Quantum tomography
- Key processing algorithms
- QKD protocols
- Quantum RNGs
- Quantum networking

Source: quantum.msu.ru
- **ITMO University QKD system** was analyzed for possible loopholes by Quantum Hacking group (then at University of Waterloo, Canada). Report publication pending.

- **Latest results:**

- **Russian Quantum Center** is also actively involved in quantum hacking research.
Quantum communication technology groups: Zavoisky Physical-Technical Institute (Kazan)

Main development directions:

- Free-space QKD
- Single photon sources
- High-dimensional quantum states
- Angular momentum photon encoding

Prof. A.A. Kalachev, director of Kazan Zavoisky Physical-Technical Institute of RAS

Automatized precise telescopic systems for free-space QKD
Main development directions:

- Optical quantum memory
- Quantum repeaters
- Fiber optical QKD
- Quantum networking
- QKD protocols
- Quantum sources

Experimental setup of ROSE quantum memory
QKD standardization in Russia

Technical Committee for standardization “Cryptography and security mechanisms”

Encryption methods
Blockchain technology
Message authentication
Digital signatures

and others...

QKD applications
Network infrastructures

Internet of things
Big data

and others...

https://tc194.ru/en/
Our view of secure quantum future

**New markets**
- Quantum communication devices
- Quantum network operators
- Quantum computing
- Security services

**Application areas**
- Robotics
- Smart transport
- Secure satellite communication
- Distributed quantum calculations

**User classes**
- Ground network nodes
- Satellites
- Unmanned vehicles
- Drones and robots
- Industrial internet

**Satellite quantum links**
- 300 km

**Quantum telecom network**
- 200 km

**Repeater node**
- 200 km
QKD for securing cyber-physical systems

- Quantum keys for securing data plane of cyber-physical systems (e.g. robots, drones)
- Robots as reliable mobile trusted repeaters for QKD networks

Project goals

- Short-term: using quantum keys for securing control and data planes of mobile robots
- Mid-term: developing mobile QKD stations (Alice module on robot)
- Long-term: developing metropolitan area QKD networks with cyber-physical and stationary nodes

Photos of the implementation: SCW QKD system module, the gamepad issuing movement commands, the mobile robot with a camera operating through a QKD-protected channel.
### QKD in space: roadmap

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>Ground station prepared</td>
</tr>
<tr>
<td>2020</td>
<td>Satellite QKD prototype developed</td>
</tr>
<tr>
<td>2021</td>
<td>QKD module adapted for satellite</td>
</tr>
<tr>
<td>2022</td>
<td>Field test on the ground</td>
</tr>
<tr>
<td>2023</td>
<td>First satellite launched</td>
</tr>
<tr>
<td>2024+</td>
<td>Development of orbital group</td>
</tr>
</tbody>
</table>

*Source: “Digital Economy: Quantum technologies” roadmap, 2019*

- All main QKD groups in Russia are involved into free-space QKD research
- These activities are to be included into several Roscosmos development programs and supported by Union state of Russia and Belarus program “Complex-SG” (2019-2023).
QKD: new international security opportunities

We are ready to work with our international partners on creating **regional and global quantum-secure infrastructures** involving backbone and metropolitan fiber QKD networks and satellite QKD channels.

**Goal:** transcontinental QKD line in Russia to unify Chinese and EU quantum infrastructures

Projected total length of quantum channels — 15,100 km
Conclusion

✔ Quantum technologies have become national research and application priorities for the next five years in Russia.

✔ Quantum key distribution technology in Russia is ready for industrial integration.

✔ Proper QKD certification and standardization procedures are in course of development both on national and international level.

✔ These developments will become a foundation for nation-wide QKD lines in Russia, acting as a unifying link between Chinese and European quantum infrastructures.
Thank you for your attention!

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