

Quantum Key Distribution Testbeds

An Up-to-Date Overview

by: Felix Trunk, Jasmin Neumann, Susanne Naegele-Jackson

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Introduction

Before a new technology can be used commercially on a large scale, first some practical experience has to be obtained. This is usually done in testbeds, where commercial hardware is used under realistic conditions.

As described in the previous WiN-Lab Research **PQC versus QKD**, Quantum Key Distribution (QKD) is somewhere between laboratory and commercial use. While commercial devices are already available, there are still some open questions. Therefore, testbeds are being set up worldwide to gain practical experience for commercial operation.

This document provides an overview of testbeds in the period 2020 to early 2024. These are not controlled laboratory experiments, but QKD realizations between field experiment and commercial network. If possible, network setups with commercial devices, long test durations and high application relevance are described. The focus is on the technologies and network topologies used, the desired goals, the actors involved and the current status (active/in development or planning). While for Germany as far as possible all currently running projects were considered, only selected projects could be considered at the European and especially global level. It is a very dynamic field in which it is virtually impossible to take all aspects into account.

Comparable documents describing selected testbeds up to 2019 and 2022 respectively are: [Quantum key distribution in-field implementations](#) issued by the European Commission and [Recent Progress in Quantum Key Distribution Network Deployments and Standards](#) by M. Stanley et al..

Germany

In Germany, there is a lot of activity in (basic) research in the field of QKD. Examples of this are research projects in the Fraunhofer and Max Planck Societies but also at various universities and universities of applied sciences. However, there are comparatively few commercializations in the form of start-ups, and although there are several small, independent testbeds, there is a backlog compared to other countries such as England, Italy or China.

Germany was or is involved in various European QKD projects such as *OpenQKD* or *EuroQCI* and there are also national projects such as [QuNET](#).

In addition to the following overview of testbeds in Germany, the [homepage of the umbrella project Quantum Communication Germany \(SQuaD\)](#) is also a good starting point for information in this area.

DemoQuanDT

Description:

long-range QKD connection with 18 Trusted Nodes between Berlin and Bonn (approx. 600 km); presumably CV QKD (*KEEQuant*)

Goals:

- research, development and demonstration of secure and cross-network QKD network management
- establishment of a reference laboratory for preparatory tests on the grid compatibility of QKD devices and interface compatibility
- construction of a quantum communication test track with fiber optic infrastructure that closely resembles existing telecommunications network
- demonstration of the entire information processing chain from hardware to application
- testing the resilience of the QKD network in the event of a fault

Status:

testbed active (schedule given in [0]), project duration: 01/2022 - 12/2024

Participants:

ADVA Network Security GmbH, Deutsche Telekom Technik GmbH, Darmstadt University of Applied Sciences, KEEQuant GmbH, Rohde & Schwarz Cybersecurity GmbH, Technical University of Darmstadt

Websites and articles: [project website](#)

Further information and papers:

- [presentation slides 2023-11-07](#)
- [overview poster 2023-06-05](#)
- [0] [presentation slides 2022](#)

Free-Space Link Jena

Description:

free space QKD connection in Jena (approx. 1.7 km) with compact QKD devices; EB QKD (*Quantum Optics Jena*)

Goals:

- demonstration of a quantum-secured video conference
- free space QKD in daylight
- heterogeneous test track: coupling of free space with fiber optics (e.g. *Jena-Erfurt Fiber Link*)
- developing more efficient and cost-effective hardware

Status:

repeated field experiments, project duration (*QuNet*): 10/2019 – 12/2026

Participants:

Abbe Center of Photonics, German Aerospace Center, Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Fraunhofer Institute for Telecommunications HHI, Friedrich-Alexander-Universität Erlangen-Nürnberg, Max Planck Institute for the Science of Light, Quantum Optics Jena GmbH; Part of QuNET

Websites and articles:

- [press release on successful field experiment 2023-07-28](#)
- [press release on successful field experiment 2022-11-23](#)
- [press release on successful demonstration 2021-08-10](#)

Further information and papers:

- [paper with details on Free-Space Link Jena field experiment 09/2023](#)
- [paper with details on the used technology 06/2021](#)

Jena-Erfurt Fiber Link/Q-net-Q

Description:

extension of the existing long-range QKD connection between Jena and Erfurt (approx. 75 km) by additional connections to Nordhausen, Sundhausen and Jena University Hospital (approx. 150 km in total), and plan for connection via Trusted Nodes to Berlin (>240 km) and Frankfurt am Main (>195 km); presumably EB QKD (*Quantum Optics Jena*)

Goals:

- field test of *Quantum Optics Jena GmbH* QKD system in existing optical fibers (*Jena-Erfurt Fiber Link*)
- integration of QKD into existing information and communication technology systems and utilization for various fields of application (*Q-net-Q*)
- testing the application potential of QKD for telemedicine software (*Q-net-Q*)

Status:

field experiments on Jena-Erfurt Fiber Link, network expansion still under construction, project duration (*Q-net-Q*): 03/2023 - 08/2025, project duration (*QuNet*): 10/2019 – 12/2026

Participants:

Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Nordhausen University of Applied Sciences, Quantum Optics Jena GmbH, Jena University Hospital; Part of QuNET and Q-net-Q

Websites and articles:

- [scientific article on expansion 2023-09-01](#)
- [press release on expansion 2023-08-31](#)
- [press release on successful field experiment 2022-09-21](#)

Further information and papers:

- [paper with details on Jena-Erfurt Fiber Link field experiment 09/2023](#)

Munich Quantum Network (MuQuaNet)

Description:

QMAN in Munich with 10 nodes (>50 km in total); DV QKD (IDQ) and EB QKD (*Quantum Optics Jena*), partial free-space connections

Goals:

- development, construction, operation and provision of a heterogeneous quantum-safe communication network for research and evaluation
- preparation of the seamless integration into today's network communications
- demonstration of the wide range of possible applications
- blueprint for the development of tailor-made, highly secure communication networks

Status:

testbed still under construction [0], project duration: 01/2021 – 12/2024

Participants:

German Aerospace Center, ID Quantique SA (IDQ), KEEQuant GmbH, Ludwig-Maximilians-Universität München, Quantum Optics Jena GmbH, Rohde & Schwarz Cybersecurity GmbH, Secunet Security Networks AG, University of the Federal Armed Forces Munich

Websites and articles: [project website](#)

- [0] [general press release on QKD 2023-11-21](#)
- [communication on the development of a KMS 2023-01-05](#)
- [press release on the commissioning of a QKD device from Quantum Optics Jena 2022-06-23](#)
- [press release on the commissioning of the first section 2021-12-07](#)

Further information and papers:

- [project info Rohde & Schwarz Cybersecurity GmbH](#)

Niedersachsen Quantum Link

Description:

long-range QKD connection between Braunschweig and Hanover (approx. 80 km); EB QKD (*Quantum Optics Jena*) and DV QKD

Goals:

- demonstration of the time- and frequency-stable transmission of single photons
- field test of quantum photonic semiconductor devices in long-distance quantum communication networks

Status:

active, project duration (QR.X): 08/2021 - 07/2024

Participants:

Leibniz Universität Hannover, Physikalisch-Technische Bundesanstalt, Quantum Optics Jena GmbH;
Part of QR.X

Websites and articles:

- [press release on the start of operations 2023-12-18](#)
- [initial press release 2021-10-28](#)

Further information and papers:

- [paper on a BB84 experiment with a semiconductor quantum dot 07/2024](#)

OpenQKD Testbed Berlin/Berlin Quantum Communication Testbed

Description:

QMAN with several nodes in the research and development network of Deutsche Telekom AG in Berlin (>60 km in total); *OpenQKD Testbed Berlin*: (Point-to-Point) DV QKD (*IDQ, Toshiba*); *Berlin Quantum Communication Testbed*: Multiuser DV QKD (*VeriQloud*)

Goals:

- demonstration of the integration of QKD into existing network infrastructure for hybrid encryption: various commercial encryption systems, KMS from *Deutsche Telekom AG* (*OpenQKD Testbed Berlin*)
- quantum-safe 5G: PQC for 5G and QKD for securing fibers (*OpenQKD Testbed Berlin*)

Status:

active, project duration (*OpenQKD*): 09/2019 - 03/2023

Participants:

Adva, Deutsche Telekom AG, ID Quantique SA (IDQ), SENETAS, Toshiba, VeriQloud; Part of *OpenQKD*

Websites and articles:

- [press release on the opening of the Quantum Lab 2023-09-04](#)
- [press release on experiment with VeriQloud 2023-05-30](#)
- [article on OpenQKD Testbed Berlin 2021-08-27](#)

Further information and papers:

- [paper containing details on OpenQKD Testbed Berlin 01/2024](#)
- [paper with details on VeriQloud QKD 04/2023](#)
- [paper with details on OpenQKD Testbed Berlin 05/2022](#)

QUBE/QUBE II

Description:

LEO QKD *CubeSat* and associated ground infrastructure; Satellite DV QKD

Goals:

- development of miniaturized (commercial) hardware for QKD satellites based on *CubeSats*
- construction of a ground station

Status:

launch of demonstration satellite planned for 07/2024 but [postponed indefinitely](#), project duration (*QUBE*): 08/2017 - 07/2020, project duration (*QUBE II*): 01/2022 - 12/2025

Participants:

German Aerospace Center (DLR), Friedrich-Alexander-Universität Erlangen-Nürnberg, Ludwig-Maximilians-Universität München, Max Planck Institute for the Science of Light, OHB System AG, Zentrum für Telematik e.V.

Websites and articles: [QUBE project website](#), [QUBE II project website](#)

- [article about planned satellite launch 2024-07-11](#)

Further information and papers:

- [DLR presentation on ongoing satellite QKD projects 2023-09-13](#)
- [paper with details on QUBE II 09/2022](#)
- [paper with details on QUBE 2018](#)
- [QUBE II in Nanosats Database](#)
- [QUBE in Nanosats Database](#)
- [article on different QKD *CubeSat* project 2024-03-26](#)

Europe

Europe is strongly positioned in the field of (basic) research. QKD is part of the major European research initiatives *Quantum Flagship* and *Horizon Europe* and there have been or are some special projects such as [OpenQKD](#) and the [EuroQCI Initiative](#) (part of *Digital Europe*), which aim to build QKD testbeds or (cross-border) infrastructure.

While in some countries, such as Italy, Poland, Spain and England, there are many start-ups and/or already pronounced activities in the QKD environment, other countries such as Germany and France are rather sluggish.

The following overview presents some of the more advanced QKD projects on the European continent in detail. In addition, the [GÉANT whitepaper QKD Concepts and Considerations](#) from 2024 also presents some other QKD projects in the *EuroQCI* context.

Austria: QCICAT

Description:

long-range QKD connections with Trusted Nodes between Innsbruck, Vienna, Graz (>200 km in total) and QMANs in Vienna and Graz; DV QKD (*IDQ, Toshiba and ThinkQuantum*)

Goals:

- QKD secured communication between authorities (*Government QKD in Vienna, QCICAT*)
- secure exchange of medical data between clinics and data center with various QKD systems (*Medical QKD in Graz*)
- research on the combination of QKD with PQC, long-range QKD with Trusted Nodes and field experiments with quantum repeaters (*QCICAT*)

Status:

testbeds still under construction but already demonstration experiments and previous testbeds, project duration (*OpenQKD*): 09/2019 - 03/2023

Participants:

ACONET, AIT, dacoso GmbH, fragmentiX Storage Solutions GmbH, ID Quantique SA (IDQ), Landeskrankenhaus Graz II – West, Medical University Graz, Quantum Technology Laboratories GmbH, Graz University of Technology, ThinkQuantum, Toshiba, TU Wien, X-Net Services GmbH; Part of EuroQCI and OpenQKD

Websites and articles: [project website](#)

- [press release on successful demonstration 2023-04-11](#)
- [ACONET press release on Austrian quantum internet project AQUnet 2021-02-16](#); no more up-to-date information can be found, probably now part of QCICAT!
- [Toshiba press release on QKD for medical and government data applications](#)
- [press release on the use of IQD devices for medical data applications 2020-12-14](#)
- [press release on QKD for medical data applications 2020-10-10](#)

Further information and papers:

- [paper on QKD network in Vienna 05/2023](#)
- [paper on free-space EB QKD in Vienna 04/2023](#)
- [presentation slides on the exchange of medical data in Graz 05/2021](#)
- [paper on China-Austria satellite QKD 01/2018](#)
- [paper on SECOQC QKD network in Vienna 07/2009](#)

Czech Republic: CZQCI

Description:

long-range QKD connections with Trusted Nodes between Prague, Brno, Ostrava and some QMANs (>330 km in total); presumably CV QKD

Goals:

- combination CV QKD and WR
- QKD secure communication between authorities

Status:

CESNET3 upgrade with QKD + T&F compatibility active, QKD use in planning, project duration: 01/2023 - 06/2026

Participants:

CESNET, e-INFRA CZ; Part of EuroQCI

Websites and articles: [project information at CESNET](#)

- [press release on the expansion of the Czech research network 2023-05-30](#)

Further information and papers:

- [press release on commercial QKD test with Toshiba devices by CETIN 2023-11-06](#)

EAGLE-1

Description:

European LEO QKD satellite project with associated ground infrastructure; Satellite DV QKD (*Tesat*)

Objectives:

long-range QKD for critical economic sectors, EU governments and institutions

Status:

satellite launch planned for 2024 [0], mission duration: 3a

Participants:

Airbus Netherlands B.V., Arianespace, ESA, ID Quantique SA (IDQ), SES, SITAEL, TESAT, TNO; Part of EuroQCI, Horizon Europe and ARTES

Websites and articles: [project information at ESA](#)

- [press release on ground station in Luxembourg 2023-11-15](#)
- [0] [press release on the use of IQD QRNG 2023-05-31](#)
- [press release on successful tender of the satellite platform to SITAEL 2022-11-17](#)
- [early press release 2022-09-22](#)

Further information and papers:

- [website of Caramuel](#) (planned European GEO QKD satellite project) 2023-12-26

England: Commercial QMAN in London

Description:

commercial QMAN in London with three nodes in circular topology to which additional users can be connected (>65 km in total); DV QKD (*Toshiba*)

Objectives:

commercial QKD network for the transport of encrypted data from the insurance and banking industry

Status:

active

Participants:

BT, Ernst & Young, HSBC, Toshiba

Websites and articles:

- [press release due to the participation of HSBC 2023-07-05](#)
- [article on the test of the commercial QKD network 2022-06-22](#)
- [press release on the start of the test of the commercial QKD network 2022-04-27](#)
- [initial press release 2021-10-05](#)

Further information and papers:

- [paper on QMAN in London 03/2023](#)

England: UKQN

Description:

long-range QKD connections partly with Trusted Nodes in the south of England between Ipswich, Cambridge, London, Reading, Bristol with extension to Southampton (approx. 500 km in total) in the *National Dark Fibre Infrastructure Service*. In addition, QMANs in Bristol (about 10 km in total) and Cambridge (about 25 km in total) and QKD satellite; DV QKD (*IDQ, Toshiba*) but also research on CV QKD and EB QKD

Goals:

- coexistence of QKD with classical data
- applications for 5G and Industry 4.0
- free-space and space-based QKD connections

Status:

active (no articles for or against can be found ...), satellite launch probably 2024, project duration (*Quantum Communication Hub*): 2014 – 2024 + extension

Participants:

ADVA, BT, Fraunhofer UK, ID Quantique SA (IDQ), Toshiba, UK Space Agency, University of Bristol, University of Kent and others

Websites and articles: [project website](#)

- [press release on the planning of a ground station in Edinburgh 2024-01-24](#)
- [press release on the status of the QKD satellite 2023-08-22](#)
- [press release on the launch of a new national quantum strategy that secures further funding 2023-03-15](#)
- [initial press release on QKD application for Industry 4.0 2020-10-01](#)
- [press release on the commissioning of the UKQN 2020-09-28](#)

Further information and papers:

- [paper on QKD in submarine cable between England and Ireland 09/2023](#)
- [paper with overview of English QKD networks 03/2021](#)
- [paper on Bristol QMAN with 5G and SDN 06/2020](#)

Greece: HellasQCI

Description:

QMANs in Athens, Heraklion and Thessaloniki with long-range connections to optical ground stations for QKD satellites; DV QKD

Goals:

- establishment of government, industry and one research testbed(s)
- applications in public services, healthcare, critical infrastructure, HPC and information and communication technology
- development of new quantum technologies for future quantum internet
- training
- connection to European satellites QKD infrastructure

Status:

testbeds still under construction but already QMAN in Athens and preliminary investigations for satellites QKD, project duration (*HellasQCI*): 01/2023 - 06/2025

Participants:

AUTH, FORTH, GRNET S.A., ICCS, ID Quantique SA (IDQ), Ministry of Digital Governance, MOH, NCSR, NKUA, NOA, Nokia, QUBI, SETU, SPH, UNILU, part of EuroQCI

Websites and articles: [project website](#)

- [article on QMAN in Athens with Nokia participation 2023-12-18](#)

Further information and papers:

- [paper on theoretical investigation of satellites QKD with small and mobile optical ground stations 04/2024](#)
- [paper on QMAN in Athens with focus on SDN 03/2024](#)
- [paper on FTTH QKD experiment 01/2024](#)
- [paper with preliminary investigations on optical ground station for QKD 03/2022](#)
- [paper on theoretical investigations of satellite QKD 11/2021](#)

Ireland: IrelandQCI

Description:

long-range QKD connections between QMANs in Dublin and Cork via Waterford (>250 km in total);
MDI QKD

Goals:

- integration of QKD into conventional communication networks
- studies on QKD applications in the public, industrial and academic sectors

Status:

testbeds still under construction, project duration (*IrelandQCI*): 03/2023 - 09/2025

Participants:

ESB Telecoms, HEAnet, Maynooth University, South East Technological University, Trinity College Dublin, University College Cork, University College Dublin, University of Galway, Walton Institute, part of EuroQCI

Websites and articles: [project website](#)

- [press release on the launch of IrelandQCI 2023-06-16](#)
- [press release on funding of industry-oriented testbed at the Walton Institute 2021-11-08](#)

Further information and papers:

- [paper on QKD in submarine cable between England and Ireland 09/2023](#)
- [CoQREATE United States-Ireland knowledge exchange project 2023-2025](#)

Italy: QUID

Description:

long-range QKD (*Italian Quantum Backbone*) connections between QMANs in Turin, Milan, Padua, Trieste, Florence, Rome and Naples (a total of >1000 km); DV QKD and TF QKD

Goals:

- national QKD infrastructure
- european supply chain
- coexistence of QKD, classical data and WR
- connection to European (space-based) QKD connection
- investigations on usable optical fibers and free-space QKD
- practical applications

Status:

testbeds still under construction but already fiber optic infrastructure and (previous) field experiments, project duration (*QUID*): 01/2023 - 06/2025, project duration (*OpenQKD*): 09/2019 - 03/2023

Participants:

ASI, Coherentia, GARR, Italian Metrological Institute, Leonardo, National Research Council, Polytechnic University of Milan, QTI, TAS-I, Telespazio, Telsy, ThinkQuantum, TIM, TOP-IX, Toshiba, University of Padua; Part of *OpenQKD* and *EuroQCI*

Websites and articles: [project website](#), [project information at INRiM](#)

- [press release on HD QKD field experiment 2024-03-07](#)
- [press release on Italy's plans within EuroQCI 2023-08-01](#)
- [press release on field experiment with TF QKD 2022-01-20](#)

Further information and papers:

- [paper on QKD in submarine cable between Malta and Sicily 09/2023](#)
- [paper on Industry 4.0 QKD application in Turin 04/2023](#)
- [paper on field experiment with TF QKD 01/2022](#)
- [paper on field experiment in Padua 11/2021](#)
- [paper on field experiment in Padua 06/2021](#)
- [paper on field experiment in Padua 12/2020](#)

Italy, Slovenia and Croatia: Inter-Europe QKD at G20 Conference

Description:

long-range QKD connection with Trusted Node in Postojna between Trieste, Ljubljana and Rijeka (approx. 200 km in total); DV QKD (QTI)

Objectives:

media-effective demonstration of QKD

Status:

completed field experiment

Participants:

Lightnet, National Institute of Optics CNR-INO, OiV, QTI, Sparkle, Stelkom, Technical University of Denmark, University of Ljubljana, Telekom Slovenije d.d., TIM, University of Trieste

Websites and articles:

- [article on successful demonstration 2021-08-05](#)

Further information and papers:

- [paper with additional details 12/2022](#)
- subsequent demonstrations at European meetings:
 - o [press release about demonstration with various European QKD manufacturers at the Digital Assembly 2023 2023-06-19](#)
 - o [press release about demonstration with various European QKD manufacturers at EQTC 2023-10-23](#)

Netherlands: Commercial Port of Rotterdam QKD Network

Description:

commercial QKD network featuring a central hub and multiple parties in the port of Rotterdam (>30 km in total); Multiuser MDI QKD (*Q*Bird*)

Objectives:

cost-efficient and scalable commercial QKD network for data encryption at the *Port of Rotterdam* to connect *Port of Rotterdam Authority* with *Portbase* and two or three other maritime logistics companies

Status:

active

Participants:

*Cisco, Eurofiber Nederland, InnovationQuarter, Intermax, Port of Rotterdam, Q*Bird, Single Quantum;*
Part of *Quantum Delta NL Programme*

Websites and articles:

- [press release from Port of Rotterdam about the ongoing project 2024-05-14](#)
- [press release on Eurofiber's participation 2024-02-13](#)
- [article about used QKD protocol 2024-11-17](#)
- [article about project 2022-11-16](#)
- [initial press release 2022-10-03](#)

Netherlands: LUQCIA/QCINed

Description:

QMANs near Eindhoven, in the province of Utrecht and between Amsterdam and The Hague each with several nodes (approx. 95 km in total); EB QKD (*QuTech*) and DV QKD (*IDQ*)

Goals:

- national testbed for applied research on QKD (*LUQCIA*)
- space-based QKD connection (*LUQCIA*)
- use of quantum systems and networks to test quantum communication technologies and integration into existing networks (*QCINed*)
- application development and testing (*QCINed*)
- test of long-range QKD and automation (*QCINed*)
- exchange of government data (*QCINed*)

Status:

testbeds still under construction but some sections already active and previous testbeds, project duration (*LUQCIA*): 05/2022 - 05/2026, Project duration (*QCINed*): 01/2023 – 06/2025

Participants:

Eurofiber, ID Quantique SA, Juniper Networks, Interdisciplinary Centre for Security, Reliability and Trust, QuTech/TU Delft; Part of EuroQCI and NextGenerationEU

Websites and articles: [project information at TU/e](#), [project information at Quantum Delta NL](#)

- [press release on successful demonstration 2023-07-07](#)
- [article about LUQCIA project 2023-06-08](#)
- [press release about delivery of IDQ QKD devices for planned testbed 2022-08-26](#); no more up-to-date information can be found!
- [article about planned testbed 2022-07-08](#)
- [press release about QKD experiment 2022-06-22](#)

Further information and papers:

- [paper on MDI QKD field test in coexistence with classical data 01/2022](#)
- [paper on Eindhoven QKD Network Testbed with focus on SDN 09/2019](#)

Poland: NLPQT/PIONIER-Q

Description:

expansion of the existing long-range QKD connection with five Trusted Nodes between Poznan and Warsaw in the *PIONIER* research network and the QMAN in Poznan in the *POZNAN* research network (approx. 380 km in total) with several nodes by additional QMANs and long-range QKD connections to Krakow and Gdansk (>1000 km in total); DV QKD (*IDQ, Toshiba*)

Goals:

- integration of the QMAN in Poznań with the Poznań-Warsaw QKD connection (*NLPQT*)
- integration of QMANs with long-range QKD connections (*PIONIER-Q*)
- connection of HPC centers to QKD infrastructure (*PIONIER-Q*)

Status:

NLPQT sections already active [0], project duration (*OpenQKD*): 09/2019 - 03/2023, project duration (*NLPQT*): 11/2018 – 12/2023, project duration (*PIONIER-Q*): 02/2023 - 07/2025

Participants:

ID Quantique SA (IDQ), PIONIER Consortium Polish Optical Internet Poznan, Poznań Supercomputing and Networking Center, Toshiba, University of Warsa; Part of EuroQCI and OpenQKD

Websites and articles: [project information at EU Funding & Tenders Portal](#)

- [0] [article on Poland's plans within EuroQCI 2023-11-15](#)
- [press release on the use of IQD devices in Poland 2022-09-05](#)
- [press release on QKD link between Poznan and Warsaw 2022-06-15](#)
- [press release on the first Polish QKD deployment 2021-06-17](#)

Further information and papers:

- [paper with details on Poznan QMAN 01/2024](#)

Poland and Czech Republic: Cieszyn – Ostrava - Connection

Description:

cross-border long-range QKD connection (approx. 75 km) between Cieszyn (Poland) and Ostrava (Czech Republic); DV QKD (*IDQ*)

Goals:

- cross-border QKD connection
- coexistence of QKD and precise time transmission

Status:

no longer active (QKD verifiable 07/2021 – 04/2022: [0], [1]), project duration (*OpenQKD*): 09/2019 - 03/2023

Participants:

CESNET, e-INFRA CZ, ID Quantique SA (IDQ), IT4Innovations, PIONIER Consortium Polish Optical Internet Poznan, Poznań Supercomputing and Networking Center, Technical University in Ostrava;
Part of *OpenQKD*

Websites and articles:

- [0] [press release on successful QKD and T&F between Poland and the Czech Republic 2022-04-28](#)
- [press release on the use of IQD devices for QKD between Poland and the Czech Republic 2021-09-01](#)
- [press release on successful QKD between Poland and the Czech Republic 2021-08-17](#)
- [1] [press release on the first Czech QKD and successful QKD between Poland and the Czech Republic 2021-07-19](#)

Further information and papers:

- [paper on cross-border QKD connection and precise time transmission 10/2022](#)
- [presentation slides on cross-border QKD connection 2021-10-15](#)

Spain: MadQCI

Description:

QMAN in Madrid with over 10 nodes (approx. 100 km in total); DV QKD (*Toshiba, IDQ*) and CV QKD (*Huawei, AIT*), partly multiuser QKD while avoiding Trusted Nodes through passive optical switches

Goals:

- establishment of a European quantum communication infrastructure (connection via space-based QKD connection)
- hardware and software development for QKD
- coexistence with existing classic infrastructure
- SDN design principle
- practical applications, e.g. for network security, protection of critical infrastructure and e-health services

Status:

testbed for application network under construction but already previous testbeds, project duration (*MadQ-CM*): 01/2022 - 05/2025, project duration (*OpenQKD*): 09/2019 - 03/2023

Participants:

AIT, Autonomous University of Madrid, Huawei, ID Quantique SA, IMDEA Networks Foundation, IMDEA Software Institute, National Institute for Aerospace Technology, Polytechnic University of Madrid, REDIMadrid, Spanish Metrology Center, Telefónica, Toshiba, Complutense University of Madrid, Vithas Foundation; Part of EuroQCI, MadQ-CM and OpenQKD

Websites and articles: [MadQ-CM website](#), [EuroQCI Spain website](#)

- [article on planned MadQCI network 2023-04-21](#)
- [article on planned MadQCI network 2023-04-20](#)
- [press release on launch of MadQ-CM 2023-03-16](#)
- [Huawei press release on QKD network field experiment with SDN 2018-06-14](#)

Further information and papers:

- [paper on MadQCI with a focus on passive optical switches 09/2023](#)
- [paper on MadQCI with a focus on SDN 08/2023](#)
- [paper on MadQCI 07/2021](#)

International

China is the clear global leader regarding research, development and practical(!) use of QKD systems. America has focused mainly on PQC and quantum computing in recent years, but there are also some projects for the transmission of entangled photons and the development of quantum memories and repeaters.

Other Asian countries such as South Korea or Singapore also have very advanced QKD programs, some of which are already taking on commercial dimensions. India, which is also investing in QKD, is still relatively in its infancy.

America

- [review article on QKD networks in America 2023-03-23](#)
- [article on American focus on quantum computers vs. Chinese focus on \(satellite\) QKD 2020-09-18](#)

Commercial networks:

EPB Quantum Network

Description:

commercial quantum network in circular topology to connect up to 10 user nodes (>10 km in total) for the distribution of entangled photons in Chattanooga based on the [Bohr-IV quantum network architecture](#)

Status:

active

Participants:

AliroNet, DiCon FiberOptics, EPB, Oak Ridge National Laboratory, Quantum Opus, Qubitekk, Qunnect, University of Tennessee

Websites and articles: [project website](#)

- [article about validation experiments by Qunnect 2023-12-20](#)
- [article about the goals of the EPB Quantum Network 2023-10-10](#)
- [press release on commercial availability 2023-07-25](#)
- [initial press release 2022-11-29](#)

GothamQ

Description:

commercial quantum network in New York with nodes in Brooklyn Navy Yard, Manhattan and Queens for the distribution of entangled photons (>40 km in total)

Status:

so far only demonstration experiments on the transmission of entangled photons

Participants:

New York University, Qunnect

Websites and articles:

- [article on stable distribution of entangled photons in commercial optical fibers in New York 2024-04-15](#)
- [article on expansion of used fiber network to Manhattan 2023-09-14](#)

Phio

Description:

commercial long-range QKD network with Trusted Nodes between Washington, New Jersey and New York (>350 km in total); DV QKD (*IDQ*)

Status:

commissioning in mid-2018; now decommissioned due to lack of commercial interest

Participants:

IDQ, Quantum Xchange

Websites and articles:

- [press release by Quantum Xchange about the first commercial QKD network in America between New York and Washington, which has since been shut down 2019-24-07](#)

Testbeds:

DC-QNet**Description:**

quantum network for the distribution of entangled photons between 6 government organizations in Washington (approx. 230 km in total)

Status:

fiber infrastructure already built but unclear whether already active use

Participants:

Army Research Laboratory, Laboratory for Telecommunication Sciences, Naval Research Laboratory, NASA, National Institute of Standards and Technology, U.S. Naval Observatory

Websites and articles: [overview poster 2022-08-20](#)

- [NIST press release with recommendations 2023-09-01](#)
- [initial press release 2022-06-27](#)

Further information and papers:

- [paper on studies on time synchronization 05/2024](#)

IEQNET/AQNET-SD/InterQnet**Description:**

long-range quantum connections for the distribution of entangled photons between (campus quantum networks in) *Argonne National Laboratory, Fermilab, Chicago and University of Illinois* (>300 km in total)

Status:

active network between *Argonne National Lab, Fermilab* and Chicago, connection to *University of Illinois* in planning

Participants:

Argonne National Laboratory (ANL), Caltech, Chicago Quantum Exchange, Fermilab, HyperLight, Northwestern University, NuCrypt, Starlight, University of Chicago, University of Illinois

Websites and articles:

- [press release about funding for InterQnet \(ANL campus quantum network\) 2023-10-16](#)
- [press release about funding for AQNET-SD \(improvement and expansion of the existing quantum network between ANL and Fermilab\) 2023-10-16](#)
- [press release with details about IEQNET 2023-02-02](#)
- [press release on the use of Toshiba DV QKD devices 2022-04-19](#)
- [press release on the exchange of entangled photons between Chicago and ANL 2020-02-19](#)

Further information and papers:

- [paper with details on IEQNET 11/2022](#)

Long Island Quantum Internet Testbed**Description:**

quantum network (mainly) for the distribution of entangled photons with 6 nodes in Long Island over fiber optics and free-space (approx. 420 km in total), possibly with a long-range connection to AFRL (>330 km)

Status:

sections already active, connection to AFRL under consideration

Participants:

Air Force Research Laboratory (AFRL), Brookhaven National Laboratory (BNL), ESnet, Stony Brook University (SBU)

Websites and articles: [overview of \(planned\) testbed](#) (probably as of end 2020)

- [press release on cooperation between AFRL and BNL 2024-01-26](#)
- [press release on funding 2022-11-29](#)
- [press release on new BNL research building and planned free-space connection 2022-05-18](#)
- [press release on the exchange of entangled photons between SBU and BNL 2020-07-23](#)
- [press release on previous campus quantum network testbed 2019-04-08](#)

Further information and papers:

- [paper on quantum link between SBU and BNL 01/2024](#)

National Plan**Description:**

coordination of already existing quantum network projects for the distribution of entangled photons, 5 steps to a national quantum internet:

- verification of secure protocols
- campus/metro entanglement distribution
- entanglement distribution via entanglement swapping between cities
- entanglement distribution between states via quantum repeaters
- multi-institutional ecosystem based on the 17 DOE national laboratories for transition from demonstration to operational infrastructure

Participants:

Argonne National Laboratory, Brookhaven National Laboratory, Department of Energy (DOE), ESnet, Fermilab, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory

Websites and articles: [blueprint for national quantum internet](#)

- [press release on DOE's blueprint for national quantum internet 2020-07-23](#)

China: National QKD Network

Description:

long-range QKD connections with over 32 trusted nodes between QMANs in Beijing, Jinan, Hefei and Shanghai (>2000 km in total) with connection to satellite QKD (as of 2021, probably much larger today and in use); DV QKD, EB QKD and in the meantime probably also CV QKD and TF QKD

Goals:

- (intercontinental) space-based QKD connections
- connection of over 150 users
- use of commercial QKD products for practical applications (connection of government, banks, hospitals and research institutions) in a practical network topology with over 20 simultaneous users
- national QKD backbone
- PQC for authentication, QKD for long-term data security
- replacing Trusted Nodes with Switches in QMANs

Status:

QKD network already active since 2016 and planned expansions probably completed (schedule given in [0] but hardly any up-to-date information about QKD networks can be found - > politics?!), satellite *Micius* still active, additional satellite *Jinan-1* active and satellite network with compact ground stations planned

Participants:

CAS, China Cable Network Co, Chinese University of Science and Technology, Hefei Institutes of Physical Science, Jinan Institute of Quantum Technology, QuantumCtek Co. Ltd.

Websites and articles:

- [article on QKD in the China-America political context 2024-02-02](#)
- [article about space-based QKD connection between China and Russia with *Micius* 2024-01-02](#)
- [article about planned Chinese QKD satellites 2023-06-03](#)
- [article about planned Chinese QKD satellite network 2023-03-10](#)
- [article about QKD experiments on *Tiangong-2* 2022-08-19](#)
- [article about EB QKD with *Micius* 2020-06-25](#)
- [announcing article about *USTC* Network 2016-10-26](#)

Further information and papers:

- [paper on 1000 km TF QKD 05/2023](#)
- [0] [presentation slides on QKD in China 14-02-2023](#)
- [paper on QMAN with 46 nodes in Hefei 09/2021](#)
- [paper on *USTC* network 06/2021](#)
- [paper on China-Austria satellite QKD 01/2018](#)

India: National Quantum Mission

Description:

long-range QKD connections between cities (several hundred km in total), QMANs with several nodes and satellites QKD between ground stations in India and with other countries; EB QKD and probably DV QKD (*QNu Labs*)

Goals:

- space-based QKD connections
- QKD applications for the military
- technology and knowledge development in the quantum sector

Status:

QKD networks and connections planned but already demonstration experiments, QKD satellite in planning, project duration (*NQM*): 2023 - 2030

Participants:

C-DoT, DOS, DRDO, IIT Delhi, ISRO, PRL, QNu Labs, SAC

Websites and articles:

- [article on announcement of a QKD satellite 2023-07-10](#)
- [article on QKD testbed in New Delhi and public call for pentest 2023-03-27](#)
- [article about Indo-American quantum agreement 2023-02-08](#)
- [press release on intention to purchase *QNu Labs* QKD equipment by the Indian army 2022-08-14](#)
- [press release on long-range QKD demonstration experiment 2022-02-23](#)
- [article on free-space EB QKD demonstration experiment 2022-02-03](#)

Further information and papers:

- [review article on the situation of quantum technology in India 2023-11-12](#)

Japan: Tokyo QKD Network

Description:

expansion of the existing QMAN with Trusted Nodes in Tokyo (approx. 220 km in total) to a national network by setting up QMANs in different cities and connecting through terrestrial and space-based QKD (>1000 km in total); DV QKD (*Toshiba*)

Goals:

- development of open testbeds for industry, universities and research institutes
- space-based QKD connections
- application-oriented investigations: financial data, medical data, combination of quantum cryptography with classical network technology

Status:

Tokyo QKD Network has been active since 2010 and is being expanded, national expansion is planned, demonstration experiments with QKD satellites

Participant:

Melco Holdings Inc., NEC Corporation, NICT, NTT DATA Corporation, SKY Perfect JSAT Corporation, SoftBank Corporation, Tohoku University Hospital, ToMMo, Toshiba Corporation, University of Aizu, ZenmuTech

Websites and articles: [website of the Quantum ICT Collaboration Center](#)

- [article on expansion of Tokyo QKD Network 2023-12-18](#)
- [press release on QKD-VPN experiment 2023-09-20](#)
- [press release on the successful launch of a QKD device to the ISS 2023-08-07](#)
- [press release on QKD demonstration experiment with distributed medical data 2022-12-28](#)
- [press release on QKD demonstration experiment with financial data in the Tokyo QKD Network 2022-01-17](#)
- [press release on QKD demonstration experiment with financial data in the Tokyo QKD Network 2020-10-22](#)

Further information and papers:

- [presentation slides on Tokyo QKD Network and planned expansion into a national network 2023-07-24](#)
- [paper on commercial aspects of satellite QKD \(in Japan\) 04/2022](#)

Singapore: National Commercial QKD Network: NQSN

Description:

redundant national QMAN in Singapore (>60 km in total) and QKD satellite; DV QKD (*IDQ, SpeQtral*)

Goals:

- national commercial QKD network of at least two operators
- international space-based QKD connections

Status:

NQSN sections already active, satellite launch expected in 2024

Participants:

CQT, ID Quantique SA (IDQ), SingTel, SpeQtral, SPTel, ST Telemedia Global Data Centres

Websites and articles: [NQSN website](#)

- [press release on SingTel's participation in NQSN+ 2023-11-30](#)
- [press release on participation of SpeQtral and SPTel in NQSN+ 2023-11-15](#)
- [article on NQSN+ launch 2023-06-08](#)
- [article on data center application of NQSN 2023-06-05](#)
- [press release by SpeQtral on QKD satellite 2022-11-16](#)
- [press release on demonstration of EB QKD in commercial optical fibers 2020-11-06](#)

Further information and papers:

- [paper on commercial QKD IPsec test between JPMorgan Chase data centers with Toshiba devices 05/2024](#)
- [paper on NQSN 03/2024](#)

South Korea: Commercial QKD Network

Description:

long-range QKD connections with Trusted Nodes between Seoul, Daejeon and Busan and presumably QMANs to connect e.g. government organizations (> 800 km in total); DV QKD (*IDQ, Toshiba*)

Goals:

- investigations on Quality of Service in heterogeneous QKD connections
- encryption of government communications
- QKD-as-a-Service

Status:

active

Parties:

Alian, Coweaver, ID Quantique SA (IDQ), SK Broadband, KT Corporation, TDSL, Toshiba Corporation, Toshiba Digital Solutions Corporation, WooriNet

Websites and articles:

- [article on certification of a KMS 2023-11-07](#)
- [IDQ press release on cooperation with SKT 2023-10-12](#)
- [article on commercial QKDaaS offer 2023-09-06](#)
- [article on planned QKD commercialization 2023-03-10](#)
- [press release on the use of IQD KMS for nationwide QKD network 2022-07-19](#)
- [Toshiba press release on planned QKD activity in Korea 2022-03-28](#)

Further information and papers:

- [paper on Quality of Service investigations 10/2022](#)