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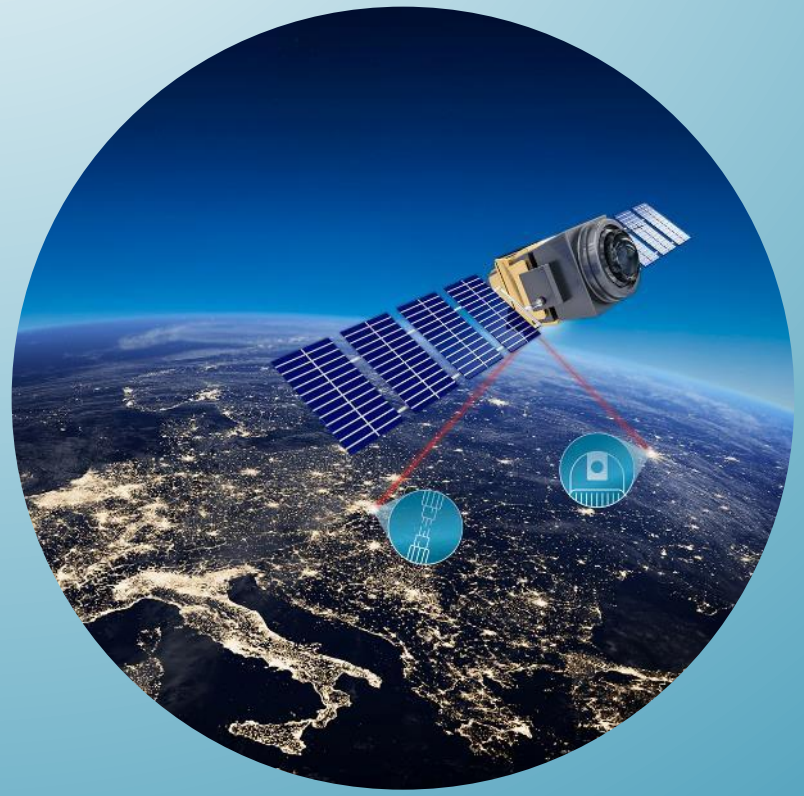

Quantum Key Distribution from Space

Martin Bohmann

Agenda

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1. Why quantum key distribution?
2. QKD basics
3. Space-based QKD
4. Quantum Technology Laboratories GmbH

Why QKD?

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Classical cryptography:

- Extremely important infrastructure
- Relies on hardness assumptions
- Not provable secure

Big threat: quantum computers

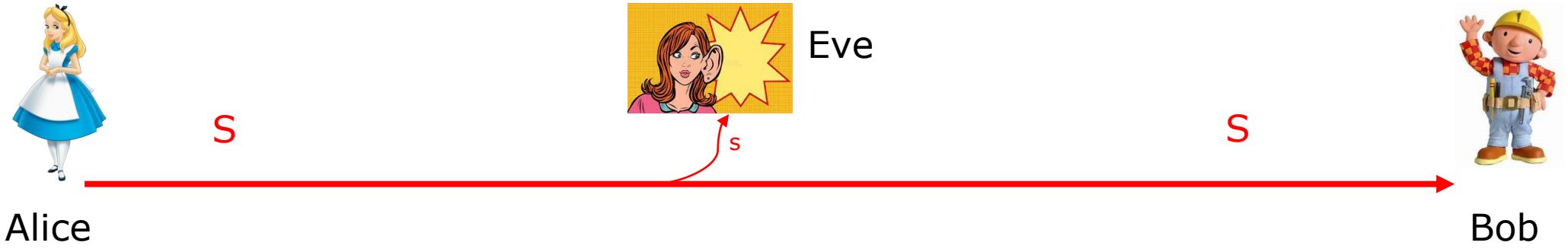
- RSA encryption based on factoring problem
- Shor's algorithm
- Long-term security

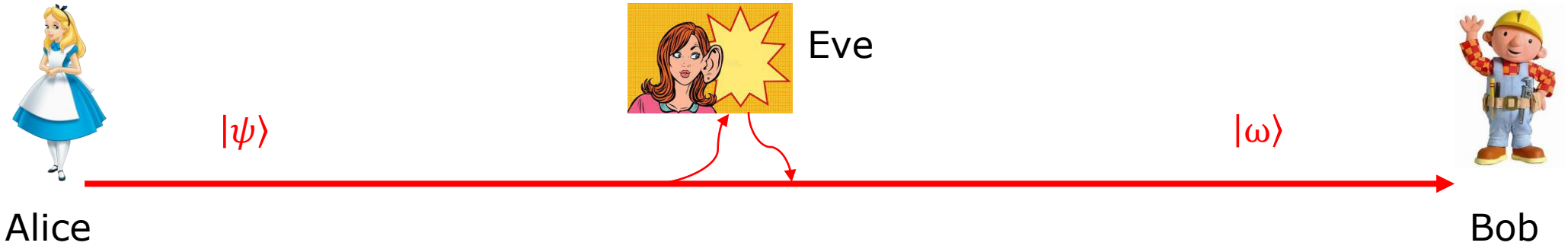
```
10101101101010110110 11
11101011HACKED11110110
00010101001000010111 11
```

Solution: QKD

- Based on laws of quantum mechanics
- Information-theoretically secure

No-cloning theorem





Entanglement

- Quantum correlation between subsystems
- Superposition principle
- Resource for may quantum applications

Separable states

$$|\psi\rangle_A \otimes |\phi\rangle_B$$

Entangled states

$$|\psi\rangle_{AB} = \sum_{i,j} c_{ij} |i\rangle_A \otimes |j\rangle_B$$

Parametric down-conversion

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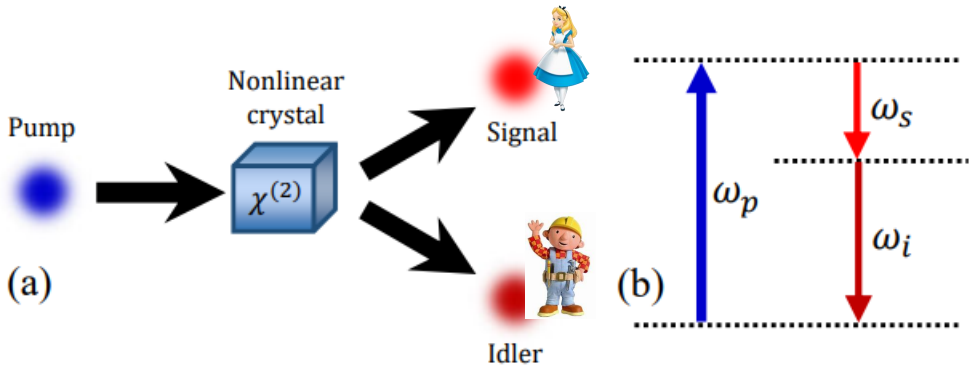
- Nonlinear optical process
- One photon into two with less energy
- Conservation of energy and momentum
- Quantum correlation between photons
- Information is carried by single photons

Polarization entanglement

$$|\phi^+\rangle = \frac{1}{\sqrt{2}}\left(|H,H\rangle + |V,V\rangle\right)$$



Distributed correlated randomness

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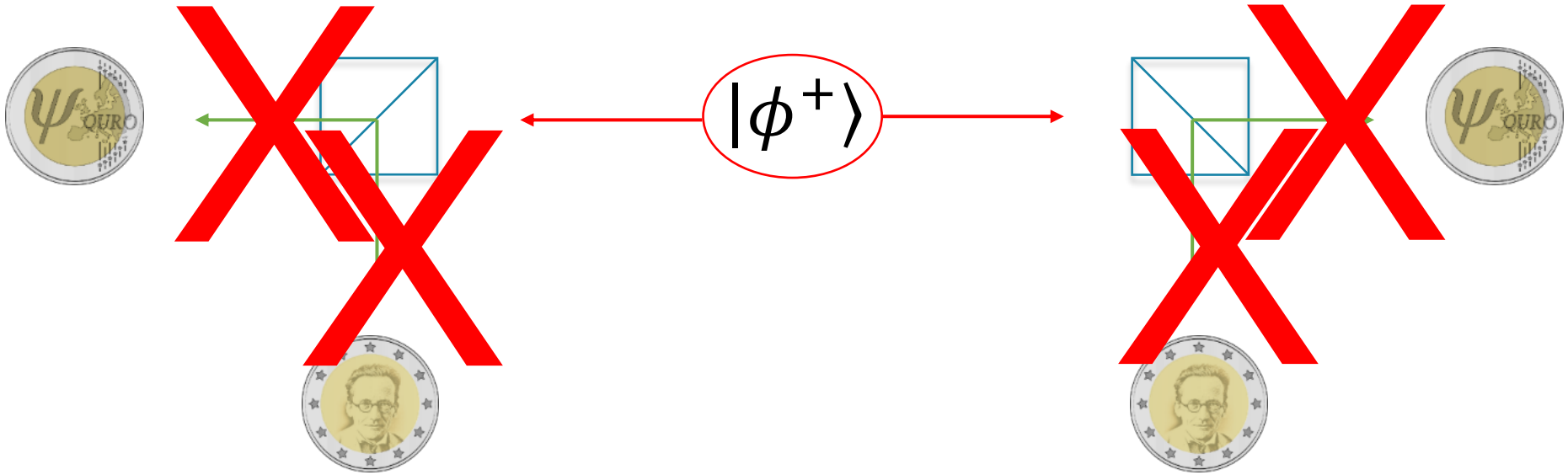
Entanglement: *correlated* randomness



Creating a key

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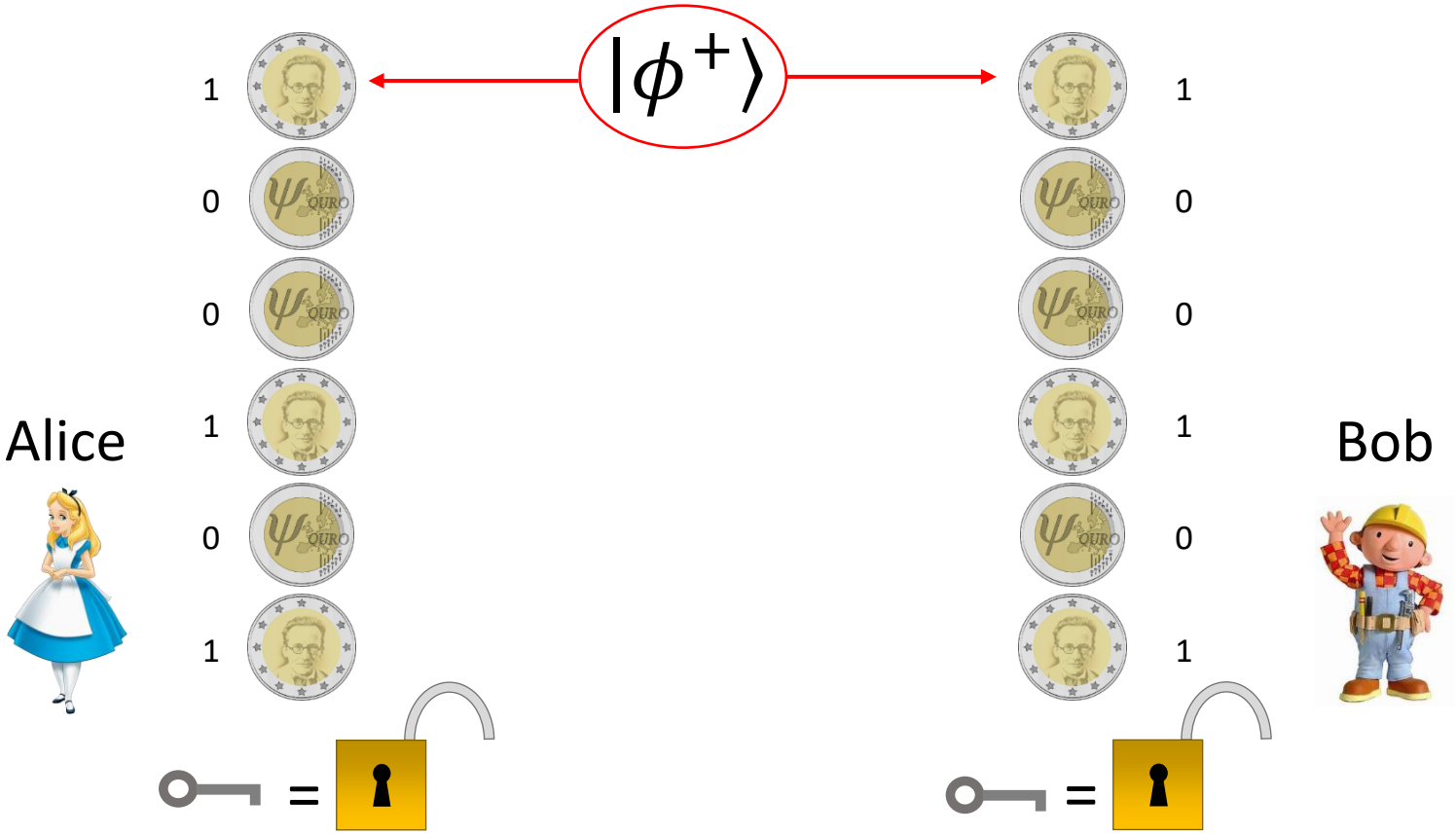
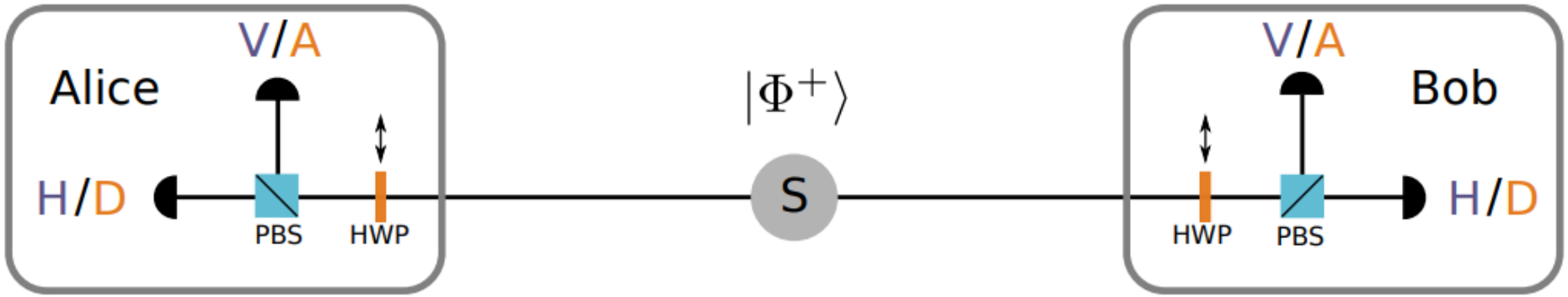
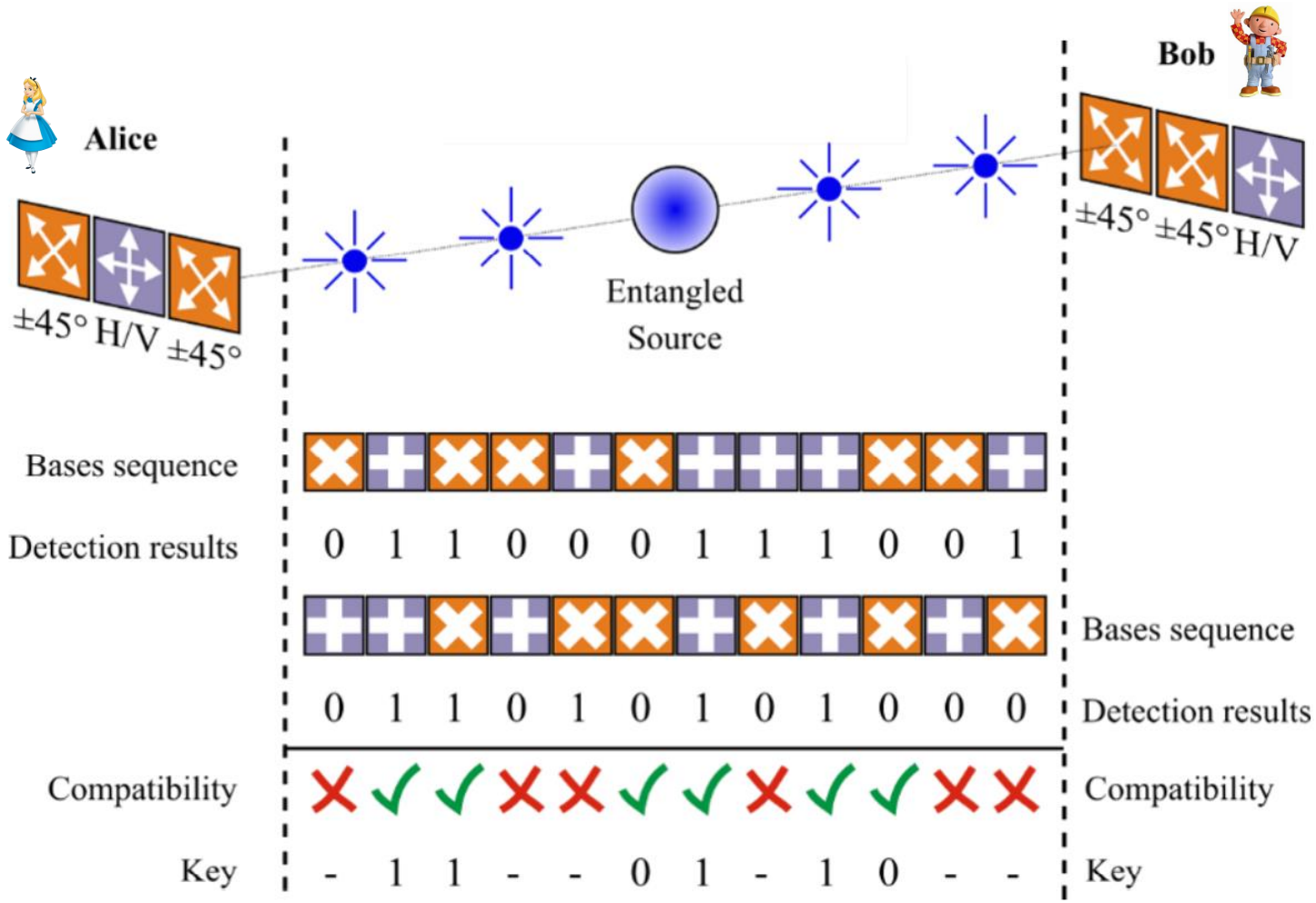


Communication scheme



Measurement in two basis needed H/V and D/A

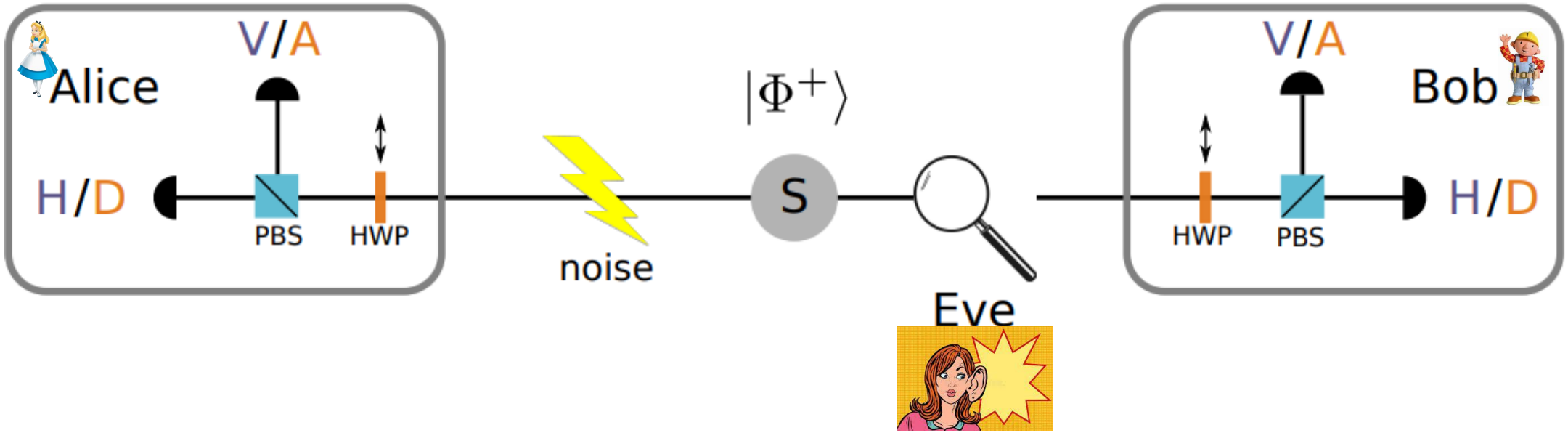
Entanglement-based QKD



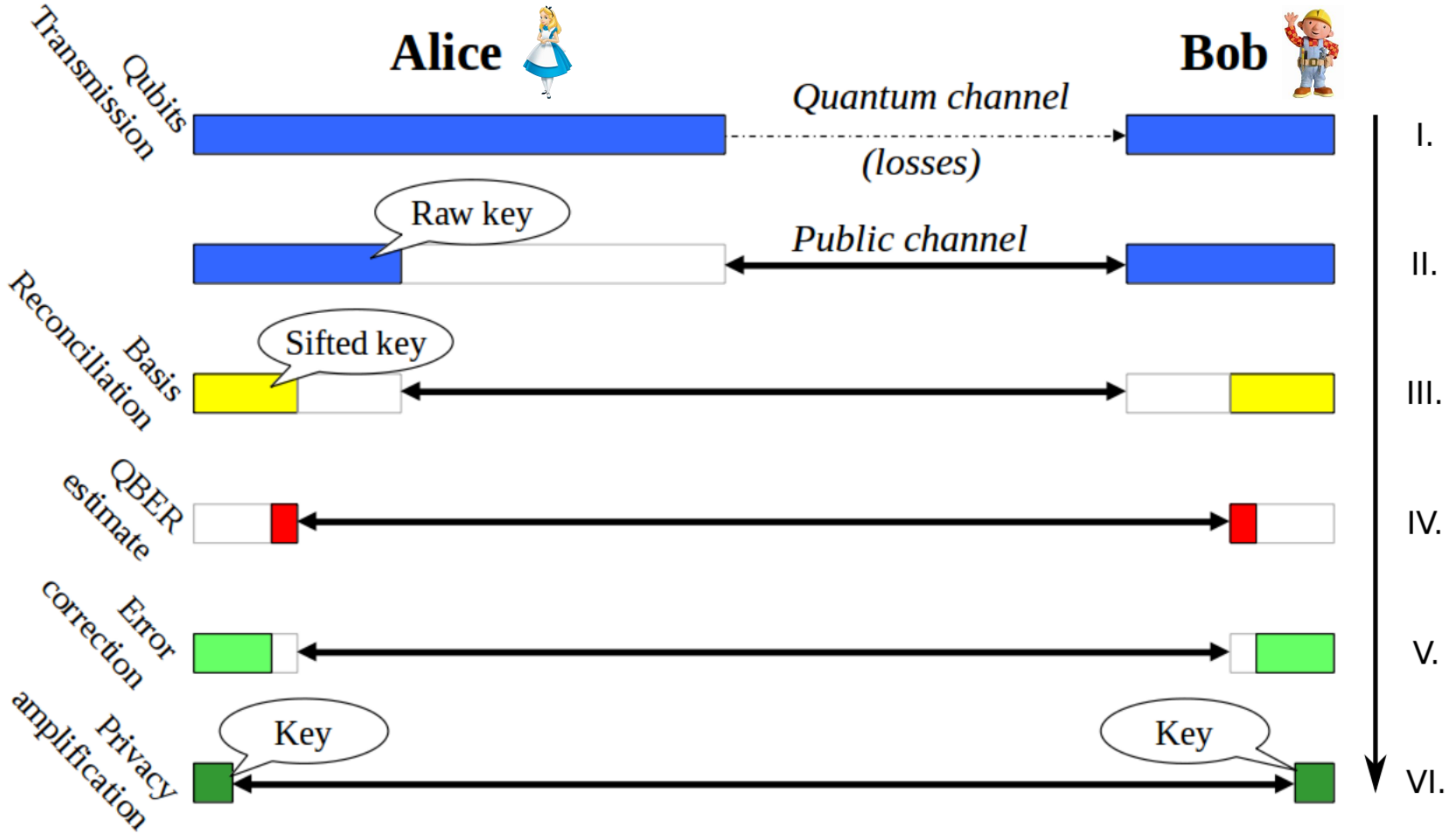
BBM92 protocol

Bennett, Brassard, and Mermin, Phys. Rev. Lett. 68, 557 (1992)

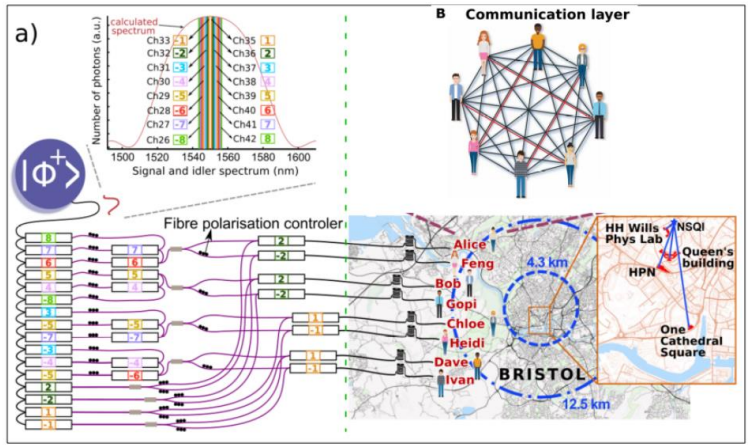
Reality

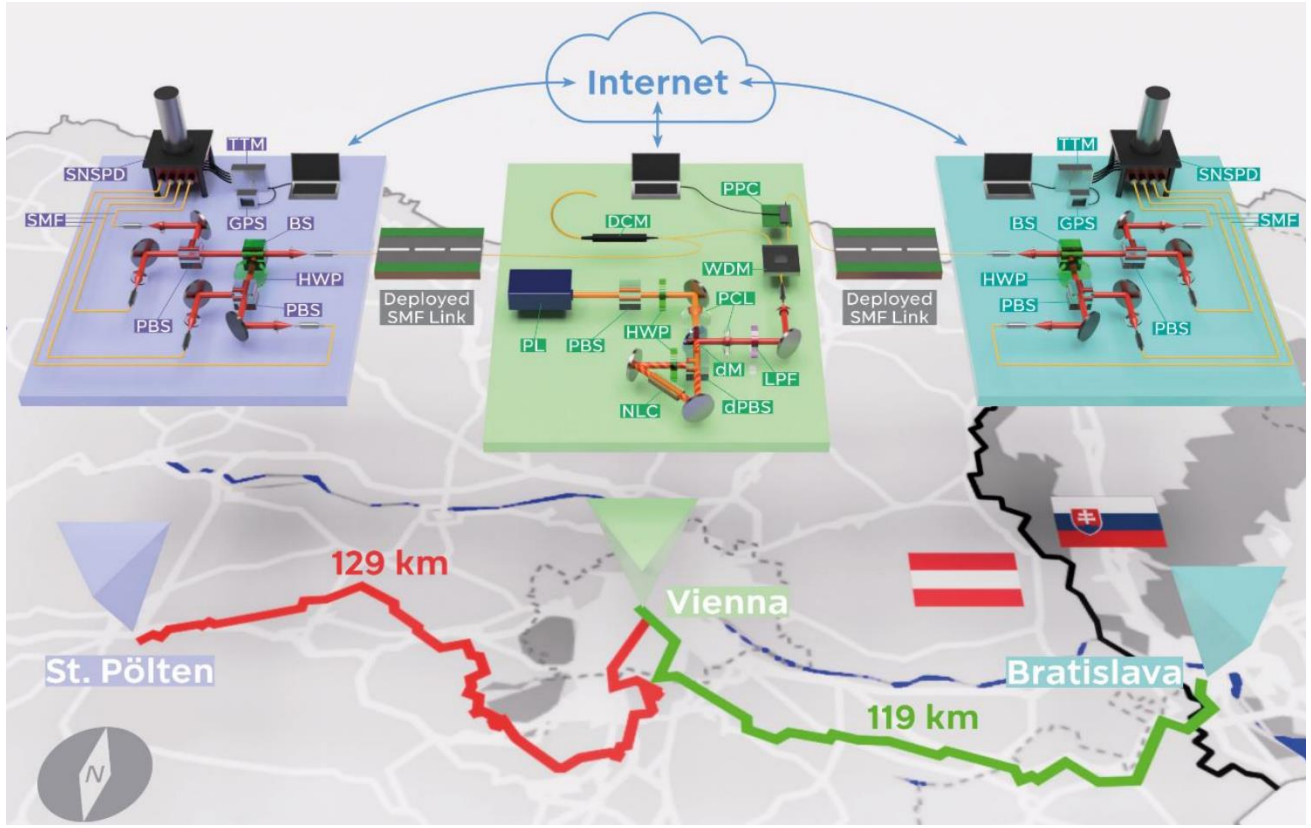


Secure key extraction



Fiber links and networks





Distance limited through attenuation!

Free-space & satellite links

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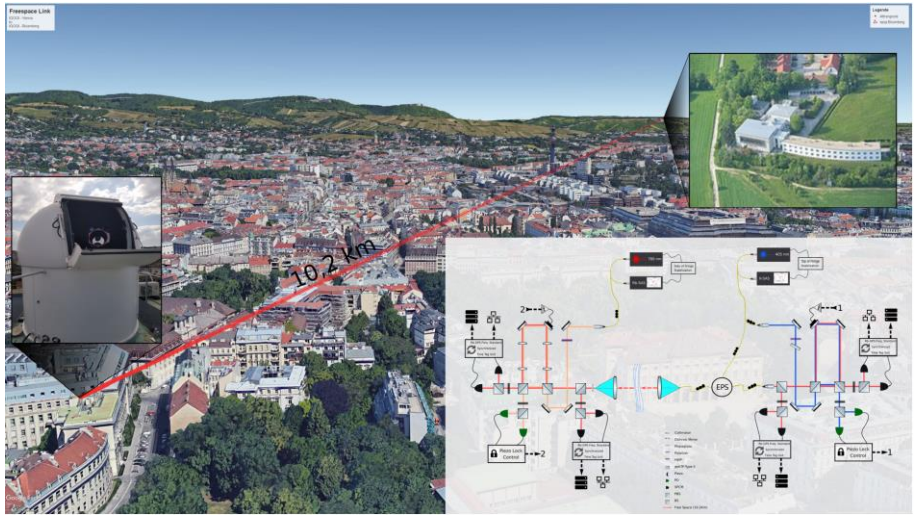
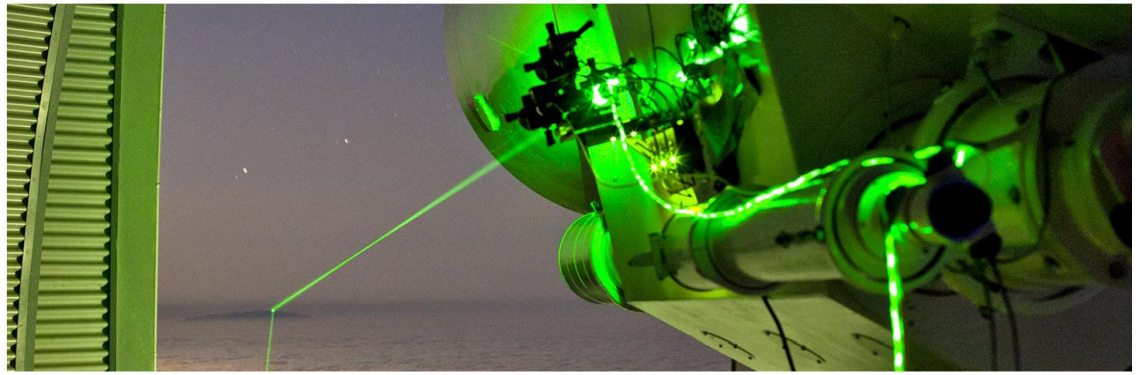
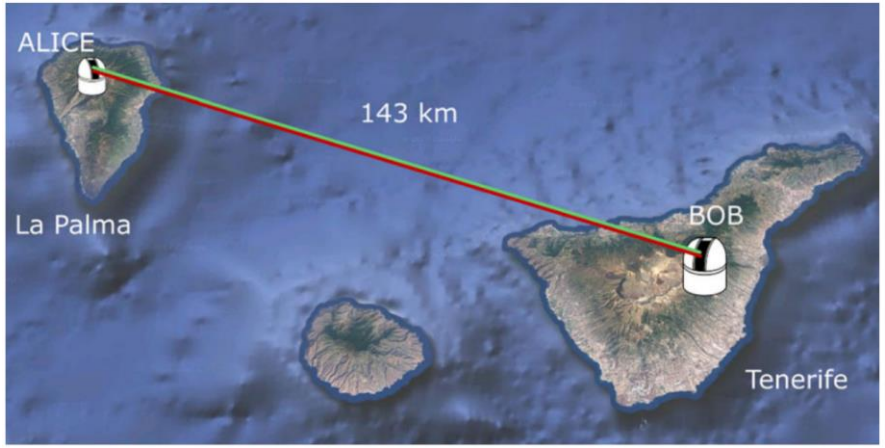
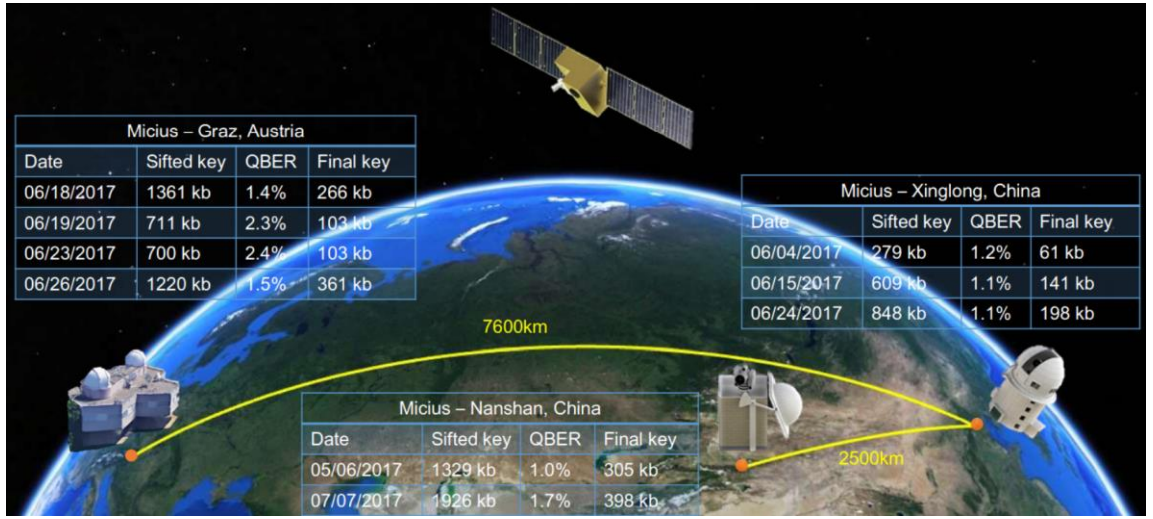
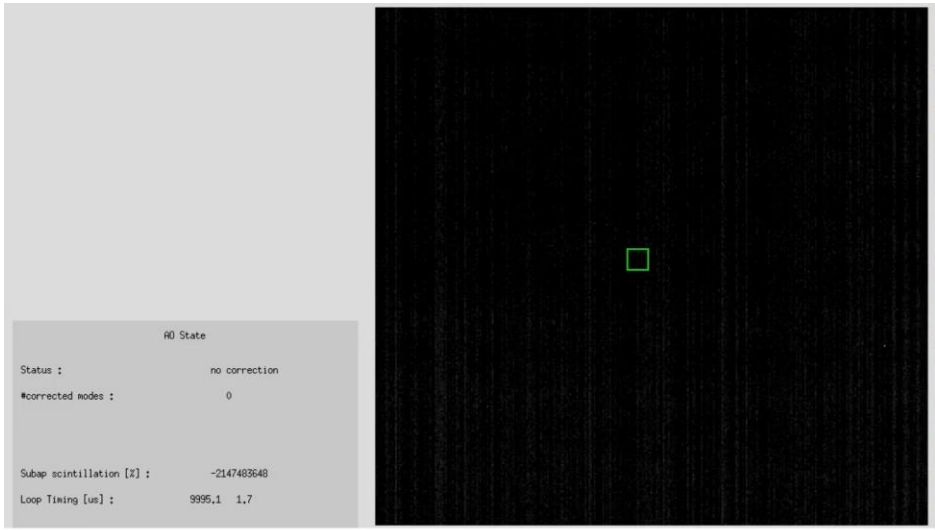


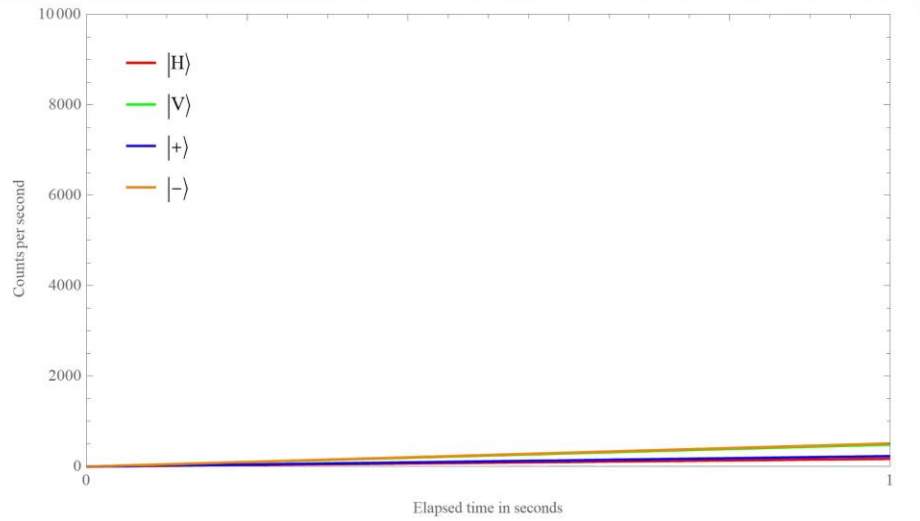






Satellite links





Polarisation	State	Counts per second
0 °	$\|H\rangle$	172
90 °	$\|V\rangle$	488
+45 °	$\|+\rangle$	232
−45 °	$\|-\rangle$	512

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2017 founded
100% privately owned
Headquarter Vienna, Austria

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Quantum Technology Laboratories

European Commission

esa
European Space Agency
Agence spatiale européenne

We've done research at

ÖAW Österreichische Akademie der Wissenschaften
universität wien
CERN
TU WIEN
Technische Universität Wien Vienna | Austria
Instituto de Astrofísica de Canarias

We've collaborated with (and many more)

NICT 情報通信研究機構 National Institute of Information and Communications Technology
Politecnico Milano 1863
cnrs
LMU Ludwig-Maximilians-Universität München
Stanford University
University of Oxford
ETSI World Class Standards
NIST National Institute of Standards and Technology U.S. Department of Commerce
ETH zürich
Max-Planck-Gesellschaft
PTB Physikalisch Technische Bundesanstalt Braunschweig und Berlin
University of Bristol
KTH Vetenskap och konst
ICFO The Institute of Photonic Sciences
Université Grenoble Alpes
Fraunhofer IOF
ASA Astro Systeme Austria
1958

Products and Capabilities

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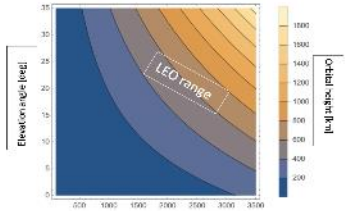
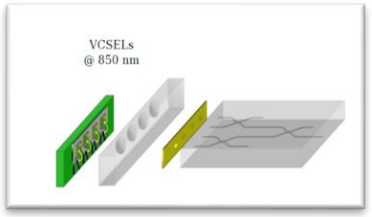
Engineering firm:
- Mission design & trade-offs
- Orbits & link budgets
- Feasibility & modelling
- QKD protocols

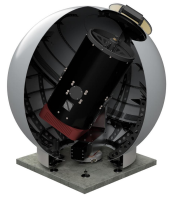


Entangled Photon Source:
- Optimized for space
- Projects up and running
- Capable for LEO and GEO

Prepare & Measure Source:
- Faint Pulse Source
- BB84 decoy-state
- Space heritage in Q4 2022



Ground Segment:
- Quantum modem
- Photon detection & electronics
- Telescope, dome, infrastructure
- First batch in production



Collaborations and partners

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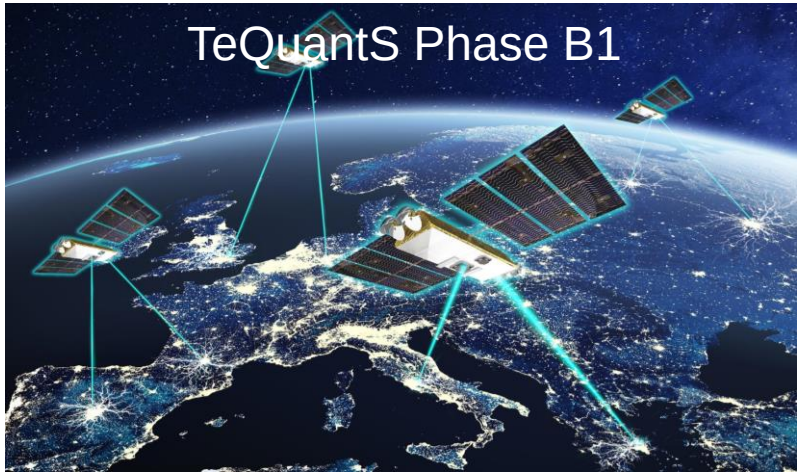
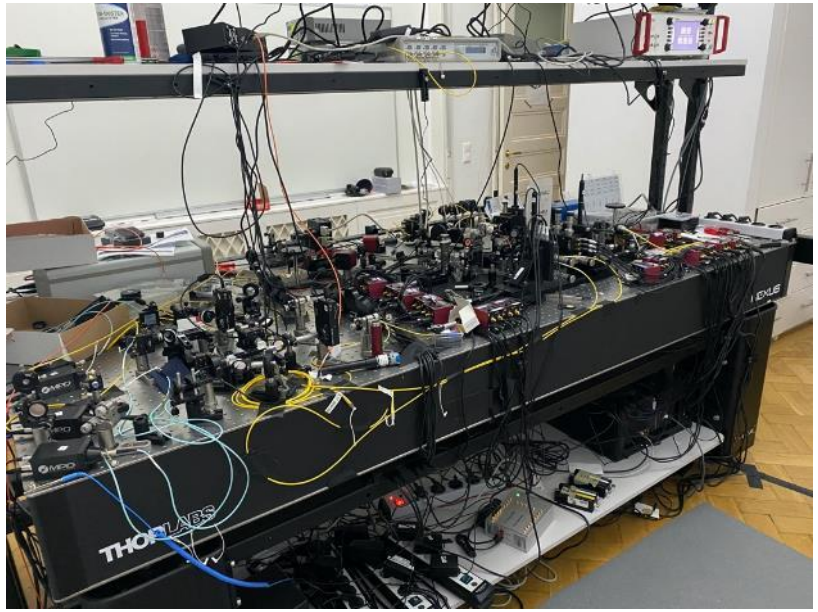
Most of the team published with Anton Zeilinger

We've collaborated with (and many more)

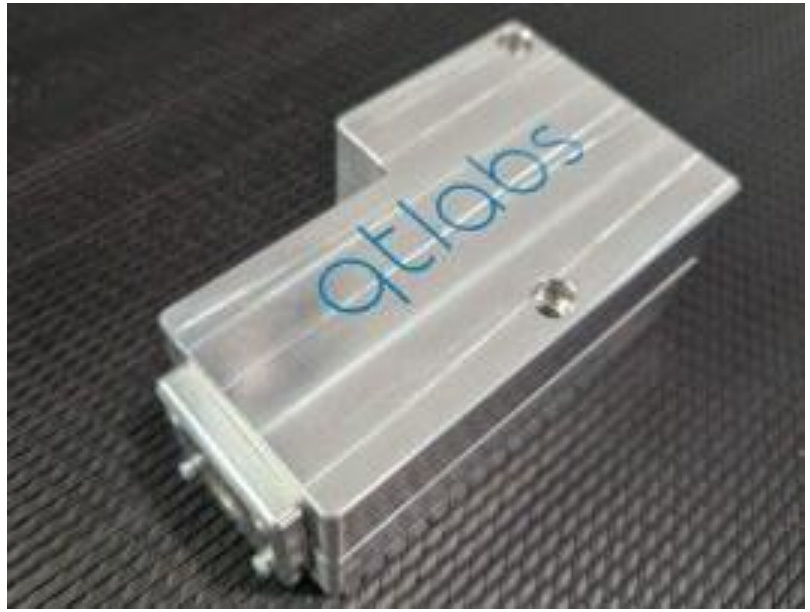
Missions and larger projects



Space segment



R&D



- Projects up and running
- TRL 4 soon TRL 6
- 810nm and 1550nm

Optical ground stations

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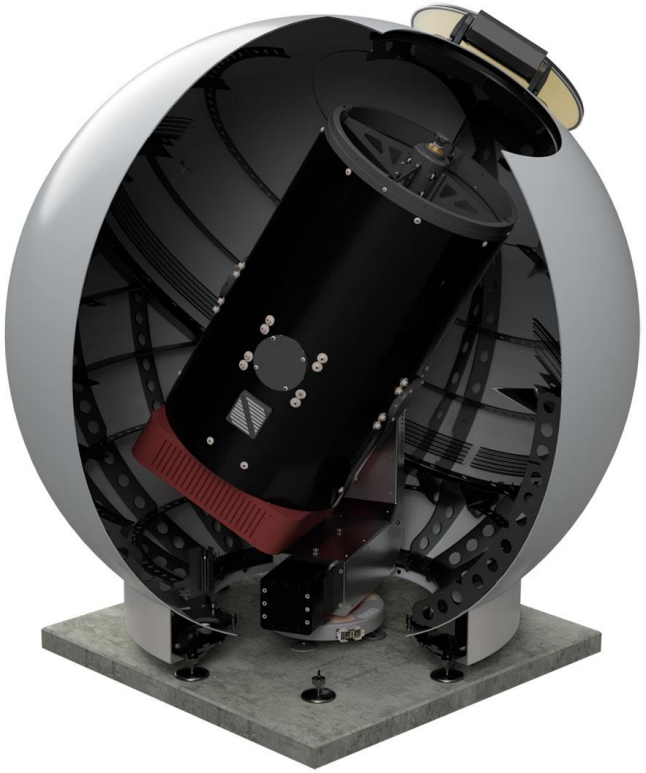

- Fully developed product
- 80 cm and 40 cm
- Complete station: telescope, mount, enclosure
- Tracking and remote operation
- Quantum receiver @ 850nm
- Training and support