Review of QIT for Network (except for QKD)

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Content

- ✓ Quantum Information Network Building Block 1: Quantum Repeater
- ✓ Quantum Information Network Building Block 2: Satellite based quantum communication
- ✓ QIT for Network: Quantum Time Synchronization

Challenge in global fiber quantum communication

(1) Photon Loss → Exponentially Reduce

0.006 bps @ 509 km

Pan & Zhang: PRL 124, 070501 (2020)

(2) Decoherence → Degrading quantum state fidelity

Solution 1: Classical Repeater with trust nodes

eg: Beijing-Shanghai Main Trunk Line

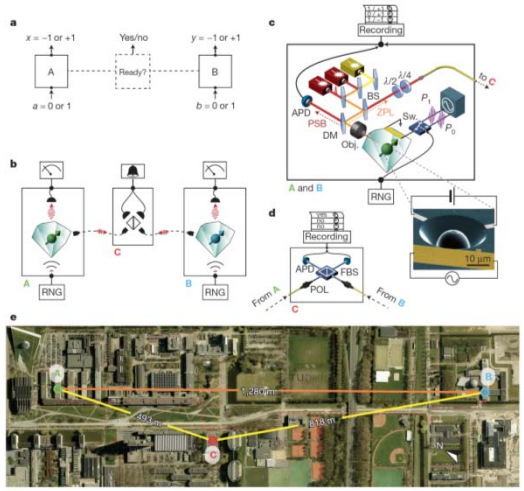
Solution 2: Quantum Repeater

- ✓ Entanglement Swapping
- ✓ Entanglement Purification
- ✓ Quantum Memory

Solution 3: Satellite based quantum network

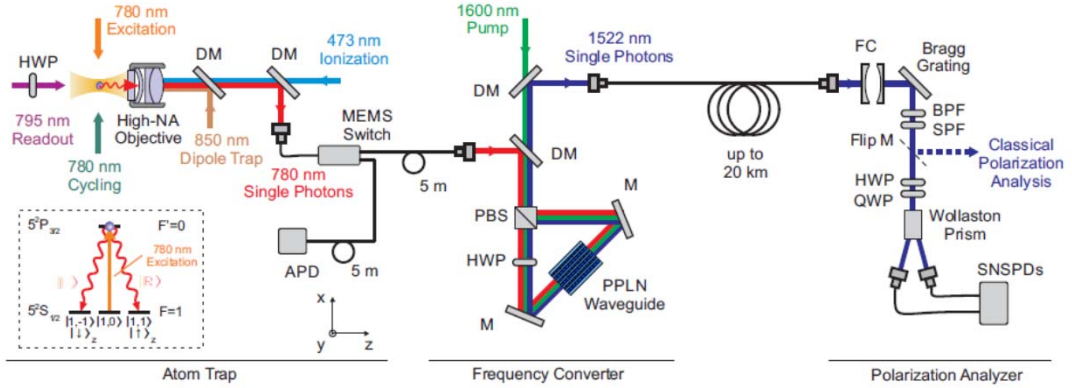
Quantum repeater -- state of the art

➢ **NV center: 1.7 km deployed fiber**



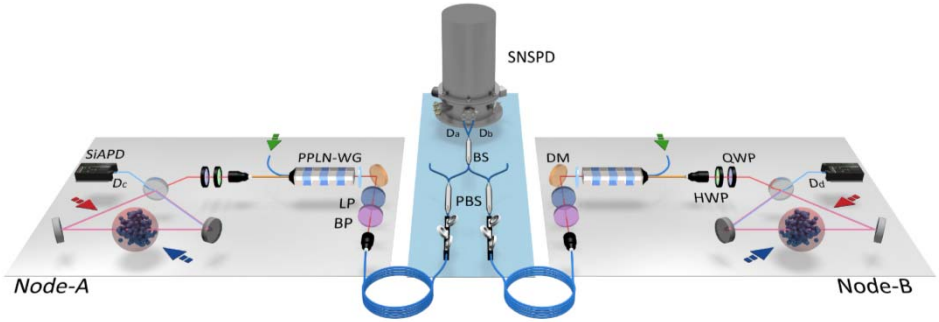
Hanson group: Nature 526, 682 (2015)

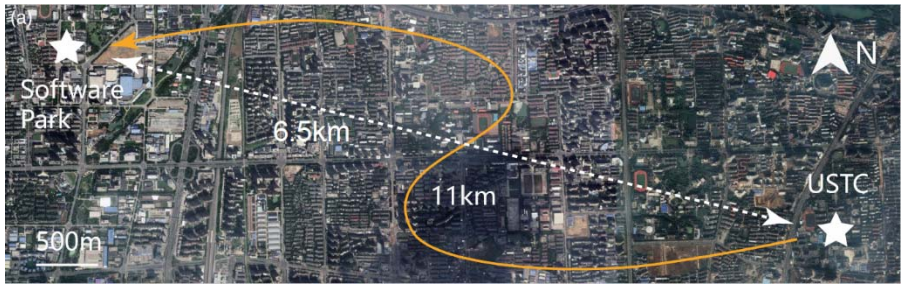
➢ **Single atom: 20 km fiber spool**



Weinfurter group: PRL 124, 010510 (2020)

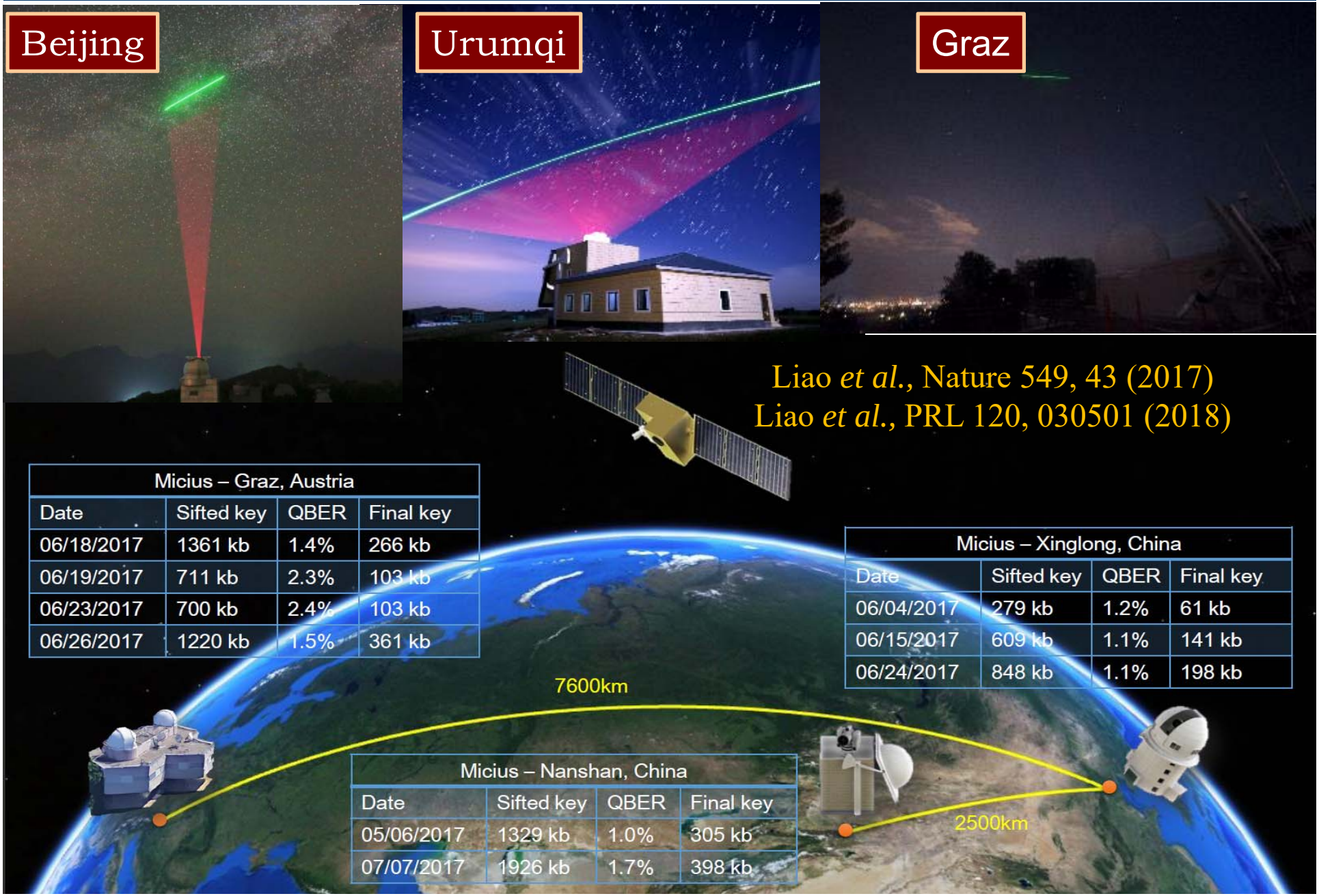
➢ **Atomic ensemble: 50 km fiber spool, 20 km deployed fiber**





Pan & Bao & Zhang: Nature 578, 240 (2020)

Satellite-relayed intercontinental QKD



Liao *et al.*, Nature 549, 43 (2017)
Liao *et al.*, PRL 120, 030501 (2018)

Micius – Graz, Austria			
Date	Sifted key	QBER	Final key
06/18/2017	1361 kb	1.4%	266 kb
06/19/2017	711 kb	2.3%	103 kb
06/23/2017	700 kb	2.4%	103 kb
06/26/2017	1220 kb	1.5%	361 kb

Micius – Xinglong, China			
Date	Sifted key	QBER	Final key
06/04/2017	279 kb	1.2%	61 kb
06/15/2017	609 kb	1.1%	141 kb
06/24/2017	848 kb	1.1%	198 kb

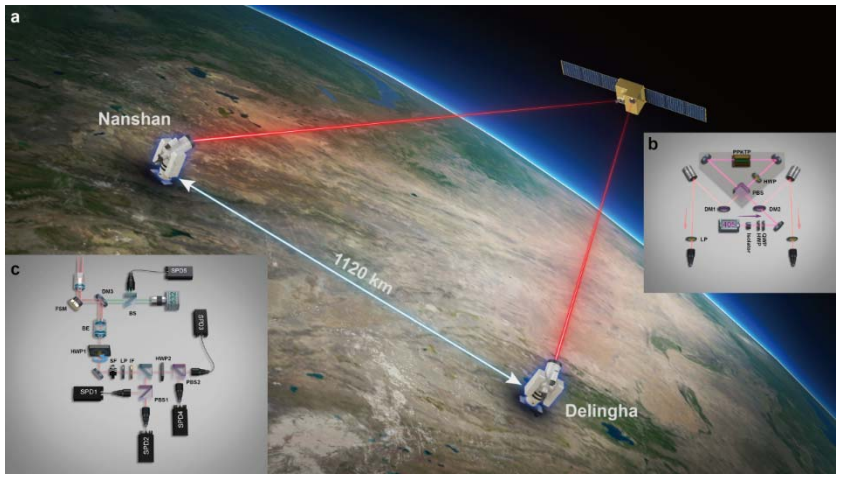
Micius – Nanshan, China			
Date	Sifted key	QBER	Final key
05/06/2017	1329 kb	1.0%	305 kb
07/07/2017	1926 kb	1.7%	398 kb

Entanglement based satellite quantum communication

Entanglement based QKD: over 1120 km to be published in Nature

- Channel Loss: 56~71dB
- Entanglement pairs received at 2/s
- Final key: 0.43 bps
- QBER: 4.51%±0.37%

➡ If load GHz entanglement source, up to 10kbits per orbit

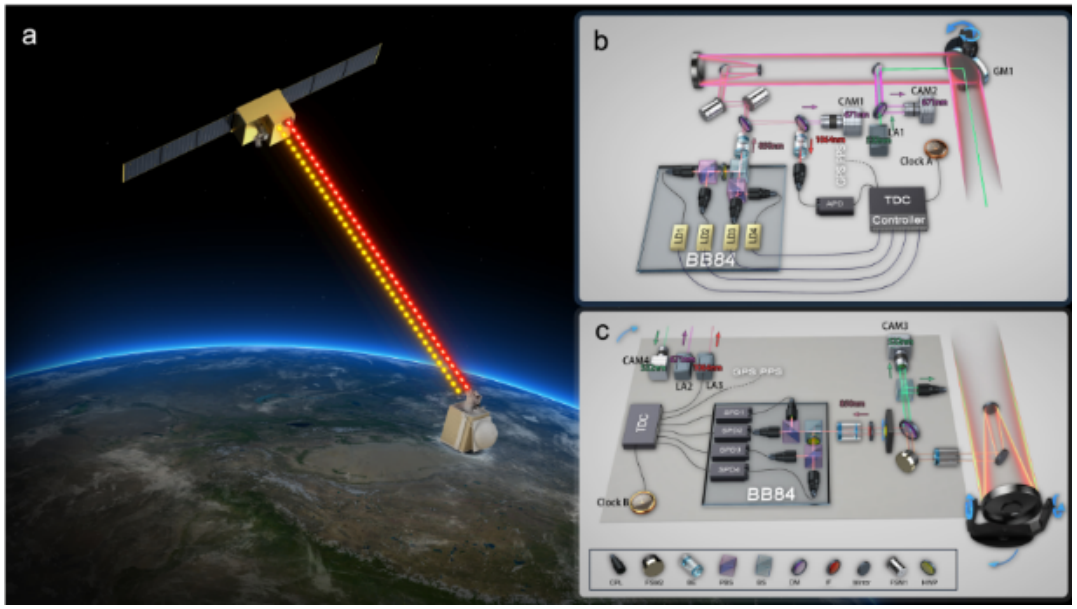


This would thus achieve the Holy Grail that all cryptographers have been dreaming of for thousands of years

--Gilles Brassard

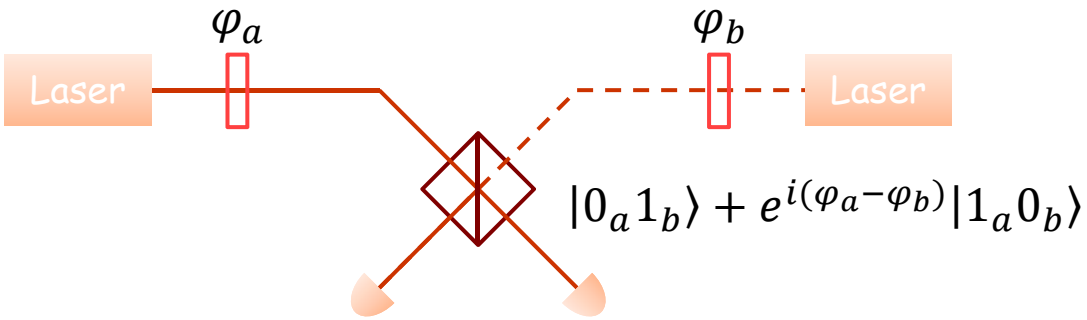
Quantum secure time transfer

Pan group: Nat. Physics doi:s41567-020-0892-y.



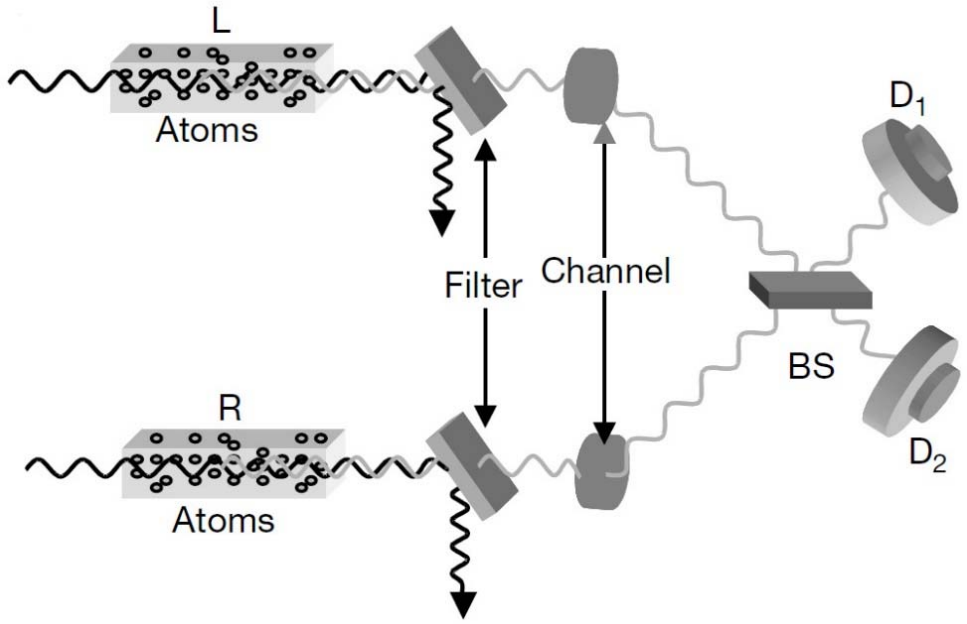
- The first secure time transfer based on satellite QKD
- Use QKD synchronization pulses and signal pulses as time signal carrier
- Use QKD final key to encrypt timestamp data
- The QKD signal cannot be forged, so that time signals cannot be forged
  - ➡ Time transfer precision: 30 ps

Time frequency transfer technology in QC



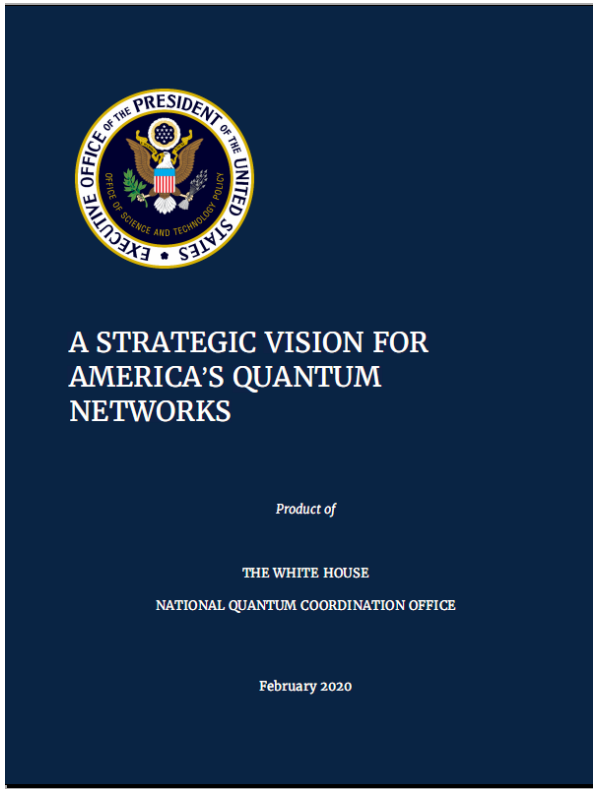
Major technology challenging for both TF QKD & DLCZ Quantum Repeater:

Stable phase interference between two separate independent lasers/light sources



Future Plan----USA

USA



- **Two specific goals**

Over the next five years, companies and laboratories in the United States will demonstrate the foundational science and key technologies to enable quantum networks, from quantum interconnects, quantum repeaters, and quantum memories to high-throughput quantum channels and exploration of space-based entanglement distribution across intercontinental distances. At the same time, the potential impact and improved applications of such systems will be identified for commercial, scientific, health and national security benefits.

Over the next twenty years, quantum internet links will leverage networked quantum devices to enable new capabilities not possible with classical technology, while advancing our understanding of the role entanglement plays.

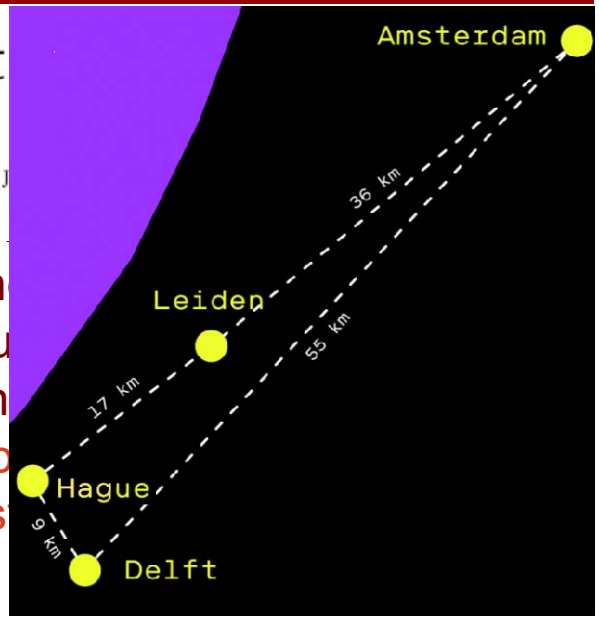
Future Plan----EU Quantum Repeater

Netherland

Deterministic delivery of remote entanglement quantum network

Peter C. Humphreys[1,3], Norbert Kalb[1,3], Jaco P. J. Morits[1], Raymond N. Schouten[1], Raymond F. L. Vermeulen[1], Daniel J
Matthew Markham[2] & Ronald Hanson[1]*

entanglement between two quantum chips faster than th
lost. Via a novel smart entanglement protocol and carefu
entanglement, the scientists led by Prof. Ronald Hanson
world to deliver such a quantum link on demand. This op
connect multiple quantum nodes and create the very firs
in the world.



The Delft scientists now plan to realize such a network between several quantum nodes. Hanson says, “Together with partners such as KPN, we want to connect four cities in the Netherlands by 2020 via quantum entanglement. This will be the very first quantum internet in the world.”

https://www.nature.com/articles/s41586-018-0200-5

Future Plan----EU Satellite Quantum Communication

esa

→ THE EUROPEAN SPACE AGENCY

"An agreement forged today between the European Commission and the European Space Agency marks the first steps towards creating a highly secure, pan-European quantum communication infrastructure.

……

It would comprise a series of quantum communication networks, linking institutional users and their critical infrastructures, and sensitive communication and data sites in Europe. ……"

http://www.esa.int/Applications/Telecommunications_Integrated_Applications/European_quantum_communications_network_takes_shape

APPLICATIONS

09/04/2019

European quantum communications network takes shape

The proposed satellite quantum communication systems would have pan-European reach

Perspective—Personal View

Quantum Repeater

- **Next 5 years**
  Several hundred km scale & metropolitan network
- **Next 10-20**
  ~1000 km quantum entanglement distribution

Although quantum purification might not be guaranteed

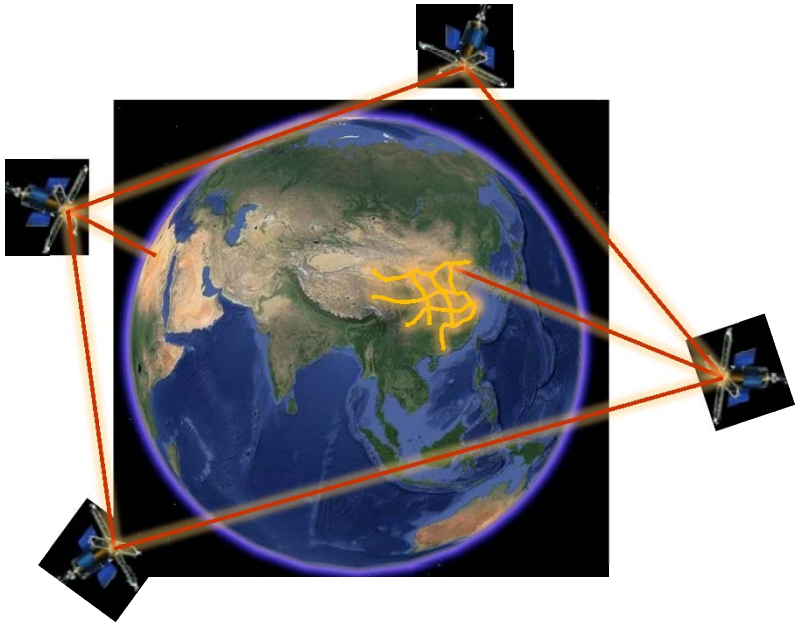
Satellite based quantum communication

- **Next 5 years**
  QKD network with nano satellite and miniature station
- **Next 10-20**
  Entanglement based quantum network

Future Prospects

- Combine QKD Network and the Network of Frequency and Time Transfer "Secure Time Transfer"
- Maintaining the phase between remote lasers to building up national wide quantum repeater & long distance TF QKD.

Future Prospects



Quantum Constellation + Fiber quantum communication infrastructure

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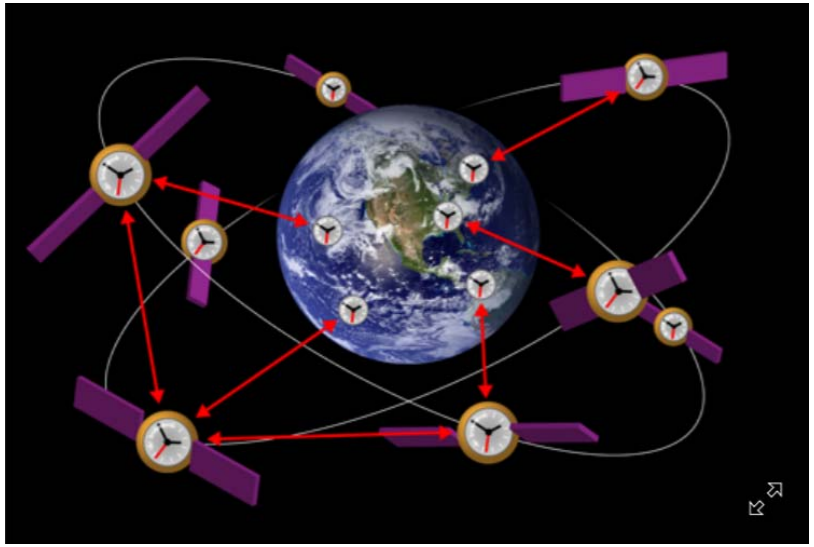
"Quantum Internet"

Future Prospects



GEO Optical Clocks + Precise Free-Space Frequency and Time Transfer

↓

"Network of Optical Clocks"

Thanks for your attention!