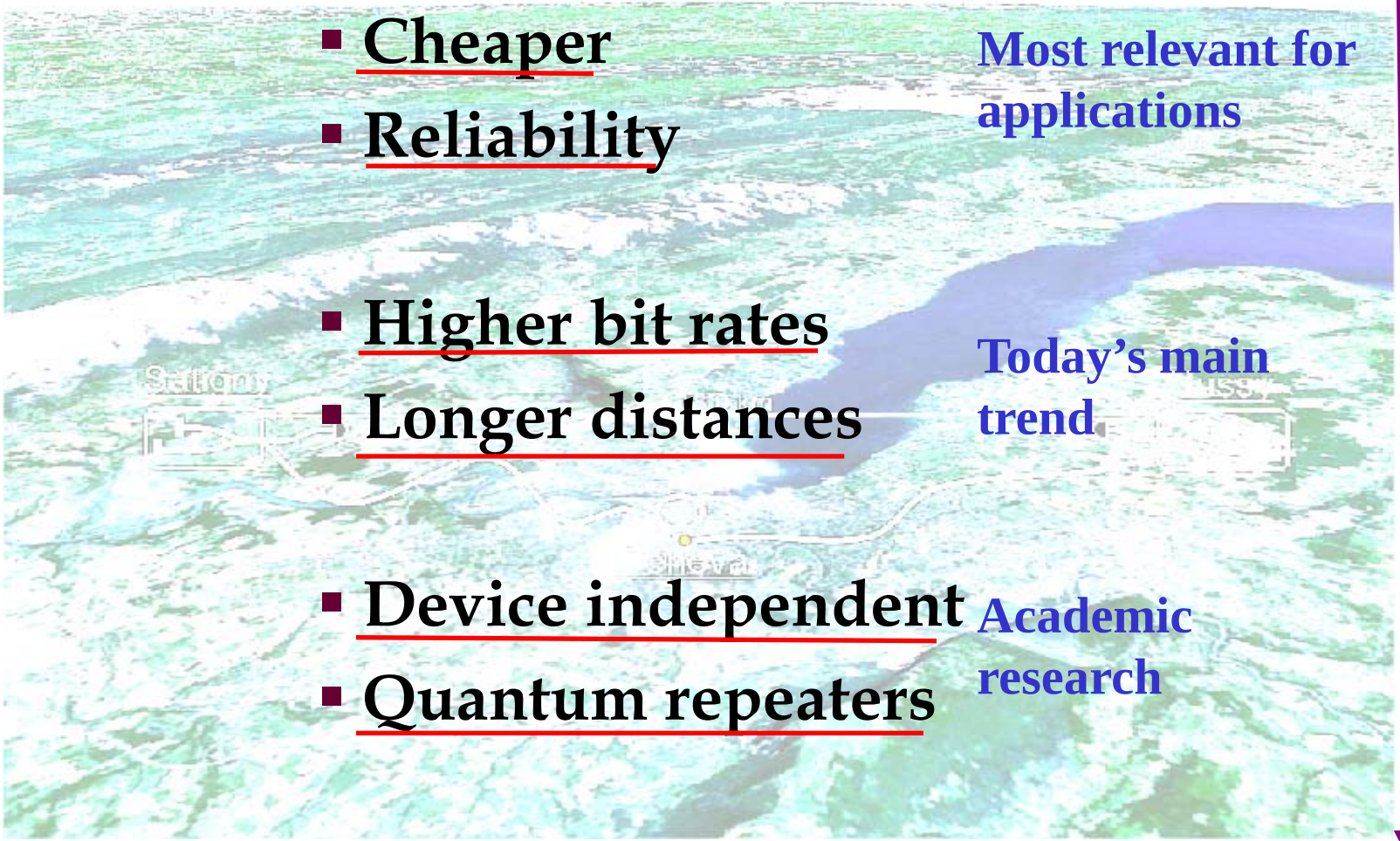
The futures of Quantum Communication

Nicolas Gisin

Group of Applied Physics
Geneva University, Switzerland

GAP Optique Geneva University



- **Cheaper**
- **Reliability**

Most relevant for applications

- **Higher bit rates**
- **Longer distances**

Today's main trend

- **Device independent**
- **Quantum repeaters**

Academic research

Applied research Fundamental

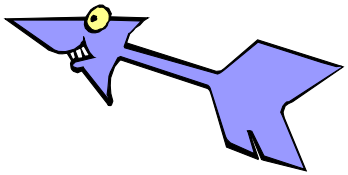
What is quantum communication

- Quantum Communication is the art of transferring a quantum state from one location, Alice, to a distant one, Bob.

- A quantum state can't be copied, hence the original is necessarily destroyed.
- Copying quantum states would violate both Heisenberg's uncertainty relations and the impossibility of faster than light signaling. Hence, the impossibility of "Q cloning" is one of the best established facts of Science.

How to realize quantum communication

- Let's represent the quantum state of a photon by a little arrow:



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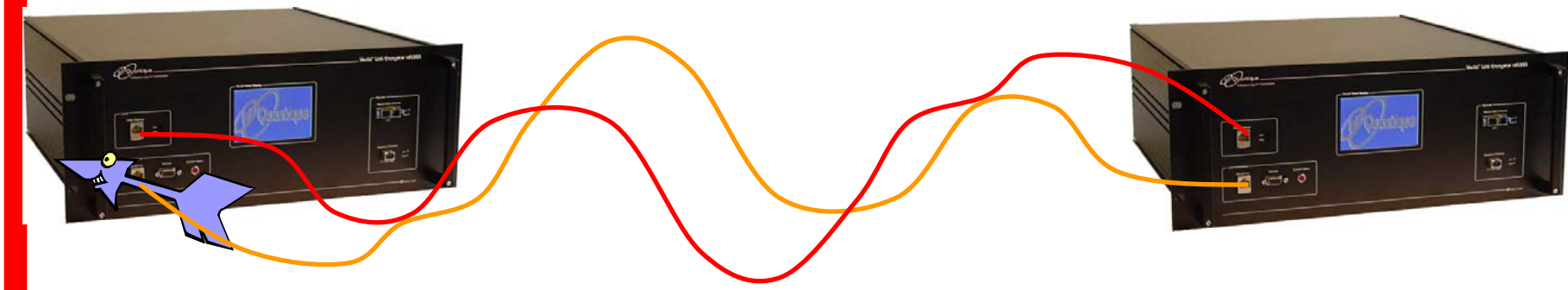
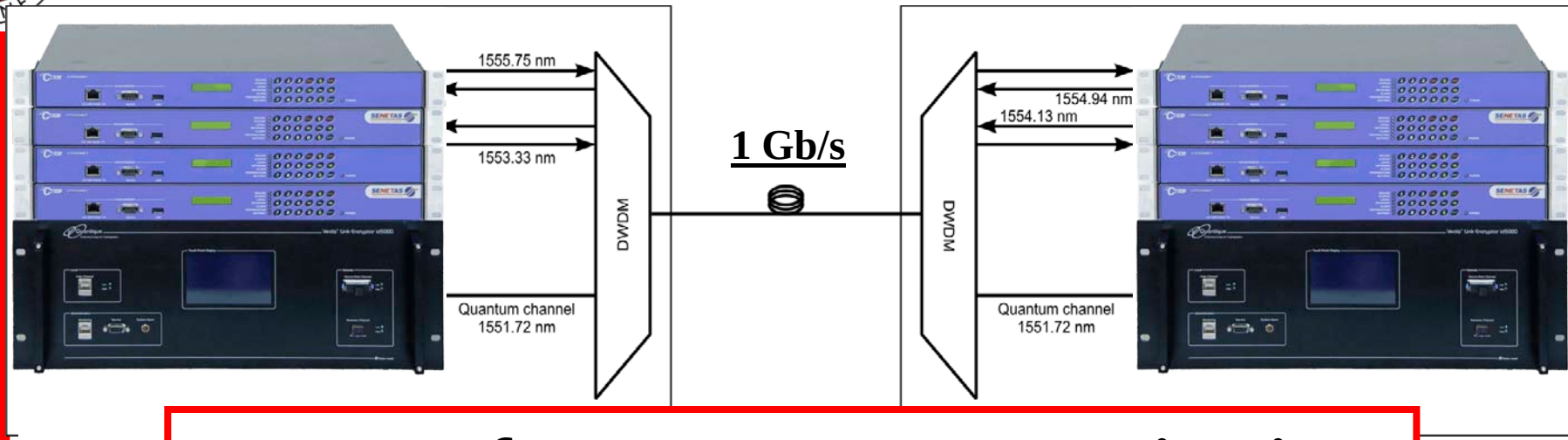
1-photon quantum communication: Quantum Key Distribution

- Encode the quantum state into a photon and send the latter from Alice to Bob:

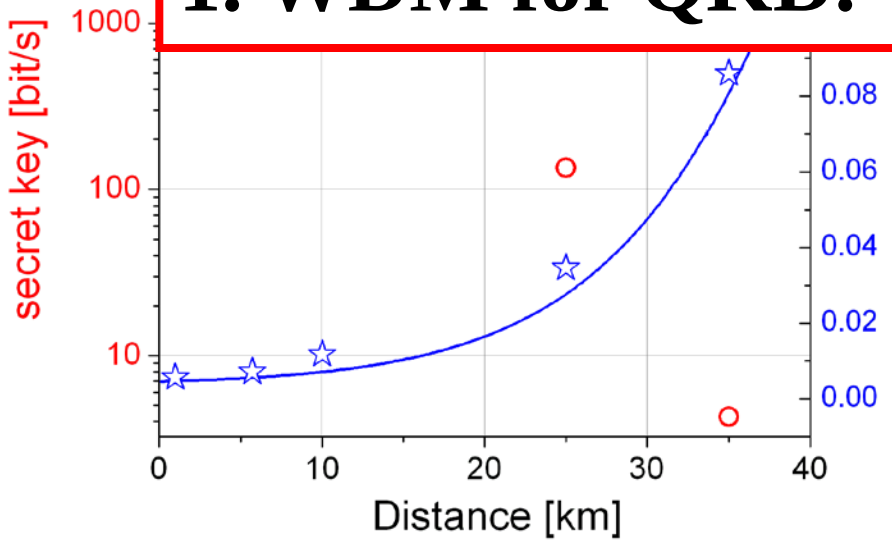


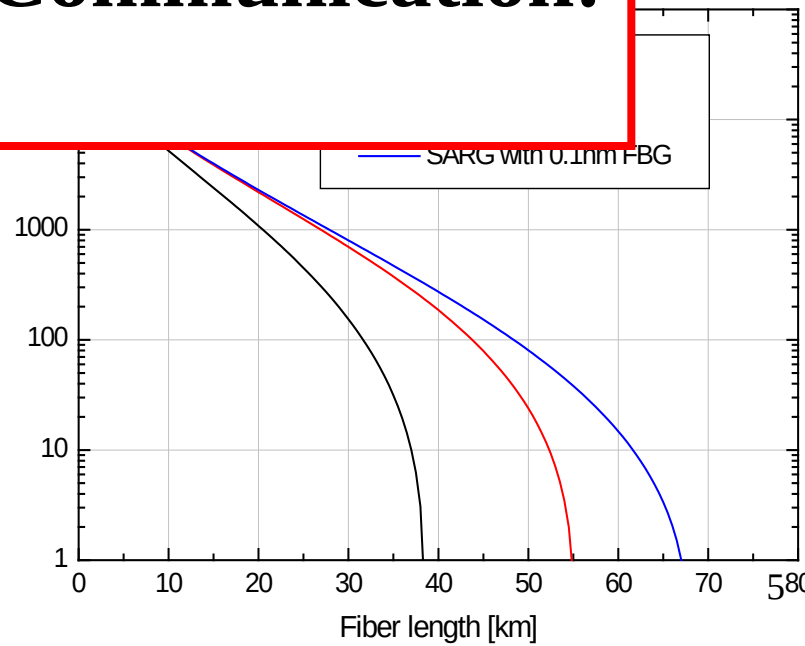
- This is pretty simple and well mastered by id Quantique SA. This is how all commercial Quantum Cryptography works already todays.

WDM: multiplex the Quantum and Classical channels on a single fiber



Futures of Quantum Communication:
1. WDM for QKD.





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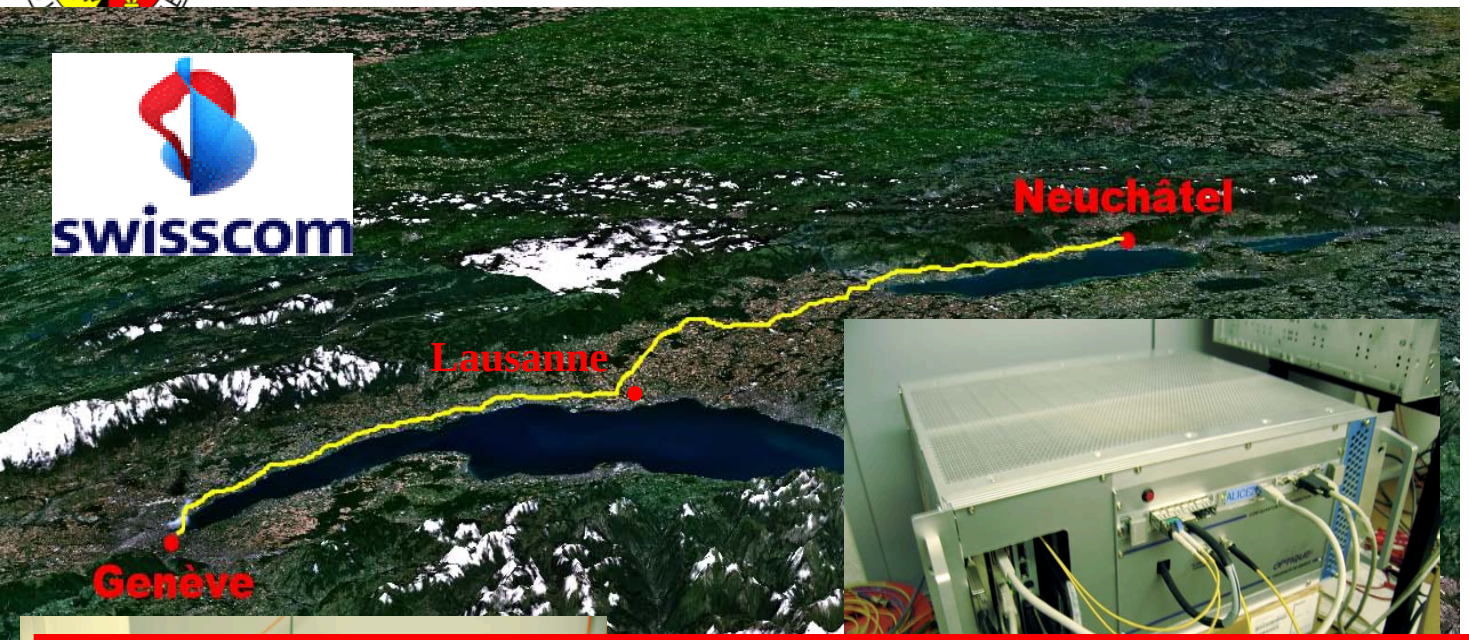
Long distance high bit-rate QKD

Optics Express 17, 13326 (2009)



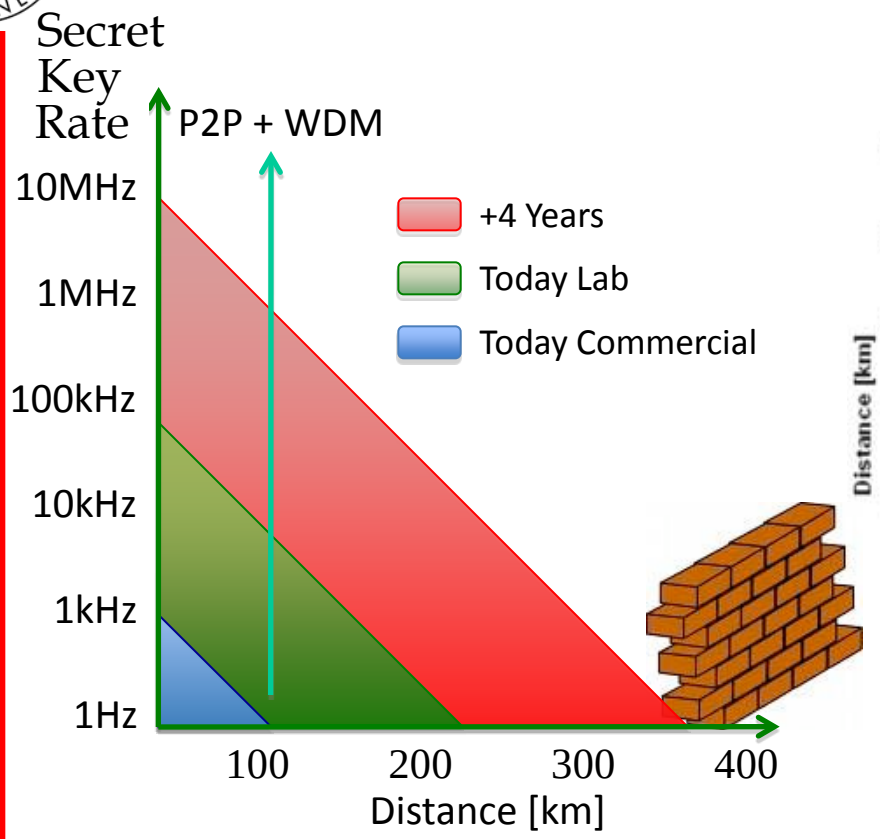
EU projects Secoqc & Sinphonia

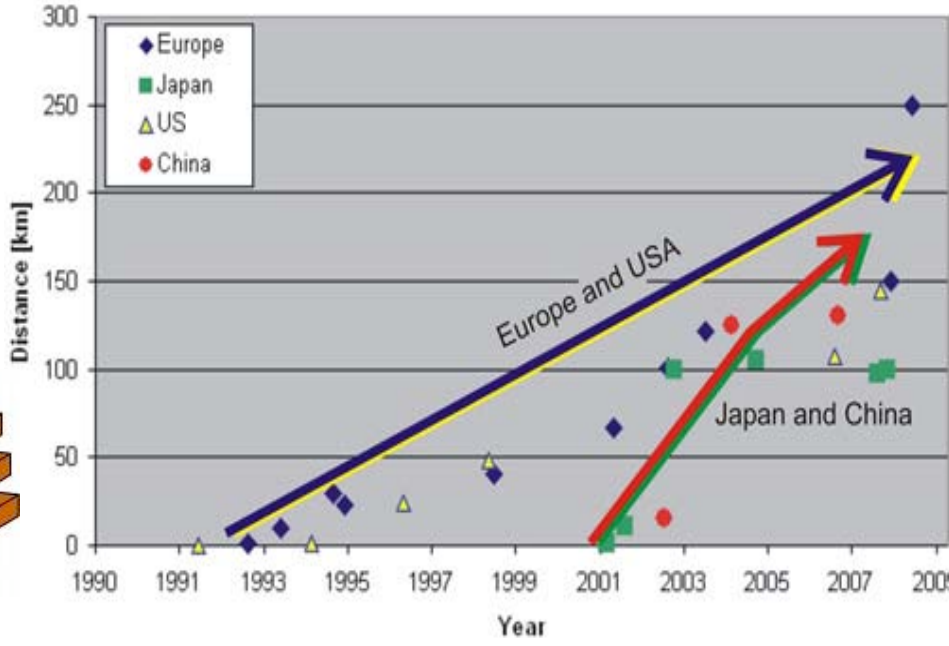
2 dark fibers
~150km
43 dB loss
(0.29dB/km)
660 MHz
Continuous real time secret key distillation

Futures of Quantum Communication:
2. QKD over hundreds of km.

Also QKD over 250 km of ultra low loss fibers from Corning Inc.
NJP 11, 075003 (2009)

Distance limitation





There is a hard wall around 400 km !

2-photon quantum communication: entanglement and nonlocal correlations

The result is random, but both dies show the same result !
One random quantum event manifests itself at both locations !
This is very difficult to understand and even to believe,
but is very well confirmed by experiments !

Sati

Jussy

Geneva

swisscom

Nature 454, 861, 2008

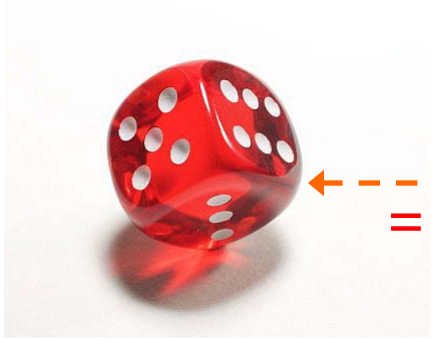
A first connection to Quantum cryptography

- **Futures of Quantum Communication:**
  3. Self-testing QKD systems.

In the future it will be possible to buy cryptographic systems even from your adversary: the observation of nonlocal quantum correlations guaranties the proper functioning of the quantum cryptographic system !

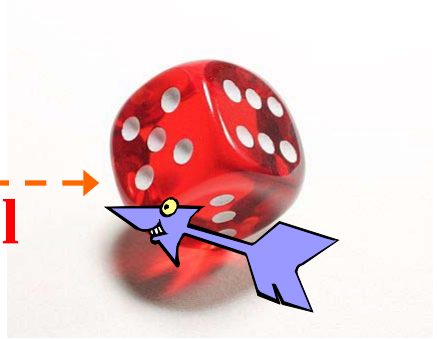
Read: Physics World, pp 28-32, September 2009

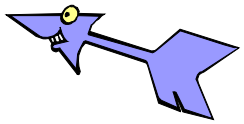
3-photon quantum communication: quantum teleportation



Entanglement

= quantum teleportation channel





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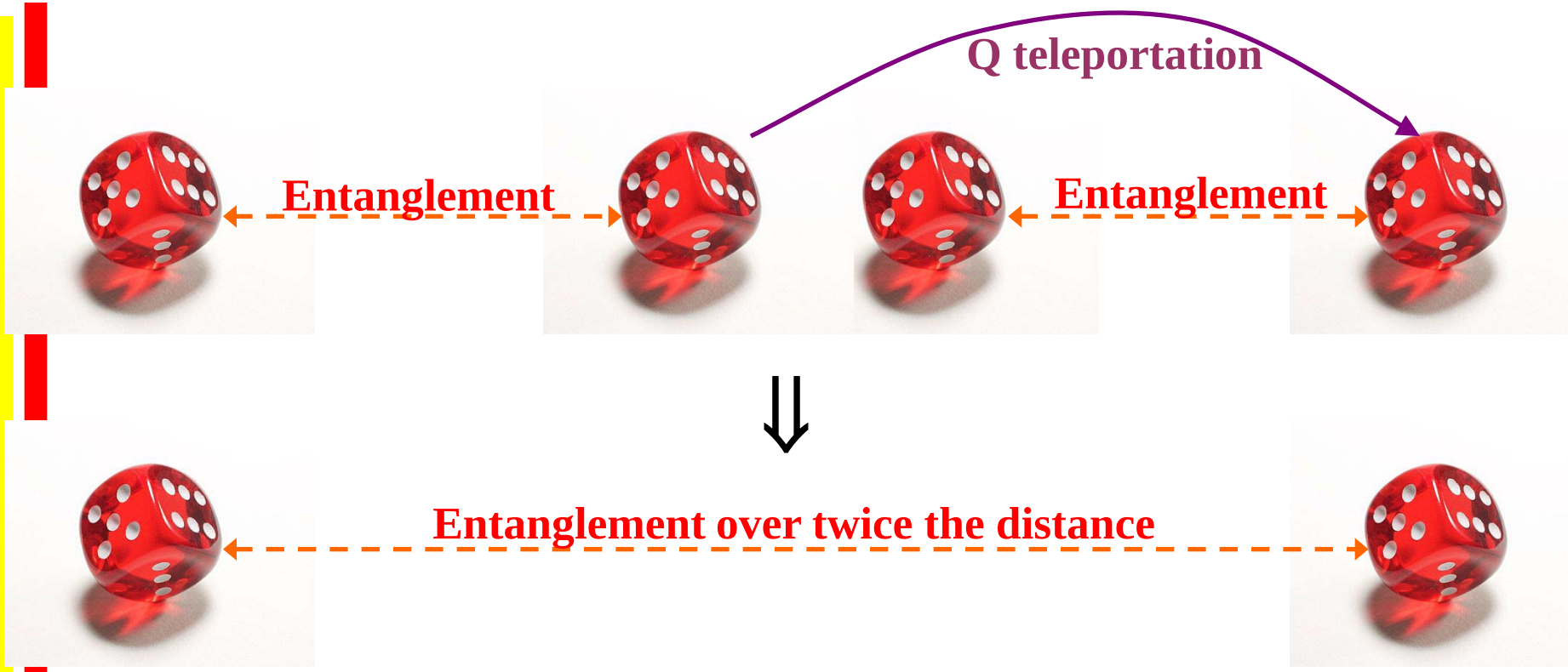
4-photon quantum communication: teleportation of entanglement



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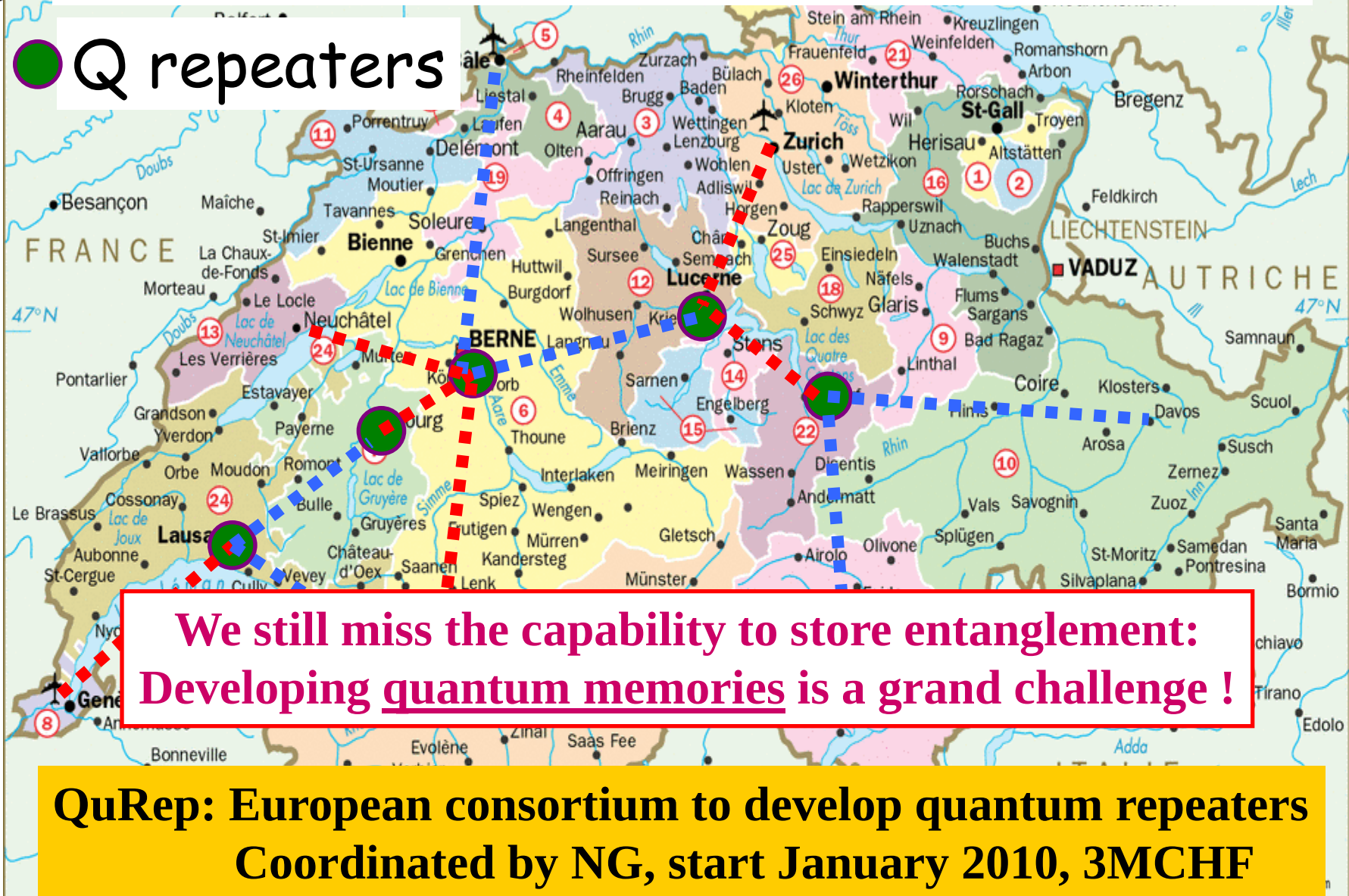
N-photon quantum communication: quantum networks, quantum internet



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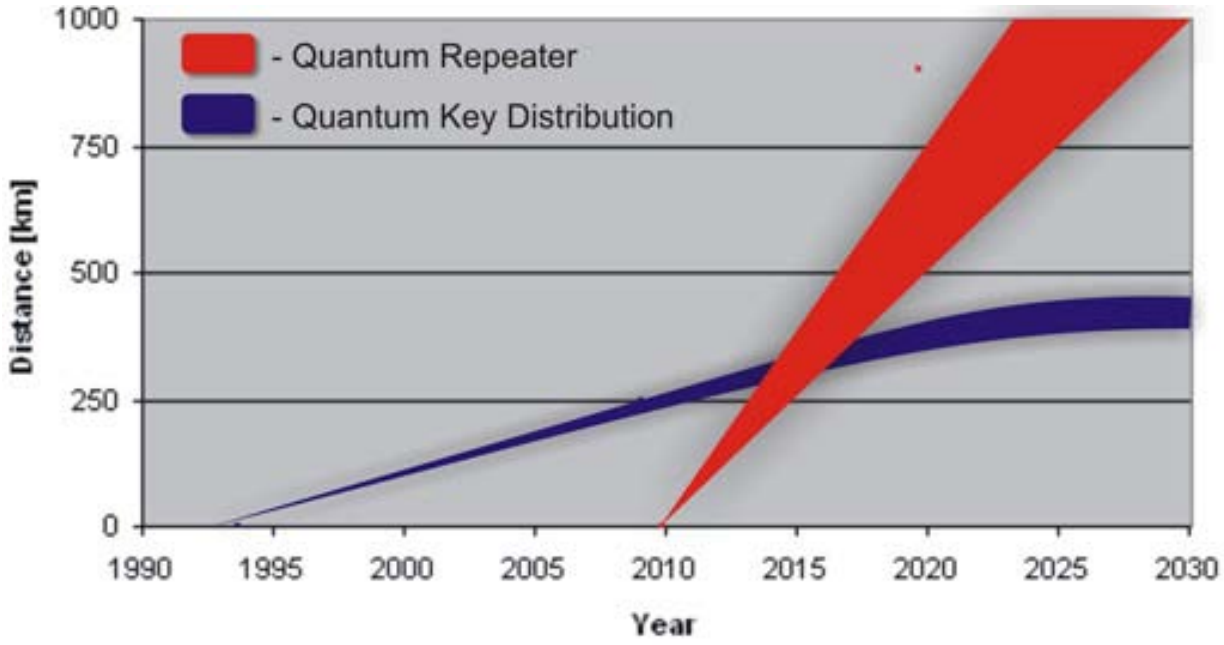
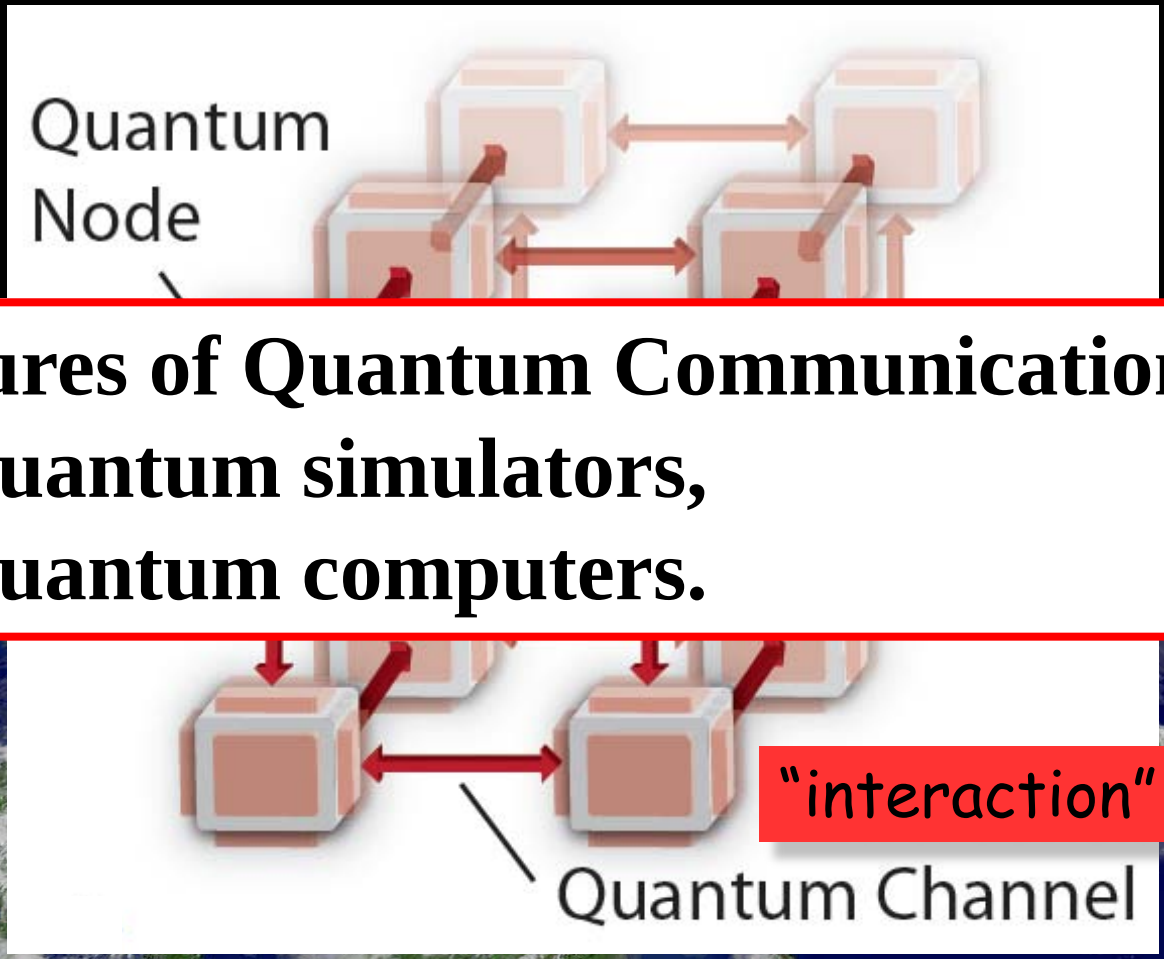
Futures of Quantum Communication: 4. Quantum repeaters for QKD networks.



Future applications

- Private queries:
  interrogate a data base without leaving a trace of the question.
- Fingerprinting:
  associate a short string of quantum bits to a long message.
- Simulation of complex physical systems and Quantum computer.

Quantum Networks as Quantum Many Body Systems



Futures of Quantum Communication:

5. Quantum simulators,
Quantum computers.

Borrowed from
Prof. H.J. Kimple
CalTec, USA

Conclusion

Futures of Quantum Communication:

1. **WDM for QKD**
2. **QKD over hundreds of km.**
3. **Self-testing QKD systems.**
4. **Quantum repeaters for QKD networks.**
5. **Quantum simulators, Quantum computers.**

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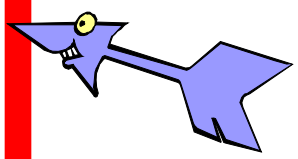
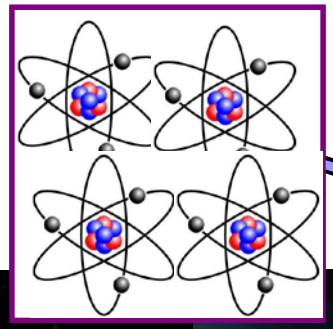
Quantum memory

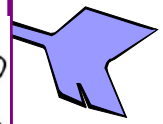
Goal: controlled and reversible mapping of a photonic quantum state onto a long lived atomic ensemble.

crystal doped with millions of ions

photon in







photon out at desired time in same Q state

Today's efficiencies ≈ 10 %

Nature 456, 773, 2008