INFIERI 2023

Global quantum networks

Daniel Felinto

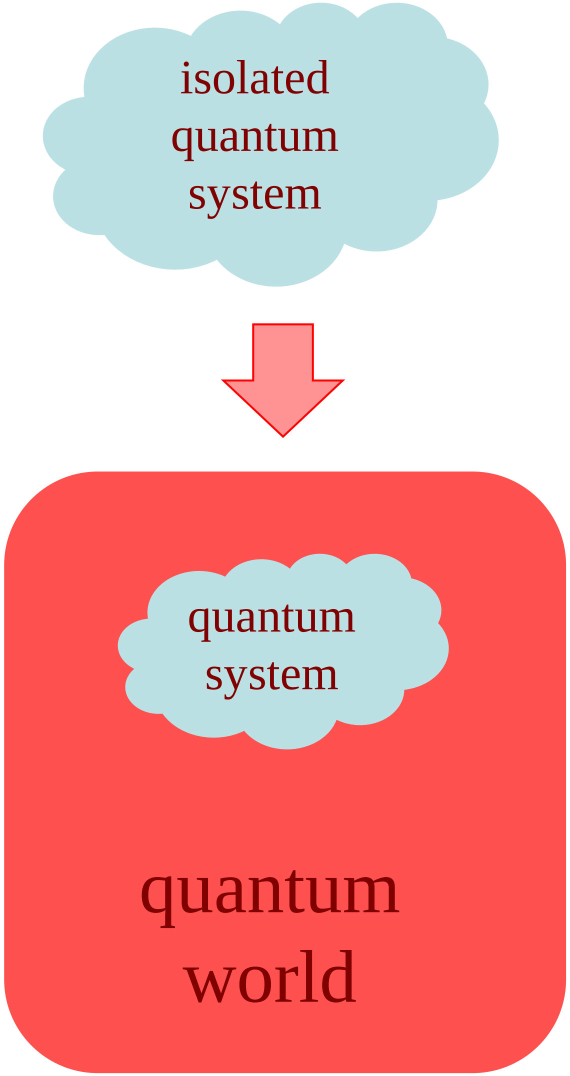
Departamento de Física, UFPE

São Paulo, September 08 2023

daniel.felinto@ufpe.br

1st meaning

2nd meaning



overview

1. Global Quantum Communication (1st meaning)
2. Global Quantum Systems (2nd meaning)
    a) Rayleigh scattering
    b) Raman scattering
3. From quantum networks to the quantum internet
4. Connecting global and local quantum networks
5. Conclusions and perspectives

2nd Quantum Revolution

1st Revolution $\Longrightarrow$ solid state physics (microelectronics, computers, lasers)

quantum devices performing classical tasks

2nd Revolution $\Longrightarrow$ quantum computing, communication, sensing

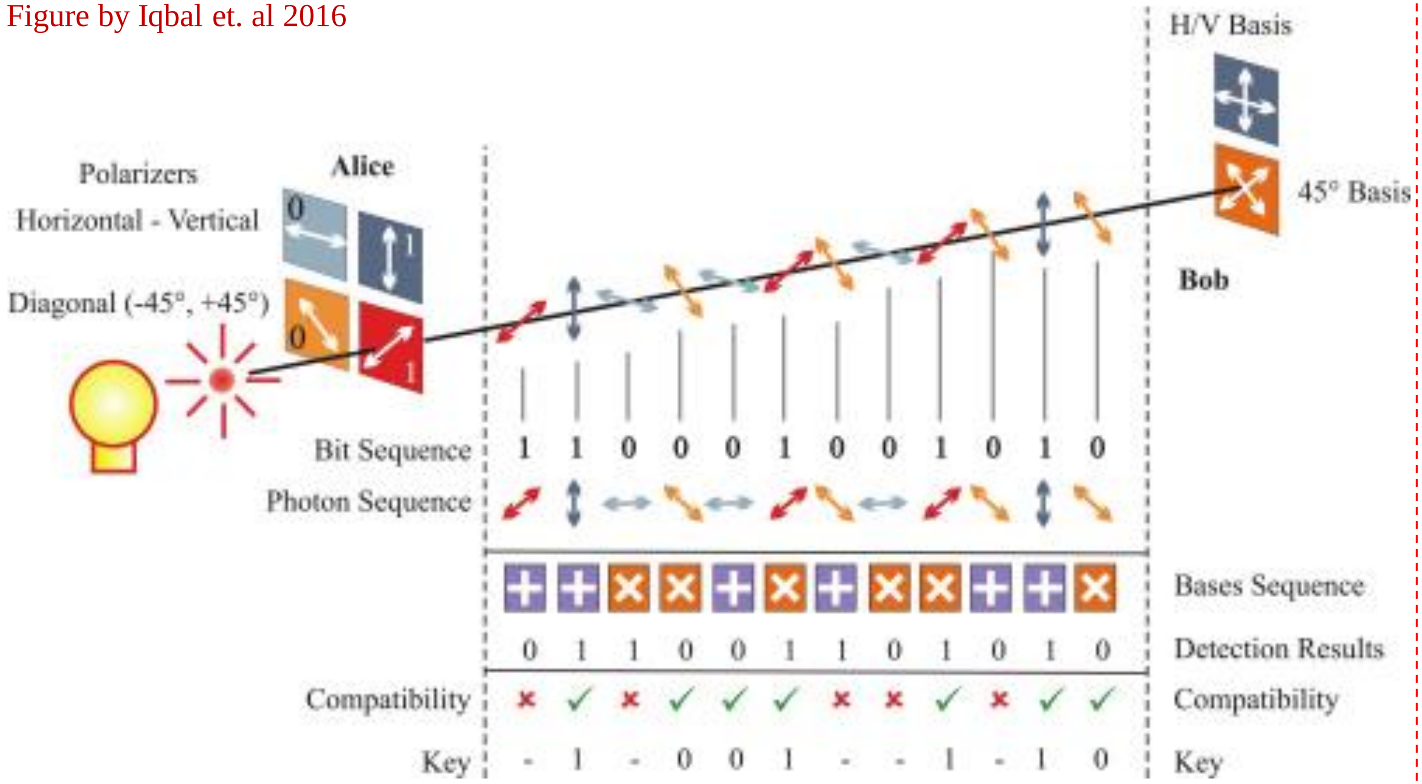
quantum devices performing quantum tasks

- Quantum strategies for solving problems
- Quantum programming
- Quantum engineering

→ Engineers and computer scientists with knowledge of quantum mechanics

1st application: Quantum Key Distribution (BB84)

Figure by Iqbal et. al 2016



No Cloning: quantum states cannot be duplicated

Completely secure public distribution of cryptographic Keys, since eavesdropper would disturb the state and could be detected

Bennett & Brassard, in Int. Conf. Computers, Systems & Signal Processing, Bangalore 175-179 (1984)

1. Global Quantum Communication

First experiment in quantum cryptography → Bennett et al., *J. of Cryptology* **5**, 3 (1992)

1999 a 2019: EUA, Suíça, UK, China, Rússia, Canada, Alemanha, Bulgaria, Polônia, Austrália, Índia, França, Japão

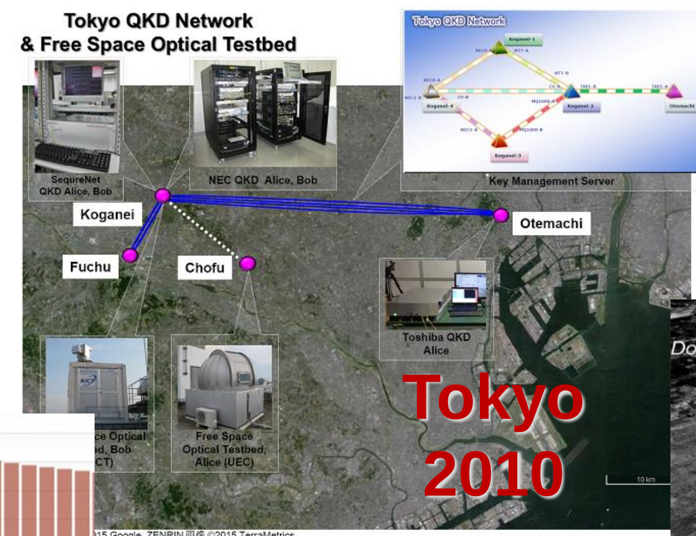
KETS
QUANTUM BLOCKCHAINS
IDQ
QAISEC
CRYPTO QUANTIQUE
Qabacus
MagiQ
agnostiq
PQSHIELD
QUANTUM DICE
ISARA
Crypto-Agile, Quantum-safe Security Solutions
TOSHIBA
Qrypt
EVERLASTING SECURITY
QRATE
QUANTUM COMMUNICATIONS
QUANTUMXCHANGE
Post-Quantum
Q→NU
Proactively Quantum™
国盾量子
QuantumCTek
⟨InfiniQuant⟩
asky
QuBalt
Quintessence Labs
Data Uncompromised
QUDOOR
启科量子
QuSecure
VERIQLOUD

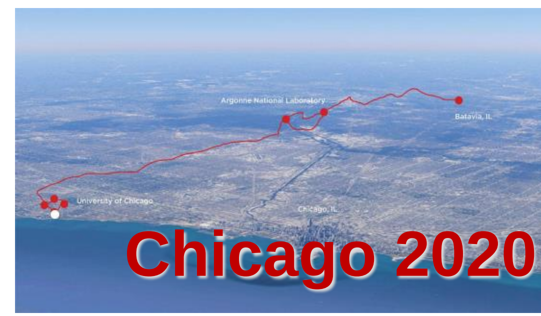
1. Global Quantum Communication

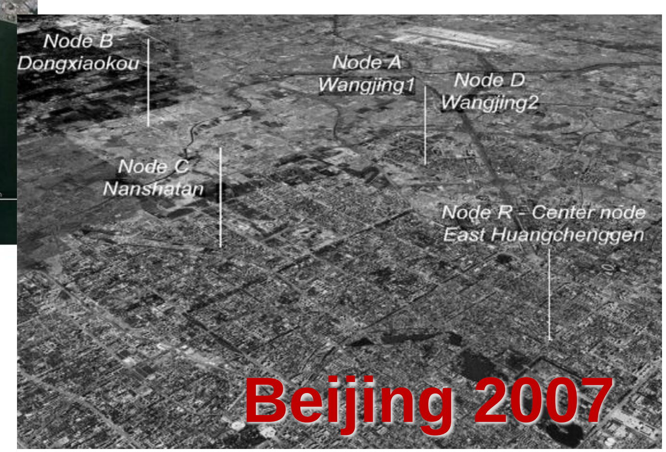
No Cloning ⇒ no amplification ➡ initial limitation to city-wide networks

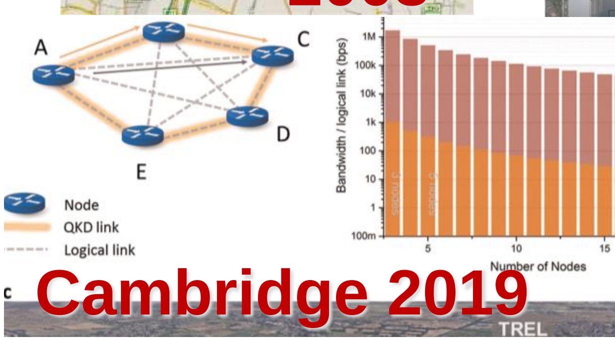
local networks

2007 First large scale application of quantum cryptography (City of Geneva + id Quantique) ➡ securing data transfer for city elections







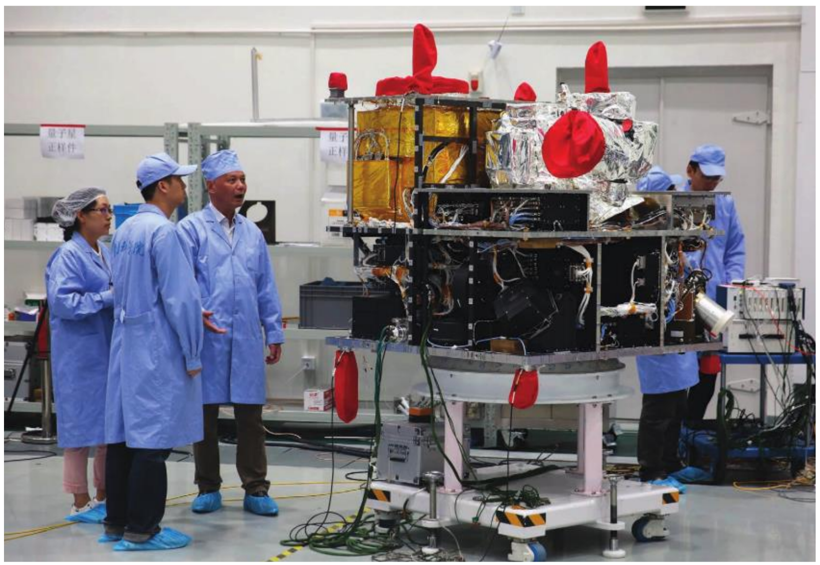


1. Global Quantum Communication

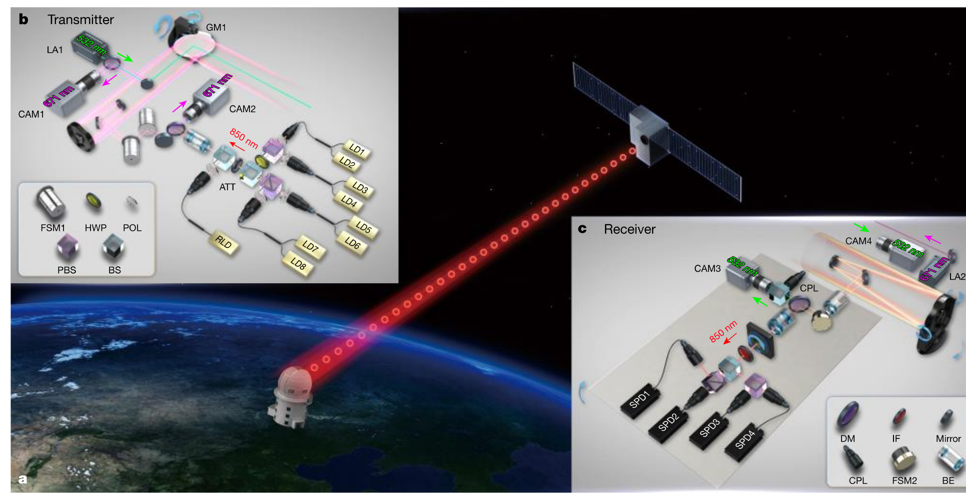
7 SEPTEMBER 2017 | VOL 549 | NATURE | 43

Satellite-to-ground quantum key distribution

Sheng-Kai Liao[1,2], Wen-Qi Cai[1,2], Wei-Yue Liu[1,2], Liang Zhang[2,3], Yang Li[1,2], Ji-Gang Ren[1,2], Juan Yin[1,2], Qi Shen[1,2], Yuan Cao[1,2], Zheng-Ping Li[1,2], Feng-Zhi Li[1,2], Xia-Wei Chen[1,2], Li-Hua Sun[1,2], Jian-Jun Jia[3], Jin-Cai Wu[3], Xiao-Jun Jiang[4], Jian-Feng Wang[4], Yong-Mei Huang[5], Qiang Wang[5], Yi-Lin Zhou[6], Lei Deng[6], Tao Xi[7], Lu Ma[8], Tai Hu[9], Qiang Zhang[1,2], Yu-Ao Chen[1,2], Nai-Le Liu[1,2], Xiang-Bin Wang[2], Zhen-Cai Zhu[6], Chao-Yang Lu[1,2], Rong Shu[2,3], Cheng-Zhi Peng[1,2], Jian-Yu Wang[2,3] & Jian-Wei Pan[1,2]



Micius
China's first quantum satellite



transmission through thin atmosphere allows to reach long distances

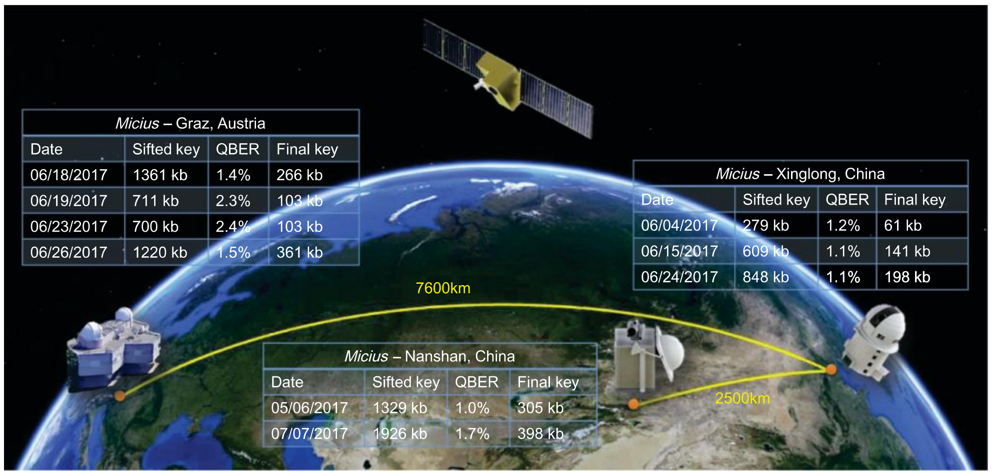
cascading links for Quantum Key Distribution

PHYSICAL REVIEW LETTERS **120,** 030501 (2018)

Editors' Suggestion | Featured in Physics

Satellite-Relayed Intercontinental Quantum Network

Sheng-Kai Liao,[1,2] Wen-Qi Cai,[1,2] Johannes Handsteiner,[3,4] Bo Liu,[4,5] Juan Yin,[1,2] Liang Zhang,[2,6] Dominik Rauch,[3,4] Matthias Fink,[4] Ji-Gang Ren,[1,2] Wei-Yue Liu,[1,2] Yang Li,[1,2] Qi Shen,[1,2] Yuan Cao,[1,2] Feng-Zhi Li,[1,2] Jian-Feng Wang,[7] Yong-Mei Huang,[8] Lei Deng,[9] Tao Xi,[10] Lu Ma,[11] Tai Hu,[12] Li Li,[1,2] Nai-Le Liu,[1,2] Franz Koidl,[13] Peiyuan Wang,[13] Yu-Ao Chen,[1,2] Xiang-Bin Wang,[2] Michael Steindorfer,[13] Georg Kirchner,[13] Chao-Yang Lu,[1,2] Rong Shu,[2,6] Rupert Ursin,[3,4] Thomas Scheidl,[3,4] Cheng-Zhi Peng,[1,2] Jian-Yu Wang,[2,6] Anton Zeilinger,[3,4] and Jian-Wei Pan[1,2]



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

Sustained an encrypted videoconference between China and Austria for 75 min

Problem: Cascanding QKD requires trusted relys (ground or satellite) that have knowledge of all keys.

Solution: to use quantum entanglement

1. Global Quantum Communication

So far, huge development on a specific communication task (QKD).

How to move forward?

Development of Quantum Key Distribution Protocols

1984: BB84 protocol with single photons

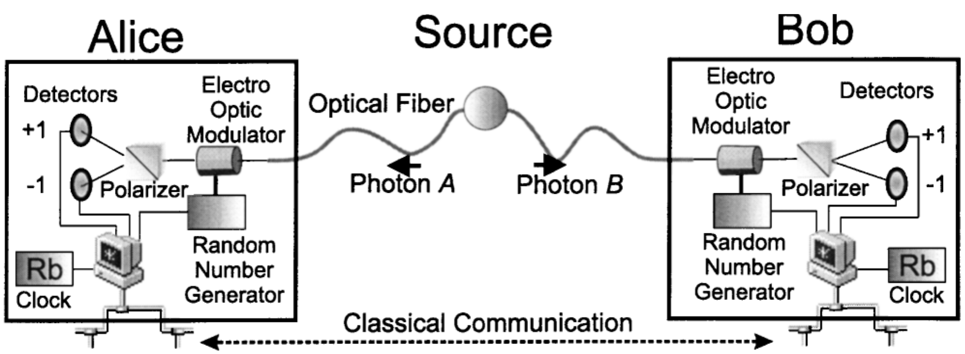
1990s – 2000s: widespread use of attenuated laser pulses (unsafe alternative to single photons)

2005: decoy-state BB84 protocol makes attenuated lasers safe for QKD

Use of attenuated laser pulses is nowadays the standard for QKD between 2 sites

1991: Ekert protocol with quantum entangled photon pairs

2000: Experimental implementation of Ekert protocol [PRL **84**, 4729 (2000); 4733 (2000); 4737 (2000)]

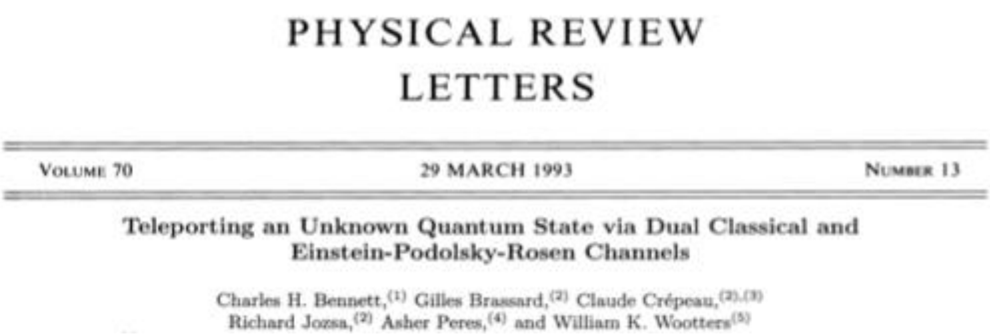


$$|\Psi^-\rangle = \frac{1}{\sqrt{2}}[|H\rangle_A|V\rangle_B - |V\rangle_A|H\rangle_B]$$

1. Global Quantum Communication

Entanglement-based quantum communication

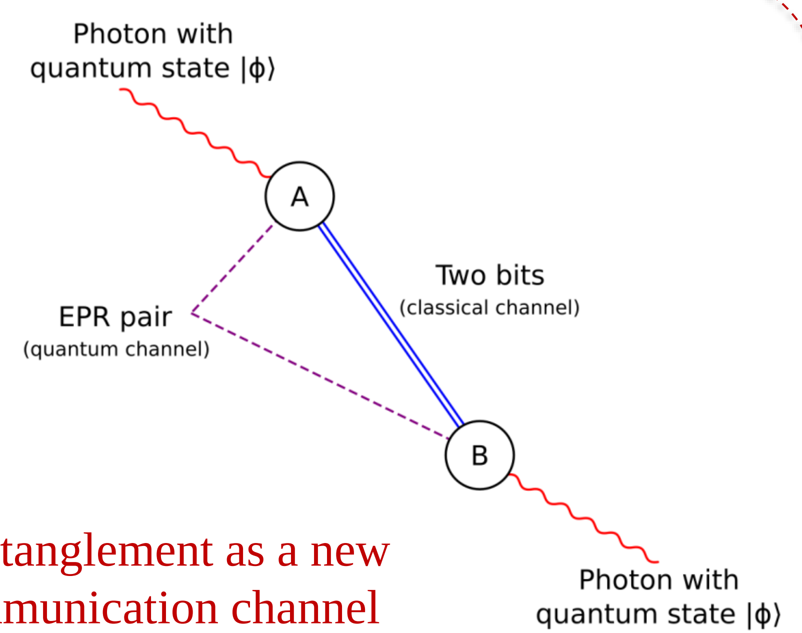
Quantum teleportation (1993)


PHYSICAL REVIEW LETTERS

VOLUME 70 | 29 MARCH 1993 | NUMBER 13

Teleporting an Unknown Quantum State via Dual Classical and Einstein-Podolsky-Rosen Channels

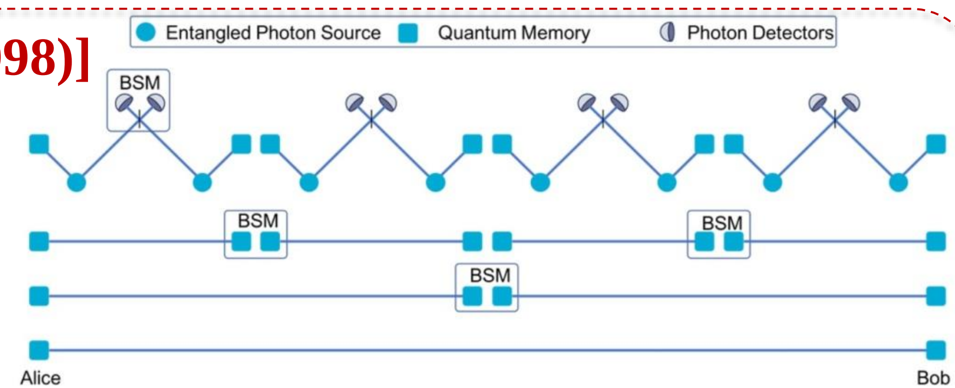
Charles H. Bennett,(1) Gilles Brassard,(2) Claude Crépeau,(2),(3) Richard Jozsa,(2) Asher Peres,(4) and William K. Wootters(5)



Quantum state cannot be copied (No Cloning), but can be transported from site A to site B if these sites share quantum entanglement } Quantum entanglement as a new type of communication channel

Quantum repeaters [PRL 81, 5932 (1998)]

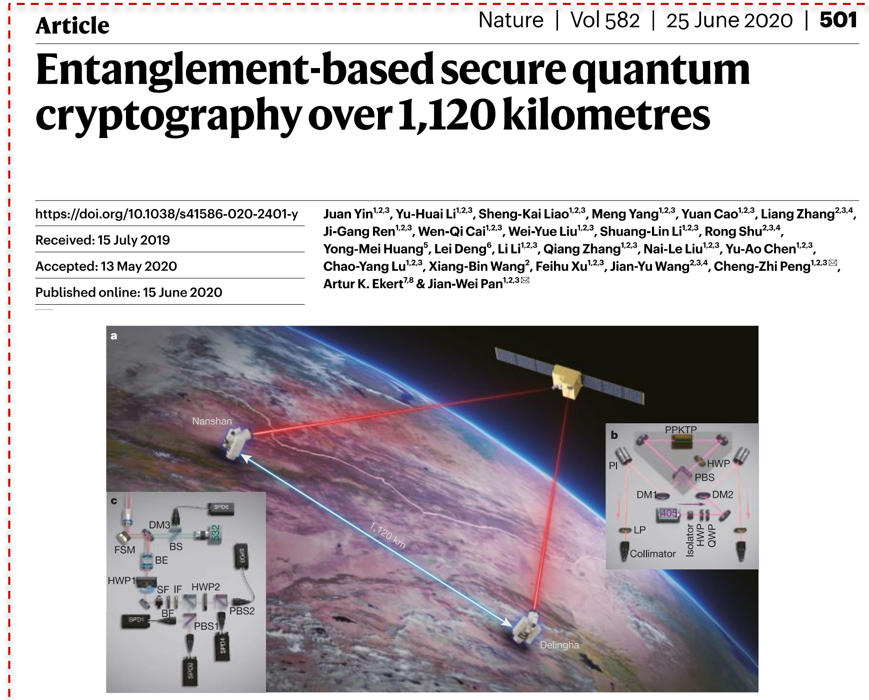
Quantum communication with entangled states is scalable (not limited by No Cloning theorem)



1. Global Quantum Communication

China's Micius satellite

June 2017: distribution of quantum entanglement between systems separated by 1200 km.



Article

Nature | Vol 582 | 25 June 2020 | 501

Entanglement-based secure quantum cryptography over 1,120 kilometres

https://doi.org/10.1038/s41586-020-2401-y

Received: 15 July 2019

Accepted: 13 May 2020

Published online: 15 June 2020

Juan Yin[1,2,3], Yu-Huai Li[1,2,3], Sheng-Kai Liao[1,2,3], Meng Yang[1,2,3], Yuan Cao[1,2,3], Liang Zhang[2,3,4], Ji-Gang Ren[1,2,3], Wen-Qi Cai[1,2,3], Wei-Yue Liu[1,2,3], Shuang-Lin Li[1,2,3], Rong Shu[2,3,4], Yong-Mei Huang[5], Lei Deng[6], Li Li[1,2,3], Qiang Zhang[1,2,3], Nai-Le Liu[1,2,3], Yu-Ao Chen[1,2,3], Chao-Yang Lu[1,2,3], Xiang-Bin Wang[2], Feihu Xu[1,2,3], Jian-Yu Wang[2,3,4], Cheng-Zhi Peng[1,2,3]✉, Artur K. Ekert[7,8] & Jian-Wei Pan[1,2,3]✉

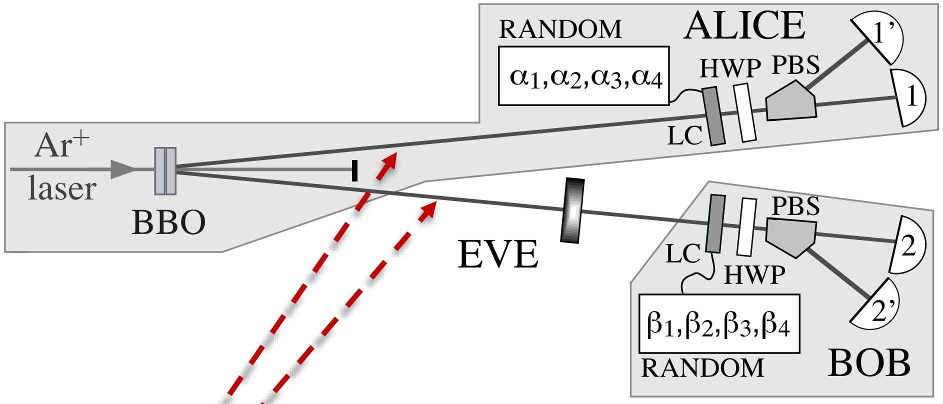
Network of satellites up 2030

1. Global Quantum Communication

source of entangled photon pairs:

Spontaneous Parametric Down-Conversion

Setup for QKD with quantum entanglement
[PRL 84, 4733 (2000)]



correlated
spontaneous emission

relatively mundane physical system

tip of the iceberg
of quantum resources

2. Global Quantum Systems

Usual quantum mechanical treatment

isolated quantum system

$$\psi$$

More realistic approach

open quantum system

world

$$\hat{\rho}$$

statistical mixture
master equation

addressing an individual system in contact to another

Even more realistic…

quantum system

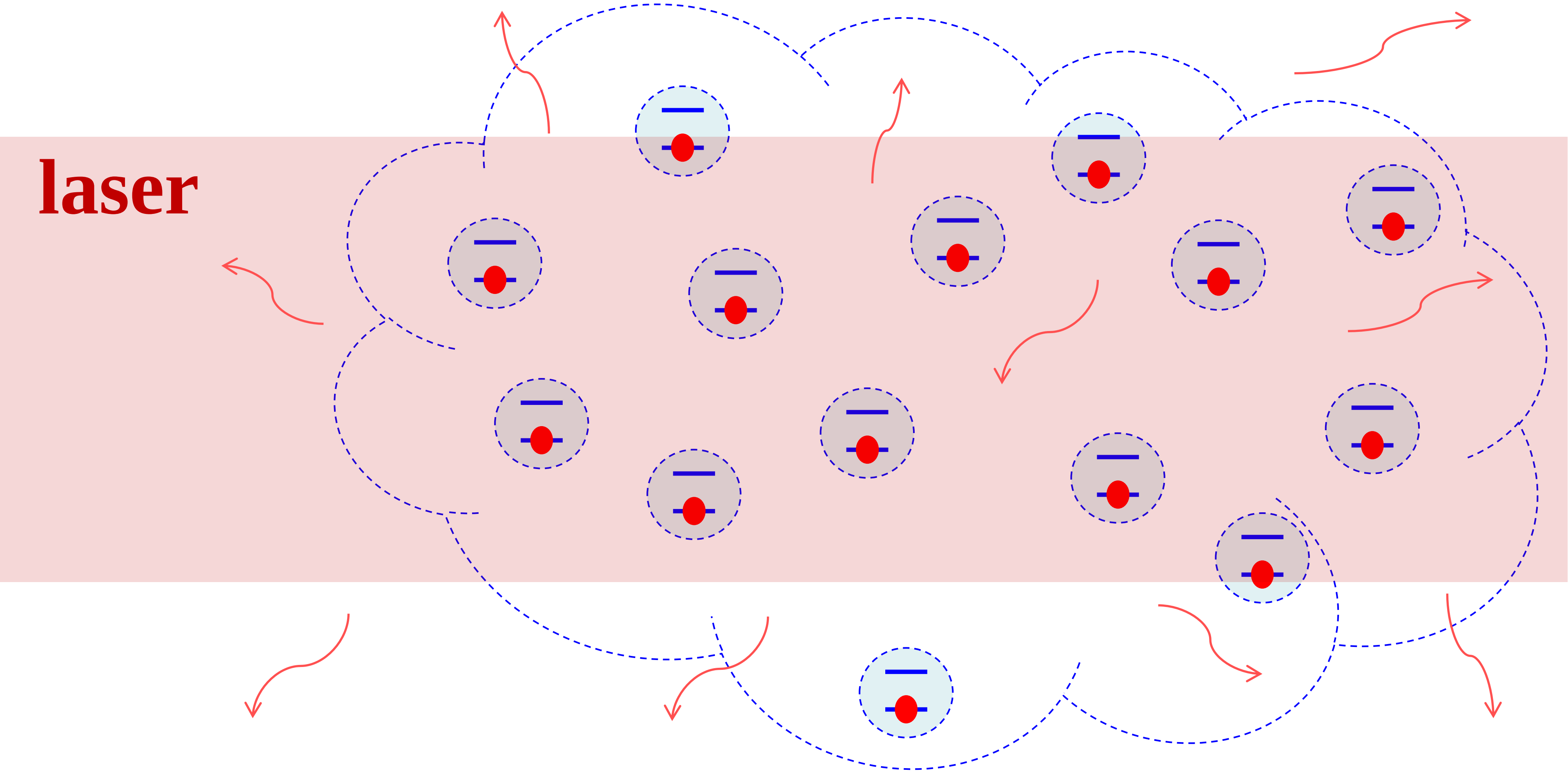
quantum world

$$\psi$$

intrinsically multi-partite
(quantum information)

addressing all interacting systems

2.(a) Global Quantum Systems: Rayleigh scattering



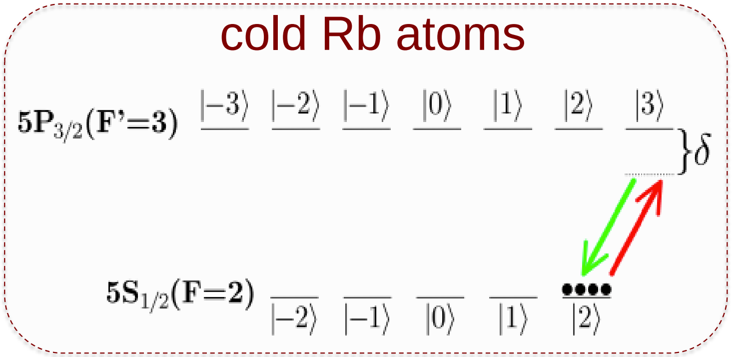
interest → simplest quantum system to model light-matter interaction
→ widely applied classical models

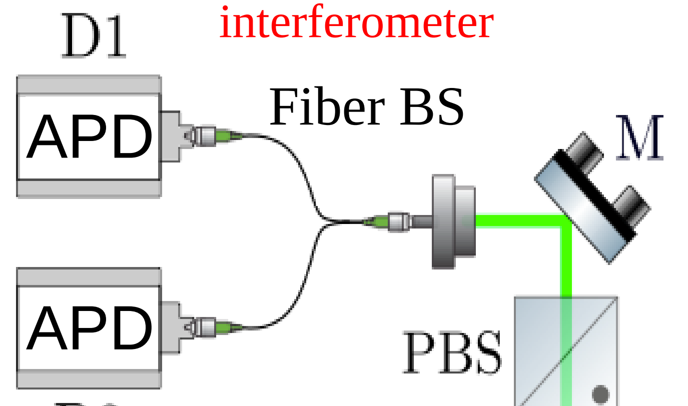
challenges → lack of structure prevents most filtering techniques
→ mix of different contributions may hide purely quantum effects

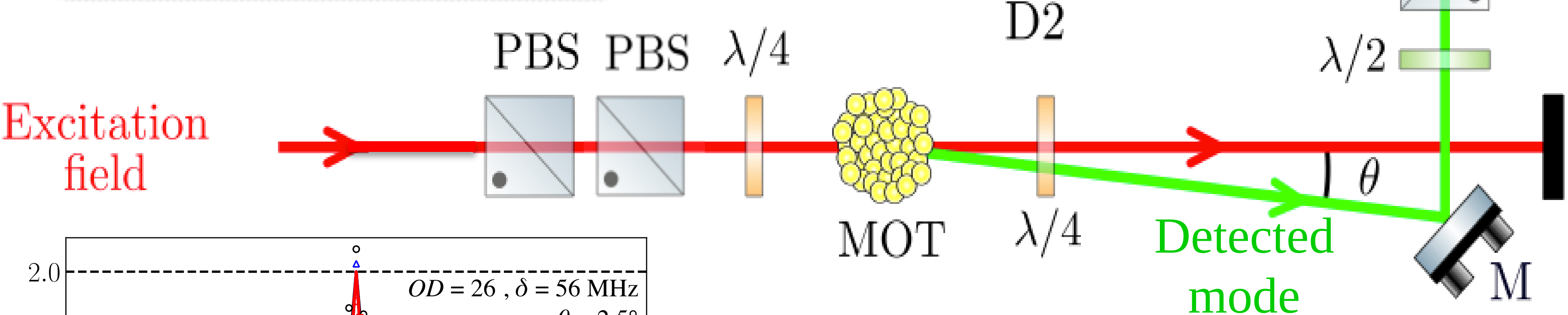
2.(a) Global Quantum Systems: Rayleigh scattering

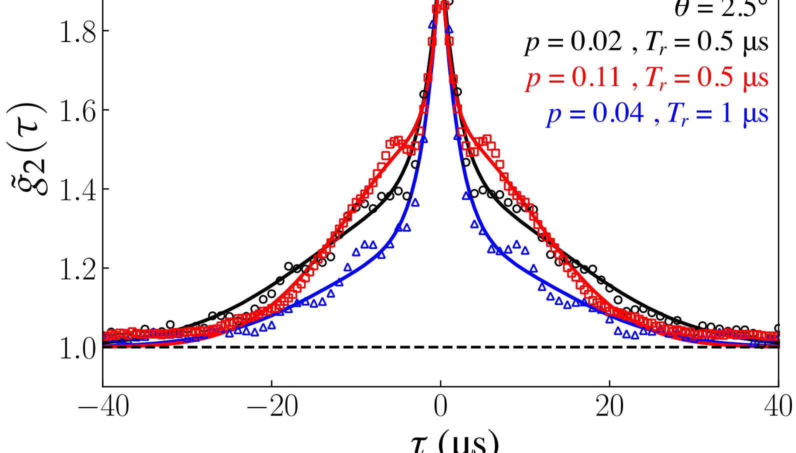
Moreira et al., Opt. Commun. **459**, 127075 (2021)

Hanbury-Brown-Twiss (HBT) interferometer









$$g^{(2)}(\tau) = \frac{\langle \bar{I}(t)\bar{I}(t+\tau)\rangle}{\bar{I}^2}$$

thermal light source

$g^{(2)}(0) = 2$

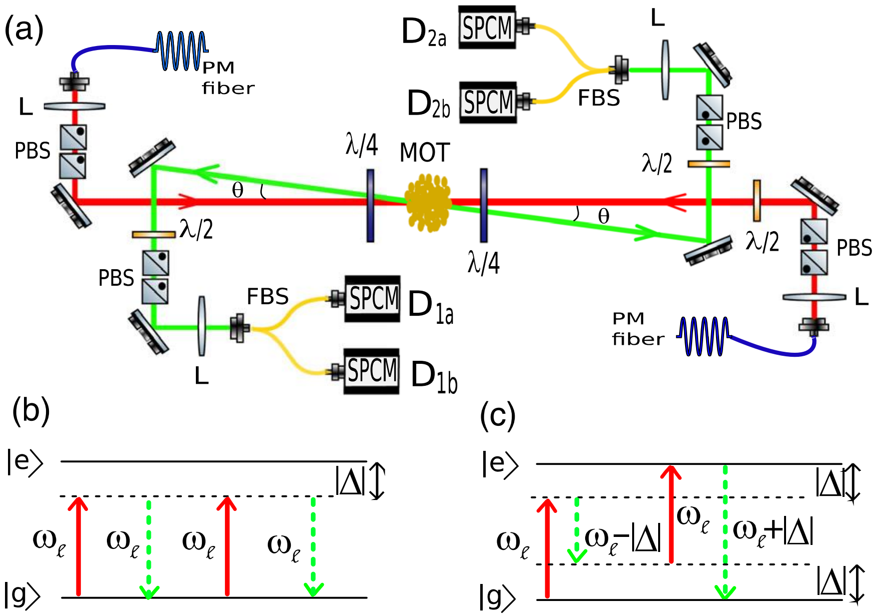
$g^{(2)}(\tau \to \infty) = 1$

2.(a) Global Quantum Systems: Rayleigh scattering

PHYSICAL REVIEW LETTERS **128,** 083601 (2022)

Observation of Nonclassical Correlations in Biphotons Generated from an Ensemble of Pure Two-Level Atoms

Michelle O. Araújo, Lucas S. Marinho, and Daniel Felinto
Departamento de Física, Universidade Federal de Pernambuco, 50670-901 Recife, Pernambuco, Brazil



Criteria for quantum correlations: Cauchy-Schwarz inequality

$$R=\frac{g_{12}(\tau)^2}{g_{11}(0)\,g_{22}(0)}$$

cross-correlation

auto-correlations

$R \le 1$: classical correlations

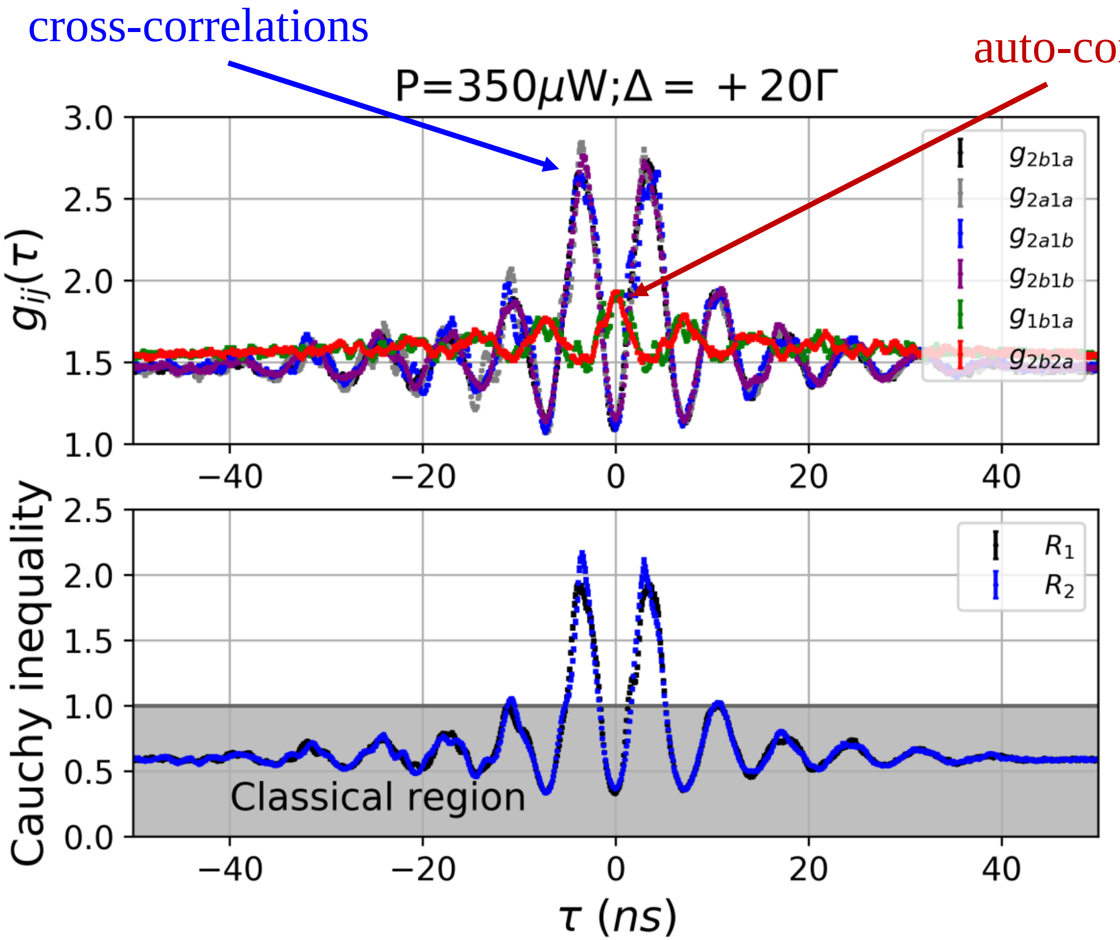
$$g_{11}(0)\approx g_{22}(0)\approx 2$$

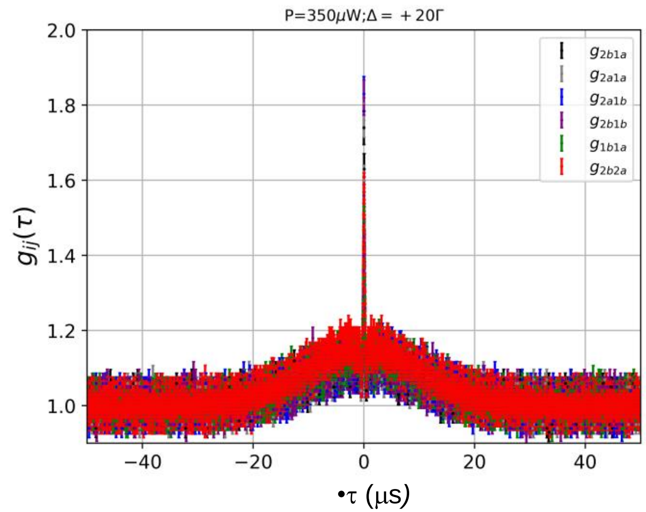
thermal states

$$g_{12}(\tau) > 2$$

quantum region

2.(a) Global Quantum Systems: Rayleigh scattering





$$R = (1.98 \pm 0.03) \not\leq 1$$

non-classical correlations!

Quantum correlations prevail over the Rayleigh scattering background

Classical models may predict some experimental results but not all

Decay of quantum correlations faster than predicted $\Longrightarrow$ **superradiance**

2.(a) Global Quantum Systems: Rayleigh scattering

Superradiance

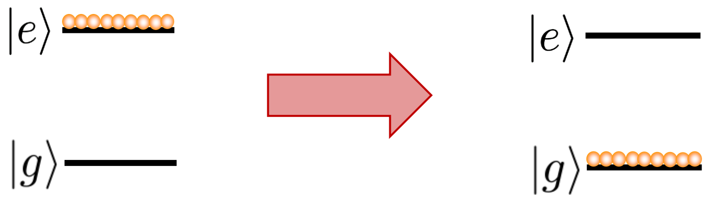
PHYSICAL REVIEW VOLUME 93, NUMBER 1 JANUARY 1, 1954

Coherence in Spontaneous Radiation Processes

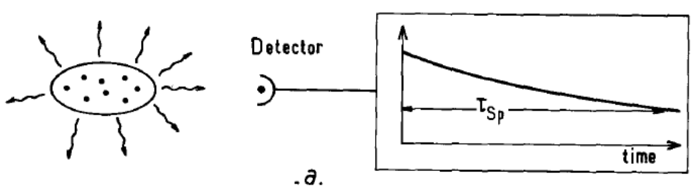
R. H. Dicke
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey

same vacuum mode shared by a large number of atoms

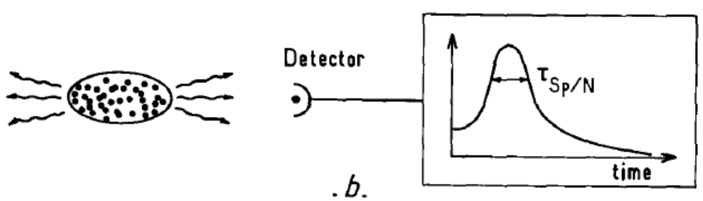
coherent coupling of atoms through the vacuum



low density or # atoms (N)



high density or # atoms (N)



1st experiment

VOLUME 30, NUMBER 8 PHYSICAL REVIEW LETTERS 19 FEBRUARY 1973

Observation of Dicke Superradiance in Optically Pumped HF Gas*

N. Skribanowitz, I. P. Herman,† J. C. MacGillivray, and M. S. Feld
Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

PHYSICAL REVIEW A VOLUME 14, NUMBER 3 SEPTEMBER 1976

Theory of superradiance in an extended, optically thick medium*

J. C. MacGillivray and M. S. Feld†
Department of Physics and Spectroscopy Laboratory, Massachusetts Institute of Technology,

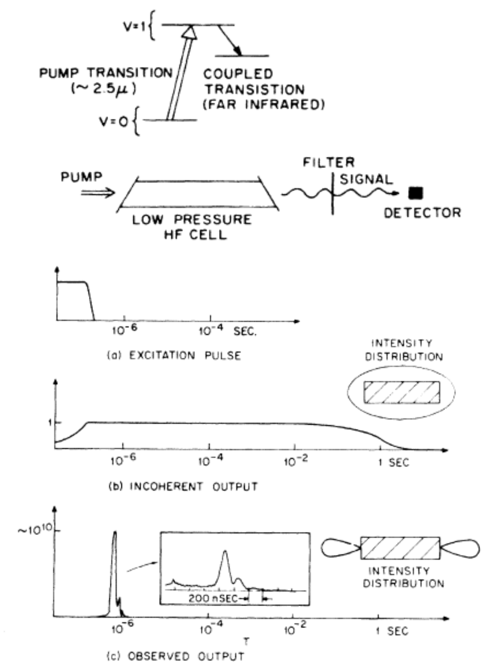
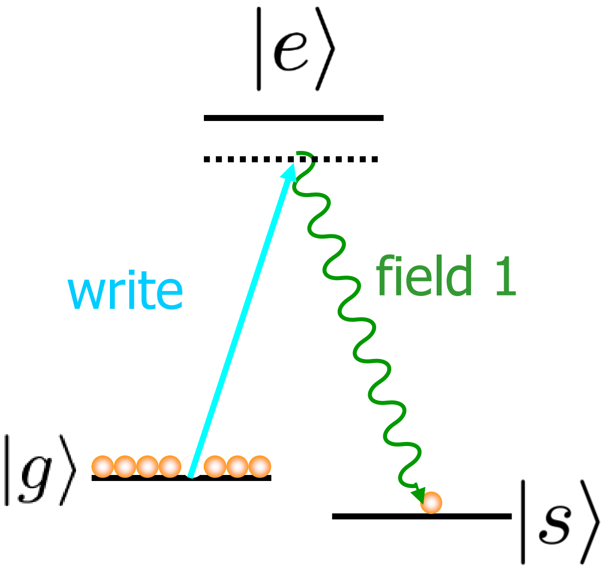


FIG. 2. Comparison of observed output and incoherent spontaneous emission. Time is plotted on a logarithmic scale. (a) Population-inverting laser pulse. (b) Output expected from incoherent spontaneous emission, exhibiting exponential decay and an isotropic radiation pattern. (c) Observed output, exhibiting ringing, a highly directional radiation pattern, and a peak intensity of $\sim 10^{10}$ times that of (b). The inset shows the time evolution of the same pulse with a linear time scale.

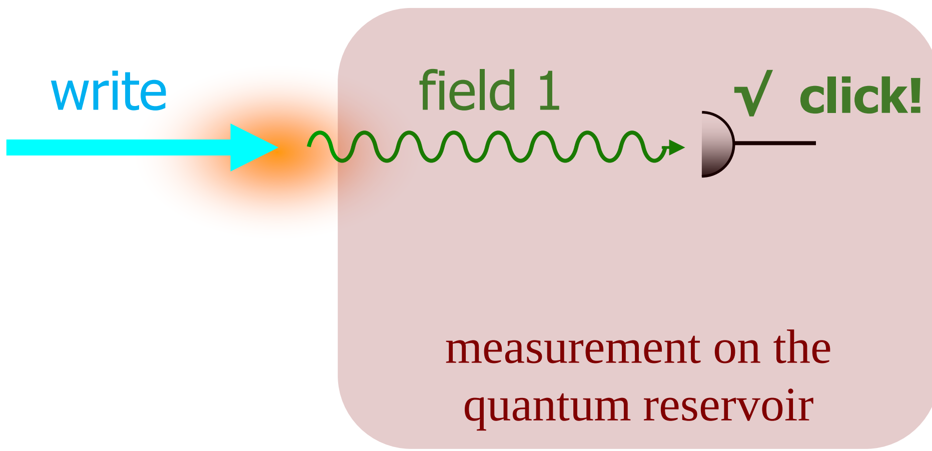
2.(b) Global Quantum Systems: Raman scattering



$$|\psi_{1at}\rangle = |0_1, 0_{at}\rangle + \sqrt{p}|1_1, 1_{at}\rangle + O(p)$$

p : excitation probability

$$|0_{at}\rangle \equiv |g, g, g \ldots g\rangle$$
$$|1_{at}\rangle \equiv S\{|s, g, g \ldots g\rangle\}$$
$$|2_{at}\rangle \equiv S\{|s, s, g \ldots g\rangle\}$$
$$\vdots$$



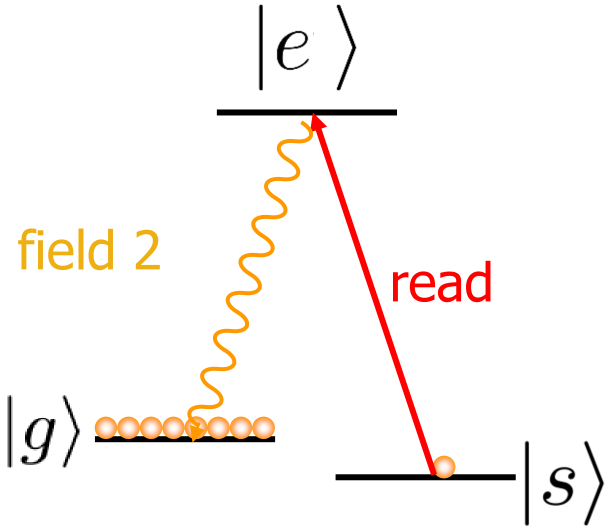
$$|\Psi_{at}\rangle \approx |1_{at}\rangle + O(\sqrt{p})$$

Conditional preparation of entangled collective state with 1 excitation

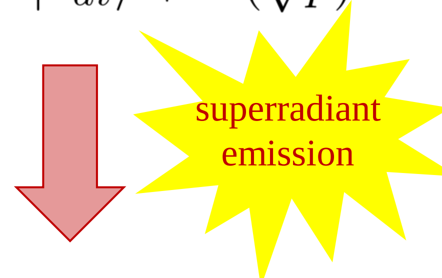
Theoretical proposal (DLCZ protocol): Duan et. al, Nature **414**, 413 (2001)

First implementation: Kuzmich et. al, Nature **423**, 731 (2003)

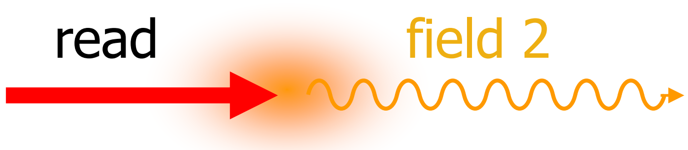
2.(b) Global Quantum Systems: Raman scattering



$$|\Psi_{at}\rangle \approx |1_{at}\rangle + O(\sqrt{p})$$

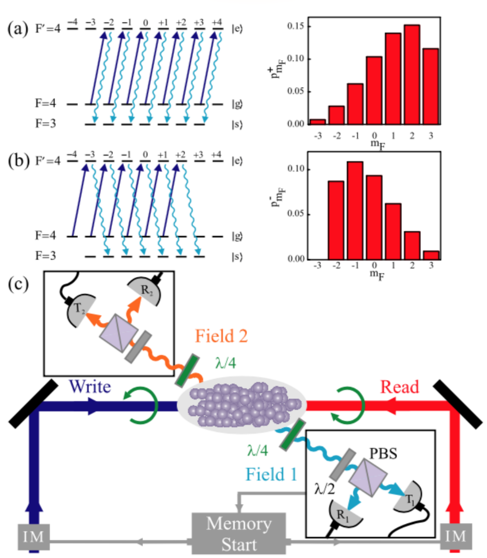


$$|\Psi_{2}\rangle \approx |1_{2}\rangle + O(\sqrt{p})$$



Fock state (no classical analogue)

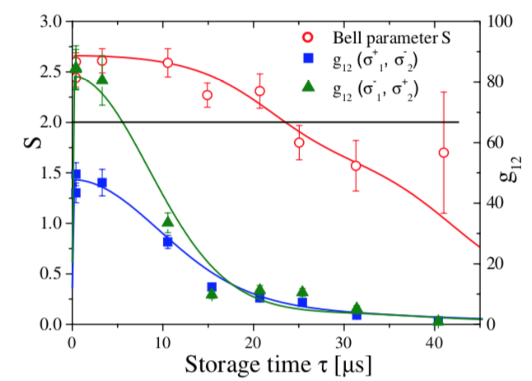
Large suppression of all other $|n_2\rangle$ components



PRL **97,** 113603 (2006) PHYSICAL REVIEW LETTERS week ending 15 SEPTEMBER 2006

Direct Measurement of Decoherence for Entanglement between a Photon and Stored Atomic Excitation

H. de Riedmatten, J. Laurat, C. W. Chou, E. W. Schomburg, D. Felinto, and H. J. Kimble
Norman Bridge Laboratory of Physics 12-33, California Institute of Technology, Pasadena, California 91125, USA



2.(b) Global Quantum Systems: Raman scattering

New Journal of Physics **15** (2013) 075030 (24pp)

New Journal of Physics
The open access journal for physics

Dynamics of the reading process of a quantum memory

Milrian S Mendes[1], Pablo L Saldanha[1,2], José W R Tabosa[1] and Daniel Felinto[1,3]

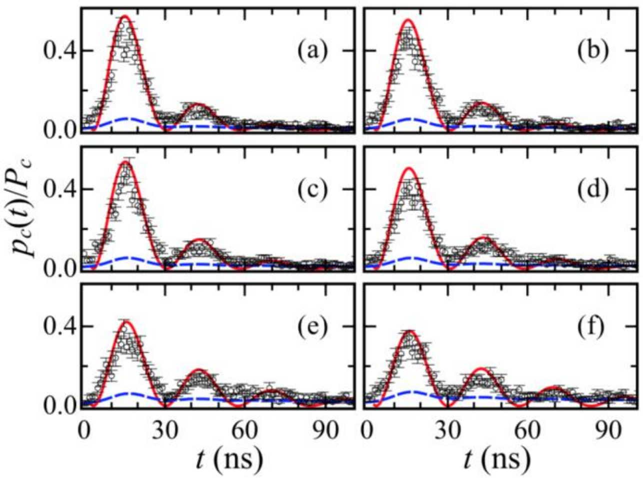


FIG. 8. (Color online) Open circles provide the normalized conditional probability as a function of time for six different optical depths: (a) 4.8, (b) 4.0, (c) 3.4, (d) 2.6, (e) 1.6, and (f) 1.0.

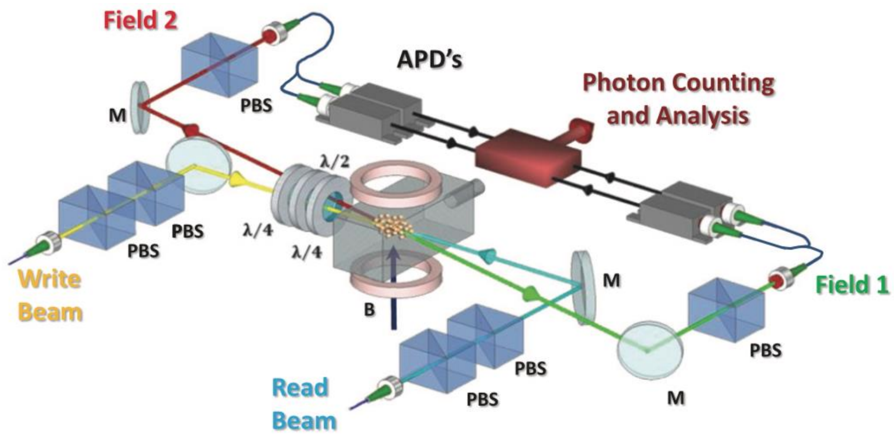
$$\frac{p_c(t)}{P_c} = \alpha e^{-\chi\Gamma t/2} \sin^2\left(\frac{\Omega t}{2}\right)\Delta t$$

$$\chi \approx 1 + \frac{N}{2W^2k^2}.$$

PHYSICAL REVIEW A **90**, 023848 (2014)

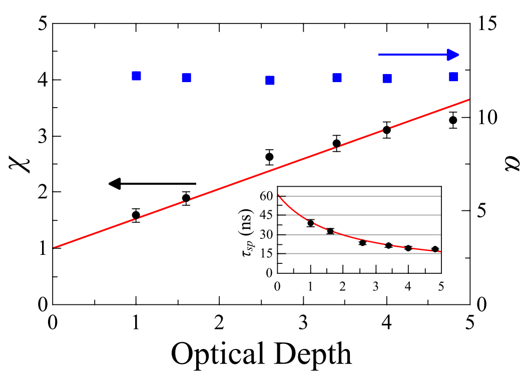
Single-photon superradiance in cold atoms

Rafael A. de Oliveira,[1,*] Milrian S. Mendes,[1] Weliton S. Martins,[1] Pablo L. Saldanha,[2] José W. R. Tabosa,[1] and Daniel Felinto[1,†]



suppression of 2-photon component (field 2)

$g_2^c = 0.23 \pm 0.06$ << **1** (coherent state)



accelerated decay

1 atom: $(\Gamma/2)^{-1}$ = 60 ns

observed: $(\chi\Gamma/2)^{-1}$ = 16 ns

Single photon emitted collectively

2.(b) Global Quantum Systems: Raman scattering

PHYSICAL REVIEW LETTERS **120**, 083603 (2018)

Experimental Fock-State Superradiance

L. Ortiz-Gutiérrez,[1] L. F. Muñoz-Martínez,[1] D. F. Barros,[2] J. E. O. Morales,[1] R. S. N. Moreira,[1] N. D. Alves,[1] A. F. G. Tieco,[1] P. L. Saldanha,[2] and D. Felinto[1,*]

Optics Communications 443 (2019) 34–43

Contents lists available at ScienceDirect

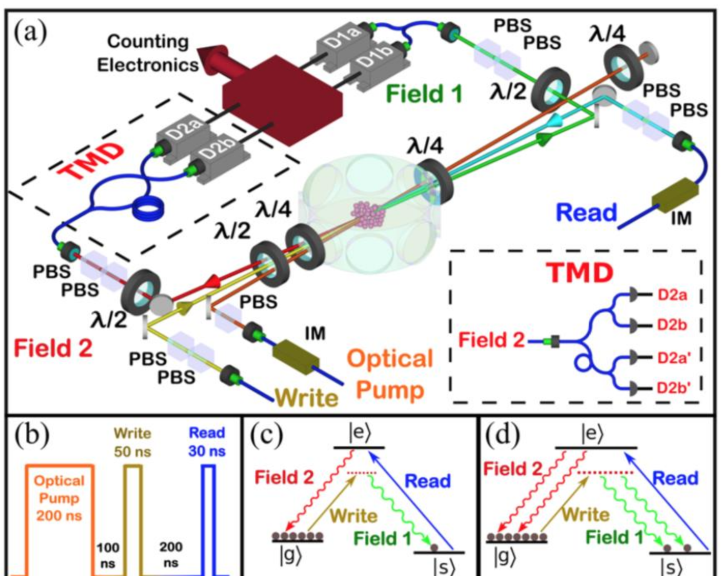
Optics Communications

journal homepage: www.elsevier.com/locate/optcom

ELSEVIER

Fock-state superradiance in a cold atomic ensemble

Davi F. Barros[a,*], Luis F. Muñoz-Martínez[b,1], Luis Ortiz-Gutiérrez[b], Camilo A.E. Guerra[c], Johan E.O. Morales[b], Raoni S.N. Moreira[b], Natália D. Alves[b], Ayanne F.G. Tieco[b], Daniel Felinto[b], Pablo L. Saldanha[a]



Beyond discussion

single photon X attenuated laser

two-photon superradiance

$$|\psi_2\rangle \propto |2_a\rangle + p^{1/2}|3_a\rangle + \cdots$$

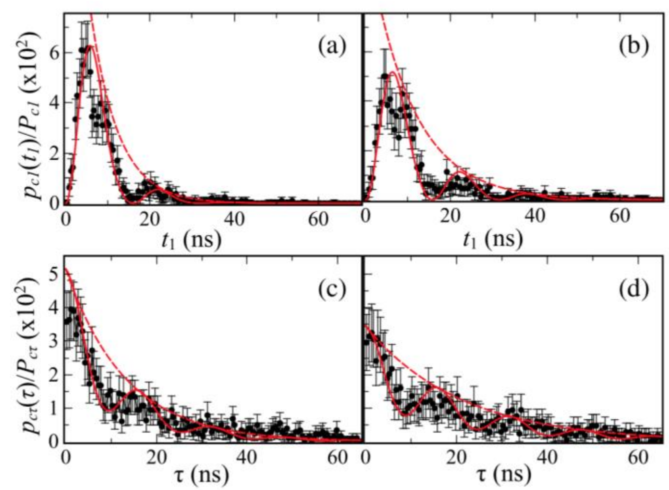


FIG. 4. Biphoton wave packets—Panels (a) and (b): Probability $p_{c1}(t_1)$ to detect the first field-2 photon at t_1, normalized by P_{c1}. Panels (c) and (d): Probability $p_{c\tau}(\tau)$ to detect the second photon at time τ after the first detection, normalized by $P_{c\tau}$.

2.(b) Global Quantum Systems: Raman scattering

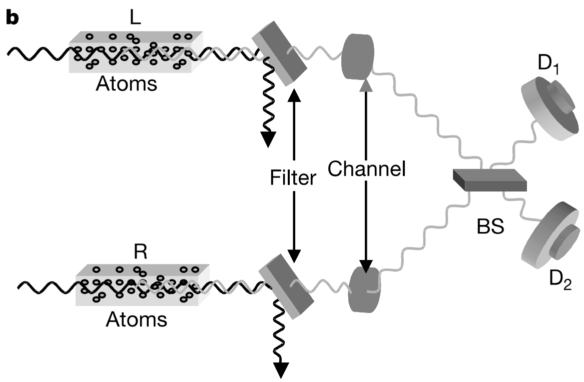
PRL **117**, 243603 (2016) PHYSICAL REVIEW LETTERS week ending 9 DECEMBER 2016

Temporal Quantum Correlations in Inelastic Light Scattering from Water

Mark Kasperczyk,[1] Filomeno S. de Aguiar Júnior,[2] Cassiano Rabelo,[3] Andre Saraiva,[4]
Marcelo F. Santos,[4] Lukas Novotny,[1] and Ado Jorio[2,*]
[1]*Photonics Laboratory, ETH Zürich, 8093 Zürich, Switzerland*
[2]*Departamento de Física, Universidade Federal de Minas Gerais, Belo Horiztone, Minas Gerais 31270-901, Brazil*
[3]*Programa de Pós-Graduação em Engenharia Elétrica, Universidade Federal de Minas Gerais, Belo Horiztone, Minas Gerais 31270-901, Brazil*
[4]*Instituto de Física, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Rio de Janeiro 21941-972, Brazil*
(Received 24 June 2016; published 7 December 2016)

Water is one of the most prevalent chemicals on our planet, an integral part of both our environment and our existence as a species. Yet it is also rich in anomalous behaviors. Here we reveal that water is a novel—yet ubiquitous—source for quantum correlated photon pairs at ambient conditions. The photon pairs are produced through Raman scattering, and the correlations arise from the shared quantum of a vibrational mode between the Stokes and anti-Stokes scattering events. We confirm the nonclassical nature of the produced photon pairs by showing that the cross-correlation and autocorrelations of the signals violate a Cauchy-Schwarz inequality by over 5 orders of magnitude. The unprecedented degree of violating the inequality in pure water, as well as the well-defined polarization properties of the photon pairs, points to its usefulness in quantum information.

3. From quantum networks to the quantum internet

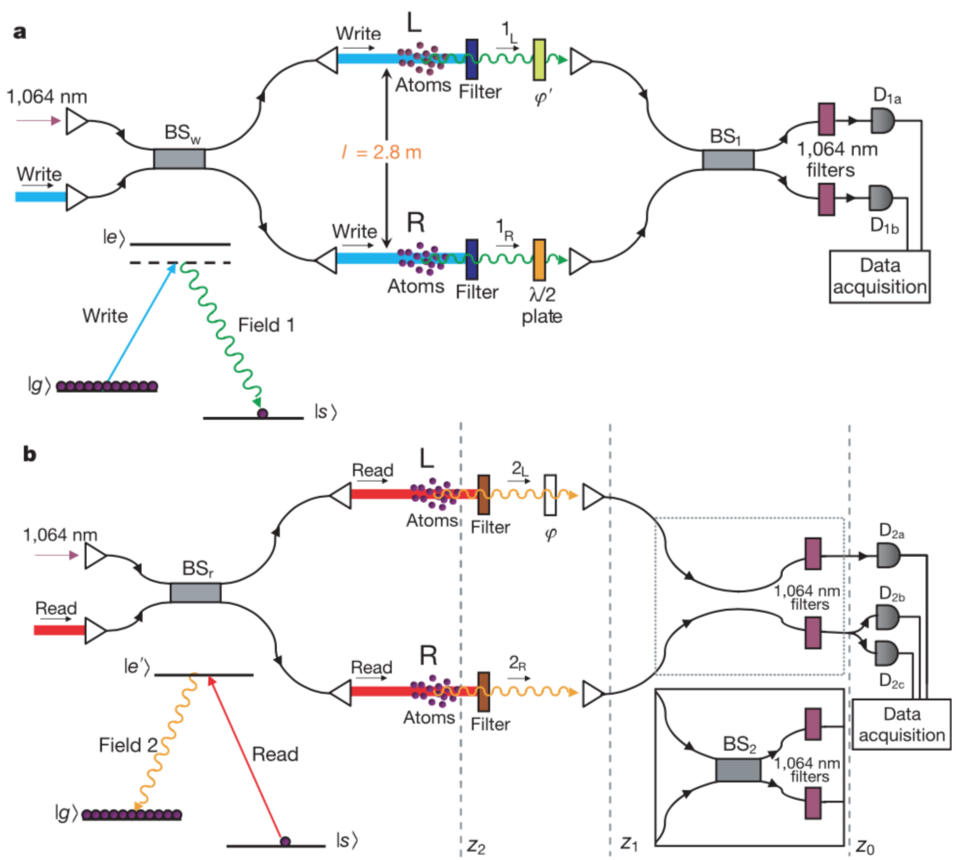


nature Vol 438|8 December 2005|doi:10.1038/nature04353

LETTERS

Measurement-induced entanglement for excitation stored in remote atomic ensembles

C. W. Chou[1], H. de Riedmatten[1], D. Felinto[1], S. V. Polyakov[1], S. J. van Enk[2] & H. J. Kimble[1]



entangled state between remote sites

$$|\Psi_{L,R}\rangle = \epsilon_L |1\rangle_L |0\rangle_R \pm e^{i\eta_1} \epsilon_R |0\rangle_L |1\rangle_R$$

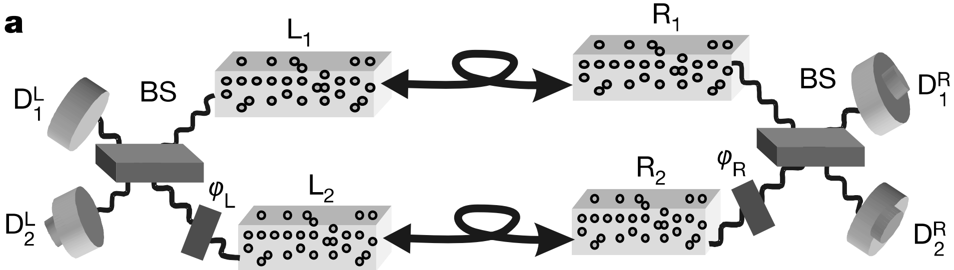
$$\tilde{\rho}_{2_L,2_R} = \frac{1}{\tilde{P}} \begin{pmatrix} p_{00} & 0 & 0 & 0 \\ 0 & p_{01} & d & 0 \\ 0 & d^* & p_{10} & 0 \\ 0 & 0 & 0 & p_{11} \end{pmatrix}$$

Concurrence: entanglement quantification (Wooters, 1998)

$$C_{1a}(\tilde{\rho}_{2_L,2_R}) = (2.4 \pm 0.6) \times 10^{-3} > 0$$

quantum entangled

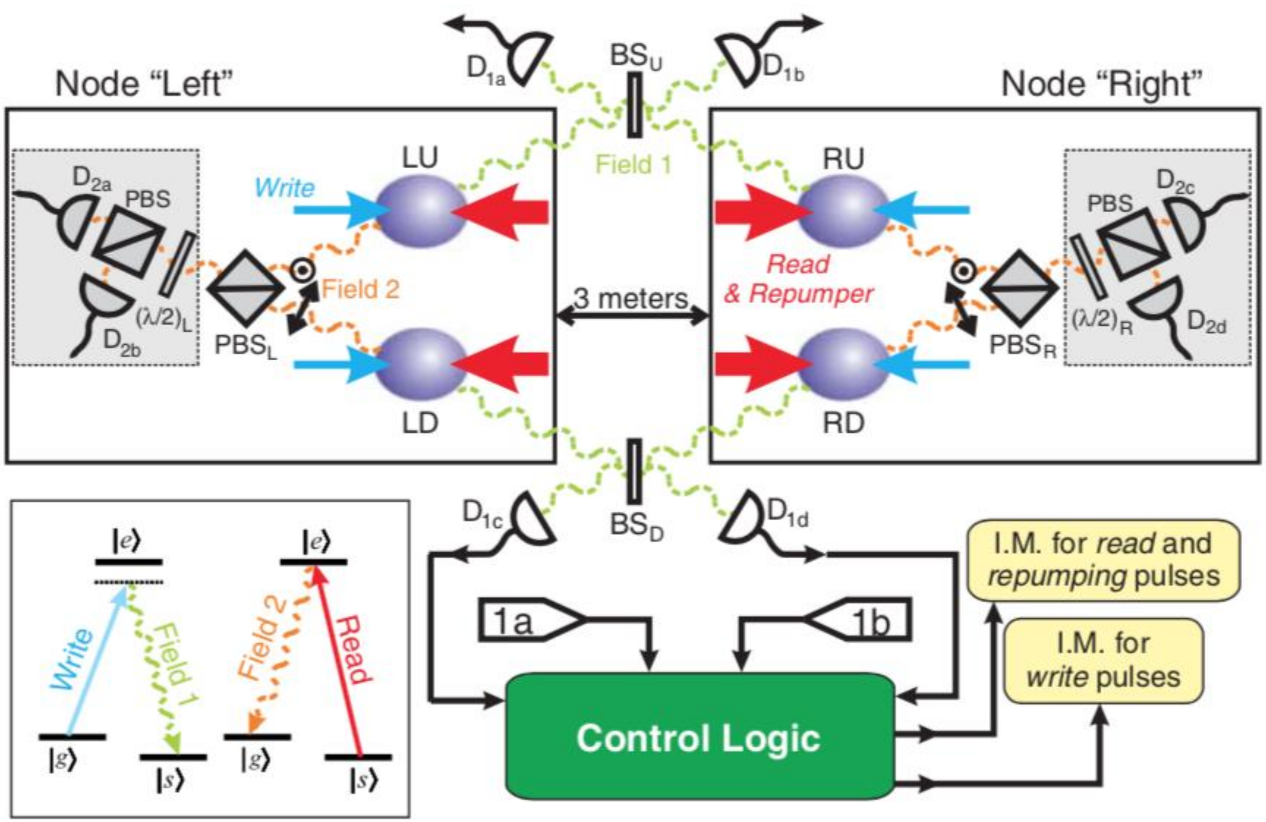
3. From quantum networks to the quantum internet

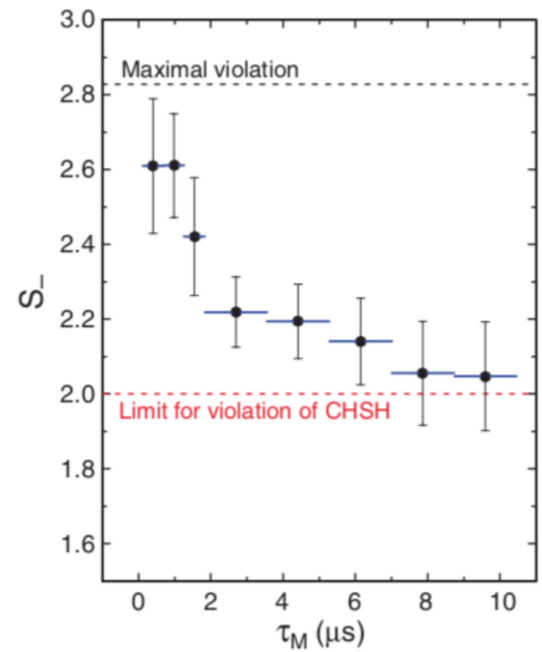


1316 1 JUNE 2007 VOL 316 SCIENCE

Functional Quantum Nodes for Entanglement Distribution over Scalable Quantum Networks

Chin-Wen Chou, Julien Laurat, Hui Deng, Kyung Soo Choi, Hugues de Riedmatten,* Daniel Felinto,† H. Jeff Kimble‡





polarization entanglement

quantum cryptography
(Ekert, 1992)

3. From quantum networks to the quantum internet

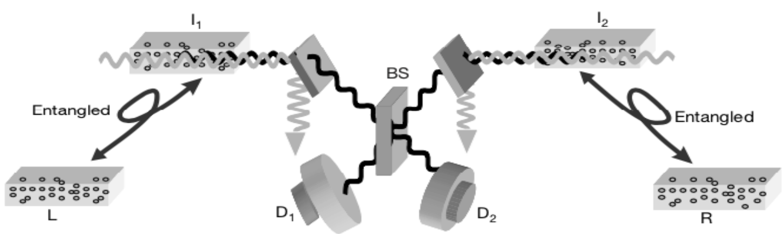
NATURE | VOL 414 | 22 NOVEMBER 2001 | www.nature.com

Long-distance quantum communication with atomic ensembles and linear optics

L.-M. Duan*†, M. D. Lukin‡, J. I. Cirac* & P. Zoller*

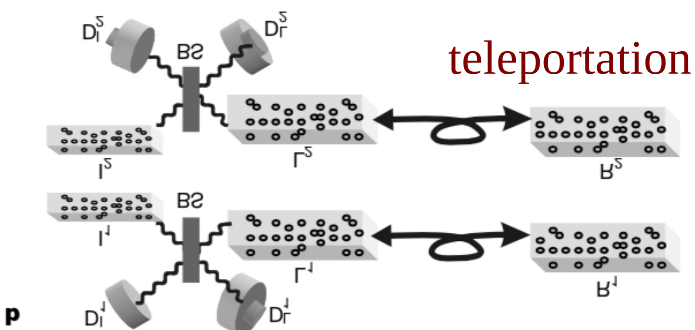
DLCZ protocol

entanglement swapping

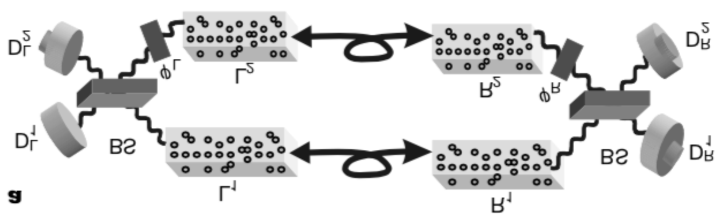


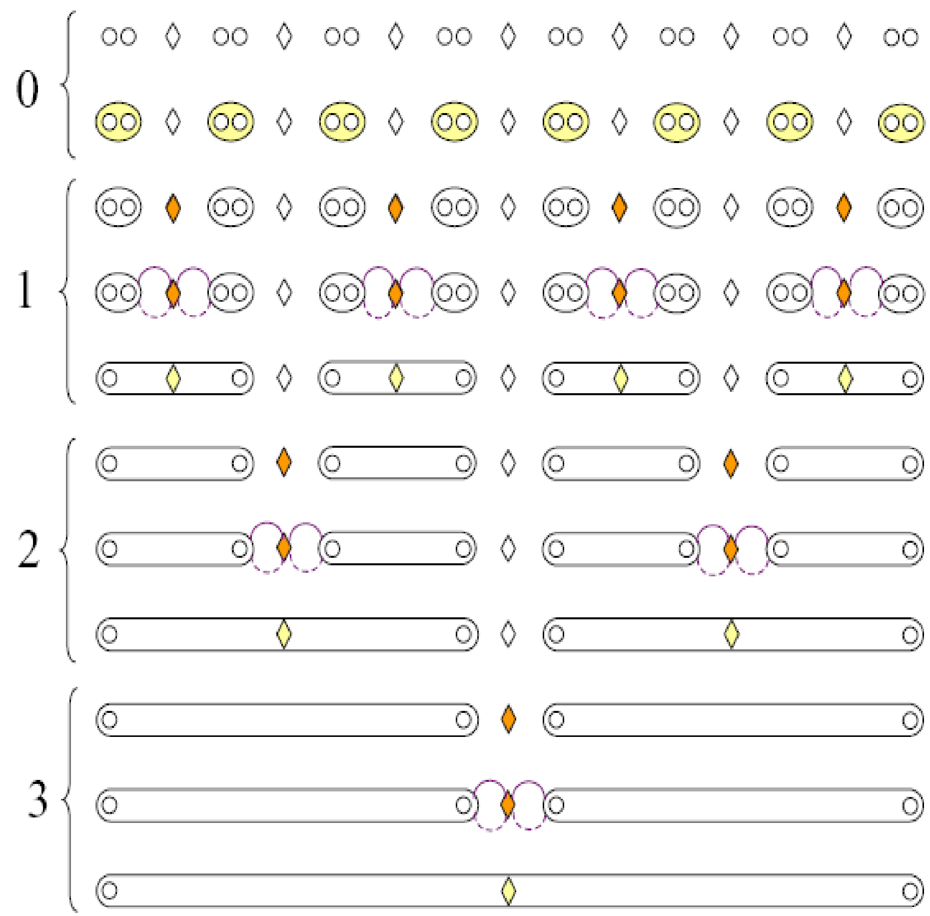
capabilities

teleportation



cryptography





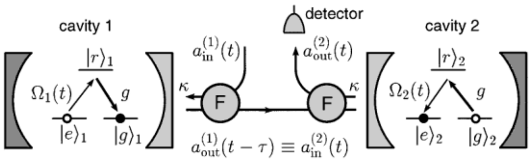
3. From quantum networks to the quantum internet

quantum networks (1997)

VOLUME 78, NUMBER 16 PHYSICAL REVIEW LETTERS 21 APRIL 1997

Quantum State Transfer and Entanglement Distribution among Distant Nodes in a Quantum Network

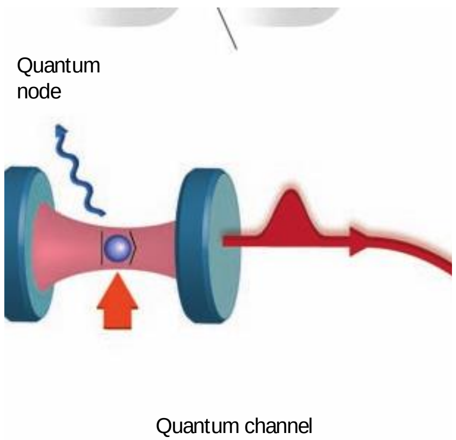
J. I. Cirac,[1,2] P. Zoller,[1,2] H. J. Kimble,[1,3] and H. Mabuchi[1,3]

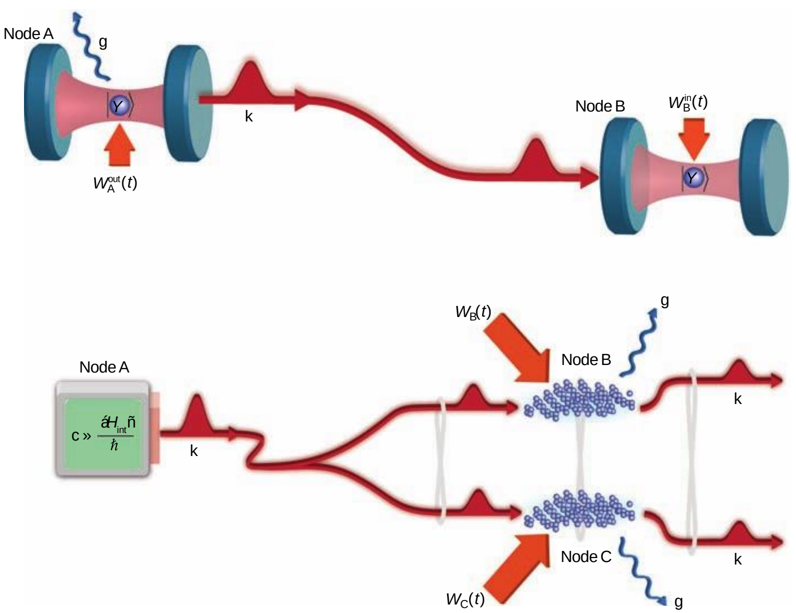


NATURE | Vol 453 | 19 June 2008 | doi:10.1038/nature07127 INSIGHT REVIEW

The quantum internet

H. J. Kimble[1]

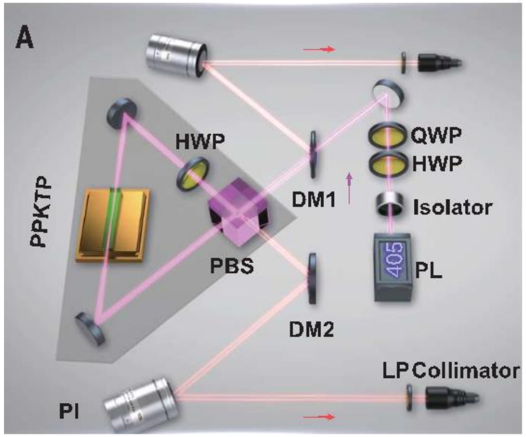




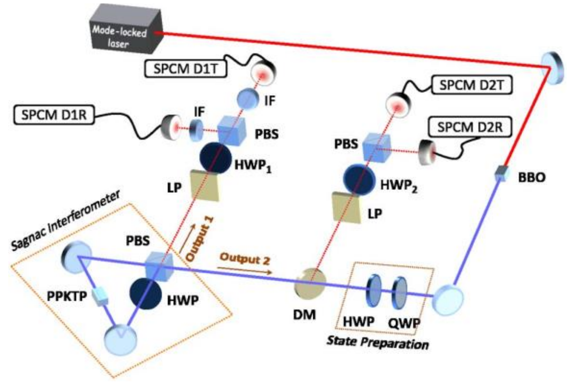
4. Connecting global and local quantum networks

Yin et al., Science **356**, 1140 (2017)

polarization entangled photon pairs at 800 nm based on Sagnac interferometer



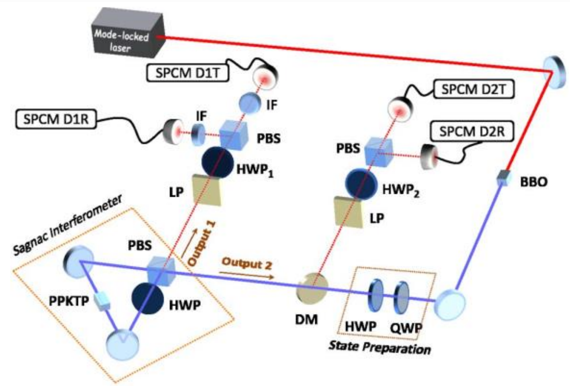
Similar source implemented at UFPE



Mendes et al., J. Opt. Soc. Am. B 32, 1670 (2015)

Moreira et al., Opt. Commun. 428, 212 (2018)

4. Connecting global and local quantum networks



Mendes et al., J. Opt. Soc. Am. B 32, 1670 (2015)

Moreira et al., Opt. Commun. 428, 212 (2018)

interaction of ultrabroad band single photons with atomic ensembles

PRL **116,** 023602 (2016) PHYSICAL REVIEW LETTERS week ending 15 JANUARY 2016

Zero-Area Single-Photon Pulses

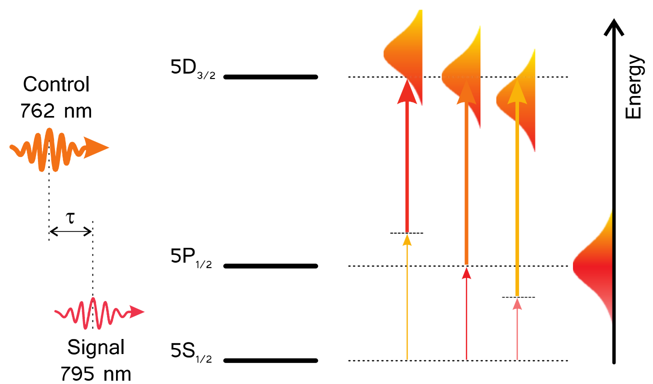
L. S. Costanzo,[1,2] A. S. Coelho,[3] D. Pellegrino,[2] M. S. Mendes,[4] L. Acioli,[4]
K. N. Cassemiro,[4] D. Felinto,[4] A. Zavatta,[1,2] and M. Bellini[1,2,*]
[1]*Istituto Nazionale di Ottica (INO-CNR), Largo Enrico Fermi 6, 50125 Florence, Italy*
[2]*European Laboratory for Non-linear Spectroscopy (LENS) and Department of Physics, University of Firenze, 50019 Sesto Fiorentino, Florence, Italy*
[3]*Departamento de Engenharia, Centro Universitário UNINOFAPI, 64073-505 Teresina, Piauí, Brazil*
[4]*Departamento de Física, Universidade Federal de Pernambuco, 50670-901 Recife, Pernambuco, Brazil*

Proposal for mapping of ultrabroad band single photons into an atomic memory

PHYSICAL REVIEW A **101**, 053426 (2020)

Enhanced absorption of weak ultrashort light pulses by a narrowband atomic medium

A. J. A. Carvalho,[1] R. S. N. Moreira,[1] J. Ferraz,[2] S. S. Vianna,[1] L. H. Acioli,[1] and D. Felinto[1,*]
[1]*Departamento de Física, Universidade Federal de Pernambuco, 50670-901 Recife, Pernambuco, Brazil*
[2]*Departamento de Física, Universidade Federal Rural de Pernambuco, 52171-900 Recife, Pernambuco, Brazil*



Pathway to connect ultrabroad band flying photons into a narrow band memory compatible to local quantum networks

5. Conclusions and perspectives

- The evolution of our understanding of quantum mechanics led to the field of quantum information, which engendered the ongoing 2nd quantum technological revolution.
- A central aspect of this revolution is quantum entanglement.
- We are just starting to understand the role of quantum entanglement in nature and its potential applications.
- We presented some of our recent work on this problem, pointing out its connection to the development of a quantum internet.

Profs: Daniel Felinto ← (Quantum Networks Laboratory – 2023)

José Tabosa
Lúcio Acioli
Sandra Vianna
Márcio Miranda
Fernando Parísio
Katiúscia Cassemiro
José Ferraz (UFRPE)
Pablo Saldanha (UFMG)
Marco Bellini (LENS)

Post-docs: Alejandro Fonseca
Alexandre Almeida
Juan C. C. Capella
Lucas S. Marinho
Michelle O. Araújo
Weliton S. Martins

Doctorate: Wellington Martins Filho
Gabriel Carvalho Borges
Milrian S. Mendes
Rafael A. de Oliveira
Luis Ortiz-Gutiérrez
Raoni S. N. Moreira
Luis F. Muñoz-Martínez
Alyson José Alves Carvalho
Davi S. Barros (UFMG)

Master: Rodrigo L. C. Santos Filho
Gabriel P. S. da Silva
Johan E. O. Morales
Lenin Fernández
Natália D. Alves
Ayanne A.F. Tieco
Paulo J. C. de Vasconcelos Filho

experiments in Recife

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico
FACEPE
FAPESP
MCTI
MCOM
cgi.br
Office of Naval Research ONR Science & Technology
CAPES

Thanks!

open positions for postdocs and grad students!