Key experiments in quantum science and technology with photons, ions and atoms

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Seminar:

Fridays, 11:00 (c.t.) - 13:00
INF 227 / Seminar room **03.404**

Presentations:

~25-30 minutes presentation
+ scientific discussion (incl. feedback form)
+ written summary
= 6 ECTS points

Web page:

https://uebungen.physik.uni-heidelberg.de/vorlesung/20251/2010

Feedback form…

SS 2025

Key experiments in quantum science and technology with photons, ions and atoms

Date: 09.05.2025
Name:

1. Talk / Write title here:
Speaker:

My notes:

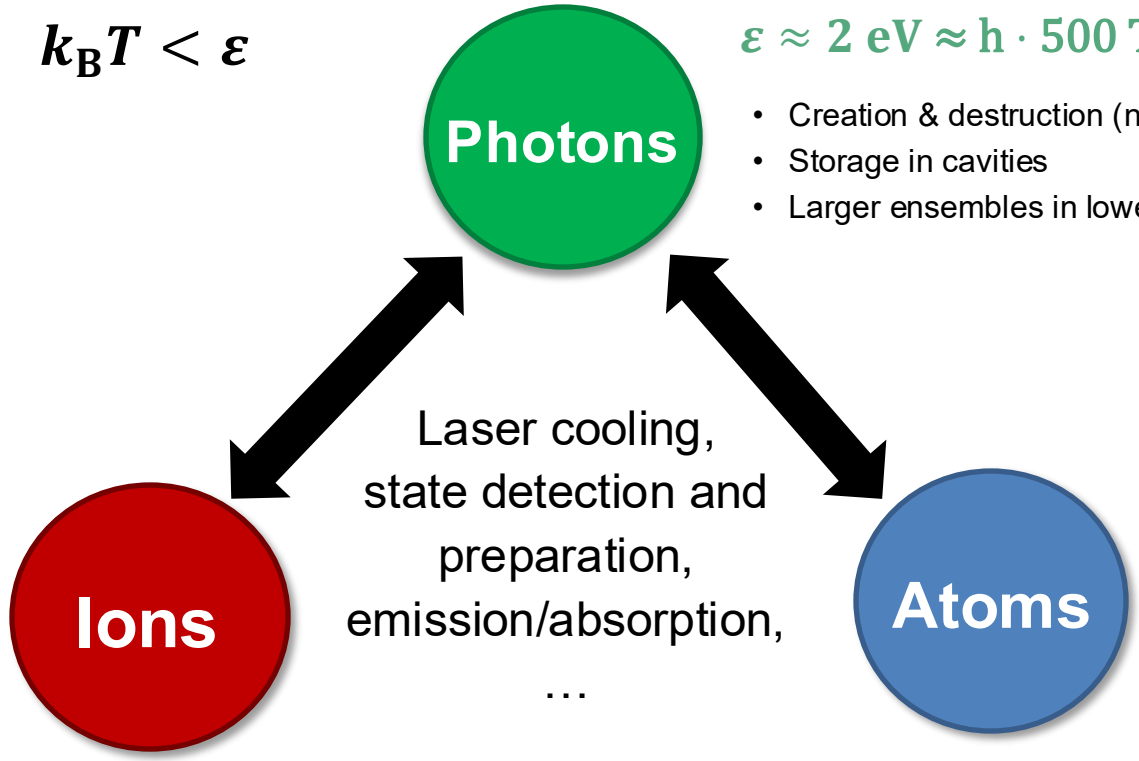
My questions in the discussion:

How was the talk? Grade please the talk in the scale 1 (best) to 5 (very hard)
Understandability:
Speed:
Slides and graphics:
Time keeping:
Discussion:

What makes it quantum ?

- **Control and read-out of quantum state**
- **Cooling to critical temperature:**

$$k_B T < \varepsilon$$



Optical transition:

$\varepsilon \approx 2\ \text{eV} \approx \text{h} \cdot 500\ \text{THz} \approx 23000\ \text{K}$

- Creation & destruction (number non-conservation)
- Storage in cavities
- Larger ensembles in lower dimensions

- Coulomb interaction
- Long storage time
- Precise motion control

- Neutral
- Large ensembles
- Tailored interactions
- Shallow traps

Trap motion:

$\varepsilon \approx \hbar\omega_{\text{trap}} \approx h \cdot (1\text{–}30)\ \text{MHz} \approx 48\ \mu\text{K} - 1.5\ \text{mK}$

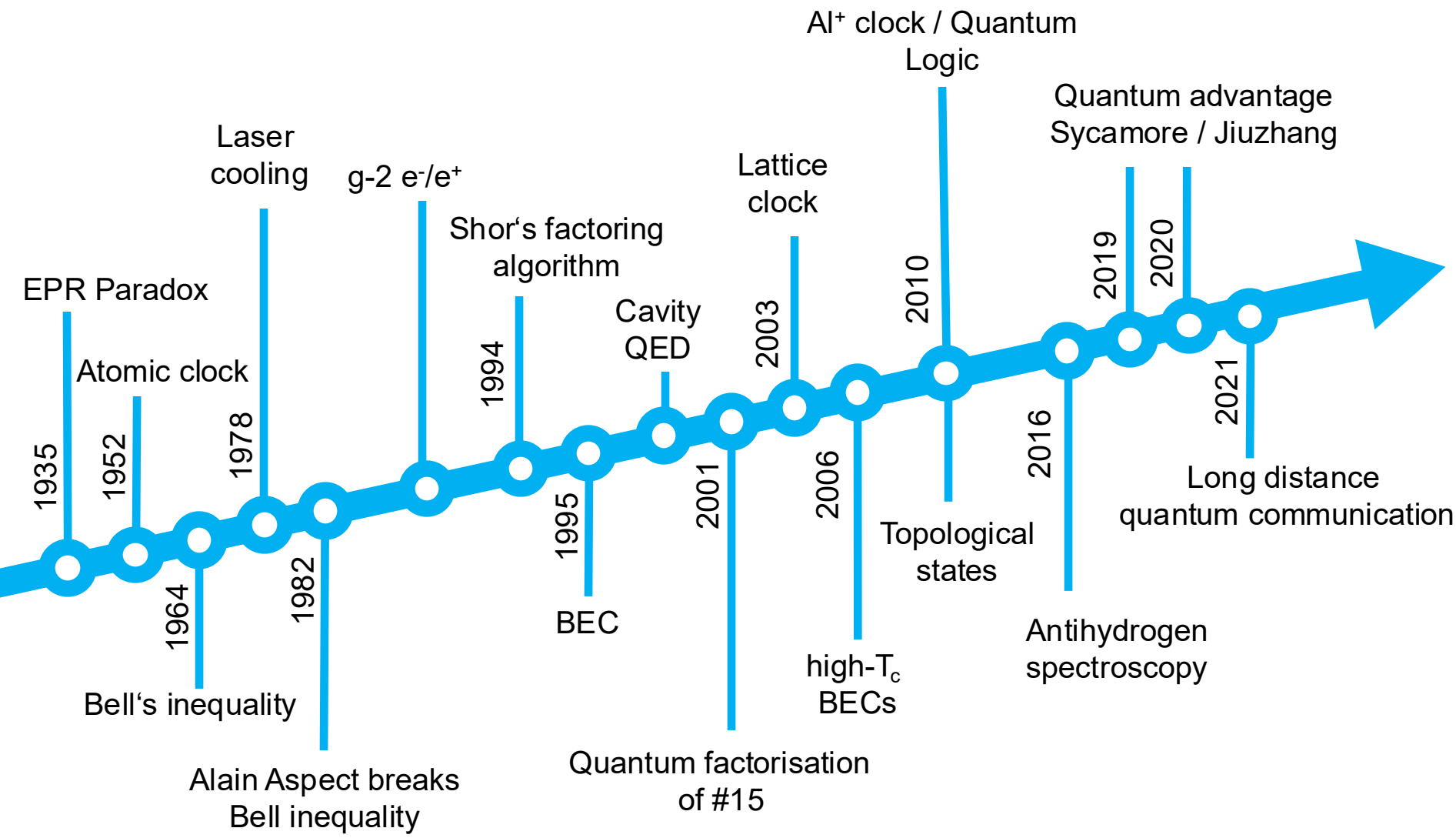
Electron spin:

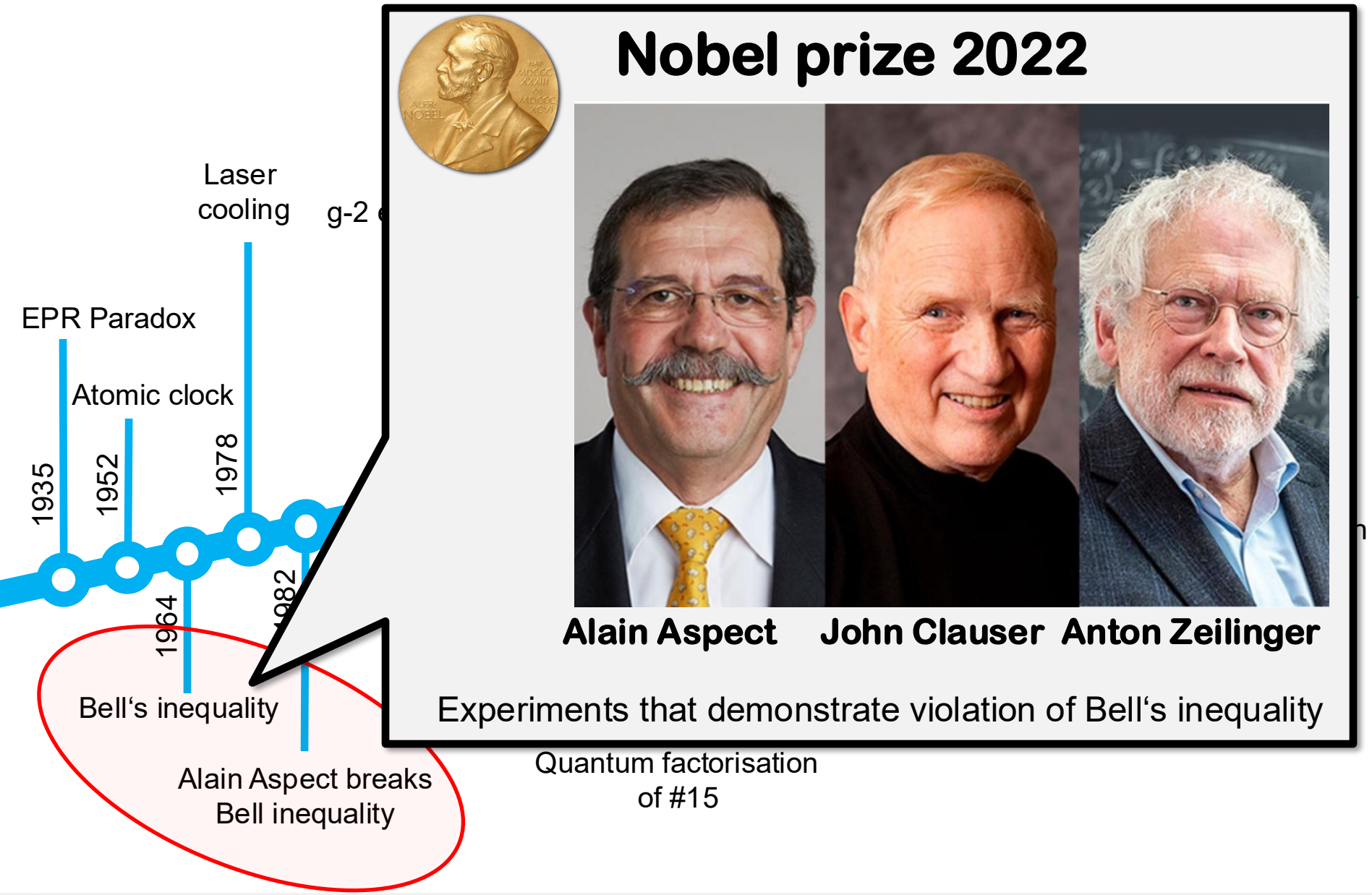
$\varepsilon \approx \hbar\omega_{\text{L}} \approx h \cdot 100\ \text{GHz} \approx 4\ \text{K}$

BEC:

$\varepsilon \approx \frac{\hbar^2 n^{2/3}}{m} \approx h \cdot (0.2 - 20)\text{kHz}$

$\approx \text{nK–}\mu\text{K}$


1935
EPR Paradox
1952
Atomic clock
1964
Bell‘s inequality
1978
Laser cooling
1982
Alain Aspect breaks Bell inequality
g-2 e-/e+
1994
Shor‘s factoring algorithm
1995
BEC
Cavity QED
2001
Quantum factorisation of #15
2003
Lattice clock
2006
high-Tc BECs
2010
Al+ clock / Quantum Logic
Topological states
2016
Antihydrogen spectroscopy
2019
2020
Quantum advantage Sycamore / Jiuzhang
2021
Long distance quantum communication


Laser cooling
g-2
EPR Paradox
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1982
Bell‘s inequality
Alain Aspect breaks Bell inequality
Quantum factorisation of #15
Nobel prize 2022
Alain Aspect
John Clauser
Anton Zeilinger
Experiments that demonstrate violation of Bell‘s inequality

Al⁺ clock / Quantum Logic

Quantum advantage Sycamore / Jiuzhang

Laser cooling

g-2 e⁻/e⁺

Shor's factoring algorithm

EPR Paradox

Atomic clock

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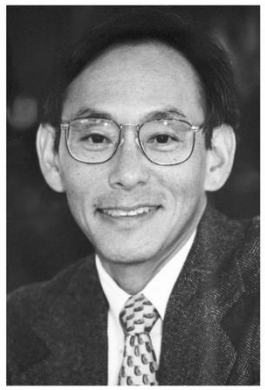
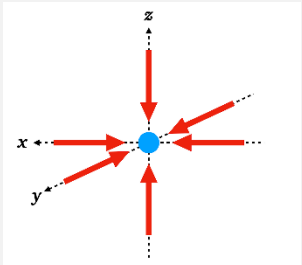
Alain Aspect breaks Bell inequality

Quantur

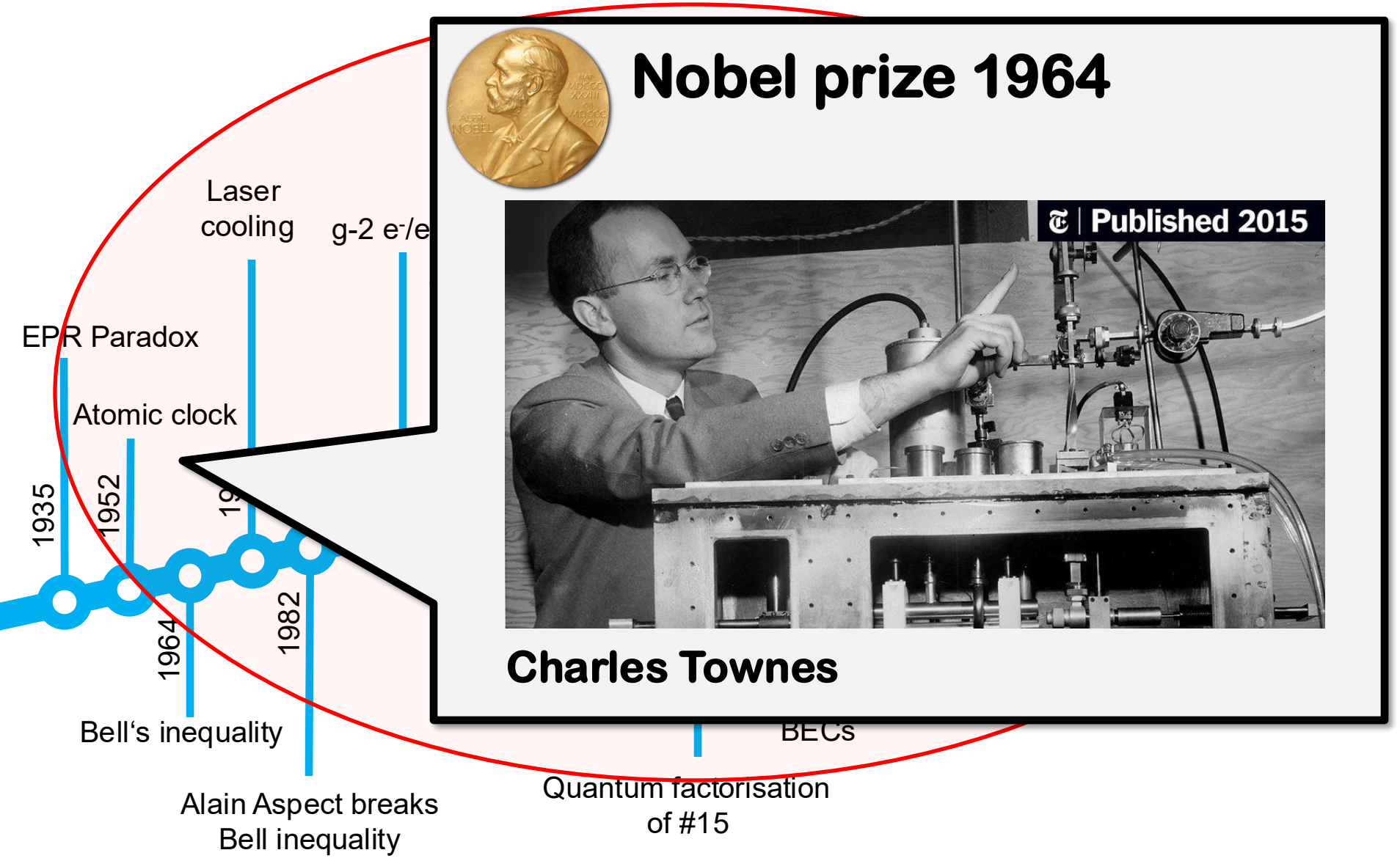
Nobel prize 1997



Steven Chu Claude Cohen-Tannoudji William D. Phillips



Development of methods to cool and trap atoms with laser light


Nobel prize 1964
Published 2015
Charles Townes
Laser cooling
g-2 e-/e
EPR Paradox
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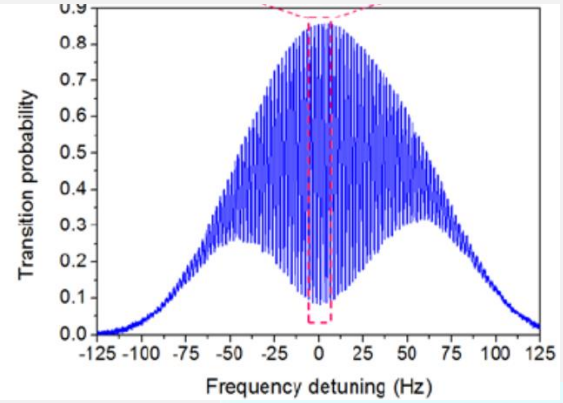
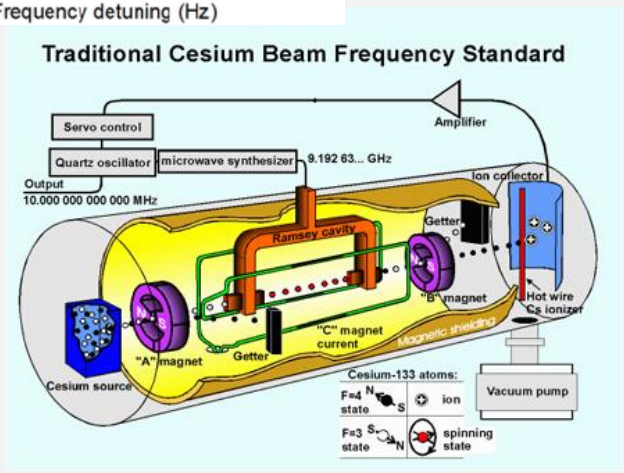
Alain Aspect breaks Bell inequality
BECs
Quantum factorisation of #15

Nobel prize 1989

Norman Ramsey





Laser cooling

g-2

EPR Paradox

Atomic clock

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Quantum factorisation of #15

Laser cooling

g-2 e^-/e^+

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Al^+ clock / Quantum Logic

Quantum advantage Sycamore / Jiuzhang

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2006

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2020

2021

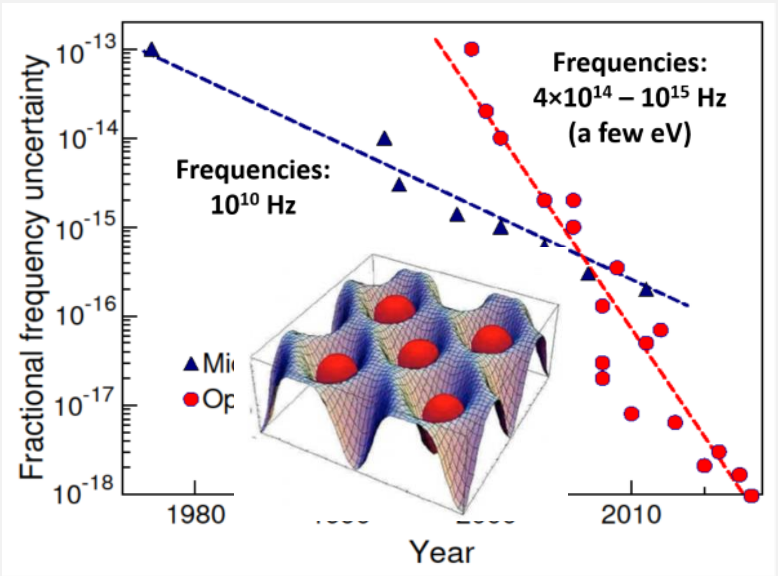
Topological states

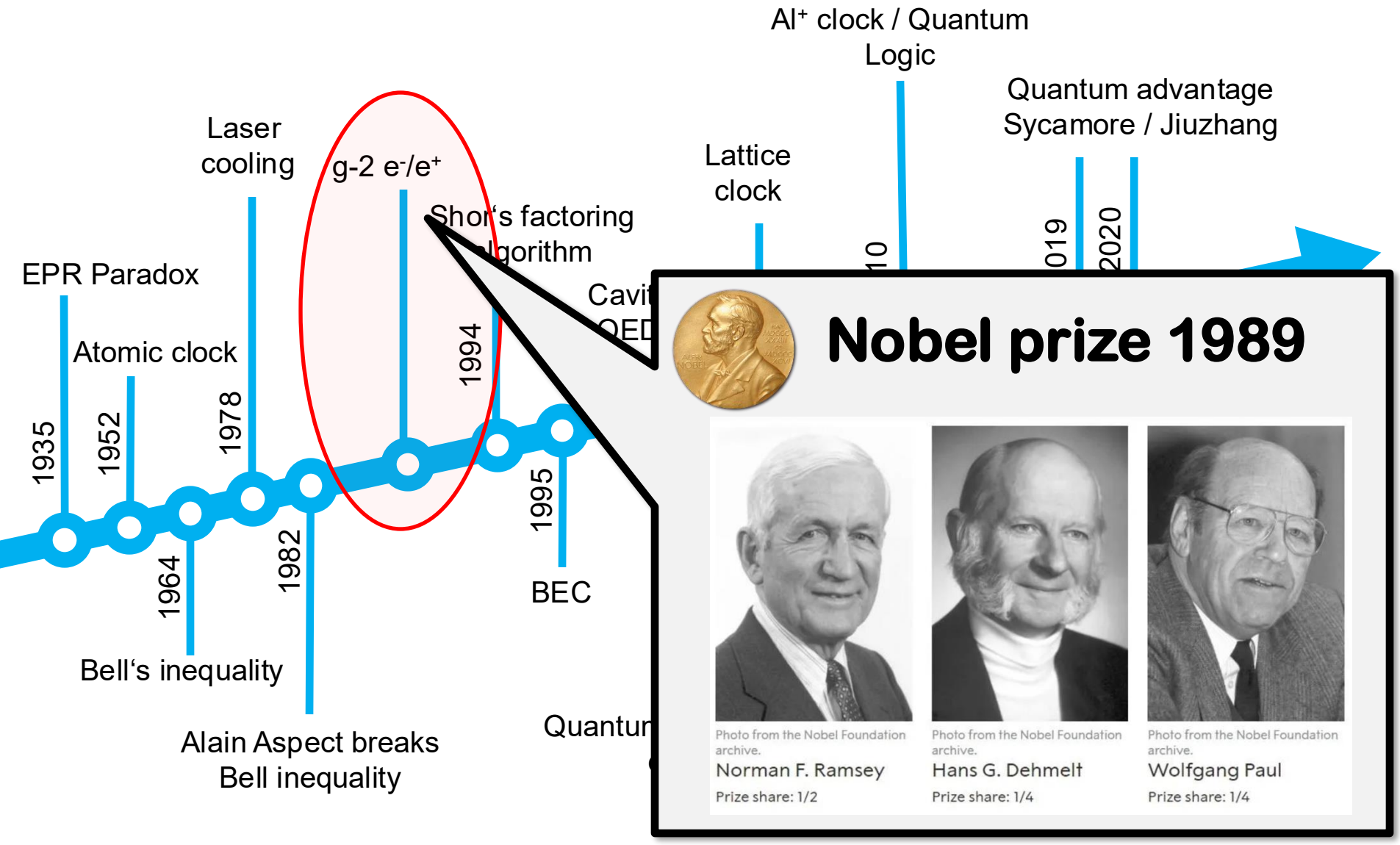
Antihydrogen spectroscopy

Long distance quantum communication

high-T_c BECs

Optical lattice clocks

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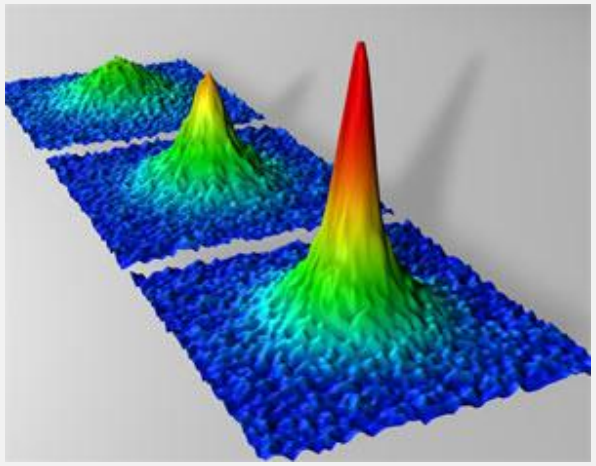
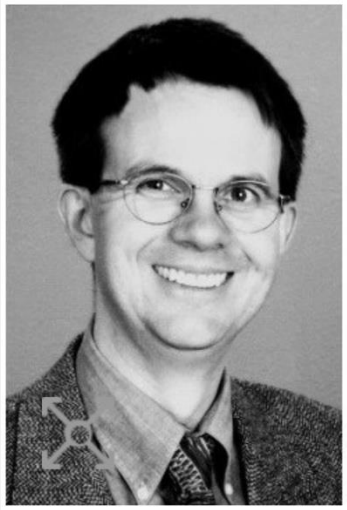
Alain Aspect breaks
Bell inequality
Nobel prize 1989
Photo from the Nobel Foundation archive.
Norman F. Ramsey
Prize share: 1/2
Photo from the Nobel Foundation archive.
Hans G. Dehmelt
Prize share: 1/4
Photo from the Nobel Foundation archive.
Wolfgang Paul
Prize share: 1/4

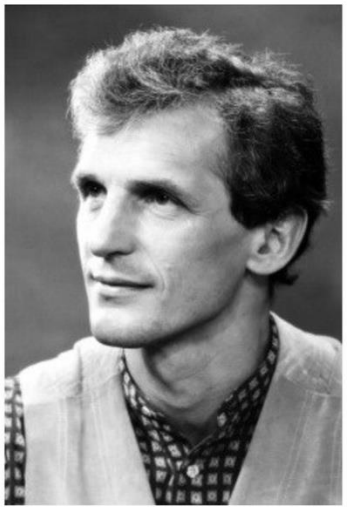
Nobel prize 2001

First gaseous Bose Einstein condensates

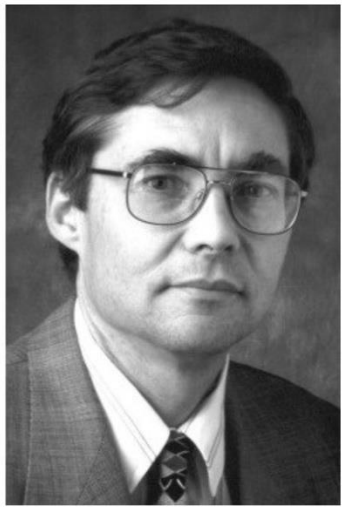




Eric Cornell



Wolfgang Ketterle



Carl Wieman

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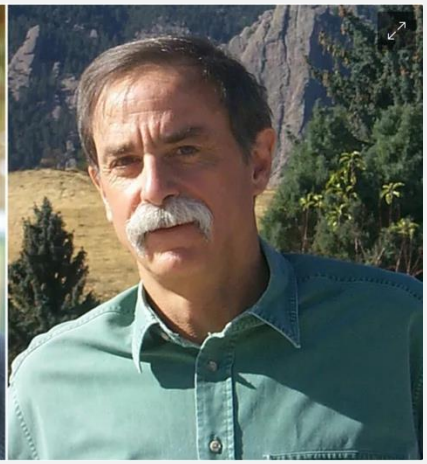
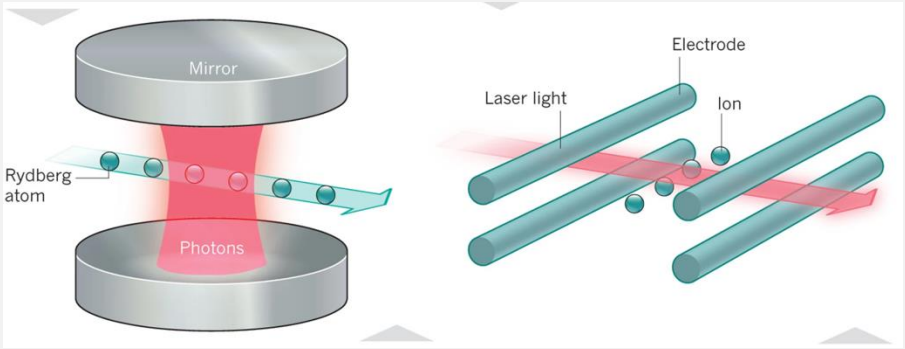
Nobel prize 2012

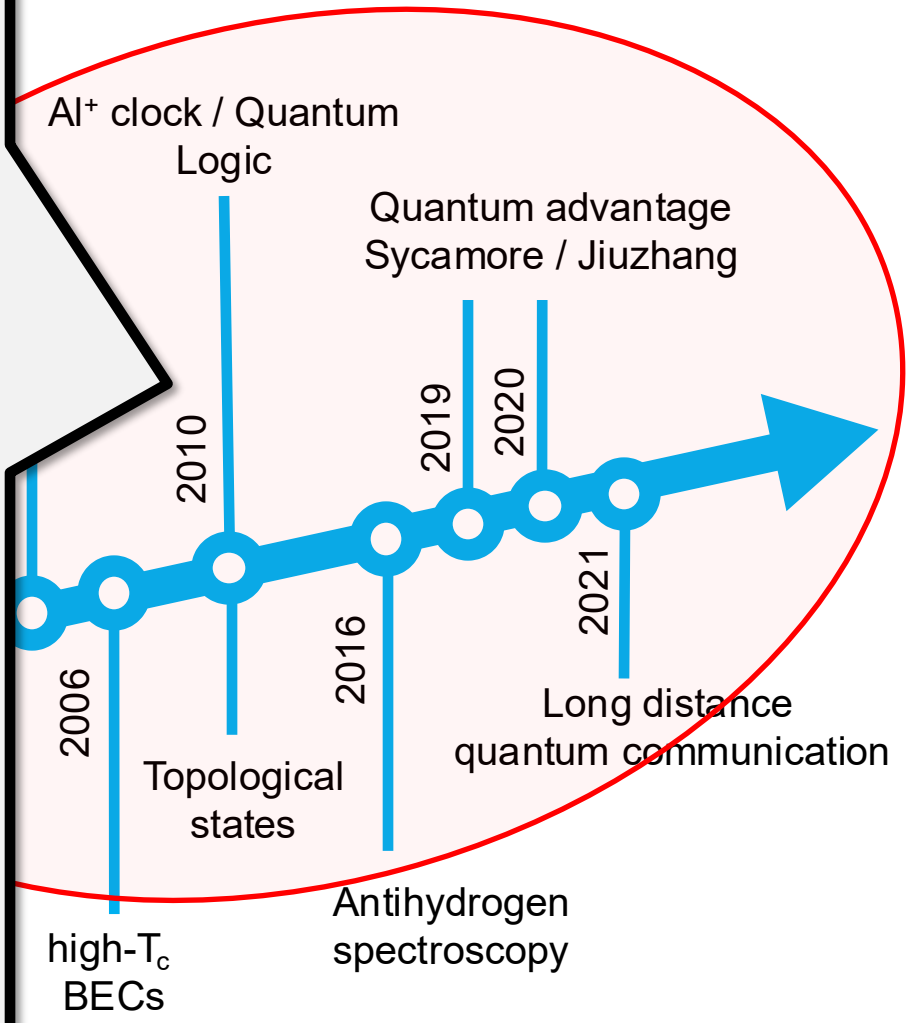
Serge Haroche



David Wineland



Manipulation of individual quantum systems



isation

Your timeline towards your presentation:

Get literature, arrange meetings →

Concept fixed → meeting → feedback →

Completed slides + meeting →

Your own test talk →

Date of presentation →

Date	Time	Topic
2025-04-25		Introduction
2025-05-02		
2025-05-09		
2025-05-16	11:15	Laser Cooling and Trapping (*)
	12:15	
2025-05-23	11:15	Bell Test Measurements (*)
	12:15	Quantum Teleportation and Quantum Key Distribution
2025-05-30	11:15	Precision mass determinations and test of matter/antimatter symmetry in ion traps (*)
	12:15	g-2: the electron magnetic moment
2025-06-06	11:15	Bose-Einstein condensation of neutral atoms (*)
	12:15	Superfluidity in lower dimensions
2025-06-13	11:15	Cavity Quantum Electrodynamics Experiments (*)
	12:15	Interacting photons: Photon Blockade
2025-06-20		
2025-06-27	11:15	Room-temperature Bose–Einstein condensation of photons
	12:15	Photonic Quantum Computing
2025-07-04	11:15	Quantum Computing with linear ion chains
	12:15	Quantum simulation with ions in Penning traps
2025-07-11	11:15	Optical Tweezer Arrays
	12:15	Quantum Simulation with Rydberg-atom arrays
2025-07-18		
2025-07-25		

Date	Time	Topic	Speaker	Ref.
2025-04-25		Introduction		
2025-05-02				
2025-05-09				
2025-05-16	11:15	Laser Cooling and Trapping (*)	Filippov, Pylyp	J
	12:15			S
2025-05-23	11:15	Bell Test Measurements (*)	Guarino, Gabriele	J
	12:15	Quantum Teleportation and Quantum Key Distribution	Kaiser, Florian	S
2025-05-30	11:15	Precision mass determinations and test of matter/antimatter symmetry in ion traps (*)	Newe, Mira Eowyn	S
	12:15	g-2: the electron magnetic moment	Rao, Srijana	S
2025-06-06	11:15	Bose-Einstein condensation of neutral atoms (*)	Becker, Cedric Vincent	J
	12:15	Superfluidity in lower dimensions	Schneiker, Robert Alexander	J
2025-06-13	11:15	Cavity Quantum Electrodynamics Experiments (*)	Linnebacher, Moritz	J
	12:15	Interacting photons: Photon Blockade	Marzel, Leonie	J
2025-06-20				
2025-06-27	11:15	Room-temperature Bose–Einstein condensation of photons	Geißler, Luca Yannik	J
	12:15	Photonic Quantum Computing	Thiery, Michel	S
2025-07-04	11:15	Quantum Computing with linear ion chains	Zobel, Nick Peter	S
	12:15	Quantum simulation with ions in Penning traps	Römer, Julius	S
2025-07-11	11:15	Optical Tweezer Arrays	Liu, Jiayi	S
	12:15	Quantum Simulation with Rydberg-atom arrays	Provencio Lameiras, Juan Carlos	S
2025-07-18				
2025-07-25				