



Photo: David J. Wineland/University of Colorado; Serge Haroche portrait: CNRS; Photo: G. L. G. / Science Photo Library; Nobel Prize medal: The Nobel Foundation

Particle control in a quantum world

Serge Haroche and David J. Wineland have invented and developed methods for measuring and manipulating individual particles according to the rules of quantum physics, in ways that were previously not thought possible.

Experiments by this year's Nobel Laureates have opened the door to accurate observation and manipulation of individual quantum particles. Single particles of light or matter are not easily isolated from their environment, and they lose their mysterious quantum properties as soon as they interact with the outside world. Thus, many phenomena predicted by quantum physics could not be directly observed.

Through their sophisticated laboratory methods, Haroche and Wineland, together with their research groups, have managed to measure and control very fragile quantum

states that were previously thought inaccessible to direct observation. The particles can be examined, counted and guided but not touched. Otherwise the magic of the quantum world disappears.

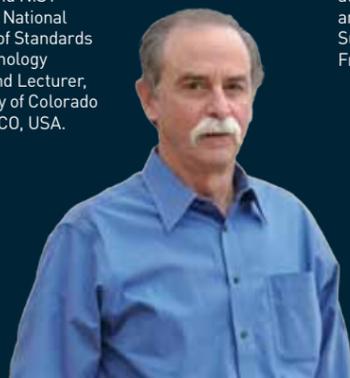
Their methods have many things in common – both Laureates use the interaction between light and matter. Wineland traps electrically charged atoms, or ions, controlling and measuring them with light, or photons. Haroche takes the opposite approach: he captures photons, and controls them with atoms sent through the trap.

Related Nobel Prizes

1933	1989	1997	2012
Erwin Schrödinger and Paul A.M. Dirac "for the discovery of new productive forms of atomic theory".	Norman F. Ramsey "for the invention of the separated oscillatory fields method and its use in the hydrogen maser and other atomic clocks", and Hans G. Dehmelt and Wolfgang Paul "for the development of the ion trap technique".	Steven Chu, Claude Cohen-Tannoudji and William D. Phillips "for development of methods to cool and trap atoms with laser light".	Serge Haroche and David J. Wineland "for ground-breaking experimental methods that enable measuring and manipulation of individual quantum systems".

David J. Wineland

U.S. citizen. Born 1944 in Milwaukee, WI, USA. Group Leader and NIST Fellow at National Institute of Standards and Technology (NIST), and Lecturer, University of Colorado Boulder, CO, USA.



Serge Haroche

French citizen. Born 1944 in Casablanca, Morocco. Professor at Collège de France and Ecole Normale Supérieure, Paris, France.



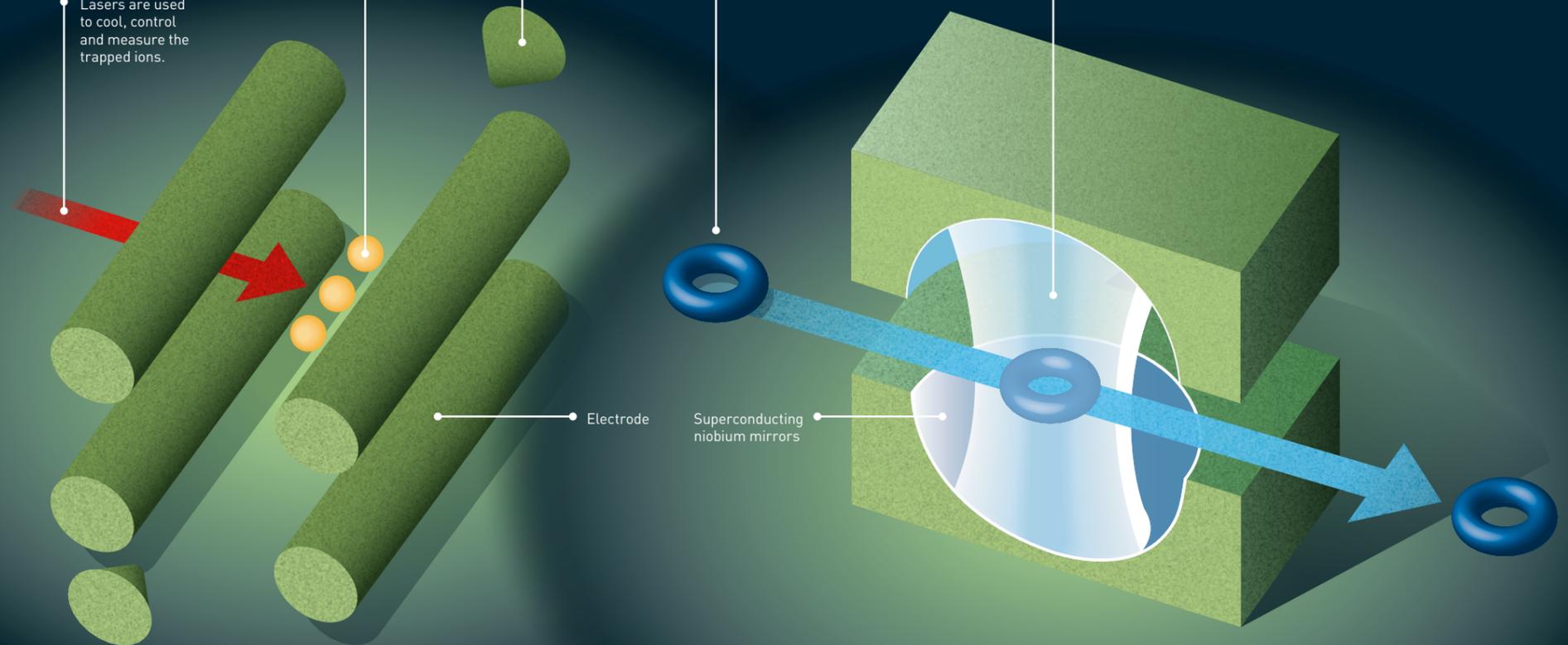
Lasers are used to cool, control and measure the trapped ions.

The ions are held inside a trap with electric fields.

Electrode

Rydberg atoms are sent into the cavity one by one.

Photons bounce back and forth between two mirrors. The distance they travel is as long as one trip around the Earth.



Electrode

Superconducting niobium mirrors

↑ Ion Trap

In Wineland's laboratory in Boulder, positively charged ions are kept in a vacuum inside a trap by electric fields. One of the secrets behind Wineland's breakthrough is the use of laser beams to suppress the ions' thermal motions. When the ion is forced into its lowest energy state, many quantum phenomena can be studied inside the trap.



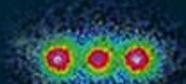
↑ Quantum Computer

Wineland's group was the first in the world to demonstrate a quantum operation with two quantum bits, or qubits. It is the very first step towards building a quantum computer, which in the future could take only a few minutes to perform calculations that would take a classical computer several years.

↑ Optical Clock

Wineland and his research team have constructed a clock with two ions so precise that it only would have lagged behind by a few seconds after 13.75 billion years, the Universe's lifetime. With such a clock, we can measure the effects of relativity, like the influence of gravitation on time with a difference in height less than one meter.

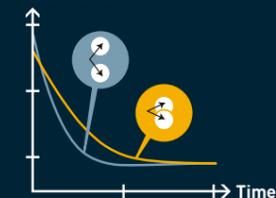
Three beryllium ions in a trap, sending out light, only a hair's width from each other.



↑ Photon Trap

In Haroche's laboratory in Paris, the photons bounce back and forth between two mirrors, about 3 cm apart from each other. The mirrors are so reflective that a single photon can be kept in the cavity for a record-breaking long lifetime of almost a tenth of a second. This permits the scientists to perform many measurements with the trapped photons without destroying them.

↑ Coherence



↑ Schrödinger's Cat

In 1935 the Nobel Laureate Erwin Schrödinger described a thought experiment with a cat in a box in order to illustrate the paradoxes of quantum physics. According to the paradox the cat is considered to be both dead and alive at the same time until someone peeks inside the box. But when the box is opened, the cat is either dead or alive.

To the left: superposition of two "cat-states" in Haroche's trap. The illustration shows the decay of the superposition; the decay is faster the more different the states are.



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