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Research Highlight

Nobel Prize 2012: Haroche & Wineland

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The 2012 Nobel Prize in Physics has been awarded to Serge Haroche and David J. Wineland "for ground-breaking experimental methods that enable measuring and manipulation of individual quantum systems".

"We never experiment with just one electron or atom or (small) molecule. In thought-experiments we sometimes assume that we do; this invariably entails ridiculous consequences", wrote[1] Erwin Schrödinger in 1952.

And yet, sixty years later, the Nobel Prize in Physics has been awarded for experimental developments that have made the measurement and control of individual atoms and photons possible. Far from being thought ridiculous, precision experiments using a single photon or a single atom are the basis of today's time and frequency standards — and of tomorrow's quantum technologies.

The precise control of individual quantum systems has been built on several other developments already recognized by the Nobel committee: trapping of ions in electromagnetic fields (Dehmelt and Paul in 1989); laser cooling of atoms (Chu, Cohen-Tannoudji and Phillips in 1997); the theory of optical coherence (Glauber in 2005); and other theoretical and experimental breakthroughs in the field of atomic physics.
The body of research honoured by this year's prize includes techniques used in two quite different, but conceptually similar, physical systems: ions in a harmonic trap and photons in a cavity. Charged particles oscillating in an electromagnetic field and chargeless light quanta bouncing back and forth between mirrors can be modelled as two-level systems coupled to a quantized harmonic oscillator — a textbook problem described by the well known Jaynes–Cummings Hamiltonian. This elegant model is the starting point for the investigation of light–matter interactions at the quantum level.

Trapped ions interact with laser light, and photons in a cavity interact with excited atoms — atoms probed by light and light probed by atoms — in the experimental techniques developed by Wineland and Haroche in the late 1990s and early 2000s to achieve fine control of quantum systems. Wineland and his group at NIST, Colorado, pioneered ion-trapping and laser-cooling techniques and developed ways of controlling the internal energy states and motional states of the atoms using laser light; hence, they were able to create complex quantum superpositions and entangled states. Serge Haroche at École Normale Supérieure in Paris devised methods of probing and controlling the quantum states of photons in a cavity through their interaction with atoms passing though the cavity.

As for the "ridiculous consequences" of playing around with single atoms; Haroche, Wineland and their colleagues have been able to perform 'Schrödinger's cat' experiments with photons and ions, creating superpositions of two states (ion-motional states or photon-number states) corresponding to the 'dead' and 'alive' feline. These experiments

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have proved influential in both understanding quantum mechanics and in developing new technologies that exploit the surprising features of the quantum world.

REFERENCES

1. Schrödinger, E. Brit. J. Phil. Sci. 3, 233–247 (1952).

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