Mysteries and Surprises in Quantum Physics

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“Cavity quantum electrodynamics” is a sub-field of quantum optics. Speaking at the EPL symposium, “Physics In Our Times” held last week at the Fondation Del Duca de l’Institut de France, Paris Professor Serge Haroche from the Collège de France and the École Normale Supérieure in Paris, explained how he and his colleagues manipulate and control single atoms and single photons interacting in a cavity, which is a box made of highly reflecting walls.

By studying the behaviour of these atoms and photons in this protected environment, the physicists can illustrate fundamental aspects of quantum theory, such as state superpositions, complementarity and decoherence. This research is related to the physics of quantum information, a new domain at the frontier of information science and physics that tries to harness the logic of the quantum world to realise tasks in communication and computing that classical devices cannot achieve.

“During the 20th century, quantum physics has given us new technologies that have changed our lives – for example the computer, the laser and magnetic resonance imaging to name a few,” explained Prof. Haroche. “However, quantum laws have counterintuitive aspects that defy common sense. This has led to a paradox: although we all take advantage of quantum physics, it remains very strange - even some of the scientists that developed the theory, such as Einstein, Schrödinger and de Broglie, were uneasy about its deep meaning,” he said.

Prof. Haroche and his team have recently succeeded in trapping a single photon in a box on the time scale of seconds and have detected this photon many times without destroying it. The researchers have achieved this by sending atoms across the box and measuring the imprint left on the atoms by the photon. This is a new kind of light detection called 'quantum non-demolition'," explained Prof. Haroche. "Until now, single photons were always destroyed upon detection."

The result means that it is now possible repeatedly to extract information from the same photon. This is important because the major part of all information we get from the universe come from light. "Developing a new way of 'seeing' could have applications in quantum science," said Prof. Haroche. "A photon could share its information with an ensemble of atoms to build up an 'entangled state' of light or matter".

Attempting to manipulate and control quantum systems raises important questions about the transition between quantum and classical behaviour. "Fundamentally, the goal is to understand nature better," explained Prof. Haroche. "Applications, such as quantum communication machines, will certainly come but what they will be useful for is not yet clear. This is why research is so exciting – unpredictable things keep happening all the time."

Prof. Haroche's group is currently working with atoms and photons in cavities but related work is being done by other groups on trapped ions and cold atoms in optical potential wells, with superconducting junction or quantum dots in solid state devices. "Although the technologies may differ widely, the quantum and information science concepts used are the same," he explained. "We are therefore witnessing a kind of unification between different fields of research that is very promising."

Source: Institute of Physics