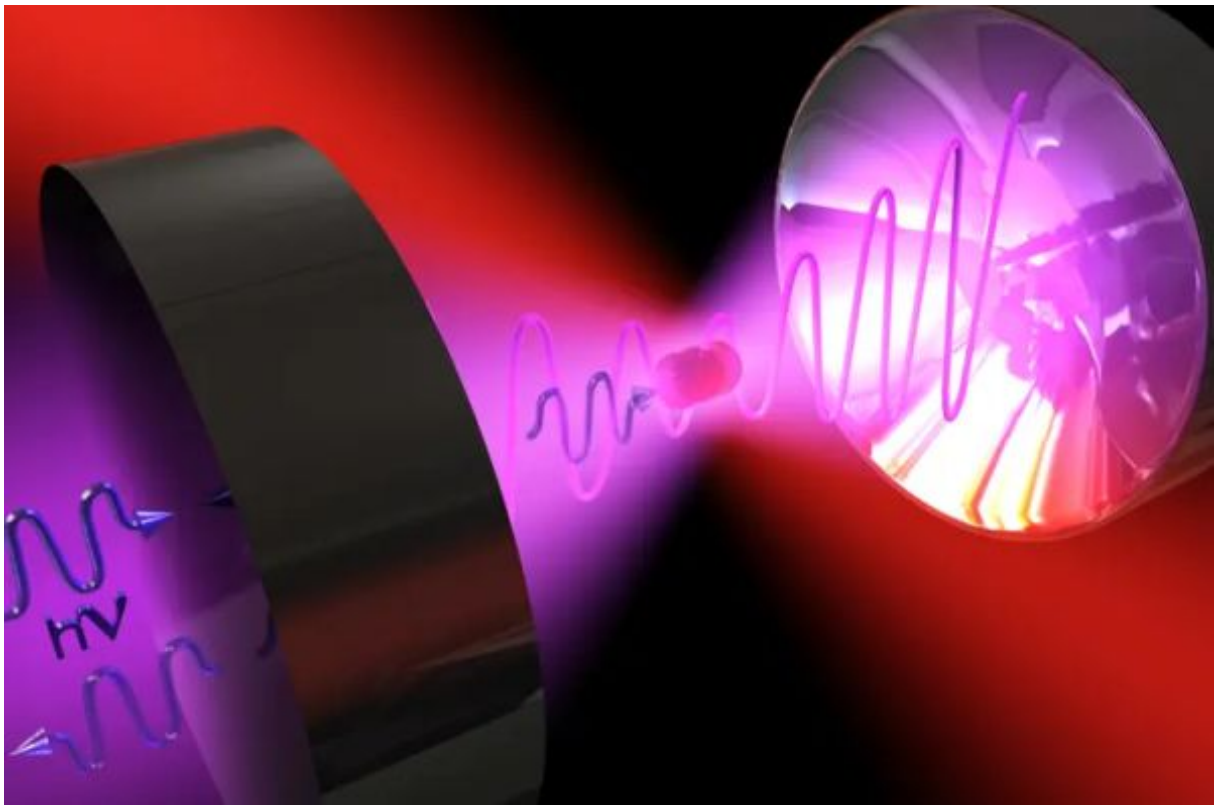

New Journal of Physics highlights ICFO?s key contributions to quantum science

The New Journal of Physics has recognized two papers featuring ICFO researchers among the ten most significant quantum articles published in the journal since its inception.

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A hundred years ago, two formalisms for quantum mechanics were put on the table. One, based on matrices, was developed by Werner Heisenberg, Max Born and Pascual Jordan; the other, on a differential equation, by Erwin Schrodinger. These approaches gave rise to Matrix and Wave quantum mechanics, respectively, setting the mathematical foundation of the emerging discipline. Thus, the United Nations has chosen 2025 to be the International Year of Quantum Science. To mark the event, the New Journal of Physics (NJP) has curated a collection of ten outstanding quantum articles published in the journal since its inception, including two significant contributions from ICFO.

Establishing levitated optomechanics as a new research area

The NJP highlighted a 2010 paper by **ICREA Prof. Dr. Oriol Romero-Isart**, Max-Planck-Institute of Quantum Optics researcher at the time and now ICFO Director; **Dr. Mathieu L. Juan** and **ICREA Prof. Romain Quidant**, both ICFO researchers at the time; and **Prof. Dr. J. Ignacio Cirac** at Max-Planck-Institute of Quantum Optics. In the article, the authors proposed applying quantum optical control and cooling techniques to levitated objects in vacuum. This idea opened the door to bringing the motion of macroscopic objects - typically governed by classical physics - into the quantum regime.

The researchers suggested levitating a dielectric nanoparticle using optical tweezers inside an optical cavity, and cooling it through the so-called sideband cooling technique. They predicted that these systems could reach the lowest possible energy level, known as the motional quantum ground-state. Once in this state, they proposed several methods to place the macroscopic nanoparticle into a quantum superposition of different energy levels. Back in 2010, no one had successfully cooled a levitated nanoparticle to its ground state. Yet, this achievement was widely believed to be a critical step toward using levitated nanoparticles, containing billions of atoms, in quantum experiments.

Finally, in 2021, the group of Prof. Dr. Markus Aspelmeyer, a close collaborator of Romero-Isart, successfully transformed the theoretical proposal into an experimental reality. By cooling a levitated nanoparticle to the motional quantum ground-state, they can now perform fundamental tests of quantum mechanics and explore the boundary between th classical and quantum worlds, something they are currently doing within a project funde with anERC Synergy Grant coordinated by Romero-Isart at ICFO. ¡¿½Since our proposal s applicable to dielectric objects, we also suggested that, in principle, the same methods cou d be applied to microorganismsi¿½, recalls Prof. Dr. Oriol Romero-Isart, lead author of the theoretical article selected by the NJP. However, the quantum superpositio of microorganisms remains an unsolved challe ge. The 2010 paper appeared the same day as another independent study by ICFO Prof. Dr. Darrick Chang and co-workers. **Both are considered pioneering works that helped establish levitated optomechanics** -the study and control of levitated nano- and micro-objects in vacuum- **as a recognized branch of physics**. Since then, levitated optomechanics has led to various applications, including enhanced acceleration and force sensors and investigations of many-particle physics. At a fundamental level, the field remains closely linked to quantum physics: by bringing a mesoscopic object of billions of atoms from the classical to the quantum regime, levitated optomechanics aims to address long-standing questions about the nature of quantum mechanics at large scales and its interplay with gravity.

Quantum technologies roadmap

The NJP also selected a 2018 roadmap article on quantum technologies from a European perspective, where ICFO and ICREA Professors **Dr. Antonio Acin** and **Dr. Maciej Lewenstein**

participated. The roadmap summarized the status, achievements and challenges of quantum technologies-communication, computation, simulation, and sensing-and two transversal areas: quantum theory and software, and quantum control.

The roadmap has served as a valuable guide to develop quantum technologies. Seven years later, despite some remaining challenges, the progress in quantum communication, computation, simulation, and sensing has been remarkable. And a century after quantum physics' inception, technologies that Heisenberg and Schrodinger could not have imagined are poised to drive profound innovations, reshaping both fundamental research and real-world applications in the years ahead.

Reference:

Oriol Romero-Isart et al 2010 New J. Phys. 12 033015. DOI 10.1088/1367-2630/12/3/033015

Antonio Acin et al 2018 New J. Phys. 20 080201. DOI 10.1088/1367-2630/aad1ea

NJP Collection:
https://iopscience.iop.org/journal/1367-2630/page/internation-year-of-quantum-sci-technol-2025