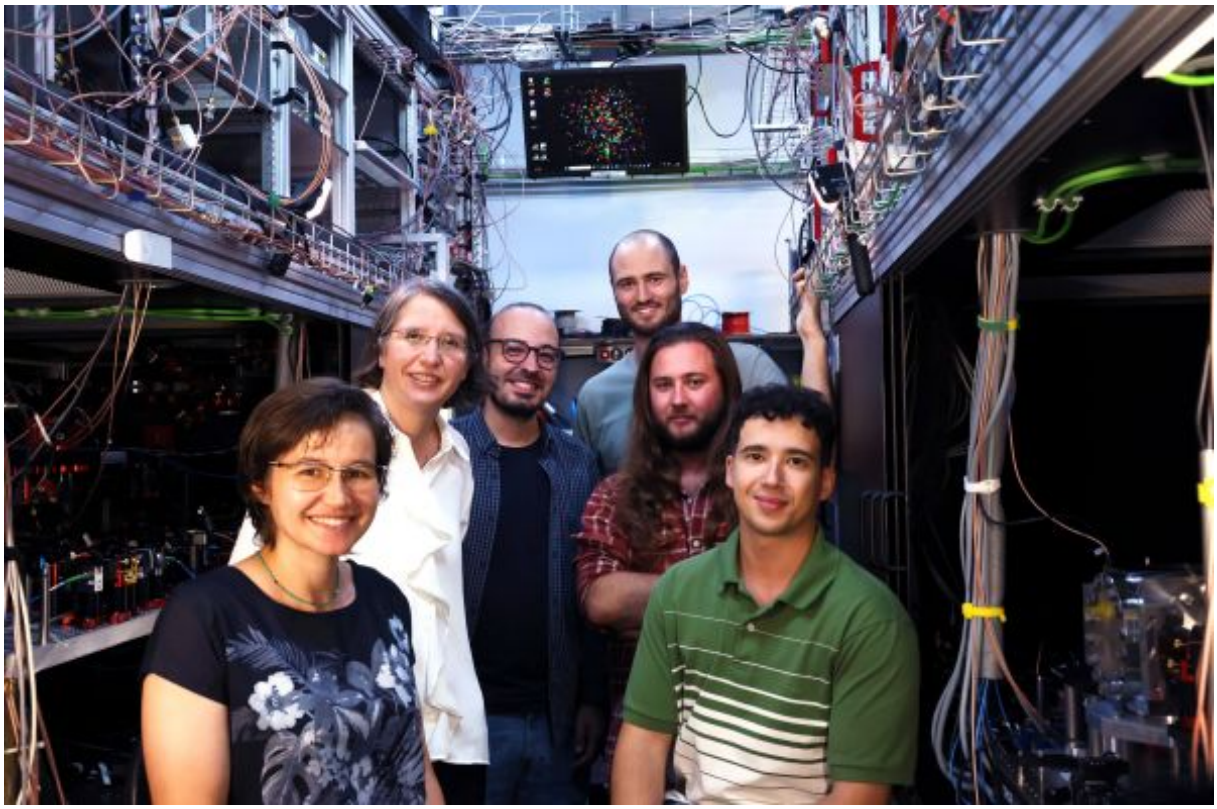


Quantum-gas microscope resolves the "color" of individual atoms in a single shot

ICFO researchers are now able to image strontium-87 at the single-atom level, and reveal its colorful set of ten different spin states. Reported in Physical Review X, this is the first quantum-gas microscope capable of detecting individual atoms with such a large number of spins all at once, a unique capability with immediate applications in quantum simulation and computing.

November 17, 2026

In 2024, researchers at the Ultracold Quantum Gases group at ICFO built a quantum-gas microscope capable of imaging individual atoms in strontium quantum gases for the first time, marking a key enabling step for quantum simulation. At that time, the researchers imaged strontium-84, a boson that has no spin. Now, **Carlos Gas-Ferrer**, **Dr. Antonio Rubio-Abadal**, **Dr. Sandra Buob**, **Leonardo Bezzo**, and **Dr. Jonatan Hoschele**, led by **ICREA Prof. Leticia Tarruell**, have used their apparatus to image **strontium-87.** This fermion features

ten different spin states, producing colorful pictures in which each individual state can be distinguished. Reported in Physical Review X, this marks the **first realization of a quantum-gas microscope that can detect individual atoms with so many available spins in a single shot**. This capability opens new possibilities for the **quantum simulation** of materials, where fermionic atoms take the role of electrons and the crystalline structure of a solid is replaced by an optical lattice created with interfering laser beams. Such systems are traditionally used to investigate the Hubbard model, a cornerstone in the understanding of high critical temperature superconductors. Remarkably, strontium-87 will allow ICFO researchers to go beyond the two spin states of electrons, creating artificial materials that feature three or more spin states. This multi-spin freedom is especially powerful for realizing exotic quantum magnetism, where the spins align in complex magnetic configurations. It could also result in spin liquid behavior, a mysterious phase of matter where they cannot decide how to order and remain suspended in a superposition of many quantum states. ?

The technique also holds promise for **quantum computing**, where researchers are exploring neutral alkaline-earth atoms like strontium as qudits (a generalization of qubits that can encode more than two possible values). Strontium-87 atoms could make an ideal qudit platform, and this imaging protocol offers a reliable readout method that remains fully compatible with the strict requirements of qudit quantum computing.

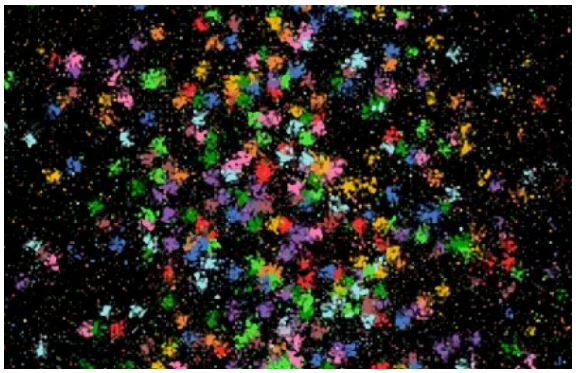
Imaging individual atoms in full color

i¿½The key ingredient for making this experiment was the red narrow-line transition f strontium,i¿½ says Carlos Gas-Ferrer, first author of the article. Thanks to this extre ely well-defined transition, a laser beam tuned to the appropriate frequency only excites the atoms in a specific spin state. These atoms absorb the laser light, become excited and, hen they are subsequently de-excited, emit fluorescence photons that the microscope can detect; all the other spin states remain unaffected and stay ?dark' to the laser. i? ½The transition is gentle enough to allow us to resolve the spin, while being strong eno gh to induce a fluorescence signali¿½, clarifies the res archer. By exploiting this property, ICFO researchers found a way to distinguish the many pins of strontium-87 atoms in a single experimental run. First, a laser excites the atoms in t e first spin state, which emit fluorescence and yield a first image with a specific color assigne to it. The atoms in the next spin state are then transferred to that same addressable state, llowing the laser to excite them, emit fluorescence, and produce a second image with a n w color a signed. The protocol thus consists of sequentially transferring the atoms from each remain ng spin state to the addressable state and inducing them to fluoresce. In this way, ICFO res archers can image and resolve the population of all ten spin states of strontium-87 in single experimental realization, obtaining images that look like multicolored confetti, w th each color representing a distinct spin state. Beyond their visual appeal, these imag

s mark a crucial experimental milestone and open exciting new avenues for quantum tech

Reference:
Carlos Gas-Ferrer, Antonio Rubio-Abadal, Sandra Buob, Leonardo Bezzo, Jonatan Hoschele, and Leticia Tarruell, Spin-resolved microscopy of 87Sr SU(N) Fermi-Hubbard systems, Phys. Rev. X, **16**, 041042 (2026).
DOI: https://doi.org/10.1103/v9sh-cq7r

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Spin-resolved single atom image of a 10-spin gas of 87Sr trapped in an optical lattice. Each fluorescence spot reveals the position of a single strontium-87 atom, with its color labeling its distinct spin state.