

High energy pushes atomic brotherhood making way for next generation quantum devices

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In a prominent advance for Indian quantum research, scientists have revealed how atoms, the building blocks of everything stop behaving as independent particles when pushed into extremely high-energy states. At this point, they begin to interact so strongly that their response to light is broadened and distorted by inter-atomic interactions.

This first global demonstration of interaction-driven distortions in Rydberg atomic signals at such high states could be a key in building the next generation of quantum computers, sensors, and communication devices.

Ordinary atoms are tiny, but Rydberg atoms are giants. By nudging an atom's outermost electron to a very high energy level, scientists create an atom that balloons in size and becomes hypersensitive to its surroundings. These peculiar atoms are central to the future of quantum computers and ultra-precise sensors. But the same sensitivity that makes them useful also makes them unpredictable.

A team from Raman Research Institute (RRI), an autonomous institute of the Department of Science and Technology (DST), cooled rubidium atoms to just above absolute zero—so cold they barely move—and trapped them with lasers and magnetic fields. This helped control and study them. Then, using beams of light, they excited these atoms into Rydberg states. Normally, the atoms signal their excitement with a neat, textbook-like pattern known as Autler–Townes splitting.

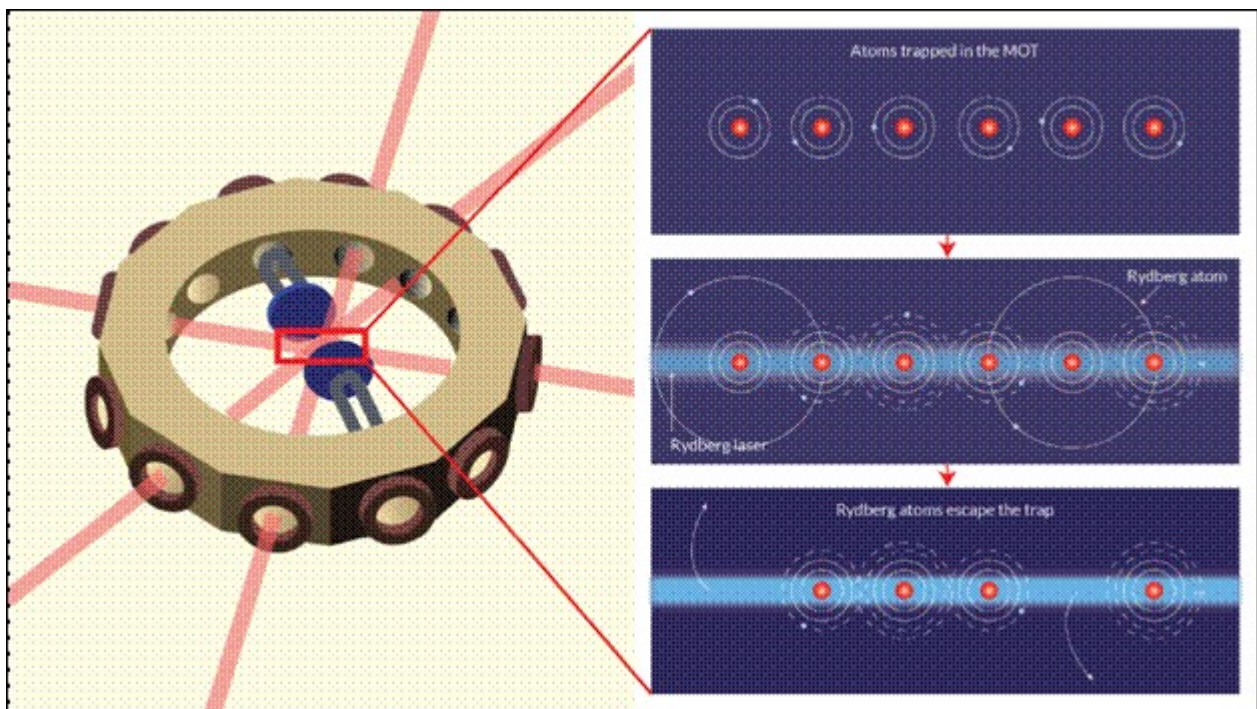


Fig. An artistic representation of the Rydberg excitation in the trapped cold atom set-up

But once the researchers pushed atoms beyond the 100th energy level, the clean pattern broke down. Instead of crisp signals, the atoms' response blurred and distorted. Far from being an error, this was the smoking gun of something remarkable: the atoms were no longer acting as loners. They were communicating, influencing,

and responding as a collective.

This interaction-driven distortions in Rydberg atoms at such high states, as a compass for quantum technology. It tells scientists where the line lies between isolated atoms (useful for precision) and entangled communities of atoms (useful for simulating complex systems). Knowing when and how atoms start “talking” to each other will be key in building the next generation of quantum computers, sensors, and communication devices.

Led by Prof. Sanjukta Roy and her PhD students Silpa B S and Shovan K Barik at RRI, with theoretical modelling by Prof. Rejish Nath's team at IISER Pune, the experiment combined delicate engineering with deep physics insight. Their custom-built detection system was sensitive enough to spot even a handful of photons, allowing them to study Rydberg atoms at dizzyingly high energy levels where others had failed.

“We have installed a highly sensitive detection system in our experiment, which is capable of detecting even a few photons emitted by the atoms. This enabled us to detect atoms at very highly excited Rydberg states $n > 100$ in spite of their low transition probabilities. We have optimized our experiment in such a way that we could measure the signal from highly excited Rydberg states with a good signal-to-noise ratio,” Dr Roy noted.

This discovery places Indian researchers firmly on the global quantum map. It shows that by cooling atoms to near stillness and then energizing them to cosmic scales, scientists can watch matter cross the threshold from individually to collectively.

This new window into understanding atomic behavior sets boundaries for future quantum technologies. In this delicate frontier, the future of quantum technologies is being written and will help create devices of the future.

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