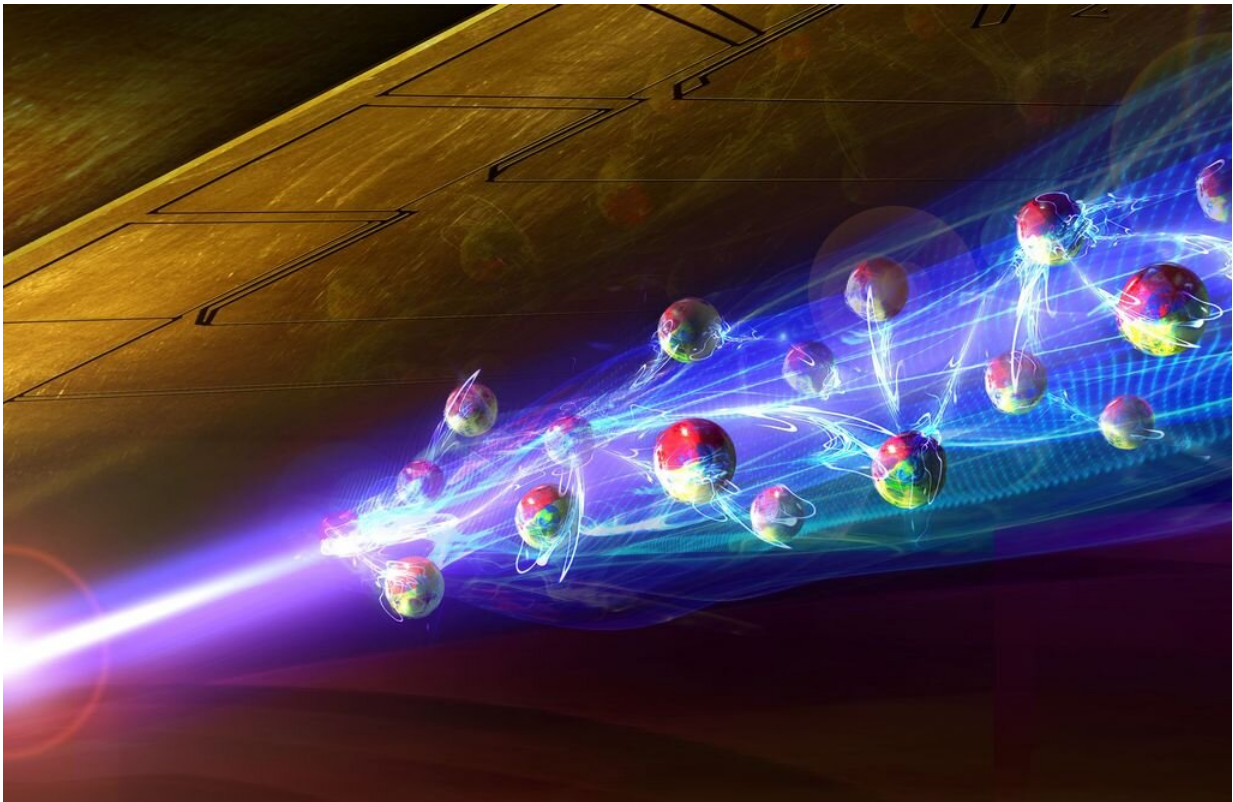


Researchers measure the binding state of light and matter for the first time

August 1 2022



The atoms are polarized by the beam of light and start to attract each other.
Credit: Harald Ritsch / TU Wien

A special bonding state between atoms has been created in the laboratory for the first time: With a laser beam, atoms can be polarized so that they are positively charged on one side and negatively charged on the other.

This makes them attract each other creating a very special bonding state—much weaker than the bond between two atoms in an ordinary molecule, but still measurable. The attraction comes from the polarized atoms themselves, but it is the laser beam that gives them the ability to do so—in a sense, it is a "molecule" of light and matter.

Theoretically, this effect has been predicted for a long time, but now scientists at the Vienna Center for Quantum Science and Technology (VCQ) at TU Wien, in cooperation with the University of Innsbruck, have succeeded in measuring this exotic atomic bond for the first time. This interaction is useful for manipulating extremely cold atoms, and the effect could also play a role in the formation of molecules in space. The results have now been published in the scientific journal *Physical Review X*.

Positive and negative charge

In an electrically neutral atom, a positively charged atomic nucleus is surrounded by negatively charged electrons, which surround the [atomic nucleus](#) much like a cloud. "If you now switch on an external electric field, this charge distribution shifts a little," explains Prof. Philipp Haslinger, whose research at the Atominstut at TU Wien is supported by the FWF START program. "The [positive charge](#) is shifted slightly in one direction, the [negative charge](#) slightly in the other direction, the atom suddenly has a positive and a negative side, it is polarized."

Light is just an [electromagnetic field](#) that changes very rapidly, so it is also possible to create this polarization effect with [laser light](#). When several atoms are next to each other, the laser light polarizes them all in exactly the same way—positive on the left and negative on the right, or vice versa. In both cases, two neighboring atoms turn different charges towards each other, leading to an attractive force.

Experiments with the atom trap

"This is a very weak attractive force, so you have to conduct the experiment very carefully to be able to measure it," says Mira Maiwöger from TU Wien, the first author of the publication. "If atoms have a lot of energy and are moving quickly, the attractive force is gone immediately. This is why a cloud of ultracold atoms was used."

The atoms are first captured and cooled in a magnetic trap on an atom chip, a technique, which was developed at the Atominstitut in the group of Prof. Jörg Schmiedmayer. Then the trap is switched off and releases the atoms in free fall. The atom cloud is "ultracold" at less than a millionth of a Kelvin, but it has enough energy to expand during the fall. However, if the atoms are polarized with a [laser beam](#) during this phase and thus an attractive force is created between them, this expansion of the atomic cloud is slowed down—and this is how the attractive force measured.

Quantum laboratory and space

"Polarizing individual atoms with laser beams is basically nothing new," says Matthias Sonnleitner, who laid the theoretical foundation for the experiment. "The crucial thing about our experiment, however, is that we have succeeded for the first time in polarizing several atoms together in a controlled way, creating a measurable attractive force between them."

This [attractive force](#) is a complementary tool for controlling [cold atoms](#). But it could also be important in astrophysics: "In the vastness of space, small forces can play a significant role," says Philipp Haslinger. "Here, we were able to show for the first time that electromagnetic radiation can generate a force between [atoms](#), which may help to shed new light

on astrophysical scenarios that have not yet been explained."

More information: Mira Maiwöger et al, Observation of Light-Induced Dipole-Dipole Forces in Ultracold Atomic Gases, *Physical Review X* (2022). [DOI: 10.1103/PhysRevX.12.031018](https://doi.org/10.1103/PhysRevX.12.031018)

Provided by Vienna University of Technology

Citation: Researchers measure the binding state of light and matter for the first time (2022, August 1) retrieved 18 June 2024 from <https://phys.org/news/2022-08-state.html>

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