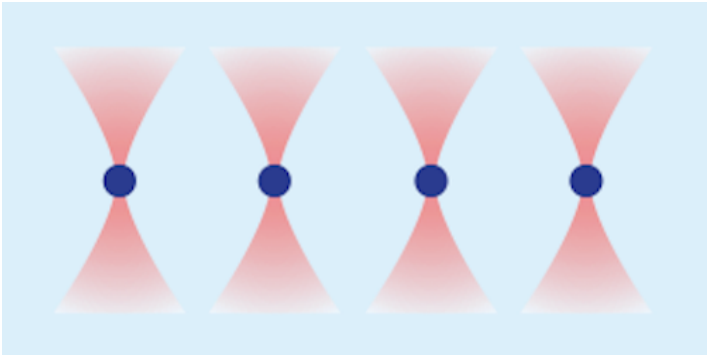
A Blueprint for a Quantum Simulator Made of Helium Atoms

New theoretical work indicates that an array of helium-3 atoms could enable more complex quantum simulations.

By **Sophia Chen**

Physicists orchestrate interactions between individual neutral atoms in arrays to simulate other quantum systems. However, the atoms can only encode information for as long as they retain their coherence, which limits the complexity of the simulations. Moving atoms faster to fit in more operations within the coherence time would circumvent that limitation. To that end, Zheyuan Li of the University of Illinois Urbana-Champaign and colleagues have proposed a blueprint for an array of the lightest, and therefore fleetest, trappable atomic species: helium-3 [**1**].

The researchers' design uses optical tweezers to trap helium-3 atoms that are in a long-lived metastable state. Unlike previous approaches, their system encodes information both in the atoms' positions in the array and in their vibrational states. The atoms' vibrational states can simulate bosonic modes, whereas the atoms' motion throughout the lattice can simulate fermionic lattice dynamics.



Credit: Z. Li *et al.* [**1**]

The speed at which atoms can move around in an array depends on their quantum tunneling rate, which is faster for lighter atoms. Li and his colleagues predict that helium-3 can be transported around the array at speeds roughly 3 times higher than have been demonstrated experimentally for lithium-6, the next lightest trappable species. They show that the energy spacings between vibrational modes of helium-3 are large, making it easy to convert an atom to an intended mode without accidentally exciting it to other levels. In addition to quantum simulation, researchers can also use the helium arrays for precise fundamental measurements, such as determining the size of nuclei, which they can compare to theoretical predictions.

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REFERENCES

1. Z. Li *et al.*, "Quantum science with arrays of metastable helium-3 atoms," **PRX Quantum 7, 033011 (2026).**