Large-scale analogue quantum simulation using atom dot arrays

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Analogue quantum systems provide an invaluable way to simulate the physics of quantum materials. Recent works on topological states in 1D chains [1] and Fermi–Hubbard physics in small 2D arrays [2] have shown that atom-based quantum dots, precision-manufactured using STM lithography, have many unique qualities advantageous to analogue quantum simulation. Here we demonstrate [3] the realization of a new platform consisting of large arrays of atom quantum dots (15,000 sites) to simulate strongly interacting, low-temperature physics. By observing a metal–insulator transition on the 2D square lattice, we demonstrate independent and precise control of the on-site interaction U and electron tunnelling t. Magneto-transport measurements further indicate the formation of an insulating state driven by Mott–Hubbard/Anderson physics, and promising signatures of correlated electron physics. Our analogue quantum simulators provide a unique platform to simulate quantum materials on arbitrary 2D lattices, and to explore many unanswered questions in the formation of quantum magnetism, topological quantum matter, and unconventional superconductivity.

References

[1] Kiczynski et al., Nature 606, 694 (2022)
[2] Wang et al., Nat. Commun. 13, 6924 (2022)
[3] Donnelly et al., Nature 650, 574 (2026)

Figures

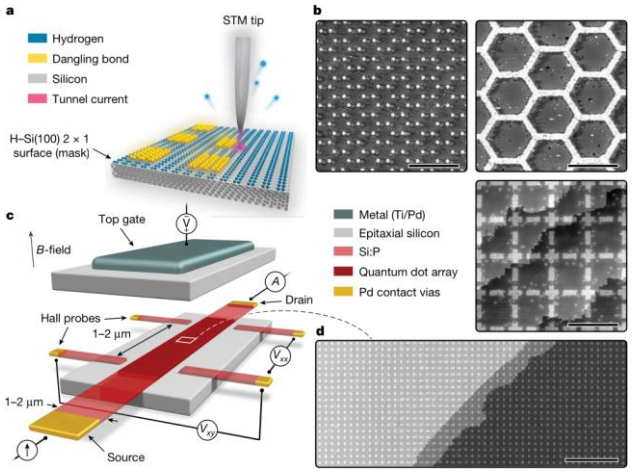

Figure 1: Large-scale quantum simulators using precision atom-based quantum dots in silicon

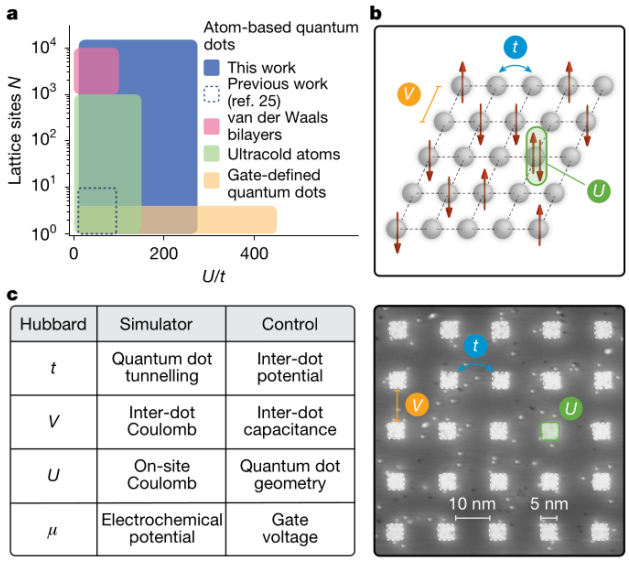

Figure 2: Simulation of strongly interacting physics on a 2D square-lattice atom dot array