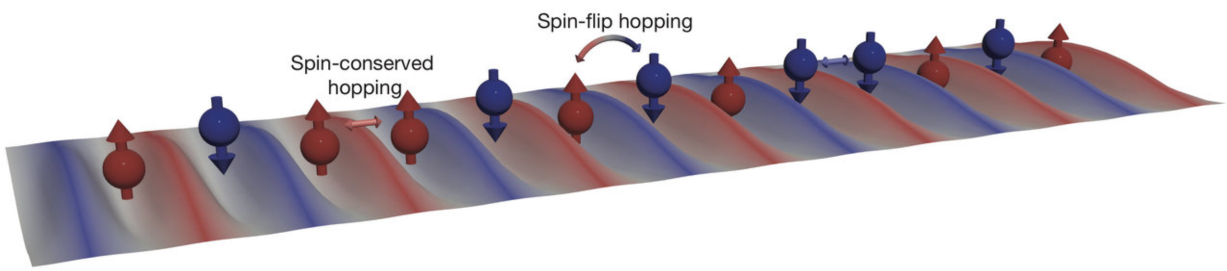
Physicists quantum simulate topological materials with ultracold atoms

March 14 2018



The quantum simulation with ultracold atoms is a rapidly moving scientific field to understand and develop the potential of topological matter. Credit: Department of Physics, HKUST

Symmetry plays a fundamental role in understanding complex quantum matter, particularly in classifying topological quantum phases, which have attracted great interests in the recent decade. An outstanding example is the time-reversal invariant topological insulator, a relatively new class of material with peculiar electronic properties, that is well understood as a symmetry-protected topological (SPT) material.

In a recent study, an international team of experimental and theoretical physicists at the Hong Kong University of Science and Technology (HKUST) and Peking University (PKU) reported the observation of an SPT phase for ultracold atoms using atomic quantum simulation. This work opens the way to expanding the scope of SPT physics with ultracold atoms and studying non-equilibrium quantum dynamics in these exotic systems.

Their findings were published in the journal *Science Advances* on Feb 23, 2018.

The shapes of objects can be classified based on topology. An exotic phase of quantum matter can be understood with underlying topology and symmetry in physical materials. The team created a synthetic crystal for ultracold atoms and for the first time emulates key properties of a one-dimensional (1-D) topological material beyond the natural condition. The ultracold atoms are 1 billion times more dilute than solids, but enable the study of complex physics because they are extremely pristine and controllable.

Classification of topological quantum phases has brought about a fundamental notion of SPT phases, which are exotic states under the protection of symmetries, and greatly expand our understanding of the fundamental nature of quantum matter. Nevertheless, by far only a small portion of theoretically predicted SPT phases have been discovered in solid state materials, mainly due to complicated and uncontrollable environment of solid-state materials which causes great challenges in realization.

"Our work predicted in theory a new type of SPT phase, which is beyond the traditional classification based on ten-fold ways, and observed in experiment such an exotic state in an engineered synthetic crystal with ultracold atoms," said Xiong-Jun Liu, assistant professor at Peking University and co-author of the paper. "This work is indeed the first experimental realization of an SPT phase for ultracold atoms, which opens a great deal of possibilities to simulate and probe novel SPT physics," Prof Liu added.

This work indeed takes the quantum simulation of topological matter to the next level which may lead to dramatic advances in material science and in quantum technology.

"Moreover, owing to the advantages of the full controllability, we expect that the present work shall push forward future studies in ultracold atom experiments of interacting SPT phases, which are broadly discussed in theory but very hard to investigate in solid-state materials," explained Gyu-Booong Jo, assistant professor at the HKUST Department of Physics and co-author of the paper.

More information: Bo Song et al, Observation of symmetry-protected topological band with ultracold fermions, *Science Advances* (2018). DOI: 10.1126/sciadv.aao4748

Provided by Hong Kong University of Science and Technology