RIKEN RESEARCH

Research Highlights : **Physics**

Emulation for understanding

08 January 2010

Controllable quantum systems that allow us to better understand complex physical processes are now within reach

Physical processes affect almost every aspect of our lives, yet physicists still grapple with understanding and modeling the behavior of many such processes—particularly complex quantum physical processes, including certain superconducting effects. To circumvent the limitations of conventional computers in tackling these problems, physicists have proposed using well-understood quantum systems called 'quantum simulators' (or 'quantum emulators') to emulate similar, but otherwise poorly understood, quantum systems. In a review of the different approaches taken in developing these simulators, Iulia Buluta and Franco Nori from the RIKEN Advanced Science Institute, Wako (and the University of Michigan, USA), have concluded that the first practical applications may soon be a reality[1].

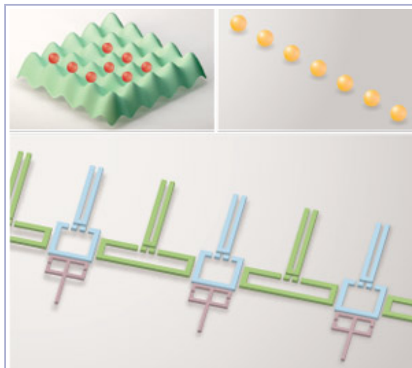

Figure 1: Schematic diagrams of three types of quantum simulators: atoms (red) held in place by an optical field (green; top left); ions (yellow) aligned using an electromagnetic field (top right); and superconducting circuits (bottom).

From Ref. 1. Reprinted with permission from AAAS.

"Quantum emulators could be employed in fields such as atomic physics or condensed-matter physics," explains Nori. However, he says, the detailed study of known physical processes is just one advantage: these controllable quantum emulators would also allow the exploration of novel physical processes that are typically hard to study.

Among the various physical systems that could be used to build a quantum simulator, one possibility is the use of regular arrays of atoms or ions that are held in place by laser fields. According to Buluta and Nori, the interactions between these atoms provide a good model for emulating the interaction between other particles in complex systems. To model electrical conductivity, for example, this type of quantum simulator can be used to study the transition from the insulating state to the conducting state, where the atoms switch from being fixed to being free to move.

Buluta and Nori also point out that electronic devices fabricated on a computer chip could be used as a controllable quantum system. In this system, small circuits made from superconducting wires possess quantum physical properties that could be used to model atomic physics problems.

These quantum systems have been demonstrated experimentally (Fig. 1); however, challenges remain until more advanced and versatile quantum simulators can be built. Synchronizing the operation of a large number of components, for example, has not yet been achieved, Buluta notes. From a theoretical viewpoint, she says that much also needs to be learned about meaningfully programming quantum simulators.

Nevertheless, Nori believes that, in contrast to the situation 25 years ago when Richard Feynman first proposed quantum simulators, the experimental demonstrations of the basic components for quantum computers completed to date suggest an optimistic outlook. "The necessary level of control of quantum systems is now within reach," he says.

The corresponding author for this highlight is based at the Digital Materials Laboratory, RIKEN Advanced Science Institute

1. Buluta, I. & Nori. F. Quantum simulators. *Science* 326, 108–111 (2009). | article

RIKEN RESEARCH **ISSN 1883-3519**