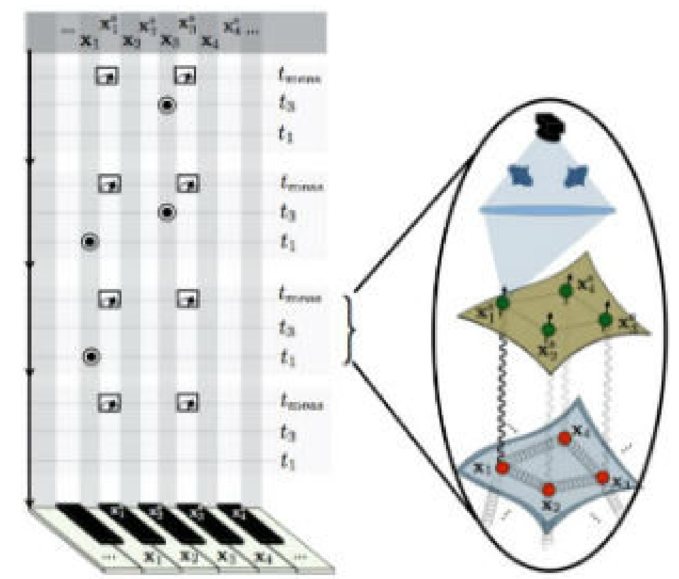
A step closer to understanding quantum mechanics: Physicists develop a new quantum simulation protocol

October 20 2017



Credit: Swansea University

For most everyday experiences, such as riding a bicycle, using a lift or catching a ball, classical (Newtonian) mechanics is perfectly accurate.

However, at atomic and subatomic scales Nature is described by quantum mechanics, formulated around 100 years ago and famously characterised by theoretical physicist Richard Feynman when he said: "I think I can safely say that nobody understands quantum mechanics".

Even today understanding the dynamics of quantum-mechanical systems composed of a large number of interacting particles remains one of the most difficult problems in physics.

To address this challenge, an interdisciplinary research collaboration of quantum information theorists from Swansea University's Physics Department has developed a new quantum simulation protocol.

In their theory study, published in *Physical Review X*, high-energy physicist Professor Gert Aarts together with Dr Markus Müller and Alejandro Bermudez propose to use cold atoms as controllable quantum sensors to experimentally access key properties of interacting quantum field theories. The results could elucidate difficult, open questions in condensed matter and high-energy physics.

Quantum field theory provides a unifying language that describes a wide variety of systems in nature across many energy scales, ranging from ultra-cold atoms in the laboratory to the most energetic particles at the Large Hadron Collider.

Alejandro Bermudez said: "A cornerstone of quantum field theory is the so-called generating functional, from which all correlations between particles can be derived." Professor Aarts added: "Usually this is considered as a mathematical tool that neatly compresses all the relevant information about the quantum field theory into a single, somewhat abstract, quantity."

In this work, the team shows how the generating functional can in fact be measured in the lab, using strings of trapped laser-cooled ions.

The key idea of the new scheme is to map the information about the generating functional onto a collection of entangled quantum sensors, encoded in electronic states of the ions.

"These quantum sensors are then coupled by a sequence of precisely-timed pulses to the quantum field, pretty much like the keys of a piano, which must be pressed at different times to produce a melody", explains Müller. "This melody - corresponding to the experimental interferometric measurement signal - contains the relevant information about the quantum field theory of interest."

The results constitute an important step in the broader topic of quantum simulations, which aim to understand problems in quantum many-body physics by means of experimental systems that can be manipulated accurately to represent the quantum field theory under investigation.

Quantum sensors for the generating functional of interacting quantum field theories. A. Bermudez, G. Aarts, and M. Müller is published in *Physical Review X*.

More information: Quantum sensors for the generating functional of interacting quantum field theories, arXiv:1704.02877 [quant-ph] arxiv.org/abs/1704.02877

Provided by Swansea University