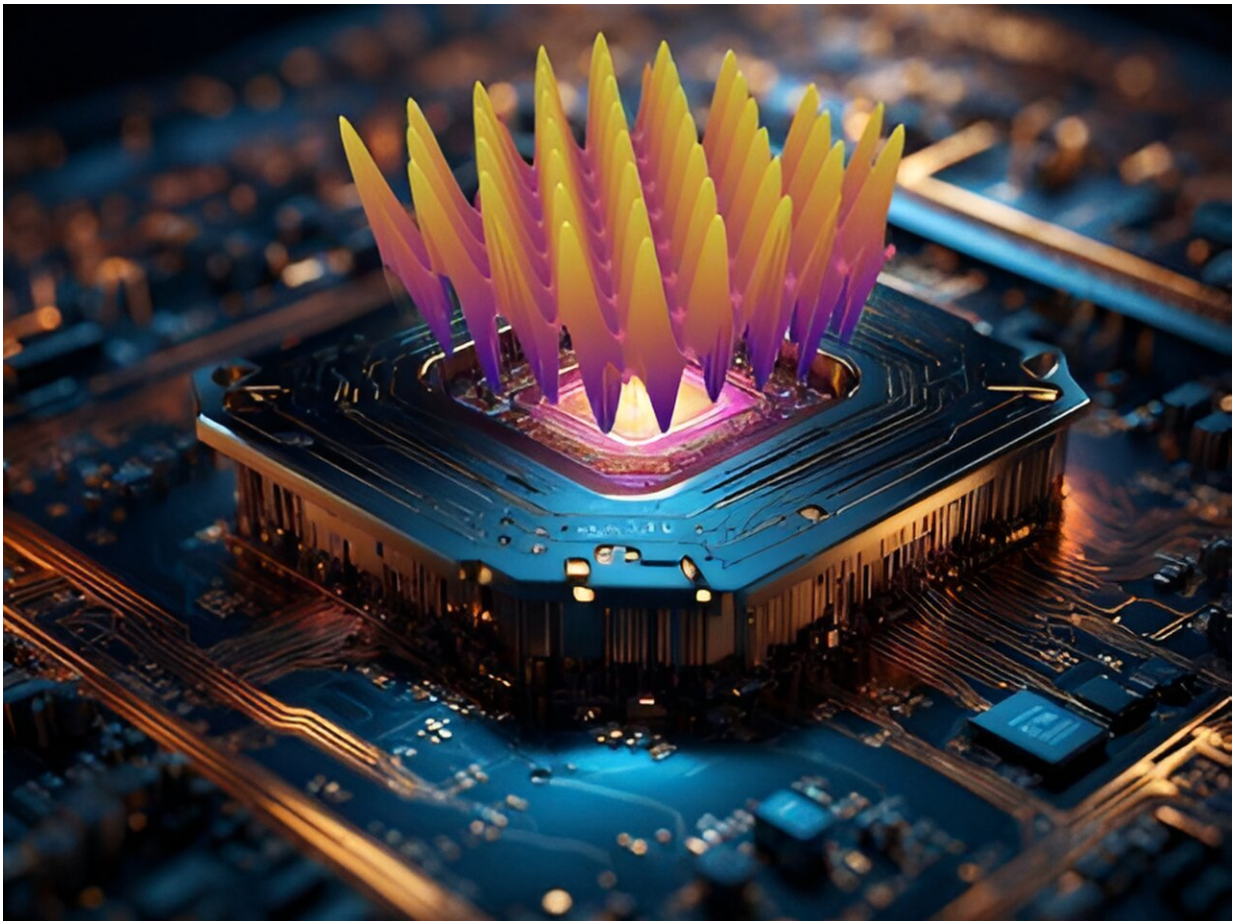


Quantum annealer improves understanding of quantum many-body systems

June 25 2024



Artistic rendition of a quantum simulation of 1T-TaS₂ being performed on the quantum processing unit of a quantum annealer Credit: Jozef Stefan Institute / Jaka Vodeb und Yevhenii Vaskivskyi

Physicists have long been pursuing the idea of simulating quantum particles with a computer that is itself made up of quantum particles. This is exactly what scientists at Forschungszentrum Jülich have done together with colleagues from Slovenia.

They used a quantum annealer to model a real-life quantum material and showed that the quantum annealer can directly mirror the microscopic interactions of electrons in the material.

The result is a significant advancement in the field, showcasing the practical applicability of quantum computing in solving complex material science problems. Furthermore, the researchers discovered factors that can improve the durability and energy efficiency of quantum memory devices. [The findings](#) have been published in *Nature Communications*.

In the early 1980s, Richard Feynman asked whether it was possible to model nature accurately using a classical computer. His answer was: no. The world consists of fundamental particles, described by the principles of quantum physics. The exponential growth of the variables that must be included in the calculations pushes even the most powerful supercomputers to their limits. Instead, Feynman suggested using a computer that was itself made up of [quantum particles](#). With his vision, Feynman is considered by many to be the Father of Quantum Computing.

Scientists at Forschungszentrum Jülich, together with colleagues from Slovenian institutions, have now shown that this vision can actually be put into practice. The application they are looking at is a so-called many-body system. Such systems describe the behavior of a large number of particles that interact with each other.

In the context of quantum physics, they help to explain phenomena such

as superconductivity or quantum phase transitions at absolute zero. At a temperature of 0 Kelvin, instead of [thermal fluctuations](#), only quantum fluctuations occur when a physical parameter like the magnetic field changes.

"One challenge in researching quantum materials is to quantitatively measure and model the phase transitions of many-body systems," explains Dragan Mihailović from the Jožef Stefan Institute in Slovenia. In this study, the scientists investigated the quantum material 1T-TaS₂, which is used in a wide range of applications, including superconducting electronics and energy-efficient storage devices.

Jaka Vodeb from the Jülich Supercomputing Center describes the approach, "We have placed the system in a non-equilibrium state and observed how the electrons in the solid-state lattice rearrange themselves after a non-equilibrium phase transition, both experimentally and through simulations."

All calculations were conducted using the quantum annealer from the company D-Wave, which is integrated into the Jülich Unified Infrastructure for Quantum Computing, JUNIQ.

The researchers could successfully model the crossover from temperature-driven to noisy quantum fluctuation-dominated dynamics. Furthermore, the scientists demonstrated that the quantum annealer's qubit interconnections can directly mirror the microscopic interactions between electrons in a quantum material. Only one single parameter in the quantum annealer must be modified. The outcome aligns closely with the experimental findings.

But the research also has practical applications. For instance, a deeper understanding of 1T-TaS₂-based memory devices can lead to a practical quantum memory [device](#), implemented directly on a quantum processing

unit (QPU). Such devices can contribute to the development of energy-efficient electronic devices, thereby significantly reducing the energy consumption of computing systems.

The research highlights the potential of quantum annealers in solving practical problems, paving the way for their broader application in various fields such as cryptography, material science, and complex system simulations. Moreover, the findings have direct implications for the development of energy-efficient quantum memory devices.

More information: Jaka Vodeb et al, Non-equilibrium quantum domain reconfiguration dynamics in a two-dimensional electronic crystal and a quantum annealer, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-49179-z](https://doi.org/10.1038/s41467-024-49179-z)

Provided by Forschungszentrum Juelich

Citation: Quantum annealer improves understanding of quantum many-body systems (2024, June 25) retrieved 17 July 2024 from <https://phys.org/news/2024-06-quantum-annealer-body.html>

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