

Using the power of symmetry for new quantum technologies

December 15 2022



Credit: Pixabay/Unsplash

By taking advantage of nature's own inherent symmetry, researchers at Chalmers University of Technology in Sweden have found a way to control and communicate with the dark state of atoms. This finding opens another door toward building quantum computing networks and quantum sensors to detect the elusive dark matter in the universe.

"Nature likes symmetries and so do we. The foundation of our experiments is an innovative engineering trick where we control and

make use of the available symmetries in a system which otherwise is very challenging to tame," says Dr. Amir Ali, researcher in [quantum technology](#) and primary author of the study.

Quantum computers have the potential to vastly surpass today's most advanced computers. A quantum computer is based on so-called quantum bits, or qubits, which have the ability to be in superposition of its possible states, 0 and 1, at the same time. This phenomenon allows quantum computers to handle vast amount of data. The superpositions are however extremely fragile, which means that they need to be protected from external disruptions to prevent them from collapsing.

Building a large-scale quantum computer therefore presents a major challenge, because with an increasing number of qubits, the collective system becomes increasingly more fragile. For this reason, a key research field is the development of large quantum networks where computing tasks are processed and distributed across different nodes of the network.

One attractive way to realize such networks is to use [artificial atoms](#) as qubits. Atoms interact naturally with light, by absorbing or emitting photons. However, ensembles of two or more atoms can exist in particular superposition states, named dark states, in which they are completely transparent to light, meaning that they neither emit nor absorb it. These dark states have great potential in quantum technology because they are immune to external influences and disruptions. For the same reason, controlling the dark states and using them to exchange information is a difficult task.

Tuning in to the tiny symmetries of atoms

Now, researchers at Chalmers University of Technology have developed a simple, high-precision method to control the dark states of a molecule

consisting of two interconnected artificial atoms. The study has been published in *Physical Review Letters*.

From [butterfly wings](#) and snowflakes to the tiniest components of our physical world, nature strives for symmetry to create balance and harmony. This is also true of the [energy levels](#) in an atom. The qubits that Amir Ali and his colleagues used consists of two coupled artificial atoms made up of superconducting circuits. When light particles—photons—are sent into the atoms through a waveguide, they can interact with the energy levels of two different available symmetries.

In previous research, only one waveguide has been coupled to the qubit with limited access to its symmetries, but the Chalmers researchers instead used two waveguides, each coupled separately to one of the symmetric states. Because of the symmetric energy distribution in the artificial atoms, one of the waveguides will be coupled to a dark state and the other to its complementary bright state. This makes them receptive to being manipulated and controlled independently of each other.

New applications in quantum technologies

This ability to control the dark states presents a new approach to applications in quantum technologies. Using the Chalmers' researchers engineering it is possible to create a quantum entanglement between the dark state and the bright state, which unlocks new ways to process quantum information and transmit it in a quantum network. Furthermore, it also allows for the development of sensors which can absorb low energy microwave photons.

A photon detector in this domain could contribute to the detection of dark matter in the universe. The researchers are also going to utilize these new results in thermodynamics to see if the laws of quantum

mechanics can be used to achieve advantages in engines or batteries.

"We can engineer synthetic molecules with unique symmetries, which leads to novel ways for these molecules to interact with microwave light. The concept we demonstrated is elegant and powerful at the same time, with applications ranging from distributed quantum computing to microwave photodetection," says Simone Gasparinetti, who is head of research in experimental quantum physics and one of the senior authors of the study.

The research was conducted at Chalmers within the framework of the Wallenberg Center for Quantum Technology (WACQT), a comprehensive research program, the aim of which is to make Swedish research and industry leaders in quantum technology.

"One of the main goals of WACQT is to build a quantum computer. But there is more to it than that. We have created an environment that encourages researchers to explore less taken paths while benefitting from infrastructure and expertise in quantum technologies, and this work is one such example," says Simone Gasparinetti.

How it works

The artificial atoms consist of electronic circuits that, just like real atoms, can only occupy a set of certain—discrete—energy levels. When they are coupled to the two waveguides, they create a shared structure that uses quantum interference to connect the waveguides to two different symmetries that the atoms' energy levels can assume.

Thanks to this coupling to the symmetries, it is easy to simply select and design the energy transitions. This can be done much more easily and effectively than has been demonstrated before, without needing to employ sophisticated phase and pulse control, which is typical in the

standard architecture.

More information: Mohammed Ali Aamir et al, Engineering Symmetry-Selective Couplings of a Superconducting Artificial Molecule to Microwave Waveguides, *Physical Review Letters* (2022). [DOI: 10.1103/PhysRevLett.129.123604](https://doi.org/10.1103/PhysRevLett.129.123604)

Provided by Chalmers University of Technology

Citation: Using the power of symmetry for new quantum technologies (2022, December 15) retrieved 6 May 2024 from <https://phys.org/news/2022-12-power-symmetry-quantum-technologies.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.