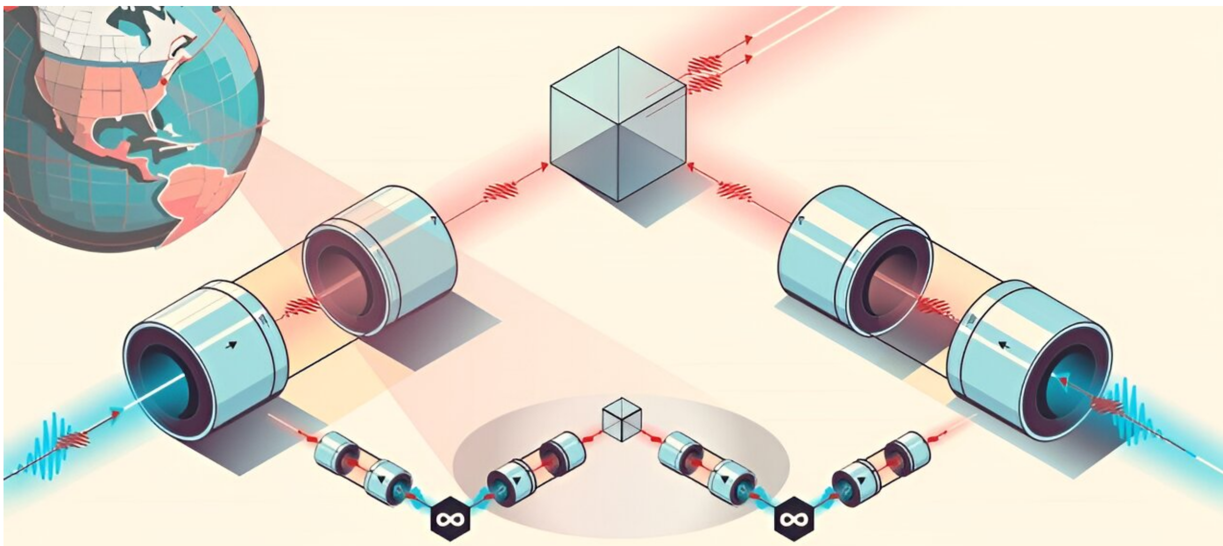
# Research team takes a fundamental step toward a functioning quantum internet

February 7 2024



A quantum repeater hop requires two sources of entangled photon pairs separated by distance L. (infinite symbols in lower inset). One photon from each pair is sent toward a central measurement node(central shaded area in figure), where they are stored in quantum memories. Their partner photons are sent in opposite directions, also stored in quantum memories separated by a distance 2L. A measurement quantifying the indistinguishability of the two photons arriving at the central node, similar to what was demonstrated by Figueroa's team, can be used to entangle the distantly located photons. Credit: Chase Wallace, Stony Brook University

Research with quantum computing and quantum networks is taking place around the world in the hopes of developing a quantum internet in the future. A quantum internet would be a network of quantum computers, sensors, and communication devices that will create, process, and transmit quantum states and entanglement and is anticipated to enhance society's internet system and provide certain services and securities that the current internet does not have.

A team of Stony Brook University physicists and their collaborators have taken a significant step toward the building of a quantum internet testbed by demonstrating a foundational quantum network measurement that employs room-temperature quantum memories. Their findings are described in a paper published in *npj Quantum Information*.

The field of quantum information essentially combines aspects of physics, mathematics, and classical computing to use quantum mechanics to solve complex problems much faster than classical computing and to transmit information in an unhackable manner.

While the vision of a quantum internet system is growing and the field has seen a surge in interest from researchers and the public at large, accompanied by a steep increase in the capital invested, an actual quantum internet prototype has not been built.

According to the Stony Brook research team, the key hurdle to achieve the potential of making communication networks more secure, measurement systems more precise, and algorithms for certain scientific analyses more powerful, relies on developing systems capable of bringing quantum information and entanglement across many nodes and over long distances. These systems are called quantum repeaters and are one of the more complex challenges in current physics research.

The researchers have advanced quantum repeater capacities in their latest experimentation. They built and characterized quantum memories that operate at room temperature and demonstrated that these memories have identical performance, an essential feature when the goal is to build large-scale quantum repeater networks that will comprise several of these memories.

They tested how identical these memories are in their functionality by sending identical quantum states into each of the memories and performing a process called Hong-Ou-Mandel Interference on the outputs from the memories, a standard test to quantify the indistinguishability of photon properties.

They demonstrated that the process of storing and retrieving optical qubits in their room-temperature quantum memories does not significantly distort the joint interference process and allows for memory-assisted entanglement swapping, a protocol to distribute entanglement over long distances and the key to building operational quantum repeaters.

"We believe this is an extraordinary step toward the development of viable quantum repeaters and the quantum internet," says lead author Eden Figueroa, Ph.D., Stony Brook Presidential Innovation Endowed Professor and Director of the Center for Distributed Quantum Processing, who holds a joint appointment at the U.S. Department of Energy's Brookhaven National Laboratory.

Additionally, the quantum hardware developed by the team operates at room temperature, significantly bringing down the cost of operation and making the system much faster. Much of quantum research is not at room temperature, but at temperatures near absolute zero which are more expensive, slower and technically more challenging to network. Thus, room temperature technology is a promising one for building large-scale quantum networks.

The team has not only accomplished room temperature quantum memory and communication results but has patented their approach. They received U.S. patents regarding quantum storage at room temperature and high-repetition-rate quantum repeaters.

"To get these fleets of quantum memories to work together at a quantum level, and in a room temperature state, is something that is essential for any quantum internet on any scale. To our knowledge, this feat has not been demonstrated before, and we expect to build on this research," emphasizes Figueroa, noting that their patented technology enables them to further test the quantum network.

Co-authors Sonali Gera, a postdoctoral researcher, and Chase Wallace, a doctoral student, both in the Department of Physics and Astronomy, worked closely with Figueroa, along with other colleagues, during the experimentation which in a sense is aiming to effectively "amplify" entanglement over distances, the essential function of a quantum repeater.

"Because the memories are capable of storing photons with a user-defined storage time, we were also able to show time synchronization of the photons' retrieval despite the photons arriving at the memories at random times, which is another feature necessary to operate a quantum repeater system," explains Gera.

She and Wallace add that some of the next steps in the team's research are to build and characterize sources of entanglement compatible with the quantum memories and to design mechanisms to "herald" the presence of stored photons across many quantum memories.

**More information:** Sonali Gera et al, Hong-Ou-Mandel interference of single-photon-level pulses stored in independent room-temperature quantum memories, *npj Quantum Information* (2024). DOI:

10.1038/s41534-024-00803-2

Provided by Stony Brook University

Citation: Research team takes a fundamental step toward a functioning quantum internet (2024, February 7) retrieved 28 April 2024 from https://phys.org/news/2024-02-team-fundamental-functioning-quantum-internet.html