# All-in-One Quantum Internet Chip Developed

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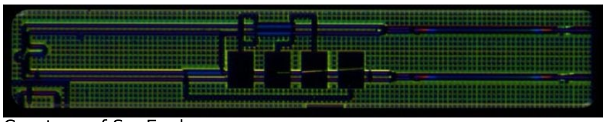

Courtesy of SynEvol
Credit: ORNL U.S. Dept of Energy

Quantum information researchers at the Department of Energy's Oak Ridge National Laboratory have, for the first time, successfully showcased a device that integrates essential quantum photonic functionalities on a single chip.

Featured in Optica Quantum, the research focuses on a type of quantum computing that utilizes photons, which are light particles, to generate qubits and facilitate the transmission and storage of information. In contrast to classical bits that signify either 0 or 1, qubits can occupy several states simultaneously due to a principle called quantum superposition. This allows for more sophisticated and potent information encoding. The study further establishes the groundwork for quantum networking, which seeks to connect quantum devices over distances—a vital move towards achieving a quantum internet.

"We're not the first to place any of these components on a chip, but we are the first to integrate these precise capabilities into a single one," stated Joe Lukens, the senior author of the study and an associate professor at Purdue University who also holds a joint faculty position at ORNL. "These chips can be produced according to standardized specifications, which is essential for enabling large-scale mass production." A product of this kind propels us past tabletop showcases and moves us closer to a quantum internet accessible to all.

The ORNL team encoded qubits onto photons and created entangled qubit pairs, which are pairs of qubits so linked that they shared characteristics even when distanced in space. The team developed broadband polarization entanglement, an essential component for different kinds of quantum networks, within a fully integrated circuit akin to the electrical transistor used by classical computers. Broadband polarization entanglement utilizes the orientation of a light wave's oscillation to store information on photons across a broad range of wavelengths.

Those photonic qubits can be sent via current fiber-optic equipment, which would reduce a significant portion of the expense of setting up new infrastructure. Such portability may contribute to a more stable and secure quantum internet.

Generating and encoding those qubits is still costly and takes a lot of time, yet integrated quantum photonics like those used on the team's new chip may aid in overcoming that challenge.

“If we manage to mass produce a chip containing all the essential components required to create the needed polarization entanglement, it will simply involve connecting the chips into a network, eliminating the need to purchase and align numerous specialized tabletop components,” stated Alexander Miloshevsky, a postdoctoral research associate at ORNL and co-author of the study.

The chip design includes essential elements like a microring resonator that facilitates the generation of entangled photon pairs, along with polarization splitter-rotators that divide the incoming light into distinct output paths based on the light's polarization. Combining the components on one chip allows for the direct creation of broadband polarization entanglement.

"Hsuan-Hao Lu, a quantum research scientist at ORNL and co-author of the study, stated that these photons work well with the existing traditional fiber-optic cable networks." “As soon as we can produce and control these photons, we can utilize standard, ready-made telecom parts for much of the remaining tasks.”

The chip showcased over 116 unique pairs of channels, or hues of light waves, for transfer. Over 100 of those channels exhibited a high fidelity – which the team referred to as a “record number.”

Utilizing microring resonators for pair generation, the team's design could eventually facilitate the development of hyperentangled qubits, which would be entangled through multiple methods, including polarization and color.

“The greater the degrees of freedom we can utilize to entangle and encode these qubits, the more information we can possibly store,” Lukens stated. A rough analogy for entanglement is a set of complex dice that, while each rolls entirely random outcomes, consistently align with one another. When various degrees of freedom — such as color, polarization, etc. — are entangled, it's akin to having multiple sets of these dice available simultaneously, each capable of facilitating communication. That is hyperentanglement.

"All these studies contribute to a broader vision that ultimately leads us to a quantum internet." We aren't certain about how the final outcome will appear, but each piece of knowledge takes us a step nearer.