Harvard John A. Paulson
School of Engineering
and Applied Sciences

A router for photons

Transducer could enable superconducting quantum networks

By Anne J. Manning | Press contact
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Applied physicists at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) have created a photon router that could plug into quantum networks to create robust optical interfaces for noise-sensitive microwave quantum computers.

The breakthrough is a crucial step toward someday realizing modular, distributed quantum computing networks that leverage existing telecommunications infrastructure. Comprising millions of miles of optical fiber, today's fiber-optic networks send information between computing clusters as pulses of light, or photons, all around the world in the blink of an eye.

Led by Marko Lončar, the Tiantsai Lin Professor of Electrical Engineering and Applied Physics at SEAS, the team has created a microwave-optical quantum transducer, a device designed for quantum processing systems that use superconducting microwave qubits as their smallest units of operation (analogous to the 1s and 0s of classical bits). The research is published in Nature Physics.

Effectively a router for photons, the transducer bridges the large energy gap between microwave and optical photons, enabling control of microwave qubits with optical signals generated many miles away. The device is the first of its kind to demonstrate control of a superconducting qubit using only light.

Paper first author and graduate student Hana Warner said the transducer offers a way to tap the power of optics when dreaming up quantum networks. "The realization of these systems is still a ways out, but in order to get there, we need to figure out practical ways to scale and interface with the different components," Warner said. "Optical photons are one of the best ways you can do that, because they're very good carriers of information, with low loss, and high bandwidth."

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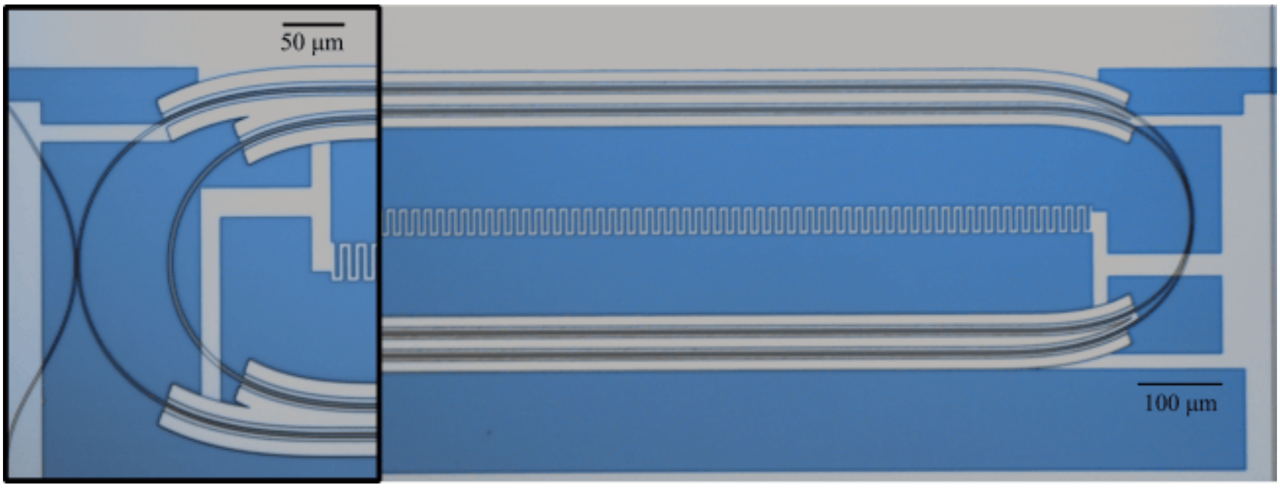
>
> **HANA WARNER**
> SEAS GRADUATE STUDENT

Superconducting qubits, which are nanofabricated circuits engineered for different energy states, are an emerging quantum computing platform due to their scalability, compatibility with existing manufacturing processes, and ability to maintain quantum superposition long enough to perform calculations.

But one of the major bottlenecks to deploying superconducting microwave qubit platforms is the extremely low temperatures at which they must operate, necessitating large cooling systems called dilution refrigerators. Since future quantum computing will require millions of qubits to operate, scaling these systems only on microwave-frequency signals is challenging. The solution lies in using microwave qubits to do the quantum operations, but to use optical photons as efficient and scalable interfaces.

That’s where the transducer comes in.

The Harvard team’s 2-millimeter optical device resembles a paper clip and sits on a chip that’s about 2 centimeters in length. It works by linking a microwave resonator with two optical resonators, allowing back-and-forth exchange of energy enabled by the properties of their base material, lithium niobate. The team leveraged this exchange to eliminate the need for bulky, hot microwave cables for controlling qubit states.

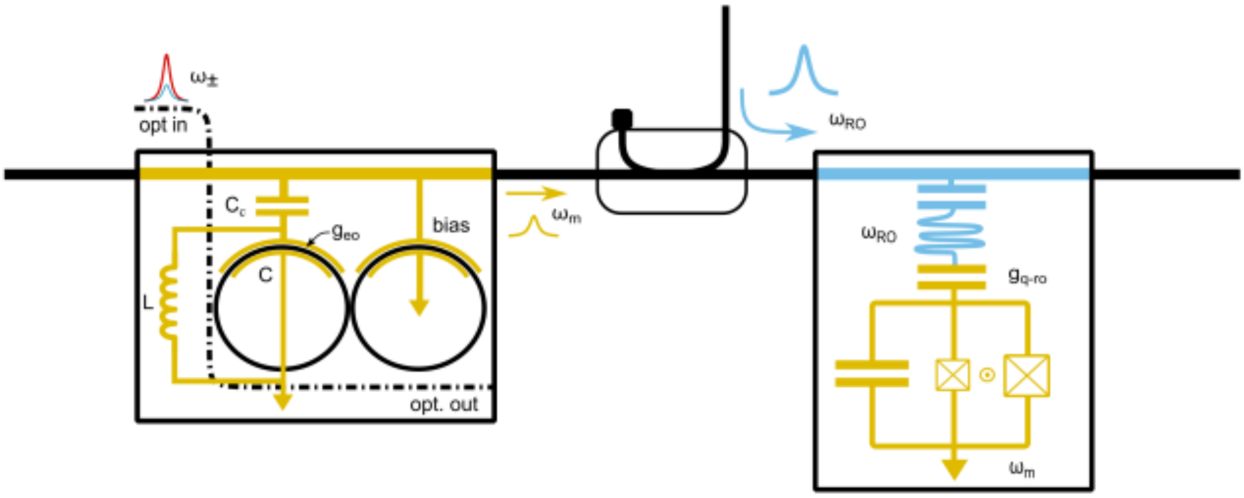


Optical micrograph of the microwave-optical quantum transducer.

The same devices used for control could be used for qubit state readout, or for forming direct links to convert finicky quantum information into sturdy packets of light between quantum computing nodes. The breakthrough brings us closer to a world with superconducting quantum processors connected by low-loss, high-powered optical networks.

“The next step for our transducer could be reliable generation and distribution of entanglement between microwave qubits using light,” Lončar said.

The Harvard team combined their expertise in optical systems with collaborators at Rigetti Computing, who provided the superconducting qubit platform on which the researchers tested their transducer and mapped out different experiments. Other collaborators were at University of Chicago and Massachusetts Institute of Technology.



Transducer-driven superconducting qubit scheme.

Fabrication of the chips was performed at Harvard's Center for Nanoscale Systems, a member of the National Nanotechnology Coordinated Infrastructure Network, which is supported by National Science Foundation Award No. 1541959.

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