A superconducting silicon-photonic chip for quantum communication

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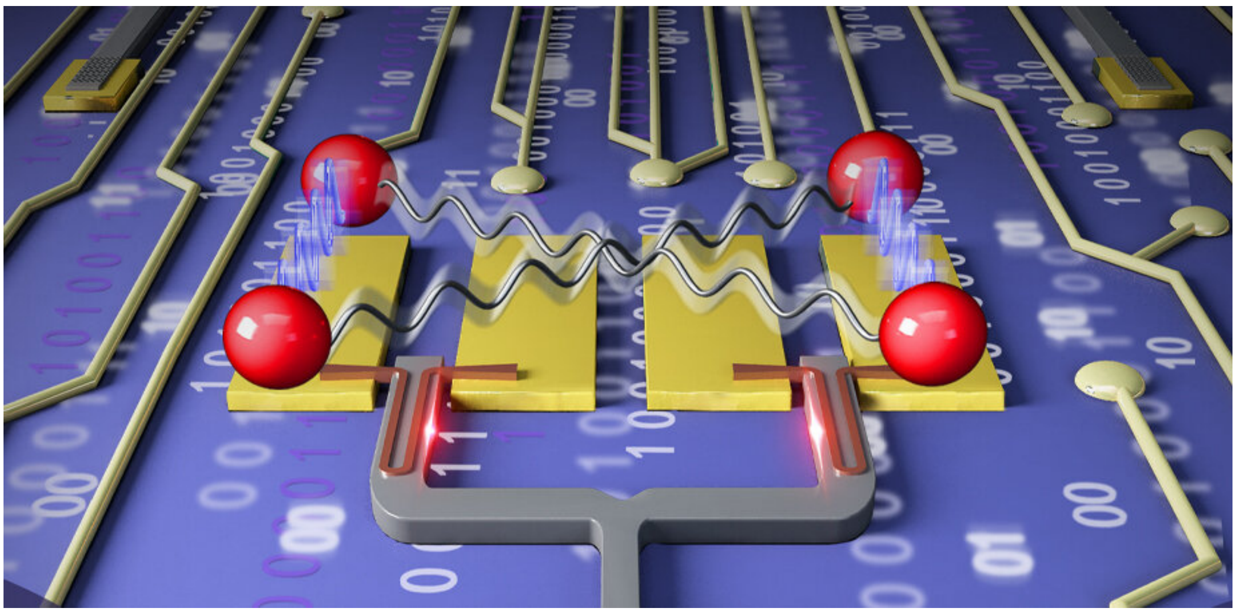
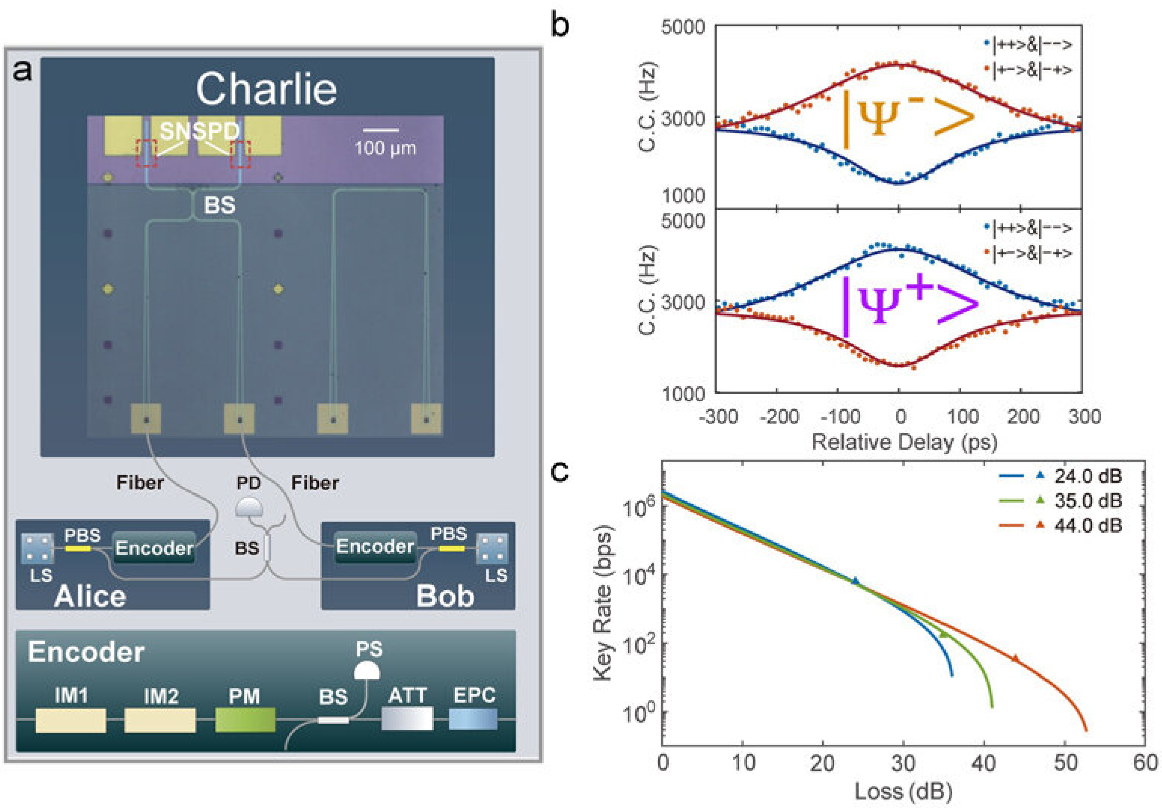


A superconducting silicon chip is used as an untrusted relay server for secure quantum communication. By harnessing the unique low-dead-time feature of the waveguide integrated superconducting single-photon detectors (red wires with hairpin shape in the middle), optimal time-bin encoded Bell-state measurements (shown in blue and grey wave-like curves between four photons, indicated as red balls) are realized. These in turn enhance secure key rate of quantum communication. Credit: MaLab, Nanjing University

Integrated quantum photonics (IQP) is a promising platform for realizing scalable and practical quantum information processing. Up to now, most of the demonstrations with IQP focus on improving the stability, quality, and complexity of experiments for traditional platforms based on bulk and fiber optical elements. A more demanding question is: "Are there experiments possible with IQP that are impossible with traditional technology?"

This question is answered affirmatively by a team led jointly by Xiao-Song Ma and Labao Zhang from Nanjing University, and Xinlun Cai from Sun Yat-sen University, China. As reported in *Advanced Photonics*, the team realizes quantum communication using a chip based on silicon photonics with a superconducting nanowire single-photon detector (SNSPD). The excellent performance of this chip allows them to realize optimal time-bin Bell state measurement and to significantly enhance the key rate in quantum communication.

The single photon detector is a key element for quantum key distribution (QKD) and highly desirable for photonic chip integration to realize practical and scalable quantum networks. By harnessing the unique high-speed feature of the optical waveguide-integrated SNSPD, the dead time of single-photon detection is reduced by more than an order of magnitude compared to the traditional normal-incidence SNSPD. This in turn allows the team to resolve one of the long-standing challenges in quantum optics: Optimal Bell-state measurement of time-bin encoded qubits.



(a) Schematic of the experiment setup. A superconducting silicon-photonic chip that performs optimal Bell-state measurements is used as the server for MDI-QKD, which allows Alice and Bob to exchange secure keys without detector side-channel attacks. (b) Destructive and constructive interference in coincidence counts when Alice and Bob send the same states (blue dots), or different states (red dots). (c) Secure key rate under different losses. Credit: Zheng et al., doi 10.1117/1.AP.3.5.055002.

This advance is important not only to the field of quantum optics from a fundamental perspective, but also to quantum communications from the application perspective. The team employs the unique advantages of the heterogeneously integrated, superconducting silicon-photonic platform to realize a server for measurement-device-independent quantum key distribution (MDI-QKD). This effectively removes all possible detector side-channel attacks and thus significantly enhances the security of quantum cryptography. Combined with a time multiplex technique, the method obtains an order-of-magnitude increase in MDI-QKD key rate.

By harnessing the advantages of this heterogeneously integrated system, the team obtains a high secure key rate with a 125 MHz clock rate, which is comparable to the state-of-the-art MDI-QKD experimental results with GHz clock rate. "In contrast with GHz clock rate MDI-QKD experiments, our system doesn't require a complicated injection locking technique, which significantly reduces the complexity of the transmitter," says Xiaodong Zheng, a Ph.D. student in Ma's group and first author of the *Advanced Photonics* paper.

"This work shows that integrated quantum-photonic chips provide not only a route to miniaturization, but also significantly enhance the system performance compared to traditional platforms. Combined with integrated QKD transmitters, a fully chip-based, scalable, and high-key-rate metropolitan quantum network should be realized in the near future," says Ma.

More information: Xiaodong Zheng et al, Heterogeneously integrated, superconducting silicon-photonic platform for measurement-device-independent quantum key distribution, *Advanced Photonics* (2021). DOI: 10.1117/1.AP.3.5.055002

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