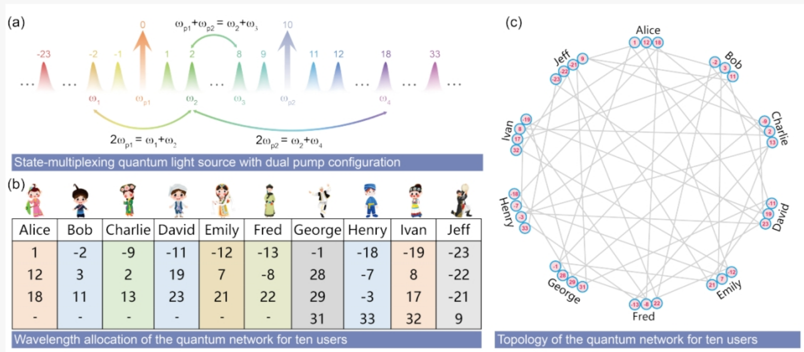
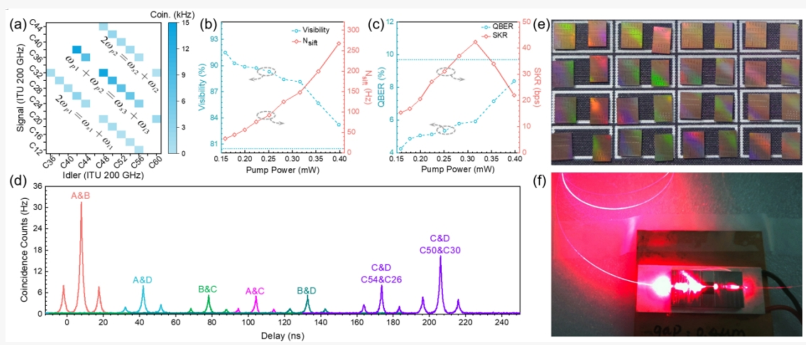
More is Less: A New State-Multiplexed Approach to Quantum Entanglement Network

FAYETTEVILLE, GA, UNITED STATES, May 27, 2025 /EINPresswire.com/ -- The fully connected quantum network with a wavelength division multiplexing architecture plays an increasingly pivotal role in quantum information technology, which aims to connect more users with less wavelength resource. Towards this goal, Scientist in China demonstrated a state-multiplexed scheme for quantum entanglement network that significantly increases user capacity without increasing the number of wavelength channels. The network topology has great potential for developing a scalable quantum network with significantly minimized infrastructure requirements.



a, State-multiplexing quantum light source with dual pump configuration. b, Wavelength allocation of the quantum network for ten users. c, Topology of the quantum network for ten users.



a, Coincidence count rates of 24-wavelength-paired photon pairs for degenerate and non-degenerate SFWM processes at pump powers at 0.32mW. b and c, shows the visibility, Nsift, QBER, and SKR of user B&D at different pump power levels. d, Histograms betwee

Quantum entanglement is the foundational resource of the quantum network, enabling various applications such as quantum communication, quantum sensing, and quantum computing. However, current schemes for fully connected multi-user quantum networks rely heavily on wavelength-division multiplexing (WDM) technology, where the required number of wavelength channels grows polynomially with the number of users. For instance, a 10-user quantum network demands 90 wavelength channels, and a 100-user network would require 990 channels. This exponential demand for the spectrum of quantum light source has become a major bottleneck to scaling the quantum network.

In a new paper published in Light: Science & Applications, a team of scientists, led by Prof. Qiang Zhou from University of Electronic Science and Technology of China (UESTC) and co-works have proposed a novel approach to overcome this limitation. The team designed a polychromatic-pumped quantum light source based on silicon nitride micro-ring resonators. Using two independent pump light at different wavelengths, they successfully generated three distinct entangled states within a single wavelength channel via spontaneous four-wave mixing, realizing quantum state multiplexing. With this source, they experimentally demonstrated a four-user fully connected quantum network using only six wavelength channels, effectively halving the spectral resource compared to conventional designs. Extrapolating the method, the team showed that a 10-user fully connected network could be achieved using only 34 wavelength channels—nearly 67% reduction in spectral demand. As the number of users increases, the savings become even more pronounced, yielding the counterintuitive effect that "more state multiplexed is less wavelength channel needed." In addition to reducing hardware complexity and optical loss, this approach also improves the performance of quantum key distribution (QKD). The researchers demonstrated a secure key rate of 1946.9 bps under the BBM92 protocol, confirming the feasibility of quantum-secure communication based on the multiplexed source.

"The combination of independently tunable polychromatic pumping allows for reconfigurable quantum networks," said first author Dr. Yun-Ru Fan. "By adjusting pump wavelengths, powers, and channel configurations, we can tailor the entanglement distribution to diverse networking demands."

"This new approach opens a promising path toward scalable quantum networks," added Prof. Qiang Zhou. "Our future work will focus on enhancing the performance of multiplexed entangled sources and exploring the coexistence of quantum and classical signals over shared fiber infrastructures."

References
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