A novel scheme to generate optical Schrodinger cat states leads to unprecedented size and preparation rate

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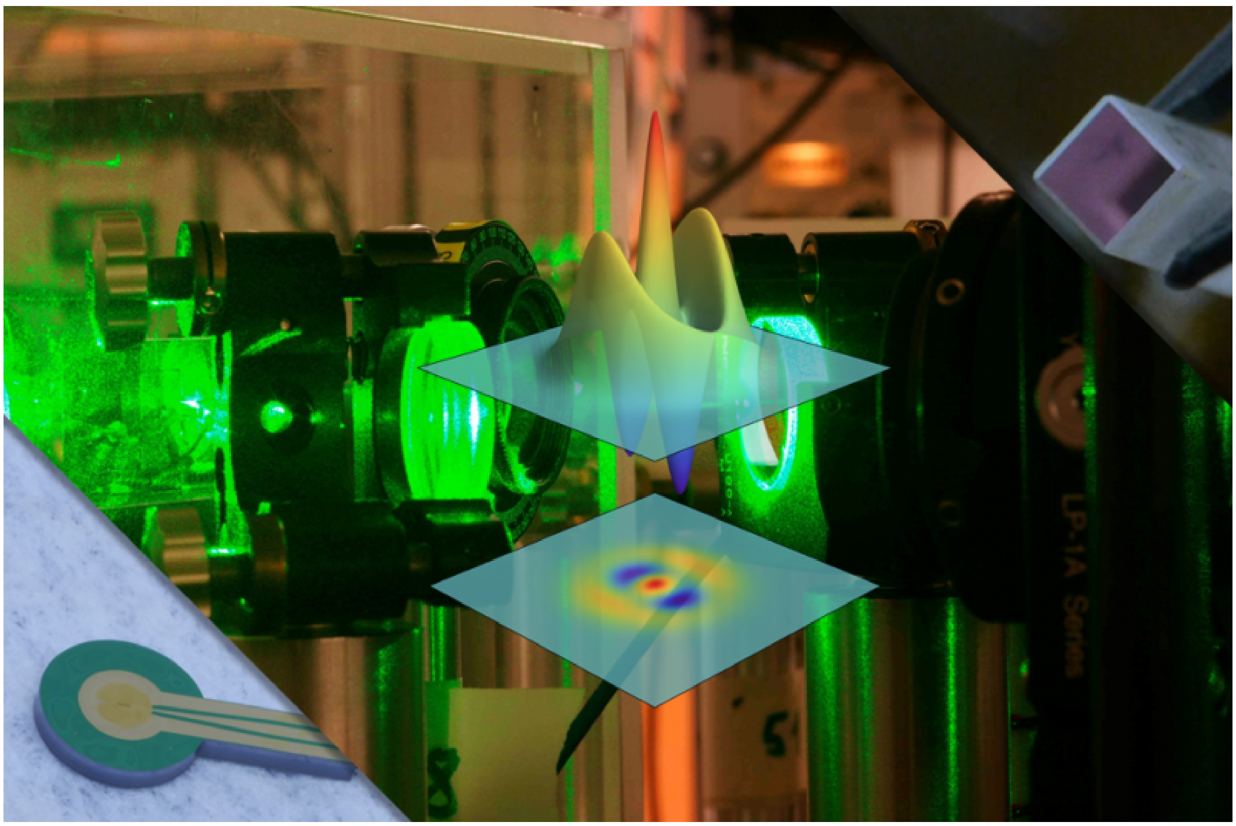

The flying Schrödinger cat state can be generated with an unprecedented size and preparation rate by combining a large escape efficiency optical parametric oscillator and high-efficiency superconducting nanowire single-photon detectors. Credit: Laboratoire Kastler Brossel – NIST

A novel scheme to generate optical Schrödinger cat states leads to unprecedented size and preparation rate.

The counterintuitive aspects of quantum mechanics were exemplified by the famous Schrödinger cat paradox, a cat simultaneously dead and alive in a box. In recent years, physicists have performed various versions of this Gedanken experiment. An "optical Schrödinger cat" now refers to a quantum superposition of two light pulses. The size of the superposition, i.e. the mean number of photons involved, is a critical parameter in experiments not only to test quantum foundations but also for applications in quantum information technology, including quantum computing, metrology and communication. Although a lot of progress has been made over the last few years, the very low generation rate achieved so far still prohibits their use in practical protocols.

In the July 10th issue of the *Physical Review Letters*, Prof. Julien Laurat and his team at Pierre and Marie Curie University in Paris (Laboratoire Kastler Brossel-LKB), together with colleagues from four other institutions worldwide, report that they have devised a novel scheme to generate such states with an unprecedented size and preparation rate. By combining an optimal optical circuit and newly developed high-efficiency superconducting detectors, they demonstrated a rate at least two orders of magnitude larger than achieved heretofore.

"This work provides an efficient way to generate large-size optical cat states with a generation rate high enough to permit subsequent operations," says Kun Huang, a graduate student who performed this experiment and the first author of the paper. "This achievement relies on the joint effort of five institutions worldwide, including NIST Boulder and JPL, where the detectors with unprecedented efficiency in the near infrared have been developed."

The method developed by the researchers relies on twin beams generated by a large escape-efficiency optical parametric oscillator (a non-linear crystal inserted into an optical cavity where the photons can bounce many times), and a subsequent two-photon detection operated by high-efficiency WSi-based superconducting nanowire single-photon detectors working at cryogenic temperature. The scheme optimally uses expensive non-Gaussian resources, such as single-photon detections, to synthesize only the key part of the targeted state, as has been analyzed by the researchers. Experimentally, the team synthesized a heralded cat state with a mean photon number equal to three and a 200-Hz generation rate. "The combination of low-loss, high-fidelity quantum state engineering with a new generation of single-photon detectors opens up an avenue of investigation," says graduate student Hanna Le Jeannic, who also contributed to this work.

This leap makes these states immediately suitable for a wealth of subsequent experiments in which they can be used as initial resources. For instance, the demonstrated free-propagating cat states will find applications in the emerging optical hybrid quantum information field where the wave and particle aspect of light are combined for the creation of heterogeneous networks. This demonstration follows other works that Laurat's group has done in recent years, including the remote creation of entanglement between particle-like and wave-like quantum bits.

More information: "Optical synthesis of large-amplitude squeezed coherent-state superpositions with minimal resources," *Physical Review Letters* 115, 023602 (2015). DOI: 10.1103/PhysRevLett.115.023602

"Remote creation of hybrid entanglement between particle-like and wave-like optical qubits." *Nature Photonics* 8, 570–574 (2014) DOI: 10.1038/nphoton.2014.137

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