Schrödinger's cats in quantum optics

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In famous Schrödinger's thought experiment proposed in 1935 [1], a living or dead cat is entangled with a state of a radioactive atom, thereby forming a macroscopic quantum superposition state. This paradox was originally used to show strangeness of quantum mechanics when applied to macroscopic objects. In modern physics, the Schrödinger's cat state (SCS) is sometimes understood as a coherent superposition of two macroscopically distinct states. Nowadays such states have been obtained in diverse physical systems, for example in ionic ensembles and superconducting circuits. In the optical domain, the SCS is a coherent superposition of two coherent states $\pm\alpha$, which are considered the most classical of all states of light.

SCS are of wide interest both from fundamental and practical points of view. Optical SCS are useful in quantum information science. They can serve as a basis for quantum computation [2], metrology [3] and teleportation[4]. Besides the applied interest, the SCS is expected to help answering a fundamental question [5–7]: at what degree of macroscopicity, if any, does the world stop being quantum?

For the most of the above applications, it is necessary to have SCSs of high amplitude so that states $|\pm\alpha\rangle$ are nearly orthogonal; this is achieved for $\alpha \gtrsim 2$ [2]. But existing methods of optical SCS preparation, such as the photon subtraction from squeezed vacuum [8] or arbitrary Fock-state engineering [9, 10] allow to generate cats only with relatively small amplitudes.

We experimentally implement two protocols of heralded SCS preparation:

1. We develop and test a hybrid protocol of loss-tolerant remote SCS engineering. We experimentally obtain a negative SCS of amplitude 1.84 and fidelity 88% despite 10 dB of total loss between the parties involved in the preparation process [11].

2. We implement a method, proposed by Lund et al. [12], of amplifying optical SCSs by linear optical manipulation and conditional measurements [13]. In the experiment, we convert a pair of negative squeezed SCS of amplitude 1.25 to a single positive SCS of amplitude 2.15 with a success probability of 0.2 and fidelity 86 %. The results are shown in Fig. 1.

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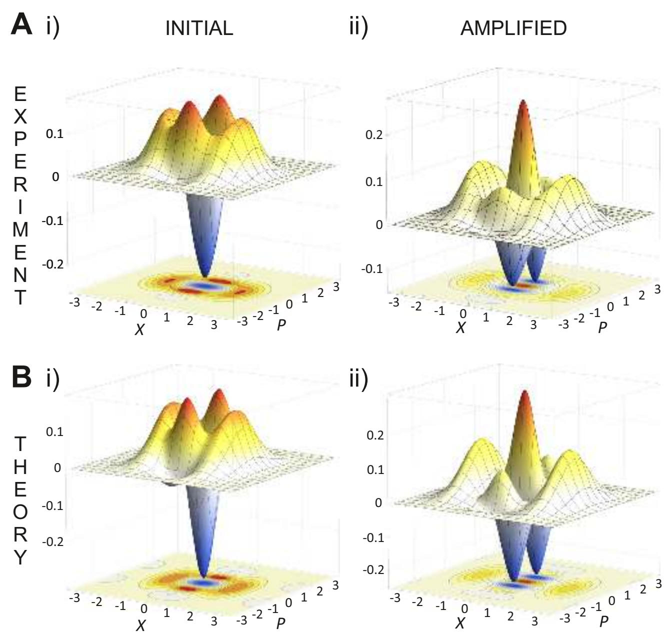

FIG. 1. Wigner functions of the initial and amplified SC states. **A**: Experimental reconstruction via homodyne tomography corrected for the total quantum efficiency of 50%. **B**: Best fit with the ideal, squeezed SC state. Left (i) [right (ii)]: initial [amplified] SC state. The best fit state is $|SC_-[1.25]\rangle$ $[|SC_+[2.15]\rangle]$ squeezed by 1.73 dB [3.47 dB]. The fidelity between the theoretical and experimental [corrected] states is 93% [86%].