

# Generation of optical Schrödinger cat states by number-resolved squeezed photon subtraction\*

Thomas Gerrits<sup>1</sup>, Scott Glancy<sup>1</sup>, Tracy Clement<sup>1</sup>, Brice Calkins<sup>1</sup>, Adriana Lita<sup>1</sup>, Aaron Miller<sup>3</sup>, Alan Migdall<sup>2</sup>, Sae Woo Nam<sup>1</sup>, Richard Mirin<sup>1</sup>, Manny Knill<sup>1</sup>

<sup>1</sup>National Institute of Standards and Technology, Boulder, CO, 80305, USA

<sup>2</sup>National Institute of Standards and Technology, Gaithersburg, MD, 20899, USA and  
Joint Quantum Institute, Univ. of Maryland, College Park, MD 20742, USA

<sup>3</sup>Albion College, Albion, MI 49224, USA

Author e-mail address: gerrits@boulder.nist.gov

We have generated and measured an approximation of an optical Schrödinger cat state by photon subtraction from squeezed vacuum. Figure 1 shows the experimental scheme. Photons are probabilistically subtracted from squeezed vacuum and detected with a photon-number-resolving transition edge sensor (TES). The detection of at least one photon indicates the presence of the cat state, which is measured by homodyne detection. Using the TES, we were able to subtract up to three photons from a squeezed light pulse and generate an optical Schrödinger cat state with fidelity of  $0.59^{+0.04}_{-0.14}$  and a size of 2.75 photons. Figure 2 shows the Wigner function reconstructed from our homodyne measurements coinciding with detecting three photons in the subtraction arm. The data consists of 1087 homodyne measurements that were acquired during a period of about 60 hours. The minimum of the Wigner distribution was  $-0.116^{+0.073}_{-0.019}$ , a clear indication for the quantum character of the generated cat state. As predicted by theory, we see an increase in the cat state size and fidelity while subtracting more photons. By improving the squeezing purity and the heralding efficiency we will be able to generate high fidelity cat states at high rates in the near future. These promising results show that high efficiency detectors with photon number resolving capabilities are the route to perform quantum information experiments with high generation rates and cat state amplitudes of  $|\alpha|^2 > 2$ .

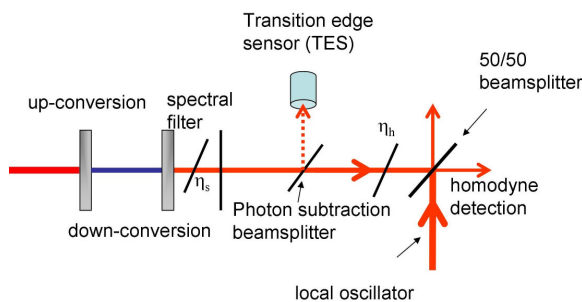


Figure 1: experimental scheme

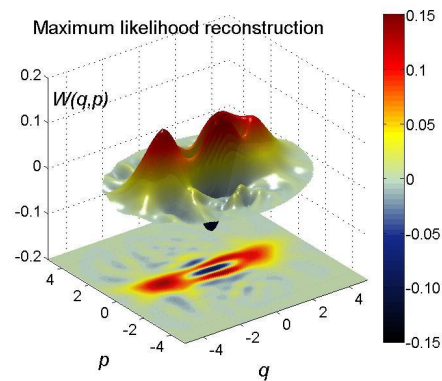


Figure 2: reconstructed Wigner distribution of an optical Schrödinger cat state