The continuous-variable approach in discrete-variable quantum optics

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Homodyne tomography, a method of characterizing quantum states of the electromagnetic field by measuring the phase-sensitive quantum noise statistics of its amplitudes, has recently been extended to the highly nonclassical domain, in particular to the single-photon state [1]. This has opened up the possibility for applying this technique to quantum information technology, where it enables for a qualitatively higher accuracy in quantum state characterization as compared to the traditional photon-counting approach.

In the experiment to be presented, we used homodyne tomography to characterize a dual-rail optical qubit which is generated when a single photon from a parametric down conversion source [2] entangles itself with the vacuum state on a beam splitter. From correlated, phase-sensitive field quadrature statistics acquired from two homodyne detectors, we reconstruct the four-dimensional density matrix which extends over the entire Hilbert space of two electromagnetic oscillators and reveals, for the first time, complete information about the optical qubit, including the vacuum and multiphoton contributions. We also demonstrate that the continuous-variable experimental data violate the Bell inequality albeit with a loophole similar to the detection loophole in photon counting experiments [3].

The dual-rail optical qubit can be viewed as an entangled ensemble of the single-photon and vacuum states and can be used as a resource for quantum teleportation [4] and remote state preparation [5] in a hybridized discrete- and continuous-variable regime. More generally, our experiments demonstrate the potential of combining discrete- and continuous-variable approaches in a single setting for quantum information processing applications.

References

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