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Ultrafast Optical Homodyne - Measuring the Fundamental Variables of Quantum Optics 10^5 Times Faster

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Homodyne measurement is a corner-stone of quantum optics. It measures the fundamental variables of quantum electrodynamics - the quadratures of light, which represent the cosine-wave and sine-wave components of an optical field. The quadratures constitute the quantum optical analog of position and momentum in mechanics and obey quantum uncertainty, indicating the inherent inability to measure both simultaneously. The homodyne process, which extracts a chosen quadrature amplitude by correlating the optical field against an external quadrature reference (local-oscillator, LO), forms the backbone of coherent detection in physics and engineering, and plays a central role in quantum information processing. Homodyne can reveal non-classical phenomena, such as squeezing of the quadrature uncertainty; It is used in tomography to fully characterize quantum states of light; Homodyne detection can generate non-classical states, provide local measurements for teleportation and serve as a major detector for quantum key distribution (QKD) and quantum computing. Yet, standard homodyne suffers from a severe bandwidth limitation. While the bandwidth of optical states can easily span many THz, standard homodyne detection is inherently limited to the electrically accessible, MHz to GHz range, leaving a dramatic gap between the relevant optical phenomena and the measurement capability. This gap impedes effective utilization of the huge bandwidth resource of optical states and the potential enhancement of the information throughput \emph{by several orders of magnitude} with parallel processing in quantum computation, QKD and other applications of quantum squeezed light. Here we demonstrate a fully parallel optical homodyne measurement across an arbitrary optical bandwidth, effectively lifting the bandwidth limitation completely. Using optical parametric amplification, which amplifies one quadrature while attenuating the other, we measure two-mode quadrature squeezing of 1.5dB below the vacuum level simultaneously across a bandwidth of 55THz using a single LO - the pump. This broadband parametric homodyne measurement opens a wide window for parallel processing of quantum information.

Topic:

Mini-workshop: Quantum Foundations and Quantum Information

Summary

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