

Photon-Number-Resolved Homodyne Detection

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Abstract

We present a homodyne detection scheme using a weak local oscillator of a few photons and photon-number-resolving detectors. We vary the strength of the local oscillator to observe where the classical treatment breaks down in the presence of loss and imperfections, which we characterise using the experimental setup.

Balanced Homodyne Detection (BHD) is a widely-used experimental technique to characterise an optical state $|\phi\rangle$. The technique is performed by interfering $|\phi\rangle$ with a strong local oscillator (LO) $|\alpha\rangle$ on a balanced beamsplitter (see Fig. 1). A quadrature measurements on $|\phi\rangle$ is obtained by measuring the difference in detector signal [1].

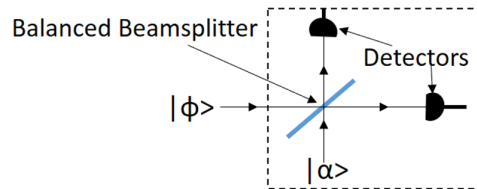


Figure 1: Schematic of the setup for homodyne detection of a signal $|\phi\rangle$

Here we replace often-used photodiodes with photon-number-resolving detectors (PNRDs) which are inherently more sensitive, meaning it is possible to use a weak LO of only a few photons, and giving us access to non-Gaussian measurements. While a strong LO can be treated classically, in the weak case a quantum mechanical description is required to describe the correct photon-number distribution [2, 3]. In the limit of $\alpha \rightarrow 0$ the measurement reduces to a projection of $|\phi\rangle$ onto the Fock-basis. Here we investigate the transition between the classical and quantum regimes.

In our experiment we used a heralded Fock state $|n\rangle$ as our signal, and Transition Edge Sensors as our PNRDs [4]. We characterised the mode overlap between $|n\rangle$ and $|\alpha\rangle$ by measuring the Hong-Ou-Mandel interference using PNRDs. We also measured system efficiency through Klyshko-style coincidence measurements with $\alpha = 0$, exploiting the photon-number correlations of our source [5]. Both of the above measurements are difficult to perform when using a strong LO and photodiode detectors.

With the above imperfections included, our experimental results agree well with theory, allowing us to see this semi-classical to quantum transition of our measurements on Fock states.

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