Experimental quantification of coherence of Quantum Measurement

Huichao Xu[12] Feixiang Xu[12], Thomas Theurer[3], Dario Egloff[3] Zi-Wen Liu[45]
Nengkun Yu[6] Martin B. Plenio[3] and Lijian Zhang[12]

[1] National Laboratory of Solid State Microstructures,
College of Engineering and Applied Sciences and School of Physics, Nanjing University, Nanjing 210093, China

[2] Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210093, China

[3] Institute of Theoretical Physics and IQST, Universität Ulm, Albert-Einstein-Allee11, D-89069 Ulm, Germany

[4] Perimeter Institute for Theoretical Physics, Waterloo, ON N2L 2Y5, Canada

[5] Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

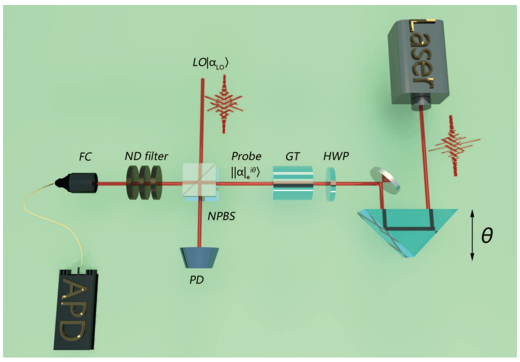
[6] Centre for Quantum Computation and Intelligent Systems, University of Technology Sydney, New South Wales 2007,Australia

Abstract

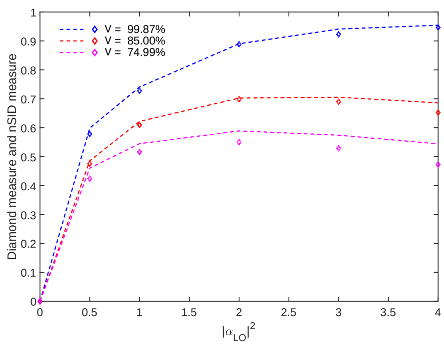
We report on the experimental quantification of coherence as a resource contained in a quantum measurement. In particular, we investigate the ability of an optical weak-field homodyne detector to detect coherence. We design an experimental set-up to reconstruct the POVMs of the detector. Then based on the quantum resource theory of coherence, we evaluate its ability to detect coherence. After that, we discuss the effects of different intensities of the local oscillator and mode overlap with the probe states on the coherence values.

Quantum coherence as a resource has been investigated in the past few years[1]. To use coherence to obtain quantum advantages, it is necessary to have access to operations that can detect coherence in the sense that the presence of coherences makes a difference in the measurement statistics. The ability of a quantum measurements to detect coherence has never been theoretically studied in a quantitative manner until recently[2].

In this work, we experimentally evaluate the value of coherence contained in a specific quantum optical detector, namely a weak-field-homodyne APD. In the first step, we reconstruct the POVMs of the detector with the method of quantum detector tomography[3]. The experimental set-up is shown in Figure1(a). For better analysis, we choose five different intensities of local oscillators(LO) and three interference visibilities for each LO. Secondly, we use the semidef-



(a)



(b)

Figure 1: (a)Experiment Set-up for quantum detector tomography. (b) Evaluated diamond measure and nSID-measure for different set of weak-field homodyne APDs with simulation(segment lines) and experiment (diamond).

inite and optimization programs to evaluate the diamond-measure and nSID-measure defined in [2] for these POVMs. The results are shown in Figure.1(b). We find that these two measures are matched well for simulated and experimental results. Besides, it shows that the deviation from the perfect mode overlap between the signals and the LO would decrease the ability of this detector to detect coherence. When the interference visibility is not very high, the coherence does not increase with intensities of LO.

[1] A. Streltsov, G. Adesso, and M. B. Plenio, *Quantum coherence as a resource*, Rev. Mod. Phys **89**, 041003 (2017).

[2] T. Theurer, D. Egloff, L. Zhang, and M. B. Plenio, *Quantifying the Coherence of Operations*, arXiv:1806.07332 (2018)

[3] L. Zhang , H. B. Coldenstrodt-Ronge, A. Datta, *et al Mapping coherence in measurement via full quantum tomography of a hybrid optical detector*, Nature Photonics **6**, 364 (2012)