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Coherent State Quantum Process Tomography

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Any quantum information device or circuit can be described as a quantum black box that maps input density matrices into the corresponding outputs. In this context, it is important to understand how the black box transforms a generic quantum state. This task requires a full characterization of the quantum process associated with the device by means of quantum process tomography (QPT). Recently, we developed a protocol, called coherent state QPT (csQPT), which recovers the process superoperator tensor by measuring, through homodyne tomography, the process outputs from a set of input coherent states. Hence, using a common laser source, at different intensities, we are able to reconstruct any quantum-optical process. Our technique is based on the fact that any input state density matrix can be decomposed in a superposition of coherent state density matrices using an approximated Glauber Sudarshan P-function. Then using the linearity of the process in the density matrix space, we can recover the effect of the process on the input state from the coherent state mapping. We applied our procedure to a quantum memory for light based on electromagnetically-induced transparency in warm Rubidium atoms and recovered the superoperator tensor in Fock basis. From this analysis we were able to predict how an arbitrary quantum state of light will be affected by storage in a memory apparatus. We tested our characterization by experimentally storing and retrieving squeezed vacuum under different experimental conditions, and comparing the results with the csQPT prediction. We observed a quantum mechanical fidelity greater then 99%. The process tomography also offers important insights into the detrimental effects that affect the storage performance and provide important feedback for the device optimization. Furthermore, we can check the memory performance against any theoretical benchmark.