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Measuring Quantum Optomechanical Self-induced Oscillations: Photon Correlation and Homodyne Tomography[1] JIANG QIAN, School of Engineering, Case Western Reserve University, FLORIAN MARQUARDT, Department of Physics, FAU Erlangen-Nuremberg, AASHISH CLERK, Department of Physics, McGill University, KLEMENS HAMMERER, Institute for Theoretical Physics, University of Hannover — Motivated by recent experimental advances in fabricating systems with large optomechanical couplings, we study the self-induced mechanical oscillations in the strong quantum regime for a single cell optomechanical system. We show that, under strong optomechanical coupling $g_M \geq \kappa$, the *persistent* state of the mechanical oscillator can have non-classical, *strongly negative* Wigner density, which can be measured by non-destructive homodyne tomography. We further propose to detect the onset of the quantum self-induced oscillation using the easier-to-measure photon two-point correlation functions $g^{(2)}(t)$. We show that there are two distinct signatures in the long-term time-average and the line-shape of $g^{(2)}(t)$ at the onset of self-induced oscillations. We show that $g^{(2)}(t)$ exhibits long-term coherence extending much beyond the optical decay time $1/\kappa$, the decay of which in the red- and blue-detune regime we explain using models of optomechanical cooling and phase noise.

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