Quantum noise imaging using atom-based squeezed light sources

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Quantum imaging - the ability to expand the limits of traditional intensity-based imaging exploiting quantum nature of light - attracts growing attention thanks to its promises to realize sub-shot-noise and/or sub-diffraction-limited resolution, non-contact imaging of distant objects, immunity to the background illumination, and many more [1]. One possible application that can particularly benefit from the quantum enhancement is imaging of photo-sensitive objects, that for one reason or another cannot withstand even moderate light exposure. Here we present a proof-of-principle demonstration of creating images of an opaque object using a quadrature-squeezed vacuum field with negligible mean photon number. Unlike most previous work that relied on parametric down conversion or four-wave mixing processes to produce two spatially correlated optical beams, we use a single, quadrature-squeezed vacuum field, generated under the conditions of the polarization self-rotation (PSR) process in resonant Rb vapor [2]. We experimentally demonstrate the ability to recover an image of an opaque mask using the non-classical noise statistics captured with a quantum limited camera. To support the experimental results, we develop a theoretical framework that takes into account the spatial multimode structure of the squeezed vacuum and its interaction with the object obstructing its path [3]. We also analyze the signal-to-noise ratio (SNR) of our images and discuss the trade off between contrast and spatial resolution of our quantum images.

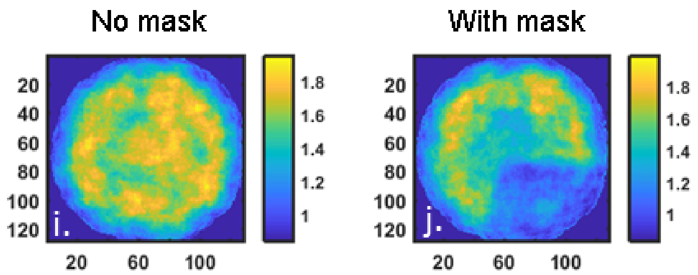

Figure 1. Recorded quantum noise maps (in pixels) for the squeezed vacuum beam with and without a square mask blocking approximately a quarter of the laser. The color scale shows the noise variance normalized to the shot noise limit.

[1] M. Genovese, "Real applications of quantum imaging," *J. Optics* **18**, 073002 (2016).

[2] M. Zhang, R. N. Lanning, Z. Xiao, J. P. Dowling, I. Novikova, and E. E. Mikhailov, "Spatial multimode structure of atom-generated squeezed light," *Phys. Rev. A* **93**, 013853 (2016).

[3] E. S. Matekole, S. L. Cuozzo, N. Prajapati, N. Bhusal, H. Lee, I. Novikova, E. E. Mikhailov, J. P. Dowling, and L. Cohen, "Quantum-limited squeezed light detection with a camera," *Phys. Rev. Lett.* **125**, 113602 (2020).