The recent progress of ghost imaging and its potential applications in microscopy

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Ghost imaging, as a type of correlated imaging, is a novel optical imaging technique that separates the processes of object interrogation and image formation [1,2]. In a ghost imaging setup, a light source with some known spatial structures is used to illuminate the object. Light transmitted or reflected is then collected and measured with a single pixel detector (a.k.a. the bucket detector). The spatial structure of the source is customarily created using a rotating ground glass and recorded with a CCD camera in a reference arm. A more recent approach on the other hand utilizes a spatial-light modulator to create deterministic speckle patterns [3]. The image of the object is then reconstructed through the temporal ensemble average of the bucket signal with the spatial pattern of the light source.

Due to the nature of the method of image formation, the ghost image is noisy and usually requires many samplings to average out the signal fluctuations. Methods such as signal thresholding [3], high-order correlation [4,5], and the differential method [6] have been devised to improve the image visibility and the signal-to-noise ratio. The image quality in the low photon regime has also been investigated [7]. It is found that the image properties are critically affected by the photon statistics [8]. Other than the conventional approach of correlation-based image formation, the method of compressive sensing has also been applied to reconstruct the ghost image by exploiting the sparsity of the object information content to decrease the signal acquisition time [9].

Despite the various efforts to increase the image visibility and SNR, the spatial resolution of ghost images has not been improved due to the resolution limited by the spatial coherence of the light source, which is eventually tied to the spatial dimension of the source. Nevertheless, we have recently found that, by using Non-Rayleigh speckles, the width of the spatial correlation function is narrower by a fraction than that of using Rayleigh speckles [10].

In terms of applications, the use of a bucket detector for object detection enables the light illuminating the object to spread out while keeping the total signal measured high enough to overcome technical noises. This makes ghost imaging a potential platform for microscopy to prevent photobleaching and phototoxicity [11]. Finally, it has been demonstrated that, for the ghost imaging of an object in a medium, the scattering due to the medium can be mitigated to certain extent [12].

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