Maximum-likelihood image estimation using photon-correlated beams.

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Abstract:

A theory is presented addressing the fundamental limits of image estimation in a setup that uses two photon-correlated beams. These beams have the property that their photon arrivals, as a point process, are ideally synchronized in time and space. The true image represents the spatial distribution of the optical transmittance (or reflectance) of an object. In this setup, one beam is used to probe the image while the other is used as a reference providing additional information on the actual number of photons impinging on the object. This additional information is exploited to reduce the effect of quantum noise associated with the uncertainty in the number of photons per pixel. A stochastic model for the joint statistics of the two observation matrices is developed and used to obtain a local maximum-likelihood estimator of the image. The model captures the nonideal nature of the correlation between the photons of the beams by means of a simple random translation model. The mean-square error of the estimator is evaluated and compared to the corresponding conventional techniques. Conditions for the performance advantage of the proposed estimator are examined in terms of key system parameters. The theoretical predictions are demonstrated by means of simulation.