Low light imaging represents an important means for information acquisition in many areas of research. In single molecule microscopy, for example, the location of a particle often needs to be determined from images captured under low light conditions. An important goal in these parameter estimation studies is the extraction of the desired quantities with the highest accuracy possible. Indeed, in single molecule microscopy, the performance of the techniques for superresolution image reconstruction and three-dimensional particle tracking is directly dependent on the accuracy with which the position of a particle can be estimated.

Here, we describe a low light imaging method [1] that enables ultrahigh accuracy parameter estimation by significantly reducing corruption of the acquired image by the widely used electron-multiplying charge-coupled device (EMCCD) detector [2]. Our method is based on the allocation of the acquired photons over the pixels of an EMCCD detector, in a way that minimizes the deteriorative effect of detector noise and maximizes the information content of the resulting image. More precisely, it specifies the use of an EMCCD detector at a high level of signal amplification, and in a highly unconventional setting wherein the number of photons detected in each pixel of an acquired image is in general less than one on average. By following this rule of thumb, the estimation of a quantity of interest can be realized with an accuracy that approaches what would only be possible if the image were acquired with a hypothetical detector that introduces no noise.

We present the information-theoretic principle [3] behind the method, and describe an implementation that allows estimation with accuracies that approach what is only attainable with an ideal noiseless image of arbitrarily high resolution. By experimentally applying the implementation to the single particle localization problem which is of central importance to single molecule microscopy, we demonstrate the substantial accuracy advantage that is gained by using this method instead of conventional low light EMCCD imaging.