# Source Shot Noise Mitigation in Scanned Beam Microscopy

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State-of-the-art techniques for imaging samples' structures with high resolution at nanometer scale primarily depend on microscopes that scan the sample with a focused beam of particles (e.g., photons, electrons or helium ions). For instance, the use of scanning electron microscopy (SEM) in many research and industrial imaging and nanometrology applications is ubiquitous.[1] Recently however, it has been demonstrated that helium ion microscopy (HIM), in addition to reducing charging effects, can produce images with sub-nanometer resolution.[2]

Notwithstanding the progress in the pursuit of ultra-high resolution, these technologies all have the disadvantage of causing damage to the sample, due to sputtering of the focused particle beam. This has been recognized and modeled as a fundamental limit to imaging with focused beams.[3–5] The damage can have especially severe impact on biological samples but also occurs for many different types of materials. Indeed, sample damage in HIM imaging can be controlled by using lower ion doses. Consequently, studies analyzing the extent of beam damage and establishing safe imaging dose have recently appeared.[6,7]

We demonstrate that novel data processing of many low-dose measurements can yield lowered reconstruction mean-squared error (MSE) without any increase in total dose. In simulations for a sample with mean secondary electron yield ranging from 2 to 8 (as suggested by Notte et al.[8]), we obtain an MSE reduction by a factor of 2.4 (see Figure 1). Improvements are proportional to the mean secondary electron yield and can also be realized as reductions in total dose.

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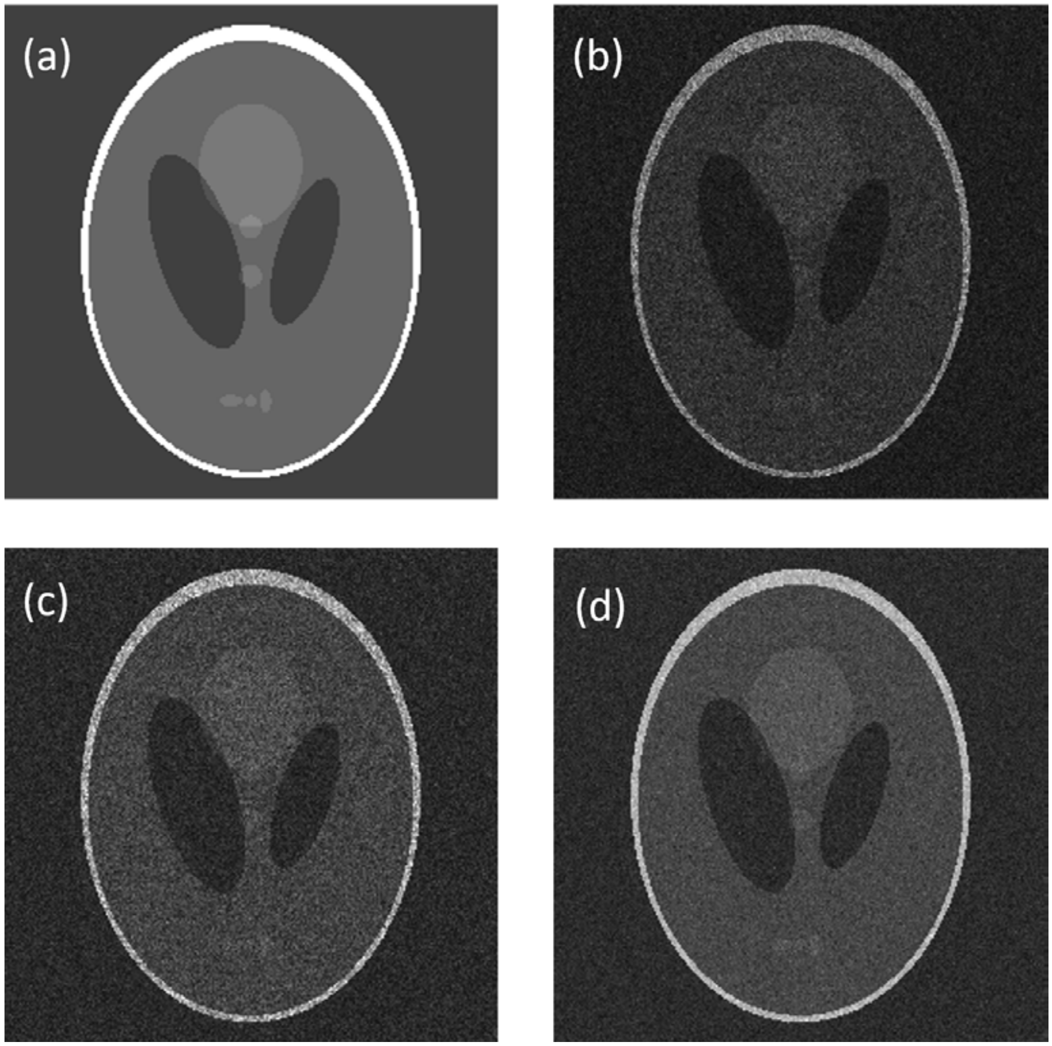


*Figure 1: Simulated HIM experiment for a sample with mean secondary electron yield in [2, 8]:* (a) Ground truth image with secondary electron yield rescaled from 2 to 8. (b) Conventional HIM image with MSE of 0.5934. (c) Maximum likelihood estimation with MSE of 0.5513. (d) Our work without dose reduction with MSE of 0.2297. These results have not utilized spatial regularization.