SHAPE AND SIZE MEASUREMENTS OF OUT-FROM-EQUILIBRIUM BOSE-EINSTEIN CONDENSATES USING IMAGE PROCESSING

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Bose-Einstein condensates (BECs) are a unique state of matter created by cooling a gas of neutral atoms to extremely low temperatures. Bose-Einstein condensates have been the subject of intense research in recent years due to their potential applications in quantum computing, to simulate complex quantum systems, as well as to develop ultra-precise sensors. BECs are highly sensitive to external perturbations, which may cause them to radically change their shape and size. As a result, it can be difficult to accurately determine these properties. In fact, investigating most features of out-from-equilibrium Bose-Einstein condensates is challenging, and it may require more elaborated digital image processing techniques than those already in use.

Previously, we proposed to study the perturbed BEC resulting images based on the determination of the density-density correlations. However, we soon realized the possibility of greatly expanding the scope of the investigation and the volume of interesting results if we brought more general concepts to the analysis, which are widely used in the image processing community. In addition, it was noted that the mathematical basis underlying the algorithms is quite general and independent of the type of image studied. The morphological changes observed in the perturbed atomic clouds as a result of excitation amplitude were observed in a consistent manner, as shown by the results. And the atomic clouds spatial spread under free fall shows some symmetry, but it was only observed under certain conditions. Our recent investigation of Pearson's correlation coefficients and fractal dimensions revealed good consistency, which suggests that the evolution to turbulent states is taking place for the highly perturbed clouds.