Holographic Generation of Optical Traps for Ultracold Atoms

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A recent area of interest in the field of cold atomic physics is the development of non-trivial spatially- and temporally-varying optical trapping geometries, with interesting examples already demonstrated using techniques including acousto-optic deflection, amplitude- and phase-modulation of trapping light. Optical traps generally offer increased trap complexity at small length-scales, but at the disadvantage of increased likelihood of small-scale potential roughness. Any local roughness in the intensity of the light pattern creates a varying energy landscape, which could cause heating or fragmentation of the atom cloud.

Fourier-engineered optical traps (those based on phase-only spatial modulation of the light to tailor the intensity in the Fourier plane of an optical system) have predominantly taken the form of arrays of discrete traps or Laguerre-Gauss beams. Recently, a new calculation method for phase-only holograms of arbitrary complexity directly addressed the issue of roughness. This algorithm, the Mixed-Region Amplitude Freedom (MRAF) [1] variant of the Gerchberg-Saxton iterative Fourier transform algorithm, calculates smooth and accurate light patterns for use as optical atom traps. However the output of this algorithm, when applied to real devices, often does not give high-quality optical traps and this output must be further adjusted. In this presentation, we introduce a simple and robust feedback-enhanced algorithm to improve the accuracy of optical traps generated by phase-only spatial light modulators (SLMs). We find that this algorithm reduces the discrepancy between target and experimental light distribution to the level of a few percent (RMS error), and we prove the generality of this approach by applying it to a variety of target light distributions of relevance for cold atomic physics.

In addition to the feedback-enhanced algorithm, we present a new method for the generation of holograms based on the direct minimisation of a cost function by a conjugate gradient local search algorithm [2]. Conjugate gradient minimisation, a well–established method for minimising high-dimensional smooth functions, is widely used in contexts such as electronic structure. Here we show that this approach successfully combines computational efficiency and algorithm versatility, allowing the accurate reproduction of a variety of target intensity profiles. With MRAF, the output quality depends critically on the initial phase guess and on the initialisation parameters, which have to be carefully chosen to suppress the formation of optical vortices during the calculation process. In contrast, with conjugate gradient minimisation, optical vortex suppression is achieved by a judicious cost function choice. Having determined these cost functions, the output quality is then largely insensitive to the initial phase guess, to the point that high accuracy can be achieved even with a random phase guess.

Keywords: COMPUTER HOLOGRAPHY, SPATIAL LIGHT MODULATORS, ABERRATION COMPENSATION.

References

[1] M. Pasienski and B. DeMarco, Opt. Express 16, 2176 (2008).
[2] T. Harte et *al.*, arXiv:1408.0188