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Optimization of curved beams features via the phase-space

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Enhanced intensity field distributions that follow curved trajectories in free-space have been a subject of intense research in recent years. These field intensity profiles, often termed accelerating beams, Airy beams, or caustic beams (CBs) have gained attention due to their weakly-diffractive *curved* nature. With their energy confined to the narrow vicinity of pre-defined trajectories, such field patterns have been shown useful for various applications. These include particle manipulation, e.g., using optical tweezers, super-resolution imaging, plasmon excitation, light-sheet microscopy, optical coherence tomography, and plasma-channel generation, to name but a few.

In previous publications [1, 2], we have introduced a heuristic method for manipulating and control several features of the 3-D CBs, such as the on-axis peak intensity profile and the lateral beam-width in the direction of the bi-normal to beam-axis. This method calculates the aperture field that radiates a caustic of rays that forms the desired intensity profile over the pre-defined curved beam-axis.

In order to improve the control over the beam properties, we present here an optimization scheme that enables a more comprehensive control over the various beam features. This is carried out by first using the heuristic method to calculate an initial aperture field and then represent the field as a set of weighted Gaussian beams emanating from a discrete spatial-directional (phase-space) grid over the aperture. This yields an accurate *sparse* representation of the field since it extracts local radiation properties of the field. Thus, the ray-based heuristic method is a-priori localized in the phase-space. This approach significantly reduces the number of parameters to be optimized in the next step.

After defining the problem over the phase-space sparse coefficient array, we minimize the aperture field energy, subject to spatial constraints over the CB field. These constraint the radiated intensity in the on- and off-axis domains to maintain the desired features of the beam about its trajectory, such as on-axis intensity profile, maximum off-axis intensity and desired lateral beam widths. To effectively solve the resulting non-convex optimization problem, we use a solution scheme in which the convenient solution of convex intermediate problems is used for iterative convergence to the non-convex one. We will present numerical simulations clearly demonstrating the effectiveness of the method to enhance the beam locality and reduce the off-axis field.

References

[1] T. Melamed and A. Shlivinski, “Practical algorithm for custom-made caustic beams,” *Opt. Lett.*, **42**, 2017, pp. 2499–2502.

[2] G. Lasry, T. Melamed, and Y. Brick, “Manipulation and control of 3-d caustic beams over an arbitrary trajectory,” *Opt. Express*, **28**, Jul 2020, pp. 20645–20659.