Beam-Steering in 2D via Non-Linear Mapping of 1D Beam-Steering

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Abstract

A laser phased array capable of 1D beam-steering can be adapted to scanning a path in 2D using free-space optics or integrated phase plates.

Index Terms

Semiconductor laser arrays, Laser beams, Beam steering, Optical devices, Integrated Optics

I. Introduction

Beam-steering technology is growing ever more important in todays world as a foundation for LIDAR for remote sensing and autonomous vehicle applications. Phased laser arrays generally allow for non-mechanical scanning of a 1D line segment (in the case of a 1D array of lasers [1, 2]) or 2D rectangular region (in the case of a 2D array of lasers [3]). We propose free-space optics and integrated photonics methods for enabling a 1D phased array to scan a path in 2D, providing scanning capabilities intermediate between conventional 1D and 2D phased arrays.

II. Free-Space Optics

Consider a 1D laser phased array capable of scanning a beam across a 1D line segment. Adding a single flat mirror would do little more than to map the line segment swept by the beam to another line segment. However, one could instead place a series a discrete flat mirrors along this line segment to redirect the beam in any desired direction, and by scanning the lasers across this 1D line of mirrors, one could scan any set of points in 2D. Further consider using a specially curved surface mirror made from interpolating the surface normal between those discrete flat mirrors. Scanning a laser across this mirror would enable one to beam-steer across an arbitrary path in 2D.

Such a curved surface mirror should be relatively simple to design as the surface normal at each point along the line is uniquely defined by the incident beam angle and desired deflection point, although it may be non-trivial to fabricate. Additive manufacturing (ie 3D printing) may provide the required flexibility in fabrication geometry. It may be possible to replace the curved mirror with a metasurface or other flat optical element that is similarly capable of deflecting the incident beam in varied directions depending on where on its length the beam is incident.

III. Integrated Phase Plates

A simple 1D laser phased array is usually capable of scanning along a 1D line segment by changing the inter-element phase difference. Consider the simplest case, a two element phased array, as shown in Figure 1a. As the phased difference between the two elements is changed, the beam in the far-field shifts along the array axis, as shown in Figures 1b-1d. Now, let's consider the case in which a pair of spiral phase plates (with differing spiral directions) is integrated on top of the two laser elements as to impart optical angular momentum (OAM), as shown in Figures 1e-1f. As the inter-element phase is swept the far-field beam evolves in a rather different fashion, as shown in Figures 1g-1i.

To analyze the beam-steering more quantitatively, we define the beam-steering angle to be the angle of average power, and we calculate it for both the Guassian phased array and OAM phased array as a function of inter-element phase difference for both the x and y axes. We plot the results in Figures 2a and 2b respectively. Figure 2a validates our intuition that the Gaussian phased array beam-steers along the array axis, but not along the array-perpendicular axis. Figure 2b, on the other hand, shows simultaneous beam-steering along both the x and y axes. If we trace the path of the beam-steering angles in 2D as we change the inter-element phase difference, as shown in Figure 2c, we find that the beam-steering is along a (non-centered) elliptical path.

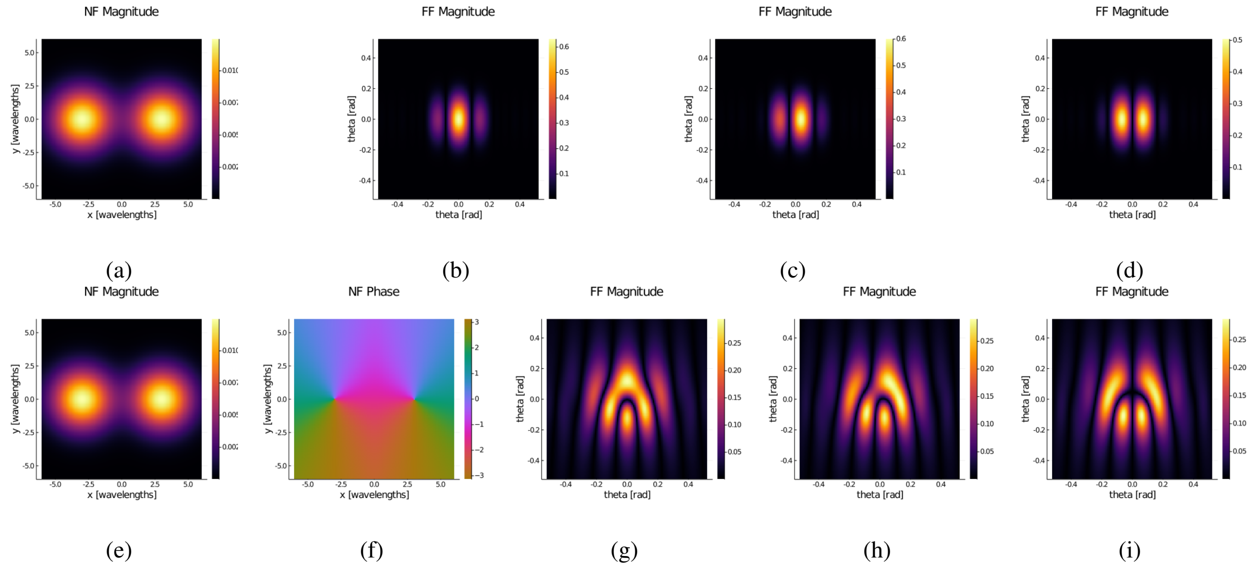

Fig. 1: (1a) Simulated near-field of a pair of coupled Gaussian modes, and (1b-1d) far-fields as the inter-element phase is varied from 0 to $\pi/2$ to π. (1e-1f) Simulated near-field of a pair of coupled OAM modes (with opposing phase spirals), and (1g-1i) far-fields as the inter-element phase is varied from 0 to $\pi/2$ to π.

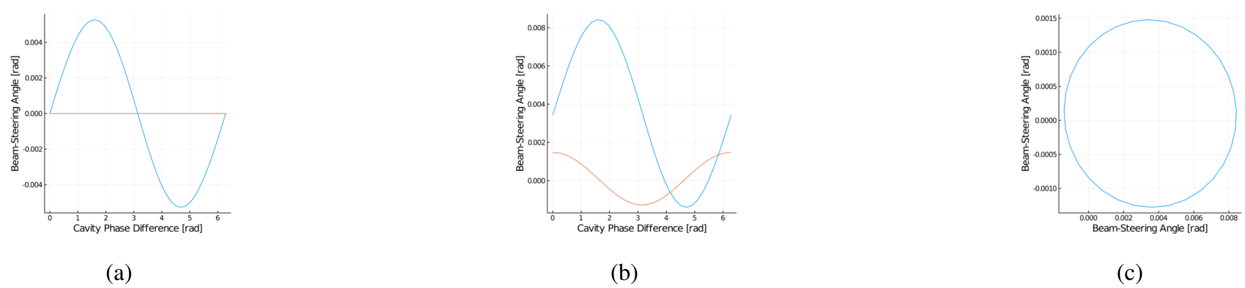

Fig. 2: (2a) The beam-steering angles as the inter-element phase is modulated for a pair of Gaussian beam and (2b) for a pair of OAM modes with opposite chirality. (2c) The path scanned by a phased OAM array.

IV. Conclusion

We assert that a 1D linearly scanning laser phased array can be adapted to scan a 2D path via non-linear mapping of some sort. In free-space optics this mapping can be implemented by curved mirrors or an equivalent metasurface, while in integrated photonics it can be implemented using phase plates, as shown by example using simulations of an OAM mode phased array. These methods help bridge the gap between the beam-steering capabilities of 1D and 2D phased arrays without resorting to moving mechanical elements. This material is based on work supported by Joint Transition Office Multidisciplinary Research Initiative, Award No. 17-MRI-0619.

References

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