Title

Collimated Beam Interference in Structured Photonics

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Abstract: A photonic structure with wide manipulation capabilities and ultrashort pulse length was previously designed and compared against a simulation wavefront model. The wavefront modeling tool was reutilized to verify approximate predicted behavior and analyze channel interactions.

INTRODUCTION

The study of light and photonic devices is invaluable for the advancement of fields such as quantum, relativistic, and particle physics.[1] Many devices which are integral to modern society are built upon the technology developed through the study of light. However, the ability to sufficiently generate and manipulate light as researchers see fit is not a straightforward process. Generating and manipulating light according to an experiment's needs may require proprietary setups, which are sometimes severely limited in their ability to adjust all parameters of light. This discrepancy is highlighted specifically in scenarios that require ultrashort pulse manipulation or moderate-to-high power levels.[1]

Lemons, et al.[1] proposed a device architecture which intends to fill part of the aforementioned gap in available technology. Their solution is based upon a phased array which splits light into multiple channels, that are then manipulated as needed before being combined into a light bullet. A user can design crucial parameters of the lights, such as phase, amplitude, CEP, pulse front, and polarization. They can synthesized complex geometrical structures with the system and compared their results alongside a simulation.

METHODS

This paper further investigates the modeling of the complex wavefronts generated by the coherent multi-channel fiber array. Lemons, et al. utilized and built a set of MATLAB tools to simulate the behavior of the output light bullet while controlling its parameters and field type.[2]

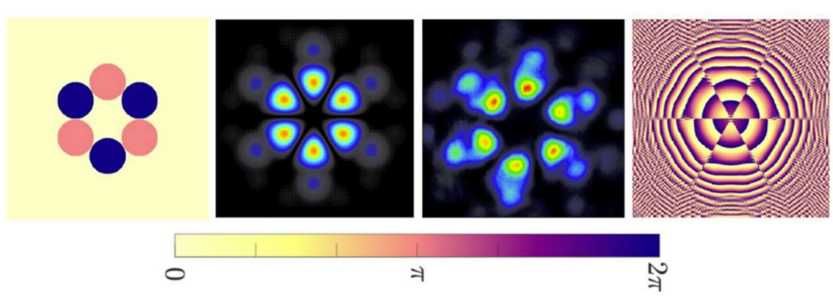


Fig. 1. (left to right) Near-field phase/amplitude combination, simulated far-field intensity, measured far-field intensity, phase distribution (Ref. [1], Fig. 2).

Figure 1 demonstrates Lemons, et al.'s[1] results for a hexagonal, 6-beamline output with an alternating phase offset of π radians. Note the phase singularity in the center of the intensity graphs, and the six radial lines of zero intensity. They compare how the near-field intensity differs to the far-field, the actual far-field behavior achieved by the real-world device, and the phase distribution of the far-field output beam.[1]

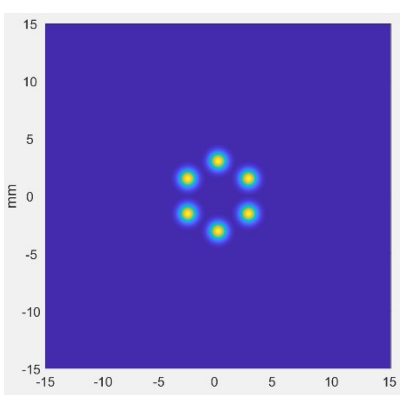
To imitate the modeling of these complex wavefronts, I utilized the Coherent Optics Propagation and Modeling tool.[3] This was originally used to model the theoretical plots in figure 1. My input parameters consisted of the following:

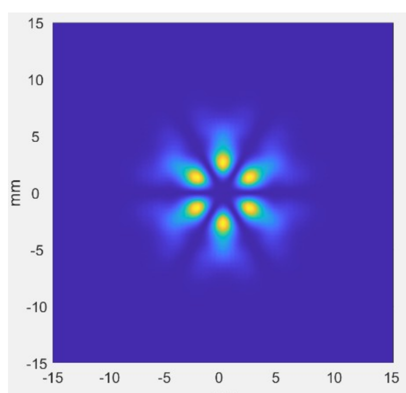
Table 1. Parameters used in Coherent Optics Propagation and Modeling Tool

Parameter	Value
Wavelength	1.55um
Computational Points	2^10
Far-field distance	8m
Aperture Dimension	3mm
Distance Between Beams	3.05mm
Field Type	Hexagonal
Rows	2

My program was based on the example file by Lemons, et al.[3] The wavelength, field type, and rows were selected to match figure 1. The output would be six channels in a hexagonal configuration with a wavelength of 1.55um. Far-field distance was computed to be significantly greater than wavelength.[3] A beamPropagation object was instantiated with the parameters from table 1. Intensity and phase graphs were plotted with functions built into the library.

RESULTS AND INTERPRETATION





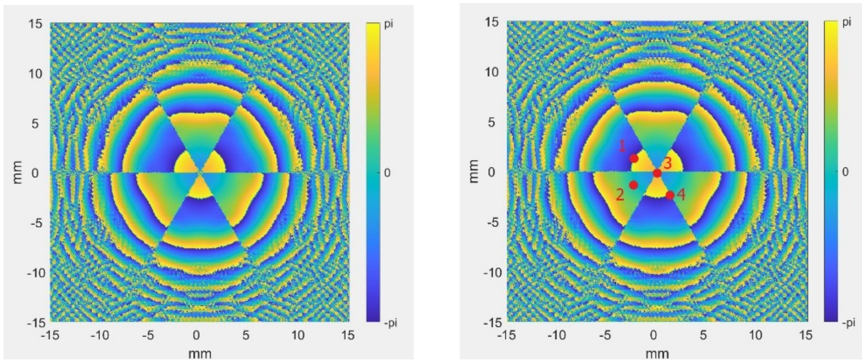


Figure 2: Near-field intensity (top left), far-field intensity (top right), far-field phase (bottom left), annotated far-field phase (bottom right)

The plots in figure 2 exhibit the results of running the simulation in the Coherent Optics Propagation and Modeling tool. The near-field intensity is exactly as expected; hexagonally arranged points of equally high intensity. The far-field intensity somewhat follows the results of figure 1. Again, six hexagonally spaced nodules of high intensity, but with a vaguely triangular shape. There are six clear axial lines of zero intensity which separate the nodules. The far-field phase, as expected, has alternating symmetry and abrupt phase changes when the phase-offset light intersects.

To discuss the far-field phase plots more clearly, there are 4 areas of interest labeled in red. At area 1, note the sharp transition in phase from π to – π. The phase seemingly "realigns" in this section, so that no destructive interference occurs. The centers of the high-intensity nodules, as shown in the intensity figures, align with this sharp transition for three out of six. Area 2 points out the remaining three nodules, which do not have this sudden phase change. However, destructive interference is still minimal, as the phase varies little in this section. Area 3 is placed at the singularity in the center of the output, where the six sections of radial symmetry meet. Light interacts at an approximately π radian phase difference, resulting in the significantly large zero-intensity zone. Area 4 refers to the intersection of two channels which are phase-shifted π radians from each other. This interaction creates the six symmetric axial lines of low intensity.

CONCLUSIONS

The output wavefronts of a coherent multi-channel fiber array were successfully computed with Lemon, et al.'s Coherent Optics Propagation and Modeling tool to verify and analyze a six-channel hexagonal array. The results showed consistent behavior of the output light for both intensity and phase. The connection between the intensity and phase was explored in terms of interference interactions. The overlapping of light with π radian phase shifts results in various zones of low or high intensity that can be traced back to the far-field intensity plots.

In future work, it would be interesting to examine the effect of varying the initial phase offset in this phase configuration. A $\pi/2$ initial phase offset produces a significantly different intensity and phase output, and other values may also provide contrasting insight.[1]

REFERENCES

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3. Lemons, Randy and Sergio Carbajo. "Coherent Optics Propagation and Modeling." GitHub, https://github.com/slaclab/CCPM/releases/tag/1.0.0