Title
Laser Modulation with Phased Arrays

Author
KHAN, SHAFEE

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Shafee Khan

[1]Undergraduate Student Review, UCLA Samueli School of Engineering, Majoring in Electrical Engineering, 405 Hilgard Ave, Los Angeles, CA 90095, USA
**shafeekhan@g.ucla.edu*

ABSTRACT:
This study discusses coherent beam laser architecture using a N = 7+1 phased array configuration. Adjusting individual beamlines enables control of beam properties, and I propose that increased discretization will increase the fidelity of the results.

INTRODUCTION:
This research focuses on utilizing the principle of coherent beam combination to control intrinsic beam properties. These properties include field amplitude, carrier-envelope phase (CEP), relative phase, and polarization. It is already possible to modulate the amplitude and phase using simple light modulators, however trying to modulate CEP and polarization becomes more complex. The ability to modulate CEP and polarization allows us a greater level of complexity when it comes to synthesizing light beams. Phased arrays are able to modulate these various properties and synthesize coherent beams with modulated characteristics, creating unique wavevector distributions[2,3,4,5]. Each element of the phased array is called a beamline. Phase and amplitude modulation is achievable with OAM and vortex beams, however only the relative phase modulation between beams is controllable[2,3].

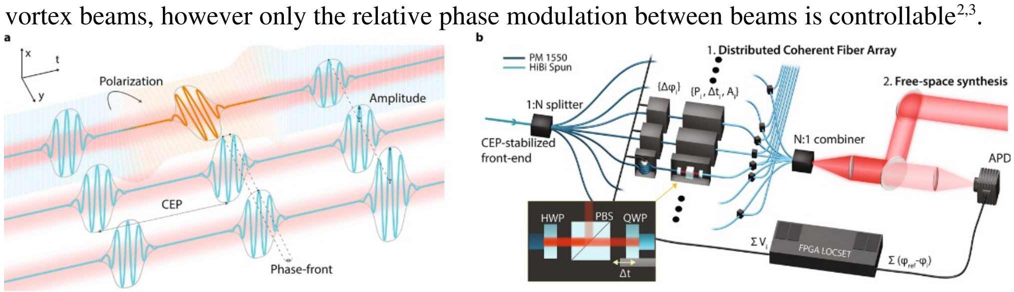

Fig. 1. Optical Comb EM Field Distribution (left) and Multi-channel Fiber Array (right)[1]

As shown in Fig.1a, a laser is passed through a front-end stabilizer to ensure coherent phase matching between the beamlines, which is necessary to generate wavevector distributions. In the experiment, the beam is passed through a 1:N (where N = 7+1) splitter, which splits the laser into 7 controllable beamlines, plus one reference line. Each individual fiber can modify different components of a beam by masking different properties of the wavevector. For instance, the polarization of the beam can be modified using a polarizing beam splitter and changing the polarization of the beam mask. After each of the beamlines have been modulated, the 7 beamlines are resynthesized with a N:1 combiner. A photodiode detects the seven collated beamlines as they recombine into different arrangements.

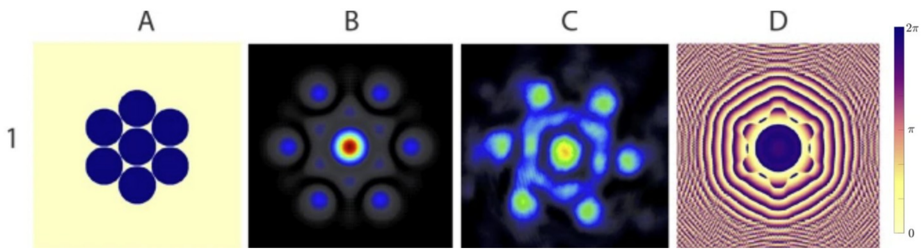

Fig. 2. Near and Far Field Phase and Amplitude[1]

Fig.2. demonstrates a hexagonal arrangement of beamlines. Fig.2A. is a simulated near field phase distribution of each of the 7 beam lines, where each of the beamlines share the same phase offset. Fig.2B. and Fig.2C. are the calculated and measured far-field intensity distributions. Fig.2D. is the measured far-field phase distribution. These graphs, specifically the phase fronts, give an idea of the topography of the wavefront polarization.

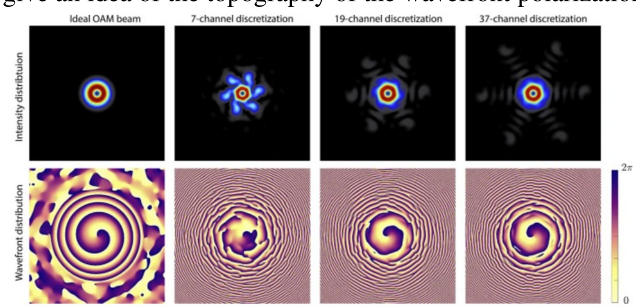

Fig. 3. Effect of Increased Discretization on Resolution of Intensity and Phase[1]

By increasing the discretization of the beamlines (i.e. increasing the total number of channels), far field intensity and phase measurements get closer to the idealized initial beam arrangement. The researchers in the paper make measurements based on limited discretization (N = 7 + 1). This restrictive discretization reduces the resolution of the measured results. Utilizing a supplementary MATLAB repository for simulating different beam distributions relevant to this experiment, we can increase the discretization beyond 37-channels in MATLAB simulations to see how far field behavior will change as we increase the number of channels from 7, 19, 37, 61, to 91.

METHODS:

The researchers use a mode-locked laser oscillator to deliver 140mW of power in 175 fs pulses, and stabilize the CEP using a feed-forward system[6]. The beam is then split into two separate beamlines, which are then stretched and spiced into additional fibers using Er:fiber amplifiers. Beamline modulation must begin with first aligning the CEP of the seven incoming channels. A single photodiode maximizes the amplitude as mapped by a reference beamline, and a phase error is generated.

The researchers simulate the system using a DFT, plotting the magnitude and angular spectrum of the collated beamlines after they have passed through the phased arrays. The researchers created a MATLAB repository titled “Coherent Optics Propagation and

Modeling" that was supplementary to the article. This repository allows us to simulate and plot the spectrums for increased number of beam channels, arranged in a hexagonal pattern. To increase the number of beam channels in the simulation, we add consecutive layers on top of a single channel. Mathematically, you can increase the number of beam channels according to this formula:

$$\# \text{beams} = (3 * (\#\text{layers} - 1)^2) + (3 * (\#\text{layers} - 1)) + 1$$

Which is why our channel increments go from 7, 19, 37, 61, to 91 and so on. Utilizing this repository, I was able to graph the effects of increased discretization on the phase and intensity of a hexagonal distribution of beamlines.

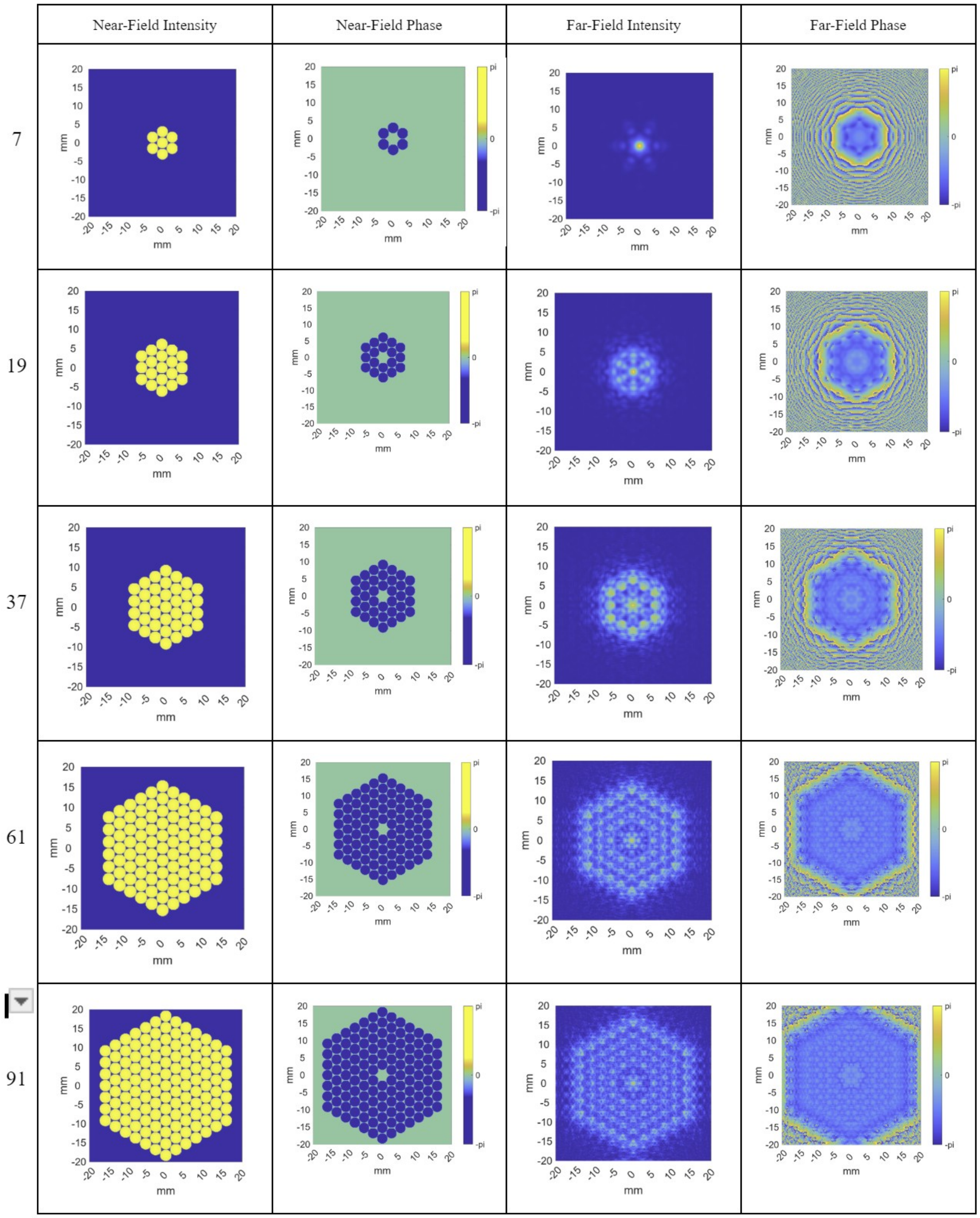

Fig. 4. Effect of Increased Discretization on Resolution of Intensity and Phase (Shafee Khan)

RESULTS AND INTERPRETATION:

With lower levels of discretization, both far-field phase and amplitude spectrums do not share a clear resemblance to the original near-field spectrums. However, by increasing the

discretization of the beamlines, the spectrums of the amplitude and phase gain greater resolution and share a larger resemblance to the near-field spectra.
The convergence of the far-field pattern to resemble the near field can be considered a positive outcome, as it signifies a high level of coherence and precision in the synthesized beams. When the far-field pattern closely resembles the near field, it indicates that the controlled spatial and temporal characteristics of the beams are effectively maintained over a large distance. This could have important applications in the realm of communication, where increased fidelity of the beam properties is essential.

CONCLUSIONS:

In the original experiment, the researchers limited their discretization to 7 channels plus a reference node, which as shown in Fig.4, will limit the resolution of the collated beam. This begs to question why the researchers chose to limit their discretization. There are tangible technological complexities inherent in maintaining coherence, synchronization, and control over a larger array of beamlines. Managing a higher number of channels could escalate the technical challenges and experimental intricacies.

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