A Critique of Stylistic & Operational Methods to Turbocharge Scientific Inquiry

Ben Yang,[1*] Rita Gimelshein,[1] and Sergio Carbajo[1,2]

[1]Department of Electrical and Computer Engineering, UCLA, Los Angeles, CA, USA
[2]Linac Coherent Light Source, Stanford Linear Accelerator Centre (SLAC), National Accelerator Laboratory, Menlo Park, CA, USA
**byang164@ucla.edu*

Abstract: Light is a promising medium due to structural versatility. The ability to control the variance of topology across space and time present unique probing opportunities. This review paper considers the laser architecture Lemons et.al.[1] demonstrate & provides two critiques: one operational & one stylistic.

INTRODUCTION

Light has historically been exploited as a medium for probing, data transmission, and is the primary means with which we observe the world. In the frontier of structured light, there is a need for increased programmability for diverse advanced applications from quantum computing to optical communications. Previous work in this arena have demonstrated structured light using spatial light modulators. They realize applications such as optical tweezers and holographic display technology. However, this system fails in moderate and higher power levels (above MW- & W-levels)—resulting in the inability to achieve structured light in strong-field laser-matter interactions and free-space optical communications among others. Within the realm of femtosecond pulses capable of Kw-Level power, many approaches have been taken from phased arrays as alternative sources for cohere2nt combination to vortex and orbital angular momentum (OAM) beams[2,3,4]. Yet, only modulating the phase between beams, these approaches fail to demonstrate continuous amplitude modulation, active polarization, and carrier-envelop (CEP) modulation which expands the family of synthesized beams available. Thus, on the road towards ever-more precise manipulation of light's wide variety of properties, Lemons et.al.[1] present a self-encapsulated laser based architecture which allows for real-time adjustment of spatio-temporal wave vector distributions. They synthesize various vector map topologies in both spatial and temporal dimensions—presenting a system which can design light bullets that individually tunes field-amplitude, carrier-envelope & relative phase, and carrier-polarization. The demonstration of such a system opens a vast array of transformational research in molecular physics, optical particle trapping, and optical communications to name a few.

METHODS

Wholistically, the paper presents a scientifically sound demonstration of a novel laser architecture affords the opportunity to live-tune a family of parameters to create ever more varied light bullet topologies. However, there are two main critiques of the paper which should be addressed in future publications to enable ease of understanding and elevate future literature. This section examines the two critiques.

CRITIQUE 1: Including Raw Data

In the process of generating visuals, it is an unfortunate reality that scientific rigor is often sacrificed for more cohesive visual arguments. If raw data is provided & made easily accessible to readers, this remains an unfortunate compromise of academia. However, when raw data and/or simulation protocols is not provided and/or is expired, this becomes a significant issue. In the methods sections pertaining to Polarization vector map calculations, Lemons et.al. comment about "reduc[ing] the number of plotted vectors to reduce visual clutter without eliminating the shape of the evolving field" in reference to their Figure 5. This should immediately raise flags as, despite the intentions of each respective author, any case where data is withheld or redacted should be treated with care—especially when the paper presents only figures as outputs and does not include raw unprocessed data. While the authors most definitely did not draw erroneous conclusions from their collected data, the slippery slope of redacting data for "visual reasons" can be illustrated with the following figure:

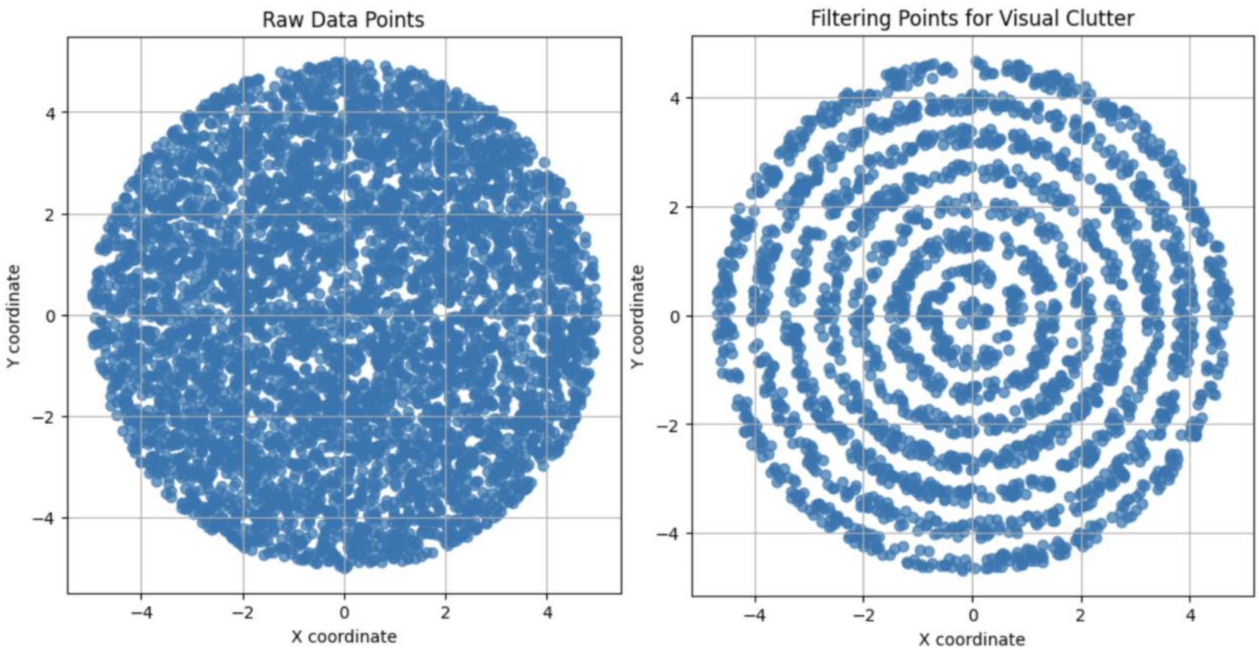

Fig. 1 Exaggerated visualization of the potential erroneous visual arguments that can be made when we reduce data or filter results to selectively demonstrate a conclusion.

No doubt an exaggeration, the point still stands. With the raw plot, there seems to be no visible interference pattern and the plot looks visually cluttered. If we arbitrarily redact data points to "reduce visual clutter" without any evidence proving the original raw data provided the same interference pattern, we are committing a critical error. In the supplementary information section, the code for generating these plots is included which, upon closer inspection, indicate that data points are distributed randomly within a circle. Yet, if only the right most visual was provided, one would be made to believe the data points were clearly indicating a circular slit diffraction pattern. Scaling this up to the integrated & complex system which Lemons et.al. demonstrate that is extremely hard to recreate, readers have no way of recreating and verifying the results without investing large amounts of time and laboratory resources. Thus, it is critical to include raw data when presenting scientific results and especially when those results are lightly edited for the sake of a better visual argument.

As an aside, links to code repositories and other supporting data for modeling or simulation should be permanent links and/or included verbatim to not throw 404 exception errors. In the process of attempting to simulate the beam propagation model, the "publicly accessible" numerical model for complex field synthesis led to a GitHub repository which no longer existed. While after tracing through the linked paper, one could reconstruct the numerical model, this is still a barrier and negatively impacts the ease of data reproduction—disincentivizing readers to perform due diligence. With the wealth of

CRITIQUE 2: Importance of Section Headers

On the stylistic side, a major critique of the Lemons et.al. paper is the lack of section titles. In both online and print format, the body of the article only has an introductory section with no further headers describing results or discussion. While having a complete narrative and logical flow helps significantly in understanding despite the lack of section headers, headers remain imperative to provide accessible, glanceable information. This point is even demonstrated in Lemons' methods part of the paper, which has distinctive headers to delineate different supplemental information sections (e.g. Polarization vector map calculations). The lack of section titles cannot also be attributed to stylistic guidelines from the journal as many Sci Reps articles still include the basic body of paper sections: Introduction, Results, & Discussion[6]. Note that the power of these sections is especially amplified in the web access of articles as the sidebar allows for readers to quickly jump to the relevant information. If academia, especially engineering fields, is ontologically committed to the dissemination of new knowledge and novel procedures, it is to make the process of understanding publications as simple as possible. This is significantly helped by section headers which provide a reliable skeleton that readers—no matter their formal background—can trust to provide structure to any research paper.

CONCLUSIONS

Thus, to elevate future literature to the next level, it is important to keep in mind both critiques. First, when presenting visually edited data in figures, it is imperative to include access to the raw data to enable readers to easily recreate the data processing methods. This is especially important if the demonstrated architecture becomes widely adopted and more groups and labs attempt to use it in their systems. Second, section headers with hyperlinks should be utilized for future writing to better enable glanceable information, further speeding up the adoption of the demonstrated system. If all necessary parties adopt the critical practices to ease information dissemination, scientific progress can first be turbocharged amongst in-field parties and second, be more readily understandable to experts of other fields and the public at large.

REFERENCES

1. Lemons, R., Liu, W., Frisch, J.C. et al. Integrated structured light architectures. Sci Rep 11, 796 (2021). https://doi.org/10.1038/s41598-020-80502-y
2. Müller, M. et al. 3.5 kW coherently combined ultrafast fiber laser. Opt. Lett. 43, 6037–6040 (2018).
3. Wang, L.-G., Wang, L.-Q. & Zhu, S.-Y. Formation of optical vortices using coherent laser beam arrays. Opt. Commun. 282, 1088–1094 (2009).
4. Hou, T. et al. Spatially-distributed orbital angular momentum beam array generation based on greedy algorithms and coherent combining technology. Opt. Express 26, 14945–14958 (2018).
5. B. R. Masters, "Three-dimensional microscopic tomographic imagings of the cataract in a human lens in vivo," Opt. Express **3**(9), 332–338 (1998).
6. Song, X., Coulter, F.J., Yang, M. et al. A lyophilized colorimetric RT-LAMP test kit for rapid, low-cost, at-home molecular testing of SARS-CoV-2 and other pathogens. Sci Rep 12, 7043 (2022). https://doi.org/10.1038/s41598-022-11144-5

SUPPLEMENTARY INFORMATION

Code for raw plot generation:

```
import numpy as np
import matplotlib.pyplot as plt

def generate_random_points_in_circle(radius, num_points):
    """
    Generate random points within a circle.

    Parameters:
    radius (float): The radius of the circle.
    num_points (int): The number of points to generate.

    Returns:
    np.ndarray: An array of (x, y) coordinates.
    """
    # Generating random angles
    angles = np.random.uniform(0, 2 * np.pi, num_points)
    # Generating random radii
    radii = np.random.uniform(0, radius**2, num_points)
    # Adjusting radii distribution to be uniform within the circle
    radii = np.sqrt(radii)

    # Converting polar coordinates to Cartesian coordinates
    x = radii * np.cos(angles)
    y = radii * np.sin(angles)

    return x, y

# Parameters
radius = 5  # Circle radius
num_points = 5000  # Number of random points to generate

# Generating points
x, y = generate_random_points_in_circle(radius, num_points)

# Plotting
plt.figure(figsize=(6, 6))
plt.scatter(x, y, alpha=0.7)
plt.title("Raw Data Points")
plt.gca().set_aspect('equal', adjustable='box')
plt.xlabel("X coordinate")
plt.ylabel("Y coordinate")
plt.grid(True)
plt.show()
```

Code for filtered plot generation:

```
def generate_random_points_in_circle(radius, num_points):
    # Generating random angles and radii
    angles = np.random.uniform(0, 2 * np.pi, num_points)
    radii = np.random.uniform(0, radius**2, num_points)
    radii = np.sqrt(radii)

    # Converting polar coordinates to Cartesian coordinates
    x = radii * np.cos(angles)
    y = radii * np.sin(angles)

    return x, y

def apply_interference_pattern(x, y, num_waves):
    # Apply a sinusoidal pattern to simulate interference
    pattern = np.sin(num_waves * np.sqrt(x**2 + y**2))
    mask = pattern > 0  # Only keep points where the sinusoidal pattern is positive

    return x[mask], y[mask]

# Parameters
radius = 5
num_points = 5000
num_waves = 10

# Generate points
x, y = generate_random_points_in_circle(radius, num_points)

# Apply interference pattern
x_filtered, y_filtered = apply_interference_pattern(x, y, num_waves)

# Plotting
plt.figure(figsize=(6, 6))
plt.scatter(x_filtered, y_filtered, alpha=0.7)
plt.title("Filtering Points for Visual Clutter")
plt.gca().set_aspect('equal', adjustable='box')
plt.xlabel("X coordinate")
plt.ylabel("Y coordinate")
plt.grid(True)
plt.show()
```