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Integrated structured light architectures

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Abstract: A configuration consisting of coherent multi-channel coherent fiber rays along with devices which control specific properties of light gives us the ability to control the amplitude and phase distributions of light bullets.

Introduction: It has been desirable by engineers to control the different parameters that light possesses for varying applications with structured photonics. To this day there are properties of light that we are unable to control, but experimentally we can create light bullets with a sufficient amount of degree of freedom to design the beams for varying applications. Fig. 1 shows the experimental configuration that we are able to control the amplitude, as well as the phase of the output light bullets. There are spatial light modulators (SLM for short) that involve changing the shape of a light source. When a linearly polarized light enters the SLM, the light gets manipulated by a liquid crystal, where the pixels are oriented in different directions and the refractive indexes vary. Birefringence comes into play by the varying refractive indexes between the ordinary axis and the extraordinary axis of the light crystal pixels. The engineer can control the orientation of the pixels within the SLM by applying a voltage that sets the direction and phase delay. The signal that the SLM receives is unchanged when there's no voltage applied to the system, resulting in a phase front of the reflected wave being the same as the phase front of the incident wave. What the SLM outputs when the control signal voltage is applied is a light that has unique parameters and properties, forming a structure that varies in complexity depending on how the engineer changes the liquid crystal orientation. We can use SLM's for holography, as well as creating the desired light structure needed for specific applications.

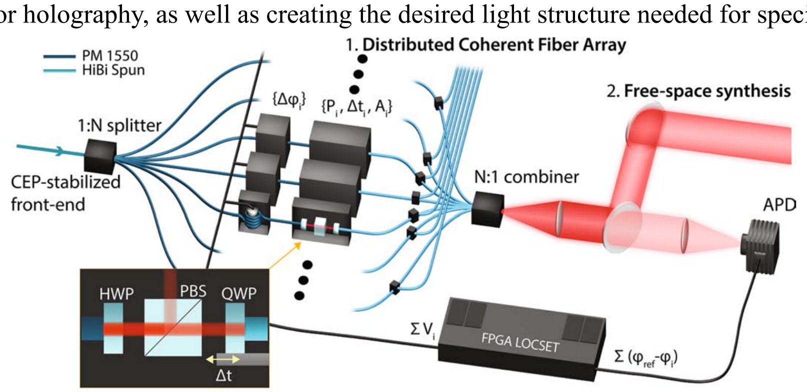


FIG. 1.) A CEP-stabilized front-end with a distributed coherent fiber array

The light bullet and the analysis can be found under "Results and Interpretation". This experiment is groundbreaking for further research in fields such as molecular physics.

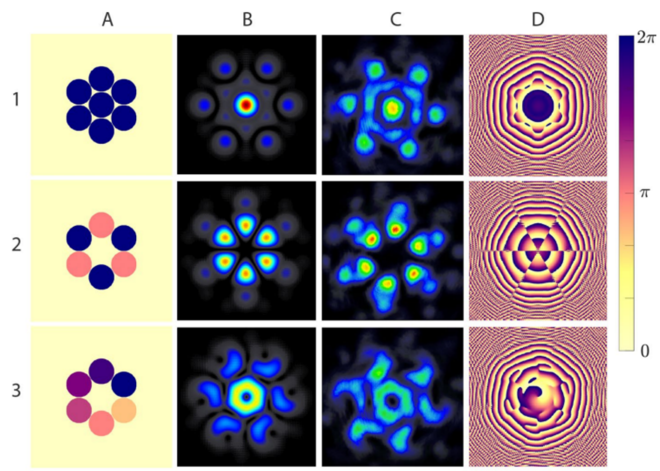
Methods:

Multi-channel phase modulation: FPGA-based LOCSET

Channel and power stability can be accomplished with the alignment and modulation of all of the beams that enter every coherent fiber array. One beam acts like a reference for the rest of the beams produced by the 1:N splitter. Inside of the modulators for the individual beams contains a half wave plate, a polarizing beam splitter, and a quarter wave plate. When the beams enter their corresponding half wave plate, the beam's polarization orientations are changed while maintaining the optical polarizations. After the beams leave the half wave plate and the polarization beam splitters, they enter a quarter wave plate to maintain their circular polarization states. An optical phase error is then obtained from every beam and this can be used to establish an optical coherence to allow us to program the desired phase, amplitude, and field distributions.

Results and Interpretation:

Fig. 2 illustrates the intensity field distributions and the phase distributions from several light bullets. By programming the structure we can create the desired laser pulses with specific amplitude and phase distributions. Row 1 Column A depicts the ideal OAM beam, and going down the column we see different combinations of the near-field phase and amplitude of the light bullet segments. Column D shows the phase distributions and as we can see, we are able to design the distributions to have it gain gradually or alternating in phase[1].



Near-field phase- and amplitude combinations (column A) and their corresponding retrieved (column B) and measured synthesized far-field intensity (column C) and phase distributions (column D)

The more modulator channels the design has, the more ability we have in designing a phase distribution that's more complex and technical. You are able to integrate cylindrical or helical phase fronts, where the phase distributions follow a spiral-like pattern.

Conclusion:

The structure shown in Fig. 1 is reliable for engineers and scientists to manipulate the properties of light sources for desirable wave pulses. This research is an important milestone as it allows us to control the intensity and phase distributions of light bullets. The result of this research opens up the door to further research for molecular physics, quantum mechanics, and photonics. With the results of the experiment we can promise a future where quantum computing is a more valuable resource than it is currently, as well as the transmission of information via signals and light are enhanced. The field of structural photonics can be more broadened to potentially find methods of modulating light properties that are currently not possible.

References:

1.Lemons, R., Liu, W., Frisch, J. C., Fry, A., Robinson, J., Smith, S. R., & Carbajo, S. (2021). Integrated structured light architectures. *Scientific reports*, *11*(1), 1-8.