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A Laser Architecture That Enables Light Bullets with Built-in Programmable Structure

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Abstract: This article introduced and explored the practical application of a generalized laser architecture that can exploit light adaptively with freedom by using a light bullet design with built-in programmable structure that combines field-amplitude, carrier-envelope and relative phase, and polarization.

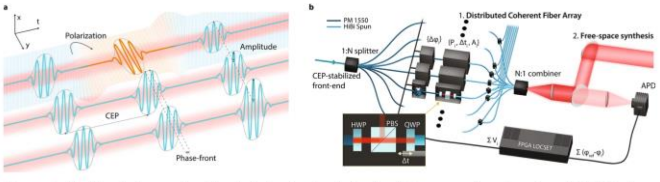
INTRODUCTION

Structured photonics have numerous practical applications due to its capabilities of using custom spatio-temporal variant field vector, amplitude, and phase distribution, for example, optical communications and sensing, particle trapping, and even molecular physics and quantum physics. However, although the future applications of structured photonics are promising, there are still limitations on all degrees of freedom towards further development with adaptable structure on the existing engineering techniques such as phase and spatial modulators.

This paper poses a solution by introducing a synthesized phase arrays with a built-in programmable structure to enable obtaining a precisely controlled structure of light bullet, which allows for individually controllable field-amplitude, carrier-envelope and relative phase, and polarization. The beamlines are maintained in a coherent relationship within an optical comb, so that the primary field can generate a unique spatio-temporal wavevector distribution.

METHODS

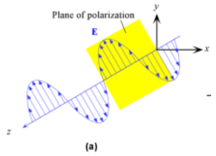
The above-mentioned configuration of coherent optical comb is shown in Fig. 1.a, where the electromagnetic field distribution is controlled and synthesized. Fig. 1.b illustrates the arrays of beamlines of field-amplitude, carrier-envelope and relative phase, and –polarization.



(**a**) conceptual depiction of a transversely and longitudinally coherent optical comb and the corresponding primary elements that define how the electromagnetic field distribution will synthesize; and (**b**) the experimental configuration via coherent multi-channel coherent fiber array with a common CEP-stabilized front end, independent phase ($\Delta\phi_i$), amplitude (A_i), polarization state ($\wp_i$), and timing (Δt_i) controls, and active locking via FPGA LOCSET using a single avalanche photodiode (APD) in the far-field. The output coherent output can be delivered in the form of a distributed coherent fiber array or the form of a free-space synthesized pulse.

Fig. 1. (a) conceptual depiction of a transversely and longitudinally coherent optical comb and the corresponding primary elements that define how the electromagnetic field distribution will synthesize; and (b) the experimental configuration via coherent multi-channel coherent fiber array with a common CEP-stabilized front end, independent phase (Δϕi), amplitude (Ai), polarization state (℘i), and timing (Δti) controls, and active locking via FPGA LOCSET using a single avalanche photodiode (APD) in the far-field.

From the lectures, we learned that electric fields of linearly polarized waves oscillations defined along a to the direction of propagation, z, perpendicularly, resulting field vector E and z will define a polarization plan.



In this particular case, we want the propagation between plans to satisfy not vector propagation but scalar propagation, and to do so, angular frequencies, resultant finite, and discrete grid is introduced.

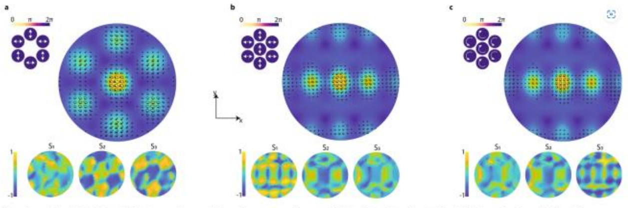
When calculating the vector maps, Stokes parameters are utilized. Seven images, which contain the full field as well as each of the six projections of the Poincare sphere are mixed to obtain the Stokes parameters $\{S_0, S_1, S_2, S_3\}$. The six projections with size X by Y are a polarizing beam splitter and a camera, which is then broken down into a set of smaller images with size x by y that is later to be normalized. Next step is error correction; the images are divided into n by m macro pixels, containing the mean of a subset of true pixels, such that $\alpha x=X$ and $\beta y = Y$. The Stoke parameters can now be calculated using the sub-divided images. Eccentricity, tilt relative to fixed axis, and chirality are also necessary to generate the polarization ellipse, there the eccentricity, e (shown in equation (1)), and the tilt, θ (shown in equation (2)), can be calculated by:

$$\boldsymbol{e} = \sqrt{\frac{2\sqrt{\boldsymbol{S}_1^2 + \boldsymbol{S}_2^2}}{1 + \sqrt{\boldsymbol{S}_1^2 + \boldsymbol{S}_2^2}}} \qquad (1)$$

$$2\boldsymbol{\theta} = \tan^{-1}\frac{\boldsymbol{S}_2}{\boldsymbol{S}_1} \qquad (2)$$

And with the chirality determined by the sign of S_3, we now have obtained all desired parameters for the polarization ellipse.

RESULTS AND INTERPRETATION



Experimental results of polarization topography evolution with corresponding near-field configurations (top left) and Stokes projections (bottom) for alternating linear (**a**), asymmetric linear (**b**), and asymmetric circular polarization coherent synthesis (**c**).

Fig. 2. Experimental results of polarization topography evolution with corresponding near-field configurations (top left) and Stokes projections (bottom) for alternating linear (a), asymmetric linear (b), and asymmetric circular polarization coherent synthesis (c).

From Fig.2, we can observe that the polarization topography of the beamlines and that the phase-fronts are adaptively evolved by both CEP and LOCSET phase control.

CONCLUSIONS

The new laser architecture has proven to be effectively able to generate coherent beamlines with a built-in programmable structure to generate light bullets with a level of freedom like never before. Such breakthroughs will significantly incent the development of structured optical applications in the fields of physics and medical, and more.

REFERENCES

1. Lemons, Randy, et al. "Integrated structured light architectures." Scientific reports 11.1 (2021): 1-8.