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Programmable Polarization of Light using Integrated Structured Light Architectures

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ABSTRACT

Structured light is an integral tool across many applications, but is constrained by lacking control mechanisms. A laser architecture proposed by Lemons, R., et al. promises extensive spatio-temporal field control and programmability for polarization[1].

INTRODUCTION

All light has structure of some form, whether it be induced artificially or naturally. This structure of light allows for many applications across many different fields, a few examples being in fiber-optic networks, quantum entanglement, distance sensing, etc.[2] One of the first applications of artificially structured light is Young's double slit experiment in 1801, which demonstrated wave behavior in light by using structured light in the form of fringes, which is a form of one dimensional intensity structured light, formed from interference of a plane wave caused by the double slits[3].

In the last few decades, numerous advancements in technology and understanding of the properties of light have allowed for increasingly more degrees of freedom in the manipulation of structured light. One of the more notable advancements is the development of the orbital angular momentum (OAM) carrying beam structure, one usage of which is a drastic increase of data transmission through optical fiber, with a transmission rate of 2.5 terabytes per second being demonstrated[4].

The laser architecture proposed by Lemons, R., et al. is stated to be capable of producing light bullets of a programmable design that can be adapted for various applications by taking advantage of recently developed techniques, such as vortex and OAM beams, alongside tiled phase array[1]. This architecture would be able to program all of the defining parameters of a three dimensional wave vector of light, those parameters being phase, amplitude, polarization, pulse front, and carrier-envelope phase (CEP). The architecture consists of 8 beamlines being split off from a source before being combined again for the output, with 7 of the beamlines used to manipulate parameters and 1 beamline used as a reference[1]. This review seeks to verify the programmability of polarization using this architecture.

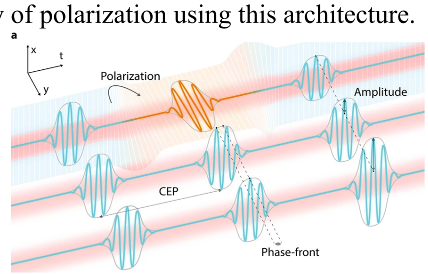

Figure 1. Conceptual image of the beamlines that will synthesize into a programmed light bullet[1]

METHODS

The polarization of light at a point can be defined by its local polarization ellipse. The local polarization ellipse itself is determined by the Stokes parameters, $[S_0, S_1, S_2, S_3]$. The Stokes parameters are defined in terms by the x and y components of the amplitude and phase as:

$$S_0 = E_x^2 + E_y^2, S_1 = E_x^2 - E_y^2, S_2 = 2E_xE_y cos(\theta_x - \theta_y), S_3 = 2E_xE_y sin(\theta_x - \theta_y)$$

In this case the Stokes parameters are not calculated with the amplitude and phase of the x and y components of the field, but with the normalized projection of the field onto six points of the Poincaré sphere, with the points corresponding to linear horizontal, linear vertical, linear diagonal upright, linear diagonal upright, linear diagonal downright, right hand circular, and left hand circular, polarization states. As the projection is normalized, S_0 will be 1, and the other Stokes parameters will have values between -1 and 1.

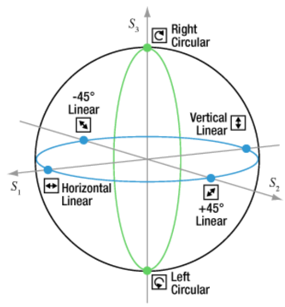

Figure 2. Diagram of a Poincaré sphere with the projected points and Stokes parameters indicated[5]

A normalized ellipse is defined by its eccentricity and its tilt relative to the axis. As a polarization ellipse is of interest, another parameter, the chirality of the ellipse will also need to be defined. The eccentricity (e), tilt (θ), and chirality(χ) are defined in terms of the Stokes Parameters as:

$$e = \sqrt{\frac{2\sqrt{S_1^2 + S_2^2}}{1+\sqrt{S_1^2 + S_2^2}}},\ 2\theta = tan^{-1}(\frac{S_2}{S_1}),\ \chi = sign(S_3)$$

Using the previous equations and the experimental data, the programmability of polarization of the light bullet using the proposed architecture by Lemons, R, et al. can be verified.

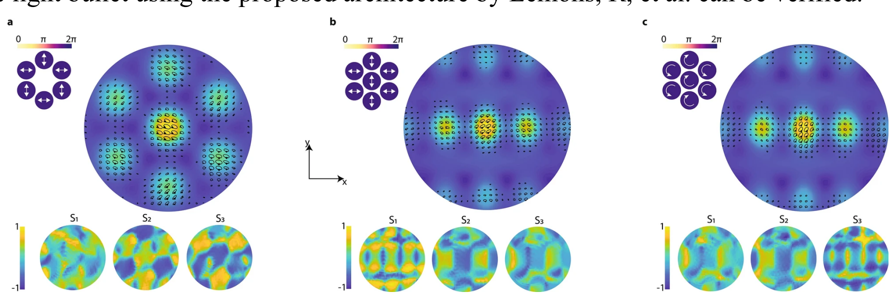

Figure 3. Experimental results for the far-field evolution of the polarization ellipses (top right) of the proposed architecture, along with the near-field polarization configuration (top left) and the Stokes parameter projections (bottom), for alternating linear (a), asymmetric linear (b) and asymmetric circular (c) polarizations[1]

RESULTS AND INTERPRETATION

The Stokes parameter projections of the various polarizations were calculated using MATLAB and the data points provided in the paper on the laser architecture by Lemons, R, et al. and the laser propagation model also developed by Lemons, R, et al.[6]

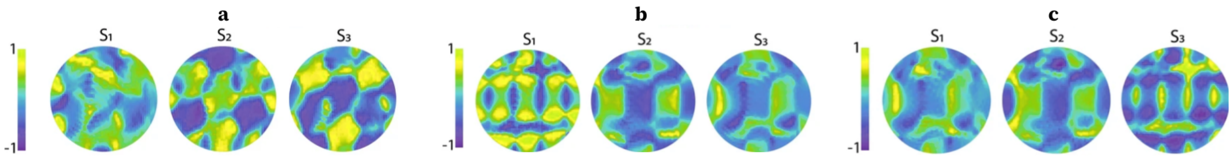

Figure 4. Calculated Stokes parameter projections for alternating linear (a), asymmetric linear (b) and asymmetric circular (c) polarizations

The calculated Stokes parameters match very closely with the experimental results provided by Lemons, R, et al., indicating that the proposed laser architecture is capable of accurately generating light bullets with programmable polarizations.

CONCLUSION

In conclusion, the calculated Stokes parameters projections are consistent with the experimental results demonstrated, indicating that the laser architecture proposed by Lemons, R, et al. is able to consistently generate light bullets programmed with complex far-field polarizations with great accuracy. This would mean that the light generated with this architecture, under the assumption that the other parameters are programmable, would have fine control over parameters compared to current laser architectures. One application of this would be that the light generated using this architecture would be able to transmit far more information due to the programmable nature of the light bullets generated by the architecture.

Further work on this field would be to verify the programmability of the other parameters of the laser architecture, such as the CEP and pulse front, along with increasing the amount of control the architecture has over the parameters of its generated light. This is of particular importance for the parameters in the far-field, as current techniques for the generation of complex far-field waveforms are lacking in fine control.

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