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User-Control of Intensity and the Polarization Vector in Integrated Structured Light Architectures

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Abstract:
The experimental demonstration being reviewed proposes a light architecture that allows for further user programmability of a light beam's characteristics, with a primary focus on intensity and polarization, to take advantage of its optical topologies.

INTRODUCTION

The characteristics of light affect the optical properties and phenomena of which the light displays. Within nature, evolution has granted some animals the ability to manipulate light, creating the visual phenomena recognized as the color-changing abilities of an octopus or the iridescence of a jewel beetle[1]. However, in the attempts to engineer the structure of light, the scientific community has been limited by the abilities of the technology meant to do so. The paper being reviewed displays a proof-of-concept in how laser architecture can be developed such that the characteristics of light may be user-programmable, allowing the ability to exploit the phenomena and properties of light produced within different configurations of these characteristics.

The proposed architecture creates phased arrays made up of the elements of amplitude, carrier-envelope and relative phase and polarization, all of which are able to be controlled individually. The CEP is stabilized so that each of the beamlines have an absolute reference phase which they are phase-locked into with a field-programmable gate array (FPGA). Every beamline also uses the FPGA to create a reference beamline in which a phase modulator is able to enforce a user-defined phase relationship between each beamline and the reference[2]. For this discussion, the use of the half waveplate, polarizing beam splitter, and quarter waveplate to control each beamline's intensity and polarization will be elaborated upon.

METHODS

The half waveplate and the quarter waveplate are key components to control each beamline's polarization vector. The quarter waveplate is able to transform linearly polarized light into circularly polarized light when the fast axis of the plate is at 45 degrees to the incoming polarization plane. It is also able to turn elliptically polarized light to linearly polarized light. The half wave plate with the fast axis at 45 degrees to the polarization plane has the unique ability of being able to rotate the polarization by 90 degrees[3]. This could mean transforming p-polarized light to s-polarized light or vice versa. In the same sense, it is also able to change right-handed circular polarization to left-handed. The combination of the half and quarter waveplate is what gives this experimental demonstration full user-control over the polarization of any given wave. A user would be able to transform p-polarized light to s-polarized light (with the half wave plate), linear light to circularly polarized light (with the quarter wave plate) that is either right-handed or left-handed (with quarter waveplate and the half waveplate). All of these combinations are also possible in the reverse transformation by the same process. The use of both a half wave plate and a quarter wave plate also eliminates the need for a mirror, which is often used so to switch the circular polarization from one handedness to the other (for the overarching goal of the transformation of s- or p- polarization to the other polarization) with the only waveplate used being the quarter waveplate. This process is what allows the laser architecture to have full control over the polarization of any given wave.

Often, when the polarization of light is transformed, such as with a quarter waveplate and a non-polarizing beamsplitter, a maximum of only 25% of the light can be on the desired path and another 25% into the other path. This is because this configuration loses 50% of the intensity on the first pass through the linear polarizer and then 50% of that (for a total 75% intensity loss) on the second pass through the linear polarizer. This is the common tradeoff of controlling the polarization of a light beam. However, this loss in intensity can be prevented, as is done in the experimental demonstration, through the use of a polarizing beamsplitter[4]. The purpose of the polarizing beamsplitter in the proposed laser architecture is to allow light to pass through it through an alternate path without attenuation, or any loss of energy through this passing.

RESULTS AND INTERPRETATION

The main results of this study would consist of the proof-of-concept of an integrated structure of light architecture that contains an array of many elements which are user-controlled or programmable. It establishes the need for a fiber array that is multi-channeled yet coherent, with a common front end such that CEP is stabilized, providing absolute phase consistency for each of the beamlines. The imposition of a user-defined phase relationship between each beamline and the reference beamline is possible with the use of a phase modulator, in particular, one consisting of a piezoelectric transducer-based fiber stretcher) and a computer-interfaced FPGA. The intensity and polarization vector as controlled features can be achieved by a half waveplate, polarizing beamsplitter, and quarter waveplate[2].

CONCLUSIONS

The main conclusion of this experimental demonstration is that with the proposed light architecture, it is possible to manipulate many more of the characteristics of light than in previous, more recent feats of engineering[2]. Now that the ability to engineer the spatio-temporal distribution of these characteristics is no longer inhibited by the limits of technology, this newfound programmability opens up the possibilities for which the topology of light may be designed and utilized.

REFERENCES

1) Doucet SM, Meadows MG. Iridescence: a functional perspective. J R Soc Interface. 2009 Apr 6;6 Suppl 2(Suppl 2):S115-32. doi: 10.1098/rsif.2008.0395.focus. PMID: 19336344; PMCID: PMC2706478.

2) 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

3)“Basic Polarization Techniques and Devices.” *JLAB*, Meadowlark Optics, Inc, https://www.jlab.org/accel/inj_group/laserparts/Basic_Polarization_Techniques.pdf.

4)“Understanding Waveplates and Retarders.” *Edmund Optics Worldwide*, Edmund Optics, https://www.edmundoptics.com/knowledge-center/application-notes/optics/understanding-waveplates/.