Title

Review of Integrated structured light architectures (Final Assignment for ECE170A)

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Review of Integrated structured light architectures

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Abstract: This review explores the effects of some of the parameters that can be tuned in the laser showcased in the original paper, particularly on the CEP discretization step.

Introduction: The authors showcase a laser system that can generate programmed and precise structured light. It is based on a coherent beam combination with LOCSET and CEP. The main claim of the paper is the programmability to be able to do real-time, dynamic adjustment of the beam property which leads to complex light structures that can have great applications like optical tweezers, which are very useful in experiments where high precision is crucial.

This laser architecture enables the design of light bullets, with programmable structures by having control over field amplitude, carrier-envelope phase, polarization, and time delay. The ability to generate optical pistons through modulating time delays extends control to have high-resolution pulse timings.

The authors also claim their architecture is adaptable to many different situations like an unguided, guided, or hybrid system. They have also developed numerical methods of reconstructing and optimizing the fields that can be used to control the light's properties and adjust for any potential use.

Precise and highly coherent lasers have become ubiquitous in optical communications[1], sensing[2], and much more. This review will focus on a demonstration made using many existing technologies to materialize a highly tunable architecture to intrinsically emit light with certain properties.
Demonstrations were done with a focus on a free-space synthesis beam that would be used to conduct experiments or other. The architecture can accommodate guided or hybrid systems. The paper mentions the development of numerical methods of solving and optimizing fields which is important for non-conventional forms of light.

Methods:
LOCSET: Optical phase control is achieved using this method, channels are overlapped on a photodiode, which gives feedback to achieve maximum amplitude, each channel is demodulated and then has its phase error accounted for. This permits very complex optical modulation, even though channels have to be realigned periodically.

Carrier-envelope phase-stabilized front-end and beamline controls: The oscillator output splits into two beamlines, one for feedback and one for other measurements, the carrier-envelope offset stabilization makes sure, using a local oscillator that is mixed with that signal that the beam is at a stable offset, the other feedback loop is to detect long term drift. Phase control is done using phase modulators that have a bandwidth over 10kHz, up to seven independent modulators work individually to have coherent combinations and stable phase locking.

Beam propagation model: Fast Fourier Transform using angular spectrum allows simulation of free space propagation of beams in the far field based on Rayleigh-Sommerfeld diffraction. The model treats polarization by propagating two perpendicular components separately and then summing their intensities.

Analysis:

We investigate some of the claims, mainly of the different multi-channel settings on the CEP-stabilized-front-end. The role of the CEP is to split the beam into many different beams that have different frequencies and delays that give the beam a longer coherence. The paper showcases many different near field beams with different CEP discretization, at 7, 19, and 37 channels. Interestingly the number of channel discretization seem to leave a wider and wider "star" effect in the beams' near field which is highly detrimental in far field.

Taking the Fourier transform of these intensity distributions leads to interesting far-field approximations: The ideal OAM is graphed for the sake of comparison and reference. It is clear upon looking at these beams that 19 channels looks to be close to a sweet spot, where the cardinal directions have a low intensity compared to the other two discretizations and has an intense center. The other two discretizations seem to have a broad widening of the beam which is undesirable in many occasions.

Ideal OAM beam 7 Channel 19 Channel 37 Channel

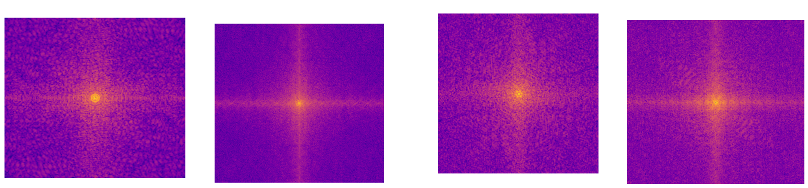

Fig. 1 Fourier transform of the intensity distribution of the beams showcased in Figure 5 in [3]

REFERENCES

[1]Wang, J. et al. Terabit free-space data transmission employing orbital angular momentum multiplexing. Nat. Photonics 6, 488 (2012).

[2]Lavery, M. P. J., Speirits, F. C., Barnett, S. M. & Padgett, M. J. Detection of a spinning object using light's orbital angular momentum.

Science (80-.). 341, 537–540 (2013).
[3]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