Title

A Review of “Integrated Structured Light Architectures”

Author

tremblay, brendan REMI

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Brendan Tremblay

Peer Review, ECE 170 Publications Department, UCLA Electrical and Computer Engineering Department, 420 Westwood Plaza, Los Angeles, California, 90095.
brendantremblay@g.ucla.edu

Abstract: This paper is a review of the success certainty of the guiding fibers and carrier-envelope phase stabilization of the Universal Light Modulator (ULM) proposed in "Integrated Structured Light Architectures".

Introduction:
Structured photonics has become a vital area of scientific innovation in the past few decades and recently. These include, but are not limited to, communications[1], sensors[2], metrology[3], and molecular physics[4]. If this is the case then the precision of laser generation tools is of the utmost importance for these applications. Lemons et al in "Integrated Structured Light Architectures" propose the ULM as a method to better generate light by design to achieve higher peak and average power levels.

Methods, Results, and Interpretation:
The ULM operates through the superposition of individual beamlines, which are "made to collapse and generate unique spatio-temporal wavevector distributions"[5]. For successful operation, it's necessary that each beamline, or comb, is polarized in a way that prevents undesired interference. Therefore, the ULM utilizes Spun High Birefringence (SPUN-HiBi) fibers "designed to preserve circular polarization"[5].

Polarization-maintaining (PM) fibers take advantage of intentionally designed birefringence to ensure that each polarization mode of light will propagate optimally. The most commonly used geometries for PM fibers are PANDA, elliptical jacket, and bowtie. In the context of the ULM, guiding fibers are fabricated in a Bow-Tie geometry to prevent thermal and/or vibration-induced signal fade/drift caused by stress-birefringence. Feng and Tsubokawa[6] demonstrated that, even at nanosize, bowtie fibers perform sufficiently for industry circuit applications. By calculating the power of each polarization mode, they generated the polarization extinction ratio (PER), shown in Figure 1, which stayed relatively constant regardless of the angle of bend in their guiding fiber. Therefore, regardless of the connections within the ULM, its HiBi fibers ought to lock the beamlines' polarization modes.

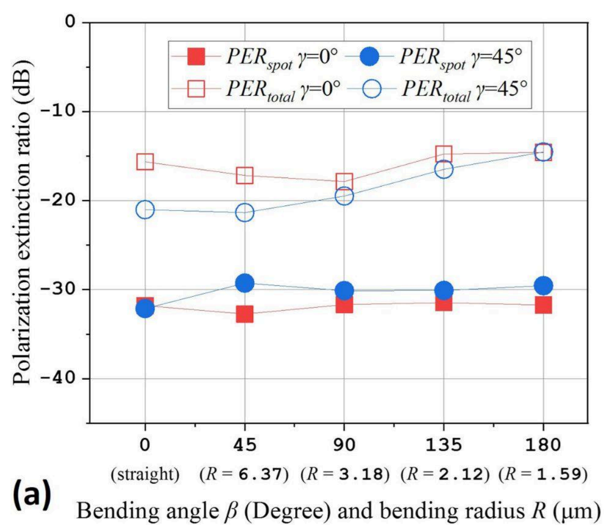

Figure 1. PER vs bending angle of guiding fiber[6]

Additionally, the ULM front end utilizes a carrier-envelope phase (CEP) stabilized by a feed-forward technique to guarantee "pulse-train phase consistency across all beamlines"[5]. Successful operation of the CEP is dependent on the slippage rate between the carrier and its envelope, f_{CEO}, within the oscillator. The formula for this slippage rate, given by Koke et al, can be defined as,

$$f_{CEO} = \frac{\Delta\phi_{CE}}{2\pi} f_{REP},$$

where f_{REP} represents the pulse repetition of the laser, in this case 204 MHz, and $\Delta\phi_{CE}$ represents the phase difference between the generated pulses. For the sake of device design, f_{CEO} is usually set which gives designers a set of acceptable phase differences to ensure successful operation. Below is an edited form of the above formula for the sake of simplicity. Lemons et al design the remainder of their ULM system on the principle that f_{CEO} will not be guaranteed at 80 MHz, but rather range from 80 $\pm$ 2.5 MHz. The below formula and this frequency range were used to calculate the values in Figure 2.

$$\Delta\phi_{CE} = 2\pi \frac{f_{CEO}}{f_{REP}}$$

Figure 2. Acceptable phase differences in degrees and radians.

Carrier Envelope Frequency, f_{CEO} (MHz)	Acceptable phase difference, $\Delta\phi_{CE}$ (degrees)	Acceptable phase difference, $\Delta\phi_{CE}$ (radians)
77.5	136.764	2.387
80	141.192	2.464
82.5	145.584	2.541

Using the results from Table 1, I found the range of acceptable pulse-to-pulse delays in femtoseconds to be [0.066, 0.071]. This corresponds to acceptable pulse-to-pulse jitters of [0.377, 0.405] mrad, relative to the pulse duration of 175fs. Therefore, their claim that their CEP feed forward system "ensures single-digit mrad pulse-to-pulse jitter"[5] is true.

Conclusions

It is safe to conclude that the SPUN Hi-Bi fibers used for beamline propagation would ensure each individual beamline's polarization for any arbitrary light modulation scheme. Additionally, my calculations demonstrate that the greatest possible pulse phase difference would still be small enough to ensure CEP stabilization for the sake of the ULM's operation.

References

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