

Multi-colour beamsteering for optical wireless communications using spatial light modulators

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Abstract—This paper reports results from a single-hologram beamsteering system that uses multi-plane hologram generation to allow simultaneous beamsteering of the red and green components of white light. Gigabit-per-second transmission is demonstrated using eye-safe levels of optical power.

Keywords— visible light communications, beamsteering, wavelength-division multiplexing, optical wireless communications, spatial light modulators

I. INTRODUCTION

High capacity optical wireless systems that use steered narrow beams for communications have the potential to meet some of the exponentially growing demand for wireless communications [1] [2]. Research progress in visible [2] and infrared [1], [3] beamsteering shows promising results in gigabit data rate regimes. Among various choices of beamsteering devices, liquid crystal spatial light modulators (LC SLM) are attractive as they can enable point-to-multipoint communications, and are solid-state, thus eliminating potentially unreliable mechanical actuators. There is extensive work on techniques for display of colour images using SLMs [4], [5], and in this work a multiple-plane hologram generation technique is used to steer RGB sources for data communications.

II. BEAMSTEERING SYSTEM

A multiple-plane hologram generation technique initially proposed for image display is employed. Details of an algorithm can be found in [4], [5]. Ideally, red green and blue components would be steered to allow a white light spot to be steered. However, the hazard due to blue light severely limits the overall power that can be transmitted from an SLM based transmitter, limiting data rate, so for this demonstration only green and red components are considered.

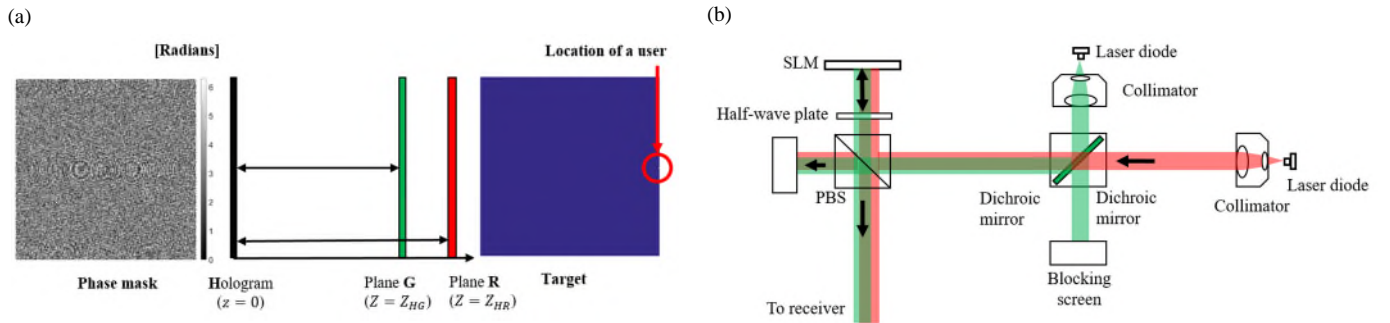


Fig. 1. (a) diagram of multi-plane hologram generation and (b) schematic of the transmitter.

We aim to steer red and green beams to a user whose location is known at the transmitter and is located at z_{HR} , as shown in Fig. 1 (a), by constructing a phase mask via iterative propagation between the object and the hologram planes. The user location is used to generate a target intensity image which is used as an input to the multi-plane hologram algorithm. A red wavelength λ_{Red} is used as a reference beam to construct a phase mask. Two target images of red and green channels are located at z_{HG} [Plane G] and z_{HR} [Plane R] respectively, where $z_{HG} = \lambda_{Green} z_{HR} / \lambda_{Red}$ and λ_{Green} is the green wavelength. For each iteration, a backward Fresnel diffraction integral is first computed to create a complex amplitude field at the hologram plane. Then, forward propagation from the hologram plane to Plane G and to plane R is calculated. Finally, the algorithm outputs the phase mask. The phase mask, which is displayed on the SLM, is illuminated with red and green reconstructing beams. For the red wavelength at which the hologram is designed, a red spot is focused at Plane R as the wavelengths of the reference and reconstruction beams are the same. The green wavelength reconstructs a spot at Plane G, and then light propagates to Plane R such that a slightly defocused green spot overlaps with the red spot.

III. EXPERIMENTAL DEMONSTRATION, DISCUSSION, AND CONCLUSIONS

Fig. 1 (b) shows a schematic of the transmitter. Laser diodes (green Osram PL520, and red Thorlabs L658P040) are collimated polarised and combined. These then illuminate a ferroelectric SLM (Forth Dimension Displays SXGA) that operates in a binary phase mode. An arbitrary waveform generator (AWG) generated a modulated signal, which was then boosted by an RF amplifier (20 GHz BW). The lasers were driven by the AWG, which supplied a 1Gb/s 2-PAM (pulse-amplitude modulation) pseudorandom binary sequence (PRBS) data stream and a DC bias supply (Rohde&Schwarz HMP4040) was supplied via bias tees. The steered beam propagated over a distance of 0.5m and was detected by a free-space photodetector (Hamamatsu Photonics APDs C5658, 1 GHz bandwidth), and the resulting signal was captured by an oscilloscope, for offline processing. Q-factors were obtained from an eye diagram of the received signal. BER was then estimated via the measured Q factors.

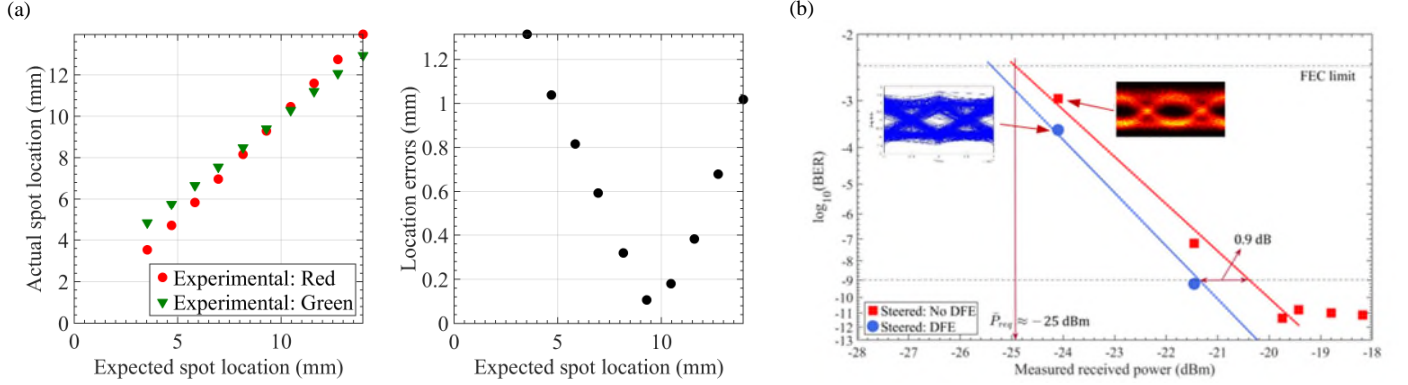


Fig. 2. Experimental results: (a) spot locations and (b) bit error rate performance of a green channel.

In order to validate steering capability, the spot location was examined. Fig. 2 (a) shows the steering spot location of red and green channels. Red and green spots can be steered to close to the same location. The deviation between red and green channels comes from imperfect source alignment and collimation, including laser collimation. In addition, the bit error rate (BER) performance of the beamsteering-based VLC link was measured [see Fig. 2 (b)]. The overall 3-dB bandwidth of the link is ~ 210 MHz (limited by the laser transmitters). A data rate of 1 Gbit/s per channel is achieved at a receiver sensitivity of -25 dBm at the forward error correction (FEC) limit 3.8×10^{-3} . To improve link performance, decision feedback equalisation (DFE) [blue] at the receiver side was used, with a 6-tap T/2-spaced feedforward filter and 1-tap feedback filter. Eye diagrams of unequalised [red] and equalised [blue] links at a received optical power of -24.1 dBm are shown. At a $\text{BER} \leq 10^{-9}$, receiver sensitivity without DFE is -20.5 dBm, and is improved ~ 0.9 dB when DFE is applied. In conclusion, we have demonstrated gigabit visible light communications using beamsteering based on multi-plane hologram techniques.

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