Phase Light Modulation: Encryption and Light-Based Information Transmission

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KEY CONCEPTS

Phase Light Modulation (PLM):

A binary spatial light modulator like a DMD can't directly change the phase of light, but it can fake it. Phase Light Modulation (PLM) uses clever patterns of on/off micromirrors to shape laser light in ways that simulate phase changes.

Digital Micromirror Device (DMD):

A DMD is a tiny device made up of many small mirrors that move. Each mirror acts like a pixel and reflects light. For our research, we used a DLP670S which had a resolution of 2716x1600 representing the maximum quality of images we can display.

Graphical User Interface (GUI):

Software package provided by Texas Instruments serving as a control interface to manage light patterns and display settings for the EVM. Prepares the DMD to project phase files.

Galilean Beam Expander (*Figure 1*):

A Galilean beam expander uses two lenses to make a laser beam wider or narrower without changing its direction. A concave lens spreads the beam, and a convex lens straightens it back out, making it larger.

Evaluation Module (EVM):

Hardware board used to test and try out optical components without building a full setup. It's commonly used in DLP systems to test DMD chips or in laser optics to explore beam shaping and modulation.

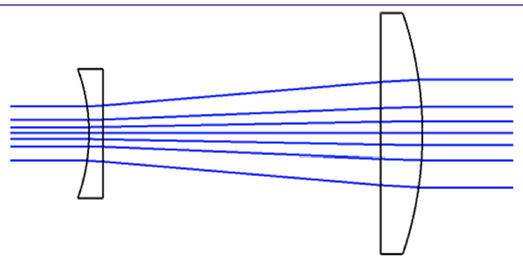

Figure 1. Galilean Beam Expander

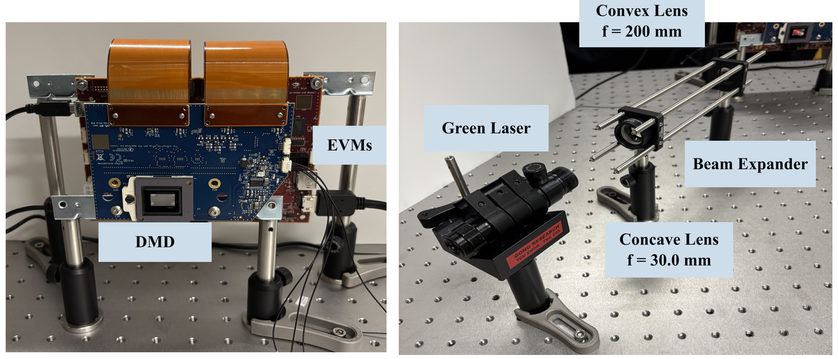

Figure 2. PLM System Setup

ABSTRACT

The goal of this research was to enable information transmission through light using a Phase Light Modulation (PLM) module to decode and display encrypted information. We conducted a literature review and set up an evaluation module capable of sending encrypted messages and transmitting data without the need for optical cables. Our setup includes a laser light source, a beam expander, a Digital Micromirror Device (DMD) controlled by an electronic control board, and a laptop running the software GUI provided by Texas Instruments. We conducted various experiments with these components to optimize the design and explore potential applications. Our findings highlight the potential of this technology for future data transmission and optical devices.

APPLICATIONS

The PLM system we experimented with proved to be capable even in novice hands. The full capabilities lie within many other industries such as medical, defense, and communications. If a different DMD were used that operated more efficiently in infrared light, an infrared laser beam could be expanded for use in many scenarios that include data transmission outside of the visible light spectrum.

Encrypted optical communication can be achieved by layering phase -encoded messages using a DMD, ensuring that only the intended recipient can access the data. The phase file alone is meaningless without the correct EVM settings, operating conditions, and alignment. Infrared light can add an extra layer of security, making the transmission harder to detect. For long-range data transmission, the DMD and beam expander allow for adjustable focal points and image size, enabling clear projection over distances. This makes it useful in scenarios where traditional communication methods are not ideal, with infrared further enhancing operational privacy.

Surface Defect Inspection: Due to the high resolution, refresh rate, and precise tuning offered by the EVM, a special pattern can be projected onto surfaces to locate dents, scratches, or cracks in a material. Inspections can be done visually or paired with other image capturing systems to swiftly find imperfections of varying severity.

RESULTS

Using the setup shown in Figure 2, created bmp files, and a Matlab code to create the desired PLM hologram to be displayed based on the desired target images and animations. We got the results shown in the following figures.

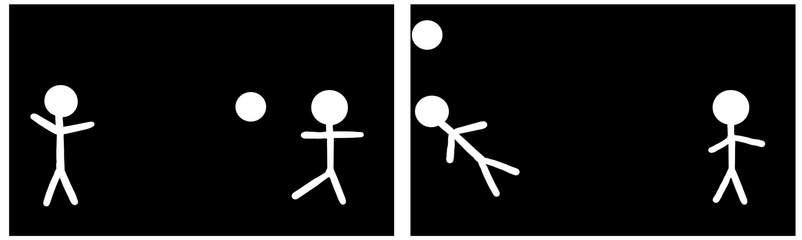

Figure 3. BMP images

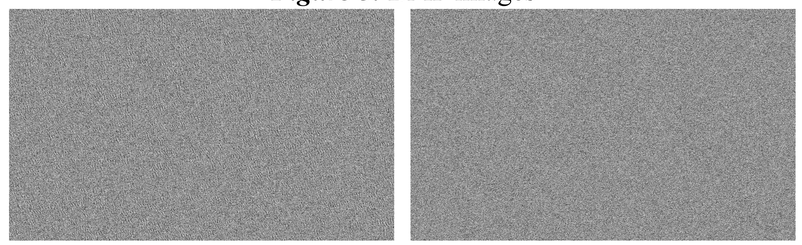

Figure 4. Output file for PLM Hologram

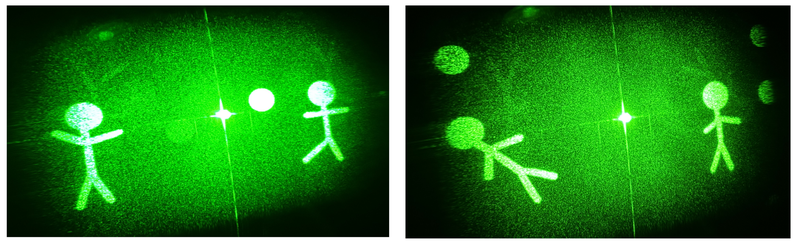

Figure 5. Reconstructed image from EVM

After testing, the best settings, resolution, focal length, and laser, were determined. Figure 6 shows the resulting image, which is sharp and precise, and helped us identify potential applications.

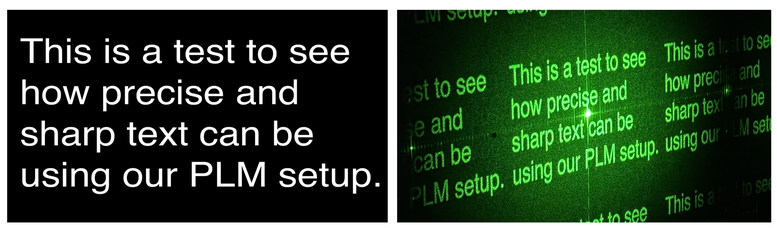

Figure 6. Testing the quality of an image using PLM