Reviving a Spatial Light Modulator for Digital Holography

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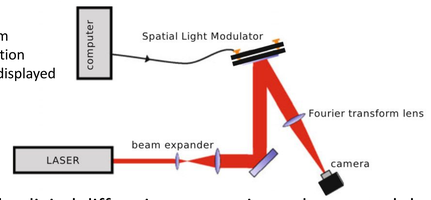
Abstract

Digital holography uses Spatial Light Modulators (SLMs) to manipulate light with high precision. This research focuses on using a Cambridge Correlators SDE1024 SLM to generate bar patterns for digital holography. SLMs control the amplitude and phase of coherent light beams, operating on a grayscale range of 0-255, which allows for both binary phase grating and fine beam control. I developed a Python script to generate and export digital holograms to the SLM. The images displayed are based on the interference pattern of two plane waves, with fringe spacing determined by $\Delta x=\lambda/\sin\theta$. Over the summer, I created a Python code and PyQt GUI to calculate and control digital holograms for the SLM, enabling exploration of applications like holographic optical tweezers. Future work will focus on refining hologram manipulation techniques to enhance applications in digital holography.

Background

Holography is a technique that records and reconstructs light waves to produce three-dimensional images. Traditional methods involve using two coherent light beams—one serving as a reference beam and another interacting with the object to form an interference pattern.

Fig 1. simple optical system measuring far-field diffraction pattern from a hologram displayed on an SLM [1]



A single beam and a digital diffraction pattern is used to control the second beam's interference. In this case, the SLM (spatial light modulator) creates the digital diffraction pattern. This method is pivotal in advanced optical applications such as optical tweezers by developing code that controls diffraction patterns to generate digital holograms.

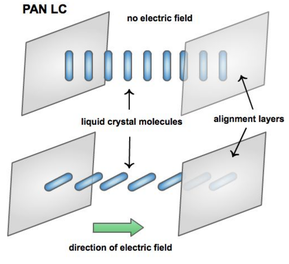
Spatial Light Modulator

The Cambridge Correlators SDE1024 is a reflective liquid crystal on silicon (LCoS) spatial light modulator.
Its specifications include:

- **Resolution: XGA, 1024×768 pixels**
- **Pixel Size: 9×9 µm**
- **Bit Depth: 8 bits, providing 256 phase shift levels**
- **Phase Range: Up to 0.8π for red light (λ = 635 nm) [3]**

The SLM operates by reflecting incident light off a liquid crystal cell, which modulates the phase of the reflected light based on the applied voltage. [4]

Fig 2. SLM liquid crystal molecules [7]



Methods and Materials

SLM Configuration: The Cambridge Correlators SDE1024 Spatial Light Modulator was used to project a bar pattern, which acts as a phase grating.

Pattern Generation: A Python script with PyQt was developed to create a grayscale bar pattern, converting it into a phase modulation image for the SLM. The script allowed for fine-tuning of bar width, brightness, and gradient intensity through adjustable sliders.

Mathematical Model: The spacing between bars (δx) was calculated using $\delta x = \lambda / \sin\theta$, where λ is the wavelength (632 nm). The bar pattern's phase shift ranges from 0 to 2π, corresponding to grayscale values from 0 to 255.

Challenges: The initial VGA connection issues were resolved by switching to an HDMI interface, addressing compatibility and analog-to-digital conversion problems. VGA connection without an HDMI adaption was not compatible with windows 11.

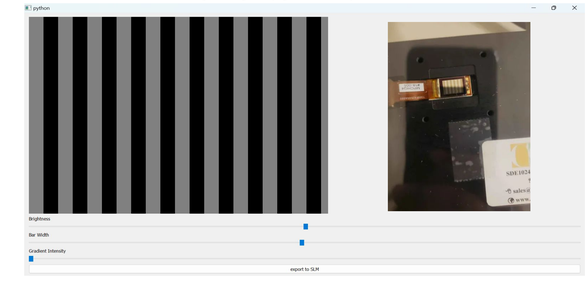
Results

Bar Pattern: The generated bar patterns displayed clear interference fringes, demonstrating the SLM's capability to create high-contrast diffraction patterns.

Gradient Pattern: The gradient patterns validated the SLM's precision in modulating phase shifts across the pixel array.

The program successfully exported the manipulated images to the SLM for beam steering in real time. The images can be viewed with a sheet of polarizing film tilted until the picture is visible .

Fig 3. Digitally generated pattern



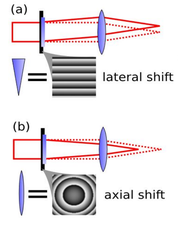


Fig 4. Lateral and axial shift patterns [1]

Discussion

This project builds on previous work by further exploring the capabilities of the Cambridge Correlators SDE1024 SLM, enhancing its application in digital holography through the development of Python-based bar pattern generation for precise beam control.

The SLM effectively generates bar and gradient patterns with clear interference fringes.

Adapting VGA to HDMI improved output quality and made the SLM compatible with a windows 11 device.

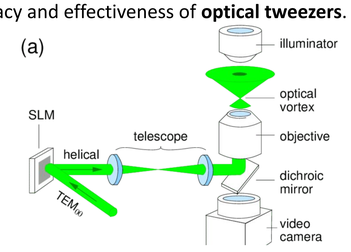
builds upon previous work by Rachel Sampson in 2014 in LTC working with the same SLM, demonstrating how cost-effective SLMs can be optimized for beam steering.

The successful integration of modern computing tools with the SLM suggests a pathway for further enhancing its capabilities/implementation in digital holography.

Future Work

The next step in this project would be to refine this digital holography technique for precise manipulation of microscopic particles. This includes exploring new configurations to improve the accuracy and effectiveness of **optical tweezers**. [5]

Fig 5. holographic optical tweezer setup [2]



It will also be beneficial to continue to develop python code to generate more complex patterns to export to the SLM. These patterns will also be adjustable through sliders and therefore make beam steering easier.

Because this SLM is more **affordable** than typical models, we can explore its potential in various scientific and medical applications, potentially making advanced holography techniques more **accessible** and applicable to fields like medicine and research.

Acknowledgements

This work was supported by a grant from the Simons Foundation. I also would like to thank Dr. Harold Metcalf for the invaluable discussions, and the Stony Brook LTC members for their insights and support. Additionally, a huge thank you to Archbishop Molloy High School, Mary Mallia and Edit Boral.

Simons Summer Research Program

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