Configuration of the Spatial Light Modulator

Firuz Farhodov

Freehold, New Jersey

Firuz5616@gmail.com

***Abstract*— This paper discusses how the Spatial Light Modulator (SLM) works in different research papers and how diverse its use can be. The two research papers use the SLM in completely different ways, making it optimal to show its diversity. The SLM becomes a new tool to help work on optical research.**

Paper 1 "OBSERVATION OF QUANTUM ENTANGLEMENT USING SPATIAL LIGHT MODULATORS,**" the paper uses Liquid Crystals as the medium in the Alignment Layer. It demonstrates the SLM effectiveness in quantum entanglement and how accurately it can capture quantum entangled photons.**

Paper 2 "ELECTRO-OPTIC POLYMER SPATIAL LIGHT MODULATOR BASED ON A FABRY–PEROT INTERFEROMETER CONFIGURATION,**" the paper evaluates the best alignment medium for a high speed requirement, the research search shows Electro-optic was preferred over Liquid Crystal (LC), but not ideal.**

I. INTRODUCTION

The Spatial Light Modulator (SLM) is a device used in optics and photonics to control and manipulate spatial light properties, such as their intensity, phase, polarization, or wavelength in a 2-D plane. The SLM is starting to gain attention for its usefulness in many industries[1]. SLM can be seen in essential applications such as adaptive optics, digital holography, lasers, material processing, and pulse shaping.

II. SPATIAL LIGHT MODULATOR DESCRIPTION

The Spatial Light Modulator is comprised of five parts: Substrate layer (Anti Reflective coating), Electrode layer (electrode), Active layer (Alignment Layer), Dielectric layer (Dielectric Mirror), and Protective layer (Electrode Pixels). Each holds an essential role in the SLM.

A. Layer Description

Substrate layer (AR): The substrate layer is the base material upon which the SLM is built. It provides mechanical support and stability for the device. Typical substrate materials include using glass or silicon depending on the purpose of the substrate.

Electrode layer (Electrode): Above the substrate there is usually a layer of transparent electrodes. These electrodes are used to apply an electric field to the active layer of the SLM, which is often made of liquid crystal material or another electro-optical material. The electrodes are patterned to define the pixels or regions that can be individually controlled.

Active layer (Alignment layer): The active layer is where the actual modulation of light occurs. This layer contains the material that responds to the applied electrical signals by changing its optical properties. In liquid crystal SLMs, this layer consists of molecules that can be reoriented to modify the phase or polarization of incident light.

Dielectric layer (Dielectric Mirror): In some SLM designs, an additional dielectric layer may exist between the active layer and the electrodes. This dielectric layer can help improve the performance and efficiency of the

SLM by providing better control of the electric field distribution within the active layer.

Protective layer: On top of the active layer, there is often a protective layer. This transparent layer protects the delicate active layer from external factors such as contamination, moisture, and mechanical damage.

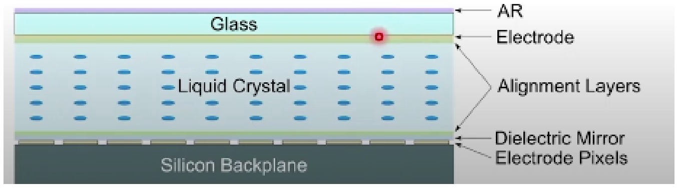

Fig. 1 The image above shows the five layers that make up the SLM.[2]

B. Material

Liquid crystal SLMs use liquid crystal material as the active element. They consist of a layer of liquid crystal sandwiched between glass or plastic substrates. The liquid crystal layer is divided into an array of pixels, and each pixel can be individually controlled by applying an electric field to change the orientation of liquid crystal molecules, thus altering the phase of light passing through that pixel.

III. SPATIAL LIGHT MODULATOR HISTORY

The invention of the SLM came from contributions by several different scientists and engineers. Each added a new feature, which helped improve SLMs

A. Contributors to the Spatial Light Modulator

Dennis Gobar invented holography (1947) and won a Nobel prize (1971)[3]. Contributed the first steps to building SLMs. Larry Hornbeck, a Texas Instrument engineer, invented the digital micromirror device (DMD), a type of SLM during the 1980s[4]. A Dutch physicist, Ferdinand Zernike, developed the concept of phase contrast microscopy, which relies on the phase modulation of light. His work contributed to the understanding of phase modulation, which is a vital function of some SLMs. Other researchers developed liquid crystal spatial light modulators (LC-SLMs) in liquid crystal display (LCD) technology. LC-SLMs have found applications in optics and displays. Researchers in adaptive optics, such as Claire Max[5], have played a significant role in developing deformable mirror SLMs (DM-SLMs) for correcting distortions in optical systems, particularly in astronomy.

B. Spatial Light Modulators Today

There are many different versions of the SLM, each with its niche purpose. Using Google patents, many SLM versions are owned by Texas Instruments. Fig. 2 below was filed for a patent in 1995. The image below Fig. 2(Fig.3) is another version of the SLM owned by Texas Instruments. This patent was issued in 1989.

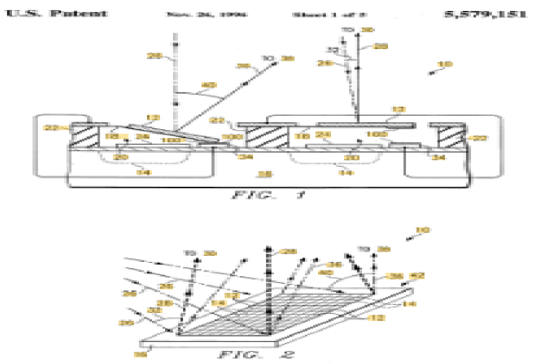

Fig. 2 Above shows the patent of the SLM in 1995.[6]

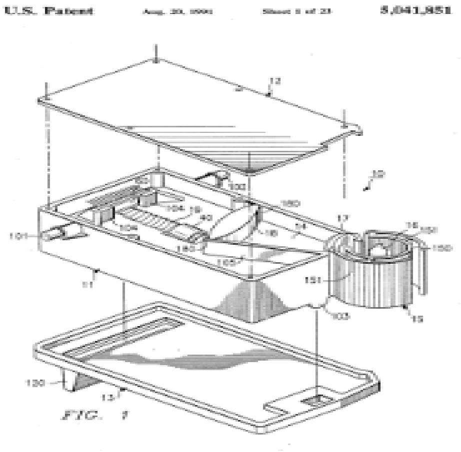

Fig. 3 Above shows the patent of the SLM in 1989[7]

IV. Overview of “Observation of quantum entanglement using spatial light modulators”

Paper one discusses the SLM as a more effective way of precisely updating data without the need to realign the optical system. Usually, when looking at Quantum entangled photons, they would have to realign and interchange between different holograms carefully. Using the SLM allows users to examine the behavior of the coincidence count rate. It also allows users to measure both angular and linear momentum.

A. Paper 1 results

Fig. 4 from paper one shows a fixed-phase relationship between the pump and the down-converted beam. If the pump is spatially coherent, the measurement of a spatially coherent mode in one of the down-converted beams, if detected in coincidence, is a spatially coherent mode in the other beam. This data shows how the two photons are quantumly entangled. Suppose a grating is placed in one beam, and the spatially coherent state is recorded. In that case, scanning the other photons' angular position will result in the diffraction pattern being observed in the coincident count rate.

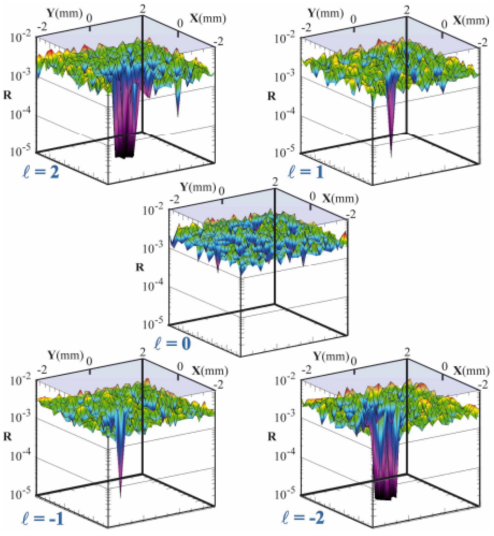

Fig. 2. The measured ratio, **R**, between coincidence and single channel count rate as a function of lateral displacement of the various holograms, displayed as logarithmic surface plots.

Fig. 4 The measured ratio, R, between coincidence and single channel count rate as a function of lateral displacement of various holograms, displayed as logarithmic surface plots. The image essentially backs up the usefulness of the SLM when recording data.[8]

Overall, the paper investigates the SLM and how it could help collect data on quantum entangled photons. Their main focus was on observing the correlations of orbital angular momentum states and ghost diffraction experiments arising from the entanglement of linear momentum and linear position. They also raise questions about the angular form of the Heisenberg uncertainty principle.

V. Overview of "Electro-optic polymer spatial light modulator based on a Fabry–Perot interferometer configuration"

This paper uses the SLM based on a Fabry-Perot interferometer configuration. They use a Fabry-Perot interferometer configuration because the liquid crystal frequency ranges around 300 kHz while the Fabry-Perot interferometer is around 800 kHz. They use an electro-optic (EO) polymer as an active medium since it can perform well at the high levels that liquid crystal cannot withstand. The high level of speed is too much for the LC, which could make it heat up to where it can cause effects on the experiment. The paper says that the SLM could be used to track high-voltage optics without. Images are presented throughout the paper proving that the SLM works as expected.[9]

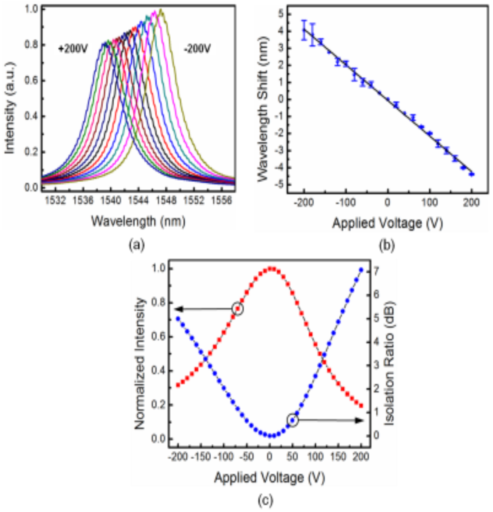

Fig. 5. (a) The spectral shift for one pixel as applied DC voltage is varied from −200V to 200V. (b) The average peak wavelength shift as applied DC voltage is varied from −200V to 200V. A linear fit to the data is performed. (c) The average normalized intensity and isolation ratio as applied DC voltage is varied from −200V to 200V.

Fig 5. Shows how a shift in voltage will affect the isolated ratio and the intensity. The The image solidifies the usefulness of the SLM in this scenario as well, as it is able to give accurate data.[9]

VI. Paper 1 vs. Paper 2

The most significant similarity that the two papers have is that they both use the SLM as their system for their experiments. Using the SLM to track quantum entangled photons and high voltage kHz with great accuracy.

A. *Difference of setup between Paper 1 and Paper 2*

The setup for the quantum entanglement lab is straightforward. When a UV ray of quantum entangled photons goes through the two mirrors, their properties will be observed. That is why there is a SLM for one photon to make sure it passes by to determine if the phases match in the end. The lab data showed that the research matches the single channel and coincidence channel, meaning they can estimate what is happening with the quantum entangled photon. In the quantum entanglement paper, They use a liquid crystal SLM to track the entangled photons and see if they are doing what they are supposed to do. In the other paper, they use an electro-optic (EO) polymer medium in the SLM to look at frequencies at high voltage. They have different active mediums: one is a liquid crystal (LC), and the other is electro-optic (EO). The laboratory setup for the second paper consists of more equipment including an ND filter, Fiber Collimator, Spatial Filter System, Mirror, Lenses, and other machines to record data. The image below shows the setup for paper 1 and paper 2.

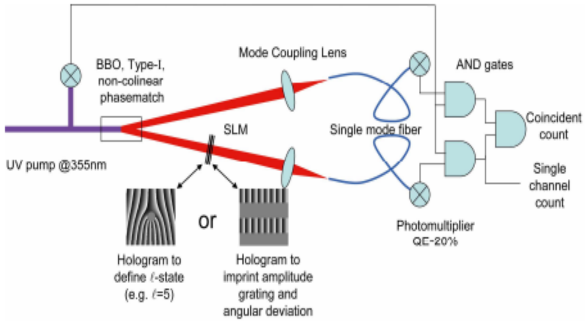

Fig. 1. Experimental configuration for optical demonstration of quantum entanglement between photon pairs arising from parametric down-conversion. The key component for manipulating the detected photon state is a programmable spatial light modulator.

Fig 6, shows the setup for Paper 1

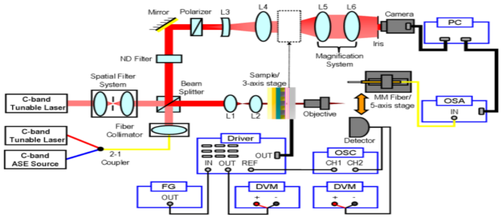

Fig. 4. Characterization setup for SLM. The upper portion of setup is used for measuring throughput of the SLM while the lower portion is used to characterize each pixel individually. The driver is a custom built 64 channel high voltage amplifier. FG: function generator, DVM: digital voltage meter, OSC: oscilloscope, OSA: optical spectrum analyzer, PC: personal computer, and L: lens.

Fig. 7 shows the setup for Paper 2

VII. CONCLUSION

Comparing these two papers using the SLM in entirely different ways shows how useful it can be in many fields of study. One thing that can be improved from these experiments is the quickness of the SLM collecting data and the capability, as after a certain point, more than the power the experiment demands from the SLM would be needed, as seen in research paper 2. The SLM is a useful tool in physics and can evolve to examine small photons in different ways to help grow the field of optical physics.

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