SLM Based Holographic Data Encryption for Security

Aswathy. J. R
P G Scholar,
Optoelectronics and Communication Systems
Department of ECE
TKM Institute of Technology
Kollam, India

Mr. Sajan. Ambadiyil
Research Scientist, Head
C-DIT
Thiruvananthapuram

Prof. Helen Mascreen
Head of the Department
Department of ECE
TKM Institute of Technology
Kollam, India

***Abstract* — Holographic data storage has been considered as a promising data storage technology by its outstanding characteristics of parallel storage, security, high density, fast data transfer rates. Several holograms can be multiplexed throughout the same storage medium by changing some attributes of the reference beam like wavelength, angle or some other multiplexing techniques and makes HDS a volumetric data storage technology. In addition hologram which looks similar can be used to store different data, which provides security to the stored information.The level of security can be increased, if it is possible to record variable data, such as 1D and 2D barcode, in the same hologram. Then holograms will be different for each other provided the same general security features for all. This level security can also be verified by using a system, contain a laser source, CCD detector array and barcode reader , which will reduce counterfeiting. Also the difficulty in producing an original hologram which is expensive and time consuming can be overcome by mass produced replicas from the original which are relatively inexpensive.**

Keywords — Hologram, Holographic Data Storage (HDS), Laser, Interference, Data Security.

I INTRODUCTION

Among different techniques for 3D imaging and display, holography is one of the areas that attracts attention due to its versatility and elegance, which allow recording of both amplitude and phase of a wavefront photographically, and to reproduce the exact wavefront using the recorded information optically. Holographic techniques have also been used in applications where conventional techniques already existed. The holographic technique may either enhance the range of applicability or provide a more compact solution. Optical security is a promising technology and widely used due to their parallel and high speed processing capabilities. Holograms were widely used as one of the most trusted tools for product authentication and security. Holographic storage offers higher data density, faster transfer rates and better safety of stored data

II HOLOGRAPHIC DATA STORAGE

Holographic data storage has been considered as a promising data storage technology by its outstanding characteristics off parallel storage, security, high density, fast data transfer rates. Several holograms can be multiplexed throughout the same storage medium by changing some attributes of the reference beam like wavelength, angle or some other multiplexing techniques and makes HDS a volumetric data storage technology. In addition hologram which looks similar can be used to store different data, which provides security to the stored information.The level of security can be increased, if it is possible to record variable data, such as 1D and 2D barcode, in the same hologram. Then holograms will be different for each other provided the same general security features for all. This level security can also be verified by using a system, contain a laser source, CCD detector array and barcode reader, which will reduce counterfeiting. Also the difficulty in producing an original hologram which is expensive and time consuming can be overcome by mass produced replicas from the original which are relatively inexpensive. In addition it provides high data security, which ensures the private and sensitive data from corruption and the access to it is suitably controlled. The reliability and data assurance at adverse conditions is the requirement of this century. There is a rapidly increasing demand for high capacity, secure and fast access data storage in virtually all avenues of human endeavor from medicine, education, business, communication, military and space. With the development of suitable architectures & material and cost effective availability of enabling technologies, holographic storage is well positioned to satisfy this needs in the near future

III HDS ARCHITECTURE

The holographic storage system architecture is largely determined by the type of recording medium. Broadly speaking, holographic data storage materials are divided into two classes; systems based on thin (a few hundred micrometers thick) photosensitive organic media and thick (a few millimeters to centimeters), inorganic photorefractive crystals. Thick, bulk crystals of photorefractive media are ideal for recording geometries in which a reference and object beam are incident on the medium at right angles .A typical photorefractive crystal used to investigate this configuration is iron-doped lithium niobate. A laser beam is split into two beams, a reference beam and an object beam. Data are imprinted on the object beam via a page composer or SLM. The block schematic for variable holographic data storage for data security is shown in the figure 1. The reference and object beams are focused and combined on the recording medium. The medium is photosensitive and a phase hologram is recorded. By varying the reference beam angle, hundreds of holograms are superimposed in a single location of the medium. By scanning both beams over the medium, or by translating the medium relative to the optical beams, the total recording volume is utilized. Upon illumination with a single reference beam, the corresponding data page is retrieved at the detector array. Such systems excel in having ultra short access times on the order of a few tens of microseconds and extremely fast data retrieval rates exceeding 10 Gb/s, as well as all-solid-state operation with no moving parts. The media are rewritable and information can be fixed for tens of years, if not centuries. Based on fundamental considerations, storage capacity is typically tens of gigabytes, and write times are slower than readout times by one to two orders of magnitude.

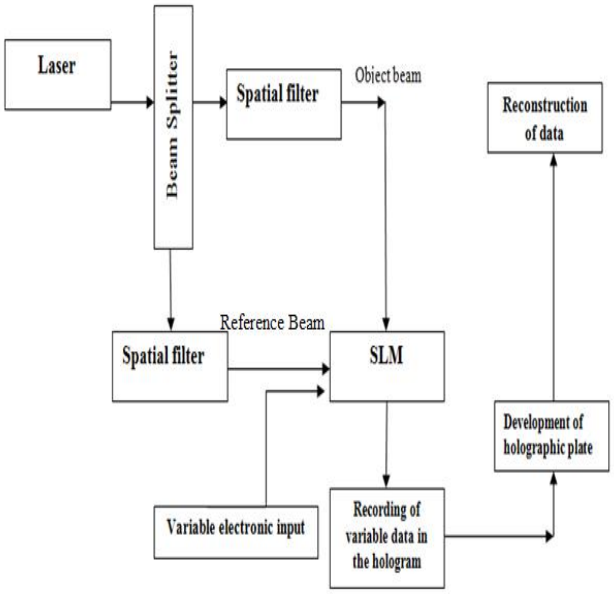

Figure. 1: Block Schematic of Variable Holographic Data Storage

IV OPTICAL SETUP OF VARIABLE HOLOGRAPHIC DATA STORAGE

The design model for a variable Holographic Data Storage is depicted in Figure 2. In this experiment an SLM is incorporated between collimating lenses to add variable data. The varying modulated data could be added through the spatial light modulator, which modulates the original beam. The modulated reference beam and the object beam together form the interference pattern for hologram recording.

Light from the He Ne laser is allowed to fall on the beam splitter. For a 4:1 beam splitter, the beam that travels through the glass is about four times stronger than what is reflected from the surface. The reflected beam and the transmitted beam is allowed to fall on two independent mirrors. Later the reflected light is spatially filtered and allowed to pass through an SLM, kept in between the collimating lens. Further the modulated signal reach the photo polymer plate .At the same time, the transmitted beam from the beam splitter passes through two adjacent mirrors and finally falls on to the same photopolymer plate to undergo the hologram recording process. In holography it is important that path difference between the reference and object beam is zero or small. In my experiment in order to maintain the path difference as zero additional mirror structures are incorporate in the object beam path. If path difference is too long the contrast of the image will be very weak and it is impossible to see the image.

Photopolymer films in tape form are applied for continuous recording of micro-holograms, synchronous with the variable data content. This is a novel, but simple data storage system and can be used to give added security, in conjunction with conventional holograms. Easy and on site verification by applying special reading devices and dedicated software is the other charm of the proposed system. Moreover, for added protection, variable key based data encryption can be applied effectively.A Liquid Crystal Spatial Light Modulator is used to display a two dimensional binary pattern of ones and zeros which act very much like miniature open and closed shutters representing the information to be stored. Generally Security holograms contain only fixed data with a certain and inflexible level of security. The level of security can be increased, if it is possible to record variable data, such as 1D and 2D barcode, in the same hologram. Then holograms will be different for each other provided the same general security futures for all.

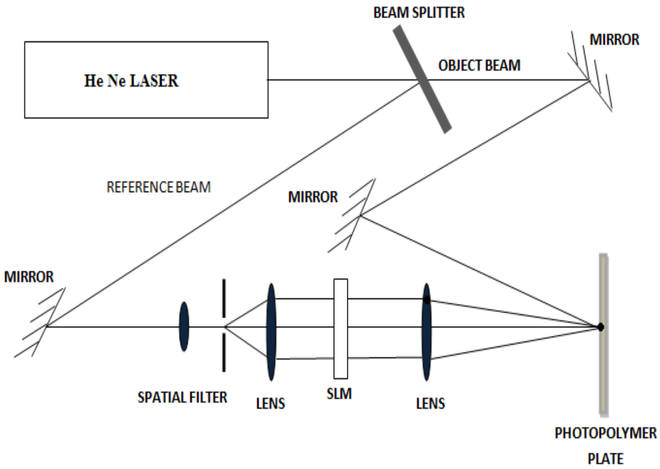

Figure. 2: Optical Setup for Variable Holographic Data Storage

Holograms are riskier to counterfeit if they include variable information such as serial numbers, dates, or encoded personal information. As embossed holograms are mechanically reproduced, it is not practical to holographically record variable information in them. However, it is possible to record variable information in the process of applying holographic hot stamping foil to a substrate as shown in figure 3.SLM is the device used for data encryption.SLM is a relatively new optical device and it is able to alter the intensity of pixels in an optical field propogating through it.A simple example of an SLM is transparency on an overhead projector,the pixels in the beam's cross section have different intensities after passing through the transparency and the beam is spatially modulated.

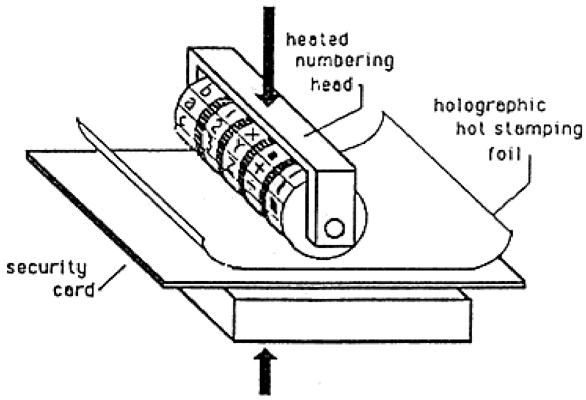

Figure 3. Variable Information by Hot Stamping

V. RESULTS AND DISCUSSION

A. Factors Affecting the recording of a Hologram

The principal factors which must be taken into account in a practical setup to obtain good result are as follows:

- *Vibration Isolation*

Any change in the phase difference between the two beams during the exposure will result in a movement of the fringes and reduced modulation in the hologram. Most commonly, to avoid mechanical disturbances, all the optical components as well as the object and the recording medium are mounted on a stable surface. Air currents, acoustic waves and temperature changes are also major problem. Their effects are usually minimized by enclosing the working area

- *Fringe Visibility*

To produce a hologram that reconstructs a bright image, the interference pattern formed at the recording medium by the object and reference waves should have a high contrast as possible. This is because the amplitude of the diffracted wave increases with the modulation depth of the interference pattern that is recorded

The contrast of the interference pattern at any point in the hologram plane is measured by the fringe visibility which is given by the relation,

$$V = (I_{max}-I_{min})/(I_{max}+I_{min})$$

Where I_{max} and I_{min} are the local maximum and minimum values of the intensity.

- *Beam Polarization*

Most gas lasers have Brewster angle windows on the plasma tube so that output beam is linearly polarized. Maximum fringe visibility is obtained if the angle between the electric vectors of the two beams is zero. This condition is automatically satisfied irrespective of the angle between the two beams, if they are both polarized with the electric vector normal to the plane of the optical table. On the other hand, if they are polarized with the electric vector parallel to the surface of the table, the angle between the electric vectors is equal to the angle θ between the two beams and in the extreme case where the two beams intersect at right angles, the visibility of the fringe drops to zero.

- *Beam Splitters*

To optimize visibility of the fringes at the hologram plane it should be possible to vary the ratio of power in the beam, illuminating the object to that in the reference beam.

- *Exposure Control*

An accurate spot photometer is required to measure the irradiance due to the object and reference beams in the hologram plane, so as to set the beam ratio R at a suitable value. Because of the limited dynamic range of the photographic material used for holography, the object illumination should be adjusted so that the irradiance in the hologram plane due to it is reasonably uniform. Precise control of the exposure is required to ensure to maintain a good diffraction efficiency and avoid nonlinear effects. It may not be enough to maintain a specified exposure time as the laser light may be fluctuating during the exposure. To overcome this a electronic exposure control unit can be used which integrates the irradiance in the hologram recording plane and closes the shutter at a preset value of radiant exposure.

Exposure time (sec)	Input (mW)	Output (mW)	Diffraction Efficiency
27	7	1	14.3
30	7	2	28.6
	7	2	28.6
39	7	3	42.9
40	8	4	50.0
42	9	5	55.6
45	9	3	33.3

Figure 4: Diffraction efficiency during different exposures.

- *Film Exposure*

The material used to record the hologram must respond to exposure to light with change in its optical properties. The complex amplitude transmittance, T of such a material can be written as,

$$T=\exp(-\alpha d)\exp[-i(2\pi nd/\lambda)$$

Where α is the absorption coefficient of the material, d is the thickness n is the refractive index .Figure 3.8 shows the Curve of amplitude transmittance |t| against exposure (E).

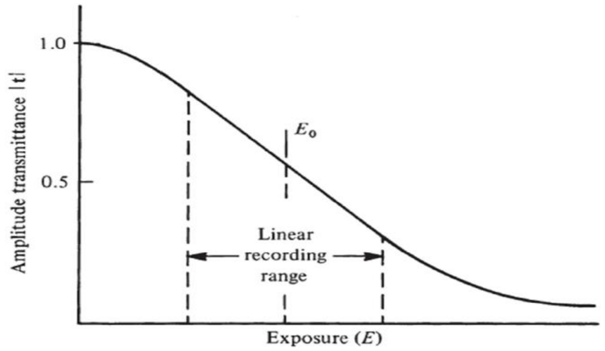

Figure 5: Curve of amplitude transmittance |t| against exposure (E).

On analyzing the result shown in figure 4, a graph could plotted showing difference in diffraction efficiency at various exposures. From such a graph shown in figure 6 we could analyse that maximum diffraction efficiency is obtained when a exposure of around 42 seconds is provided.

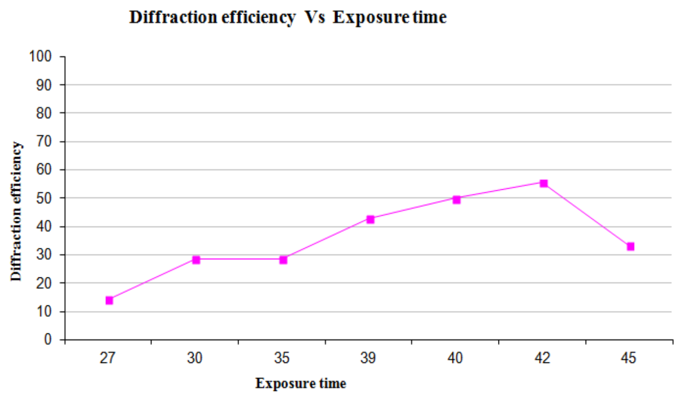

Figure 6:Diffraction efficiency vs exposure time curve

The main objective of variable holographic data storage is that they provide additional data security. Hologram which looks similar can be used to store different data, which provides security to the stored information. On analyzing the figure 7 one may think that both the photographic plate may contain the same information, but it is not the fact. Even though they look similar the data encoded in it is different and could be decoded only by the intended person who knows the angle frequency and other parameters used to record such data within it. Thus providing additional data security and will be difficult to counterfeit.

Figure 7 :Variable data recorded in photographic plate

VI.CONCLUSION

Designed the optical setup to record a transmission hologram and the recording is done in a photopolymer plate. Once we obtain the photopolymer material for the holographic plate, the hologram can be shot. Photopolymers are systems of organic molecules that rely on photoinitiated polymerization to record volume phase holograms. Characteristics such as good light sensitivity, real-time image development, large dynamic range, good image stability and relatively low cost make photopolymers one of the most promising materials for holographic applications The most important property of photopolymer systems is that they can spontaneously develop their holographic image during recording without the need of post-exposure processing steps. This real-time recording characteristic eliminates the need for complicated development procedures and makes it a promising candidate for data storage applications. Photo polymerization is not a reversible process and hence photopolymer holograms cannot be erased and reused. They are suitable materials for write-once-read-many (WORM) applications only which provide data security.

Hence concluding that by designing the optical setup for recording transmission hologram with variable data, data security can be achieved. Spatial filtering setup for reference and object beam helps to generate good quality holograms .Mirror and beam splitter had been made using vacuum deposition system, which helps to remove the noise content and thereby high quality holograms . Holograms are riskier to counterfeit if they include variable information such as serial numbers, dates, or encoded personal information. As embossed holograms are mechanically reproduced, it is not practical to holographically record variable information in them.

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