Proposal for a high capacity memory based on Lippmann interference photography

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Summary

We investigate the storage capacity of an optical data storage setup based on Lippmann interference photography. We have used computational simulations to demonstrate the possibility to achieve data capacities as large as those achievable with common holographic techniques.

Introduction

Nowadays, there exists an enormous interest for holographic data storage. On the one hand architectures based on holography have already proved their ability to reach very large data capacities [1]. On the other hand, Lippmann interference photography was proposed a long time ago for implementing a data storage device [2], however in this first demonstration, the material thickness was very small and the capacities were consequently quite modest.

Basically, a Lippmann photographic plate consists of a glass plate coated with a transparent and sensitive layer. The uncoated side is exposed to the light with the emulsion in contact with a mirror [3]. The incident light is reflected back on itself causing interferences. This establishes standing waves in the emulsion at half the wavelength of the incident light, which react with the photosensitive layer. The plate is then processed so that the recording standing wave patterns are transformed in refractive index Bragg gratings. Illuminating the processed layer at normal incidence with light reproduces the image: for each pixel of the image, the Bragg gratings retro-reflect the exact wavelengths previously used for data recording.

In this work, we investigate the influence of the material thickness on the image resolution and on the wavelength selectivity in order to assess the application of Lippmann interference photography to high capacity data storage.

Proposed architecture based on Lippmann's technique

Our arrangement consists of bits of data, which are first imprinted by a spatial light modulator (SLM) on the beam (see Fig. 1). This modulator is imaged onto the Lippmann's mirror set beneath the photosensitive layer. This beam, at normal incidence, interferes with its reflection and thus records a complex Bragg grating in the sensitive layer. Several images can be recorded at different wavelengths. Once all images are recorded, and after removing the mirror, each image is selectively retrieved by opening all pixels of the SLM and with the very wavelengths used for the recording. With this geometry, the material thickness can be larger than the depth of focus of the images so that the light form the various pixels is allowed to interfere. This idea is the key to obtain large diffraction efficiencies and to get wavelength selective gratings.

Although being close to holography, this arrangement is not a holographic set-up because the beam used for readout differs from the two beams used for recording. We thus expect image distortion during readout. To estimate this distortion (and thus the signal to noise ratio SNR), and the wavelength selectivity, we have modelled our architecture using the first Born's approximation, and the plane wave decomposition of the amplitudes of the beams to propagate these amplitudes using Fast Fourier Transforms (FFT) [4]. The image beam is as a square pixel matrix of transparent (ON) or opaque (OFF) pixels chosen at random. The wave front is thus modulated in intensity but with a uniform phase onto the mirror. For reading out, all SLM pixels are transparent.

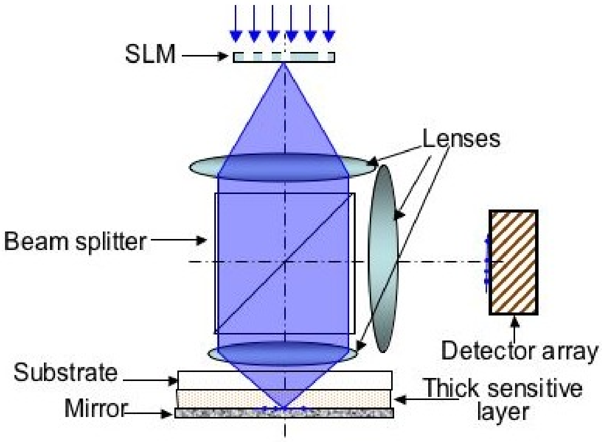

Fig. 1. Proposed architecture for Lippmann data storage. The device is shown during the recording.

Results and Conclusions

Using these simulations, we have demonstrated that sensitive layers thicker than the image depth of field can be used for data storage. Because Lippmann storage differs from holography, even in the absence of any system noise (optical scattering, electric noise), the retrieved images are distorted. Nevertheless, the computed histograms of the "On" and "Off" pixels are well separated giving a SNR compatible with numeric data storage. The recorded Bragg gratings present a wavelength selectivity similar to the one of a uniform Bragg grating of the same thickness. The capacity of such a storage system is thus expected to be as large as those of conventional holographic storage devices. Furthermore, this architecture presents additional advantages for example, a great optical stability for recording the interferences and a small requirement on the coherence length.

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