Wavelength multiplexed memories based on Lippmann interference photography

Kevin Contreras, Gilles Pauliat, Carole Arnaud, Gérald Roosen

Wavelength-multiplexed memories based on Lippmann interference photography

Kevin Contreras, Gilles Pauliat, Carole Arnaud, Gérald Roosen
Laboratoire Charles Fabry de l'Institut d'Optique,
CNRS, Univ Paris-Sud, Campus Polytechnique, RD 128, 91127 Palaiseau cedex, France.
Email : gilles.pauliat@institutoptique.fr

Introduction

We proposed a new architecture to record wavelength-multiplexed data in a page-oriented approach. The proposed technique is based on Lippmann interference photography [1-3]. Lippmann interference photography has many features in common with reflection holography as described by Y. Denisyuk [4]. It uses interferences to record images in the thickness of the recording media, although the phase of the image wave is not recorded conversely to what happens in holography. In this presentation, we demonstrate, using computer simulations and analytical modellings, that Lippmann architectures lead to data storage capacities similar to wavelength-multiplexed holographic data storage systems. The main advantage of Lippmann architecture is its simplicity but the price to pay for this advantage is a distortion of the recorded data that should be taken into account during the data retrieval.

Proposed architecture

Lippmann ideas were applied to data storage a long time ago [5,6], nevertheless, all these systems are in a bit oriented approach [7-10]. We propose to record pages of data using the Lippmann approach in a medium whose thickness can be much larger than the depth of focus of the image [11]. The proposed architecture is shown in figure 1. During recording, the data page displayed by the Spatial Light Modulator (SLM) is imaged onto the mirror, so that the incident beam interferes with its reflection inside the thick recording medium and thus records a Bragg grating. During readout, this mirror is removed and all SLM pixels are opened. The Lippmann plate is thus illuminated by a plane wave. The Lippmann Bragg grating diffracts light that is detected by the detector array set in an image plane of the mirror.

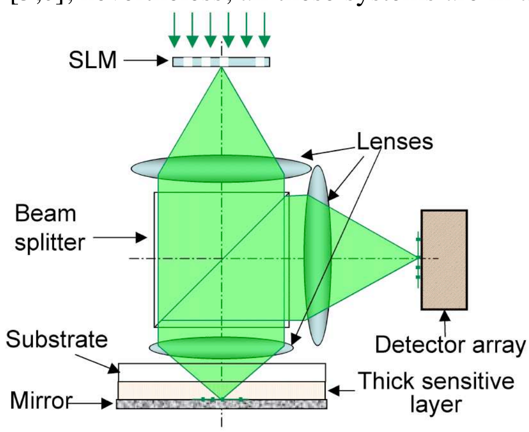

Fig. 1. Proposed architecture for Lippmann data storage.

Results and conclusion

We propose an analytical modelling of this architecture as well as numerical simulations similar to those developed for holographic memories [12]. An example of a simulated binary array displayed on the SLM and the corresponding retrieved intensity image are shown in figure 2 (right and left) for data recorded in a 30 μm thick material with a 0.8 μm pixel pitch.

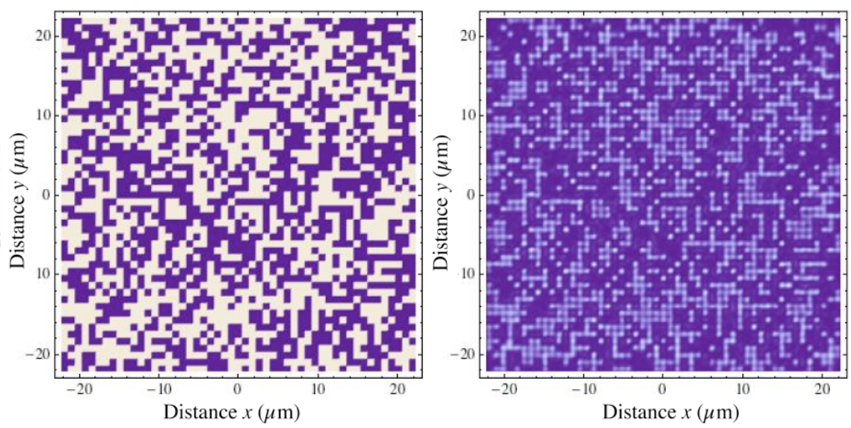

Fig. 2: Data page to be recorded (left) and retrieved image (right)

The spatial resolution of this image is just limited by the numerical aperture of the optical components of the imaging system, but not by the Lippmann recording and readout process. It is not affected by the fact that the recording layer is thicker than the depth of field of the image. It is interesting to note that the retrieved image is slightly distorted, i.e. all "ON" pixels are not exactly on the same level, some are brighter than others. This distortion should not be confused with noise. It results from a deterministic process and is inherent to the Lippmann recording process. Indeed, Lippmann storage differs from holographic storage: the reference wave used for recording is the image beam itself. This recording reference beam thus differs from the reference beam used for reading out. This difference results in distortions in the retrieved image. We will explain how to manage and to reduce these distortions so that all data can be retrieved without ambiguity.

Because of the material thickness, the Lippmann Bragg grating exhibits a wavelength selectivity. Therefore, several data pages can be wavelength-multiplexed in the same location. This wavelength Bragg selectivity is similar to the wavelength Bragg selectivity of uniform Bragg gratings [13]. The data capacity is therefore similar to those of conventional wavelength-multiplexed holographic data storage [14,15]. Furthermore, this architecture presents additional advantages: for example, a great optical stability for recording the interferences and a small requirement on the coherence length. Although Lippmann photographic process has never attracted a great interest in the field of optical storage, we think that this technique presents large potentialities that just wait to be exploited.

Acknowledgements

K. Contreras gratefully acknowledges the support of the Programme Alban, the European Union Programme of High Level Scholarships for Latin America (E07D401978PE).

References

[1] G. Lippmann, "La photographie des couleurs", C. R. Hebd. Acad. Sci. **112** 274 (1891).
[2] G. Lippmann, "Sur la théorie de la photographie des couleurs simples et composées par la méthode interférentielle", J. Phys. (France) **3** 97 (1894).
[3] P. Connes, "Silvers salts and standing waves: the history of interference colour photography", J. Optics **18** 147 (1987).
[4] Y.N. Denisyuk, "Imaging properties of light intensity waves: the development of the initial Lippmann ideas", J. Optics **22** 275 (1991).
[5] H. Fleisher, P. Pengelly, J. Reynolds, R. Schools, G. Sincerbox, "An optically accessed memory using the Lippmann process for information storage", *Optical and Electro-Optical Information Processing* (MIT Press, 1965).
[6] A.S. Hoffman, "Optical information storage in three-dimensional media using the Lippmann Technique", Appl. Opt. **7** 1949 (1968).
[7] A. Labeyrie, J. P. Huignard, and B. Loiseaux, "Optical data storage in microfibers", Opt. Lett. **23** 301 (1998).
[8] G. Maire, G. Pauliat, G. Roosen, "Homodyne detection readout for bit-oriented holographic memories", Opt. Lett. **31** 175 (2006).
[9] P. Wu, Z. Liu, J. J. Yang, A. Flores, M. R. Wang, "Wavelength-multiplexed submicron holograms for disk-compatible data storage", Opt. Express **15** 17798 (2007).
[10] F. Guattari, G. Maire, K. Contreras, C. Arnaud, G. Pauliat, G. Roosen, S. Jradi, C. Carré, "Balanced homodyne detection of Bragg microgratings in photopolymer for data storage", Opt. Exp. **5** 2234 (2007).
[11] K. Contreras, G. Pauliat, C. Arnaud, G. Roosen, "Application of Lippmann interference photography to data storage", J. Europ. Opt. Soc. Rap. Public. 08020 Vol 3 (2008)
[12] P. Várhegyi, P. Koppa, F. Ujhelyi, E. Lorincz, "System modeling and optimization of Fourier holographic memory", Appl. Opt. **44** 3024 (2005).
[13] H. Kogelnik, "Coupled wave theory for thick hologram gratings", Bell Syst. Tech. J. **48** 2909 (1969).
[14] K. Curtis, C. Gu, D. Psaltis, "Cross talk in wavelength multiplexed holographic memories", Opt. Lett. **18** 1001 (1993).
[15] G. A. Rakuljic, V. Leyva, A. Yariv, "Optical data storage using orthogonal wavelength multiplexed volume holograms", Opt. Lett. **17** 1471 (1992).