Simplified architectures with homodyne detection for high capacity Lippmann data storage

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Summary

Lippmann interference architectures are alternatives to holographic memories for high capacity data storage. We propose a homodyne scheme for these systems, which simplifies their use.

Introduction

Lippmann storage systems are close to holographic memories: binary data are encoded as pixels on an image beam by means of a spatial light modulator. This data page is imaged into the plane of a mirror set beneath the recording medium. Conversely to holography, the image beam interferes with its reflection onto this mirror, and not with an external reference beam [1-3]. These interferences record a grating in the sensitive material. The absence of any reference simplifies the architecture at the expense on stringent requirements on the set-up [4]. The advantages of the Lippmann systems justify these constraints.
Several pages are successively recorded, each at a specific wavelength. The readout is performed with a plane wave at the wavelength used for recording. In conventional Lippmann systems, the mirror is removed during readout, and only the diffracted intensity is detected. On the contrary, we propose to let the mirror in place. During readout, the diffracted amplitude thus interferes with the plane wave corresponding to the readout wave reflected onto the mirror. This homodyne scheme and some of its variants were discussed for bit-oriented memories previously [5,6]. We present this homodyne detection for page-oriented Lippmann systems.

Example of implementation

The optical set-up used for this demonstration is derived from the scheme described in reference [4]. It is fed by a filtered supercontinuum source that can be continuously tuned from 460 to 600 nm with about a 3 nm full-width of half maximum of the amplitude. The low spectral density power of this source allows detecting the recorded data but it is not sufficient for recording. This recording is thus performed with two lasers at 532 nm and 473 nm. The recording arrangement is a stack made of a partially reflecting dielectric mirror deposited on a glass substrate. Its intensity reflectivity is 8%. The recording layer is glued on this mirror and covered by a plastic quarter-wave plate. For this recording material, we use the full color Bayer photopolymer Bayfol® HX whose sensitive layer is 16 µm thick. The bottom of the glass substrate is painted with a light absorbing black material to prevent any scattering from light transmitted by the mirror. A zoom of a data page recorded at 532 nm and retrieved at 530 nm is shown in top of Fig.1 left. The pixel pitch is 0.88 µm for a numerical aperture of 0.6. It should be compared to the original data shown in the bottom of Fig.1 left in which the black color corresponds to no light (pixels OFF). The two curves in Fig.1 right, demonstrate a good agreement between the experimental wavelength selectivity in this homodyne scheme with the theoretical wavelength selectivity taking into account the material thickness and the spectral linewidth of the tunable readout source. The small wavelength shift between the two curves results from a very small material expansion. Before recording we deliberately strongly pre-exposed the material to limit the diffraction efficiency of the subsequently recorded image, thus demonstrating the effectiveness of the homodyne detection. The diffraction efficiency is indeed about 3.5% without this homodyne detection.

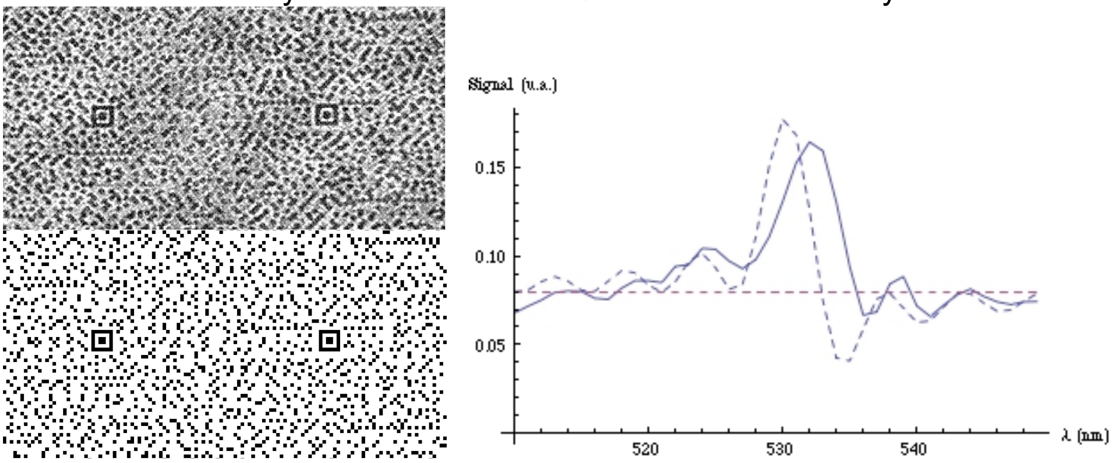

Fig. 1: Left: comparison between original page (bottom) and the retrieved data page (top). Right: detected signal for the whole page versus the wavelength, experimental curve in full line and simulation in dashed line. The dashed straight line corresponds to the mirror reflectivity of 8%.

It is interesting to note that the intensity information of the retrieved image is duplicated in its phase. Indeed the readout wavelength is not exactly the Bragg wavelength (we work at the peak of Fig. 1 right). This off-Bragg readout shifts the phase of the "ON" pixels compared to the phase of the "OFF" pixels. This additional phase information is used to reinforce the contrast of the intensity images. Typically a slight defocus of the imaging system transforms the phase information into an intensity pattern. Using such an improved set-up we have been able to use a mirror whose reflectivity is 100%; 100% of light is reflected and a uniform bright image is detected. However a slight defocus during the readout allows to transform this phase information into an intensity pattern and to retrieve the data page.

Conclusions

Homodyne detection in Lippmann architectures is implemented by just letting in place the "Lippmann" mirror during readout. We use the phase shift on the diffracted beam produced by the off-Bragg diffraction process to enhance the contrast of the detected images. This allowed us to use 100% reflectivity mirrors.

References

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