Recording high-resolution wavelength-multiplexed data pages in a Lippmann data storage system

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Recording high-resolution wavelength-multiplexed data pages in a Lippmann data storage system

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1. Summary

Although wavelength-multiplexed page-oriented Lippmann data storage architectures present similarities with reflection holographic memories, we evidenced that simple rules must be followed to reach the same high storage densities.

2. Lippmann data storage systems

Applying the Lippmann interference color photographic technique [1] to numeric data storage was proposed more than 40 years ago [2]. These early works were abandoned, presumably because of technical constraints, and they have been nearly forgotten and completely overwhelmed by works on holographic data storage in spite of the very strong similarities between these two interferometric processes [3]. We believe that the recent development in tunable sources and recording materials have completely alleviated these constraints. Thus, for several years, we have been revisiting these Lippmann techniques in both a bit-oriented approach [4,5] and in a page oriented approach [6,7]. In page-oriented Lippmann memories, each data page is printed on the signal beam by a spatial light modulator, SLM, the optical wavelength being the address of the page. The signal beam impinges at normal incidence on the thick recording medium and interferes with its reflection over a mirror set beneath the recording medium. This arrangement is close to Denisyuk holography except that, in holography, the second beam (corresponding to the signal beam reflected over a mirror in case of Lippmann storage) is a plane wave. Nevertheless, using the reflected signal beam instead of a plane wave presents many advantages [6,7]: simplification of the architecture, more stable interferometric set-up, shorter coherence length required… The prices to pay for these advantages are some strict constraints on the optical arrangement and on the alignments. Simple, but strict, rules must be followed for the conception of a Lippmann memory otherwise the retrieved data are buried under noise.

We built such a Lippmann memory following these rules. Our set-up is shown in Fig. 1 left. The data pages, from a chromium mask or from a SLM, are imaged onto the Lippmann mirror. We selected these masks, or SLM, with a very high fill factor, more than 90%. These masks are pure amplitude images with no phase information as the phase is not correctly coded in Lippmann architectures. The optical imaging system is made of a video lens and a 0.6 NA microscope objective. It is designed so that the pupil of the whole system is set at infinitum relatively to the mirror. This insures that the zero order of the signal beam is a plane wave. It thus corresponds to the plane wave used for reading out the data pages during which the SLM is fully open. A piezo-electric translation stage moves the microscope objective to focus the data page onto the mirror; this mirror being adjusted by a tilt platform to be exactly perpendicular to the image beam. Without these tight adjustments, a ghost image is visible in the retrieved pages. We presently only use 3 wavelengths: 650 nm for the set-up alignments (the recording medium being not sensitive at this wavelength), 473 and 532 nm to multiplex the pages at each location. Moving the recording medium provides spatial multiplexing. The photosensitive material is a 12 μm thick holographic plate [8]. The Fresnel reflection "silver halide emulsion – air" acts as the Lippmann mirror. Retrieved data pages are grabbed with a CCD camera. A quarter-wave plate (not shown in Fig. 1) glued onto the recording medium and the polarizing beam splitter redirect the diffracted light towards this CCD camera. We checked the absence of any visible crosstalk between two different pages recorded at the same location and retrieved at their recording wavelengths. In Fig. 1 right, we present a retrieved data page at 532 nm. The pixel pitch is 0.88 μm, close to the maximum spatial resolution achievable with the 0.6 N.A microscope objective. It is important to note that, similarly to holography, the spatial resolution of this image is not limited by the material thickness: the image depth of

focus, about 2 µm, is much smaller than the material thickness. We thus benefit of the strict wavelength selectivity of thick material without loosing the high resolution brought by the large numerical apertures.
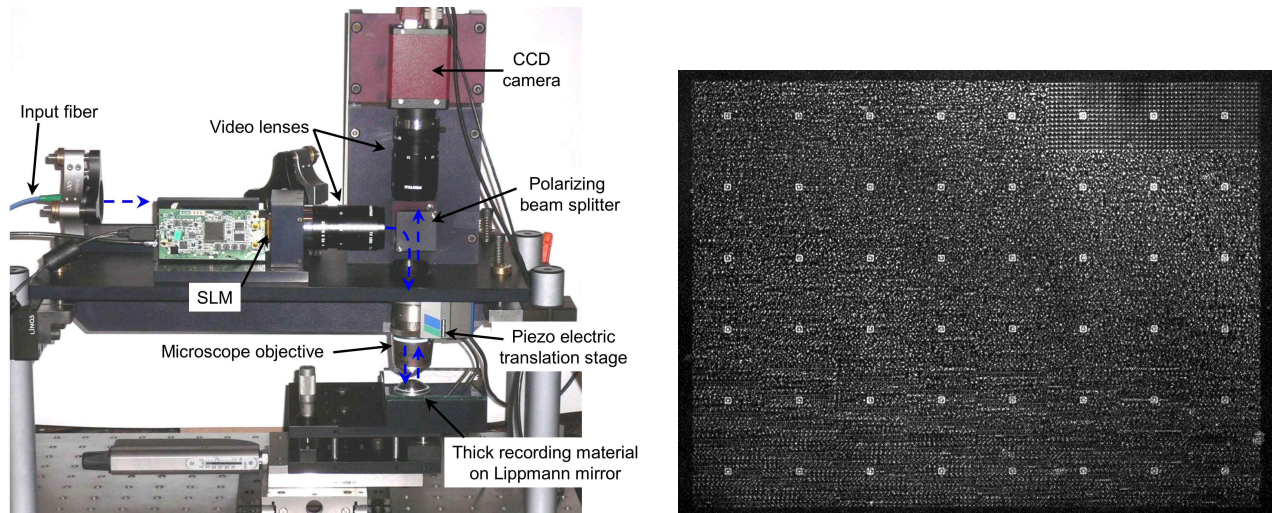

Fig 1.: Left : Lippmann data storage system, the blue dashed arrows represent the light path; Right: example of a retrieved data page with a 0.88 µm pixel pitch.

3. Conclusion

If no special care is taken, the readout data pages can be very noisy in page-oriented Lippmann storage in thick materials. Using simple conception rules, we demonstrated the readout of high quality pages in materials thicker than the image depth of focus. Taking into account that the wavelength selectivity is the same as in reflection holography, we thus conclude that the data capacity of Lippmann storage is comparable with the capacity of more conventional holographic approaches.

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