Superresolution in holographic microscope by numerical reconstruction

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Summary

We show how, by means of a electro-optically flexible phase grating, it is possible to increase synthetically the numerical aperture of an interferometric imaging system, thus improving the spatial resolution of the numerically reconstructed images in two dimensions. Exploiting the grating diffraction effect, it is possible to achieve a resolution enhanced up to three times compared to the usual holographic microscope without the diffraction grating.

Introduction

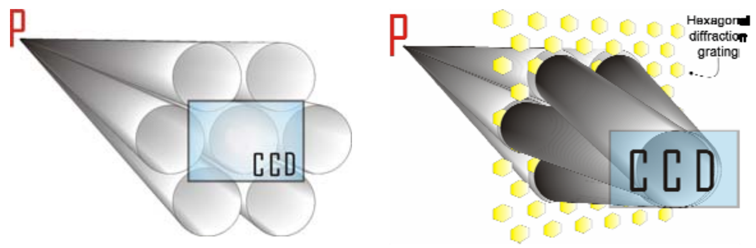
Digital holography techniques have found a wide range of applications in many research fields such as, for example, quantitative phase microscopy or three dimensional imaging[1-4]. This technique presents several advantages in respect to the classical optical holography, deriving, above all, by the possibility to manipulate the digital wavefront to extract quantitative phase information.

However, digital holography presents also some disadvantages caused by the low spatial resolution of the electronic devices used to acquire the holograms in respect to the high resolution (up to 5000 lines/mm) of the photographic emulsions used in optical holography. Usually, to increase the resolution of an optical system it is needed to augment its numerical aperture. In this work[5], we obtain super-resolved images using the diffraction effect of a 2D grating to collect parts of the spectrum diffracted by the object which otherwise would fall outside the CCD array.

Experimental Methods

In the experiment set-up we use a phase grating fabricated in a lithium niobate substrate through the electric field poling process. A two dimension (2D) hexagonal lattice of inverted ferroelectric domains is formed after selective application of an external electric field at room temperature. Then both sides of the poled sample are covered with a thin conductive layer (ITO), that acts like a transparent electrode. Thanks to the electro-optic effect the phase step can be changed with continuity over all the 0 to 2π range by applying a variable voltage. The grating is inserted in the optical path between the object and the CCD.

Fig. 1a and fig. 1b show the ray diagrams of the object waves with the voltage switched on and off, respectively. Basically, when the grating is switched on, seven digital holograms, corresponding to the zero order and to the six first diffraction orders of the grating, are recorded and spatially multiplexed onto the same CCD array. Through the numerical reconstruction of the multiplexed hologram, the seven reconstruction coming from the different multiplexed holograms are automatically superimposed and a super-resolved reconstructed image is obtained.

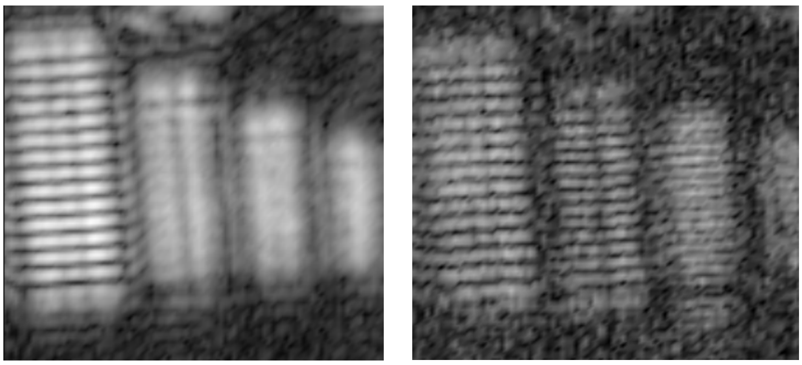


(a) (b)

Fig.1. The ray diagrams of the object waves: (a) without the grating in the setup and (b) with the grating in the setup.

This is the main advantage of the proposed technique in respect to other methods used to enhance the numerical aperture, in which different multiplexed holograms are superimposed by means of difficult numerical procedures.

Fig. 2a shows the amplitude reconstruction of the digital hologram acquired when no voltage is applied to the electro-optic grating, while in Fig.2b is shown the super-resolved image obtained through the proposed technique. The resolution enhances up to three times along each of the diffraction directions.



(a) (b)

Fig.2. (a) Amplitude reconstruction of the digital hologram acquired when no voltage is applied to the electro-optic grating, (b) super-resolved image obtained through the proposed technique.

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