Simple optical setup implementation for digital Fourier transform holography

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Abstract. In the present work a simple implementation of Digital Fourier Transform Holography (DFTH) setup is discussed. This is obtained making a very simple modification in the classical setup arquiteture of the Fourier Transform holography. It is also demonstrated the easy and practical viability of the setup in an interferometric application for mechanical parameters determination. The work is also proposed as an interesting advanced introductory training for graduated students in digital holography.

Introduction
Digital holography is the well knowing Gabor development where the holographic media, usually photographic film or plates, is replaced by a CCD (Charged Coupled Device) of the same kind found in any digital photographic camera [1]. The significant characteristic of digital holography is the process of image reconstruction, that uses computer specific programs, in general based in Huygens-Fresnel diffraction [2] concepts to reconstruct the object image digitally. In the present work a simple implementation of digital Fourier transform holography setup [3] is discussed, with an application, the analysis of a Polydimethylsiloxane (PDMS) silicone rubber, used as the adhesive shear joint. The mechanical behavior of this material is analyzed by digital holography. The present work is also proposed as an interesting experimental proposal devoted to advanced training for graduated students in digital holography.

1. Digital Fourier Transform Holography
The digital hologram of a Fourier transform of light beam diffracted from the object is obtained when the distance from the plane containing both the object and the reference light source is far from the hologram plane. When the hologram has been formed in far-field condition, the complex amplitude of the objective wave G(p,q) can be reconstructed from the amplitude transmission T(x,y) of the recorded plane starting from the Fresnel-Kirchhoff integral[2] is obtained the Fresnel Transformation [4]
where $E_R$ is the amplitude of the reference wave, $\lambda$ is the wavelength and $z$ is the distance from the object to the recording plane. In the case of DFT holography, the phase factor is slowly variant in far field condition and could be neglected. So, the propagation of the beams falls in the Fraunhofer diffraction limit. This is the basic of DFT holography (figure 1). In this case, the reconstruction equation is described by a pure Fourier transform equation adapted to a CCD as recording sensor of $N^2$ pixels of $\Delta x \Delta y$ area, with recorded intensity pattern discretized in intervals of $N\Delta x$ and $N\Delta y$ [4], then the reconstruction equation in the discretized form yields

$$G(m,n) = \frac{E_R}{\lambda z} \sum_{k=-N}^{N-1} \sum_{l=-N}^{N-1} T(k,l) \exp \left[ -i2\pi \frac{km}{N} + \frac{\ln}{N} \right]$$

(2)

where the phase factor is absent.

In the present work a simple implementation of digital Fourier transform holographic setup is discussed. Basically, it is proposed a holographic configuration (figure 2) where the necessity of a plane containing both the object and reference light source (figure 1) at distance $z$ is replaced by a virtual reference light source from the collimator C that reproduces the same optical propagation conditions to obtain the DFT hologram. The advantage is to have a possibility to make holograms in many different practical situations in an easy and straightforward way.

Figure 1. Usual DFT holographic setup.
Figure 2. The proposed holographic setup.

Figure 3. Fourier transform hologram of a simple object.

2. Interferometric application

The simple described setup was applied for the analysis of the single lap joint for load transfer from one adherent to another by a simple pure shearing mechanism considered (figure 4).

The results were obtained through an interferometric procedure, i.e., two holographic images of the single lap joint, in the undeformed and deformed states, were taken using the experimental arrangement. The sum of both images produces the fringe pattern shown in figure 5. With this result the displacement curve (figure 6) is obtained. The figure 7 shows the stress x strain curve for different loads.

Figure 4. Sample.
Figure 5. DFT interferometric hologram of the sample adhesive part.

Figure 6. Horizontal displacement for a load 400g.

Figure 7. The stress x strain curve.
3. Conclusion
In conclusion, a simple implementation of digital Fourier transform holographic setup is discussed. Basically, it is proposed a DFT holographic configuration, where the plane containing the object and reference light source is replaced by a separated virtual reference light source. This configuration reproduces the same optical propagation conditions to obtain a DFT hologram as the classic way. It is also demonstrated the easy and practical feasibility of the setup in an interferometric application for mechanical parameters determination.

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