Dynamic holographic interferometry with digital holography

Stefan Hertwig, Johnnes Bühl, Holger Babovsky, Armin Kiessling, Richard Kowarschik

Institute of Applied Optics, Friedrich-Schiller-University of Jena
mailto:oik@uni-jena.de

With help of the digital holography it is possible to create arbitrary reference states, so that this new reference can be compared to the actual state. So, a larger area of changes can be detected and the full dynamics of a process can be observed. To reduce the disturbing speckle-structure, we propose a method of phase encoding of the illumination wave.

1 Introduction

The digital holographic interferometry is wideley used during the last years to measure the deformations, oscillations [1] and also the shape divergences [2] between different pieces or between master and sample.

The principle already is known from the classical holographic interferometry. Both own at first sight the same disadvantage, that with big deformations the originating interference fringes may appear very close and can not be separated any more.

But the digital holography and the digital holographic interferometry (DHI) distinguish themselves above all by the advantage, that one can choose an arbitrary reference state out of the stored holograms.

Moreover, the recording, storage and reconstruction processes can be realized in real-time. In some cases it even is possible to reduce the speckles.

Besides, the dynamic change in the object can be pursued on a real-time basis, as well as it can be evaluated later on.

2 Experiment

The experimental setup is shown in figure 1.

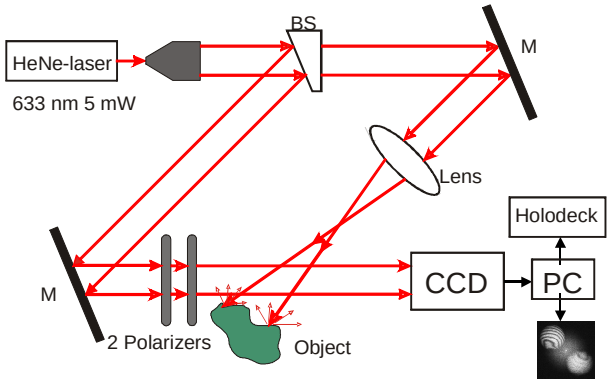

Fig. 1 *Experimental setup to realize digital holographic interferometry.*

The laser beam is split by the beam splitter in a reference wave and the illumination beam. To simplify matters, a plane wave was used as reference wave. The polarizers help to adjust the appropriate intensity ratio between the object wave and the reference wave.

A software package, called Holodeck, was used to carry out the recording of the hologram as well as its reconstruction at quasi real-time (5 - 10 frames/second).

The coherent overlay of reconstructed amplitudes of two states results in a picture with interference fringes. Figure 2 shows the example of a thermal deformation of a table-tennis ball.

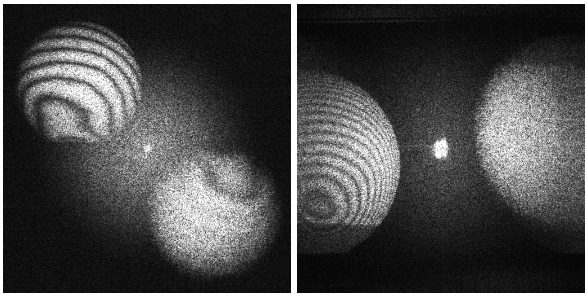

Fig. 2 *Interference fringes characterizing the thermal deformation of a table-tennis ball after a) 10 s and b) after 15 s*

It is obvious, that the interference fringes in Fig.2b) are not evaluable for the whole object.

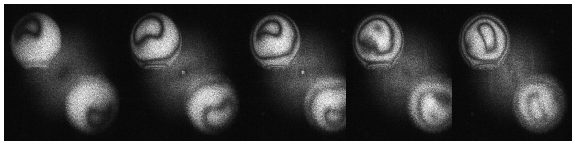

Fig. 3 *Deformations in the first 5 s in steps of 1s*

Figure 3 shows a series of interference fringes characterizing the dynamics of the deformation in steps of 1s, and figure 4 illustrates similar dynamics in steps of 5 s.

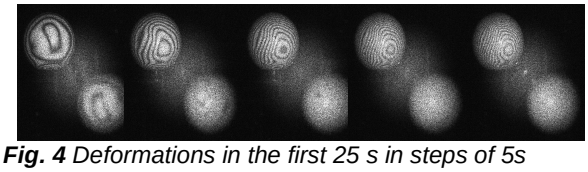

Fig. 4 *Deformations in the first 25 s in steps of 5s*

Obviously it is not possible to separate the interference fringes of the whole object for time differences of at least 15 s. The classical holographic interferometry, could not be used to determine the deformations over a long range of time.

With help of the digital holography it is possible to record all states of the object in time and use an arbitrary state as a new reference state. Therefore, the following states can be compared to this one. Hence, a larger area of changes can be detected and therefore, the full dynamics of a process may be observed.

The figures 5 an 6 show the thermal deformations for intervals of 5 s between the 0^{th} and 5^{th} second, between the 5^{th} and 10^{th} second, between the 10^{th} and 15^{th}, and finally between the 20^{th} and 25^{th} second respectively.

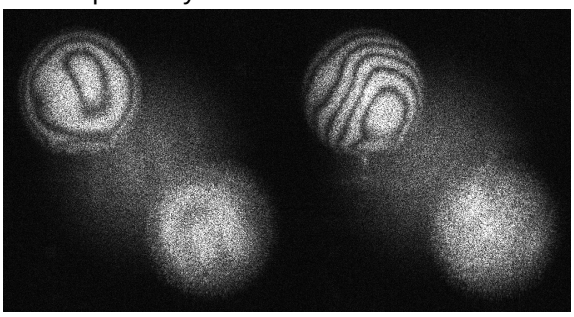

Fig. 5 *left) interference of the states at the 0^{th} and 5^{th} s right) interference of the states at the 5^{th} and 10^{th} s*

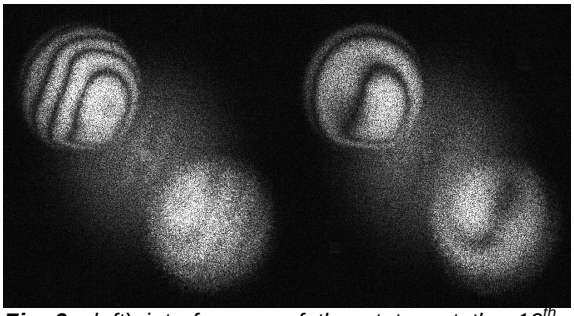

Fig. 6 *. left) interference of the states at the 10^{th} and 15^{th}s right) interference of the states at the 20^{th} and 25^{th}s*

3 Reduction of speckles

In the case of comparing only two different object states, we propose a method to reduce the disturbing speckle-structures without loosing resolution in the object. To achieve this goal, a phase encoding of the illumination wave has to be realized by a scattering plate and a liquid crystal on silicon device (LcoS).

The scattering plate is put in front of the object (figure 7). In each of the two states of the object a series of holograms will be recorded with different phase distributions of the illumination wave. After the reconstruction of the holograms, the amplitude pairs contain different states but the same phase encoding will be superimposed. Afterwards, they will be incoherently summarized. The result illustrated in figure 8 is a speckle reduced interference pattern.

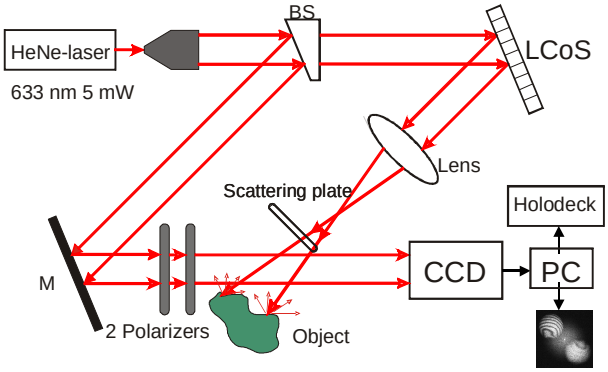

Fig. 7 *Experimental setup to reduce speckle pattern*

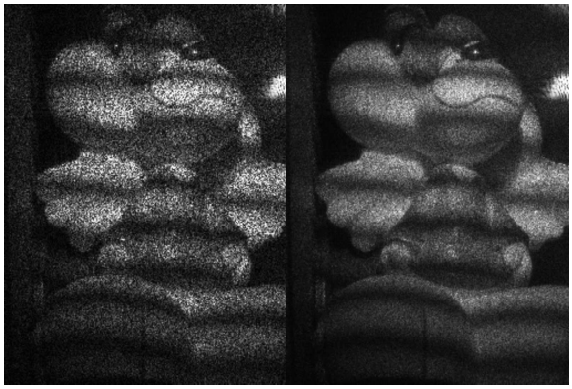

Fig. 8 *left) speckle pattern in a single interferogram right) reduced speckles by combining 5 interferograms*

4 Summary

We demonstrate that the range of dynamics of the deformation increases by using digital holography and show the possibility of speckle reduction by phase encoding of the illumination wave.

References

[1] U. Schnars, W. Jüptner: Digital Holography, Digital hologram recording, numerical reconstruction, and related techniques (2005) Springer Berlin Heidelberg New York

[2] *http://www.ndt.net/article/v07n04/osten/osten.htm*