MEASUREMENT OF LARGE DISPLACEMENTS BY HOLOGRAPHIC INTERFEROMETRY

PhD thesis

dr.univ. RÁCZKEVI BÉLA

Consultant: DR. GYÍMESI FERENC

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Research preliminary

Holographic interferometry is the application of holography for measurements, that is why it is understandable to realize the method in practice. However, the general theory of holographic interferometry with some very important questions are left undiscussed or treated by practical approximations. These questions are for example the accuracy and the upper limit of measurements. The usual upper limit in practice is far below the the theoretical upper limit.

One possibility to increase the upper limit is the difference holographic interferometry (DHI) developed by Zoltán Füzessy and Ferenc Gyímesi at Budapest University of Technology and Economy. This method makes optical or interferometric subtraction, the fringes to be compared are not appeared, only the difference fringes are created. The DHI is a unique method, other technics with the same quality are not known. However, there exists a similar possibility of direct comparation in speckle interferometry, but these speckle methods give so-called correlation fringes with less visibility. The quality of the fringes can be increased by image processing techniques, but the correlograms are basicly more noisy than the interferograms.

The aim of the research

The aim of the research is to analyse in theory and in practice the unemployed possibilities of increasing the upper limit of holographic interferometry – predicted theoretically by Walles and Schumann. – in two different approaches. One way is the optical magnification oh the dense interferometric fringes and filtering the image noise by computer, and considering the higher order effects in phase and visibility of fringes, which can not be neglected at large displacements.

The other way to increase the upper limit is applying holographic illumination by real images. This is the principal effect in difference holographic interferometry and this idea can be extended into the difference electronic speckle pattern interferometry (DESPI). The other aim on this way is the analysis of the effect of other error sources: false reversing of the holographic image and imperfect positioning the test object. The appearance of these error factors means that the non-corresponding points of the objects are included in the comparison.

Methods of research

This work has been done in the holographic laboratory of the Department of Physics at Budapest university of Technology and Economy. Te research instruments were as usual in optics, like dark room, floating table, high-power Argon- and Krypton-ion lasers with long coherence, optical mirrors, beam-splitters, collimators. The research arrangements were build up by combining these elements.

The theoretical part of my research is based on the theory of localization, visibility and phase of holographic interference fringes developed by Walles in his Ph.D. thesis and extended for difference holographic interferometry by Gyímesi-Füzessy. I used in my calculations the Debye-integral describing the light intentensity distribution near the focus, the van Cittert-Zernike theorem from classical interferometry and the dyadic-product represantation of the deformation tensor.

New scientific results

1. I have **proposed** a **new**, **simple method** to detect **in-plane** rigid body displacements, which are disturbing the localization of the interference fringes. I have pointed out that the phase and visibility of the fringes are disturbed by the in-plane component of displacement. Filtering this effect is very important detecting out of plane displacements. I have **developed the theory** of the method that satisfies this requirement and I have proven its ability in practice. [1]

2. I have **proven experimentally** that the **accuracy** of the phase difference formula in holographic interferometry is strongly influenced by the **out of plane displacement** and by the **aperture** of the observing optical instrument – especially at large displacements. I have **recognised** the necessity of applying the **same optical circumstances** in the points of the **whole object**. Otherwise the interferometric phase can not be determined correctly. The same optical circumstances were served by **Fourier-filtering** with optical magnification. [2],[7]

3. I have **proven experimentally** that the **visibility** of holographic interferometric fringes **depends on** the ratio of the **out of plane displacement** to the **focal depth** of the observing system. I have measured the damped oscillation of the visibility till 5 periods. The same optical circumstances were served by **Fourier-filtering** with optical magnification [2] , [7]

4. I have **shown theoretically** that the optical **magnification does not change** the **phase** of the interfeometric fringes. According to the **van Cittert-Zernike theorem**, the correlation propagates like waves and it will be constant between two points independently of the optical imaging. I have **recognised** the consequence of the van Cittert-Zernike theorem that the interference fringes have high visibility if the corresponding image points are submerged in the focal spot of the imaging instrument. The **minimal resolvable distance** of the optical system is the **upper limit of holografic interferometry** [2]

5. I have **proven experimentally that** the holographic illumination using **cojugated object waves** - the basic idea of diffrence holographic interferometry – can be extended to the **electronic speckle pattern interferometry** (TV hologrphy) and it is possibile to realise the holografically illuminated electronic speckle pattern interferometry. [3]

The experiments show that the stability of the optical arrangement is more critical in difference speckle pattern interferometry than in the holographic case; I have stabilised the optical arrangement using **active fringe stabilization**. [4,5]

6. I analysed the error factors of holographic illumination in difference holographic interferometry. I have **estimated** the **error** of the difference-displacement measurement as a function of **misalignment** of holographic illumination. I have **shown theoretically** that the **conditions for positioning** the illumination and the test object are determined by the **maximal spatial frequency** of the **master or the test interfrerogram**: the higher the density of the fringes, the higher accuracy is needed for illumination. [6]

Publications relating to the results

Journals

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Other publications

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