Lenseless coherent imaging by multi-plane interference detection

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A sequence of interferograms of an object is generated at different planes. A technique for reconstruction is developed and applied to micro-objects down to sizes of 1 µm. The technique includes the reconstruction of the complex amplitude. First experimental results are given.

1 Introduction

In holography a known reference wave is used for generation of a hologram and for its reconstruction [1]. In inline holography the size of samples is restricted because they have to act as a distortion of the reference wave. The aim is to overcome this limit by using multiple plane interference detection.

2 Multi-plane interference detection

The whole complex wave front is given in all planes, if amplitude and phase of a wave front are known in one plane. This can be considered as a three-dimensional interference pattern. Therefore the intensity distributions in different planes are coupled with the phase distributions by the diffraction relations. This relation can be used to reconstruct the complex wave front by measuring the intensity distribution in different planes (fig. 1).

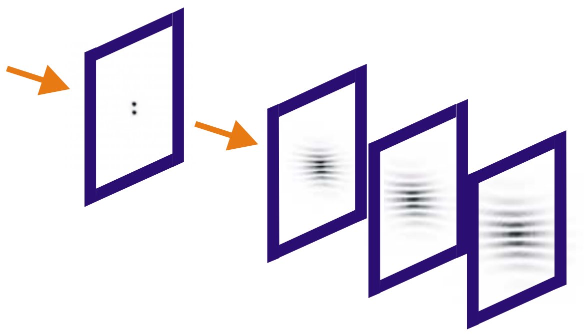

Fig. 1 *Schema of multi-plane interference detection*

There exist iterative algorithms to reconstruct the wave front from two or more intensity measurements. Gerchberg-Saxton [2] and Yang-Gu [3] algorithms use assumptions about the object (e.g. pure amplitude or pure phase object). Algorithms by G. Pedrini [4], Y. Zhang [5], W. Osten and J. Tiziani avoid these assumptions for macroscopic objects. The aim is to resolve microscopic objects with a resolution down to 1 µm. Interferograms are measured in distances of 5 µm … 1000 µm of the object plane.

3 Algorithm

(1) a complex field is initialized in the plane z_0 where the object is assumed to be

(2) the field is propagated by the diffraction relation to the planes $z_1 \ldots z_n$, where the interference patterns are measured

(3) the intensities in the planes $z_1..z_n$ are calculated

(4) the mean square between calculated and measured intensities is minimized by conjugated gradient method optimizing the complex field at z_0

4 Experiments

Pinholes on a glass wafer were used as sample objects. The pinholes were illuminated by a mercury lamp at a wavelength of 546 nm. To decrease and adjust the pixel size a microscope lens was used (fig. 2).

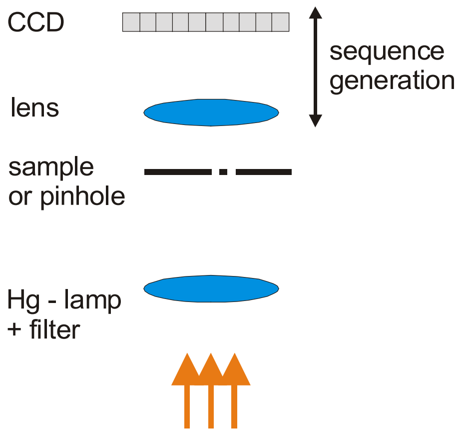

Fig. 2 *Experimental setup for multi plane interference detection by coherent imaging*

In order to test the resolution of the experimental setup interferograms of two pinholes with a distance to each other of 4 µm were considerd (fig. 3). The diameter of the pinholes was 1.4 µm. The interference patterns were measured at distances of 38 µm, 42 µm and 48 µm from the pinholes. The object was reconstructed from these three images.

The measured FWHM of the reconstructed pinholes is 1.5 µm. The measured distance between the pinholes is 4.1 µm. This is in agreement with the original dimensions.

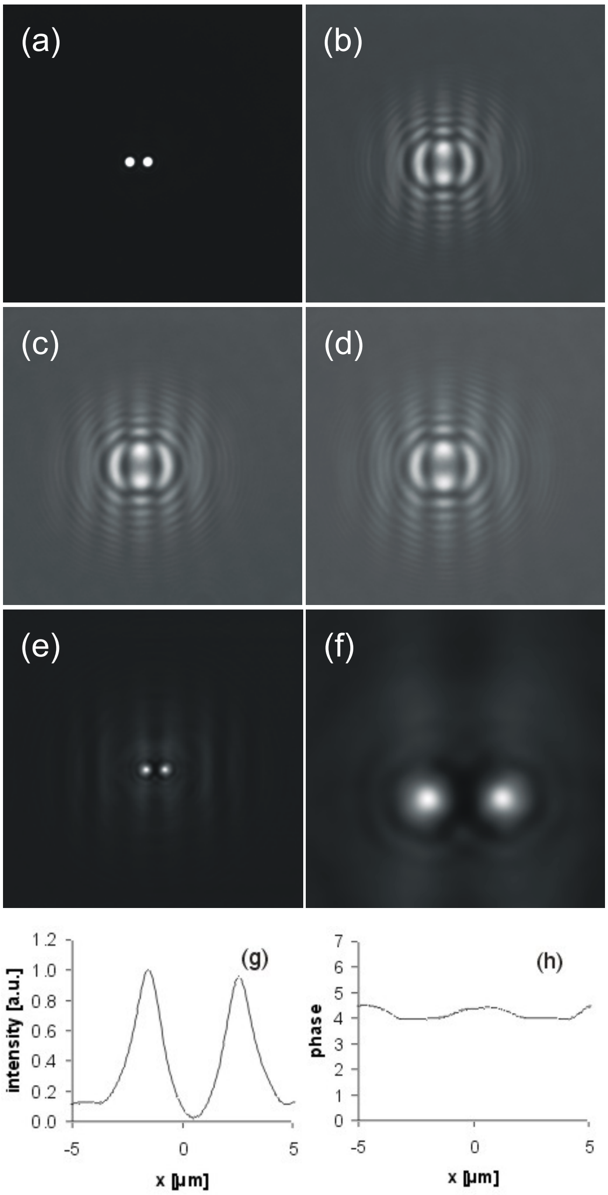

Fig. 3 *double pinhole with a diameter of 1.4 µm, distance between pinholes 4 µm (a); interference pattern at a distance of the object plane of 38 µm (b), 42 µm (c) and 46 µm (d); reconstructed object (e); enlarged section of the reconstructed object (f); intensity cut: distance between the two pinholes 4.1 µm, FWHM = 1.5 µm (g); phase cut (h)*

5 Conclusions

By using the presented algorithm microscopic objects can be reconstructed by multi-plane interference detection. The lateral resolution in experiments is 1 µm … 2 µm. No reference wave is used and no knowledge about the object is required.

Acknowledgment

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References

[1] D. Gabor: "Microscopy by reconstructe wavefronts" in *Proc. Roy. Soc.* A **197**: 454 – 487 (1949)

[2] R.W. Gerchberg and W.O. Saxton, Optik (Stuttgart) **35**, 237 (1972)

[3] G. Yang: "Gerchberg-Saxton and Yang-Gu algorithms for phase retrieval in a nonunitary transform system: a comparison" in *Appl. Optics* **33**(2): 209-218 (1994)

[4] G. Pedrini, W. Osten, Y. Zhang: "Wave-front reconstruction from a sequence of interferograms recorded at different planes " in *Opt. Letters* **30**(8): 833-835 (2005)

[5] Y. Zhang, G. Pedrini, W. Osten, H.J. Tiziani: "Whole optical wavefileds reconstruction from double or multi in-line holograms by phase retrieval algorithm " in *Opt. Express* **11**(24): 3234-3241 (2003)

[6] R. Riesenberg: "Pinhole array and lenseless microscopic micro-imaging", *DGaO-Proceedings*(**2005**), *106th Conference of the DGaO*, *http://www.dgao-proceedings.de/*