Numerical Simulation for Microholography with Short Wave Lengths

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Cross-links:

Ultrafast Holografic Surface Measurement

Breast Cancer Research

Methods of holographic investigation of microscopic biological objects such as live cells are under development at caesar in cooperation with the Laser Laboratory Göttingen. For recording and reconstructing images of biological objects, lasers operating in an extreme ultraviolet (EUV) range (the wave length varies from 13 to 248,5 nm) have to be used. Such EUV-laser facilities with the required characteristics are at the disposal of the Laser Laboratory Göttingen. Special methods for cells preparation based on the local evaporation of water by means of intensive laser pulses with subsequent transfer of cells to the gas phase are developed at the Microliquids GmbH (Göttingen).

In physical experiments, transparent biological objects are emulated by gas beams. Intentionally introducing local non-symmetric disturbances into the gas beam emulates the microstructure of the object. The disturbed interference pattern recorded by a CCD-camera is then compared with the non-disturbed one. Fig. 1 outlines the corresponding experimental setting.

It should be noted that the reconstruction of transparent three-dimensional objects from their holograms is a complicated problem. From the physical point of view, it seems to be impossible to reconstruct a single slice of the object because the information about all slices is mixed in the hologram. Mathematically speaking, any 2D-image obtained using Fresnel transformation is a mixture of data coming from all the object's slices. Therefore, one needs more than only Fresnel transformations to reconstruct transparent 3D-objects from their holograms. The reconstruction of microscopic objects is more challenging because the dimensions become comparable with the wavelength.

An iterative algorithm towards solving this problem is proposed by L. Yu and L. Cai (Journal of Optical Society, Vol.18, no.5, 2001). The method uses operations both in the frequency and amplitude domains. It is demonstrated that the reconstruction of object's slices is possible if the distance between them is not too small.

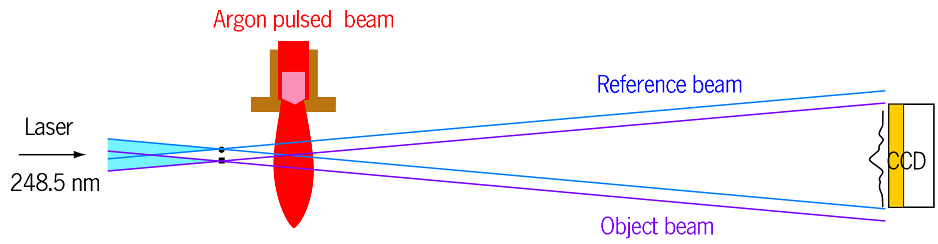

Figure 1: Experimental setting for recording holograms using EUV-lasers.

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In the caesar Modeling group, numerical simulations of microholography with short wavelengths have been started with the objective to develop an algorithm and software appropriate for the investigation of microscopic transparent objects. At the moment, the freely distributed program LightPipes developed at Delft Technical University is intensively used for the modeling. One of the advantages of this software is the possibility to build-in self-written modules.

Fig. 2 illustrates the reconstruction of a 2D-object from its hologram for the experimental setting similar to that presented in Fig. 1. The object is modeled using a 2D-transmission mask shown in Fig. 2a. The wavelength is 248.5 nm.

A basic step in the reconstruction process is the reconstruction of the object phase in the recording plane. Fig. 3 gives an example of such a reconstruction in the case where the object is modeled as a 3D-phase mask.

Cooperation:

Laser Laboratory, Göttingen

Microliquids GmbH, Göttingen

a) b) c)

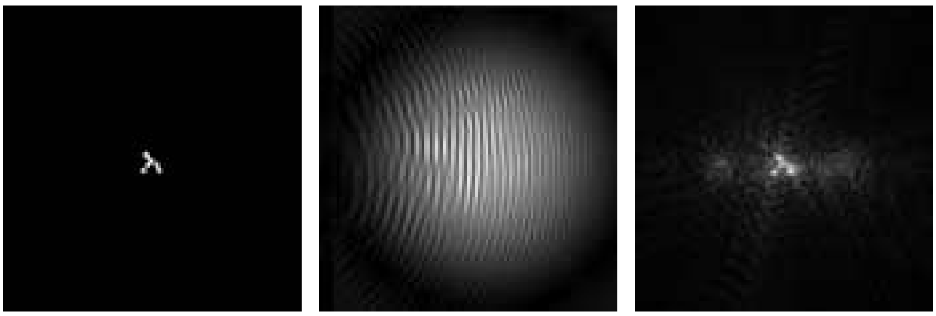

Figure 2: a) transmission mask (object), b) interference picture, c) reconstructed image.

a) b)

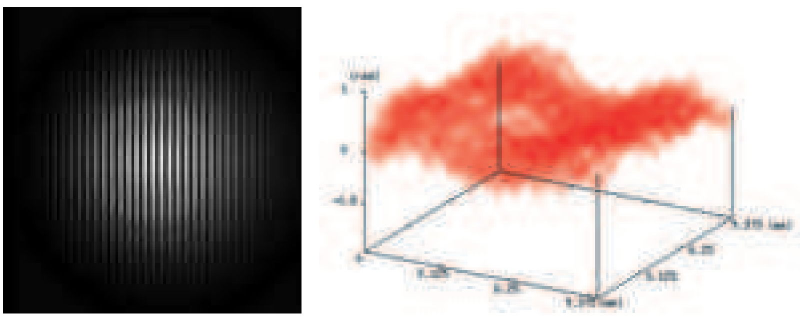

Figure 3: a) Interference picture (hologram) for a 3D-phase mask, b) the object's phase in the recording plane reconstructed from the hologram.