Numerical Optical Sectioning for 3D Holographic Images with EUV Lasers

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The development of compact, coherent extreme ultraviolet (EUV) laser sources has opened new opportunities for the implementation of imaging schemes with nanometer resolution using setups that fit on a tabletop.[1] One such scheme is holographic recording using EUV lasers. In a recent paper, we demonstrated that, through a careful analysis of the numerically reconstructed holographic images, it is possible to obtain three-dimensional information from a single high numerical aperture EUV Gabor hologram.[2]

For this demonstration, we used a highly coherent tabletop capillary discharge laser emitting at 46.9 nm to record the hologram.[3] The test object was a tilted semitransparent aluminum thin film, the surface of which was covered with a random distribution of opaque latex spheres that were about 465 nm in diameter. The holograms were recorded in poly-methyl methacrylate (PMMA), a high-resolution photoresist.

We created the surface modulation in the PMMA by exposure and development and subsequently scanned it with an atomic force microscope to generate digital images of the holograms. The numerical reconstruction based on a Fresnel propagator[4] produced a set of images of the object. We retrieved depth information by analyzing the different reconstructed images to identify the distance between the object and the hologram surface, indicated as z_p in part (a) of the figure. Small changes in z_p reconstruct slightly different images, in which the latex spheres' markers located at the correct z_p give sharper images than those markers "out of focus."

This effect can be observed in (c) and in the line-outs shown on the right, where two vertical cuts through an in-focus (top) and an out-of-focus (bottom) marker are shown. Finding the distance z_p for the optimum reconstruction of the individual markers and combining this information with the *x-y* coordinates allowed for a complete determination of the marker position in the three spatial coordinates; this enabled the reconstruction of the surface of the test object. This procedure is similar to optical sectioning but is performed on a digitally reconstructed image. For the geometry used in this experiment, the depth resolution was approximately $\delta z = 2.8\ \mu m$, while the lateral resolution was limited to 164 nm.[2]

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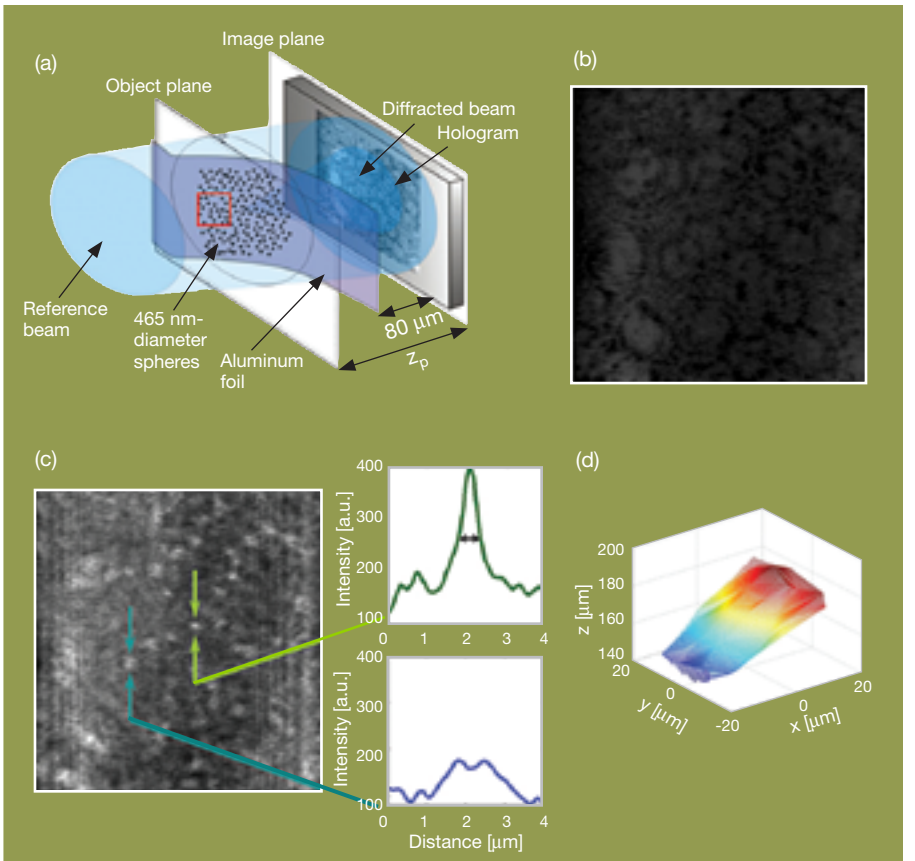

(a) Experimental setup of the Gabor's hologram recording. (b) Hologram recorded as a relief pattern in the surface of PMMA resist and digitized with an atomic force microscope. (c) Numerical reconstruction of the hologram shown in (b). The plots on the right are intensity profiles of a marker in focus (top) and a marker out of focus (bottom). (d) Reconstruction of the surface of the tilted membrane obtained by interpolation of the positions of the markers.