HIGH-RESOLUTION, WIDE-FIELD HOLOGRAPHIC MICROSCOPY VIA SPATIAL-FREQUENCY-DOMAIN APERTURE SYNTHESIS

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For many applications involving the microscopic inspection of large samples, a large field of view and high resolution are required at the same time. Combining these features has always been a challenge in classical microscopy, due to the restrictions of high-numerical aperture (NA) objectives. We have developed a digital holographic imaging technique [1] that not only overcomes these restrictions but also features a long working distance and the ability to extract quantitative phase information. Digital focusing and aberration correction are easily performed on the acquired image data.

The technique operates on the principle of synthetic aperture. Multiple recorded holograms access different regions of the object's spatial frequency spectrum. Off-axis sample illumination and/or off-axis light collection allow high spatial frequency information to pass through the low-NA system. The spatial frequency range accessed in each recording depends on these angles and the illumination wavelength. The spectral regions are then "stitched" together to form a large synthetic aperture, from which the object can be reconstructed using the digital Fourier transform. As successively greater numbers of holograms are combined in this manner, the quality of the reconstruction will improve. The theoretical synthetic transfer function is greatly enhanced at high spatial frequencies relative to the transfer function of conventional, high-NA microscopy.

The three parts of Fig. 1 show reconstructions of an Intel Pentium Pro CPU target from holograms recorded with off-axis sample illumination and on-axis detection. Part (b) is due to a single hologram, parts (a) and (c) to the synthesis of multiple holograms recorded by varying the azimuthal illumination angle. Additionally, parts (b) and (c) are zoomed-in versions of the square highlighted in part (a). The size of the synthetic aperture of part (c) is approximately six times that of part (b), and a corresponding resolution improvement and decrease of speckle size reduction is clearly apparent.

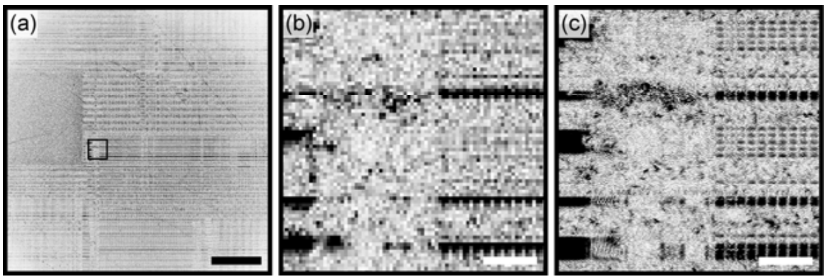

Figure 1: (a) Full field reconstruction (amplitude modulus) of a Pentium Pro processing unit synthesized from 39 overlapping holograms (scale bar: 500µm); (b), (c) zoom in on highlighted area. Single hologram and synthetic reconstruction respectively (scale bars: 50µm).

[1] S. A. Alexandrov, T. R. Hillman, T. Gutzler, and D. D. Sampson, "Synthetic aperture Fourier holographic optical microscopy", Phys. Rev. Lett., vol. 97 , no. 16, 168102, 2006.