Unconventional Imaging by Synthetic Aperture

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The inline holographic microscopy uses for sample illumination a pinhole. This arrangement is extended by using a pinhole-array for a coherent illuminated synthetic aperture. Both resolution and throughput can be increase by synthetic aperture.

1 Digital holographic microscopy

Digital inline holographic microscopy is an unconventional imaging [1], [2] and [3]. We use an extended arrangement shown in fig. 1 [3].

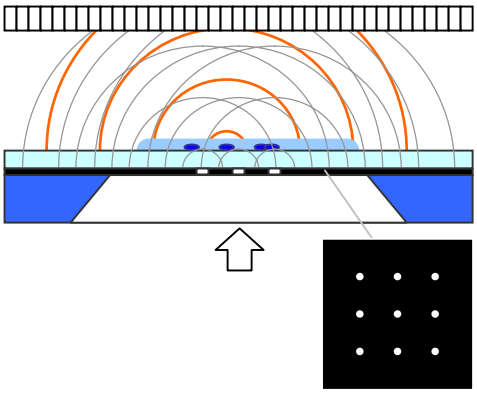

Fig. 1 *Inline holographic microscopy: Coherent illumination by a laser source and a pinhole-array, the pinhole-chip is carrying the samples on a spacer-layer, CCD as a screen.*

The coherent illumination of one pinhole generates a sample illumination creating an object wave. The uninfluenced part of the pinhole wave acts as reference wave. Especially the reference wave can be modified by the use of a synthetic aperture generated by a pinhole-array (fig. 1).

For microscopic resolution a high numerical aperture (small pinhole) is needed. The light flux is limited by application to bio-samples and therefore the signal of a CCD (in distance of a few millimeters) is limited. It will be shown that the signal of the CCD can be increased by using synthetic aperture without increasing the intensity of the laser source.

In this paper the performance of imaging with coherent illumination and synthetic aperture is considered with respect to lateral resolution and throughput.

2 Throughput of synthetic aperture illumination

Fig. 2 shows the intensity of inline illumination by a single pinhole in dependence of the diameter. It is known that with decreasing pinhole diameter (and increasing numerical aperture) the intensity of illumination essentially decreases.

Fig. 3 compares the illumination intensity of a single aperture with that by a pinhole array (which generate a synthetic aperture) with the same diameters (2 µm). The illumination intensity of synthetic apertures is increased by interferences, especially in larger distances.

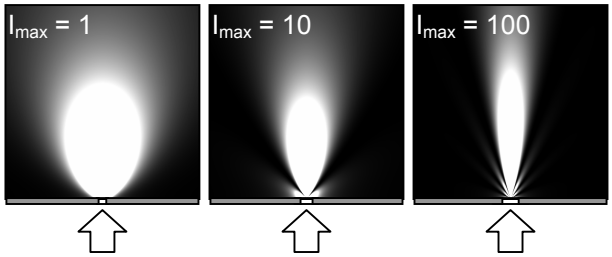

Fig. 2*: Single aperture: The known illumination cone in dependence of pinhole diameter 0.6 µm, 1 µm and 2 µm (from left to right), apertures 1, 0.65 and 0.32, respectively, wavelength 532 nm (simulation). To compare the pictures an adaptation of the scale of relative intensity is necessary (difference of two orders of magnitude). Small pinhole-diameters generate a large aperture but an essentially decreased throughput.*

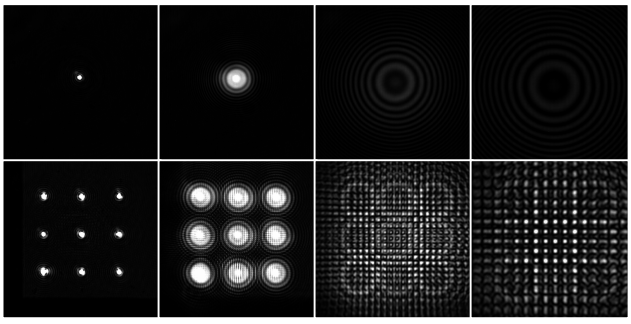

Fig. 3: *Single aperture and synthetic aperture with 9 pinholes (diameter 2 µm, distances 16 µm): The illumination pattern for the sample in the distance z to the pinhole plane (z = 0, 15, 60, 100 µm from left to right) (experimental results), λ = 633 nm. The intensity of illumination by the single aperture is reduced with increasing distance to the pinhole much more than in case of the pinhole array. The field of synthetic aperture illumination is extended with respect to the single pinhole, but structured (a micro-scan is needed).*

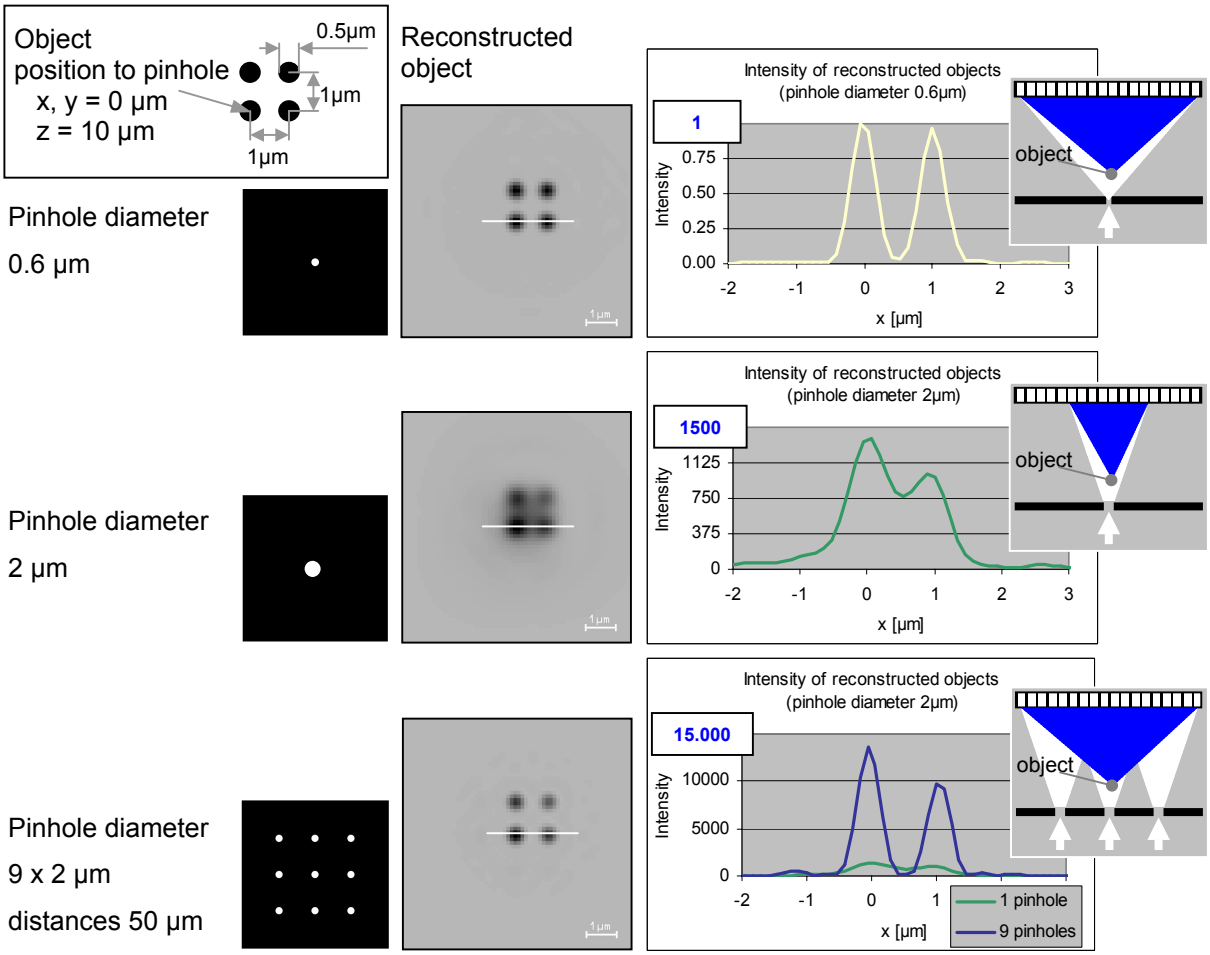

Fig. 4: *Single pinhole and synthetic aperture illumination (simulation) and resulting lateral resolution and intensity. Results of microscopic opaque object (see above, distance z = 10 µm to the pinhole plane), row from left: used pinhole-chip, reconstructed object with cut, resolution and intensity, schematic setup. The resolution of the synthetic aperture illumination with larger pinhole-diameters (2 µm) (e.g. small apertures) can reach that of a large aperture. In the example the throughput is increased by several orders of magnitude.*

3 Pinhole array and resolution

Fig. 4 compares possible resolutions and throughputs of single pinhole illumination with those of a synthetic aperture example. The resolution and the throughput increase if it is compared the result of object illumination by a single pinhole with a diameter of 2 µm with that of an array of 9 x 2 µm (fig. 4 middle and below). It is possible to increase the resolution by synthetic aperture illumination, because the detectable numerical aperture of the object wave can be increased. If the results of single pinhole illumination with a high aperture (0.6 µm) are compared to those of an array (9 x 2 µm), the resolution is the same, but the throughput is increased essentially for the array.

The given example has been selected to show the advantages. In reality the CCD limits the advantage (more pixels and smaller pixel pitch). So the development of CCD and CMOS imaging arrays enables the development of synthetic aperture arrangements. The conditions will be considered in detail elsewhere.

Acknowledgement

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References

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