Development of a lensless microscope

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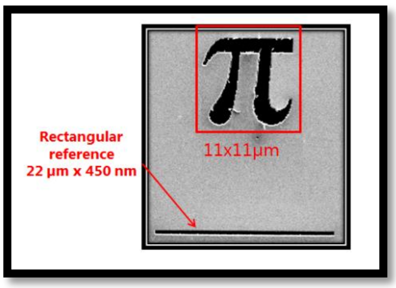
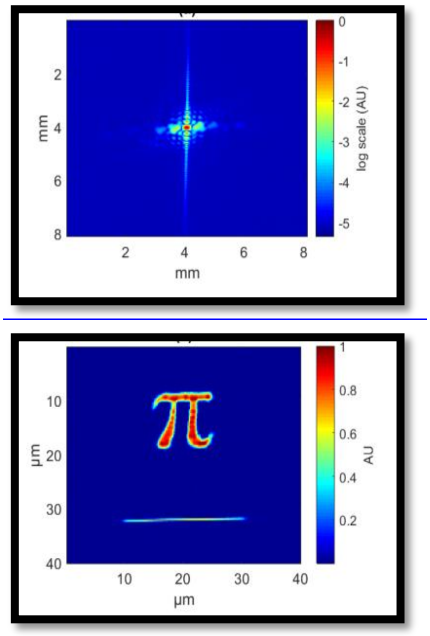
Lensless imaging is a promising technique that can take many forms in terms of experimental configurations: high harmonic generation, laser diodes… In any case, the principle remains the same: a coherent beam illuminates a sample, forming a subsequent diffraction pattern on the other side, which is detected with a CCD camera. Since the phase information is intrinsically lost during the detection, one has to apply phase retrieval algorithms. Different techniques exist : Coherent Diffractive Imaging (CDI), Fourier Transform Holography (FTH) using circular references to encode the phase in the diffraction pattern [3], HERALDO (rectangular references)…

In the CEA – Saclay, lensless imaging has been performed on the LUCA beamline (Laser Ultra Court Accordable). X rays are generated through high harmonic generation under vacuum via the interaction between a Ti:Sa laser beam (800nm) and a gas jet (argon or neon). The aforementioned reconstruction techniques have been used.

For industrial purposes, we propose a new lensless design, using a laser diode and a CCD camera in the ambient air, forming a compact experimental setup with high performances. Although the wavelength is increased to 400nm (UV diode), one gains a lot in terms of space, number of photons, easiness of alignment, and signal to noise ratio.



Drilled sampled via *a Focused Ion Beam (FIB), on a gold membrane. A rectangular reference is also drilled to allow for holographic reconstruction of the phase, in addition to the "usual" iterative techniques that do not need references.*



Experimental diffraction pattern (top) and the corresponding reconstruction (bottom) using a "difference map" iterative algorithm.

To validate and increase the versatility of the prototype, different configurations have been tested. More specifically, binary 2D objects, with a typical size of 20µm, detected in the far field, reconstructed with existing phase retrieval algorithms, give a resolution down to the wavelength (400nm).

We also performed 3D imaging, by using a pupil with circular references and by placing in front the sample we want to look at. Then, Fourier Transform holography is performed to reconstruct the wavefront in the pupil's plane. Thus, the pupil serves as a support for the field reconstruction that can subsequently be back-propagated. This technique has been used in reflection geometry in the past [2]. We reconstructed a biological sample and a test target with a resolution of a few microns.

Finally, we performed in-line holography. With this technique, the field of view can be extended to a few mm and go down to a few hundred of microns, with a resolution of a few microns. The twin image is eliminated *via* an iterative algorithm [1]. With this technique, amplitude and phase can be retrieved, thus it is possible to perform phase contrast microscopy. We used, once again, biological samples and a test target to perform 3D imaging with this technique.

References

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