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Multibeam Ptychography: Nano Resolution at Macro Scale

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X-ray ptychographic microscopy and computed tomography are indispensable non-invasive materials characterization methods for studying the internal structures of solids in many fields, from chemistry, catalysis, and material science to cultural heritage, with the improvement of X-ray sources, such as the upgrade of 3rd and construction of 4th generation synchrotrons, X-ray ptychography experienced explosive development and reached single-digit nm resolution. However, up to now, the ratio between the field of view and resolution for X-ray ptychography is in the range of 100 - 1000; thus, a compromise is needed since it is not typically feasible to scan large samples with high resolution, and on a short timescale; this directly affects the representativity of many studies. The acquisition speed in ptychography is ultimately limited by the amount of coherent photons in the incident beam. Thus, using an incoherent fraction of the beam can greatly increase the imaging speed. This approach is successfully used in multibeam ptychography (MBP), where multiple parallel beams irradiate the sample (Fig.1); the imaged area then is expanded by the number of beams used in irradiation. This can expand the domain of X-ray ptychography to larger samples or more rapid measurements compared to conventional single-beam imaging. MBP with hard X-rays has been previously demonstrated in a limited regime with up to three parallel beams and energies below 10 keV [1].
In the present work, we have developed and manufactured tailored lens tower arrays of 12 compound doubly concave lens towers [2] equipped with unique phase coding plates for creating diverse multiple parallel beams at energies above 13 keV. Recent advances in 3D laser nanolithography enabled achieving an unprecedented aspect ratio of the lens towers of more than 100:1. In the imaging experiments, we have demonstrated the application of MBP in various conditions and with different real-life samples: a Siemens star test pattern, a porous Ni/Al2O3 catalyst, a microchip (Fig.2), and gold nano-crystal clusters.
rucially, the performed reconstructions achieved the same spatial resolutions as conventional single beam ptychography reconstructions using similar experimental parameters. As our work demonstrates, high-resolution ptychographic imaging is no longer limited to small samples or with substantial subsampling of larger samples. These results open the perspective towards high-throughput tomographic imaging of thick samples with ptychography, which currently is not feasible due to the X-ray beam's very low coherent fraction at higher energies (> 20 keV).
References
[1] M. Lyubomirskiy, et al., Sci. Rep. 12, 6203 (2022)
[2] M. Lyubomirskiy, et al., Opt. Express 27(5) (2019)

I plan to submit also conference proceedings

No

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