Rotation-free holographic imaging with extended arc reference

Pengfei Lan, Eiji J. Takahashi Katsumi Midorikawa

Extreme Photonics Research Group, RIKEN Advanced Science Institute

Imaging of the constructs of the samples is of fundamental importance for a wide range of investigations in material, biological and optical sciences. The recent development of coherent x-ray sources based on synchrotron, free electron laser and high harmonic generation provide us a powerful tool for high-resolution imaging. We have also developed the table-top high-power high harmonic x-ray sources in our laboratory. Nevertheless, compared with the visible and near-infrared lights, the high-quality optical lenses and mirrors are quite scarce in the x-ray region. This has stimulated an increasing interest to develop the lensless imaging technique.

Coherent diffractive imaging (CDI) is one recently developed lensless imaging technique. The great advantage of CDI is that the resolution is, in principle, only limited by the illuminating wavelength. Therefore, very high resolution is possibly realized using the x-ray sources. Nevertheless, we have to face the difficulty of the convergence of phase-retrieval algorithms, which is very time consuming.

Fourier transform holography is another simple and high-resolution lensless imaging technique. Conventionally, a pinhole is utilized as reference. The optical system of this approach is quite simple and has been successfully utilized in many applications. The drawback lies in the low visibility of the interference fringe due to the weak reference wave coming through the pinhole. A recently developed technique, called holography with extended reference by autocorrelation linear differential operation (HERALDO), has significantly alleviated this problem by taking an extended slit or polygonal reference instead of the pinhole. However, the resolution of HERALDO is limited by the sharpness of the edge of the reference. Moreover, HERALDO requires a priori knowledge of the orientation angle of the corner or slit reference. It is not so easy for accurately determine the orientation angle of the sample, especially for the micro samples.

To overcome these problems, we have proposed a rotation-free approach of holography by using an extended arc reference, which is called ARC-HERALDO. We have also developed a two-step algorithm to retrieve the sample without a prior knowledge of the information of the sample and reference. More importantly, this scheme enables us to overcome the resolution limits introduced by the reference and optical system. Therefore it promises to achieve the diffraction-limited resolution. Also high contrast interference fringe can be recorded. We have demonstrated our scheme using a visible light of 532-nm laser. The designed sample has been successfully reconstructed from the diffractive pattern without a priori knowledge of the information of the sample and reference. It can be straightforwardly extended to the short wavelength region, where a high resolution is expected to be obtained. Because the x-ray light is invisible, our rotation-free scheme allows us to easily align the optical beam and sample. It is more attractive for the applications of imaging the microsample with x-ray lights.

To realize high resolution imaging, we have developed the high-power high harmonic x-ray sources and imaging system for CDI and also our ARC-HERALDO schemes. By using our energy-scaling method, the output energy of our x-ray source can be achieved to 1 microjoule and 90 nanojoule at 30 nm and 13 nm, respectively. Also, we have designed and successfully fabricated the 3-micrometer-size sample with electron beam lithography method. The sample contains “R” pattern and a reference pinhole or slit. The width of the slit is 100 nm. By using our high harmonic x-ray source, we can expect a resolution less than 100 nm. Now we are performing this experiment to reconstruct the image of our sample with HERALDO and CDI methods.