Type of presentation: Oral

IT-11-O-2383 Coherent imaging beyond detector area and Abbe limit, towards atomic resolution

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In a typical imaging experiment, data analysis relies on the recorded data during the experiment. In coherent imaging, this could be a hologram or a diffraction pattern obtained with light, electrons, X-rays, or any other type of radiation with wave nature. The achievable resolution is determined by the numerical aperture of the experimental setup limited by the size of the detector area.

We present a method that allows extrapolation of an experimental record beyond the area detected during the experiment by using intrinsic wave properties, namely their continuity in space. The amplitudes of the scattered waves are mapped onto the detector area and allow retrieval of the phase distribution. Once the complex-valued distribution of the scattered waves are retrieved, we extrapolate them to the full space extend, far beyond the detector area. As a result, the object reconstructed from such extrapolated interference pattern exhibit a higher resolution than provided by the initial experimental record [1-2]. The most attractive feature of our technique is that it does not require a new experiment as it can be applied to an already existing experimental record. The interference pattern can numerically be post-extrapolated to the full 2π hemi-sphere leaving the wavelength as the only resolution limiting factor.

An example is shown in Fig. 1, where a small section of a noisy interference pattern created by two point sources displaying less than three interference fringes is extrapolated to a much larger interference pattern. As a result, the two point sources can be resolved in the reconstruction. Fig. 2-3 show application of the technique to experimental optical in-line holograms and diffraction patterns.

The post-extrapolation technique is especially interesting when applied to electron or X-ray interference patterns as it can reveal atomic resolution from low-resolution images. Moreover, the extrapolation can also be applied to crystalline structures where diffraction patterns exhibit distinct Bragg peaks, such as graphene, see Fig.4. Diffraction patterns of graphene [3], could be extrapolated to reveal higher-order Bragg peaks and achieve enhanced resolution in the reconstruction, as shown in Fig.4.

We will present the application of this extrapolation method towards holograms and diffraction patterns of both, non-crystalline and crystalline structures, demonstrating its application for different types of waves: electrons, X-rays and THz waves, and we will also address the possibility of three-dimensional extrapolation.

1. Latychevskaia, T. and H.-W. Fink, Applied Physics Letters, 2013. 103(20): p. 204105.
2. Latychevskaia, T. and H.-W. Fink, Optics Express, 2013. 21(6): p. 7726-7733
3. Longchamp, J.-N., et al., Phys. Rev. Lett., 2013. 110(25): p. 255501.

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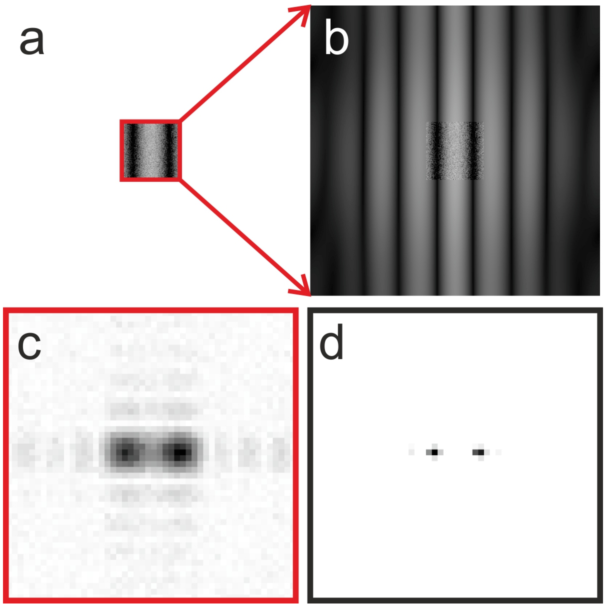

Fig. 1: Fig.1. Extrapolation of an interference pattern. (a) Fraction of an interference pattern created by two point-scatterers. (b) Extrapolated interference pattern. (c) and (d): Image of two point sources reconstructed from (c) the fraction of the diffraction pattern and (d) from the extrapolated interference pattern [1].

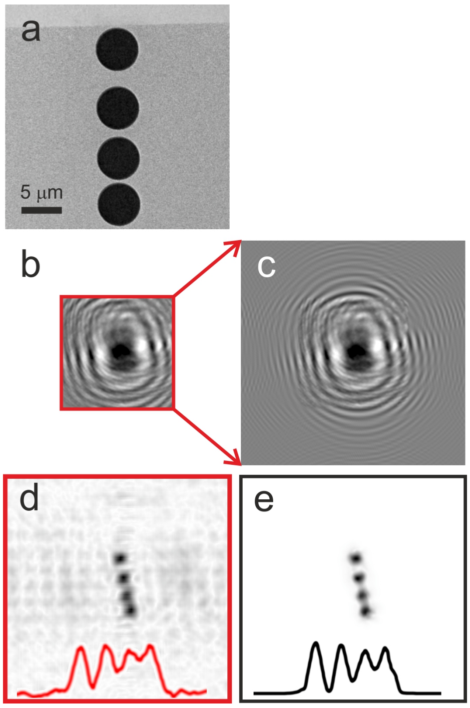

Fig. 2: Fig.2. Extrapolation of an in-line hologram. (a) Scanning electron micrograph of the sample and (b) its experimental optical hologram. (c) Extrapolated hologram. (d) and (e): Object reconstruction from hologram (b) and the extrapolated hologram (c), respectively. The insets shows the intensity profiles [2].

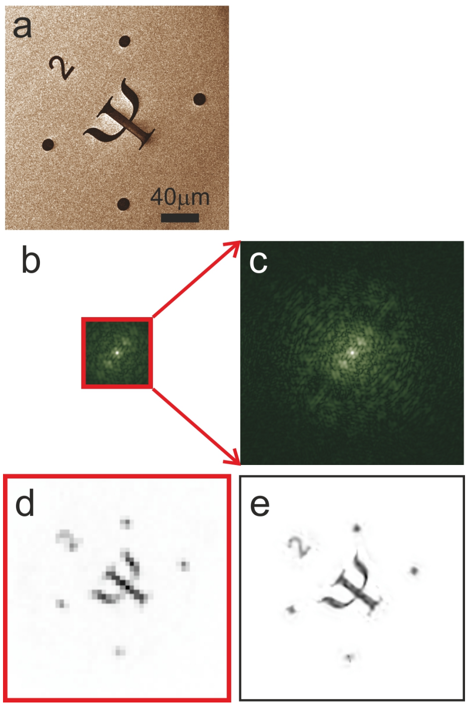

Fig. 3: Fig.3. Extrapolation of a diffraction pattern. (a) Scanning electron micrograph of the sample. (b) Piece of its optical diffraction pattern. (c) Extrapolated diffraction pattern. Reconstructions of the sample obtained from (d) the piece of diffraction pattern and (e), the extrapolated diffraction pattern [1].

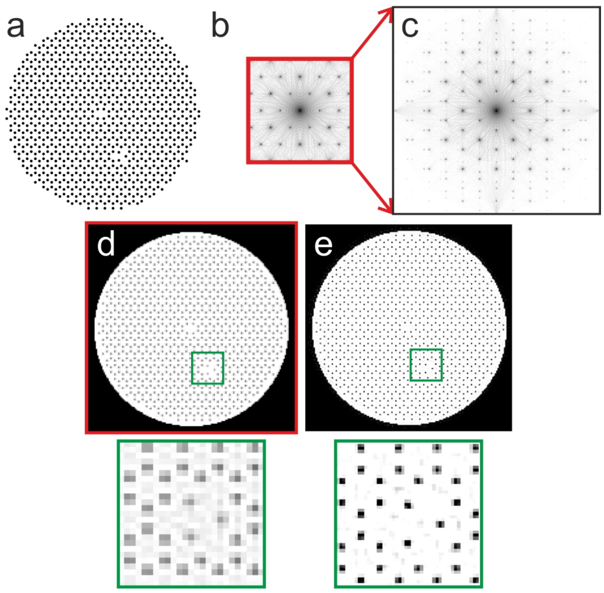

Fig. 4: Fig.4. Extrapolation of a simulated diffraction pattern of a crystalline structure. (a) Graphene patch containing 1003 carbon atoms with two divacancies and (b) its diffraction pattern. (c) Extrapolated diffraction pattern. (d) and (e): Reconstructions of the sample obtained from (b) and (c), respectively.