Reconstruction of complex-amplitude from quantized diffraction patterns by one-shot ptychography

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1. Introduction

Ptychography is a coherent imaging technique that has been applied in x-ray, optical, electric domains [1]. By this method, the complex-amplitude of an object is retrieved from a set of diffraction patterns obtained by localized illuminating probes, which are overlapped with their neighbors. Ptychography generally requires a long time to record necessary diffraction patterns for scanning the object plane with a probe. Therefore, this technique is difficult to apply to moving objects. To solve the problem, we have proposed a one-shot ptychography in which diffraction patterns are captured at a moment using polarization and defocus variations [2]. In the implementation, the intensities of the diffraction patterns are quantized at an image sensor and also degraded by a noise. In this report, we show simulation results about the capability in reconstruction of complex-amplitude and robustness to the noise.

2. One-shot ptychography

Figure 1 shows an assumed optical setup of one-shot ptychography. A coherent illumination beam is separated into two orthogonal linearly-polarized beams with polarizing beam splitters (PBSs), and they irradiate a complex-valued object at the front focal plane of a lens (focal length; f) with overlapping. In the capturing, the light is divided into four paths, and diffraction patterns in the individual paths are recorded using CCDs at the back focal plane and the defocus plane distant from the focal plane by Δ. Thus, four diffraction patterns with different pairs of polarizations (horizontal and vertical) and recording positions (in-focus and defocus) are captured. The complex-amplitude of the object is retrieved from these signals using a ptychographic iterative engine (PIE) [3].

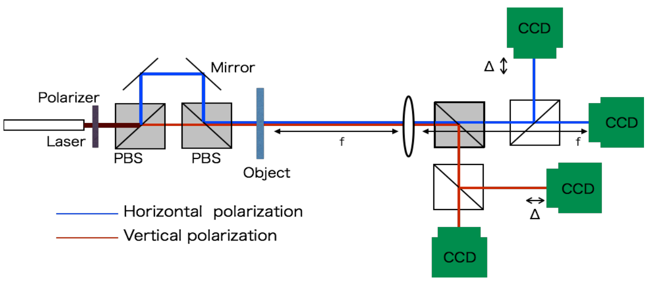

Fig. 1. Optical setup of one-shot ptychography

3. Simulation results

We performed computer simulation to evaluate one-shot ptychography with the PIE. It is assumed that f = 80 mm, wavelength λ = 632.8 nm, and Δ = 10 mm. Each CCD has 1024 × 1024 pixels of 7.4 μm × 7.4 μm size with a 16-bit dynamic range. Figure 2 shows the simulation results of reconstructing the complex-amplitude of an object. Figures 2(a) and (b) are the intensity and phase of the object, respectively. When the two probes shown in Fig.2(c) illuminate the object in the highlighted region shown in Fig. 2(d), the reconstructed intensity and phase of the object by one-shot ptychography are shown in Figs. 2(e) and (f). The result shows the proposed method can retrieve the complex-amplitude from diffraction patterns quantized by the 16-bit image sensor. The root mean square error (RMSE) between the measured and calculated diffraction patterns are used to evaluate the robustness for the noise. Figure 2(g) shows RMSE values after 1500 iterations on the random noise, which arises in the capturing process. This result shows the one-shot ptychography system has tolerance for about 60 dB noise.

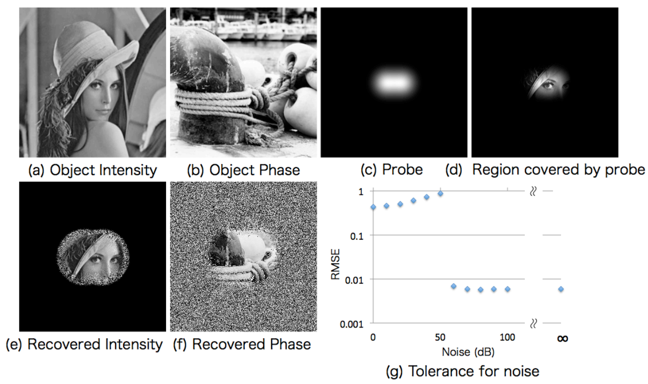

Fig. 2. Simulation results of one-shot ptychography

4. Conclusion

We investigated one-shot ptychography capable of measuring complex-amplitude of a moving object by recording four diffraction patterns in different conditions with defocus and polarization at a time. Simulation results demonstrate that the complex-amplitude of an object can be reconstructed from quantized diffraction patterns with tolerance for about 60 dB noise. Based on the results we are constructing an optical system for observing a moving object, such a live cell.

References

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[3] J. M. Rodenburg *et al.*, Appl. Phys. Lett., Vol. 85, pp. 4795-4797 (2004).