Supplemental Document

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Compressive motionless optical scanning holography: supplement

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Compressive motionless optical scanning holography: Supplemental Document

This document provides supplementary information for "Compressive motionless optical scanning holography". The CMOSH (Compressive motionless optical scanning holography) method attains layer resolve through compressed sensing (CS) principles that enable 3D reconstruction from a single holographic capture. The qualitative analysis of this technology has been demonstrated through numerical simulations in Fig. 2 (i) and optical experiments in Fig. 4 of the original text. This supplementary document mainly focuses on quantitatively discussing the depth resolution of CMOSH technology, sequence depth.

A. Supplementary Note 1. Simulation of depth resolution in CMOSH layer resolve.

In principle, without considering defocusing artifacts and twin interference, the depth resolution of MOSH mainly depends on the number of samples and sampling interval of the hologram. But the main purpose of CMOSH is to reconstruct the information of axially compressed objects without artifacts. In this case, the axial sparsity of the object, as well as the sparsity of each layer of the object itself, and the accuracy of the algorithm reconstruction will all affect the layer resolution of CMOSH. Given the theoretical challenges in quantifying these parameters, numerical simulations were conducted to empirically determine resolution thresholds.

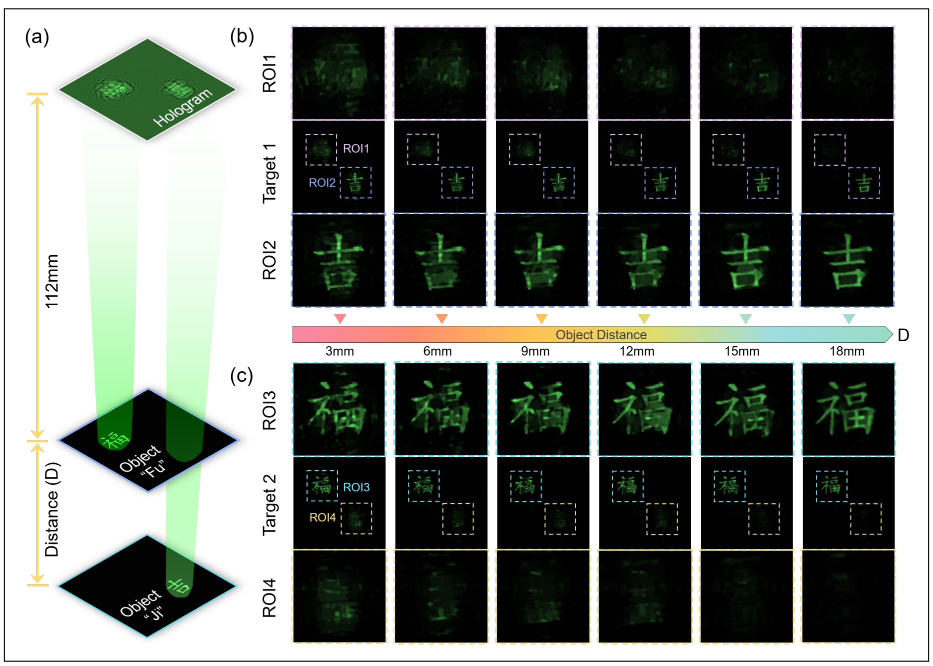

Fig. S1. Numerical simulation of BP and CS reconstruction in different distance between two objects. (a) Schematic of a multi-layer object with hologram. (b) The CS reconstruction results of object "Ji" at different distances. (c) The CS reconstruction results of object "Fu" at different distances. (Depth Range: 3mm, 6mm, 9mm, 12mm, 5mm, 18mm.).

Our simulation employed optical parameters matching experimental conditions (21.6mm × 21.6mm cross-section, 270 × 270 pixels, 532nm wavelength). To streamline the presentation content, this study selected representative numerical reconstruction results for analysis. Fig. S1 (a) shows the distance relationship between the object and the hologram, by changing the parameter distance (D) to obtain different numerical reconstruction results. In Fig. S1 (b), (c) objects were numerically positioned at incremental distances from 3mm to 18mm (increment 3mm). Among them, ROI1 and ROI4 show the defocused artifact area, while ROI2 and ROI3 show the object reconstruction image area. The reconstruction analysis reveals three distinct reconstruction states:

- **Sub-threshold regime** (3-9mm distance): While basic reconstruction remains feasible, significant defocus artifacts emerge from twin-image interference and adjacent object noise superposition. This results in compromised information integrity, rendering objects indistinguishable.

- **Transition regime** (12mm distance): When the spacing increases to 12 mm, artifact intensity shows marked reduction, though not complete elimination.

- **Optimal regime** (15-18mm distance): Near-complete artifact suppression enables clear object differentiation, and the integrity of the reconstructed image gradually increases with the increase of distance.

Given that the reconstruction results of the Transition regime (12mm distance) are significantly different from those of the Sub threshold regime (3-9mm distance), and the overall trend is consistent with the Optimal regime (15-18mm distance). So when using the hologram parameters and objects used in this article, 12mm is considered as the threshold for depth resolution. It should be emphasized that the layer resolution of the method proposed in this article is affected by multiple parameters: the number of holographic sampling points, sampling intervals, and sparsity of object information. Therefore, for objects with different sparse characteristics, the resolution threshold may shift. However, by increasing the sampling density of holograms and optimizing the sampling interval, the resolution of layer resolution can be effectively improved.

B. Supplementary Note 2. Simulation of sequence depth in CMOSH layer resolve.

In CMOSH, sequence depth is an important indicator for evaluating the axial compression capacity of holographic information. Based on the parameter setting of the theoretical imaging depth range of 112-158 mm corresponds to a sequence depth of approximately 4 frames per acquisition (i.e. sequence depth=range/depth resolution). It should be clarified that, with fixed holographic resolution and sample size, the vertical and horizontal distribution of the filling object will increase the overall information content, thereby affecting the sequence depth performance.

Numerical simulation of sequence depth also employs optical parameters matching experimental conditions (21.6mm $\times$ 21.6mm cross-section, 270 $\times$ 270 pixels, 532nm wavelength), to maintain consistency in conclusions.

Figure S2 (a) shows the distance relationship between the four layers of objects and the hologram, while the numerical reconstruction in Fig. S2 (b) corresponds to the back-propagation (BP) and compressed sensing (CS) reconstruction at the depths of the four objects. The object distance used for numerical reconstruction is a threshold of 12mm. Compared to the BP reconstruction results, although the CS reconstruction results have significantly improved, they still cannot avoid the loss of object information and residual de-focus artifacts. The overall effect is close to the 9mm situation shown in Fig. S1, approaching the resolution threshold. We believe that such minor deterioration is acceptable when faced with deep reuse of multiple objects.

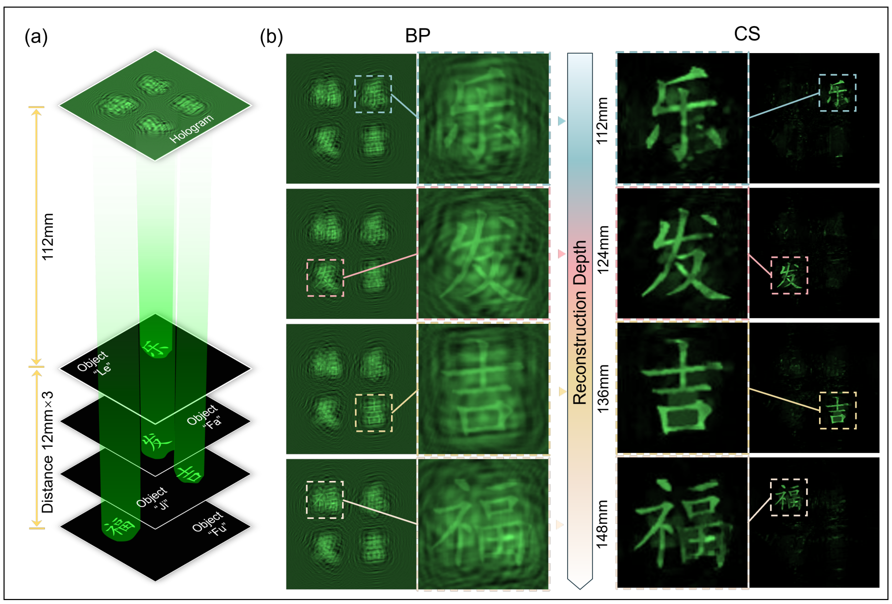

Fig. S2. Numerical simulation of four frames per acquisition for layer resolve. (a) Schematic of a four layers object with hologram. (b) The reconstruction results of four layers of objects located at different axial positions, with a spacing of 12mm between adjacent layers.