Experimental Investigation of Lensless Fourier Transform Hologram Multiple Images

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Abstract: In order to solve the problem of multiple reconstructed images in digital hologram, the lensless Fourier transform hologram is taken as an example for comparative experiment. When the same experimental light path and recording conditions are used and the only variable is the sensitive element, the reconstructed image of CCD does not appear multiple images, while the reconstructed image of CMOS appears multiple images. In order to determine the reliability of the experiment, two correlated beams were imaged with the same optical path. The experimental phenomenon is still that there are multiple images in CMOS, but not in CCD. The working principle of CCD and CMOS in digital holography experiment is different.

1. Introduction
Holography was first proposed by British physicist D. Gabor in 1947. In the 1950s, scientists such as Rogers further enriched the wavefront reconstruction theory. In 1960, the appearance of laser also opened the way for the rapid development of holography. With the continuous development of digital optical imaging devices and the popularization of computer technology, digital holography has developed rapidly and has been widely used in many fields such as three-dimensional shape measurement [1-3], vibration measurement, holographic microscopy, etc. [4-7] Currently, the most commonly used photosensitive elements are mainly CCD and CMOS. Since CCD (Charge Coupled Device) was successfully developed in Bell Laboratories in 1969, after decades of development, the technology has become more mature and the application field has been expanding; CMOS (Complementary Metal Oxide Semiconductor) that was born in 1998 as a kind of the new image sensing technology has broad development and application prospects. Both types of photosensitive elements use photosensitive diodes for photoelectric conversion to convert light signals into electrical signals. They compete and complement each other in terms of price, power consumption, image quality, resolution, and sensitivity. The working principle of the two is not essential difference. The author discovered the phenomenon of multiple reconstructed images in the digital holography experiment. This article takes lensless Fourier transform holography as an example to conduct experimental research, hoping to get the reasons for the multiple reconstructed images.

2. Experiment
Figure 1 shows a schematic diagram of the experimental device. The laser light emitted by the laser is reflected by the half mirror BL1, illuminates the object to be measured under the action of the beam expansion of the microscope objective, and is reflected on the half mirror BL2; After the light passing through the half mirror BL1 is reflected once, it is also expanded under the action of the microscope objective lens and passes through the half mirror BL2. Finally, the two beams of light interfere on the

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photosensitive element to form a hologram. The object is a mask with 3 holes, and the imaging area is the central area of the mask.

In a dark environment, we use this light path diagram to carry out an experiment of lensless fourier transform hologram reconstruction. In the experiment, select the appropriate reference light intensity, change the distance between the object and the camera, and adjust the inclination of the large half mirror to obtain a clear and reproduced image. Under the same optical path and recording conditions, CCD and CMOS were used to record the hologram.

The light intensity distribution on the photosensitive element after the interference of the object light and the reference light is

\[ I(x, y) = |O(x, y) + R(x, y)|^2 \]

We expand the formula (1) to get

\[ I(x, y) = |O(x, y)|^2 + |R(x, y)|^2 + O(x, y)R^*(x, y) + O^*(x, y)R(x, y) \]

The object-light information is in the third term of formula (2).

After performing the same fourier transform on the hologram recorded by CCD and CMOS, a reproduced image can be obtained. The recorded image is shown in Figure 2.
Judging from the results of the reproduced image, both CCD and CMOS can reproduce the image of the object. The CCD reproduced image is larger than the CMOS reproduced image. CCD can get a clearer reproduced image, with high image quality, rich detailed information, and noise in the center and on both sides. The real image and the conjugate image are centrally symmetric about the center point. The image obtained by CMOS is blurry. The image quality is poor and part of the detail information is submerged by noise. Multiple images are produced. It can be seen that the two object images in the middle are a pair, the left and right sides are a pair, and the upper and lower sides are a pair.

In summary, the difference between the two is that the reproduced image obtained is divided into three parts: zero-order, real image and conjugate image; the difference is that the image formed by CMOS contains multiple images, which leads to the resolution of the image. Reduction, information redundancy, and poor reproduction effect.

Comparing the experimental phenomenon of the black gate effect \cite{8-9}, this article preliminarily judges that CMOS has an extra structure similar to "black gate" than CCD, which will produce this kind of experimental phenomenon similar to "black gate effect". In order to verify the reliability of the judgment, the two beams of coherent light were imaged \cite{10}, and the experimental results obtained are shown in Figure 3.
Fig. 3 Hologram, reconstructed image. (a) hologram of CCD; (b) hologram of CMOS; (c) reconstructed image of CCD; (d) reconstructed image of CMOS.

3. Conclusion
This article uses CCD and CMOS as the photosensitive element, respectively, under the condition that the optical path and recording conditions are exactly the same. It is found that there are multiple images in the reproduced image of CMOS, but there is no multiple image in the reproduced image of CCD. Explain that the difference of the photosensitive element determines whether there is multiple images, and further conclude that the difference in the structure of the two causes the CMOS to have multiple images but the CCD does not have multiple images. But the quantitative relationship among them needs further research. The results and analysis of this experiment provide a reference for the future optimization and development of the two types of CCD and CMOS photosensitive elements, and also confirm the difference between the two in digital holographic imaging.

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