3-D Display: Electro-holography Based

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Abstract

The idea of displaying hologram electronically has been existed since mid 1960th. But it is still in the beginning stage due to the lacks of proper means of displaying and recording, which will bear the large amount of data contained in the hologram though holographic video and digital holography have demonstrated the possibility of displaying and photographing hologram electronically. It is expected that holography based 3 dimensional imaging system will be introduced much later than that on multiview 3 dimensional imaging methods which are being developed to generate more realistic and natural image than high definition plane images.

Introduction

Ideal 3 dimensional (3-D) image is a magnified/demagnified replica image of an object to be displayed, to fit into a given display panel. Hence the image has a real volume with occlusions and works for all four mechanisms of human's depth perception. No 3-D image method known so far, except holography can display this kind image. Holography is a photographic method which can record and reconstruct 3-D images by recording and reconstructing wavefronts reflected from object(s). The typical materials for recording the wavefronts are photosensitive media [1]. The photosensitive media can record object(s) simultaneously or in a sequence [2]. Holograms of varying scenes are also recorded on holographic films and the reconstructed images from the holograms are displayed on a retro-directive screen [3] or can be magnified with a projection objective on a screen with a spherical mirror property [4]. These holograms can be viewed as a movie but difficulties in sampling fringe data in a hologram are deterring electronic display of holograms. Recording holograms with a CCD camera as in digital holography [5,6,7] allows only recording on-axis or near on-axis hologram due to its resolution limit. The data recorded is only the amplitude portion of fringes. With this information, direct display of the recorded hologram will not produce clear object image. The on-axis hologram brings extra problems of eliminating the 0th order diffracted beam and one of the reconstructed images. Hence digital holography is mostly concerned with how to record objects and reconstruct images without the 0th order beam and one of the reconstructed images. Optical scanning holography is another method of recording holograms electronically. In this method, the object is illuminated with a time-varying interference pattern generated by crossing a frequency modulated spherical wave with a plane wave [8]. The object information is obtained from the photodiode while scanning the object with the pattern. Both digital and scanning holographies have the advantage of recording holograms electronically, but their image qualities are not enough for display. Compared with conventional holography, electro-holography is mainly concerned with how to display a hologram using the currently available display devices without image quality deterioration. The transmission and display of the hologram, and calculation of the information content in transmission-type holograms for TV systems reported in the mid 1960s [9,10], and the hologram recorded by a CCD camera is displayed through the AOM (Acousto-Optic Modulator) [11], but hologram display is still in the early stage due to the huge amount of data contained in a hologram and means to display the data amount. Displaying a hologram on the currently available means of display such as an array of LCDs (Liquid Crystal Displays)[12], DMD (Digital Micro-mirror Device)[13] and AOM had already been demonstrated, but they used mostly CGH(Computer Generated Holograms) to minimize the data amount, and eliminate the 0^{th} order diffracted beam and one of the reconstructed images. Due to these reasons, the electro-holography system is mainly concerned with the display aspect of the hologram with use of a CGH. This is the reason why the name holographic video is used for the electro-holography system.

Holographic Video

Holographic video systems have been developed for the real time display of holographic images by electro-optical means. But, the large amount of data involved with holography practically shut off the efforts of further research on it until the late 1980s [14]. The development of spatial light modulators as a high-resolution display device and a high speed computer for the calculation of the CGH helped to resume the holographic TV research. The data amount contained in a hologram of size $10 \times 10\ cm^2$ is more than 3.3×10^{11} bytes when the hologram is made with a He-Ne laser with wavelength 0.6328 μm at a 30° beam angle [15]. If the hologram is displayed at a 30Hz frame rate, the total data rate will reach 10^{12} *bytes/sec*. Even the beam angle is reduced down to 2° which barely allows the separation of the 0-order diffracted beam from the first order, the data rate, 4.5×10^9 *bytes/sec* is still too much for the bandwidth of the TeO_2 AOM. This high data amount contained in a given area of a hologram and the lack of available high resolution data sampling methods for the hologram, limited the research only to the subjects of optimizing the amount of holographic data required and properly displaying the data for the faithful reconstruction of the original image, and to find proper means of displaying holograms in real time. To make the data amount in the hologram a displayable size and at the same time find a way of increasing the bandwidth of the AOM effectively, the vertical parallax in the hologram is suppressed by calculating the interference among the rays coming from object points along the horizontal direction and making a multi-channel operation. Fig. 1 graphically demonstrates calculating CGH with horizontal parallax only (HPO). The hologram and the object is divided to have the same number of horizontal sections, then a line hologram is calculated with its corresponding object section.

A multi-channel AOM with vertically arranged parallel channels has been utilized in the holographic video system introduced by MIT [16]. This multi-channel AOM requires the assistance of an AOD (Acousto-Optic Deflector) or moving optics like a polygon mirror and an array of optical scanner to suppress holographic data flow in the AOM as an acoustic wave to achieve the stationary reconstructed images and for effectively multiplying its aperture length to display holograms with a desired width. The use of a Bragg cell with a polygon mirror to display image had been known as Scophony System [17].

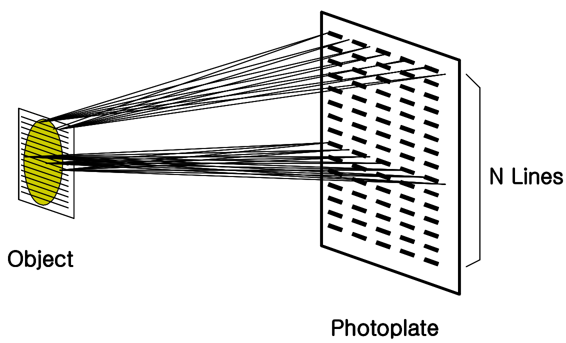

Fig. 1 Graphic illustration of calculating HPO hologram

The mirror can be replaced by an AOD[18]. The AOD is more convenient to use than the mirror because the beam deflection angle can be continuously changed by varying frequency of the applied voltage. But to obtain the required amount of suppression, the distance between AOD and image becomes too large to make a compact system. Fig. 2 shows the principle of suppressing image flow in AOM by use of the AOD.

Using the moving optics make possible to make the system more compact but it is cumbersome for many occasions. To eliminate the moving optics in the MIT system, a pulse laser operating at a 50kHz rate with pulse width of 200ns, a still polygon mirror and a multi-channel AOM was combined [19].

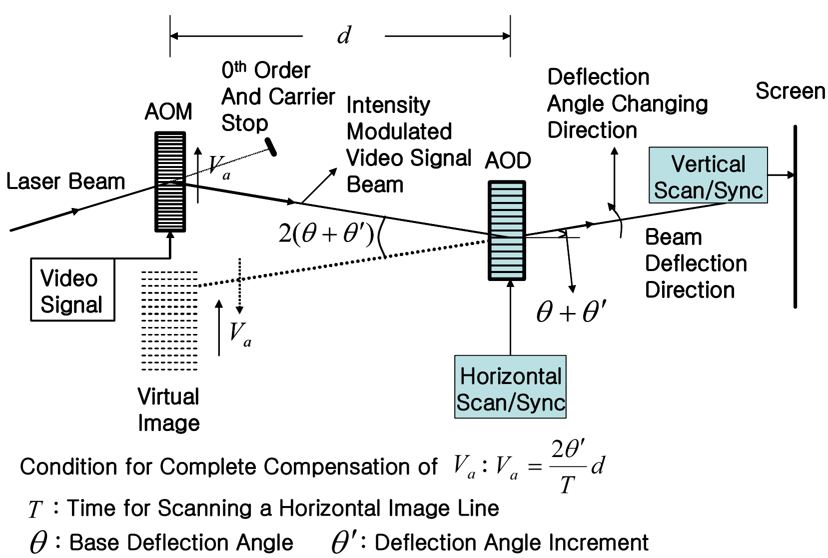

Fig. 2 The principle of suppressing image flow in AOM by use of the AOD