Holovideo for everyone: a low-cost holovideo monitor

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Abstract. This work presents an architecture for a relatively low-cost, pc-driven holovideo monitor. The geometry uses minimal optics and is built to host a multi-channel acousto-optic modulator that can be driven by up-converted VGA signals. The display’s target specifications include a standard vertical resolution (480 lines) output driven by an 18 channel acousto-optic modulator, 30Hz refresh-rate and multiple color operation. This paper reports early tests of this geometry with a single acousto-optic channel. The goal is to create a small but functional holographic display that can be readily replicated, easily driven and provide basic monitor functionality with a bill of materials in the hundreds, rather than thousands, of dollars.

1. Introduction
The holography community has a great history of resourceful individuals making sophisticated equipment with inexpensive components [1][2]. In this tradition we present this simple, relatively inexpensive holovideo display that we hope will encourage broader participation in the application and development of holographic video.

Our goal is to make the most inexpensive display possible while trying to achieve a monitor-like functionality with the following parameters

- Bill of materials of less than $500 (not including laser light source(s))
- Image extent of approximately 10cm x 5cm or larger
- Vertical resolution greater than or equal to 480 lines, HPO (Horizontal Parallax Only)
- Viewing angle greater than 15 degrees
- Frame rate greater than or equal to 30 fps
- Ability to be driven from a commodity PC with a set of three gamer graphics cards

2. Background
In order to achieve our goals we decided to build a monitor based on the MIT Mark I holovideo geometry[3]. This geometry is the most simple of the MIT architectures and allows for some flexibility in the design to allow for the substitution of low-cost parts.
2.1. Mark I Optical Path
The holographic image is created in the Mark I by descanning the aperture of the acousto-optic modulator, demagnifying the resulting long holographic line, and then vertically scanning the demagnified line to build up an image with multiple lines stacked vertically (figure 1).

2.2. Key Mathematical Relations

2.2.1. The Bandwidth Budget
The analog nature of the Mark I system allows fluid redistribution of display bandwidth between image extent, view angle and frame rate. The relationship between bandwidth and system parameters is given below:

\[ \text{bandwidth} \propto \frac{\text{extent} \times \text{viewangle} \times \text{resolution} \times \text{ framerate}}{\lambda} \]  

(1)

With increased temporal bandwidth (pixels/sec) we can either increase the display extent (i.e. the display width), the view angle, the vertical resolution (lines per frame) and the frames per second or decrease the illumination wavelength, \( \lambda \).

2.2.2. The Fourier Plane
The Fourier plane lies at the surface of the polygon and dictates the minimum size of the polygon facet or the maximum focal length of the transform lens[3] (equation 2).

\[ \Delta x \approx \lambda f_1 \frac{\Delta \nu}{V} \]  

(2)

In this equation, \( \Delta x \) is the size of the Fourier plane, \( \lambda \) is the wavelength of illumination light, \( f_1 \) is the focal length of the transform lens, \( \Delta \nu \) is the RF bandwidth of the AOM signal and, \( V \), is the velocity of the AOM pattern. The approximation is accurate for small angles and will suffice for the AOM which only sweeps through a range of a few degrees.

The size of the Fourier plane is also related to the size of the polygon sweep angle, \( \Omega \), and the product of the image width, \( d \), and the image view-angle, \( \theta \)[3] (equation 3).

\[ \Delta x = \frac{d \sin \theta}{2 \Omega} \]  

(3)
3. The Holovideo Monitor

Our holovideo monitor diverges from the Mark I in that it uses a smaller polygon scanner[4][5], the galvo follows the polygon instead of preceeding it, and there is a parabolic reflector instead of a lens at the output (see figures 2 and 3).

3.1.1. **Smaller Polygon**--The primary cost savings in our design is the choice of a commodity polygon scanner. The critical dimension of the facet is similar to that of the polygon scanner in the Mark I display so besides being smaller overall, the polygon also sweeps out a larger angle which, when coupled with a low f-number reflective optic, should allow for an increase in either display size and/or view angle (see equation 3).

3.1.2. **Reflective Optic**--The output optic is a parabolic reflector. This optic determines the size and output image of the display. A more powerful reflector will result in a smaller image with a wider view angle; a less powerful reflector will produce a larger image with the narrower view-zone.

3.1.3. **Custom AOM**--A bulk wave AOM is used in this paper to verify the monitor’s design but bulk AOMs are expensive—several times the target cost of the display—and won’t be used in the final 18 channel instantiation of the display (each channel provides 26 lines in the holographic image for a total of 480 lines using an 18 channel device). We are currently developing modulators that will provide 18 or more channels of modulated output without appreciably increasing the cost of the display. These devices will be described fully in a subsequent publication.

3.1.4. **Chassis**--Folded, waterjet-cut aluminum is used to create a structure that is both rigid and light. Extruded aluminum provides mounting locations for internal optics.

3.1.5. **Electrical system**—The holographic video monitor is driven by a commodity PC with three gen-locked, dual-head graphics cards. This bank of graphics cards provides 18 video signals (three color signals times six VGA outputs) which, in the final display, will each drive one of 18 AOM channels.
4. Results

4.1. Basic system verification and assembly --The optical and electrical breadboard setup confirmed that the system was descanning the video signal (figure 5). The optics and electronics were then placed into the monitor form factor (figure 6).

![Figure 5](image1.png)

**Figure 5.** Breadboard prototyped display (left) and scanned output (right) to verify video descanning. The gaps in the pattern on the right are the video h-blank intervals.

![Figure 6](image2.png)

**Figure 6.** Assembled monitor (diffuser removed).

4.2. Monitor Output

At the time of this writing we have produced a number of holographic stereograms which showcase the display’s ability to present images that vary with angle. Figure 7 shows three images, each projected at a different angle.
4.3. Parameters and bill of materials

**Table 1. Display Parameters**

| Parameter      | Design target | Actual to date |
|----------------|---------------|----------------|
| Size           | >10x5cm       | >10x3cm        |
| View Angle     | >15 degrees   | >10 degrees    |
| Resolution     | 480 (18 channels) | 26 (1 channel) |
| Frame Rate     | 30 frames/s   | 30 frames/s    |

**Table 2. Bill of materials for holographic video monitor**

| Part                        | Cost\(^a\) | Vendor                  |
|-----------------------------|------------|-------------------------|
| Polygon assembly            | $10.00     | Surplus Shed            |
| Vertical scanner            | $50.00\(^b\) | AJP Optics              |
| Parabolic reflector         | $15.00     | Ebay                    |
| Aluminium plate             | $40.00     | Admiral Metals          |
| Extruded Aluminium          | $20.00     | Ebay                    |
| Lens/mirrors                | $26.00     | Surplus Shed            |
| Boards/electronics          | ~$300.00   | Digikey/Advanced Circuits |

TOTAL: $461.00

\(^a\) These prices are approximate.

\(^b\) To achieve the parameters given in table 1 the vertical scanner must be refitted with a longer mirror.

5. Conclusion and future work

We have demonstrated early test images from a pc-driven holographic video monitor that is readily replicable and an order of magnitude lower in cost than earlier versions of this architecture. Next, we intend to maximize the display size, angle and resolution. This holographic monitor geometry, with relatively little modification, should be able to support a display output width approaching a maximum of 40 cm with a 10 degree viewzone (or 10 cm width with a 38 degree viewzone). Now that the geometry has been validated, we intend to replace the low bandwidth modulator with an inexpensive, high bandwidth modulator, of our own design, capable of providing a full vertical output resolution of 480 lines. With this new modulator in place we will have developed a low cost, standard resolution, holographic desktop monitor.
6. References

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