Single DMD time-multiplexed 64-views autostereoscopic 3D display

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ABSTRACT

Based on previous prototype of the Real time 3D holographic display developed last year, we developed a new concept of auto-stereoscopic multiview display (64 views), wide angle (90°) 3D full color display.
The display is based on a RGB laser light source illuminating a DMD (Discovery 4100 0,7") at 24.000 fps, an image deflection system made with an AOD (Acoustic Optic Deflector) driven by a piezo-electric transducer generating a variable standing acoustic wave on the crystal that acts as a phase grating. The DMD projects in fast sequence 64 point of view of the image on the crystal cube. Depending on the frequency of the standing wave, the input picture sent by the DMD is deflected in different angle of view. An holographic screen at a proper distance diffuse the rays in vertical direction (60°) and horizontally select (1°) only the rays directed to the observer. A telescope optical system will enlarge the image to the right dimension.
A VHDL firmware to render in real-time (16 ms) 64 views (16 bit 4:2:2) of a CAD model (obj, dxf or 3Ds) and depth-map encoded video images was developed into the resident Virtex5 FPGA of the Discovery 4100 SDK, thus eliminating the needs of image transfer and high speed links

Keywords: 3D display, DMD, integral display. Autostereoscopic, AOM, AOD, Holographic display,

1. INTRODUCTION

We have tested last year the possibility of the realization of a multiview display using a single DMD [1]. It is known that to have a good 3D auto-stereoscopic display using multiview (i.e. lenticular or barrier) is needed more than 32 views [2]. This is impractical today with present technology, as it means display with more than 64k horizontal pixels. An approach to solve the problem is to use multi-projection systems (Holografika et al.[3]), which are impracticable for dimension and cost. One of the solutions could be use of DMD as it's high frame rate (33.000 fps compared to the 120 fps of an LCD display) permits the so-called Time Multiplexed Display, that means the use of a single display which, in turns, display all the point of view of the scene taken each from different position.

These images are then sent to a scanning system, which redirects the image to the appropriate projecting lens system. The images, enlarged at full screen, are sent "from different directions" to a holographic screen which act as a vertical diffuser and horizontal image selector. This means that there are many points of view overlapped and coming from each projection lens and the screen is like an optical directional selector, so that each observer sees only the image that is directed to him. Obviously, as the angle of diffraction of the screen is about 1°, one eye of the observer will receive only one image and the other another image, giving so the sensation of a 3D image. Fig.1 is a simplified sketch of the system.

We have modified our first prototype to do a multiview projectione system. Instead of projectin "hololines" to create a seuqential image, we used a set of diverging lens (objective) which enrlarge and project the whole image onto the screen.

As each lens is of ½ " of diameter, the whole set is about 32" large thus projecting a point of view each separated of ½".

The magnification of the single lens is such that it projects an image of about 32" and directed to the center of the screen so that all the images averlap each other. In this way, each vertical line of the screen receives light from a 64 different position, each representing a differen point of view, like a moving slit looking a the whole scene.

The tests gave good results but it was very hard to set-up the system due to the precise positioning of the galvo scanner.We tried different method of scanning system and we movend onto directional light scanner.

We modified the first version of the system so that instead of projecting a sequence of lines, which are horintollay compressed pictures, the sistem will project onto screen a compleete sequence of enlarged image which are the points of views, as shown in fig. 2.

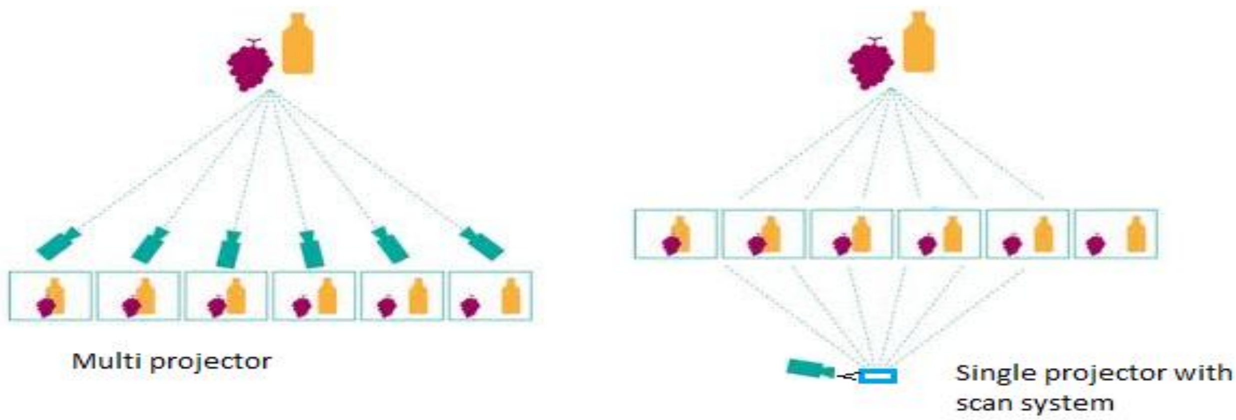


fig1 difference from multi projection and time multiplexed projection.

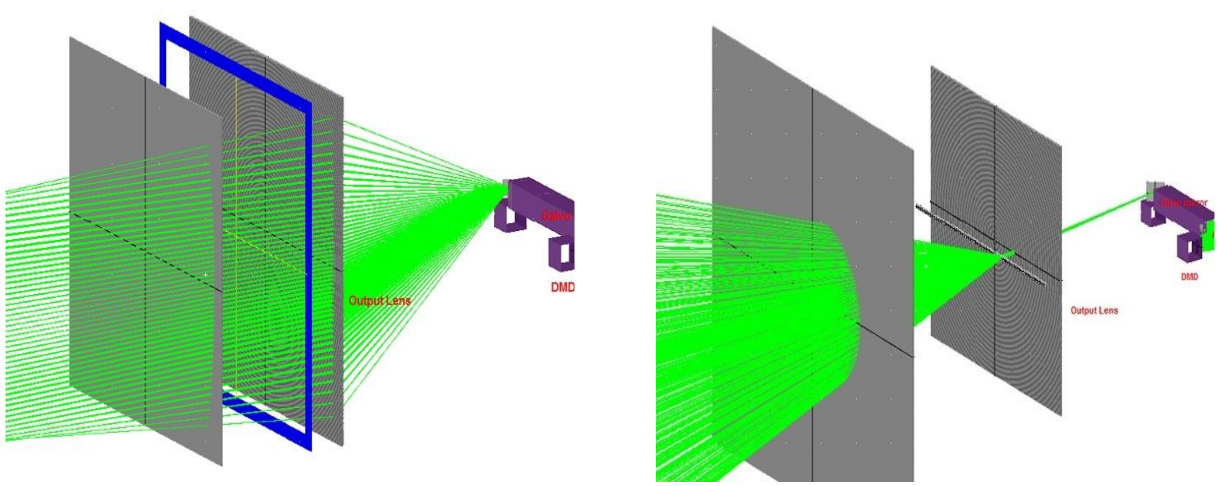


fig 2 difference from line projection and image projection

2. System overview

2.1 Scan system

Some easy considerations show that if we want a 64-point of view at 50Hz, we need a 64x50= 3,200 fps scan rate.

This is impractical for actual LCD display while for the DMD, being a digital device, i.e. it displays only 1 bit image, we have to multiply the scan rate to the 8 bit planes, which gives 25.560 fps, that a DMD can do, with some kind of amplitude modulation of the light. This means that we cannot modulate in PWM, as is normally done with standard projector, but we have to modulate the incident light that goes to the DMD in a way that each bit plane has it's proper light amplitude, i.e. 1,2,4,8,16,32,64,128 steps increment. This can be easily done if the light is generated from a device that can be controlled in amplitude in a fast time, like LED or Laser.

Some consideration must be done on the scanning system. There are many kind of scanner; some are based on a "moving mirror" like the well-known galvos or polygonal mirror[4], each one with some good things and obviously with some problem. Some other based on MEMS device, other based on crystal and the Acousto-opto effect. We have tested all the solution.

1) Galvo scanner:

The needing for the galvo are 2: small angle time and dimension of the mirror. As we have to scan 64 position at 30Hz, this gives a scan rate of 1920 fps and an image time of 520. µS. As the minimum time to load a complete 8 bit image on the DMD is 8x 40 =320 µS, there are only 200 µS to move the scanner to the next position, so the small angle constraints must be of this time[4]. This is a very small for actual galvo scanner as the minimum available is about 230 µS (it depends also of the size of the scan mirror). We made some special methods (patent pending) to combine the movement of the galvo with the load of the image, in order to use the complete time of 520 µS useful for "load and move". The real question is that the optical angle of scan is about 35° and this needs a special optics with very low FOV (we tested either pre or post scan lens) to project and focus a small image (about ½") focused at the seta of output projecting lenses, which are 32" wide.

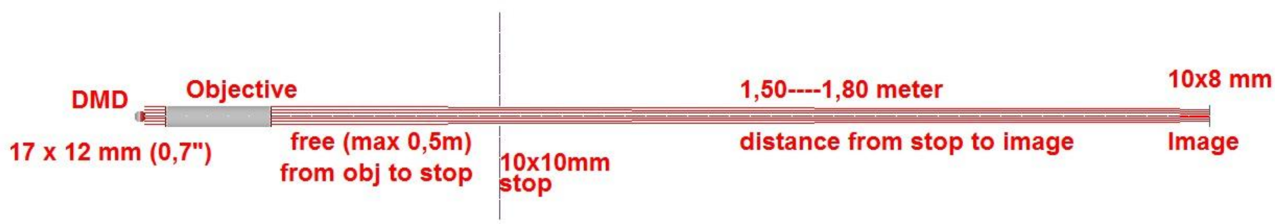


fig3 metrics for galvo scanner, the mirror is at stop position

2) Polygonal mirror

We used an 8 side polygonal mirror driven at 360 rpm. Each face of the polygon scans 64 1 bit image, a complete turn of the polygon scans the 8 bit plane of the image. As the polygon is continuously rotating, a special "pulse" light has to be sent to the DMD, to eliminate a blur on the image. This pulse duration is computed as a function the longitudinal speed of 1 pixel on the output projection lenses. In this way the duty cycle of the laser is 1/1024 for each image[5].

3) AOD

We tested different types of AOD[6] [7], but due to the very small angle of deflection (about 3°), they will need a complex optics to enlarge the angle or a very big object to image distance. This is under development.

4) MEMS

We have under testing different MEMS device. At the moment it seems the better solution as long as we can have a MEMS of at least 10mm x10mm.

All this methods concern the time-multiplexed display, which are all a simplification of the multi projection display.

2.2 Directional display

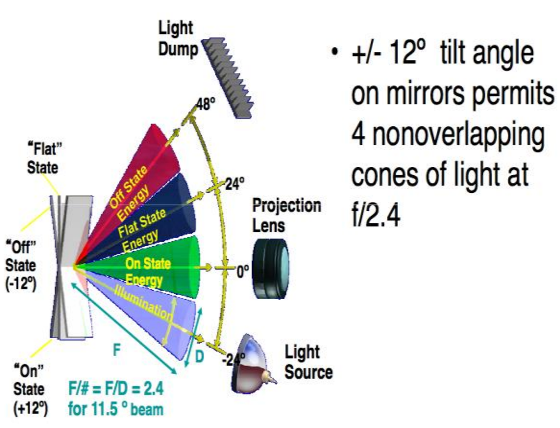
There is another way to have a good 3D image that is the Directional Display.

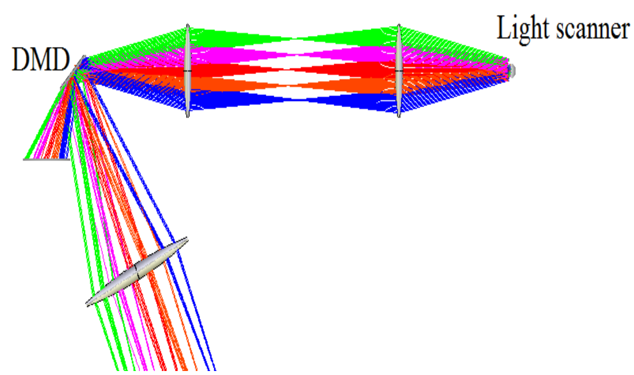
Directional display means that the display itself redirects the image on the proper direction. This is the case of lenticular or barrier display that, with a device attached to the screen, use 2 or more pixel to for each point of view. This gives lack of resolution even with the new 4k display. i.e. to have a good image (1024x768) there are only 4 point of view, and increase the latter means reduce the resolution. So, the future of 3D isn't in that direction, and we moved into another direction.

As the DMD is an intrinsic on-off device, we tried to make an "analog DMD" (patent pending). There are two ways to do that, **move the light or move the image**.

2.3 Moving the light source

Move the light is what has been done with HDDD [6]. Essentially, it is based on different LED light source that illuminate the DMD at different angles, giving a directional image which is collected from a common lens and the displayed onto a vertical diffuser:





As can be seen from the above picture, there is a 24° of movement freedom relative to light that goes to the DMD. This means that if the light change it's position also the reflected picture change its position on the projected space. This effect has been used from Takaki [10] [11] [12] to make their HDDD (High Density Directional Display). We tried a single light source and a scanning system instead of a discrete LED source, to generate a "cone of light" that illuminate the DMD.

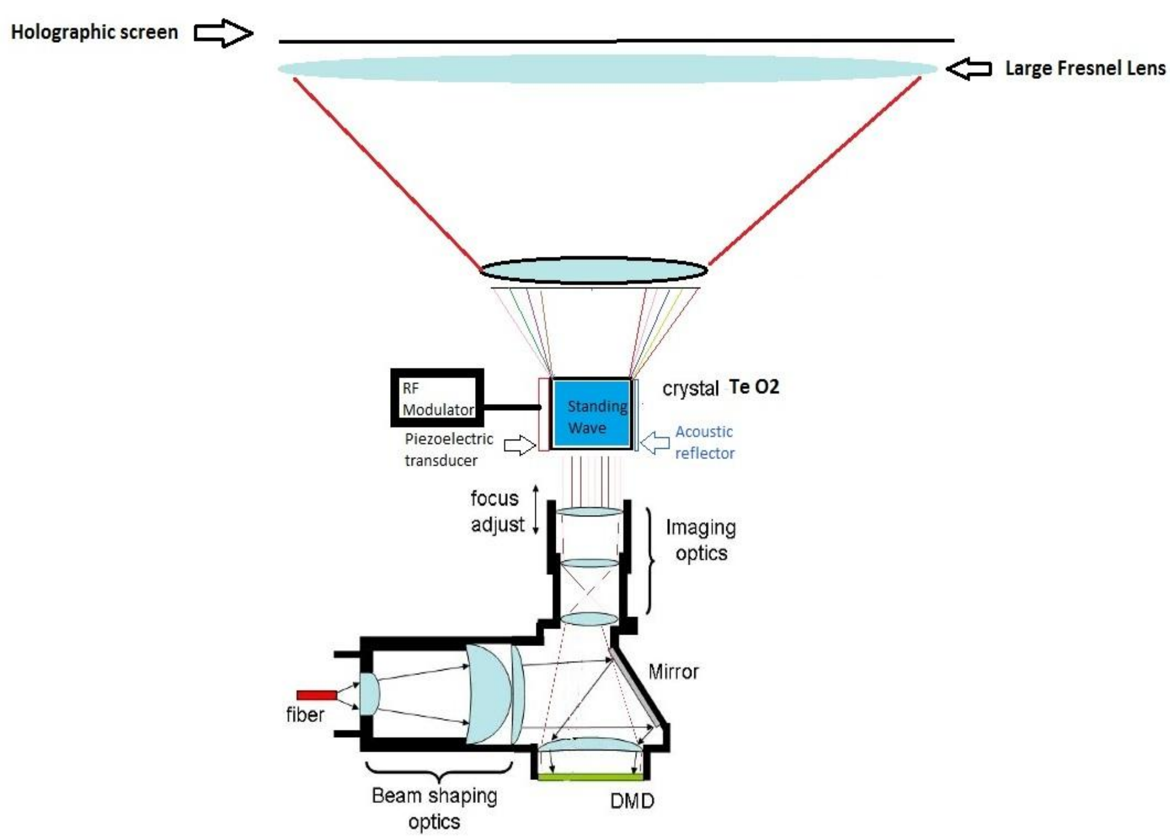
We have under development (and patent pending) a system that uses a scanning light system instead of discrete LED, which illuminate a single DMD device.

This scanning system will move the direction of light into a solid cone of 24° giving the capability of a 64 different directions and so 64 different point of view. Each direction is synchronized with a particular image of that point of view.

All this can be done only with a high-speed frame rate DMD.

2.3 Moving the image

Another solution of the Directional Display is to move the image. This could be done if the DMD was not a two-state device but a continuous device, i.e. the micro mirrors moves from off position to on position in 64 steps. We don't know if Texas has this on their development plans, so we create a device that will do this. We use an AOD (Acoustic-opto deflector), which is a crystal of dioxide of Tellurium (TeO_2), and is well known on the laser community [8]. It can act as a amplitude modulator or direction deflector of a laser beam. Depending on the frequency of the acoustic wave transversal to the optical wave, a variable grating is generated into the crystal, which act as a deflector of the incoming rays. We are developing a special driving system, which will be available as a paper after the disclosure of the patent.



3. Experiments and results

We make many experiments and test on all the system above described, and we set two groups working on scanning systems and on directional displays. We plan to build for the end of this year a set of prototypes to establish the best way to proceed. As there are many patents pending over these projects, we cannot describe the complete systems, but they will be available as soon as the patent are accepted.

4. IMPROOVEMENTS

The realization of a low cost real time 3D holographic display has been tested and demonstrated. The use of high frame rate microsdisplay like DMD permits a fast loading of pictures up to 30.000 frames per second. The engine built will be a good starting point to develop different display type, from holographic to multiview display.

The main properties of the system are:

- 64 (or more) 1024x768 views at 50” screen dimension.
- Angle of view of 110°
- Compact and stackable mount (50” wide, 30” height, 25” depth)
- 550 nit with laser sources of 5W Green, 2,5W Red and 2,5 W Blue
- Direct CAD model visualization (Obj, 3Ds, DXF)
- 8:4:4 GRB display with dual DMD
- High speed USB or Gigabit input
- Software Hologui for setting, testing and streaming.
- Software and GUI to control the system.
- Purpose of this project is the realization of a big sized display (50 inches) by adopting technologies presently existing and developing an original scanning system, together with a control electronic circuitry, which allows the visualization of a 64 multiview in real time.

5. CONCLUSION

We tested different method to realize a low cost multiview 3D display using a single DMD for each color. The assumption is that to have a good 3D image we need at least 64 points of view. This is impossible with existing flat panel display without decreasing resolution. A new concept of display has to be developed and this could be done with multiview displays and directional screen. This means that is necessary a very high picture frame rate that can be made with the use of DMD. To have a directional image there are different methods: a scanning system, which projects the image, displayed on the DMD from different position. This is the same as to use 64 “physical” projectors but use only one DMD display. This is possible with the high frame rate of the DMD and with a new concept of light modulation, which is possible using light sources that can be modulated in amplitude in a fast time. Another method of 3D is the use of directional light that illuminates the DMD. This can be done with discrete light sources or with variable angle light sources. Some special optics is needed because of the Lagrange invariant, as the ratio of image size and angle of view is constant. We tested also a different solution, using the DMD as an “analog” device rather than digital, with a AOD in front of the DMD. This last solution is the one that we are developing and it seems that could have good results.

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