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## High resolution imaging for 3D multi-user displays

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# High resolution imaging for 3D multi-user displays

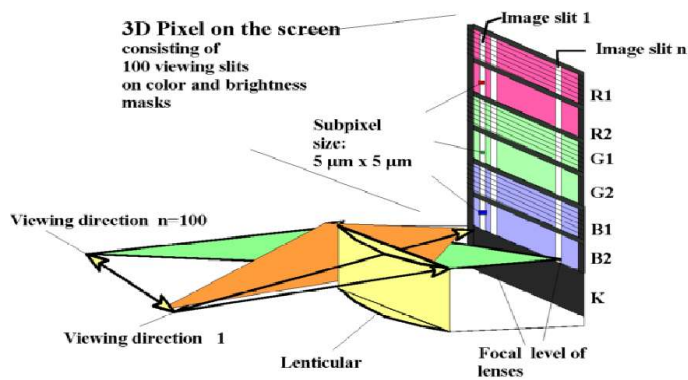
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## Abstract

This paper presents the system and realization concept of a 3D color display offering a multiple of depth levels in front of and behind the display screen itself. These new display features will be achieved by an arrangement of lenticular glasses. A future 3D multi-user LC display can be modeled by a 3D photo display which uses a film instead of liquid crystals.

The 3D Photo Display has been presented at the CEBIT 2003 and offers up to 100 views of objects or landscapes to the user. It looks like a hologram but offers full color quality.



*Figure 1* describes the color subpixel arrangement for the first ( $n=1$ ) and the last ( $n=100$ ) perspective views for a single lens. Depending on viewers position, the complete view is displayed in full image resolution.

*Figure 1:* 3D Pixel Arrangement

The next high-resolution generation will display 68 views with  $2048 \times 1472$  pixel each. The print prototype will be finished in the next weeks, while the high-resolution multi-viewer electrical display is in progress. The realization will base on a LCoS or OLED display.

## Motivation

The clearly most important kind of sense for human beings is vision, about 70 percent of everyday perception are taken by our eyes. Thus the transmission of useful information is performed best by using pictures, even prehistoric men could make cave paintings, as several of them have been discovered.

We are living in a three-dimensional world. The standard approach of adding time extends this number to four. Early attempts until medieval times could manage only two dimensions. In the 15<sup>th</sup> century in Italy *Leonardo da Vinci* achieved a certain breakthrough. He was one of the first who could represent correctly perspective in sketches and paintings. Of course, this doesn't constitute the entire new dimension, although perspective remains, beside occlusion and shading, an important monoscopic depth cue.

A much better depth impression can be achieved by using the stereoscopic depth cue in addition. The approach relies on the simulation of nature, a concept which has been successful in technology frequently. Due to eye separation two slightly different pictures are presented to our eyes. Leaving aside the also challenging problem of the generation of the different views, we'll concentrate on the separation of the views to the left and to the right eye.

The result of achieving this perfectly will be a high-quality, almost immersive 3D impression, a fundamental step towards *Virtual Reality (VR)* or at least *Augmented Reality (AR)*. Special care should be taken to preserve color information and resolution quality.

## Related Technology

Several techniques have been proposed. Among the most popular ones the adoption of polarized light (perpendicular or circular) occurs. Glasses with complementary filters are to put on.

Another possible thing to do is time-division multiplexing. As late as in the eighties progress in LCD technology allowed for the construction of so-called *shutter glasses*. Left and right part open alternately synchronized to the screen which has to be driven at twice the normal frequency.

Thirdly, view separation by color filters can be used. This technique is referred to as *anaglyph stereo*. Although this type has evolved a lot, moderate reduction in color quality is typical.

Additionally, there are so-called *Head Mounted Displays (HMDs)*, devices with two different screens right in front of your eyes. Resolution is limited and over the time wearing the cabled unit becomes more and more inconvenient.

Holography may be impressive, even color with three different wavelengths corresponding to red, green and blue is possible nowadays. But strong constraints on the properties of the required laser light (e.g. coherence) are always given.

Summing up these technologies, all proposed types suffer from the need for special, expensive or uncomfortable equipment. Even health problems like eyestrain and headaches are reported. The main reason is the discrepancy between accommodation and convergence.

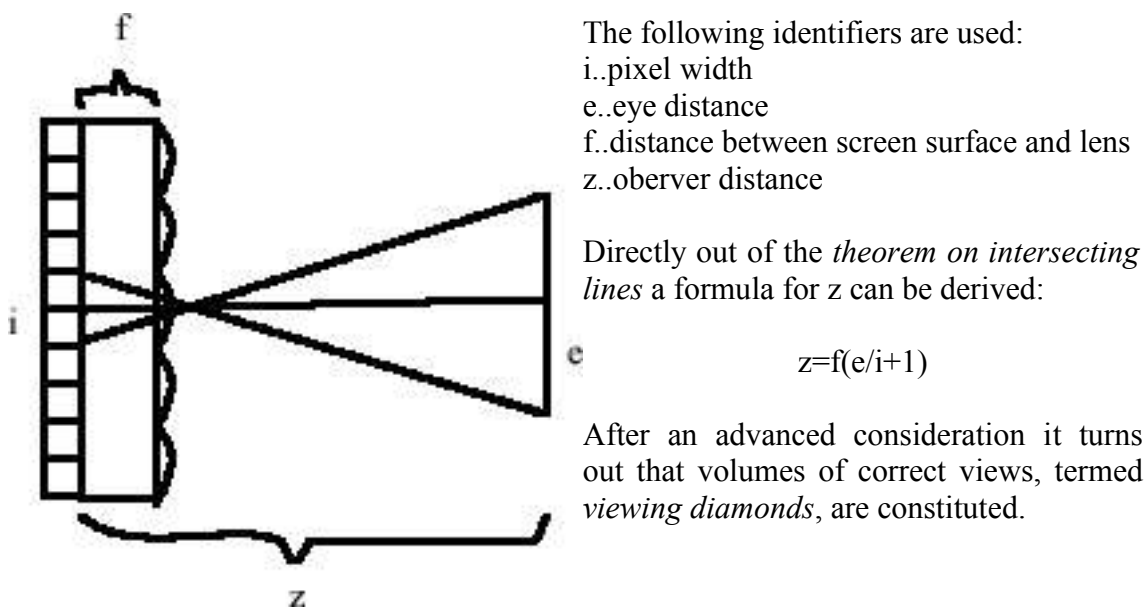
Based on that observations, *autostereoscopic displays* were introduced in the nineties.

## Autostereoscopic Displays

The term “auto-” refers to the discontinued need for glasses-like equipment. In contrast to the time-division multiplexing used for shutter-glasses, spatial multiplexing is applied here. In a basic configuration, there are just two views (left and right) for one user, which are multiplexed horizontally. Today, only TFT- and plasma displays are provided with a sufficiently exact and tiny subpixel geometry. Later products could be based on LCoS- or OLED-technology.

Optical devices, like cylindric or prismatic lenticular systems or, as a cheaper alternative, barrier stripe masks, are placed onto the display. They manage to change the optical path of light in such a way, that in each case only the appropriate subpixel columns are directed to the left and right eye respectively. Major drawbacks of barrier stripe masks are the considerable decrease in luminance and the apparent disturbance lines in the picture.

An illustration of restrictions on the observer position is given in *figure 2*.



*Figure 2:* Restrictions on the observer distance

## 3D multi-user displays

Offering just two views, the autostereoscopic approach stays behind freedom of movement for the viewer and multi-user capabilities. The first weakness can be solved by using *eye- or head-tracking systems*, based on IR (infrared light), US (ultrasonic) or visible light (video) [1]. This introduces, in most cases, the inconvenience of wearing small reflective units (passive) or even transmitters (active). Nevertheless, in comparison to the glasses-requiring techniques, such systems can be considered as quite comfortable. An efficient implementation of *motion prediction* can compensate for delay times [2][3]. As a result, a real-time system is obtained.

The straightforward extension of the use of just two perspectives leads to a multiplexing of several views (source images), up to 100. It is then necessary to decompose the sequence of perspectives by a lenticular system. Thus an entire sector convenient for stereoscopic viewing is established. Since the lenses are aligned vertically, the 3D-look-around effect is restricted to lateral motion.

## Implementation

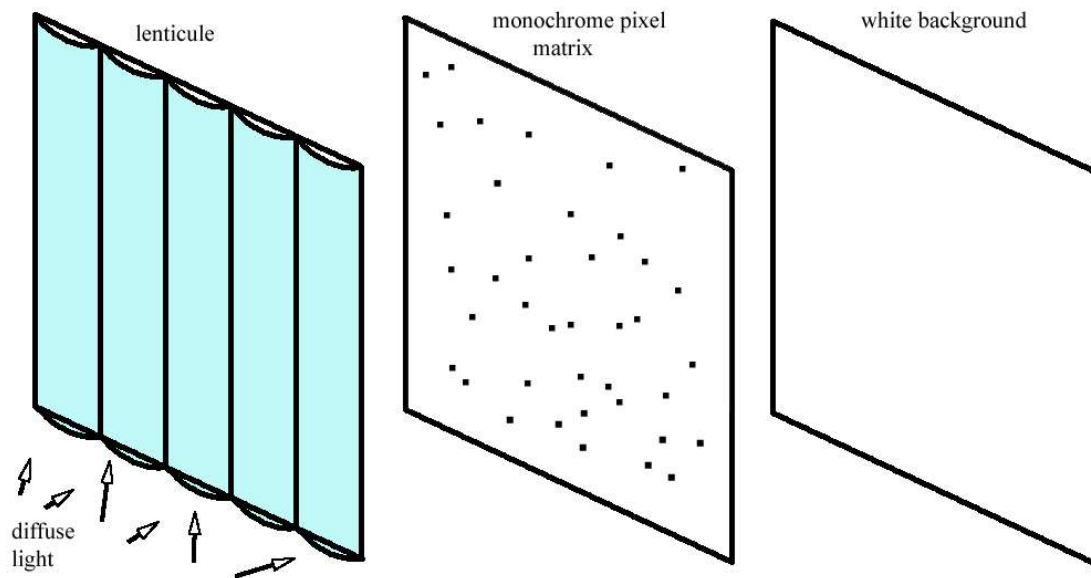
There are three differently advanced configurations which will be described in this chapter.

The first one, variant (a) in *figure 3*, consists of just three layers and is capable of visualizing only monochrome and static 3D multi-user images. A pixel matrix, typical on an exposed transparency, is arranged between a normal white background (no lighting is needed) and the lenticular glass. Just the diffuse daylight suffices. The ratio between the lens pitch and the horizontal pixel size determines the maximal achievable number of included views, see *figure 1*.

Of course, one way of improvement is to enable full color images, too. This can be done by inserting a fourth layer with a periodical sequence of RGB color filter stripes. With a certain number of subpixels, say  $s$ , mapped to each basic color,  $s+1$  color values can be achieved. This gives a total of  $(s+1)^3$  different colors since the human brain merges the tiny color subpixels together. A pitch of the RGB pattern as long as twice the lens pitch turns out to be convenient. By applying a clever coding algorithm even the use of the same mask for both variants (a) and (b) holds, since color values can be compensated locally, similar to the *Phase Alternating Line (PAL)* television system.

Unfortunately, the color filters take away too much brightness. So the backside has to be replaced by a background illumination. Another obvious drawback is the decrease in vertical resolution by a factor of  $3s$ . Since resolutions up to 5080 dpi are possible on transparencies, a satisfactory result still can be achieved.

The general structure of variant (b) is shown in *figure 4*.



*Figure 3:* Variant (a) of a 3D multi-user display (static, monochrome)

The next step forward is to make a real (dynamic) display by using *OLEDs (Organic Light Emitting Diodes)*. Their luminance is sufficient itself, therefore no more additional lighting required. A breakthrough was reported by a research group in Dresden in December 2003. The light efficiency of OLEDs might even reach that of fluorescent tubes or energy saving lamps [4]. In comparison to variant (b), this variant (c), with its main feature sketched in *figure 5*, comes along with a constant value  $s$  of four.

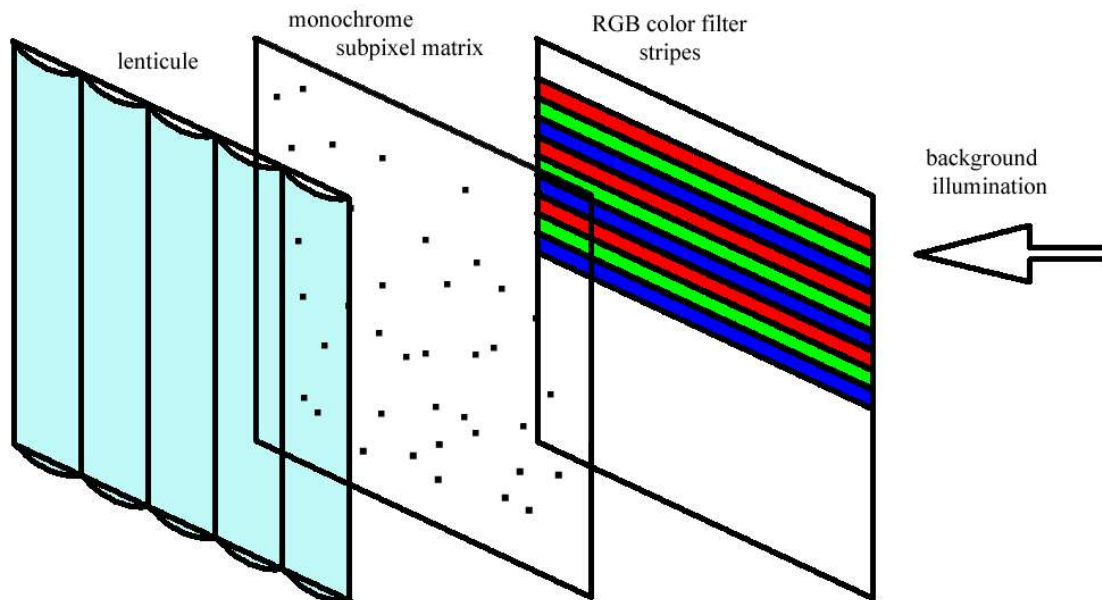
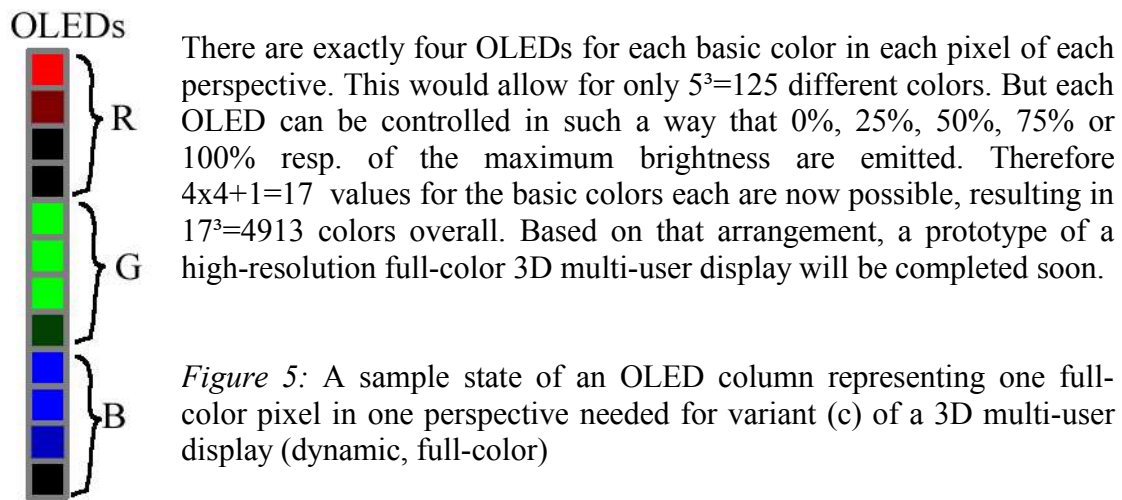


Figure 4: Variant (b) of a 3D multi-user display (static, full-color)



## Applications

Obviously, a main application with mass market chances would be 3D television [5]. The multi-user feature is essential, because families or friends sitting together in the living room want to share the great 3D impression.

Another important sector is the appropriate visualization of medical datasets, e.g. from *CT (Computed Tomography)* or *MRI (Magnetic Resonance Imaging)*. A group of doctors could stand in front of a 3D multi-user display, discussing the diagnosis. Since these methods tend to complement or even to substitute conventional X-ray examination more and more, the field appears promising. Another medical data source could be advanced endoscopy. An endoscope equipped with several cameras delivers the different views.

Architects need to present their designs to partners or the public. While using 3D building representations yet, models are still required in most cases. This can be changed by the greatly improved, immersive 3D feeling provided by the 3D multi-user display.

## References

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