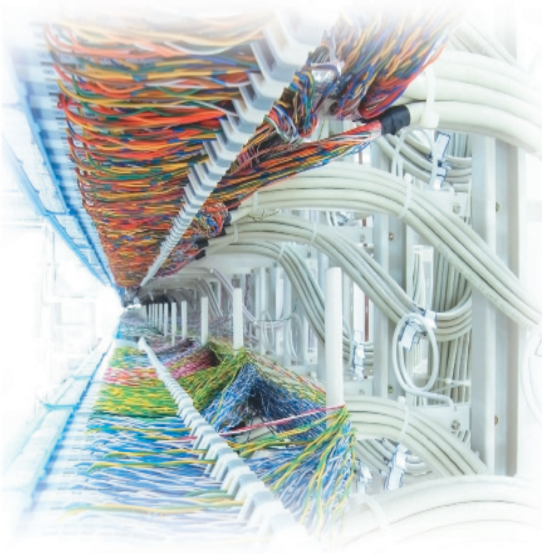
3D Displays without Glasses: Coming to a Screen near You



George Lawton

The most common 3D displays require users to wear special glasses, which has limited the technology's popularity. Now, researchers and vendors are working on glasses-free 3D displays.

A long-sought-after goal of the display industry is to give viewers the ability to watch still and moving images in 3D.

There are already 3D displays being sold with TVs and some laptops. However, the most cost-effective and widely available techniques rely on special glasses to create the 3D illusion, which is neither convenient nor optimal for viewers.

Many users don't like wearing the glasses or lose them easily, and they give some viewers headaches or eyestrain.

Now, though, researchers and vendors are making progress with autostereoscopic displays to generate 3D images without glasses.

Autostereoscopic technologies are just starting to show up in handheld cameras, camcorders, game devices, and phones by vendors such as Fuji and Nintendo.

The larger formats are being adapted for 3D billboards by companies including Alioscopy, Magnetic 3D, and Tridelity Display Solutions.

However, vendors are encountering challenges to making such displays technically and commercially viable for mass-market TVs.

"Although everyone would love to see a glasses-free solution, there are too many tradeoffs, primarily with image quality," said Chris Chinook, president of Insight Media, a market research firm.

"There is a growing body of evidence that 3D really has benefit," said Nick Holliman, senior lecturer at Durham University. His research found that people could do spatially related tasks—such as navigating a maze in a computer game—20 percent more accurately on a 3D screen.

However, 3D has a long way to go and numerous hurdles to clear before it can achieve commercial success.

BEGINNINGS

A person's eyes see the same scene from two slightly different angles. The human optical system combines the two images to yield an accurate 3D view of the scene. 3D displays work the same way.

The first autostereoscopic effect was incorporated into a painting by G.A. Bois-Clair in 1692 in France. He used the parallax-barrier technique, combining multiple images painted in alternating strips with a line of metal bars—arranged across the front of the painting—that blocked one set of strips from each eye.

Parallax-barrier techniques were applied to photographs in 1903 and movies in 1941.

In the 1920s, researchers began investigating an approach using a lenticular lens array—a group of lenses designed so that when viewed from slightly different angles by a person's eyes, they magnify different images—arranged across a display.

Work began on electronic autostereoscopic displays in the 1990s, said Durham University's Holliman.

The biggest-selling commercial 3D device has been the parallax-barrier-based Sharp SH 251iS mobile phone, which was introduced in 2000 and has sold about 2 million units, he estimated.

AUTOSTEREOSCOPIC APPROACHES

There are two broad classes of autostereoscopic display: *multiview* and *light field*.

A multiview display uses optics to render two or more views of a scene, which the user's optical system fuses into a single 3D image.

Light-field displays, on the other hand, recreate the actual pattern of light—including its direction and angle of arrival—coming from all parts of a 3D object. This yields a better sense of depth.

Multiview displays

Multiview techniques render vertical slices of a single image on a 2D display.

Techniques. Parallax barriers, formed with either wires or a layer of material containing a series of carefully placed slits, block one set of views from each eye.

Lenticular lenses direct the light from one set of views to one eye and the other set to the other eye.

3D systems that use glasses rely on the multiview principle.

In one example of this approach, an image consists of two versions of the same scene, in different colors and spaced slightly apart. Glasses with colored lenses filter out one version of the scene to one eye and the other version to the other eye. The viewer's optical system then fuses them into a single 3D image.

The once-popular stereoscopes, invented in 1838, consisted of two lenses and cards with photos of the same image from slightly different angles. Viewers looking through the lenses at a card saw the image in 3D.

Multilight approaches use specially placed lights and prisms that alternately direct the light from multiple views of an object to each eye.

For this technique, Microsoft has developed an improved wedge lens and the ability to track a user's eyes so that the system can better target the light at one or more viewers.

Implementations. Sharp pioneered an LCD-based parallax-barrier filter that can be dynamically adjusted for different viewing angles.

When the filter is switched on, vertical elements turn opaque, occluding alternating lines of the screen from each eye.

A Hammacher Schlemmer 3D camera, the Nintendo 3DS game console, and Tridelity monitors employ this technology.

Alioscopy, LG, and Magnetic 3D are using lenticular technology in large advertising displays.

3M has produced the first commercial multilight display, used in Fuji cameras and in a new Texas Instruments cell-phone module.

Light-field techniques

Light-field displays generate pixel-like elements that transmit image-brightness data and information about the direction and angle that light rays would travel from an object to a viewer's eyes. This makes it easier for the optical system to interpret the image properly.

In contrast, multiview displays generate pixels with brightness but not angular information.

Light-field displays thus better enable the accurate convergence necessary for effective 3D viewing, said Insight Media's Chinook. They also reduce eyestrain.

In addition, the displays deliver more accurate depth information, which is important in medical- and scientific-visualization applications, said University of Valencia professor Manuel Martinez.

Integral imaging. The integral-imaging approach to autosteroscopy uses an array of lenses in front of a single camera or multiple cameras to capture the same scenes from slightly different perspectives. A special lens combines these images to generate a 3D image consisting of an array of viewing elements that transmit brightness and viewing-angle information.

This creates a 3D image in both vertical and horizontal planes, which makes it easier to maintain the effect for viewers of different heights or as a viewer stands up or sits down.

Multiview techniques create 3D images only in vertical planes.

Because integral-imaging views are blurry, Martinez explained, high-quality commercial integral-imaging displays will require much higher resolution than they currently have.

Toshiba spokesperson Kaori Hiroki said the company plans to introduce a new line of TVs this year based on integral-imaging technology.

Volumetric. Volumetric light-field displays—pioneered by vendors such as Actuality, which Optics for Hire acquired in 2009—create an image using a mirror or LED array that is spinning or vibrating within a glass cylinder or sphere.

Light transmitting an image comes from the spinning or vibrating element before reaching the user. As the element moves, it generates a separate version of the 3D image for each viewing angle. These views converge to create a 3D effect.

Sony has demonstrated a prototype volumetric display called Ray Modeler, which uses a rotating array of LED lights. This 3D display can produce color moving images viewable without glasses from any position around a cylinder.

A challenge for volumetric displays is the sheer amount of data required. Generating different images for each of the 360 degrees of viewing availability creates significant data-management requirements.

Guided light. Guided-light techniques use special holographic prisms that organize multiple high-end projectors' output into a single 3D image.

The Holografika HoloVizio, which Figure 1 shows, uses algorithms to determine how to recreate the light field from a 3D scene by directing each LCD projector to generate the appropriate pixel combination. The holographic grating on the front of the display combines the light from the separate projectors into a single 3D image for each viewer.

Holografika software developer Atilla Barsi said the display's projection technology and computer cluster are expensive. The company's display that measures 72 inches diagonally costs about $130,000, while the 32-inch display is about $13,000.

OBSTACLES

Because they entail complex projection and display technologies, autostereoscopic 3D systems cost substantially more than traditional 3D displays.

Outside of movie theaters, 3D displays are new and untested, while autostereoscopic technology is even more immature. And currently, resolution and performance aren't optimal.

To render multiple viewing angles for a group of users, lenticular and barrier techniques lose resolution.

Moreover, they offer a limited number of viewing angles from which users can see 3D images, said Adrian Travis, senior scientist in Microsoft's Applied Sciences Group.

Andrew Jones, a research programmer at the University of Southern California's Institute for Creative Technologies, said the ICT is working on eye-tracking technology that could let viewers see 3D images from more vertical positions than are now possible.

Light-field techniques are considerably more expensive than multiview approaches because they require specialized optics and software tools, large amounts of data, and more computation.

Volumetric displays don't scale well because of the engineering challenges in building larger spinning elements that offer the necessary precision, said Jones.

The optics required cause guided-light displays to be large and expensive.

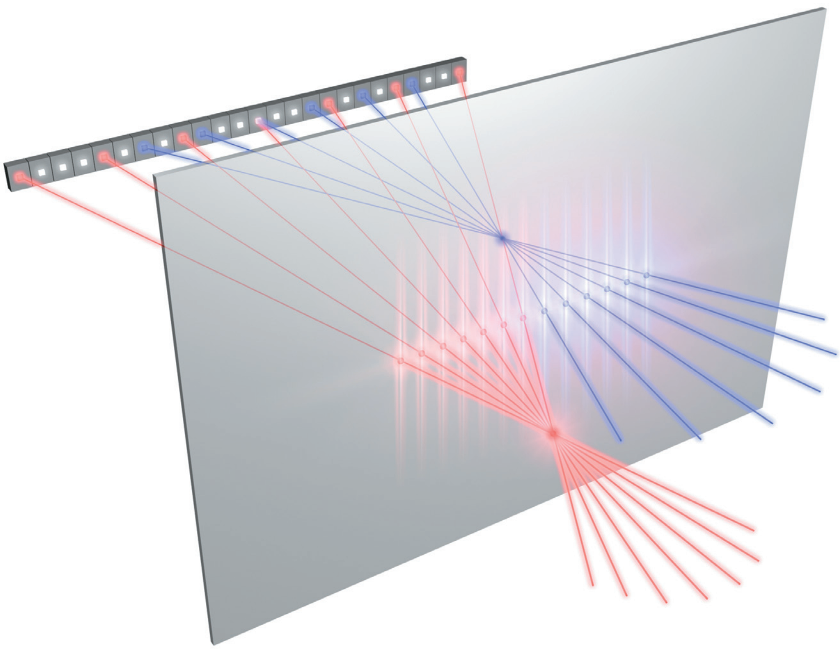

Source: Holografika

Figure 1. The Holografika HoloVizio display uses multiple projectors and other technologies to recreate the light patterns from a scene so that viewers see a 3D image.

Autostereoscopic 3D displays could prove helpful in teleconferencing, according to Jones. Expensive 3D displays could be particularly useful in high-end data-visualization and medical applications.

Durham University's Holliman said he doesn't expect autostereoscopic displays to replace glasses-based systems in movie theaters in the near future because they aren't cost-effective for large-screen venues.

But, he said, they could become popular in the consumer market—in phones, games, and TVs—in the next 5 to 10 years as manufacturers refine the approach.

The technology will take off in portable devices—such as cameras, photo displays, and game systems—because viewers can more easily adjust their positions to maintain the 3D effect, predicted Jennifer Colegrove, director of display technologies at market research firm DisplaySearch.

She also anticipated that 3D will be used increasingly in billboards and other advertising displays.

However, Colegrove said the majority of 3D displays will continue to require glasses because of autostereoscopic technology's higher costs and performance limitations.

Between 2009 and 2018, DisplaySearch estimates, the overall worldwide 3D-display market will grow from $300 million to $22 billion, compared with an increase from $20 million to $2 billion for autostereoscopic displays.

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