NOVEL DISPLAYS ISSUE

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The Future of Real-Time Holograms

REAL-TIME HOLOGRAPHIC 3-D DISPLAYS

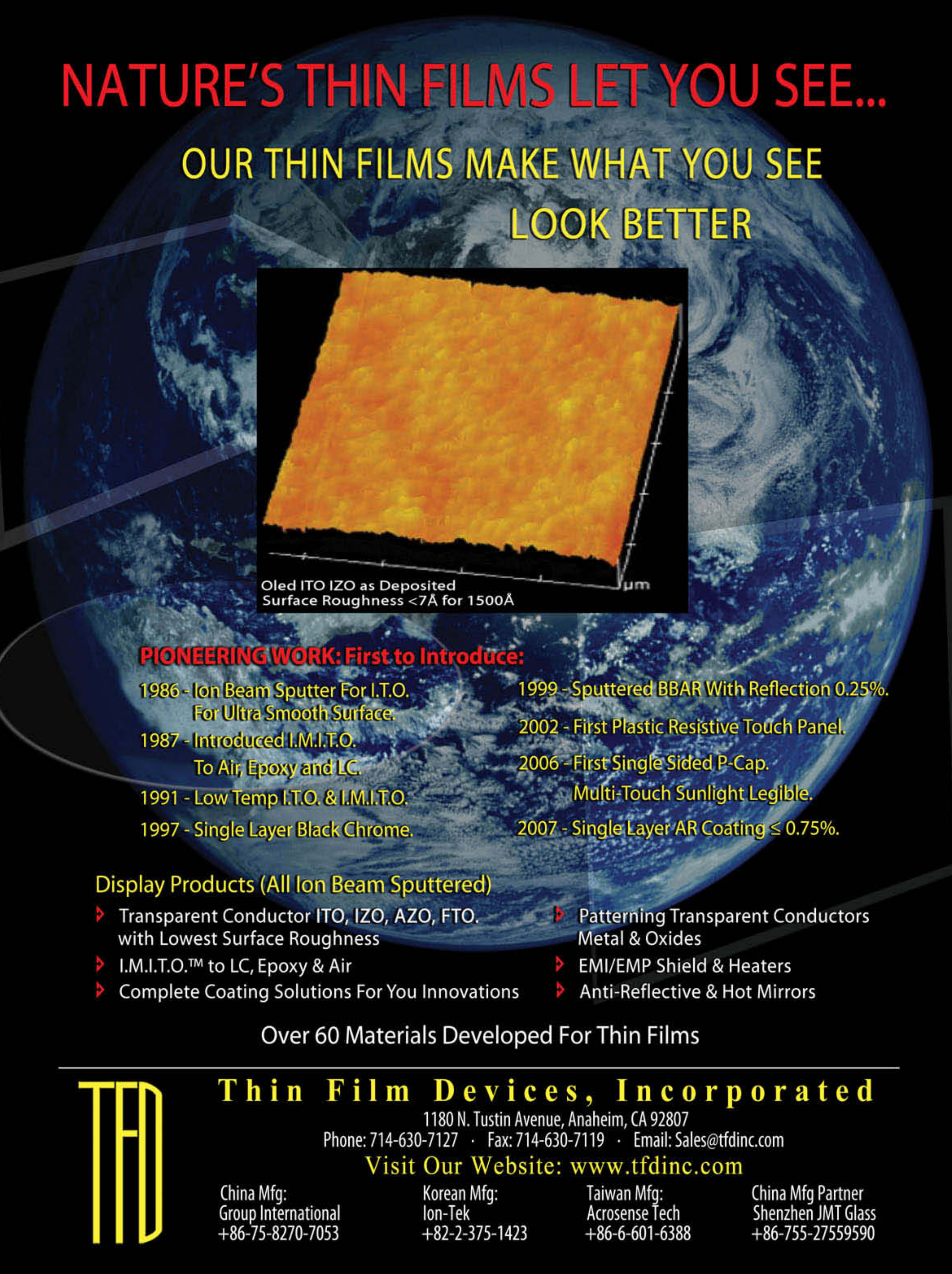
NOVEL LASER PROJECTION ROBOT SYSTEM

HOLOGRAPHIC TV: HOW MUCH PROCESSING POWER IS NEEDED?

MICROFLUIDICS USED FOR NEXT-GENERATION USER INTERFACE

Plus

Market Landscape for Cutting-Edge Displays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OUR THIN FILMS MAKE WHAT YOU SEE LOOK BETTER
Oled ITO IZO as Deposited
Surface Roughness <7Å for 1500Å
µm
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1986 - Ion Beam Sputter For I.T.O. For Ultra Smooth Surface.
1987 - Introduced I.M.I.T.O. To Air, Epoxy and LC.
1991 - Low Temp I.T.O. & I.M.I.T.O.
1997 - Single Layer Black Chrome.
1999 - Sputtered BBAR With Reflection 0.25%.
2002 - First Plastic Resistive Touch Panel.
2006 - First Single Sided P-Cap. Multi-Touch Sunlight Legible.
2007 - Single Layer AR Coating ≤ 0.75%.
Display Products (All Ion Beam Sputtered)
Transparent Conductor ITO, IZO, AZO, FTO. with Lowest Surface Roughness
I.M.I.T.O.™ to LC, Epoxy & Air
Complete Coating Solutions For You Innovations
Patterning Transparent Conductors Metal & Oxides
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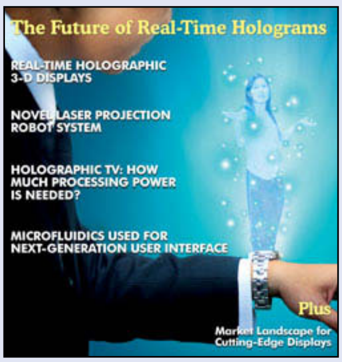
ON THE COVER: *It's probably going to be a while before holographic video displays the size of the biggest living-room TV that you can buy today become available. However, for desktop monitors or 26-in.-diagonal displays , it's not outrageously far in the future.*



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contents

Next Month in *Information Display*

TV Technology Issue
- Real-Time Holographic TV
- Next-Generation TV
- The European TV Market
- The Pre-Holiday TV market

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editorial

The Brave New World of Displays

by Stephen Atwood

I wish I had my very own holographic real-time display to enjoy. Wouldn't we all like that? Not so long ago, we could enjoy stereoscopic 3-D in only a few select venues or through the use of very specialized projectors. Today, we can easily purchase and set up a stereoscopic display and watch real-time content with it. The technology is still a little young in terms of the ergonomics but there is plenty of content available and several ways to get it into your home to enjoy it. But stereoscopic is not the same as truly immersive 3-D. To get to the next level you either need to find a way to directly convert matter to energy and back again in real time or you need something like a holographic display.

The first reported work directly on holograms appears to date back to 1947, when physicist Dennis Gabor developed the holographic method, and his company, Thomson-Houston in the UK, filed for a patent. Several sources say that his work was focused on electron microscopy and his efforts led to the discovery of electron holography, which did not involve visible light.

After the development of lasers in the early 1960s, people discovered ways to record holographic images on recording mediums by capturing the interference patterns of the laser light reflected off three-dimensional objects as compared to the reference laser light itself. These recordings could then be re-illuminated by lasers or later by incoherent light sources to re-create the original images in 3-D as though they were floating in space. These are what most of us have seen and know today as holograms. You can find them in many places, sometimes even on your credit card. However, the holographic processes are generally fixed in time and usually involve only static images.

With this context, which to me seems very similar to the early days of still photography and stereoscopic cameras, I have been eagerly watching the industry, looking for signs that real-time holographic displays are about to emerge. And yes, I'll confess I'm being overly futuristic in even allowing us to use the term "Holographic TV" in this issue. But after speaking with several experts who are actively working in this field, I am convinced that we can at least begin to start thinking about this eventuality with, if nothing else, a little imagination tempered by some industry context.

Back in 2008, authors Hagen Stolle and Ralf Häussler (*Information Display*, July 2008) told us how you could construct a holographic projector using a spatial light modulator, but then revealed the grim realities about the need to render literally billions of pixels in real time to make a large-screen holographic projection display practical. In the same issue, authors Savas Tay and Nasser Peyghambarian discussed their work using Photo-Refractive (PR) polymers to store the images in an analog optical method. As long as the recording medium can retain the image long enough, and be erased fast enough, it can be used to make holographic images that change in real time. One advantage of analog image storage is that you do not inherently need to break up the image into digital pixels. This is similar to the early days of analog television when the video signal was written onto the phosphor screen just as it came out of the camera, avoiding the need for high-bandwidth digital image processing.

After 2008, things seemed to be pretty quiet for a few years. Then, in 2011, I attended an imaging conference where I heard about the work being done by Pierre-Alexandre Blanche at Arizona State University, which involved cognitive studies on 3-D *vs.* 2-D maps and making holographic displays with PR polymer recording mediums.

(continued on page 23)

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Sony and LG Introduce 84-in. 4K TVs

Quite literally, some of the biggest attention-getters at the IFA consumer electronics show in Berlin last August were the 84-in. 3840 × 2160-pixel resolution television sets from both Sony and LG. Sony's unit, the XBR-84X900, features an LED-edgelit LCD with built-in speakers, full network capability, and passive-glasses-based 3-D (Fig. 1). LG's 84LM9600 is also an LCD with LED edge-lighting. It comes with network capability and 2.2 Sound speakers with two subwoofers, as well as passive-glasses 3-D.

There are larger TVs – Panasonic makes a 103-in. plasma unit (as well as specialty TVs in even larger sizes) and Sharp is now offering a 90-in. LCD – but not many. And there are smaller TVs with 4K resolution from several manufacturers. What stands out about these 84-in. TVs is their size in combination with their resolution – 4 times that of HD. *CNET* reporter Geoffrey Morrison is just one of many experts who believe that 4K alone is not a selling point. "…at the sizes most people buy and at the distances most people sit from a TV, 1080p is largely unnecessary, making 4K ridiculous overkill," he wrote recently, adding that 84 in. is not a "normal" size and would probably make the added resolution from 4K content more discernible.[1]

The availability of said 4K content is an issue. At this time, virtually none exists for home TVs and so the 4K set you buy today may likely show upconverted 1080p content for the foreseeable future. A small yet clearly visible disclaimer appears on the same Web page on which LG's new set is touted: "No 'ultra definition' or '4K' content is currently available. No broadcast or other standard currently exists for '4K' or 'ultra definition' television and the unit may not be compatible with such standards if and when developed."[2]

It's a chicken and egg situation somewhat similar to the early days of HD or 3-D – does the content or the platform come first? (In the case of both HD and 3-D, content development was even farther along than is 4K right now.) That the platform has led the march in the case of 4K is driven in part by set makers' desire to have a hot feature with which to sell more TVs. (For more about this, see this issue's Display Marketplace by Paul Semenza, who describes the current environment for both 4K and OLED TVs.)

In the meantime, these sets from Sony and LG will still provide a big, beautiful picture, if you have the kind of home and wallet that can handle them. At a price tag of $24,999 for the Sony and $19,999 for the LG, they won't be in every home. As technology writer Richard Lawler observed in a review of the Sony for *Engadget*, for about the same money, one could buy "a decently equipped 2013 Ford Focus."[3] The LG unit has been shipping in Korea and should be available in North America in October 2012. Sony is currently taking preorders for its unit, which will also be available in Q4 '12.

Fig. 1: *Sony's XBR-84X900 features an LED-edgelit LCD with built-in speakers, full network capability, and passive-glasses-based 3-D.*

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[1]http://reviews.cnet.com/8301-33199_7-57508010-221/hands-on-ish-with-lgs-4k-tv/
[2]http://www.lg.com/us/ud4k
[3]http://www.engadget.com/2012/09/06/lg-84-inch-4k-uhdtv/

–Jenny Donelan

Microfluidic Technology Enables New User Interface

We live in a highly tactile world. However, our daily interactions with technology, from tablets to automobiles, are becoming more and more flat. The next wave of user interface will re-incorporate dynamic physical features with the introduction of a novel deformable membrane technology that integrates into standard touch displays and surfaces.

by Nate Saal

DATA-ENTRY ERRORS, poor typing speeds, and lack of tactile feedback are some of the problems that consumers encounter when using virtual touch-screen keyboards and touch-input devices. Interacting with a touch screen requires constant visual monitoring. While possibly inconvenient in an application such as a game, a touch interface with its lack of physical buttons or other haptic-feedback scheme can be dangerous in an automotive environment where touch screens are used for tasks such as changing the radio station or interacting with the navigation system.

The Tactus Tactile Layer™ panel was developed to provide a next-generation user interface with real physical buttons, guidelines, or shapes that rise from the surface of a touch screen on demand and can be employed without visual confirmation from the user. The Tactile Layer component is a completely flat, transparent, dynamic layer that sits on top of the touch sensor and display. The thin layer deforms and buttons or shapes of a specific height, size, and firmness emerge from the surface when triggered by software API, a proximity sensor, or an other event. Users can feel, press, and interact with these simulated buttons just as they would with the buttons on a physical keyboard (Fig. 1). When the buttons are no longer needed, they recede into the surface and become invisible.

This new interface from Tactus Technology was launched at Display Week 2012 and was awarded SID's Innovation-Zone trophy for Best Prototype (and the Grand Prize in the Eureka Park Challenge from CEA shortly afterward). The interface allows different pre-configured sets of buttons, such as a QWERTY keyboard, to be raised (emerging out of the touch screen) or lowered (receding back into the touch screen) based on the application need. Not just limited to keyboards

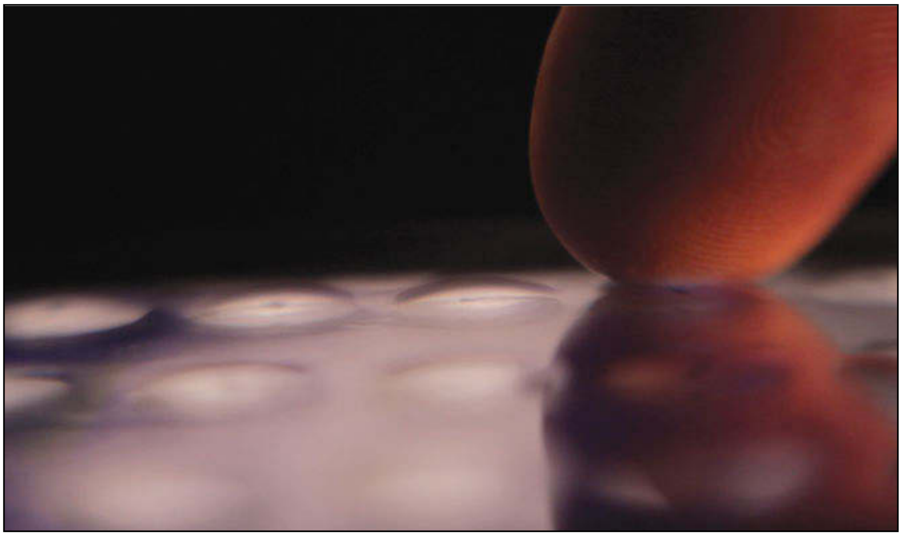

***Fig. 1:** The Tactus Tactile Layer can deform so that keyboard buttons or other shapes emerge from the surface.*

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and on-screen buttons, the tactile technology can also be integrated off-screen, such as on the bezel or the backside of a device.

How the Tactile Layer Surface Works

The tactile panel is easy to integrate; it simply replaces the glass or plastic cover layer that sits on top of a touch sensor and display. It is a thin, flat, smooth, and transparent cover layer varying in thickness from about 0.75 to 1 mm that has certain special properties.

The top-most layer of this multi-layered stack consists of an optically clear polymer. A number of micro-holes connect the top layers of the panel to a series of micro-channels that run through the underlying substrate (Fig. 2). The micro-channels are filled with a fluid whose optical index of refraction matches that of the surrounding material, making it fully and evenly transparent when light from the display passes through (Fig. 3).

Increasing the fluid pressure causes the fluid to push up through the holes and against the top polymer layer, making it expand in specific locations (Fig. 4). This enables an array of physical and completely transparent buttons to rise out of the surface. A small internal tactile controller that interfaces with the processor of the touch-screen device controls the rise and fall of the buttons.

The tactile controller allows a proximity sensor or a software application to control the state of the buttons (Fig. 5). For example, the buttons can be triggered to rise whenever the software calls for the virtual QWERTY keyboard.

It takes less than 1 sec for the buttons to rise or recede. Once formed, the buttons are stable and users can rest their fingers on them or type on them just like a regular keyboard. When the buttons are not needed, the controller triggers a reduction of the fluid pressure. The buttons recede back into the Tactile Layer panel and the surface becomes smooth and flat again. The panel size as well as the size, shape, and firmness of the buttons are fully customizable. Buttons can be of any shape – circles, rectangles, ovals, squares, long thin lines, or even ring- or donut-shaped.

The Tactile Controller is the main fluid drive mechanism. It comprises an actuator, valving, and a fluid reservoir. A typical tablet form-factor device with a QWERTY keyboard configuration requires less than 2 ml of fluid. The fluid is a proprietary oil that is odorless, colorless, non-toxic, and, critically, non-conductive (otherwise, it would negatively impact the touch-sensor function). In the event of a catastrophic failure, the fluid will not harm any other components in the device. Additionally, since the tactile panel is independent of the touch sensor and display, even if the panel were to fail, the core device function would remain intact, similar to devices today that still operate with a shattered screen.

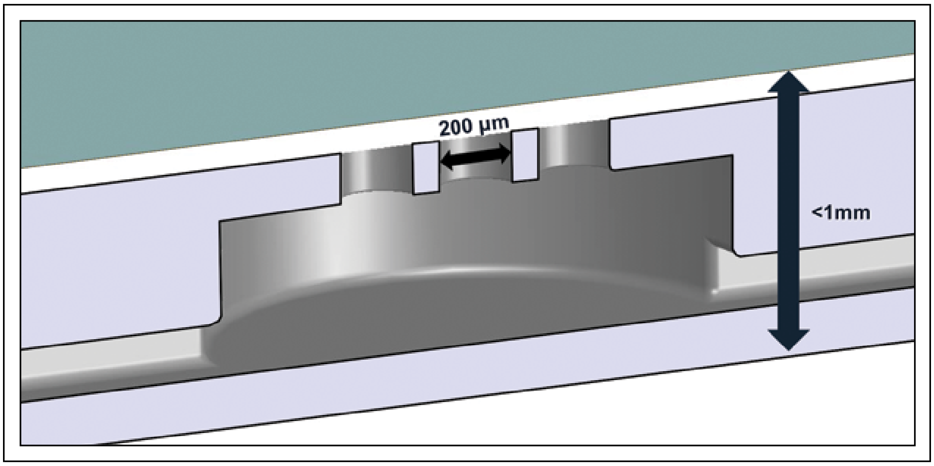

Fig. 2: A cross section of the Tactile Layer panel shows the microfluidic channels (light blue) and the embedded microstructure (dark gray) with micro-holes, which in this example are 200 μm wide.

The buttons' height (from high to low) and feel (from soft to rigid) can be controlled, allowing consumers to choose and set their personal preference. It is possible to create almost any type of button configuration or layout on a panel. Multiple button sets can also be configured on a single panel, enabling different groups of buttons to be raised at different times, depending on the interface needs of the user.

Input Comparisons

When considering typing applications, alternative typing methods such as finger swiping, predictive text, auto-correction, and voice input have all been devised to improve the accuracy and efficiency of inputting text.

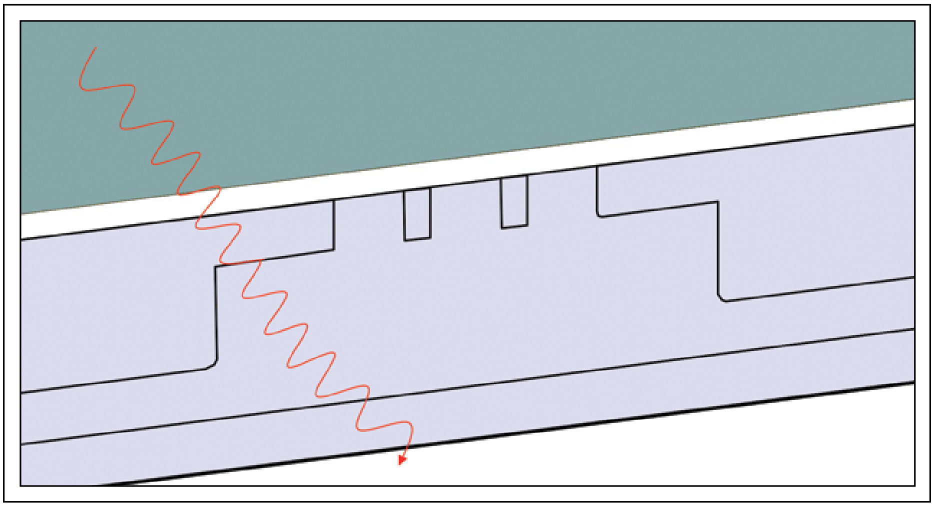

Fig. 3: The micro-channels contain an indexed-matched fluid that hides the embedded structure.

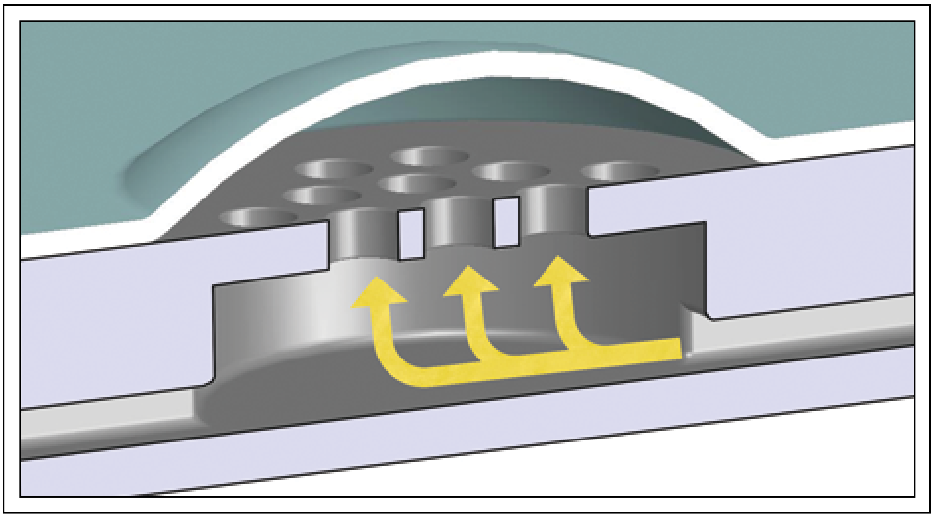

Fig. 4: Increasing the fluid pressure in the panel causes the top layer to expand, creating physical buttons.

Haptic technology provides feedback that simulates a physical button experience. Much like a clicking sound that occurs when a button is pressed, haptics can help users understand when an input has been made. Vibration-based haptics, for instance, uses vibratory feedback to mimic the feeling of resistance when pushing a virtual button. Current haptic technologies, however, fall short in assisting users in properly locating their fingers on a screen or keyboard. Touch-typers need the "home row" for orientation and thumb-typers need to be able to glide across keys; without these interface capabilities, mistakes will continue to be frequent.

Think about how most input systems function: users locate the target, touch it, then trigger it. What users need is the ability to orient their fingers by touching and feeling the screen, and only then input data with an intentional push of their finger or fingers. Many current capacitive touch-screen devices have an inherent problem in that as soon as you touch the screen, input is triggered. Even if input is triggered on liftoff, this still does not allow users to rest their hands on the screen the way they would when touch typing on a physical keyboard.

What if you could touch a touch screen without triggering input? At first glance, this seems to run counter to how touch screens function today. The answer lies in creating a new dimension of touch – literally by enabling a touch screen to deform in the Z-axis, moving the finger further away from the touch panel.

Capacitive touch screens work by measuring a change in capacitance as a finger moves closer to the touch surface. Tactus takes advantage of this mechanism, using it to enable users to rest their fingers on the buttons and as a result only input data when the buttons are pressed down. When the Tactus buttons are flat (recessed), a finger touching the screen or resting on a button lies close to the underlying touch sensor, strongly changing the local capacitance. But when the buttons are raised, the distance between the top of the buttons and the touch sensor is increased. As a result, when a finger rests on top of a raised button, it is further away from the touch sensor, and there is a relatively smaller change in capacitance. When a finger presses a Tactus button down, the capacitance changes as the finger comes closer to the touch sensor. The difference in capacitance due to finger-sensor distance may be used by the touch system to clearly distinguish between a finger resting on the buttons compared to when buttons are being pressed.

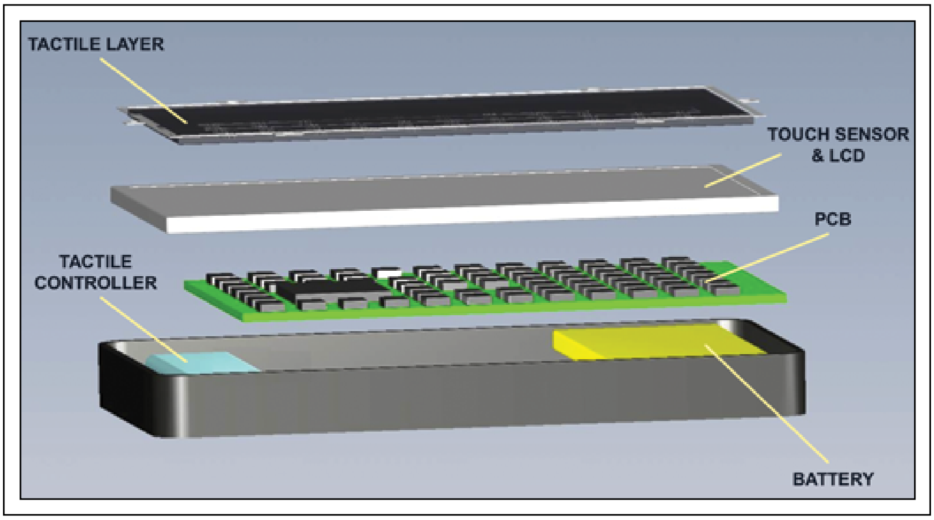

Fig. 5: The Tactile Layer panel at top integrates into a typical touch display stack, replacing the flat, static cover layer with a dynamic, physical surface. The Tactile Controller (bottom) drives fluid in and out of the panel.

Power-Consumption Issues

The power consumption used by the tactile controller to actuate the panel is exceedingly low. The tactile system runs off of 3.3 V with a peak current of 300 mA over the activation period of about 1 sec. In a frequent usage scenario with 100 activations in a day, power consumption would be less than 1% of a typical 1500-mAh battery. Once the buttons are raised, they remain enabled for as long as they are needed – be it a few seconds or several hours – without any additional power consumption.

This is possible because the pressure used to raise the buttons remains constant even when the power to the system is shut off. When the buttons are pushed down, the inherent internal pressure causes them to automatically pop back up each time without additional power consumption. In contrast, haptic vibration-based solutions consume battery power with each button push, so the more a user types, the more power is consumed.

Market Opportunities

Tactus predicts that its innovations will have significant impact for the use of microfluidics in display applications and touch screens. In its first public demonstrations, Tactus showcased its technology on a 7-in. prototype Google Android tablet. The demonstration system was the result of a new partnership between Tactus and Touch Revolution (Redwood City, CA), a unit of TPK Holding Co., Ltd. – the largest-volume glass projected-capacitive multi-touch-screen manufacturer in the world.

Tactus is currently working with industry partners such as touch panel, display, and touch-controller companies to provide complete solutions that can easily be integrated by device OEMs. Smartphones and tablets are obvious candidates for tactile interfaces. Some individuals resist or have resisted the move from a smartphone with a physical keyboard to a touch-screen device. Many who purchase a tablet also buy a physical keyboard accessory for easier typing. In just 3 years, the nascent tablet market has grown to about 60 million units in 2011. Tactus can help transform these devices typically used for content consumption into devices for content creation.

Another important aspect of this technology is its ability to reach segments of the population that cannot currently operate touch screens. The blind and visually impaired, the elderly, and those lacking fine motor skills because of diseases such as arthritis or Parkinson's, either struggle or find themselves completely unable to use 'buttonless' touch-screen-based systems and devices. Providing a tactile interface on touch-screen devices is important for people with vision impairment or those who lack fine motor skills.

The medical and public-safety industry is another likely avenue for the technology because the buttons allow for easier typing while also providing a smooth surface that can be easily sanitized. When the buttons are retracted, the unit can be easily wiped clean of germs and disease that regular keyboards trap and may even spread among users. Contamination of mobile and computing devices has been validated by scientific research and is becoming a significant concern for hospitals and medical facilities. This technology can also be used to make a wide variety of medical devices significantly more portable. For example, ultrasound systems – even "portable" ultrasound systems – have a separate screen and keyboard, making them heavy and bulky.

In summary, the evolution of the haptic interface into the tactile interface is upon us. The ability to use portable devices for content creation via a "contextual" keyboard that appears only when needed, or video controls on a remote that disappear when no longer needed, is the opportunity presented by microfluidics applied to touch-screen technology. As the technology for dynamic surfaces advances, even more opportunities for user interfaces and tactile experiences will be developed that will far surpass the ideas presented in this article. It's an exciting opportunity for both OEMs and end-users. ■

Virtual Remote Controller Enables New Laser-Projection-Based Applications

A novel pan-tilt user-interface (UI) robot system uses a scanning MEMS projection head in combination with a depth sensor. The UI robot system can detect and track a hand, then project a virtual-remote-controller (VRC) image onto the top of a palm or table.

by Masafumi Ide, Kaoru Yoda, Yosuke Abe, Shinpei Fukaya, Takeo Komiyama, Tomohiro Tamura, Kouhei Arakawa, and Takaaki Nozaki

USERS increasingly expect to be able to access and interact with digital information even when they are not sitting in front of a computer. For many applications, the ideal information display would be lightweight and portable. To this end, our research team at Citizen Holdings Co., Ltd., developed a design for a Virtual-Remote-Controller (VRC) system in which a tiny ceiling-mounted laser-projector robot pans and tilts to track a user's hand as the user moves around a room. The robot also projects an image with touch-screen interaction (Fig. 1). Our VRC system was selected by SID's Innovation-Zone (I-Zone) committee as one of the prototypes and new technologies to be shown in the first-ever I-Zone at Display Week 2012 last spring.[1,2] The system generated a great deal of interest from attendees.

The laser projector has a focus-free feature that helps the projector display icons or images onto the palm of a hand without auto-focusing optics. This makes it possible to reduce the size and cost of the projection head unit. Once the operating action disappears via a specific action (*e.g.*, pressing the return button, as in Fig. 1(b), in which a close-up of an alarm-clock image is shown), the VRC system automatically shuts off the projection, and the pan-tilt head returns to a pre-programmed or "home" or "park" position until it senses a hand moving and the process starts over again.

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Creating the Laser-Display Infrastructure: Teaming Up with New Applications

Compact visible-range laser modules, including green lasers, have recently become widely available. These modules will be a key factor in creating new markets, especially for mobile or embedded pico-projection systems.[3,4] We developed a specific application using this laser technology by focusing on a simple UI system. The system is designed so that a user can access any network or other remote-controlled equipment without smart phones or other electrical equipment.

Previously, other research groups had developed projection-based palm-interface systems using a conventional projector[5] or a mobile or wearable projector[6,7] with a camera for image processing. Although the fixed-projector approach does not need any moving parts, the accessible area is limited by the size of the projection area, and the system may need to become bigger as a result. In addition, the size of a hand or palm is very small compared to the whole projection area, so the projector uses only a fraction of the output power capability. On the plus side, the mobile- or wearable-projector approach is suitable for pico-projectors, although the user has to carry around the projection equipment.

Our novel UI robot prototype is based on a laser pico-projection system, which can be used as a VRC with hand tracking.[8,9] The laser-projection head, mounted on a pan-tilt unit, can be separated from the laser-light-source module by a single-mode optical fiber.[10] The system can deliver images of icons or switches for a simple VRC onto a palm or table. Because the projection area can move via a pan-tilt unit, the output power of the projector can be minimized for a small target area only. Consequently, the projection UI robot can be created in a small form factor that can be used with a VRC system in a room or other living space.

Display Generations and Negative-Distance Approach

We propose a new class of display devices, using laser light sources, that are able to find a viewer autonomously and provide useful contextual information. To place the new UI robot system in a larger context, it is useful to review the history of display technologies briefly and to categorize displays as a function of their distance from a viewer.

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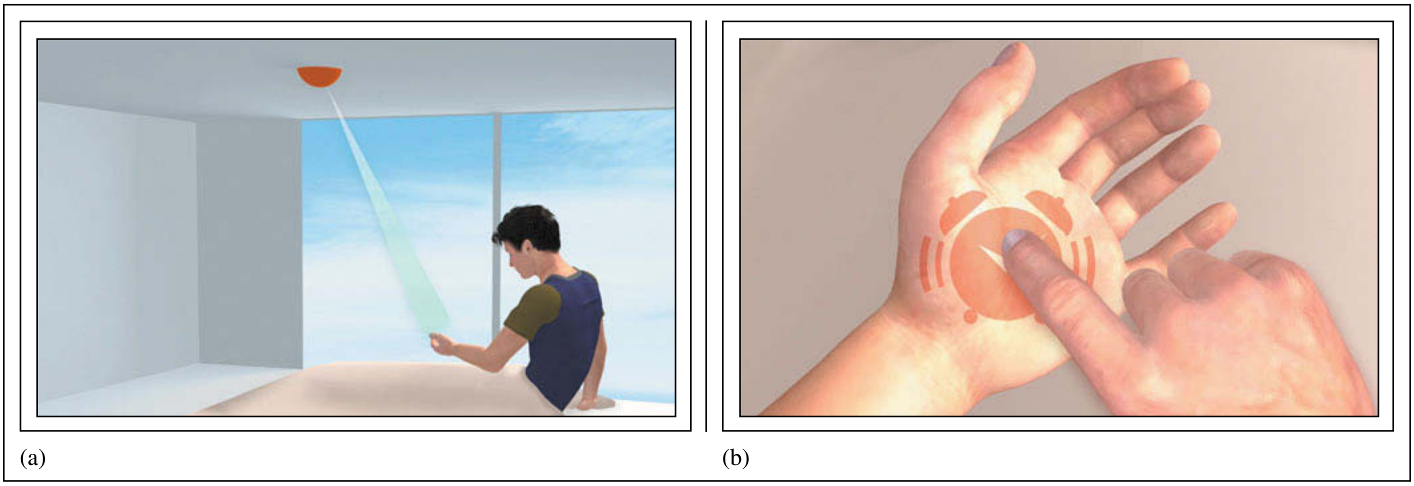


Fig. 1: The Virtual Remote Controller (VRC) system uses a tiny ceiling-mounted laser projector robot (a) that pans and tilts to track a user's hand as he or she moves around a room. (b) The robot projects an image with touch-screen interaction onto the user's hand.

Each generation of display technology is closely associated with its contents and applications and is constantly changing. Earlier display technologies evolve and flow into later display technologies and vice-versa. Beginning with the invention of large screens for cinema in the 1890s, initial "displays" were designed to be experienced from a long distance. Television broadcast led to CRT developments, including a reduced screen size meant for a reduced distance from the viewer. Then personal computers and Internet access promoted the development of a laptop PC with a flat-panel display and input devices designed for closer use yet. At present, hand-held smart phones and tablet PCs with a touch-screen user interface have become dominant. Figure 2 shows a conceptual diagram of the distance between a viewer and a display.

In terms of the distance from a viewer to a display,[11] the distance has reached near-zero when we use touch screens and the user is in contact with the display. There are some new frontiers[12] in "negative distance" regions, in which the viewer can be considered to be "in" the display, or the display in the viewer. Immersive displays should be categorized in these negative distance regions.

There are also similarities among each generation; for instance, a viewer needs to seek and find displays before using them in order to access the information appearing on them. Our team sought to define another negative-distance region relating to the directionality of this seeking activity and to describe the distance from a machine toward a viewer (as opposed to the distance from the viewer toward the machine) as an inverse or reverse distance[13] defined by the direction at first contact because the researchers consider the direction from a viewer to the machine as a positive direction.

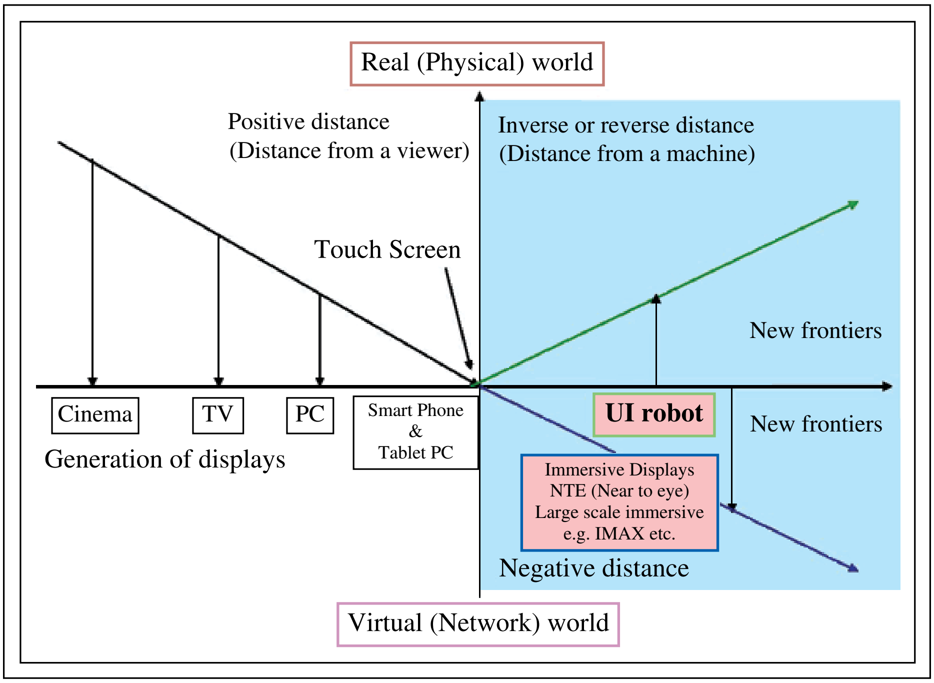


Fig. 2: The distance from a viewer to a display is depicted from farthest distances at left to closest distances at right.

Projection UI Robot System

Our research team applied an integrated second-harmonic-generation (SHG) laser using a Periodically Poled Lithium Niobate (PPLN) waveguide on a Si platform[14] to a green laser (532 nm) for an RGB fiber pigtail module. Figure 3 shows an RGB fiber pigtail module that is integrated with

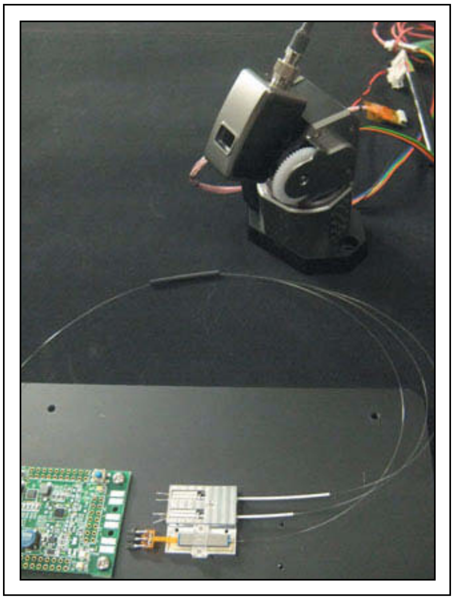


Fig. 3: The robot system's projector head and fiber combiner are at upper right and the RGB fiber pigtail laser module and controller board are at lower left.

R and B direct lasers (based on TO-38 packages).

Each color output is combined with an RGB fiber combiner and delivered to the scanner head. While one-color lasers or color combinations other than RGB could be used with the UI robot system, RGB's advantages include compatibility with existing pico-projection engines such as those used in near-to-eye and head-mounted displays. Such compatibility will make it easier to port the robot-system technology to additional applications in the future. Figure 4 shows the structure of the UI robot system, which includes a pan-tilt scanning MEMS projection head connected to a laser source delivered by a single-mode fiber and a depth sensor. The pan range of the MEMS heads is ± 60° and the tilt range is ± 50°.

Fig. 4: The projection UI robot system prototype structure includes a pan-tilt scanning MEMS projection head connected to a laser source by a single-mode fiber.

Table 1: A conceptual comparison between a common pico-projector and a VRC shows differences in throw and viewing distance, among other variables.

	Common Picoprojector	Virtual Remote Controller
Throw distance	Short (0.3–1 m)	Long (up to 3 m)
Viewing distance (from a viewer)	Medium (1–3 m)	Short (0.3–0.7 m)
Screen (image) size	Large (*e.g.,* 40-in. diagonal)	Small (palm top size less than 8 × 8 cm^2)
Display resolution	High (more than SVGA)	Low (QVGA-VGA or less)
Device operation	Handheld (manual operational movement)	Pan-tilt head (automatic operational movement)

It is possible to achieve the small-form-factor scanner head because of the separation between the light source and the controller boards. The projection head is small enough to embed the scanner head anywhere. The weight of the whole scanner projection head is only 25 g.

Table 1 shows the conceptual comparison between a common pico-projector and a projection UI robot. Both use similar optical engines; however, there are major differences in throw distance, screen size, and resolution.

The differences come from their target applications. Common pico-projectors target high-resolution displays with a small form factor; on the other hand, UI robots are only responsible for interactive virtual icons and other images used for manipulating other equipment.

Applications

We believe that this UI robot system can be used as a ubiquitous and intuitive UI. In order to demonstrate its ability and practicality, we fabricated a prototype of the UI system. For the VRC prototype system employing a UI robot (Fig. 5), we used an ASUS Xtion sensor (ASUS TeK Computer Inc.) as a depth sensor.

This system can serve one user (or hand) at a time and is deployed on a "first come, first served" basis. In the case of a tabletop system, for instance, a depth sensor tracks a hand; after that, the projection head projects

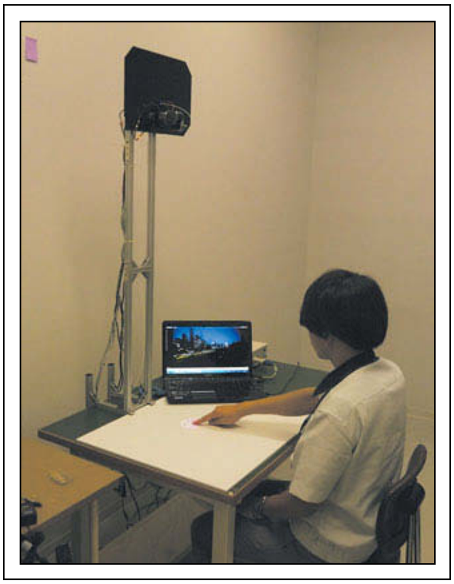
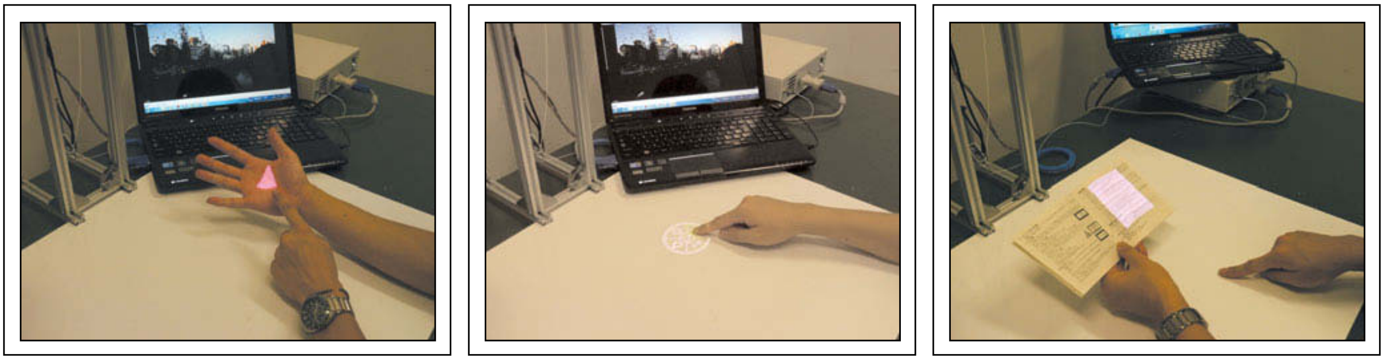


Fig. 5: This VRC prototype shows the projector overhead. The depth sensor works as a motion sensor when the user comes into its field of view. If the user shows some specific gesture for the input mode such as spreading his fingers slightly, as shown in Fig. 6 (a), the scanner head tracks the user's hand using a pan-tilt head and the depth sensor's near-infrared (NIR) image information. When the user presses the virtual image on his palm using his other hand, the VRC can detect the action and remotely control the equipment.



(a) (b) (c)

Fig. 6: One possible application (a) uses a virtual control image on the palm of a user's hand. Other possibilities are a tabletop icon (b) and a lighting area for an object such as a book (c).

appropriate icon images onto a palm or tabletop. During the operation, the sensor keeps tracking other hands at the same time and places each hand on a waiting list (*e.g.*, up to five). If the first hand performs the exit operation or does not specify any command operation in a given period of time (*e.g.*, 30 sec), the right of operation will be transferred to the next hand on the list. Especially for a palm input mode, a waiting list is effective only if the hand is available from the field of view (FOV) of the depth sensor.

Another form of the VRC is "a tap on table" system. The user can draw the virtual switch on the tabletop by a double tap. The user can also operate some functions such as the fast-forward, fast-rewind, and volume-control buttons on a Windows media player via the VRC [Fig. 6 (b)].

The UI robot system can also be applied to a lighting robot system. In this case, the light from the projection system is used as lighting with a virtual remote controller and object-tracking feature. The brightness or direction of the light is adjusted by the virtual controller. The selected projection or lighting area for the object [*e.g.*, a book in Fig. 6(c)] can be followed by the pan-tilt head of the UI robot.

Ultimate Applications

Our team has proposed a new class of display applications in conjunction with a VRC system using a UI robot prototype that employs a MEMS-based pan-tilt laser projection head in combination with a hand-tracking sensor. Many of these applications are for home or office use. We also believe that this VRC system using the UI robot can be effective in public spaces such as hospitals, for instance, where it might help prevent the spread of infectious diseases that are transmitted through touch. This novel class of display technology should open the door to new laser projector-based applications and hence to many new user experiences.

Acknowledgments

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OLED and 4K × 2K TVs: Oxide TFTs Could Help Make Both Happen.

In 2012, two new approaches to TV have come to the forefront: large-sized OLED and 4K × 2K LCD TVs. Both involve technical challenges, and in their first versions are likely to carry price tags in the $10,000-and-up range. The path to mass adoption is not yet clear. However, the technology called oxide-TFT technology could play a key role in the development of either or both of these approaches.

by Paul Semenza

IN RECENT YEARS, new features in flat-panel TVs have included high color gamut, 3-D, LED backlights, thin, ultra-slim bezel, 120–480-Hz frame-rate driving, fast response time, and high brightness. The majority of TV households around the world have switched to flat-panel TVs as their national broadcast systems have converted from analog to digital and to HD (high definition). In some cases, the above features have been instrumental in selecting a TV, but not in driving new or additional TV purchases. So with sales growth at a standstill, the industry is searching for the next new technology that will drive it forward. During the past year, OLED and 4K × 2K TVs have emerged as the leading candidates. While there have been small (less than 20 in.) OLED TVs produced in the past, the current focus is on 55-in. screen sizes, in HD format (1920 × 1080). The 4K × 2K sets currently coming to market all are LCDs; while it is possible to produce 4K × 2K OLED TVs, existing manufacturing techniques are limited to HD.

For large-sized OLED TVs, the promise is in a thinner set with image quality superior to today's LCD TVs. However, panel makers are struggling to enter into mass production; despite having made large investments in cutting-edge factories, significant manufacturing challenges have yet to be solved for large sizes. NPD DisplaySearch estimates that the manufacturing cost for a new OLED TV is 10 times that of a high-end LCD TV of the same size. Thus, despite the great promise of OLED TV, manufacturers have delayed the start of mass production while they improve manufacturing processes.

The 4K × 2K (specifically 3840 × 2160 pixels) format, also referred to as ultra-high definition (UD), has four times the number of pixels of full HD displays, currently the state of the art in resolution for TVs. To many, this enhanced resolution gives a level of reality that surpasses any 3-D effects, without artifacts. (Some would go further, suggesting 8K × 4K is ideal.) As higher resolution becomes standard in mobile devices such as smart phones and tablet PCs, there is greater consumer awareness, and, unlike for other new features (such as smart, connected, 3-D TV, and LED backlights), viewers can easily observe the effect of higher resolution. For TVs greater than 60 or 70 in., some argue that full HD is not good enough, as the pixel density is quite low. Thus, LCD-TV panel makers have developed many 4K × 2K panels.

At the IFA consumer electronics trade show in Berlin last September, Samsung and LG competed once again for the position of leading OLED-TV developer, although the commercial availability was left unclear. Other TV brands, which are not currently able to develop OLED TVs, responded with 4K × 2K TV announcements, seeking to jump ahead in the large-panel commercialization race (Table 1). Chinese, Japanese, and also Korean brands introduced a range of 4K × 2K TVs and indicated that they plan to come to market in 2012. While there are only two OLED-TV panel suppliers at present, there are several 4K × 2K panel suppliers.

Oxide TFT: Filling the Gap Between High Performance and Low Cost

Many producers of OLED TV and 4K × 2K panels have been investigating oxide-TFT technology as a candidate for the active-matrix backplane. For OLED TV, a-Si TFTs have not been shown capable of providing the current required to drive large arrays of OLEDs (as opposed to LCDs, which are driven by voltage). For 4K × 2K panels, a key issue is the ability to drive millions of pixels at high frame rates (limited by RC time delays). While, at present, nearly all 4K × 2K panels are a-Si TFT-LCDs, many panel makers expect that oxide TFT will be a more economically feasible approach to producing such panels.

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Table 1: These next-generation TV technologies were demonstrated at IFA, August/September 2012. Panel and set makers are currently focused on 50-in. and larger screen sizes for both OLED and 4K × 2K TVs.

	OLED			4K × 2K		
Origin	**Brand**	**Size (in.)**	**Panel Maker**	**Brand**	**Size (in.)**	**Panel Maker**
Korea	Samsung LGE	55 55	Samsung Display LG Display	Samsung LGE	70 84	Samsung Display LG Display
Japan				Sony Sharp Toshiba	84 60 55 84	LG Display Sharp AUO LG Display
China				Hisense Haier ChangHong THTF	50 65 65 55 50	CMI CMI CMI AUO CMI

The most common oxide-TFT technology is IGZO (indium gallium zinc oxide). The most important characteristic of oxide TFTs is electron mobility. Traditional a-Si has an electron mobility of 0.5 cm^2/V-sec, while IGZO is 10–30 cm^2/V-sec, and LTPS is the highest at 50–150 cm^2/V-sec, depending on the operating temperature. However, LTPS requires eight or nine photomask steps, including laser annealing and ion implantation, which are complex steps. IGZO is similar to a-Si, as the TFT structure of IGZO is bottom-gate inverted staggered, just like a-Si; IGZO does require one additional mask step compared to a-Si, for a total of six. In general, IGZO appears to be the easiest approach for an existing a-Si panel maker to move to high-mobility panel production.

There are disadvantages to IGZO. Because it is a metal oxide, oxygen, a very active material, is used in the process, and threshold-voltage stability is very low. Also, the uniformity of the electron mobility is lower than that for a-Si or LTPS. Finally, IGZO uses rare-earth metals (indium and gallium), which introduces risk in procurement and cost increases.

Panel Makers' Strategies for Oxide TFT

In Taiwan, AU Optronics Corp, (AUO) is converting some Gen 6 and 8 capacity to oxide TFTs, mainly for AMOLED backplanes. In addition to shifting some Gen 6 capacity to oxide TFTs, BOE is planning on implementing oxide TFTs at its Gen 8 fab as well as building a new Gen 8 IGZO fab in Beijing. Chimei Innolux is less enthusiastic because it does not have a concrete plan to develop large-sized AMOLED TVs. Its parent, Foxconn, is building a Gen 6 LTPS fab in Chengdu, where it plans to implement oxide TFTs for AMOLED backplanes. While it is expected that the same line could produce both IGZO and a-Si TFTs for LCD backplanes, it is not anticipated that lines will be able to switch between IGZO TFTs for OLED backplanes and IGZO or a-Si TFTs for LCD backplanes.

LG Display has shifted some capacity to IGZO in its Gen 8 fabs, which will be used to produce 4K × 2K LCD panels and AMOLED backplanes. The company is also shifting some capacity at its Gen 5 and 6 fabs. Samsung Display has only shifted some Gen 5 capacity to oxide TFTs, but its strategy may be changing.

Sharp has been the most aggressive at moving to oxide TFT. Since 2011, Sharp has begun transforming its Gen 8 to IGZO to produce high-resolution LCDs for tablet PC panels. In 2013, Sharp plans to start changing its Gen 10 gab over to oxide TFTs for the production of 4K × 2K LCD-TV panels.

In the future, new fabs will be designed to be IGZO compatible, but most current IGZO capacity is being converted from a-Si (Table 2). Because IGZO production is more complicated than a-Si, there are yield and cost tradeoffs. Just because a-Si capacity is converted to IGZO does not mean it will produce only oxide FPDs; the production mix will depend on costs and the market. Most panel makers are looking to utilize oxide TFTs for AMOLED TVs or 4K × 2K LCD-TV panels, although as mentioned, most 4K × 2K production has used a-Si, and the leader in oxide TFT, Sharp, is focused on LCDs for tablet PC panels.

4K × 2K: Technically Feasible, but Infrastructure-Limited?

One significant difference between 4K × 2K and OLED TV is that 4K × 2K requires changes in the production chain – from TV cameras and studios, through content distribution and transmission to the set at home – that are more like the HD and 3-D transitions. The key issues are the compression of video files to manageable sizes, delivery of video files, playback, and connection of the player to the display. Current compression technology (H.264/MPEG-4) results in very large amounts of data for 4K × 2K content; not only does doubling the resolution produce four times the pixels, movies are also transitioning from the standard 24 fps to 48 fps, an additional doubling of the data. As a result, movie files can be in the terabytes. A new compression standard – HEVC (high efficiency video coding, also referred to as H.265) – is being created, but it is not yet mature.

Early encoders will be large and relatively inefficient; similarly, HEVC decoder ICs will be few and costly at first. In decoding, 4K × 2K will require extra memory. Six frames will be necessary in storage for HEVC decoding and such large volumes of data and high frame rates will put a strain on memory bandwidth.

Even with HEVC, the problem of delivery remains. Internet speeds and content-delivery networks are not good enough to support such data traffic. For disc formats, 4K × 2K would require a re-write of the Blu-ray specification to support the standard and a new generation of players with 4K × 2K decoding and output. In the short term, 4K × 2K playback Blu-ray players that up-scale are appearing. While the marketing benefit of a player with 4K × 2K output is obvious, it is less clear why such up-scaling should be done in the player and not the TV set. The display connection is actually fairly simple, with HDMI able to handle the data within the 1.4a specification.

Table 2. Many panel makers have plans to shift to oxide TFTs in 2012–2013.
Source: *DisplaySearch Quarterly FPD Supply/Demand and Capital Spending Report*

				Substrates (1,000 Sheets)							
				2012				2013			
Manufacturer	**Factory**	**Gen.**	**Tech.**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
AUO	AUO Taichung L8A	8	a-Si/IGZO			2	10	10	10	10	10
	QDI Lungtan L6B	6	a-Si/IGZO			2	5	10	10	10	10
BOE	BOE Hefei B3	6	a-Si/IGZO				2	5	10	10	10
Chimei Innolux	ILX Jhunan T2	6	a-Si/IGZO	15	15	15	15	15	15	15	15
LG Display	LGD Paju P8	8	a-Si/IGZO					10	20	30	40
			IGZO		4	8	8	8	8	8	8
	LGD Paju P9 G8	8	a-Si/IGZO		20	50	60	65	65	65	65
	LGP Kumi P4	5	a-Si/IGZO		50	50	50	50	50	50	50
	LGP Kumi P6	6	a-Si/IGZO							5	10
Samsung Display	SEC Chonan L6 Wing	5	a-Si/IGZO		3	15	20	20	20	25	25
Sharp	SHP Kameyama 2 IGZO	8	IGZO	20	20	27	40	40	47	60	60
	SHP Sakai 1 IGZO	10	IGZO							10	14
Grand Total				35	112	169	210	233	255	298	317

For broadcasters, the problems are more complicated. In satellite and cable, 4K × 2K could be transmitted today, assuming that decoder devices were available. However, the increase in bandwidth would require extra channels and thus extra satellite transponders. Since 4K × 2K will cost roughly 4 times that of an HD channel, it would need to provide increased revenues. For terrestrial broadcasters, spectrum is scarce, and it is likely that terrestrial 4K × 2K would not be feasible until HEVC becomes mature and is similar to MPEG-4 HD. It is worth noting that even today, 1920 × 1080p broadcasts are rare; most are interlaced, with many broadcasters actually downscaling to 1440 × 1080i and then stretching in decode.

As in 3-D, 4K × 2K display technology is ahead of the rest of the content chain. HD broadcast took more than 20 years to bring to maturity. NHK and the BBC have indicated that they make significant changes every few decades and appear to be focusing on what they consider achievable in that time scale – 8K × 4K, not 4K × 2K. Any product launches in the meantime will have to survive incomplete content-delivery infrastructures. Therefore, at this time, 4K × 2K does not appear to have strong interest from broadcasters.

However, there are other possible applications, such as a family communication screen that combines conventional TV tasks with others currently done by such devices as noticeboards, refrigerator doors, *etc*. These would be used at far closer ranges, where such resolution would be perceivable and valuable. The PC industry is also seeing a resurgence in increased resolution; the latest MacBook Pro has 2880 × 1800 pixels and Apple's competition is sure to respond. 4K × 2K could be the start of a broader rethink of TV's function as the best screen in the house, encompassing new applications.

Let the Market Decide

At the beginning of 2012, it appeared that OLED TV would be the leading new TV technology. However, manufacturing challenges have slowed the launch. Meanwhile, other panel makers have jumped into the fray with high-resolution LCD TVs. Both of these technologies are expected to be very expensive when they first become commercially available – perhaps just under $10,000 for a 55-in. OLED TV and over $20,000 for an 84-in. 4K × 2K LCD TV. (See this issue's Industry News for an overview of the 84-in. 4K TVs recently introduced by both Sony and LG.) Whether either crosses the chasm to mass adoption will depend on the perceived benefit, in terms of design and performance, as well as in functionality – can consumers use these sets for things that "old-fashioned" HDTVs or smaller OLEDs cannot do? ■

Real-Time Dynamic Holographic 3-D Display

Using a proprietary thin film with a super-fast holographic response and no applied electric field, the authors have produced a real-time dynamic holographic display-concept demonstration with holographic images that can be refreshed on the order of a millisecond without crosstalk. The film's combined properties make it suitable for a large-sized, real-time, dynamic, color, holographic 3-D display.

by Hongyue Gao, Xiao Li, Zhenghong He, Yikai Su, and Ting-Chung Poon

HOLOGRAPHY[1-4] is a technique for displaying real objects or scenes in three dimensions. A holographic display provides realistic 3-D imagery, allowing an observer to perceive light with the naked eye as it would be if scattered by an actual object or scene. This technique has attracted considerable attention in recent years. Large-sized and static holographic displays, including full-parallax holographic stereograms created by using special holographic recording materials, and very small-sized and dynamic holographic displays based on current commercially available spatial light modulators (SLMs), have been realized by some companies and scientific research institutes. However, a large-sized, dynamic, full-color, holographic 3-D display has proved elusive, due to several technology limitations.

Recently, however, dynamic holography has progressed substantially due to the discovery of some new holographic materials. In 2010, a holographic 3-D telepresence, dynamic and near real time, was presented by Blanche *et al.* in *Nature*, in which a holographic display that can refresh images every 2 sec was demonstrated in a photorefractive polymer as a holographic material.[4] Recently, a quasi-real-time holographic display with a refresh rate of five holographic images per second was reported by Kinashi *et al.*[5] However, these achievements do not yet represent real-time dynamic holographic displays.

In this article, we describe how we created a real-time, dynamic holographic display by using holographic recording thin film with a super-fast optical response. Holographic images can be refreshed on the order of a millisecond without crosstalk using this new film. Both the formation time and self-erasure time have been shown to be around 1 msec, with the film being completely self-erased in each cycle. Moreover, because there is no need to apply any external electric field onto the thin film, it is easy to fabricate it into a large size without the need for creating true pixels because there is no required matrix-addressing structure. We think this holographic film is potentially suitable for a large-sized holographic display because it will produce higher resolution and a much larger viewable area than existing commercially available spatial light modulators (SLMs).

As is known, human observers can see and process the scattered light from an object, which includes intensity information as well as wavefront/phase information. In conventional photographic two-dimensional displays, only intensity information is recorded and subsequently displayed. Therefore, the wavefront/phase information of the object cannot be reconstructed. In holography, coherent light is used to record interference between light scattered from the 3-D object and a reference beam to form a hologram in the recording medium [see Fig. 1(a)]. Hence, both the intensity and wavefront/phase information of the object are recorded. To reconstruct the original 3-D object, we simply illuminate the recorded holographic information, *i.e.*, the hologram, with a coherent reference beam [see Fig. 1(b)]. However, this does not present a perfect holographic technique. It is necessary to solve some practical problems in terms of the size of the hologram, real-time response, resolution of the recording medium,

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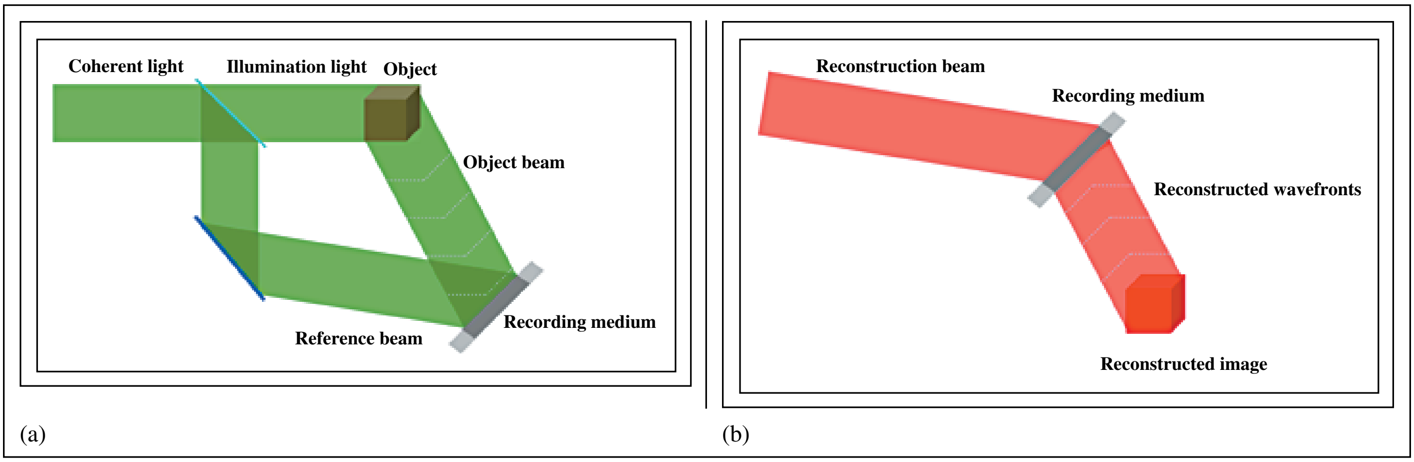

Fig. 1: (a) The holographic recording process and (b) the reconstruction process.

color issues, *etc.*, to create a true 3-D holographic video display. We have studied holographic 3-D displays for several years and recently obtained some interesting results in terms of real-time versions of such displays.

For this purpose, our team developed an experimental holographic film that is fabricated by sandwiching a mixture of a liquid crystal and a photosensitive material with two glass substrates. We used a sample of this experimental film in a thickness of about 50 µm in a 3 cm × 2 cm size. We measured the response time of the thin film and found that we could achieve performance suitable for a real-time holographic display. The experimental setup for this holographic display is shown in Fig. 2. A reference beam and an object beam, which are derived from a Nd:YAG laser (λ = 532.8 nm), are set to be *p*-polarization by a half-wave plate. A spatial light filter, an SLM, and a lens are placed in the object beam path, where the spatial information of an image is displayed on the SLM. A He–Ne laser beam (λ = 632.8 nm) is also set to be *p*-polarization to probe the writing region of the sample.

In this experiment, we used an SLM to form the test images because this is an easy way to carry real-time dynamic image information onto the signal beam. However, the SLM is not used as a holographic display.

Here, our experiment is basic research used to demonstrate that a real-time dynamic holographic display can be realized in this film,

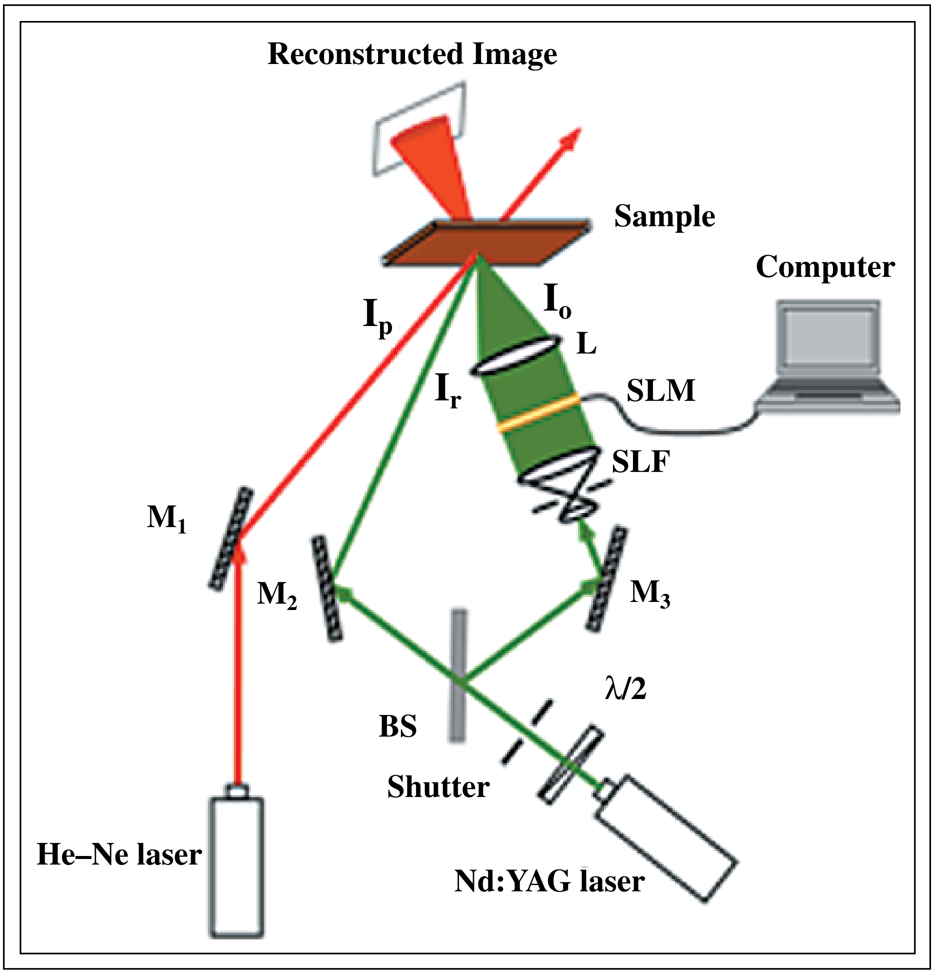

Fig. 2: An experimental setup for a holographic display uses a liquid-crystal thin film without an applied electric field as a sample. Ms are mirrors, BS is a beam splitter, λ/2 is a half-wave plate, L is a lens, SLF is a spatial light filter, SLM is a spatial light modulator, I_o is the object beam, I_r is the reference beam, and I_p is the readout beam or reconstruction beam.

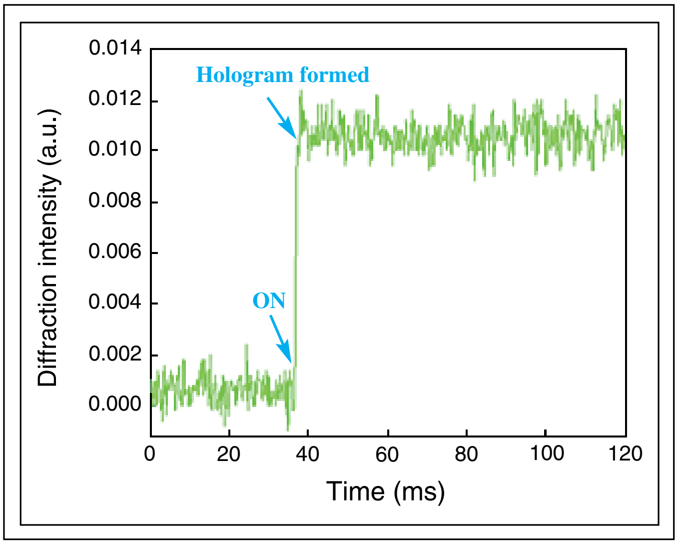

Fig. 3: (a) Hologram formation and (b) the self-erasure process appear with "ON" and "OFF" denoting that the writing light is turned on and off, respectively, illustrating a response time of the order of 1 msec.

and the SLM is a practical way to modulate the signal light to obtain dynamic incident images.

The hologram formation time and self-erasable time in the film are both about 1 msec measured by an oscilloscope,[6] as demonstrated in Fig. 3. The graph in Fig. 3(a) shows that the hologram can be formed immediately in the sample once the recording light is turned on. The film is actually recording the hologram, which is carrying all the information of a 3-D image, not just combining multiple coherent light paths. In Fig. 3(b), it is shown that when the writing or recording light is turned off, the recorded hologram can be self-erased completely. There is no need to use any light or electrical field to erase it.

If the response of the holographic material, especially the erasure of the hologram, is not fast enough, the recorded hologram cannot be erased completely, and then the diffraction efficiency of the following hologram will be affected and multiple images will be reconstructed from the holograms at the same time. This crosstalk is a potential problem in a holographic display. We demonstrated a holographic video display without crosstalk between holograms with this film. Figure 4 shows a real-time display of a rotating letter "B".

The next step of our research is to study the color holographic display in an RGB model. As we know, an original color image includes red, green, and blue components. They should be recorded in three holograms. During the display process, the RGB images should be read out from these holograms, and then combined into a color image, as shown in Fig. 5. We believe that with the development of our work, further improvements could bring this film into practical holographic color display applications. Although we have not demonstrated this technology yet, we have studied RGB model color holographic displays and are improving the results.

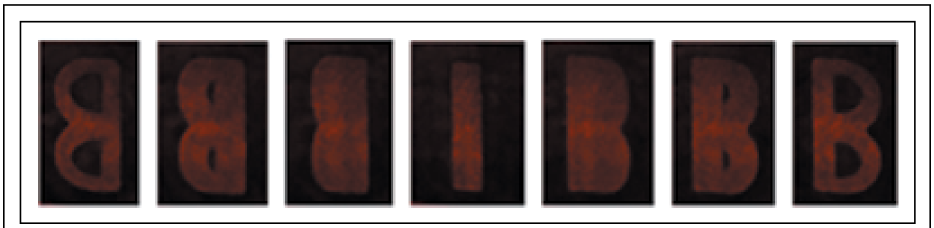

Fig. 4: These seven snap shots are from a real-time holographic display video.

Looking Forward

The film that we have created and are studying has much faster response times and higher resolutions and is more easily fabricated into a large-sized holographic display than current commercial SLMs. We hope to develop this film into a holographic TV platform in the future. Such a holographic TV would include a writing system, a display screen, and a readout system. The hologram would be recorded in the display screen by using the writing system, and then be read out from the display screen by the readout system to reconstruct the image. The response of this film is superfast; therefore, we think a large-sized hologram cannot be written in the film by mechanical scans, as has been previously been demonstrated.

We have demonstrated angular multiplexing, peristrophic multiplexing, and other multiplexing modes in this film. Holographic multiplexings, *i.e.*, multiple holograms synchronously displayed at a single location of the thin film, have also been demonstrated[6] by our research, which shows the feasibility of an RGB-model color holographic display.

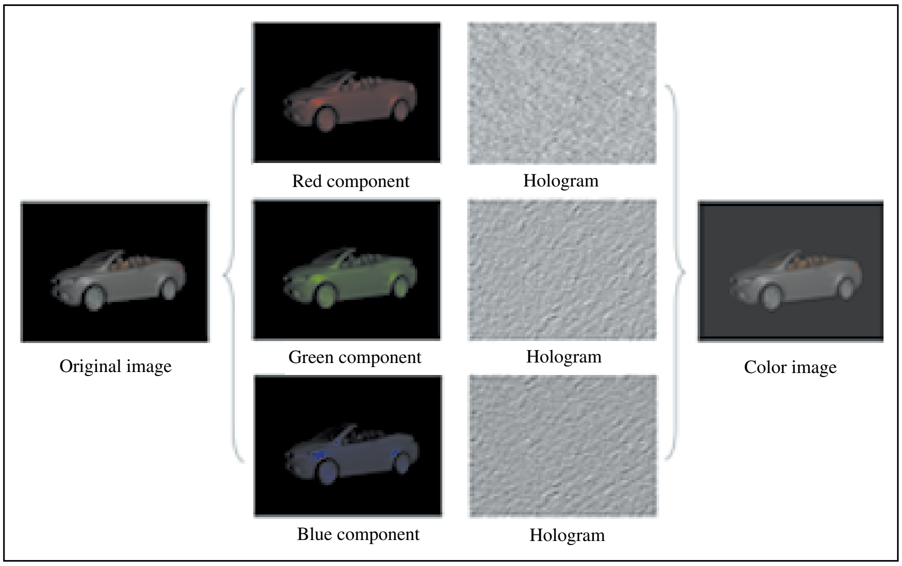

Fig. 5: The above color holographic display is based on an RGB model.

We have also created concept designs for a holographic TV system. If this system can be made, it will be large and heavy at first, much like early projection systems. But we think it is important to create a holographic TV. The writing system, display screen, and readout system are difficult but not impossible to implement. With proper funding, we think we could make this holographic TV in 5–10 years.

In terms of future research, we also would like to slow down the response of the material, especially the hologram erasure, which is too fast for the requirements of this application. If the perfect holographic material can be achieved, mechanical scans could be used as a writing method, and the entire system would be greatly simplified.

Acknowledgments

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Holography Power: A conversation with MIT Media Lab's V. Michael Bove, Jr.

Information Display recently had the chance to talk to V. Michael Bove, Jr. about data processing and other logistical challenges designers face in order to render real-time holographic TV images. (One of the Frontline Technology stories in this issue, "Real-Time Dynamic Holographic 3-D Display," discusses a possible approach to creating such a TV.) Bove heads up the Object-Based Media Group at the MIT Media Lab. He is co-author with the late Stephen Benton of the book Holographic Imaging (Wiley, 2008) and served as co-chair of the 2012 International Symposium on Display Holography.

Compiled by Jenny Donelan

V. Michael Bove, Jr.

Q: From today's vantage point, what would it take to encode, stream, and make set-top boxes that could decode and render holographic TV images?

A: Something that people observed in the '60s, '70s, and '80s about holographic television was that's a lot of pixels. Even now, it's unrealistic to think of transmitting all the necessary pixels in a large, high-resolution, optically captured holographic image. Even if you could, there's a bigger problem, which is if you make a hologram, using coherent capture, you're making it for a particular size of display that has to have RGB light sources of given wavelengths. These must match the wavelengths of the lasers that you use to capture the scene, and so forth. So, it's not terribly flexible, even if you had the bandwidth for dealing with it and even if you had the high-powered pulsed lasers for scene capture.

People are not for the most part thinking about doing holographic capture and then sending the hologram onto a holographic display, but rather about capturing enough information about a scene in such a way that it could be turned into a hologram.

This is doable with a CGI model of a scene – you know everything about it – but for a real scene, you either need a range-finding camera, a lightfield camera, or an array of small ordinary cameras. Somehow you're going to take the information about the shapes of the objects or about the lightfield coming from the scene and you're going to convert that into data so you can make a hologram. One of the nice things about doing that is those representations from a lightfield camera or an array of parallax images are a bit easier to compress and transmit over networks than a hologram. The problem is you then need the computation in the display not just to decode the data but to generate the hologram, so you have to be able to generate the diffraction patterns in real time. If you're working with a 3-D model, then you have to do the rendering of the model before you can even generate the diffraction patterns.

I should mention that the work we've been doing at the Media Lab with the electronic holographic displays has been horizontal parallax only because that makes the problem a bit more computationally tractable. If you have full parallax, then you need millions of pixels per scan line and millions of scan lines.

And there are other things you can do to make things simpler. A company called SeeReal is doing an eye-tracking display for which they can make the views very narrow because they can steer the images to where your eyes are. Since a hologram's pixel pitch relates to the view angle, if you are going to make a hologram that has, say, one degree of viewing angle, you don't need so many pixels. That makes the computation a lot easier.

Q: With the understanding that the requirements vary according to how the hologram is created, compressed, and streamed, roughly how much processing power would be required to operate a holographic TV in somebody's living room someday?

A: In the early 1990s, my research group's collaboration with the late Stephen Benton's group involved building specialized computational hardware. We built a desktop super computer for doing just that. About 10 years later, I realized that the graphics-processing units in PCs or game consoles were becoming fast enough that you could potentially use them to generate holograms. In about 2003, we found that in fact you could do about as well with GPUs as with our special-

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Q & A with Michael Bove

ized hardware. GPUs get faster every year and so that's been the direction we've taken since then.

***Q:** What would be the size of a holographic display in terms of processing power? Will we need the equivalent of a roomful of computers?*

A: For horizontal parallax, you could probably build a holographic display for a living room with somewhere in the neighborhood of a dozen or two GPUs in it. For full parallax, even GPUs are not going to completely solve the problem. You're probably looking at hundreds of GPUs and that's not quite practical. Something to be aware of is that graphics processors are very, very fast, but they're also very power hungry. The higher-end GPU cards that come in fancy PCs are largely heatsinks and fans. We find we run into trouble keeping them cool and powered if we want to put just three or four of those in a small box. If you're talking about putting a lot more into a unit for a consumer, it would use a lot of electricity, and run hot, and make noise.

***Q:** Do you see any kind of holographic TV available in the next 5 years? Ten years?*

A: The takeaway is that we are not, as long as we're talking about horizontal parallax only, orders of magnitude away from having enough computation to do that kind of thing. We are driving our holographic displays in the lab with a handful of GPUs, and they work.

However, one of the "gotchas" in holographic video displays is that unlike typical TVs, as you increase the size of the screen, the number of pixels has to grow, which leads to scaling problems. Eventually you run into a bottleneck somewhere, whether it's computation or interconnects or whatever. So it's probably going to be a while before we have holographic video displays the size of the biggest living-room TV that you can buy at Best Buy today. However, if we're doing desktop monitors or 26-in.-diagonal displays or something similar, it's not outrageously far in the future.

Look for V. Michael Bove, Jr.'s full-length article on holographic TV in the next issue of *Information Display*. ■

continued from page 2

In the article "Toward the Ultimate 3-D Display" in our February/March 2012 issue, Pierre reported his success in making demonstration holographic displays up to 17 in. with update rates on the order of a few seconds or less. This further fueled my enthusiasm for the subject.

So, here we are in the fall of 2012 and a group of authors from Shanghai Jiao Tong University in China and Virginia Tech in the U.S. report their discovery of a self-erasing holographic recording medium that could indeed become the foundation of a real-time display. Their Frontline Technology article titled "Real-Time Dynamic Holographic 3-D Display" describes how they have demonstrated the ability to create 3-D images from images rendered on a spatial light modulator, without the need for billions of pixels, and still create at least a concept demonstration of a real-time holographic display – *i.e.*, a television, for example. But, in order for any approach like this to work, you still need to render a tremendous number of pixels very quickly.

To understand how big a challenge that would be, we contacted Dr. V. Michael Bove from the MIT Media Lab and asked him whether it would be possible to harness enough processing power to make such a holographic display work. We were pleasantly surprised to learn that it's not inconceivable, and maybe even practical in the next 5–10 years, as he explains in his Q&A interview with our own Jenny Donelan. Oh, there are a number of caveats, but after you read both of these articles I think you will come away with the same optimism I have.

By now you might realize this is our annual novel technology issue, where we put our usual skepticism aside to find new and unique topics. For this issue, we had help from the University of Washington's Brian Schowengerdt, who assigned the holographic piece mentioned earlier, as well as our next two Frontline Technology follow-ups from the highly successful Innovation-Zone exhibits at Display Week in Boston this year. The first is from author Nate Saal at Tactus Technology and is titled "Microfluidic Technology Enables New User Interface." Tactus has developed a method to make tactile buttons and physical surface features appear and disappear on the surface of a touch screen through the use of fluid pressure and preformed membranes. With this technology, Tactus can literally raise a fully functional tactile keyboard from the surface of a projected-capacitive touch screen to allow typing, then collapse the keys and leave the surface flat and smooth to work again as a touch surface. I was skeptical until I tried it; now I'm convinced this will see some mainstream applications in the near future.

The next article describes the development of a new user-interface concept called a Virtual Remote Controller (VRC). In their article, "Virtual Remote Controller Enables New Laser-Projection-Based Applications," the authors explain how they can use a ceiling-mounted camera and laser system to create an immersive virtual remote control system they call a "UI Robot." Their work shows the kind of imagination and creative thinking we like to encourage. They have several ideas for how to create practical applications from their concepts, but my first thought was about how many times I lose the remote for my TV. If my TV remote really becomes my own hand, maybe I'll be able to find it when I need it.

In the end, though, we come back into the world of TVs. Our Display Marketplace this month is written by contributing editor Paul Semenza and is titled "OLED and 4K × 2K: Oxide TFT Could Help Make Both Happen." In his analysis, Paul describes how two distinct high-end TV trends are emerging, one by way of full HD OLEDs in the 55-in. size, as were demonstrated at Display Week this year. The other trend is from the LCD camp, trying to build enthusiasm for Ultra-Definition (UD) 4K × 2K panels in a range of very large sizes. Both of these are high-end trends meant to spark new life, and yes, bring new margins into the TV consumer market. The UD trend has problems from the standpoint of lack of infrastructure and standards, but like moths to bright LEDs, our industry cannot contain the urge to make more pixels and larger displays even if it means getting well ahead of the symbiotic content creation and distribution industries it needs to survive. Regardless of which trend you look at, a key part of the success may rely on the success of cxide TFT technology, specifically IGZO.

Needless to say, putting this issue together was a lot of fun – even if I had to use a conventional keyboard instead of a tactile touch screen and a 2-D LCD instead of a fully immersive holographic version. With all these great innovations to look forward to, I hope you will be able to get as excited about the future as I am. ■

Upcoming Event: LatinDisplay 2012, November 26–30

Putting on a display event in the geographically and economically diverse market of Latin America requires a collaborative effort from a wide range of sources. This year's LatinDisplay/IDRC is organized by the Society for Information Display, SID's Latin American Chapter, Mackenzie Presbyterian University, Associação Brasileira de Informatica (ABINFO), and Centro de Tecnologia da Informação Renato Archer (CTI). It is sponsored by Brazilian funding agencies and the Brazilian government.

LatinDisplay 2012 will take place at Mackenzie Presbyterian University in São Paulo, Brazil, on November 26–30 and will include a scientific and technical symposium; a panel discussion; an exhibition; business meetings; the DisplayEscola (Display School); meetings of the LTN SID Chapter, BrDisplay Network, and Ibero American Display Network; and more. Last year's event featured nearly 200 symposium papers. LatinDisplay is the premier Latin American event for displays and related technologies and plays a key role in developing display technology and the display industry in South America and in Brazil in particular.

"LatinDisplay 2012/IDRC 2012 is bringing scientists from all over the world to present the latest advances in displays to stimulate new research and business relationships and to encourage those new to the field. Our university is honored to host this important event," says Prof. Dr. Benedito Aguiar, the Rector of the Mackenzie Presbyterian University and the General Chairman of LatinDisplay/IDRC 2012.

"LatinDisplay 2012/IDRC 2012 is an important tool for supporting the Brazilian Industrial Policy of the Federal Government for displays and related technologies," says Dr. Victor P. Mammana, the Director of CTI and Co-Chairman of LatinDisplay 2012/IDRC 2012.

For more information and to register for LatinDisplay 2012/IDRC 2012, visit: http://www.abinfo.com.br/latindisplay or contact General Chairman Benedito Aguiar at reitor@mackenzie.br or Co Chairman Victor Pellegrini Mammana at victor.mammana@cti.gov.br or latindisplay2012@abinfo.com.br or the Organizing Committee at latindisplay2012@abinfo.com.br. ■

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SID International Symposium, Seminar & Exhibition

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May 19–24, 2013

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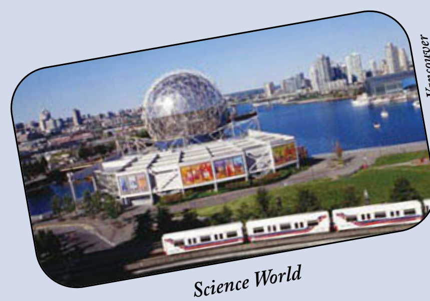

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Science World

Display Week will be held May 19–24 at the Vancouver Convention Centre, with the exhibition open from May 21–23. Display Week is the once-a-year, can't-miss event for the electronic information display industry. The exhibition is the premier showcase for global information-display companies and researchers to unveil cutting-edge developments in display technology. More display innovations are introduced year after year at Display Week than at any other display event in the world. Display Week is where the world got its first look at technologies that have shaped the display industry into what it is today; that is, liquid crystal display (LCD) technology, plasma display panel (PDP) technology, organic light emitting diode (OLED) technology, and high definition TV, just to name a few. Display Week is also where emerging industry trends such as 3D, touch and interactivity, flexible and e-paper displays, solid state lighting, oxide TFTs, and OLED TV are being brought to the forefront of the display industry. First looks like these are why over 6500 attendees will flock to Vancouver, Canada, for Display Week 2013. Display Week 2013 will cover the hottest technologies in the display marketplace.

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The I-Zone will give attendees a glimpse of cutting-edge live demonstrations and prototypes of the display products of tomorrow. Researchers from companies, startups, universities, government labs, and independent research labs will demonstrate their prototypes or other hardware demo units for two days in a dedicated space in the main Exhibit Hall. The "Best Prototype at Display Week," to be selected by the I-Zone Committee, will be announced at the Awards Luncheon.

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