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REPORT

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The Vision for Microvision

Microvision's systems will beat the competition in every category: cost, quality, compactness, power-efficiency, and versatility. It's no contest.

I first visited **Microvision** (MVIS) in 2001. I wrote about the company in the June 2002 issue of *Dynamic Silicon* and, again, in the July 2004 issue of the *Gilder Technology Report*. Whenever I visit the company, see its demonstrations, or think about its potential, I become enthusiastic about its opportunities. It always seems to have many more opportunities than it has the money to exploit and it always seems to be on the verge of a breakthrough. This time is no exception: I came away as enthusiastic as ever and just as sure that the company is on the verge of market success. The heart of Microvision's many opportunities is its MEMS (mircroelectromechanical system) mirror.

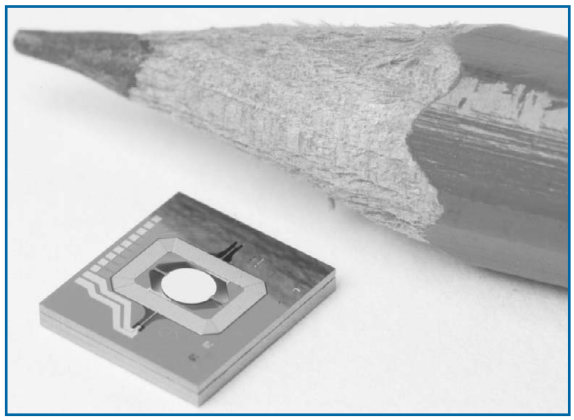

Figure 1. Microvision's MEMS mirror is crystalline silicon: it measures 1.5 x 1.6 mm.

When I visited the company five years ago, we talked about head-up displays (HUDs) for the military, viewfinders for digital cameras, and barcode readers. At that time, the company struggled with expensive packaging for its scanning mirror and with the optics and light sources. Most of the development money came from the U.S. Army's support of projects to build head-mounted displays for helicopter pilots. Today, with MEMS packaging challenges resolved, Microvision's near-term opportunities now include a range of commercial and even consumer applications.

The market for solid-state displays is growing rapidly. Solid-state displays are everywhere: cell phones, cameras, laptop computers, signs, and home-entertainment systems. There are so many different applications that the market almost defies classification. No one display is ideal for all uses. For this report, I divide the market into augmented-vision, see-through displays; color microdisplays; and large-scale projection displays.

Augmented-vision, see-through displays are for personal use; they augment the viewer's ambient environment. In typical applications, a small display might be mounted close to the eyes to offer information for a vision-oriented task. Attention is on ambient clues but the user occasionally looks at information in the field of view put there by the augmented-vision display.

A color microdisplay is also meant for personal use and is mounted close to the user's eye or is embedded in a consumer device, such as a camera. The color microdisplay differs from the augmented-vision, see-through display in that the visual field is occluded; the user concentrates on the display to the exclusion of the surrounding environment. This configuration is also referred to as a "look around display."

Large-format projection displays project an image and they are not mounted near the viewers' eyes. Projection displays include projectors with back- and front-illuminated screens, head-up displays, and large-scale solid-state displays, such as those for computers.

Augmented vision

Microvison's Nomad is the third generation of its augmented-vision displays and is its proof of commercialization for industrial products. The head-worn Nomad mounts a transparent window in front of one eye. This connects to a hands-free, wearable computer that can have a WiFi connection to a server. First volume sales were in automotive maintenance, where field trials demonstrated productivity gains of 20 to 40 percent. Repair technicians access maintenance manuals on the shop's server while still in position to use the information.

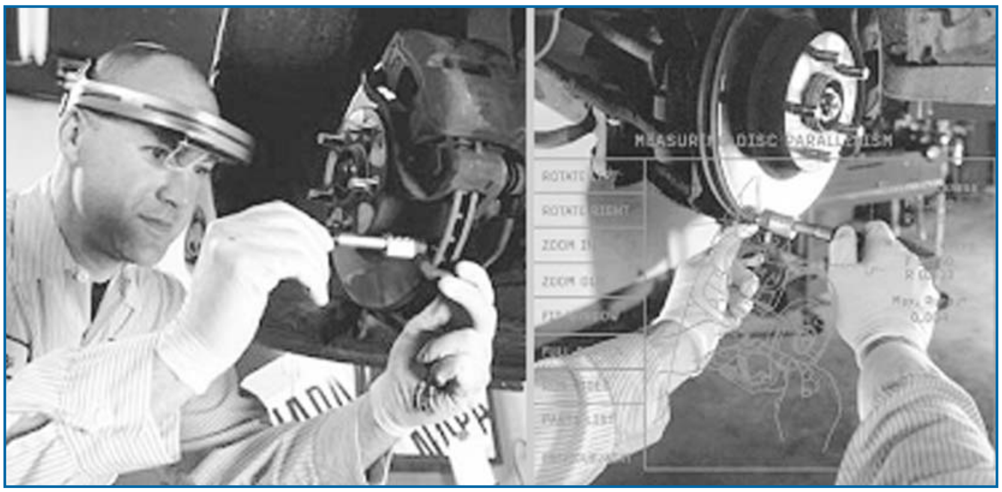

Figure 2. Microvision's Nomad augmented-vision display.

The Nomad uses a MEMS mirror that is etched from bulk silicon to form a single-crystal reflecting surface that is hinged in the x and y axes. This hinged mirror operates like the remote-control side mirrors on a car: electrical signals tilt the mirror in two directions to control the viewer's image.

In the Nomad, a red laser is aimed at the mirror. Electromagnetic actuators move the mirror so that the reflected beam traverses a "raster" pattern. A raster scan is the way the cathode-ray tube of an old television set paints its picture, except that Microvision's raster pattern is a zig-zag that paints an image in both horizontal directions and from top to bottom. The image is created by varying the brightness of the laser. When the laser is off, the only photons reaching the eye come from the ambient environment. When the laser is on, its photons add to those from the ambient environment. Because of the beam's zig-zag pattern, alternate lines are read out of memory into a buffer that reverses the order of presentation. Every other horizontal line is written backwards. The system paints red SVGA (800x600) images directly onto the user's retina, overwriting incoming ambient light. The dynamic range, a measure of the display's ability to produce contrast at differing ambient light levels, is 5000:1 for this system. Visual dynamic range is a synonym to the auditory dynamic range of a sound system, which is the ratio of the loudest undistorted sound to the lowest sound or to the noise level.

The industrial version of the Nomad is popular in the maintenance shops of several major auto manufacturers and it will soon be invading aircraft maintenance, trucking, and other applications where hands-free, wireless access to shared centralized databases is valuable in the work area. For construction sites, the display device can be mounted to a hard hat.

There are more-expensive versions with advanced features for military applications.

A red laser emitted the photons in Nomad's initial versions, but Microvision began adding other colors about a year ago. Next could be a two-color version. There does not appear to be a need for full color, as users' primary attention is on the ambient environment, and electronic information is merely an "annotation."

For augmented vision, Microvision has no peers; its competitors mount a postage-stamp-size display somewhere in the field of vision. The user has to look around the small display, which imposes a large rectangular blind spot in the field of view. These displays, which might be on the order of 18x25 mm, typically have QVGA or VGA resolution (320x240 or 640x480).

The contrast ratio, which is the brightness of white compared to the brightness of black, for a small active display might be 80:1. Printing on good paper has a contrast ratio of about 20:1; active displays do better because they emit photons rather than simply reflecting them. Small displays are built using the same methods and materials as those used for computer displays but as they are small they have miniature pixels. Because they are mounted so close to the eye, they give the impression of a screen that may look as large as a laptop screen (and they create a blind spot of corresponding size). These small displays have the same manufacturing, contrast, resolution, yield, and dynamic range limitations that beset their larger relatives.

Color microdisplays

Embedded. One type of color microdisplay is on cell phones and cameras. It is a small active or passive display. My folding cell phone has two such displays. The passive LCD on the outside is easy to see in daylight, but it requires power-hungry illumination to be seen at night. Inside, the color LCD cannot be read if the ambient light is too bright or too dim. The web access is limited by whatever caricature of a web page will fit its diminutive screen. The display on my digital camera has similar shortcomings. It's invisible in daylight, it eats batteries, it's marginal as a viewfinder, and it offers only a visual hint of the five-megapixel images in the camera's memory.

Neither display type does the job. The cell-phone and camera displays offer low contrast ratio, poor dynamic range, high power consumption, miniscule image, and lousy resolution.

Here's Microvision's approach.

The cell phone could replace its color LCD with a Microvision display, with the electronics embedded in a standard cell-phone case. The Microvision display, based on light-emitting diodes, would look to the user like a full-size SVGA laptop display and would enable viewing unmodified web pages. The difference between Microvision's virtual display and an ordinary laptop display is easily seen in the superior quality of the Microvision-generated image, which has vibrant, saturated colors and outstanding contrast in any ambient light. And this performance comes for milliwatts instead of the laptop's watts.

Why is the laptop's display such a power-hog compared to Microvision's display? The laptop builds its image by mimicking, either actively or passively, a printed page. It is electronic paper. It is difficult to make electronic paper with uniform contrast and readability for the whole range of lighting conditions. When you view a printed page illuminated by an external light source, an infinitesimal portion of the light striking the page makes its way into your eye to create the image that you see. Microvision's display avoids the intermediate step of creating electronic paper and sends the photons directly to your eye. The photons scattered from the image that didn't reach your eye are wasted; Microvision doesn't create them, which increases the efficiency of its systems thousands of times over systems that mimic paper and broadcast images in every direction.

Instead of looking at the tiny display on the back of your camera, imagine looking into a viewfinder to find what appears to be a huge, full-color, full-resolution image that doesn't just look like, but actually *is* the image you just captured—or are considering capturing. That's what's possible with Microvision's camera viewfinder.

Immersive. The second type of personal display is new to the market. It is the same near-the-eyes display already described, only moved from the periphery of attention to the center of attention, with the rest of the field of view being blocked. These glasses offer an immersive experience for data display, games, and movies.

Microvision's display can do a better job here too. Microvision has compared its full-color prototype to a typical LCD-based system from a Japanese competitor. In immersive applications, Microvision's display offers a field of view both horizontally and vertically that is 50 percent larger, resolution that is six times better, and contrast that is almost a hundred times better.

It would be difficult for a conventional liquid-crystal display to achieve a wide field of view because the panel is flat, which causes increased distortion in the image at greater distances from the center. It is difficult for flat-panel displays to achieve a field of view greater than thirty degrees horizontal and to stay within a package size that is truly "wearable." It is much easier for Microvision to solve this problem. Microvision, with some technical development, expects to ultimately offer displays having a field of view of from 50 to 80 degrees. Looking at such an extensive field of view would be comparable to watching a wide-screen cinema near the front row.

I'm looking forward to the version of cool-looking, sunglass-like goggles that will replace my desktop displays. My current system sports three flat-screen displays. The right display, with a vertical orientation and running at 1600x1200, is for email and page edits. The middle display, with a horizontal orientation and running at 1600x1200, is for the web browser and for reference material. The left display, running at 1280x1024, holds the directory, instant messaging windows, and miscellaneous information. The Microvision display goggles will displace my office-heating, space-wasting displays with a gigantic, and perhaps even adjustable, desktop work area. I could keep as many documents and references as I wish open simultaneously. Even better, the display doesn't control my posture and position; I can sit comfortably to concentrate on my work. Now, if we could just get rid of that keyboard…

Microvision says I can have these wrap-around desktop or laptop goggles two to three years from when "the market" says it is ready to entertain this new usage pattern. In other words, there are no fundamental barriers to building these goggles; product timing depends on Microvision's assessment of the market and upon its resource allocation. Current versions of the display have already achieved today's desktop standard (SVGA). Increasing the display's resolution is relatively straightforward. One way to increase the mirror's output is to employ a column of light sources. Instead of a single red, blue, and green diode, the light source could be a column of eight or more RGB rows on an integrated substrate.

With nerds and professionals as early adopters, Microvision can cost-reduce its display goggles until they are affordable for consumer gaming and video applications. Along the way, Microvision will be increasing the field of view and the resolution of its displays and it will begin to experiment with 3D. While 3D display has subtle and compute-intensive complexity, Microvision's goggles will be an enabler for 3D applications. Someday, Microvision will deliver virtual reality for $200.

Complement 3D image generation with the capability of Microvision's augmented-vision display. Combine these 3D, augmented-vision goggles with precision GPS and wireless access to sophisticated databases and Superman-like X-ray vision becomes possible. Using the location information and the databases, Microvision's imaging system could overlay

TELECOSM TECHNOLOGIES

Advanced Micro Devices	(AMD)
Agilent	(A)
Altera	(ALTR)
Analog Devices	(ADI)
Broadcom	(BRCM)
Broadwing	(BWNG)
Cepheid	(CPHD)
Corning	(GLW)
Equinix	(EQIX)
Essex	(KEYW)
EZchip	(LNOP)
Flextronics	(FLEX)
Intel	(INTC)
JDS Uniphase	(JDSU)
Microvision	(MVIS)
National Semiconductor	(NSM)
NetLogic	(NETL)
Power-One	(PWER)
Qualcomm	(QCOM)
Semiconductor Manufacturing International	(SMI)
SK Telecom	(SKM)
Sprint Nextel	(S)
Synaptics	(SYNA)
Taiwan Semiconductor	(TSM)
Texas Instruments	(TXN)
Wind River Systems	(WIND)
Xilinx	(XLNX)
Zoran	(ZRAN)

Note: The Telecosm Technologies list featured in the Gilder Technology Report is not a model portfolio. It is a list of technologies that lead in their respective application. Companies appear on this list based on technical leadership, without consideration of current share price or investment timing. The presence of a company on the list is not a recommendation to buy shares at the current price. George Gilder and Gilder Technology Report staff may hold positions in some or all of the stocks listed.

Altera (ALTR)

PARADIGM PLAY: SOFTENING HARDWARE, HARDENING SOFTWARE

SEPTEMBER 19: 18.83; 52-WEEK RANGE: 17.75 – 24.26; MARKET CAP: 7.02B

Altera has tweaked downward its gross margin forecast through 2006—*good* news for savvy investors ready to take advantage of a market overreaction that has punished the stock almost 14% since the update. Essentially, nothing has changed at Altera. Technologically, the company continues to pursue a high-volume, general-purpose path, while rival Xilinx is tending to add more custom features to its chips, thus proliferating parts and diffusing talent, energy, and manufacturing costs across more products. As for revenue, Altera reaffirmed its 2% sequential growth forecast for the September quarter, which comes on the heels of 5% growth in June and 10% in March, driven by sales of its newest products, including the high-end Stratix II and low-end Cyclone II families of field programmable gate arrays (FPGAs). Introduced last year as the first high-density, 90-nanometer FPGA, Stratix II includes Altera's adaptive logic modules. By contrast, Xilinx's new hard-core embedded microprocessors will increase the specialization of its chips and may take it away from the inherent advantages of general-purpose programmable logic devices by emphasizing performance over adaptability.

But what about the margins? Nothing to worry about there, either. Altera lowered its forecast for the current quarter to a high 66–67% from a lofty 68–69% and also lowered its forecast through 2006 to 66% from 67%. Management's long-term, realistic target has always been 65%, and smart investors have been modeling accordingly and focusing on the technology.

Xilinx is looking at margins of 61–62%. Yet despite healthier margins, inventory, and growth, at $18.83 Altera trades at a significant discount to rival Xilinx, with a forward PE (through September) of 26.9 compared to Xilinx's 32.8. The pessimistic view would claim that Altera's still solid PE is simply more realistic when compared to Xilinx's overblown PE and that, therefore, Altera does not offer an investment opportunity. However, this flies in the face of the paradigm, which predicts rapidly expanding markets for programmable logic, used wherever fast adaptation of new demands is more desirable than the utmost in chip density and performance. — *CB*

Analog Devices (ADI)

PARADIGM PLAY: ANALOG EVERYWHERE & SOFTENING RADIOS

SEPTEMBER 19: 37.07; 52-WEEK RANGE: 32.65 – 41.66; MARKET CAP: 13.80B

Analog Devices needs a Brian Halla (see page 5). A veteran independent device manufacturer of 40 years with a goodly share of the world's scarce analog design talent, ADI is one of the three leaders, along with Linear and Maxim, in high-performance analog semiconductors. So … why are they taking on the likes of Texas Instruments in digital signal processors (DSPs)? Having already fallen 4% sequentially in the April quarter, sales of DSPs slid another 17% in July as wireless handset customers in Asia turned to ADI's competitors. Thankfully, the core analog business has increased to 84% of sales, but even there a flat sequential quarter was uninspiring, as gains in computer, consumer, medical, defense, and industrial instrumentation sales were offset by declines in the automatic test equipment, automotive, and communications segments. Not surprisingly, fab utilization decreased and total sales slid 3.5% to $582m. In a halfway solution to its digital angst, management will refocus DSPs out of wireless and into the automotive, industrial, instrumentation, and consumer markets where they think they stand a better chance and margins should also be higher.

ADI remains financially fit. Cash and short-term investments of $2.8b dwarf current liabilities of $415m, and the company holds no long-term debt. During the July quarter, ADI generated $180m in cash from operations, far exceeding capital expenditures of $19m. Gross margin increased sequentially from 57.4% to 58.1% due to a favorable product mix and cost reductions. Operating expenses also declined, by about 4%, helping to nudge EPS up a penny to 32 cents. Management expects another nudge to 33 cents this quarter on sales growth of 1% to 4%. Based on these projections, the stock trades at a rich forward PE of 30 for the fiscal year ending October. — *CB*

JDS Uniphase (JDSU)

PARADIGM PLAY: COMPONENTS GALORE FOR THE FIBERSPHERE

SEPTEMBER 19: 1.79; 52-WEEK RANGE: 1.32 – 3.65; MARKET CAP: 2.59B

What's it feel like to be profitable? After more than half a decade, JDSU is still trying to find out. In its latest attempt to reach the elusive goal, Kevin Kennedy & Company purchased privately-held Acterna and will soon be reporting income from the acquisition. Acterna sold for $450m in cash and $310m in stock, making it JDSU's first major acquisition since SDL in 2000 and opening to the company a whole new business supplying test and measurement gear for optical, cable, access, and other communications customers, including Verizon, AT&T, BellSouth, SBC, and Comcast. With annual revenues of $490m, Acterna becomes JDSU's largest segment at 42% of sales.

If you're expecting big things, however, you may be disappointed. Based on JDSU's and Acterna's margins, restructurings, and revenue forecasts, we estimate an EBITDA profit of some $16m per year or a penny per share for the combined entity. Maybe we should pretend it's a Big Penny. Or, maybe we should just admit that the penny isn't there. For a company that chronically acquires, divests, and restructures, you can't ignore the cacophony of charges, write-downs, and eternal expenses forever bloating GAAP baggage. For example, the latest round of restructurings includes the sale of major manufacturing facilities, the sale of the front-surface mirror and cable businesses, the consolidation of laser operations, and the integration of Agility Communications with its monolithic tunable lasers and 90 employees … to be followed by the downsizing or closing of three additional unnamed locations in North America … and so on. It's even getting too much for JDSU, which delayed its 2Q earnings call by several weeks to sort it all out.

Acterna doesn't bring JDSU even close to a positive GAAP bottom-line, which settled to a loss of $146m or 10 cents per share last quarter. Perhaps JDSU's stagnant consumer and communications lines will perk up or maybe Acterna will ascend, but management hasn't even hinted at such a prospect. At $1.79 per share, investors are buying JDSU at an enterprise value of 2.3x forward sales, including Acterna—no bargain for a stalled company lacking an innovative technology to set it apart in any of three challenging markets, even if it *is* the Big Boy of telecosm components. — *CB*

Microvision (MVIS)

PARADIGM PLAY: HEADS-UP TELEPUTER DISPLAYS

SEPTEMBER 19: 5.70; 52-WEEK RANGE: 4.15 – 8.00; MARKET CAP: 122.45M

On September 19 Microvision signed a letter of intent with Bosch, one of the world's largest automotive suppliers, to jointly develop heads-up displays (HUD) for cars. Bosch boasts annual sales of 40 billion euros and is a key supplier of instrumentation and entertainment components to many of the world's largest automotive OEMs. With GPS navigation now becoming more widespread, more advanced HUDs are needed to display high resolution, multi-color graphics on the windshield. We note Audi's statement that it will begin installing laser-based HUDs in its cars, and we believe Microvision is a key technology player.

While HUDs represent a large near-term market but do not yet yield revenue, another automotive product has begun to kick in. The company's Nomad automotive technician display system achieved sales of $669,000 in the quarter, about $500,000 worth coming from the U.S. Army. Honda and other automakers have announced their dealerships have begun using the system for maintenance and repair. Hunter Engineering, meanwhile, a key supplier of wheel alignment and brake systems at some 65,000 locations, is cooperating with MVIS to deploy Nomad and says technicians initially are achieving 30% productivity increases.

At the end of the June quarter, cash on hand was just $2.3m. In August, MVIS raised $5m, converting half of its existing $10m in preferred shares into equity capital. Then on September 1, the company announced it would periodically sell up to $35m in common stock and warrants and said it had executed a $1.5m private placement of common stock and warrants, with the warrants exercisable at $6.50 per share.

Fully $3.7m of the company's $4.7m in June quarter sales were contract revenues. Although contract revenue may now begin to decline, revenue from the Nomad system and Flic bar code scanners, and later from HUDs and consumer devices, should mostly make up for lost government work in the short term and totally overwhelm such a loss in the long term. The company expects sales of $4.1 to $4.5m in the September quarter. Given the company's unique optical technologies, massive potential markets, and not-outrageous current market cap of $122m, we believe MVIS will be able to raise sufficient funds to overcome its short-term financial challenges without significant dilution. — *BTS*

National Semiconductor (NSM)

PARADIGM PLAY: ANALOG LEADER AND IMAGER PIONEER

SEPTEMBER 19: 25.01; 52-WEEK RANGE: 14.50 – 26.67; MARKET CAP: 8.65B

National reported sales of $494m for the quarter ending 28 August, *down* 10% from the year earlier quarter. Yet over the same period, National's stock *more than doubled*. You could call it Brian Halla's paradox, but we prefer to call it Halla's paradigm alignment. Over the past year, the gutsy CEO has focused National's resources on high-margin analog products in markets such as power management, amplifiers, and interface and data conversion, while pruning nonaligning units such as the Advanced PC division with its digital and mixed-signal IP, the cordless phone business in Europe, and the Singapore test and assembly plant, which specialized in high pin-count digital packages. (A newly opened test and assembly facility in Suzhou, China, supports National's analog business along with a facility in Asia.)

While shedding those unhealthy revenue pounds, Halla's analog diet has made National fit and trim for the coming teleputer marathon. Already gaining share in the wireless handset and display markets, bookings for standard linear products grew 14% sequentially as new orders for portable power management and audio products grew much faster than the company average due primarily to strong demand from mobile phone and flat-panel display customers. Thus sales are beginning to rebound, having risen 5.7% sequentially in the August quarter with another 5% increase forecast this quarter. Gross margin improved from 50.6% in November to a record 56.2% in August, and net long-term cash increased from $489m to $647m over the past year even as the company bought back $275m in stock last quarter. National plans to purchase an additional $400m of stock during the coming months in a sign that it considers the current forward PE of 22.5 a fair value. With the mobile generation still gestational, the bullish Halla has only just begun. — *CB*

Synaptics (SYNA)

PARADIGM PLAY: ANALOG-DIGITAL INTERFACES FOR HAPTICS

SEPTEMBER 19: 18.66; 52-WEEK RANGE: 15.03 – 41.19; MARKET CAP: 451.27M

Synaptics shares are up 24% from their recent low of 15, though at $18.66 they still trade at less than half of their 52-week high. A rocky relationship with Apple, which last winter propelled SYNA to stardom with its famous iPod scroll wheel, now clouds SYNA's future. In early September CFO Russ Knittel confirmed SYNA's non-presence in the new iPod "nano" and reiterated the company's "lack of visibility" with Apple, leading him to estimate fiscal 2006 year-over-year revenue could decline by 10%. Coming on the heels of 56% sales growth in 2005, investors are reevaluating the company.

But even with a 10% decline in fiscal 2006 sales, the company still would trade at a price-to-sales multiple of just 2.5. The company enjoys $4 per share in net cash and is still highly profitable. Meanwhile, the notebook PC market, where SYNA and competitor Alps sell 93% of the world's touchpad interfaces, continues to expand. Notebooks comprised 28% of the $200b PC market in 2004 but are expected to reach 38% in 2008. SYNA is also branching out into desktop and PC peripherals, putting its capacitive touch interfaces wherever you might find buttons, switches, or LCD screens.

Although the loss of business at Apple is a significant blow, the iPod has seen its market-share peek and now will contend with numerous direct and indirect competitive products, from rival MP3 players to satellite music devices to music-streaming mobile phones. It is these markets, which could total 1 billion units annually in the near future, where SYNA is focusing much of its energy. Its capacitive touch pads are perhaps even more advantageous in small mobile devices than in the conventional PC market where they have been so successful. SYNA's technology is just 0.15 millimeters thick compared to one to several millimeters for competitive solutions. Key to touch-sensitive LCD screen applications, SYNA's arrays are also more transparent, transferring 98% of the light to the user.

Although this billion-device portable media market will not immediately replace the iPod revenue loss, over the coming years it will more than make up for the Apple business. In the meantime, SYNA's touchpad dominance among the 10 largest PC makers and its healthy balance sheet provide downside protection.

Also noted: In June SYNA invested an additional $4m in digital imager revolutionary Foveon and thus retains an ownership interest in the "low teens." — *BTS* the real-world view with in-context visual information. Walls and floors could become semi-transparent with visual overlays of what lies beyond the normally opaque surfaces.

Imagine yourself as the chief engineer in charge of remodeling a large office complex. You could work your way through the buildings auditing the feasibility of proposed changes by looking into the various walls and floors that are to be altered. Studs, weight-bearing structures, ducts, and utilities within the walls and floors would become visible, without sacrificing the viewer's normal visual context. This may seem infeasible or something for the distant future, but the enablers are here today.

Once the consumer version of Microvision's goggles is available, you will no longer need to find wall space for a giant flat-screen entertainment display. The goggles will give you a virtual screen equivalent to an 80- to 100-inch display. You won't have to accommodate the display; the goggles go to where you will be comfortable.

Projection displays

Projectors. My friend Alan has about fifty kids. (I don't have any, so even three or four seem like fifty to me.) In any event, the family has a regular "movie night." On movie night, Alan connects his laptop to the home's stereo speaker system and to a projector that normally puts people to sleep with PowerPoint slides. The popcorn comes out and it's instant home theater.

The PowerPoint projector that Alan uses creates images through a system that employs a "DLP" chip from **Texas Instruments** (TXN). DLP stands for digital light processing and is the trademarked branding that TI uses to describe its sophisticated projector chip with its 1.3 million MEMS mirrors. There's one moving mirror for each pixel in a 1280x1024 image. The next time you have the opportunity before or after a presentation using one of these projectors (almost all projectors these days), walk up to the screen. You can see the individual pixels, each one representing one of the moving mirrors on the surface of the TI chip. Unlike Microvision's continuously varying mirror positioning, each of TI's mirrors has two positions: "on" and "off." In the "on" position, the light shining on the mirror is reflected onto the screen; in the "off" position, the light is reflected away from the screen (where it is wasted as heat).

The projection system creates an image by illuminating the surface of the MEMS DLP chip. The mirror for each pixel that is not in the image is deflected so that its light does not reach the screen. For a color picture, expensive systems use one DLP chip illuminated by red, one by green, and one by blue. Cheaper color systems time multiplex illumination of one chip with the same three colors by inserting a color wheel between a bright white light source and the chip. In the DLP-based projector, the illuminating sources are on all the time and the mirrors are moved to control whether a particular color reaches the screen for a particular pixel. For gray-scale images, the mirror, which can be switched off and on up to several thousand times a second, is left off for a greater percent of the time to create a darker pixel. These systems create vivid images with millions to trillions of colors.

A Microvision projector uses the single-mirror MEMS chip and an associated application-specific integrated circuit (ASIC). (There's a unique ASIC for each application class.) The mirror is moved in x and y to create the scanned image. Red, green, and blue light sources illuminate the mirror. The mirror positions the beam of photons on the screen and the light sources are modulated to determine both the color and the intensity of the color that reaches the screen at any point.

How can Microvision compete with Texas Instruments, which has sold more than five million DLP-based systems? To answer this question, we can begin with the primary differences between a Microvision-based system and a DLP-based system. Both are capable of generating vivid images, but there are differences in chip cost, in power, and in resolution.

With respect to cost, building a chip with 1.3 *million* moving mirrors, where a single defect renders the chip useless, is more expensive than building a chip with only one moving mirror. The Microvision system has a cost advantage with its moving-mirror chip.

Illumination, the primary user of the system's power budget in the DLP-based system, is on all the time. In the Microvision system, light sources are modulated directly, leading to lower overall power use.

The DLP-based system's resolution is fixed by the geometry of its mirror array. If the mirror array is 1280x1024, then that's the maximum resolution of the image. In Microvision's display systems, resolution is "dialed in" through the size and speed of the single mirror—higher-quality images imply more resolution. To increase the resolution of its DLP-based displays, TI will have to redesign the chip, increasing the number of its moving mirrors. Either individual mirrors will be smaller or the chip will be larger. Cost, yield, and performance will suffer. Each increment in resolution forces a new chip design. In Microvision's display systems, resolution could be selectable, from desktop display to wide-screen HD.

Figure 3 is the light engine for one of Microvision's near-the-eye display systems. It's sitting on a quarter. Wires power the three light emitting diodes (LEDs), which are attached to a color combiner and then to a simple lens system. That's it; it's that compact and efficient. Once cost-effective laser diodes (as opposed to LEDs) become available, it will be possible to apply this "laser light engine" to construct a *pocket-size projector*. If this unit became commercially available in the next couple of years, you could be playing a movie or PowerPoint presentation from the next-generation iPod.

It won't be long before there's no need to carry around a bulky laptop computer. All you'll need will be the pocket projector or Microvision goggles, plus a roll-up keyboard and a next-generation iPod.

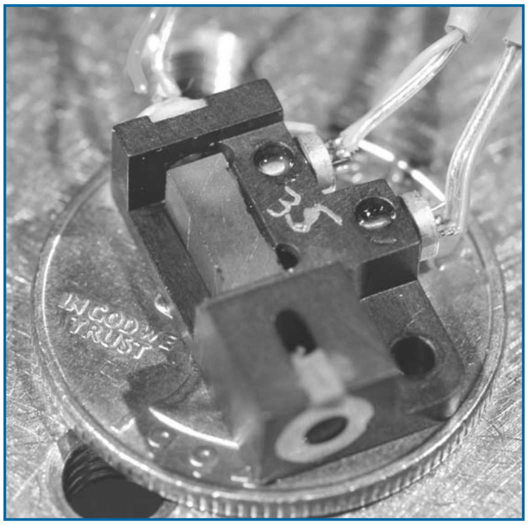

Figure 3. The laser light engine for Microvision's near-eye display systems.

Head-up displays. There's a big future for head-up displays (HUDs) in automotive applications. HUDs shipped a hundred thousand units in 2004. Shipments for 2005 should be twice that. Shipments are expected to increase to four million units a year by 2010. Consumers like them. As unbelievable as this may sound to the "more horsepower" crowd (which includes me), a significant majority of consumers prefer a HUD over a larger engine for the same total price. HUDs are gaining popularity for safety, for convenience, and for their leading-edge technology image.

The HUD's image appears directly in front of the driver, just above the steering wheel and looks as if it is on the road between the driver's car and the next vehicle in front. Displayed information can include engine, drive-train, and suspension performance; inside and outside environmental conditions; position and directions from navigation systems; or road, news, and traffic updates available over wireless links. These displays may encourage drivers to adopt a safe following distance as a byproduct of keeping the HUD's image free of color clutter from a car that's too close in front.

Current HUDs bury a very bright display screen below a large hole in the dashboard. The display shines onto the windscreen, which is specially engineered to reflect the display's image to the driver. These display systems require precise mechanical alignment and they use slightly modified windscreens to minimize any secondary or "ghost" reflection. These existing display systems generate prodigious amounts of heat and they don't feature high contrast or high dynamic range. The result is that they are not bright enough in daylight and a distracting, display-sized background image leaks through at night.

Once again, Microvision has a better answer: MicroHUD. Instead of a power-intensive screen image and a HUD package that is difficult to install and align, Microvision's MicroHUD beams image photons directly at the windscreen and incorporates the facility to electronically manipulate and shape the image to ease installation. Enough of these photons are reflected to produce a high-contrast image for the driver. The contrast ratio of the MicroHUD is 1000:1 even at low brightness settings; its dynamic range is millions to one. Because the MicroHUD creates only the photons in the image, there's no screen area to bleed through at night. The result is a high-contrast image in daylight or at night.

Initial versions of the MicroHUD create a 600x250-pixel virtual image (as opposed to the real image, which is on the windscreen) that appears to be 2.1 to 2.4 meters in front of the driver. The image can have a variety of resolutions and aspect ratios and can use any combination of red and green. Future versions of the MicroHUD will reflect full-color, daylight-readable, see-through images off the windscreen.

Microvision is working with automakers, such as **Audi**, **BMW**, **Ford**, and **Volkswagen**, and it is also working with tier-one, automotive-electronics suppliers. Microvision's MicroHUD displays could be in vehicles by the 2008/2009 model year. I won't be trading horsepower for a HUD, but I'll be looking at vehicles from these manufacturers as soon as they are available. Why do we have to wait so long? It isn't Microvision, which already has MicroHUD prototypes and evaluation kits; it is the result of long adoption cycles and conservative business practices throughout the automotive industry.

Microvision also has a version of the MicroHUD that can be built for after-market installation. This version is well-suited to boating, aircraft, and trucking applications, but it can also be installed in automobiles.

Running the device backwards: scanners and near-field cameras

As useful as Microvision's MEMS mirror is at creating images for a wide range of applications, that's not all it can do. It can also be a scanner. Combining the light sources in the system with sensors and with the mirror's raster scan *captures* an image rather than creating one. The scanned light sources illuminate the object while simultaneously a detector captures an image of that object. This imager works well over distances that are about the same as those for an ordinary barcode reader.

Figure 4. The HUD's image appears directly in front of the driver and above the steering wheel.

Here's how it works. Illuminate the object. These light sources might be red, green, and blue lasers or diodes, but it's also possible to use infrared or ultraviolet sources. These light sources bounce off the moving mirror to illuminate the object with a raster scan of photons. Some of these photons are scattered back to the mirror and bounce from there to a collector where they can be split by prisms into frequency-sensitive photodetectors. Capturing images with a range of light sources, called hyperspectral imaging, can yield a great deal of information about an object.

This near-field scanning camera captures high-resolution, glare-free images. It can capture natural-color images, but it can also capture images from sources outside the visible range and then translate them into colors our eyes can see. For example, this scanning camera, equipped with an ultraviolet light source, might be used to investigate an object's detailed surface nuances because the ultraviolet light's shorter wavelength resolves smaller features than the wavelengths of visible light can resolve. It may be possible to image at some depth into an object by using light sources operating at wavelengths that penetrate the object of interest. In addition, the scanner enables full-resolution electronic zoom, by dynamically controlling the angular sweep of the scanning beam.

Applications for scanners begin with medical imaging, especially where instrument size is critical to access or to patient comfort. A very small imaging instrument can be built with the scanning mirror on the end of a fiber-optic bundle. In the center of the bundle is a fiber cable carrying light from the illumination source. The scanning mirror sweeps this beam across the object to be imaged. Surrounding the source fiber and the scanning mirror are fiber-optic collectors that collect photons and return them to the detectors. The light source and the electronics are in the base unit so that the invasive cable can be significantly smaller than conventional cables. If you have ever had your stomach, intestines, or colon inspected with a conventional medical imaging instrument, you know just how welcome this advance is.

Where from here?

I want to experiment with one of these near-field imaging cameras. To me it seems like a new kind of microscope. It would be interesting to look at all sorts of objects with a wide variety of imaging frequencies. In fact, I have fantasized about starting a business to build these scanning microscopes for sale by **Sharper Image** (SHRP). It would be a pocket microscope capable of creating digital images. With this pocket microscope, I can see what it would be like to view objects with ultraviolet-sensitive eyes or with infrared-sensitive eyes. New worlds to explore.

Since optical signals of different wavelengths don't interfere with each other, the scanning mirror can be used with numerous sources and sensors. This can still be a power-efficient and compact design because each wavelength needs only a single source and a single detector. It's not like the image-capture chip in a camera that must simultaneously capture all five million pixels; the scanning mirror multiplexes a single photodetector (per wavelength) over the entire image. Similarly, the illuminating beam need be only strong enough to illuminate one pixel at a time for capture.

I expect Microvision's first breakout success will be in automotive HUDs. There's no alternative that can compete on cost or quality. The visual experience the MicroHUD delivers is in a class by itself, making it compelling despite the conservative and deliberate nature of automotive development.

Any of Microvision's systems will beat the competition in every category: cost, quality, compactness, power-efficiency, and versatility. It's no contest, but the markets it is trying to break into in cameras, in projectors, in displays, and in cell phones have entrenched competition and a long history of legacy development. It is a difficult sell to overcome a bias for incremental improvement over transition to a novel approach, but these breakthroughs will come and then it'll be an avalanche.

— Nick Tredennick and Brion Shimamoto
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