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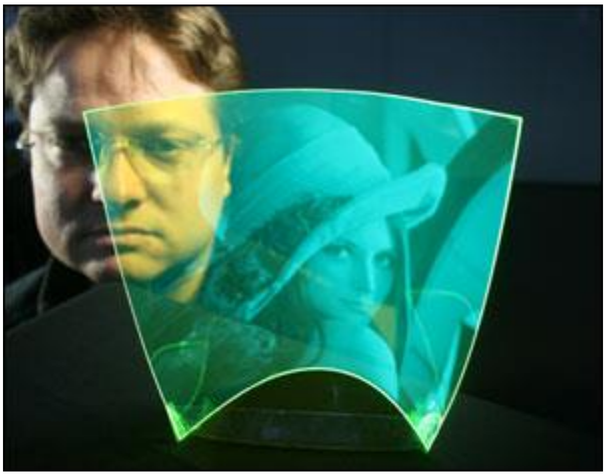
Image Sensor is Transparent, Circuit-Free

LINZ, Austria, Feb. 20, 2013 — A flat, transparent and circuit-free polymer sheet may provide an entirely new way of capturing images, or may act as a touch-free user interface that could seamlessly overlay a television or other display technology.

The new Johannes Kepler University Linz imager, which resembles a flexible plastic film, uses fluorescent particles to capture incoming light and channel a portion of it into an array of sensors framing the sheet. The imager's design features no electronics or internal components, making it ideal for a new breed of imaging technologies such as a user interface device that responds not to a touch, but rather to a simple gesture.

"To our knowledge, we are the first to present an image sensor that is fully transparent — no integrated microstructures, such as circuits — and is flexible and scalable at the same time," said Oliver Bimber, co-author of the paper that appeared in *Optics Express* (doi: 10.1364/OE.21.004796).



The world's first flexible and completely transparent image sensor was developed at Johannes Kepler University Linz. The plastic film is coated with fluorescent particles. Courtesy of *Optics Express*.

The sensor, based on a polymer film known as a luminescent concentrator, is suffused with tiny fluorescent particles that absorb a very specific wavelength and re-emit it at a longer wavelength. Some of the re-emitted fluorescent light is scattered out of the imager, but a portion of it travels throughout the interior of the film to the outer edges, where optical sensor arrays — similar to a one-dimensional pinhole camera — capture the light. A computer then combines the signals into a gray-scale image.

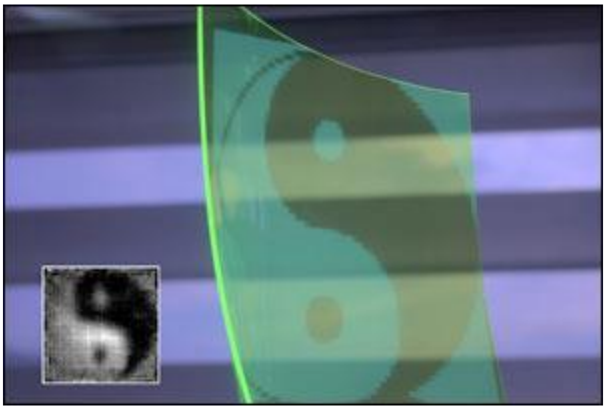
"With fluorescence, a portion of the light that is re-emitted actually stays inside the film," Bimber said. “This is the basic principle of our sensor.”

For the luminescent concentrator to work as an imager, the investigators had to determine precisely where light was falling across the entire film’s surface, a major technical challenge because, unlike the CCD camera inside a smartphone, the polymer sheet cannot be divided into individual pixels. Instead, fluorescent light from all points on the surface travels to the edge sensors. Calculating at what point the light entered the imager would be like determining where along a subway line a passenger boarded the train after it had reached its final destination and all the passengers exited at once.

The phenomenon of light attenuation, or dimming, as it travels through the polymer provided the solution. The longer light travels, the dimmer it becomes. By measuring the relative brightness of light reaching the sensor array, it was possible to calculate where the light entered the film.

The researchers scaled up this basic principle by measuring how much light arrives from every direction at each position on the image sensor at the film’s edge. They could then reconstruct the image by using a technique similar to an x-ray CT.

“In CT technology, it’s impossible to reconstruct an image from a single measurement of x-ray attenuation along one scanning direction alone,” Bimber said. “With a multiple of these measurements taken at different positions and directions, however, this becomes possible. Our system works in the same way, but where CT uses x-rays, our technique uses visible light.”



A comparison between the (ground truth) image being focused on the sensor surface and the reconstructed image (inset). Courtesy of Oliver Bimber, Johannes Kepler University Linz.

The first prototypes have a low resolution of 32 × 32 pixels because of limited signal-to-noise ratio of the low-cost photodiodes being used. The researchers are planning better prototypes that cool the photodiodes to achieve higher signal-to-noise ratios.

The resolution can already be enhanced using an advanced sampling technique that reconstructs multiple images at different positions on the film, the scientists said. These positions differ by less than a single pixel.

“This does not require better photodiodes,” Bimber said, “and does not make the sensor significantly slower. The more images we combine, the higher the final resolution is, up to a certain limit.”

The researchers envision the main application of the technology as being a touch-free, transparent user interface for computer operators or video-game players, who could use full gesture control without the need for cameras or other external motion tracking. Besides that, the sensor could be attached in front of a regular high-resolution CCD sensor to record two images at the same time at two different exposures.

“Combining both would give us a high-resolution image with less overexposed or underexposed regions if scenes with a high dynamic range or contrast are captured,” Bimber said. He also noted that the polymer sheet portion of the device is relatively inexpensive and therefore disposable.

“I think there are many applications for this sensor that we are not yet aware of,” he said.

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