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E-paper with Photonic Ink

Photonic crystals are being used by a Toronto startup to create commercial devices that offer better color and resolution than other flexible displays.

By Duncan Graham-Rowe

Scientists in Canada have used photonic crystals to create a novel type of flexible electronic-paper display. Unlike other such devices, the photonic-crystal display is the first with pixels that can be individually tuned to any color.

"You get much brighter and more-intense colors," says André Arsenault, a chemist at the University of Toronto and cofounder of Opalux, a Toronto-based company commercializing the photonic-crystal technology, called P-Ink.

Several companies, including MIT startup E Ink and French firm Nemoptic, have begun producing products with e-paper displays. E Ink's technology uses a process in which images are created by electrically controlling the movement of black or white particles within tiny microcapsules. Nemoptic's displays are based on twisting nematic liquid crystals. The benefit of such screens is that compared with traditional displays, they are much easier to view in bright sunlight and yet only use a fraction of the power.

While the quality and contrast of black-and-white e-paper displays were almost on par with real paper, color images were lacking because each pixel was limited to a single primary color. To display a range of colors, pixels must be grouped in trios. In each trio, one pixel is filtered red, another is filtered green, and the third is filtered blue. Varying the intensity of each pixel within the trio generates different colors. But Arsenault says that these old systems lack intensity. For example, if one wants to make the whole screen red, then only one-third of the pixels will actually be red.

With P-Ink, it's a different story. "We can get 100 percent of the area to be red," Arsenault says. This is because each pixel can be tuned to create any color in the visible spectrum. "That's a three-times increase in the brightness of colors," he says. "It makes a huge difference."

P-Ink works by controlling the spacing between photonic crystals, which affects the wavelengths of light they reflect. Photonic crystals are the optical equivalent of semiconductor crystals. While semiconductor crystals influence the motion of electrons, photonic crystals affect the motion of photons.

Although recently there has been a lot of research looking at using photonic crystals for anything from optical fibers to quantum computers, it's actually an ancient phenomenon. For example, photonic crystals are responsible for giving opals their iridescent appearance. "There are many organisms that have coloration that doesn't come from a dye," says Arsenault. "This is the basis of our technology."

With P-Ink, each pixel in a display consists of hundreds of silica spheres. Each of these photonic crystals is about 200 nanometers in diameter and embedded in a spongelike electroactive polymer. These materials are sandwiched between a pair of electrodes along with an electrolyte fluid. When a voltage is applied to the electrodes, the electrolyte is drawn into the polymer, causing it to expand.

The swelling pushes the silica beads apart, changing their refractive index. "As the distance between them becomes greater, the wavelengths reflected increases," says Arsenault. P-Ink is also bistable, meaning that once a pixel has been tuned to a color, it will hold that color for days without having to maintain a power source. "And the material itself is intrinsically flexible," Arsenault says.

The technology was developed with Geoffrey Ozin and Daniel Puzzo, among others, at the University of Toronto and Ian Manners at the University of Bristol, in the UK. The group demonstrated how 0.3-millimeter pixels--about the same size as many LCD displays--can independently generate a range of colors. Their results are published in the August issue of the journal *Nature Photonics*. "One single material can give all the necessary colors for a display without filters," says Arsenault.

In fact, by making the crystals slightly larger, it's also possible to take them beyond the visible-light range and into infrared, says Arsenault. The effects in this range would be invisible to the human eye but could be used to make smart windows that control the amount of heat that passes through them, he says.

This is a step forward, says Jacques Angele, a cofounder of Nemoptic. "The aim of these color-display technologies is to be comparable with paper. Unfortunately, the brightness of the [other technologies] today is limited to about 30 percent of paper."

"It's a spectacular innovation," says Edzer Huitema, chief technology officer of the Dutch firm Polymer Vision, based in Eindhoven. Even traditional screens, such as cathode-ray tubes, LCDs, and plasma displays, use three or even four differently colored pixels to generate color. "It's a major limitation for all color-display technologies," Huitema says. When the color of each pixel is controlled, not only does the color quality increase, but the resolution should also improve by a factor of three.

There is one display technology, however, that can tune individual pixel color, says Angele. Both Kent Displays, in Ohio, and Japanese electronics firm Fujitsu have been taking this approach, which, in essence, involves placing the three colored pixels on top of each other. But besides being technically difficult and expensive, this approach reduces the brightness of the colors, Angele says. "It's difficult to have an optical stack without optical losses."

Arsenault predicts that Opalux will have the first products on the market within two years, probably in the form of advertising displays. But, he says, it will be a long while before P-Ink will be in a position to completely replace traditional displays. "The caveat is that we are not at video speeds," Arsenault says.

Currently, the P-Ink system can switch pixels in less than a second, which is on par with other e-paper displays. "We're still early in our development, and there's a lot of room for [improving] the material and optimising its performance," says Arsenault.

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