Novel liquid crystal could triple sharpness of today's televisions

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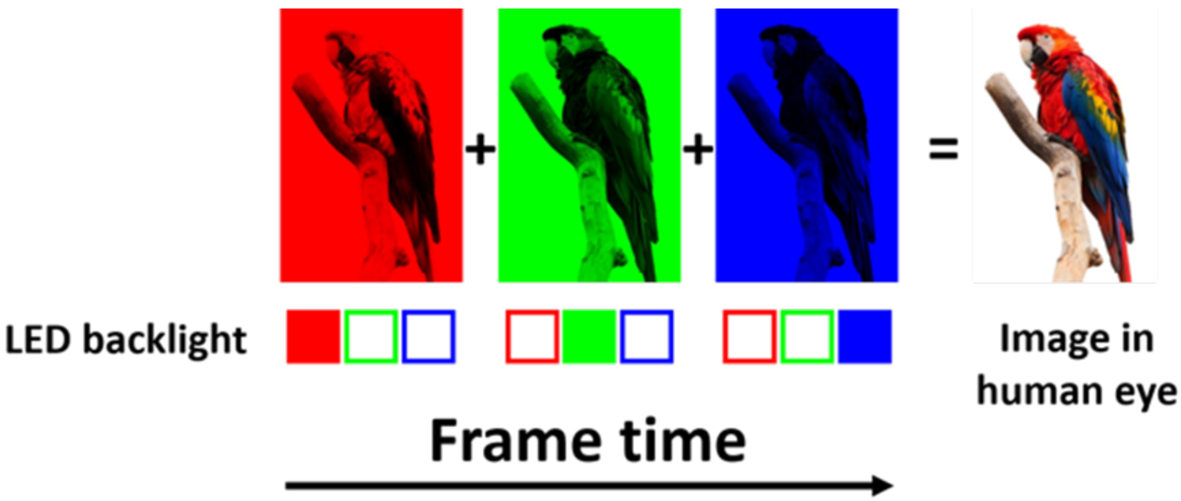

Researchers have developed a new technology that could triple the resolution density of displays. The new technology could allow field-sequential color displays where a single subpixel can be quickly switched among red, green or blue. By eliminating the color filters traditionally used to spatially divide one pixel into red, green or blue subpixels, field-sequential color displays allow the three subpixels to become three independent pixels and thus triples the resolution density. Credit: Yuge Huang and Ruidong Zhu, CREOL, The College of Optics and Photonics, University of Central Florida

An international team of researchers has developed a new blue-phase liquid crystal that could enable televisions, computer screens and other displays that pack more pixels into the same space while also reducing the power needed to run the device. The new liquid crystal is optimized for field-sequential color liquid crystal displays (LCDs), a promising technology for next-generation displays.

"Today's Apple Retina displays have a resolution density of about 500 pixels per inch," said Shin-Tson Wu, who led the research team at the University of Central Florida's College of Optics and Photonics (CREOL). "With our new technology, a resolution density of 1500 pixels per inch could be achieved on the same sized screen. This is especially attractive for virtual reality headsets or augmented reality technology, which must achieve high resolution in a small screen to look sharp when placed close to our eyes."

Although the first blue-phase LCD prototype was demonstrated by Samsung in 2008, the technology still hasn't moved into production because of problems with high operation voltage and slow capacitor charging time. To tackle these problems, Wu's research team worked with collaborators from liquid crystal manufacturer JNC Petrochemical Corporation in Japan and display manufacturer AU Optronics Corporation in Taiwan.

In the journal *Optical Materials Express*, from The Optical Society (OSA), the researchers report how combining the new liquid crystal with a special performance-enhancing electrode structure can achieve light transmittance of 74 percent with an operation voltage of 15 volts per pixel - operational levels that could finally make field-sequential color displays practical for product development.

"Field-sequential color displays can be used to achieve the smaller pixels needed to increase resolution density," said Yuge Huang, first author of the paper. "This is important because the resolution density of today's technology is almost at its limit."

How it works

Today's LCD screens contain a thin layer of nematic liquid crystal through which the incoming white LED backlight is modulated. Thin-film transistors deliver the required voltage that controls light transmission in each pixel. The LCD subpixels contain red, green and blue filters that are used in combination to produce different colors to the human eye. The color white is created by combining all three colors.

Blue-phase liquid crystal can be switched, or controlled, about 10 times faster than the nematic type. This sub-millisecond response time allows each LED color (red, green and blue) to be sent through the liquid crystal at different times and eliminates the need for color filters. The LED colors are switched so quickly that our eyes can integrate red, green and blue to form white.

"With color filters, the red, green and blue light are all generated at the same time," said Wu. "However, with blue-phase liquid crystal we can use one subpixel to make all three colors, but at different times. This converts space into time, a space-saving configuration of two-thirds, which triples the resolution density."

The blue-phase liquid crystal also triples the optical efficiency because the light doesn't have to pass through color filters, which limit transmittance to about 30 percent. Another big advantage is that the displayed color is more vivid because it comes directly from red, green and blue LEDs, which eliminates the color crosstalk that occurs with conventional color filters.

Wu's team worked with JNC to reduce the blue-phase liquid crystal's dielectric constant to a minimally acceptable range to reduce the transistor charging time and get submillisecond optical response time. However, each pixel still needed slightly higher voltage than a single transistor could provide. To overcome this problem, the researchers implemented a protruded electrode structure that lets the electric field penetrate the liquid crystal more deeply. This lowered the voltage needed to drive each pixel while maintaining a high light transmittance.

"We achieved an operational voltage low enough to allow each pixel to be driven by a single transistor while also achieving a response time of less than 1 millisecond," said Haiwei Chen, a doctoral student in Wu's lab. "This delicate balance between operational voltage and response time is key for enabling field sequential color displays."

Making a prototype

"Now that we have shown that combining the blue-phase liquid crystal with the protruded electron structure is feasible, the next step is for industry to combine them into a working prototype," said Wu. "Our partner AU Optronics has extensive experience in manufacturing the protruded electrode structure and is in a good position to produce this prototype."

Wu predicts that a working prototype could be available in the next year. Since AU Optronics already has a prototype that uses the protruded electrodes, it will only be a matter of working with JNC to get the new material into that prototype.

More information: Yuge Huang et al, Optimized blue-phase liquid crystal for field-sequential-color displays, *Optical Materials Express* (2017). DOI: 10.1364/OME.7.000641

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