

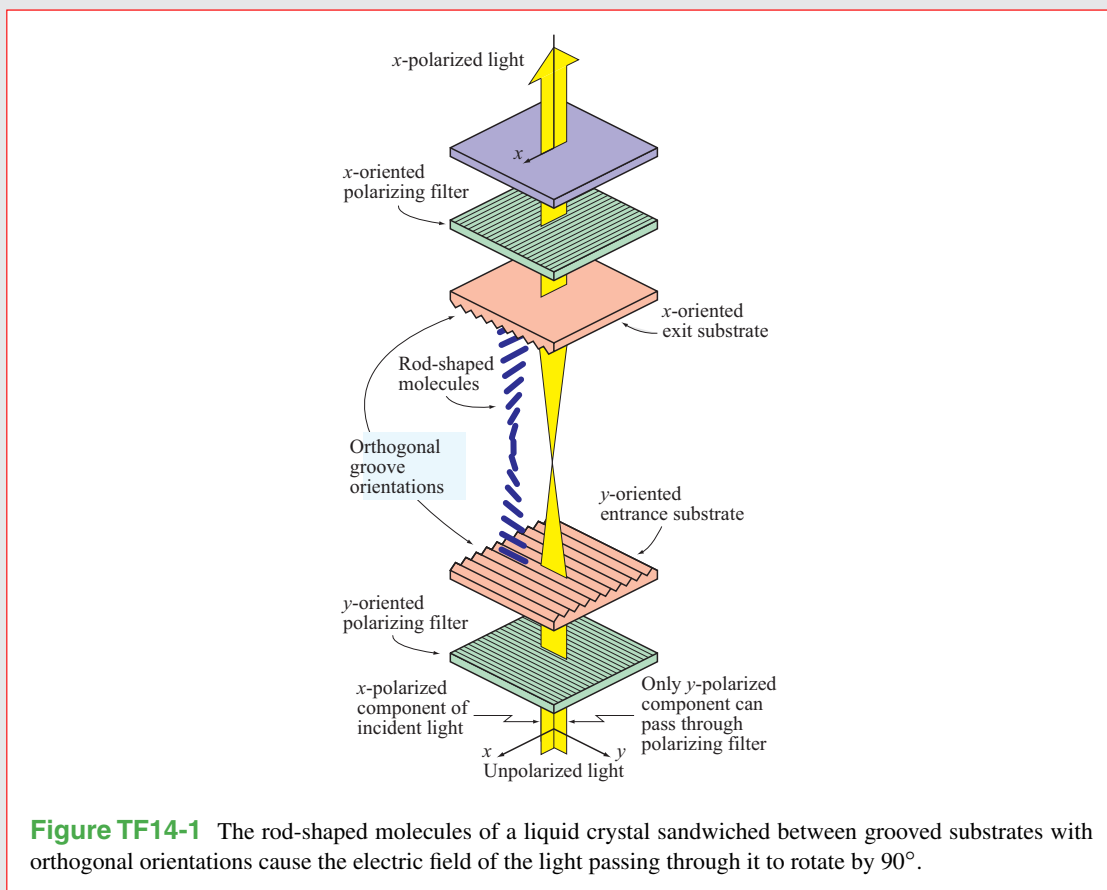
## Technology Brief 14: Liquid Crystal Display (LCD)

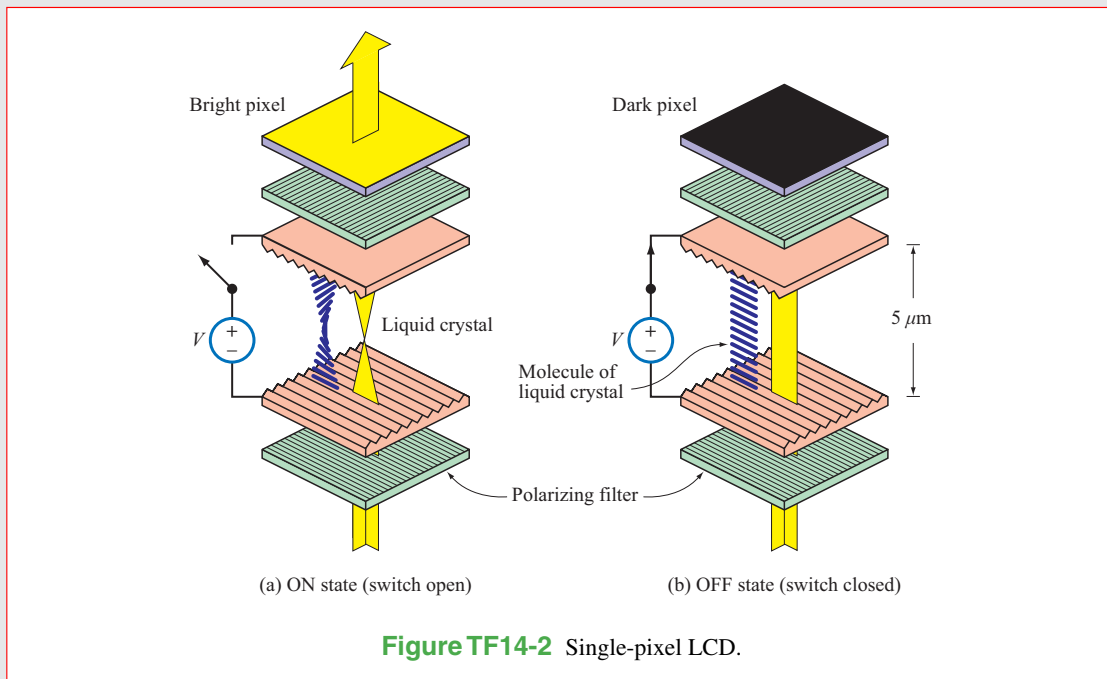
**LCDs** are used in digital clocks, cellular phones, desktop and laptop computers, and some televisions and other electronic systems. They offer a decided advantage over former display technologies, such as cathode ray tubes, in that they are much lighter and thinner and consume a lot less power to operate. LCD technology relies on special electrical and optical properties of a class of materials known as liquid crystals, first discovered in the 1880s by botanist **Friedrich Reinitzer**.

### Physical Principle

► **Liquid crystals** are neither a pure solid nor a pure liquid, but rather a hybrid of both. ◀

One particular variety of interest is the **twisted nematic** liquid crystal whose rod-shaped molecules have a natural tendency to assume a **twisted spiral structure** when the material is sandwiched between finely **grooved glass substrates** with orthogonal orientations (**Fig. TF14-1**). Note that the molecules in contact with the grooved surfaces align themselves in parallel along the grooves, from a *y* orientation at the entrance substrate into an *x* orientation at the





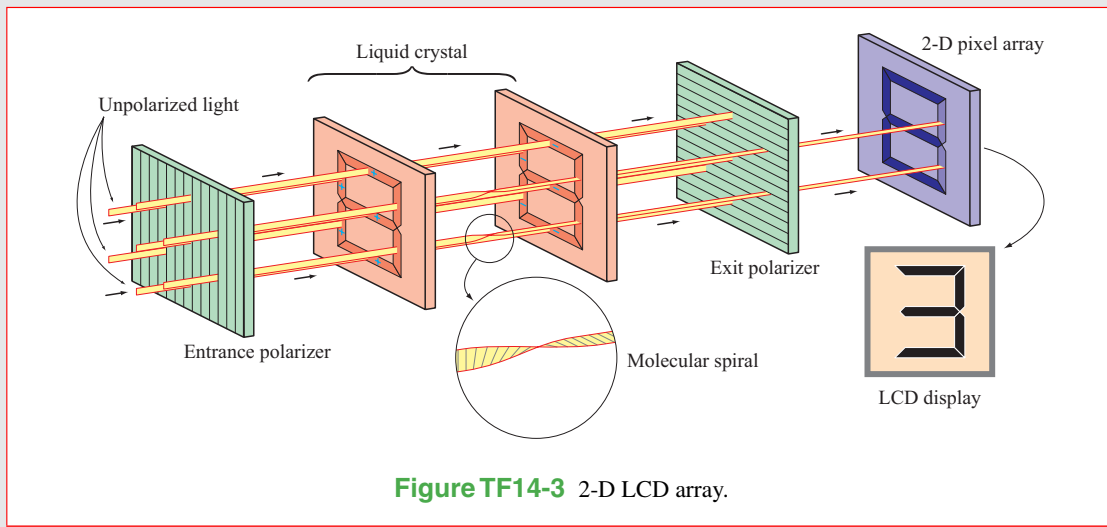
exit substrate. The molecular spiral causes the crystal to behave like a **wave polarizer**: unpolarized light incident upon the entrance substrate follows the orientation of the spiral, emerging through the exit substrate with its polarization (direction of electric field) parallel to the groove's direction, which in Fig. TF14-1 is along the  $x$  direction. Thus, of the  $x$  and  $y$  components of the incident light, only the  $y$  component is allowed to pass through the  $y$ -polarized filter, but as a consequence of the spiral action facilitated by the liquid crystal's molecules, the light that emerges from the LCD structure is  $x$ -polarized.

### LCD Structure

A **single-pixel LCD** structure is shown in Fig. TF14-2 for the OFF and ON states, with OFF corresponding to a bright-looking pixel and ON to a dark-looking pixel.

- The sandwiched liquid-crystal layer (typically on the order of **5 microns in thickness**, or 1/20 of the width of a human hair) is straddled by a pair of optical filters with orthogonal polarizations. ◀

When no voltage is applied across the crystal layer [Fig. TF14-2(a)], incoming unpolarized light gets polarized as it passes through the entrance polarizer, then rotates by  $90^\circ$  as it follows the molecular spiral, and finally emerges from the exit polarizer, giving the exited surface a **bright appearance**. A useful feature of nematic liquid crystals is that their spiral untwists [Fig. TF14-2(b)] under the influence of an electric field (induced by a voltage difference across the layer). The degree of untwisting depends on the strength of the electric field. With no spiral to rotate the wave polarization as the light travels through the crystal, the light polarization becomes orthogonal to that of the exit polarizer, allowing no light to pass through it. Hence, the pixel exhibits a **dark appearance**.



► By extending the concept to a **two-dimensional array** of pixels and devising a scheme to control the voltage across each pixel individually (usually by using a thin-film transistor), a complete image can be displayed as illustrated in **Fig. TF14-3**. For color displays, each pixel is made up of three subpixels with complementary color filters (red, green, and blue). ◀



**Figure TF14-4** LCD display.