

# Display Optics 101

## Glossary

1. **Alignment layer**: a thin (approximately 100-nanometer) coating, usually of polyimide, over the LC panel's electrodes and color filter, which is treated—typically by rubbing it in one direction—to induce liquid crystals to orient themselves in the direction of the rubbing. The panel's top alignment layer has a rub direction that is orthogonal to the bottom alignment film.
2. **Anti-glare films**: films that scatter the reflection of incident light in many directions with a matte surface.
3. **Anti-reflection films**: films that reduce the intensity of reflected light by building an index of refraction gradient or by applying the physics of destructive interference.
4. **Autostereoscopic 3D**: a binocular perception of depth without the use of special glasses.
5. **Axial luminance**: the brightness perceived by a user positioned directly in front of the screen.
6. **Backlight unit (BLU)**: the subassembly that generates and evenly distributes the light in an LCD.
7. **Bending wave technology**: a touch technology (also known as dispersive signal technology) based on the waves created when a user touches the glass surface. As the waves reach the touchscreen corners, piezoelectric sensors convert their mechanical energy into electrical signals. A controller analyzes these signals to determine a precise touch location.
8. **Bottom polarizer (LC panel)**: a film on the bottom of the LC panel that absorbs light with the wrong polarity and transmits most of the light with the correct polarity. Typically, the light reaching the LC panel has already passed through a reflective polarizer in the backlight, so it will already be largely polarized. The bottom polarizer will absorb any remaining light with the wrong state of polarization.
9. **Brightness (luminance)**: a measurement of the amount of light an LCD monitor produces; it is usually stated in nits, which are the number of candelas per square meter ( $\text{cd}/\text{m}^2$ ).
10. **Collimating multilayer optical film (CMOF)**: a single free-floating film that integrates the functions of a prism film, a diffuser and a reflective polarizer by preferentially reflecting higher angle light back to the recycling cavity, while providing higher transmission for light closer to normal incidence.
11. **Cold cathode fluorescent lamp (CCFL)**: a BLU light source that uses a discharge in mercury vapor to develop ultraviolet light, which in turn causes a fluorescent coating on the inside of the lamp to emit visible light.
12. **Color filter**: a sheet patterned with red, green and blue elements (also called subpixels) that correspond to the thin-film transistors (TFTs) on the LC panel's bottom pane of glass.
13. **Color gamut**: the subset of all visible colors that can be accurately represented by a liquid crystal display.
14. **Compensation film**: a film positioned between the bottom polarizer and the bottom glass pane in an LC panel, where it can correct for the inherent asymmetry of LC panels, which

- can limit the viewing angle. With some TN designs, a second, top compensation film provides additional correction.
15. **Contrast:** the ratio between the axial luminance of a display's brightest color (white) to that of its darkest color (black) as measured in a darkened room.
  16. **Cover sheet:** a second, less dense diffuser that is positioned between the prism film(s) and the LC panel in some devices, such as notebooks and televisions. Cover sheets are effective at removing any moiré effects caused by the interaction between these components but add thickness to the display and can reduce brightness.
  17. **Diffuser:** a film positioned above the lightguide plate, where it obscures the extractor features on the lightguide and reduces LED hotspots (a bright spot on the display screen) and headlighting (a discernible cone of light emitted from the LED). The diffuser can also increase axial luminance due to light recycling and collimation effects.
  18. **Extraction features:** features that are printed or molded on the surface of the lightguide plate. When light enters on one edge, it reflects within the plate due to total internal reflection until it hits one of these irregularities and escapes towards the LC panel.
  19. **In-plane switching:** a common type of LC panel, in which both electrodes are on the same piece of glass such that the electric field points in the plane of the display rather than pointing between one piece of glass and the other. When no voltage is applied, the liquid crystal aligns with the rub direction, which is approximately parallel to the two electrodes. Polarized light passes through the liquid crystal unaltered and is blocked by the second crossed polarizer. When a voltage is applied, the liquid crystal is rotated by the electric field and realigns toward the electric field, allowing the polarized light to be rotated and pass through the second polarizer.
  20. **Light-emitting diode (LED):** a semiconductor BLU light source in which electrons release energy in the form of photons; the energy band gap of the semiconductor determines the light's color.
  21. **Lightguide plate:** typically a sheet of low-loss acrylic that transports the light injected at the edge of the plate across the width of the display. The plate is usually dotted with extraction features that are either printed or molded on the surface.
  22. **Liquid crystal panel:** the LCD subassembly that creates shapes and colors by regulating the flow of light through red, green and blue subpixels.
  23. **Nit:** a unit of luminance equivalent to one candela per square meter (1 cd/m<sup>2</sup>).
  24. **Moiré:** an undesirable optical artifact that can occur when two or more regular patterns in an LCD (such as the lines in a prism film and in the array of subpixels) overlap. Types of moiré include pixel moiré and reflective moiré.
  25. **Multilayer optical film:** a film with hundreds of precisely-controlled layers in the thickness of a piece of paper. Some optical films have layers about 15 nm thick, much less than any wavelength of visible light.
  26. **Organic light-emitting diode (OLED):** a type of LED in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. An OLED display requires no backlight.
  27. **Pixel:** a grouping of three subpixels (one red, one green and one blue).
  28. **Prism film:** as film that uses minute surface structures to collimate the light and direct it toward the viewer.
  29. **Privacy film:** a film that uses micro-louvers to control the direction of light transmission, making the LCD screen look nearly black to anyone not directly in front of it.

30. **Projected capacitive technology:** a touch technology in which the contact is detected by measuring the capacitance at each addressable electrode. When a finger or a conductive stylus approaches an electrode, it disturbs the electromagnetic field and alters the capacitance. This change can be measured by the electronics and then converted into X, Y locations.
31. **Quantum dots:** very small—only 2 nm to 6 nm across—semiconductor structures that can be tuned to emit a specific wavelength of light, with a minute variation of plus or minus 2 nm at the peak. The output of each quantum dot is determined by its chemical composition and its size.
32. **Quantum Dot Enhancement Film (QDEF):** a thin film covered with a precisely controlled layer of quantum dots, which is sandwiched between two sheets of a protective barrier film.
33. **Reflective polarizer:** a film—in most cases, a multilayer optical film—that transmits light with the correct state of polarization needed by an LC panel. The remaining light is reflected back through the BLU to the reflective surface on the inside back of the LCD chassis.
34. **Reflective surface:** the material on the inside back of an LCD chassis that makes the surface more reflective (and less absorbent). Reflective materials include white paint, PET micro-foam, a metallic coating or a multilayer reflective mirror film such as 3M™ Enhanced Specular Reflector (ESR). The use of a multilayer reflective film will typically improve backlight efficiency by 5-15 percent (and in some cases by as much as 30 percent) over simple white reflectors.
35. **Resistive technology:** a touch technology that works on the premise of voltage being applied to a conductive, uniformly resistive surface or set of surface layers to create a voltage gradient across them.
36. **Stiction:** the frictional force that impedes smooth movement by the fingers or stylus over the top surface of a touch screen.
37. **Subpixel:** a colored element in the color filter; a grouping of three subpixels (one red, one blue and one green) constitutes a pixel.
38. **Surface capacitive technology:** a touch technology in which a person or conductive stylus creates a path for an alternating current to flow from the surface of a touch screen to ground. The current flows through the body's impedance, then through a body-to-ground impedance and back to the system ground. The position of the touchdown location is precisely calculated as being inversely proportional to the distance from the contact point to the corner.
39. **Thin-film transistor (TFT):** the tiny transistors—one for each red, blue or green subpixel—that are patterned on the bottom pane of glass in an LC panel. Increasing the number of TFTs improves resolution but reduces light transmission through the panel.
40. **Touch panel:** the subassembly that allows the user to make selections and manipulate images by simply touching the display screen with a finger or stylus.
41. **Turning film:** an alternative to prism films. A highly directional turning film has some advantages over crossed prism films—such as a slightly higher axial luminance—but it has a deleterious impact on the viewing angle and undermines the efficacy of the reflective polarizer.
42. **Twisted nematic:** a common type of LC panel. In a twisted nematic panel's default state, liquid crystals are formed into twisted (or helical) structures between two alignment

films. Light is polarized by the bottom polarizer and passes through the helical structures, exiting with a different polarity. When voltage is applied to regions of the panel, the nearby helical structures are disrupted and light is blocked.

43. **Uniformity**: a measure of the change in luminance across the area of a display.
44. **Vertically aligned**: a common type of LC panel, in which the liquid crystal molecules are aligned perpendicular to the glass when there is no voltage applied. When voltage is applied, the molecules rotate to a direction parallel to the glass. The most common type of VA panel is the multidomain vertical alignment (or MVA) design, in which the liquid crystal is induced to lie flat against the electrode in four predetermined directions within the subpixel.
45. **Viewing angle**: the maximum angle (horizontal or vertical) at which a display can be viewed with acceptable visual performance. This is usually defined as the angle at which off-axis brightness is half the on-axis brightness. (In some contexts, though, viewing angle simply refers to the degree off-axis—the angle—at which one views a display.)