

## UV LED Terminology

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**anode** – positive terminal of an LED.

**binning** – process of sorting discrete LEDs according to peak irradiance, wavelength tolerance, and forward voltage.

**borosilicate** – strong, heat-resistant, colorless, silica glass that contains a minimum of five percent boric oxide, exhibits exceptional thermal shock resistance, and transmits a greater percentage of ultraviolet energy than glass. Common material used for emitting windows, plates, reflectors, lenses, and other optics.

**cathode** – negative terminal of an LED.

**chip** – fully functioning slice of a semiconducting material, such as silicon, germanium, and gallium arsenide doped and processed to have p-n junction characteristics. Specifically, gallium nitride (GaN) is used to generate longer ultraviolet UVA and blue visible wavelengths. In referring to LEDs, chip is often used interchangeably with diode, die, and semiconductor.

**coolant** – liquid circulation material that flows over or through the heat sink in a liquid-cooled LED head in order to (1) remove excess heat energy generated by inefficiencies in the electroluminescence process and (2) maintain the desired operating temperature of the LEDs and wire bonds.

**DC power supply** – device that supplies electric energy of fixed polarity, either positive or negative, to power LEDs. DC means direct current. Direct current is an alternative to AC or alternating current.

**depletion zone** – non-conductive boundary where the positive and negative sides of a p-n junction meet.

**die** – fully functioning slice of a semiconducting material, such as silicon, germanium, and gallium arsenide doped and processed to have p-n junction characteristics. Gallium nitride (GaN) is used to generate longer ultraviolet and blue visible wavelengths. In referring to LEDs, die is often used interchangeably with chip, diode, and semiconductor.

**diode** – a semiconductor that is added to a circuit as a means of restricting the flow of electricity. It can be thought of as a switch or a valve. A key property of a diode is that it only conducts electricity in one direction. In referring to LEDs, diode is often used interchangeably with chip, die, and semiconductor.

**doped LED** – refers to an LED semiconductor material that has been impregnated with impurities during the manufacturing process to produce a specific n-type or p-type conductivity and influence the wavelength output.

**driver / driver board** – printed circuit board (PCB) that distributes the DC voltage to the LEDs or modules in an assembly and often provides additional control features.

**dual cure** – UV LED chemistry formulated to also cure with conventional microwave or electrode arc lamps.

**duty cycle** – proportion of ON time in a pulse width modulation (PWM) cycle to the total cycle time (ON + OFF) expressed as a percentage. A low duty cycle corresponds to a low power because the LEDs are OFF most of the time. 100% is fully ON, and 0% is fully OFF. 50% means that the power is ON half the time and OFF half the time. Varying the duty cycle but not the input power changes the energy density while maintaining a constant irradiance. Not all LED systems incorporate a PWM duty cycle.

**electroluminescence** – optical and electrical phenomenon inherent to LEDs in which a material emits light energy when an electric current is passed through it.

**emitting window** – flat and typically rectangular or square piece of quartz or borosilicate secured and often sealed at the base of an LED head to physically protect the LEDs while simultaneously transmitting ultraviolet wavelengths. See quartz plate.

**encapsulate** – transparent material sometimes applied to dies for protection and to seal the dies from dirt and moisture.

**forward bias** – a state that occurs when the anode of an LED is connected to the positive terminal of a voltage supply and the cathode of the LED is connected to the negative terminal. The effect of a forward bias is that the positive holes in the p region and the negative electrons in the n region of a p-n junction are pushed from opposite directions toward the depletion zone. This significantly reduces the effect of the depletion zone causing the electrons on the n-side to respond to the attractive forces of the holes on the p-side. The result is recombination, the flow of electricity, and the emission of photons.

**forward voltage** – voltage across a semiconductor diode carrying a forward current.

**integral blower / fan** – refers to the system cooling fan when it is mounted directly on the lamp head.

**integrating sphere** – an optical component consisting of a hollow spherical cavity with its interior surface covered with a diffuse white reflective coating. Also known as an Ulbricht sphere. There are small holes or openings in the sphere for inserting emitting sources. The sphere allows for a uniform scattering or diffusing of emitted light from the source such that the source's output can be measured in Watts free of any special direction. This is an R&D device and not something used on press or in the field.

**Lambert's cosine law** – radiant intensity or luminous intensity observed from an ideal diffusely reflecting surface or ideal diffuse radiator is directly proportional to the cosine of the angle  $\theta$  between the direction of the incident light and the surface normal.

**lambertian** – when an emitting surface has the same radiance when viewed from any angle. In other words, it has the same apparent brightness (or luminance).

**lambertian source** – optical source that obeys Lambert's cosine law. LEDs approximate a Lambertian source in that they have a large beam divergence and a radiation pattern that approximates a sphere.

**LED (light emitting diode)** – semiconductor, p-n junction device designed to emit specific narrow band wavelengths within the electromagnetic spectrum via a process known as electroluminescence. When a forward bias voltage is applied to the LED, current flows from the p-side to the n-side (anode to cathode). As the electrons cross the depletion zone and fill a hole, they drop into a state of lower energy. The excess energy is released in the form of a photon. The energy of the photon is directly related to the amount of excess energy

while the wavelength of the photon is inversely related to the excess energy. In other words, the higher the excess energy the shorter the wavelength. Common UV LED wavelengths are 280, 365, 385, 395, and 405 nm.

**LED array** – (1) packaged sub-assembly or module typically consisting of multiple diodes or chips that are individually wire bonded to a printed circuit board (PCB) and secured to a heat sink. LEDs can be arranged in a single line, a matrix, or other pattern. (2) full curing assembly which includes numerous modules or LEDs as well as an internal cooling fan(s) or liquid manifold with tube fittings for connecting to a chiller. Also includes a heat sink, an emitting window, and an outer enclosure. In some cases, a complete array assembly will also contain the driver boards. The array is similar in concept to a lamp head or irradiator in traditional UV curing systems.

**LED irradiator, head, lamp, lamp head, light source, LED dryer, or light engine** – full curing assembly which includes numerous modules or LEDs, a thermal heat management system, an internal cooling fan(s) or liquid manifold with tube fittings for connecting to a chiller. Also includes a heat sink, an emitting window, and an outer enclosure. In some cases, a complete array assembly will also contain the driver boards.

**LED package** – assembly containing one or several diodes and a means of electrically connecting the entire assembly to another device.

**lens** – transparent optical device used to redirect or columnate light output. In LED systems, a lens also acts to physically protect LED chips, reduce exposure to dust and moisture, and evenly spread the emitted UV radiation. A lens can be attached to each individual LED, a group of LEDs, or span the length of a line of LEDs. Often made of borosilicate or quartz. See encapsulate.

**liquid chiller or cooler** – cooling system that circulates coolant through the light source). It is used to (1) ensure the LED chips and wire bonds remain at the correct operating temperature and (2) to remove excess heat energy created by inefficiencies in the electroluminescence process. Some systems require refrigerated coolant while others use coolant cooled by ambient air blast units.

**module** – packaged sub-assembly typically consisting of multiple diodes or chips that are individually wire bonded to a printed circuit board (PCB) and secured to a heat sink. LEDs can be arranged in a single line, a matrix, or other pattern. Designs vary, but a module can also include an encapsulate, lens, or emitting window over the chips for protection and to reduce exposure to dust and moisture. A module is an array, but several modules can also be assembled together to form a larger array known as a head or irradiator.

**negative cooling** – when cooling air for a lamp head is drawn from the area surrounding the substrate or part being cured through the lamp head.

**optical device** – device used to redirect, focus, or columnate light output emitted from an LED or array of LEDs.

**pinning** – process used in UV digital inkjet printing where ink is partially cured after being jetted to reduce dot gain and provide a sharper more vibrant image or to cure the under white before additional colors are jetted on top of the white. A secondary, full cure source is required following pinning.

**plug-in-module** – packaged assembly consisting of one or multiple LED diodes that are individually wire bonded to a printed circuit (PCB) which is then secured to a heat sink. A module often includes a an encapsulate or lens over the chips for protection and to block air and moisture. A module is an array, but several modules can also be assembled together to form a larger array known as a head or irradiator.

**positive cooling** – when cooling air for a lamp head is blown into and through the lamp head. Positive cooling can be supplied through either an external blower ducted to the assembly or through an integral blower or fan mounted within or on the assembly.

**power supply unit (PSU)** – can refer to an off-the-shelf DC power supply component or the entire electrical cabinet containing the DC power supply component(s), I/O interface, AC power connection, and other items. Driver boards can be mounted in the cabinet or on the array. Sometimes referred to as the Controller if it contains the operator interface.

**printed circuit board (PCB)** – part of the LED module or array to which the individual LED chips or diodes are wire bonded or connected. The PCB provides the electrical interface between the LED chip(s) and the driver board(s).

**positive-negative junction (p-n junction)** – specially engineered diode made by growing layers of semiconductive materials. Impurities or dopants are impregnated or doped into the semiconductor layers to create p and n-type regions. These regions can be made from the same or different semiconductor materials. The two sides of the diode are referred to as the anode (+) and the cathode (-) respectively. Current flows from the p-side of the diode to the n-side when connected to a DC power source.

**pulse width modulation (PWM)** – modulating or varying the width of a pulse. This is a digital signal that employs a duty cycle to vary the ON time that power is delivered to an electronic component. Varying the duty cycle but not the input power changes the energy density while maintaining a constant irradiance. Not all LED systems incorporate a PWM duty cycle.

**quartz filter** – see quartz tube (3).

**quartz plate** – plates made from quartz or borosilicate that allow UV energy to penetrate with minimal loss in irradiance and are mounted in front of the lamp head. Another term for emitting window.

**quartz tube** – an open tube made from a silicate material. The tube is placed in front of a UV lamp head or inside the assembly and flooded internally with nitrogen. Parts traveling through the tube, such as fiber optics, are safeguarded from exposure to air and ozone in order to improve cure.

**remote blower** – refers to the system cooling fan when it is mounted separate from the lamp head and ducted into the lamp head assembly.

**semiconductor** – substance that can be made to conduct electricity or be an electrical insulator depending on its chemical composition. The conductivity and output wavelength of the semiconductor varies depending on its material construction, impurities (dopants), and concentration of dopants. Common semiconductor base materials include silicon, gallium nitride, gallium arsenide, and gallium phosphide.

**solid-state electronics** – circuits or devices built entirely from solid materials and no moving parts.

**total power** – rate of energy transfer expressed in Watts or Joules/sec. For LEDs, total power is measured in an integrating sphere.

**wire bond** – electrical connection or solder joint between the LED chip and the printed circuit board (PCB). There are two wire bonds between each LED and the PCB. These wire bonds occur at the anode and the cathode.