# UV Luminescence Sensor Application Handbook





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#### INTRODUCTION

UV luminescence sensors can do jobs that photo eyes cannot do, and they cost much less than machine vision systems. This handbook explains how UV luminescence sensors work, gives guidance on how to choose the right type of UV luminescence sensor for your application, presents a series of examples of how they are used, and provides a listing of suppliers of UV luminescent materials that can be used to make products detectable by a UV sensor.

# UV AND VISIBLE LIGHT

Ultraviolet light (UV) covers the optical spectrum from about 380 nm to 220 nm. UV luminescent sensors use the region from 320 nm to 380 nm, known as near ultraviolet, or black light.

300 nm	400 nm	500 nm	600 nm	700 nm	
← Far UV Near	UV		Visible		IR>

The visible portion of the electromagnetic spectrum extends from about 380 nm to about 780 nm, and near ultraviolet ("black light") from about 320 to about 380 nm.

# LUMINESCENCE, FLUORESCENCE AND PHOSPHORESCENCE

Strictly speaking, luminescence is the emission of light without heat. A firefly's tail is luminescent. We will consider two forms of luminescence:

*Fluorescence* is the emission of visible light as a result of excitation by ultraviolet (UV) light, the emission ceasing when the excitation is removed. Signs and other things that light up under blacklight are fluorescent. A fluorescent lamp consists of a glass tube coated on the inside with a material that glows when excited by UV light produced by an electrical discharge in the mercury vapor inside the tube.

*Phosphorescence* is the ability to be excited by visible or UV light and to continue to give off light after the excitation is removed. So-called "glow-in-the-dark" materials are phosphorescent. A phosphorescent material will glow under UV light, but then continue to glow after the UV light is turned off.

While these are the official definitions, you may find the three terms used almost interchangeably in literature about this subject.

#### WHAT IS A UV LUMINESCENT SENSOR?



A UV luminescence sensor detects things that glow (fluoresce) under ultraviolet light; it's essentially an automated black-light system. It sends out a beam of UV light (generally between 350 and 380 nm), detects the resulting visible glow, and produces an electrical output signal that can be used to control equipment or trigger an indicator.

# CHOICE OF UV WAVELENGTH



An ultraviolet wavelength of about 370 nm is a good choice for UV sensor applications.

The UV source can be either an LED or a discharge lamp. UV LEDs are available with outputs ranging from below 300 nm to about 400 nm. The best choice is around 370 nm; any longer wavelength and the UV light starts to move into the visible region. Any shorter and the LED becomes more expensive, and its light can become hazardous to the eyes.

Discharge lamps generally (high-pressure mercury type) have an output wavelength of about 365 nm, but they have a lifetime of only about 4000 hours, in contrast to the 100,000-hour lifetime of a UV LED.



UV sensing has numerous advantages over its two main alternatives, photoelectric sensors (photo-eyes) and machine vision systems.

A UV sensor can be used in many of the same applications as a photoelectric sensor and give more reliable results. For example, the detection of clear objects is difficult with a standard photo-eye. If the transparent objects glow under ultraviolet light a UV sensor can detect them very reliably. A photo-eye will often have difficulty detecting a mark on a similar-colored background. A UV sensor does not have this problem because when struck by UV light the target will fluoresce in a different color.

UV sensors can be used in many applications in which an expensive vision system might otherwise be needed. The detection of caps or labels on bottles, for example, might require a vision system with a memory of the image of a cap or label in any orientation. If the cap or label glows under UV, a UV sensor can detect it easily and dependably, and at much less cost than a vision system.

UV sensors can detect things that are inherently invisible. For example, they can tell if a bearing has been lubricated, because the grease fluoresces under ultraviolet light. They can tell if adhesive has been applied to tape uniformly. They can detect leaks of oil, coolant, or other materials. They allow markings to be applied to products without regard to aesthetics, because under normal light the markings are invisible.

#### APPLICATION EXAMPLES



Vehicle manufacturer uses UV sensors to make sure that connecting rod bearing caps have been installed in the right orientation.

- A vacuum cleaner manufacturer uses UV sensors to detect glue on bags, and to detect clear coatings on wired parts.
- A prominent vehicle manufacturer uses a UV sensor to make a screw driver unit activate when a UV mark is set on a connecting rod.
- A technical fabric manufacturer uses UV sensors to detect yarn adhesive on fabric weavers.
- A global supplier of automotive components and sub-systems uses UV sensors to detect the presence of a UVcurable gasket.
- Another global supplier of automotive components and sub-systems uses UV sensors to detect the presence of operator ID tape on ignition wire.
- A maker of automated systems and solutions for the assembly, testing and packaging of products in the automotive and other industries uses UV sensors part identification to detect a UV mark on a HVAC unit on the production line.



A bearing manufacturer uses UV sensors to detect the presence of lubricant on bearings.

• A prominent international food company uses UV sensors to detect UV-enhanced FDAapproved inks used to print date codes on packages, and to detect glue on packages.

- A supplier of interior, exterior, and under-the-hood automotive components to the automotive industry uses UV sensors in a tape application, for detecting adhesive on metal cylinders and for checking for the presence of an adhesion promoter on parts.
- A supplier to the automotive industry uses UV sensors to detect rivets marked with UV material.
- A paper manufacturer uses UV sensors to detect glue on a paperboard background.
- An industrial fabric manufacturer uses UV sensors to detect a patch on a web. The webs are then made into bags.
- A supplier to the automotive industry has three uses for UV sensors: 1.) Flocking application. 2.) Paint application. 3.) Lubricant presence application.
- A sawmill operator uses UV sensors in a cross-cut ("Chop Saw") system to optimize wood yield, increase efficiency and profitability, and reduce downtime to near zero. The sensor resists the heavy dust produced when wood is cut on a high-speed production line. A high intensity UV LED enables the sensor to detect UV marks on the logs to provide



the coordinates for the wood cutting machinery. A long optical focus length compensates for variability in the distance of the wood from the sensor, and also allows the sensor to be mounted away from flying wood chips.

- A UV sensor detects the presence of adhesive between laminates of plastic film and at the seams of trash bags. The sensor's high resolution and UV LED intensity control enable it to compensate for light diffusion that makes it difficult to distinguish between the plastic and the adhesive. Sensor operating parameters are easily adapted to the application, and the digital display provides the necessary visual feedback to the operator. Operator adjustments and setup are easy to perform, and the sensor's long sensing range allows it to be mounted out of a dirty environment. Less down time, as well as less cleaning and sensor adjustment, increase production time and improve efficiency.
- A luminescence sensor detects the presence of gum while ignoring optical brighteners in ISO 92 paper. The sensor is not affected by the presence of a highly luminescent background that can interfere with the detection of the luminescent target material. The sensor overcomes this problem by closely controlling transmitted light and by providing a digital display of reflected light intensity. Additional firmware and A/D circuitry improve resolution. The result is reliable detection of the gum while ignoring the bright paper background. In addition, the amount of luminescent pigment in the gum can be reduced, lowering the cost of the gum and extending its shelf life. The resulting cost savings and increased quality helped result in an ROI of many times the original investment.

• A luminescence sensor detects the presence of a precise bead of adhesive on different types of packaging materials. The sensor can be adjusted to compensate for variations in the adhesive bead size and in background color and reflectivity. The operator interface allows for fine calibration of the



sensor for a given adhesive and background. The result is tight control over adhesive dispensing, which improves quality and reduces nonconforming product. Lower material use, and the resulting long-term gains in both productivity and quality control, allowed this project to pay for itself in less than three months.

## MORE EXAMPLES OF THE USE OF LUMINESCENCE SENSORS

- **Furniture Making –** Detecting the presence of excess glue in a joint of wood furniture.
- Cracks and Leaks Used as tracers to find leaks of oils, refrigerants.
- Automotive Inspecting a muffler pipe for the presence of a copper fitting.
- Adhesive Tape Measuring the amount of adhesive sprayed on a roll of tape. When a nozzle gets clogged, the sensor provides feedback leading to an alarm condition. Also, detecting a UV mark that indicates where tape should be cut.
- **Lumber** Inspecting lumber for the proper coating of clear fungicide. Grading and sorting lumber prior to cutting and trimming.
- **Food Packaging –** On ring-tab cans, detecting a transparent seal that prevents the seam from rusting. Detecting the presence of straws attached to juice box containers, when the orientation of the straw is too variable for a vision system.
- **Pharmaceutical** Detecting the presence of labels, pills, and plastic tamper-proof seals on bottles.
- **Clothing –** Detecting the presence of a fluorescent thread, to verify that a seam has been sewn.
- **Packaging –** Detecting the presence of glue on cartons, the presence of surgical staple cartridges.
- Electronic Assembly Detecting the presence of tape on wiring harnesses.
- **General Industrial** Detecting the presence of paint on a part and ensuring that paint guns are working correctly. The UV sensor is set up at the exit of the paint booth and it triggers an alarm if there is no paint on the part. Also, detecting cyanoacrylate glue used to bond a hose clamp to a hose. The sensor detects the presence of the glue before allowing a machine to position the clamp in place.

# WHAT'S INSIDE A UV LUMINESCENCE SENSOR

A UV luminescence sensor has four main components:

- A UV source, which is usually an LED, but sometimes a discharge lamp.
- A lens that directs the UV light toward the target and focuses the returning visible light onto the photodetector.
- A photodetector that detects the visible light emitted by the target when UV light strikes it.
- Electronics that control everything and produce the output.



The diagram above also shows a beam splitter, which separates the UV and visible light, and a condensing lens that helps focus incoming visible light onto the photodetector.

## HOW TO TELL IF A UV SENSOR WILL WORK IN YOUR APPLICATION

A UV sensor can be used to detect any substance that fluoresces naturally, including many greases, some adhesives, starches, varnishes, epoxies, wood, paper, labels, and textiles.

In addition, fluorescent pigments can be added to many materials, such as polymers or synthetic fibers. Other materials can be marked with fluorescent ink or paint.

The paint can be the same color as the material to which it is applied, and the ink can be completely transparent, so the markings are invisible in ordinary light.

#### FLUORESCENT AND LUMINESCENT MATERIALS

Some materials, like greases and starches, for example, fluoresce naturally under ultraviolet light. Other materials do not, but can be made to respond with UV-sensitive materials.

In some cases a UV pigment can be incorporated in the material, while in other cases they are applied to the surface.

UV pigments can be added to a wide variety of materials, including plastics (clear or opaque), paper and synthetic fibers.

They can be applied to objects in the form of ink, paint, chalk, or crayon.

## **CHOOSING A UV LUMINESCENCE SENSOR**

**Operating distance –** UV Sensors are available with operating distances ranging from a few millimeters to 350 mm. Operating range can be set by installing the appropriate lens to focus the UV spot at the desired distance. Finer adjustments can be made by adjusting the intensity of the UV light, and by setting the detection threshold.

**Spot size** – The size of the spot of UV light projected on the target can be adjusted (by selection of detector and lens) from a wide area down to a dot a fraction of a millimeter across. A small spot makes it possible to check for both presence and positioning of a target, while a large spot gives a stronger return and can make alignment less critical.

**Discriminating against background –** UV sensors tend to be tolerant of a variety of backgrounds. This is aided by the fact that the UV light (and hence the visible light that returns to the detector) is pulsed. The detector will respond to pulsed light and ignore steady light.

Sometimes it is desired to detect fluorescent marking on a surface that is itself fluorescent, like invisible ink on paper or fabric that contains brighteners (brighteners are actually UV-fluorescent materials that cause material to look extra white because they fluoresce under the UV in sunlight). Under these conditions it may be necessary to choose a UV marking material whose fluorescence color is markedly different from that of the substrate. Under extreme conditions, it may be necessary to mount a colored filter in front of the detector to filter out the interfering color, although this is a rare occurrence.

**Receiver spectral response –** The ranges of visible wavelengths (colors) that UV sensors can detect varies from model to model. Some, like the EMX UVX-300, can detect anything from 350 nm (UV) to 1000 nm (near infrared). Others use optical filters to restrict spectral range to particular colors.

**Switching speed –** UV sensors are available with response times ranging from 0.1 ms to 4 ms. Most also have adjustable time delays. Faster switching speeds allow faster operation.

**User interface –** The displays and controls on UV sensors, as on most sensors, vary widely. In general it is important to have provisions for adjusting as many parameters as possible, including UV output level, detection threshold, hysteresis, null offset, and output pulse stretching. Some units have color-coded LEDs to indicate when certain levels have been reached, while others have a numerical display. The latter is useful in setup because it tells how much visible light the sensor is picking up. When ambient illumination is high it may be difficult to see the illuminated portion of the target, and the numerical signal-level indication makes aiming and adjustment easier.

Another useful feature is an analog output, which can be used as an input to a quality-control program. If average light levels go down over time it is possible to take corrective action before targets start to be missed.

## **NEXT GENERATION SENSORS**

Recently a new generation of UV luminescence sensors has emerged, with features that make them more powerful and provide for robust performance. Here are some highlights to look for:

**Distance From Target –** The new generation UV sensors work reliably at 10 or even 12 inches from target as small as a dime. The farther the sensor is from a moving target, the less chance that it will be hit by a moving part or have its lens hit with dirt.

**Speed –** Production speed is important in this competitive environment and the new generation sensors can see a target the size of a quarter moving at speeds of over 4000 feet a second. Some sensors also have stable modulated light source and noise immune electronics preventing misses or false triggering.

**Display** – Older model UV sensors typically indicate when the sensor detects a target by switching a green LED to red, but not much else. Newer UV sensors let users see the intensity of the luminescence displayed in a numerical value. Same with intensity of the UV light, gain and hysteresis. So the setup is easy and fast.

**Outputs –** There is no longer a need to stock a different sensor for each output configuration: NC PNP, NO PNP, NC NPN and NO NPN. The new generation of UV sensors configure their outputs to NC/NO via external controls and the PNP/NPN selection is done automatically by the sensors without operator intervention. In addition, new sensors are available that include analog output.

**Remote Lock** – Quality control is an issue in any manufacturing process. To ensure that the machine operator cannot tamper with the sensor settings, a feature enables the sensor controls to be locked remotely via a software command. To prevent tampering in the past, UV sensors had to be hidden from the operator or mechanically locked.

**Rugged Enclosure** – Plastic is good for many applications, but plastic lenses are not. They scratch easily and are damaged by many chemicals used in manufacturing processes. High quality glass lenses are a must and having a metal case for the sensor adds durability.

**Lens Attachments –** As we all know, sometimes corrective lenses are needed to better see small or faint targets. The new breed of UV sensors is designed to accept additional lenses that enable engineers to achieve a smaller spot size or more intense light spot.

## **MARKING METHODS**

**Manual** – The simplest way to make something glow under ultraviolet light is to mark it by hand, and suppliers provide a wide variety of chalks, crayons and pens. UV crayons are the favored method for putting grade-markings on lumber at the sawmill. UV sensors can then direct saws to extract the maximum of usable material from each log. UV crayons work well on rough surfaces, and do not wash off, so weather will not degrade the marks. UV chalk is useful where marks are to be strictly temporary, as it washes off easily with water. UV pens are available with a choice of waterproof or washable invisible ink. These are often used for security purposes and to mark and identify documents.

The next-simplest method of manual UV marking is with a stamp pad. It is useful in any industrial operation in which it is useful to mark an item that has been handled, as for example in quality control inspection, assembly processes, etc. It is also used to mark people for access control to events, and for anti-counterfeiting on documents.

**Automatic** – *Contact methods* are essentially mechanically operated felt-tip pens or stamps. They provide clean, fast, accurate parts identification without atomization, so they avoid problems with overspray and spatter. They also economize on materials: 2 oz of material can mark 20,000 to 40,000 parts.

Automatic computer-integrated spring-contact markers are available in a wide variety of nib sizes (from 1/8" bullet to 1 1/2" round) and shapes (square, triangle, or rectangle).

*Noncontact methods* allow marking of parts with irregular shapes, parts in motion, parts that are hot, etc.

A jet (non-atomizing) application directs a short stream or jet of material at the item to be marked. Since there is no atomization, overspray is avoided. This method is good for damp or oily parts, as the jet action helps displace the contaminant. It is a good choice for color coding and QC marking.

Spray application can be used to apply a stripe on a moving part or a band on a rotating part. Advantages include less need for aiming, and the ability to cover a larger area with one application. The disadvantage is that the spray can get on other things.

**Adding colorant to materials –** UV pigments can be added to printing inks, adhesives, plastics (e.g., polyethylene, polypropylene, polystyrene, polyamide, ABS), pulps, oils, antifreeze, and other materials, and encapsulated in synthetic fibers in low concentrations.

Considerations in pigment selection include color in visible light, fluorescence color, particle size, softening point, minimum processing temperature, heat stability, solvent resistance, light fastness, need for opacity (which can be achieved by use of opacifiers like titanium dioxide and zinc oxide), specific gravity, chemical compatibility, solubility in various solvents, and more.

**UV Marking Inks** – UV-sensitive "invisible" inks and fluorescent-enhanced pigmented (visible) inks, both solvent-based and water-based, are available in many different dry times. Properties to consider when selecting UV inks include:

*Visibility and color in visible light* – Invisible ink can be used in areas where visible marking would be inappropriate, and can carry information that need not be made readily apparent.

Fluorescent color - This will vary with the application.

Alkaline and acid bath resistance – Alkaline wash resistance is useful for industries where strong chemical washers are used, such as heavy machining operations in automotive engine, axle, and transmission plants.

*Oil penetration power* – This is useful where heavy oils and/or coolants are prevalent and marking must be done on an oily surface. These could include heavy machinery manufacturing, engine, axle, and transmission plants, oil quenched pipe, tubing or strip mills.

*Drying speed* – Fast-drying ink resists smudging if parts must be handled soon after marking. Drying times measured in seconds may be required for fast moving web, strip, or tubing manufacturing.

*Combustibility* – Solvent-based inks must be chosen with care in areas where ignition is a possibility.

*FDA Approval* – UV-enhanced FDA-approved inks are available for food and pharmaceutical applications.

# SUPPLIERS OF UV LUMINESCENT MATERIALS

Company	URL	Location	Products
Amark	www.amark-flm.com	Gresham, OR	Fluorescent lumber markers, wax and pigment
Amantech	www.amantech.com	Raleigh, NC	Fluorescent pigments & dyes
American Coding & Marking Ink Co.	www.americancoding.com	Plainfield, NJ	Fluorescent inks
Associated Chemists, Inc.	www.achemists.com	Orangeburg, SC, Portland, OR	Lumber marking inks, dyes, stains
Beaver Luminescers of Beaver Cloth Cutting Machines	www.luminescers.com	Newton, MA	Luminescent pigments and inks
Carco, Inc.	www.carcousa.com	Detroit, MI	Fluorescent Inks and equipment to apply them
Cleveland Pigment & Color Co.	www.clevelandpigment.com	Cleveland, OH	Fluorescent pigments
Day-Glo Color Corp.	www.dayglo.com	Cleveland, OH	Fluorescent Inks, pigments
Dixon Ticonderoga	www.dixonusa.com	Heathrow, FL	Fluorescent chalk, crayons
Foxfire-RDT	www.foxfire-rdt.com	Richmond, BC, Canada	Fluorescent lumber markers
Functional Materials, Inc.	www.functionalmaterials.com	Stoatsburg, NY	Fluorescent pigments
Honeywell Lumilux	www.lumiluxpigments.com	Seelze, Germany	Fluorescent pigments
LA-CO Industries/Markal	www.laco.com	Elk Grove Village, IL	Fluorescent crayons
Organic Dyestuffs	www.organicdye.com	Providence, RI	Fluorescent pigments, dyes
Risk Reactor	www.RiskReactor.com	Huntington Beach, CA	Fluorescent dyes, pigments, paints, tracers
Spectra Systems Corp.	www.spsy.com	Providence, RI	Fluorescent pigments, inks
Spectronics Corp.	www.spectroline.com	Westbury, NY	Fluorescent leak detection dyes

#### **CALIBRATION AND INTEGRATION**

Because UV luminescent materials and pigments are invisible under a normal light spectrum, UV sensors are difficult to tune without some indication of what they are reading. Most UV sensors use simple LEDs that indicate luminescence or that the set point has been reached.

The UVX 300 sensor from EMX numerically displays the intensity of each reading (relative reflection and threshold.) This feature makes it easy for the operator to tune the sensor and saves valuable engineering time, because it eliminates the need to blindly adjust sensor intensity and check the results over multiple test runs.

In addition, some sensors allow for user control of hysteresis for further precision tuning.

Most UV sensors have either auto-teach or manual calibration. Auto-teach calibration makes the sensor easy for low-skill operators to calibrate. Manual calibration provides the ability to be finely tuned.

UV sensors provide analog or discrete output. The advantages of analog output include the ability to "measure" the intensity of returned signal, the ability to track process variations for SPC and SQC applications, and easier sensor setup.

Some UV sensors also have auto-detect for PNP/NPN, which simplifies integration.



#### **ABOUT EMX INDUSTRIES**

Since 1987, EMX sensors have been trusted in industrial automation and for gate and door control. EMX sensors are used in automotive, packaging, labeling, metal stamping, paper and wood processing, plastics, electronics and pharmaceutical manufacturing. Direct inquires to salessupport@emxinc.com.

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