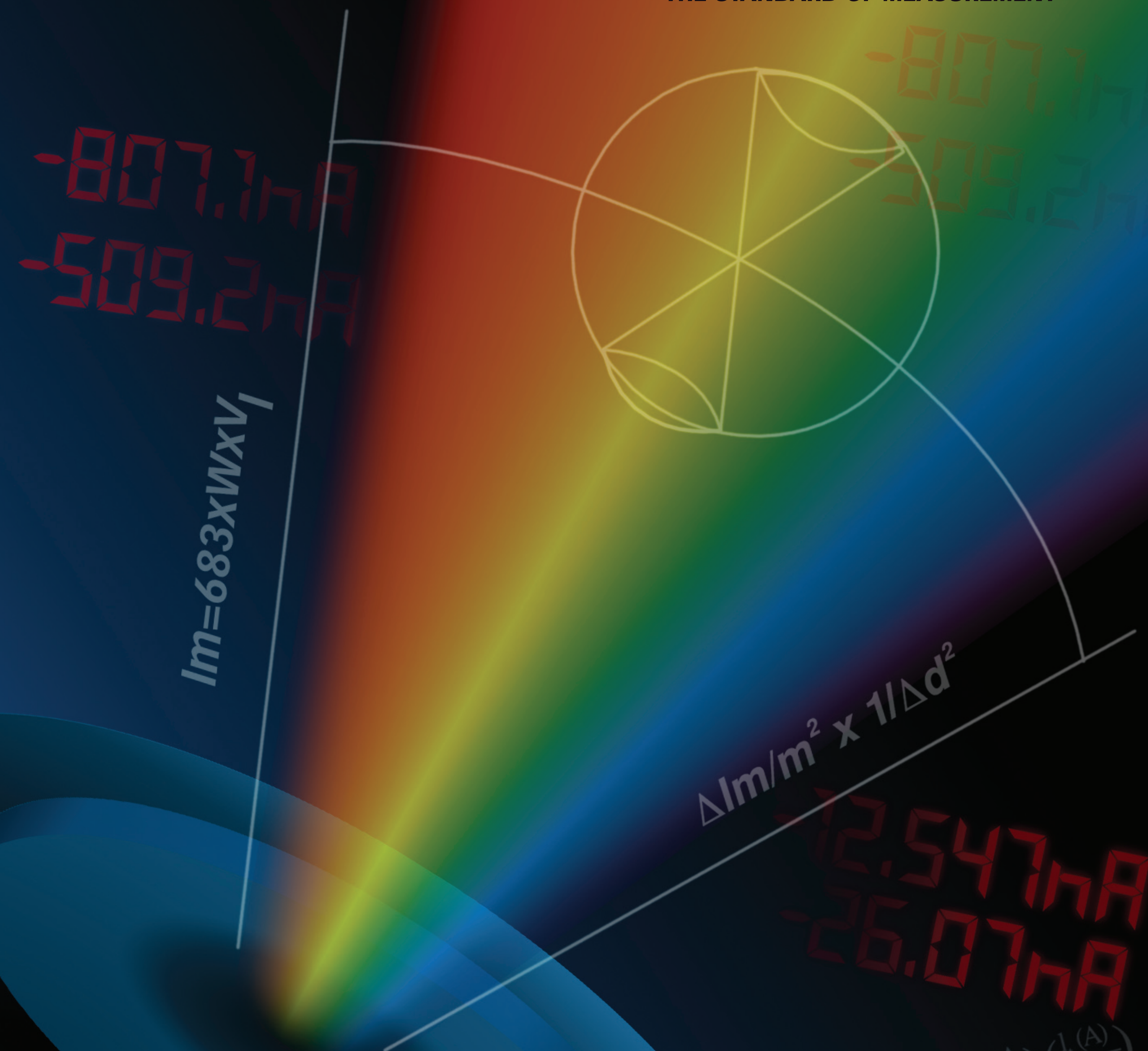
UDT INSTRUMENTS

THE STANDARD OF MEASUREMENT



The Guide To PHOTOMETRY

UDT INSTRUMENTS

THE STANDARD OF MEASUREMENT

Photometry Guide Contents

UDT INSTRUMENTS
THE STANDARD OF MEASUREMENT

To Our Valued Customers

HISTORY

The early beginnings of UDT Instruments can be traced to 1967 when a small group of inventors at United Detector Technology (UDT) began manufacturing the first commercially available transimpedance amplifiers for planar-diffused and Schottky barrier silicon photosensors. Over the next several years, this same group of people went on to pioneer leading-edge technological innovations for photometers, radiometers, fiber-optic power meters and optical position-sensing instruments. By the early 1980's, this highly skilled and successful group grew into an autonomous entity known as UDT Instruments.

Drawing on the momentum generated by UDT's precision photometric instruments,the company developed an inventive handheld colorimeter for the growing television and computer peripherals markets.The development of UDT's SLS9400 colorimeter promises to strengthen our company's position as a leader in precision electro-optics instrumentation, while meeting the stringent demands of a multitude of CRT calibration requirements. UDT is poised and ready to excel to greater technological excellence with only one goal in mind: to meet and exceed the ever-changing needs of its customers worldwide.

SERVICE

We at UDT Instruments stand behind our products and the companies who use them. For this reason, we continue to service those same light-measuring instruments that we built twenty years ago. By offering these services to our customers, both new and established, we stay involved with our products and extend a personal touch to our business relationships. We know of no other company in our industry that hires more qualified sales engineers, people who really understand light measurement principles and practices. By hiring such knowledgeable engineers, we ensure you that you will get the best electro-optic instruments to fit your application and budget.

QUALITY

The instrument you receive is certain to be reliable and accurate. We maintain a Quality program that affects every indicator module, sensor head, and optical accessory we sell. And when it comes time for re-calibration, upgrades, or repairs, you'll discover that our service and metrology departments reflect this same commitment to quality and personalized service.

To Our Valued Customers

TECHNOLOGY

UDT Instruments has always been and continues to be at the forefront of light measurement technology. We hold U.S. and worldwide patents on our QED products, which are absolute radiometric reference standards in the visible and near IR spectrum. Our QED-200 product won a prestigious IR-100 award as one of the 100 most significant U.S. inventions in 1986. These products were developed in conjunction with the National Institute of Standards & Technology (NIST) and the National Physical Laboratory (NPL). UDT Instruments continues to work with the NIST under Cooperative Research And Development Agreements (CRADA) in order to develop even more state-of-the-art products into the 21st Century.

PUBLICATIONS

In addition to our comprehensive "Guide To" tutorial series, UDT regularly publishes articles in trade journals and other scientific literature which we've made available as application notes to explain subtle details and applications of our technology.

PROFESSIONAL SOCIETIES

UDT is committed to supporting the industry through its professional society affiliates. We are proud to be sustaining members of:

- Society of Photo Optical Instrumentation Engineers (SPIE)
- Optical Society of America (OSA)
- National Association of Broadcasters (NAB)
- Laser Institute of America (LIA)
- Illuminating Engineering Society of America (IES)
- Society For Information Display (SID)

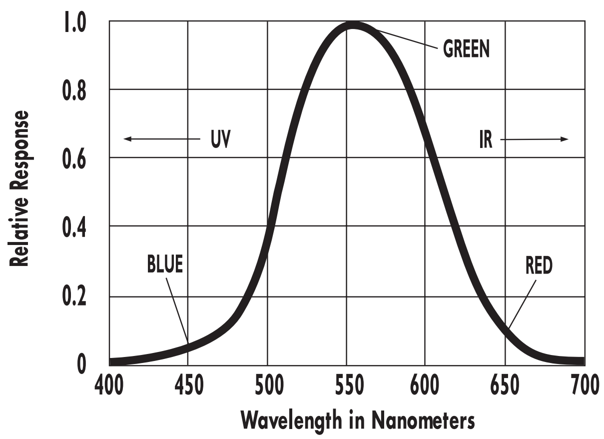
UDT also actively participates in the Council for Optical Radiation Measurement (CORM) and the Commission Internationale l'Eclairage (CIE).

WARRANTY

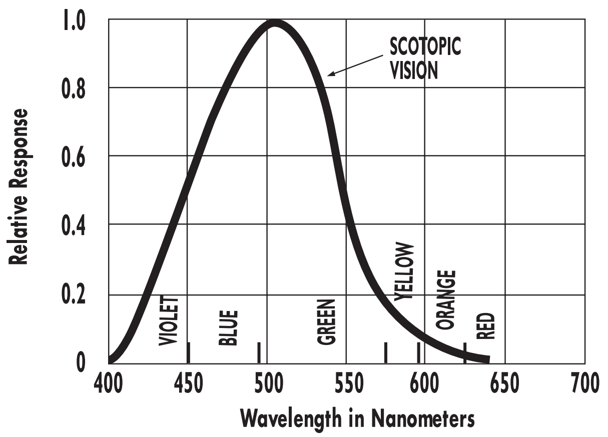
UDT Instruments warrants that its products are free from defects in material and workmanship under normal use and service for a period of one year from the date of shipment from our factory. UDT Instruments's obligation under this warranty is limited to the replacement or repair of any product determined to be defective during the warranty period, provided the product is returned to the factory pre-paid. This warranty does not apply to any equipment that has been repaired or altered, except by UDT Instruments, or which has been subject to misuse, negligence, or accidents. It is expressly agreed that this warranty will be in lieu of all warranty of merchantability. No other warranty is expressed or implied. UDT Instruments is not liable for consequential damages.

Application Information

INTRODUCTION



CIE phototopic response curve.



CIE scotopic response curve.

Photometry is the science concerned with measuring human visual response to light.

Because the eye is a highly complex organ, this is by no means a simple task. It involves the meeting of many disciplines: psychology, physiology, and physics among them.

Photometry can be said to have become a modern science in 1924, when the Commission Internationale de l'Eclairage (CIE) met to define the response of the average human eye. The Commission measured the light-adapted eyes of a sizable sample group, and compiled the data into the photopic curve. Simply stated, the curve reveals that people respond strongest to the color green, and are less sensitive to the spectral extremes, red and violet.

The eye has an altogether different response in the dark-adapted state, wherein it also has difficulty determining color. This gave rise to a second set of measurements, and the scotopic curve.

Having defined the eye's spectral response, CIE sought a standard light source to serve as a yardstick for luminous intensity. The first source was a specific type of candle, giving rise to the terms footcandle and candlepower. In an effort to improve repeatability, the standard was redefined in 1948 as the amount of light emitted from a given quantity of melting platinum.

Application Information

BASIC CONCEPTS

Wavelength (nm)	Vλ CIEPhotopic Luminous Efficiency Coefficient	Photopic Lumen/Watt Conversion Factor
380	0.0000	.05
390	0.0001	0.13
400	0.0004	0.27
410	0.0012	0.82
420	0.0040	2.73
430	0.0116	7.91
440	0.0230	15.7
450	0.0380	25.9
460	0.0600	40.9
470	0.0910	62.1
480	0.1390	94.8
490	0.2080	142.0
500	0.3230	220.0
510	0.5030	343.0
520	0.7100	484.0
530	0.8620	588.0
540	0.9540	650.0
550	0.9950	679.0
555	1.0000	683.0
560	0.9950	679.0
570	0.9520	649.0
580	0.8700	593.0
590	0.7570	516.0
600	0.6310	430.0
610	0.5030	343.0
620	0.3810	260.0
630	0.2650	181.0
640	0.1750	119.0
650	0.1070	73.0
660	0.0610	41.4
670	0.0320	21.8
680	0.0170	11.6
690	0.0082	5.59
700	0.0041	2.78
710	0.0021	1.43
720	0.0010	0.716
730	0.0005	0.355
740	0.0003	0.170
750	0.0001	0.820
760	0.0001	0.041

Photometric to radiometric conversion factors.

The basic unit of photometry is the lumen, which is related to its radiometric analog, the Watt, by:

$\mathrm{lm} = 683 \times \mathrm{W} \times V\lambda$

Where Vλ is the relative luminosity, a coefficient scaled to visual response. Unity occurs at the eye's peak response wavelength, 555 nanometers.

Two useful laws in photometry recur: the inverse square law and the cosine law. The first defines the relationship between illumination from a constant-intensity light source and its distance from a surface. It states that the intensity per unit-area on the surface, varies in inverse proportion to the square of the distance between the source and surface, or:

$\Delta \mathrm{lm}/\mathrm{M}^2 \;\alpha\; 1/\Delta d^2$

Accordingly, successive illuminance measurements are only as accurate as the control of source to surface distance. Further, if illuminance is known at one distance, it can, barring interference, be calculated for any distance.

The cosine law indicates the intensity of light on a surface of fixed area, varies with incident angle. In fact, the intensity falls off as the cosine of the angle. This results because the projected surface area, in the plane perpendicular to incidence, is proportionally reduced.

Thus in measurements of environmental lighting, sensors require cosine correction to account for off-axis light. Without it, considerable errors will occur, especially with bright sources at low incident angles (e.g., windows). This often accounts for the difference in readings between two photometers.

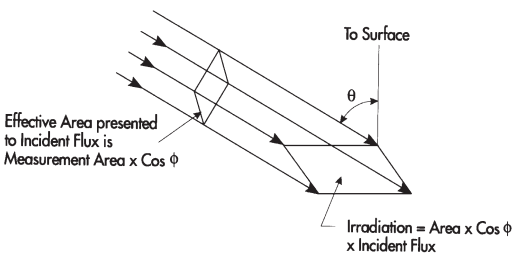
The cardinal challenge in photometry is to recreate the spectral response of the human eye. But electronic sensors have distinct response characteristics which bear no resemblance to the CIE standard observer. Therefore, these sensors must be spectrally corrected. Two techniques are conventionally used to accomplish this: wavelength scanning, and detector/filter matching.

Scanning can be accomplished with discrete-wavelength, scanning monochromators, or multi-channel detectors. In either case, the intensity of a light source is measured wavelength-by-wavelength, and then the results are mathematically fitted to the photopic curve. For this reason, such techniques do not occur in real time, and require microprocessor control. Scanning approaches offer high accuracy, but tend to be costly, and complex to operate.

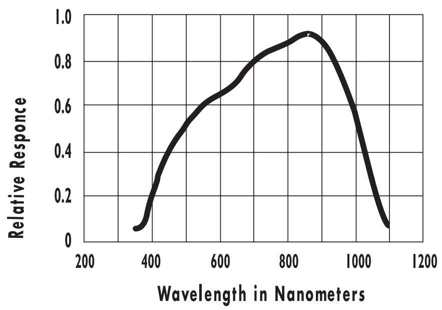
Optical filtering offers a simple and cost-effective solution. With only one photo-current signal to process, single-channel electronics can be used. Also, recent advances in filter design, and improvements in solid-state detectors, allow this method to rival scanning systems for photometric accuracy.

Application Information

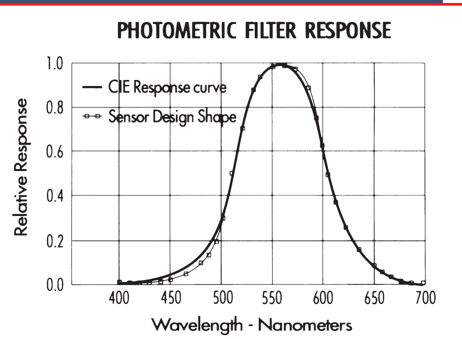
BASIC CONCEPTS



The intensity of off-axis light decreases relative to the cosine of incident light.



The typical spectral response of silicon photodetectors.



UDT Instruments photometric filters match the CIE curve to within 1% total area error.

This filter-matching technique involves the layering of colored-glass filters over an optical detector. Each element functions to attenuate selective wavelengths until the detector's response simulates the CIE curve. Planar diffused silicon photodiodes offer the best photosensor characteristics, since they afford high sensitivity and linearity throughout the visible spectrum. Using silicon photodetectors, and advanced filter designs, UDT Instruments matches the CIE human eye response curve within 1% total area error. This is the best match achievable, according to CIE.

There is another more important specification of the quality of a photometric detector and that is the f_1^1 value. This is defined by the CIE and is a numerical value assigned to the average deviation of the photometric detector's response from the CIE curve. An $f_1^1 < 1.5\%$ is the best possible laboratory grade detector while an $f_1^1 < 3\%$ is considered suitable for most applications.

However, the relationship between a given detector and filter is delicate. Once the two have been matched, they should not be interchanged with other photometric detector/filter pairs. Each detector exhibits unique response characteristics that require a specific combination of filter layers and thicknesses.

Once the detector's response is fixed, it is calibrated using the transfer of standards technique. This requires a detector of known response, which can be obtained from the National Institute of Science and Technology (NIST). A detector/filter pair is positioned before an optical source with constant wavelength and intensity characteristics (usually a tungsten halogen lamp). The electrical output of the detector under test is then compared to the standard detector's output.

Once the sensor's luminous response is determined, it can be matched to a precision gain-controlled electronic amplifier and readout system.

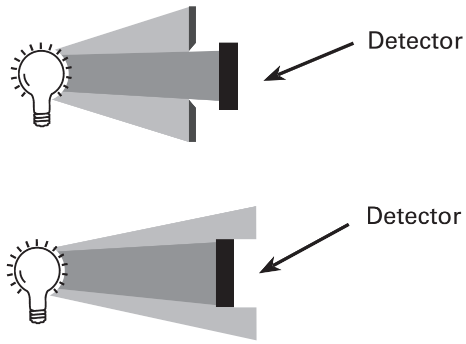
Calibration by Transfer of Standards

R_t = Responsivity of the test detector (A/lm)
R_r = Responsivity of the reference detector (A/lm)
I_t = Measurement of the test detector (A)
I_r = Measurement of the reference detector (A)

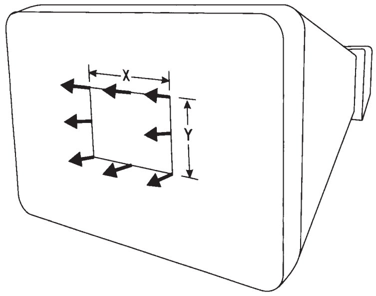
$$R_t\left(\frac{A}{lm}\right)=R_r\left(\frac{A}{lm}\right)\left(\frac{I_t(A)}{I_r(A)}\right)$$

Application Information

IMPORTANT TERMS



In illuminance measurements, area is determined by the detector unless there is an external aperture.



Luminous exitance is calculated by measuring luminous flux and dividing by the source's area.

Luminous Flux

Luminous flux is expressed in lumens, the fundamental unit of photometry. It is a measure of the total optical output of a visible light source.

The measurement requires all of a source's power to be concentrated on a detector. This can be a problem with divergent sources like LEDs, and lamps. In these cases, integrating spheres are often used.

Illuminance

Illuminance is a measure of the amount of visible light incident upon a prescribed surface area. In English units, one lumen of flux falling on one square foot is termed a footcandle. The metric equivalent, one lumen per square meter, is called a lux (10.76 lux = 1 footcandle).

Of course, detectors don't have such large areas. So the area of the detector is multiplied proportionally. Special attention is due when the detector is under-filled or used behind corrective optics, since the sensor's area no longer defines the surface being illuminated.

For example, illuminance measurements are particularly susceptible to errors introduced by off-axis light. So cosine-correcting diffusers are used with the detector head. Since the cosine diffuser is essentially imaged onto the sensor, the diffuser's area, not the sensor's, represents the measurement surface.

Luminous Exitance

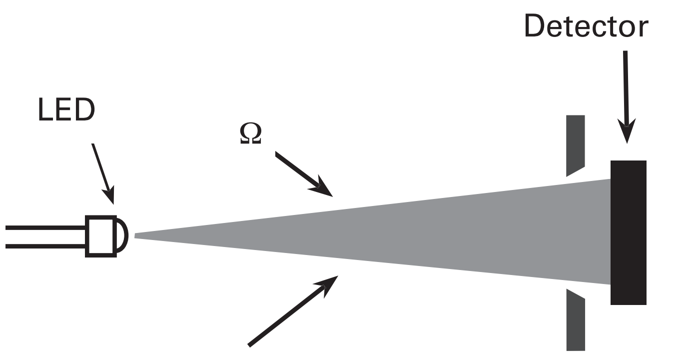
Luminous exitance is an intrinsic property of a light source. It is calculated by measuring luminous flux (lumens), and dividing by the surface area of the source. This measurement is also expressed in lumens per square meter, but is not to be confused with illuminance measurements or lux. The area referred to in luminous exitance is that of the light source, not the illuminated surface. This measurement is most applicable to emitters with flat surfaces.

Photometric Quantities and Units

Quantity	Symbol	Units	Abbreviations
Luminous energy	Q	lumen•second...talbot	lm•s...talbot
Luminous Density	U	lumen•second/m^3	lm•s/m^3
Luminous Flux	F	lumen	lm
Illuminance	E	lumen/m^2...lux	lm/m^2...lx
		lumen/cm^2...phot	lm/cm^2...ph
		lumen/ft^2...footcandle	lm/ft^2...fc
Luminous Exitance	M	same units as illuminance	
Luminance (brightness)	L	candela/m^2...nit	cd/m^2...nt
		candela/cm^2...stilb	cd/cm^2...sb
		candela/π ft^2...footlambert	cd/π ft^2...fl
		candela/π m^2...apostilb	cd/π m^2...asb
		candela/π cm^2...lambert	cd/π cm^2...L
Luminance intensity	I_u	lumen/steradian...candela	lm/st...cd

Application Information

IMPORTANT TERMS



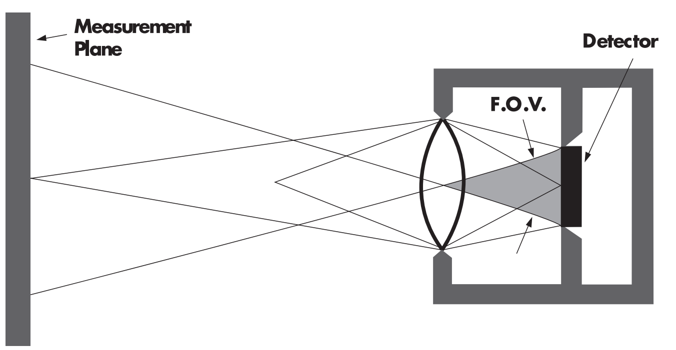
Luminous intensity is a measure of the flux emitted into a solid angle.

Luminous Intensity

Luminous intensity is also a source property, but one where the source's direction and divergence come into play. Defined as the quantity of luminous flux emitted uniformly into a solid angle, the basic unit of luminous intensity is the candela, equal to one lumen per steradian.

Several things are suggested by this definition. One, this measurement is not applicable to collimated light sources. Two, it is inaccurate for non-uniform emitters.

To calculate luminous intensity, the detector's area (or the area prescribed by the aperture in front of it), and its distance from the light source must be known. From these, the solid angle can be calculated, and then divided into the flux reading.



One luminous measurement technique involves fixing the detector's field-of-view through the use of a lens.

Luminance

Also known as photometric brightness, luminance is a measure of the flux reflected by, or emitted from, a relatively flat and uniform surface. The technique takes into account the area of the surface measured, and the angle subtended by an observer looking at it.

Luminance may be thought of as luminous intensity per unit area, and so in metric terms is expressed as candelas per square meter. But a host of other terms are used for this measurement, some to describe a circular measurement area rather than a square one (see Photometric Quantities and Units chart).

To measure luminance, the detector field-of-view must be restricted, and its angle calculated. Usually, a lens or baffle is used to achieve this. In fact, the human eye, with its lens and aperture, functions as a luminance meter.

Note that so long as the detector's field-of-view is filled, this measurement is independent of the distance between the detector and measurement planes. That's because field size and source intensity vary in direct proportion to one another as a function of distance.

Luminous Energy

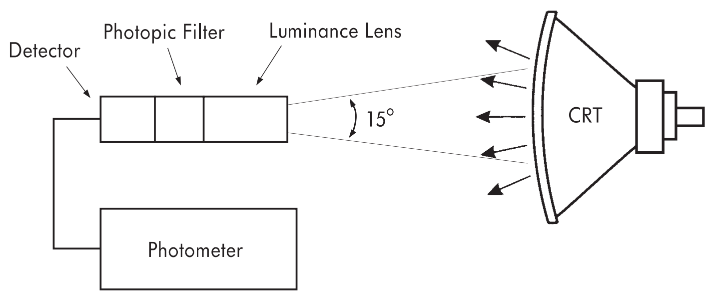
Luminous energy is a measure of the rate of flow of flux, and so is expressed in lumen-seconds. Generally, it is applied to flashed or pulsed sources.

It is also possible to measure any photometric quantity on a time-dependent basis. For instance, the illuminance of a rotating beacon in one direction could be integrated over time to yield footcandle-seconds.

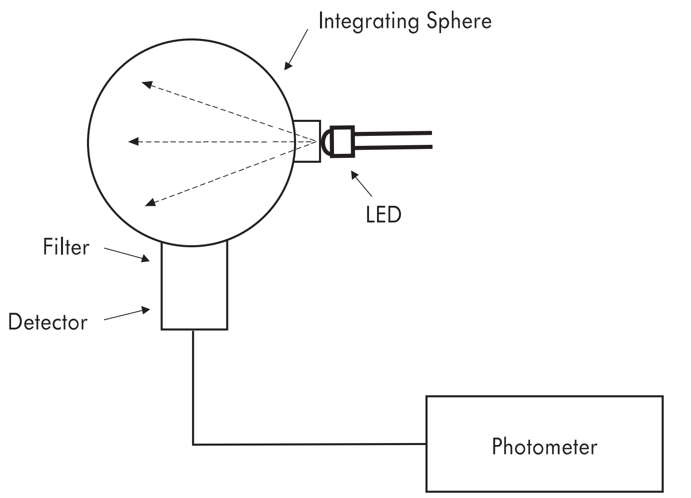
UDT INSTRUMENTS
THE STANDARD OF MEASUREMENT

Application Information

HOW TO SPECIFY A PHOTOMETER SYSTEM



CRT'S and other displays are typically measured in terms of luminance.



Integrating spheres are the most accurate means of measuring small, divergent sources like LEDs.

Specifying a photometer system is best approached in three steps. First, evaluate the source to determine which measurement technique best applies. Then, select a detector and optical system (detector head) that suit the measurement. And finally, match the detector head to the particular electronics which provide the most effective user interface for the application.

Consider the Source

Common sense goes a long way in determining the right measurement for an application. After all, photometry is concerned with the relation of light to the human eye. So, the first question is: how will people be affected by the source to be measured?

For instance, measurements of ambient or environmental lighting are concerned with people's ability to read print or safely see objects in an area. It is not the power of a particular source that is of concern, but rather how well the source lights the area of interest. For this reason, lighting for the outdoors, offices, factories, and photography are measured in terms of illuminance.

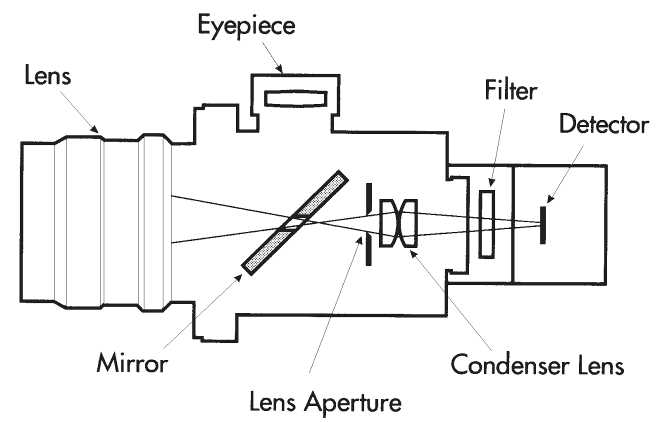
However, if in the same room or space one wished to determine the brightness of walls, fabric, or painted surfaces, the measurement changes altogether. Because now the amount of reflected light received by the eye is of concern. Since all of these surfaces are diffuse and relatively uniform, a luminance measurement would best apply.

Electronic displays such as CRTs, avionics, and automotive panels are incident directly upon the eye too. But alpha-numeric characters and line detail are generally small. So the measurement system's field-of-view must be limited or focused in order to measure only the lighted portions of the display. This is, by definition, a luminance measurement. So display brightness is usually specified in footlamberts.

Lamps are used in so many applications that it is impossible to define just one way to measure them. As previously mentioned, lamps and lamp systems for area lighting (rooms, streets, stadiums) call for illuminance measurements. But in automotive exterior lighting, headlights are usually measured for illuminance, taillights for luminance. There are a number of miniature, lensed lamps on the market, and since their divergence is of concern, they would be measured for luminous intensity. Incandescent and fluorescent lamp manufacturers specify products in terms of luminous flux (or the radiometric equivalent, watts) since these will be placed in fixtures meant to diffuse and measure their total output.

Application Information

HOW TO SPECIFY A PHOTOMETER SYSTEM



For luminance measurements requiring small fields-of-view, a lens system with view-through optics is essential.

Lasers and LEDs also require a careful approach. They are measured in radiometric terms for scientific applications. But when their potential damage to the eye is of concern, they would probably be measured for luminous flux. A lensed LED, however, is a divergent, though directional, source. Luminous intensity would best characterize it. But with surface or edge emitting LEDs, emission as a function of surface area is significant. This describes a luminous exitance measurement.

Luminous energy measurements apply to any periodic source. Pulsed LEDs, photographic flash units, strobe lights, arc lamp systems, and rotating or scanning lights are several examples of sources whose flux is time dependent.

Selecting the right detector head

The measurement type dictates your choice of detector head assemblies.

UDT Instruments offers a modular photometric sensor-head design approach. In all cases, a silicon photodetector, detector housing, and photometric filter assembly are provided. And for those luminous flux measurements where all incident light is collimated or focused onto the detector, this simple head will suffice.

UDT Model 1120 Telephotometer

However, if flux levels exceed 70 lumens per square centimeter, the detector may become saturated, and its output nonlinear. In such instances, attenuation is recommended. Neutral-density filters, apertures, or integrating spheres achieve the desired effect. The correct selection depends upon the amount of attenuation desired: it should be enough to avoid detector saturation, but not so much as to lose sensitivity and dynamic range.

The simple detector/filter arrangement is also effective for ambient measurements if all light is at normal incidence. But when off-axis light, such as from windows and peripheral sources, contributes to the total flux, a cosine diffuser is needed.

In addition to being widely applied by lamp manufacturers, integrating spheres are useful for measurements of small divergent sources like lensed LEDs or miniature lamps. These can be inserted right into the sphere's entrance port to ensure that all light is collected.

Application Information

HOW TO SPECIFY A PHOTOMETER SYSTEM

UDT Instruments Model 1120 Microphotometer

Luminance measurements require a prescribed sensor-head field-of-view. The size of the source in the measurement-field plane, and the sensor-to-subject distance determine the angle. With large, but close fields, a simple baffle (steradian shade or aperture) will do. But small images, such are those on CRTs or avionics, call for a lens system, as do measurements at a distance. A variety of lens assemblies and optical accessories are available from UDT Instruments, to accommodate most any luminance measurement, whether microscopic or telescopic.

UDT Instruments offers a wide range of optical accessories for out-of-the-ordinary measurements. These include: fiber optic probes, for convenience in measuring sources hidden in hard-to-reach places; LED measurement systems specific to either segmented or discrete LEDs; low-profile sensors for slipping into tight spaces, such as in photolithography exposure systems; and a variety of sensor heads customized for CRT luminance measurements.

Choosing electronics matched to the application

The light sensor in each UDT Instruments photometric head is a silicon photodiode. Though sensor size may vary, the output will in all cases be a low amplitude current signal. This signal will be converted into a voltage by a transimpedance amplifier circuit, and then used according to the requirements of the particular application.

Your choice of electronics depends upon the answers to a few basic questions:

1. Is field portability needed?
2. Will the instrument be interfaced with a computer?
3. Is a visual display desired, or will an analog output suffice?
4. Will more than one measurement be conducted concurrently?

UDT Instruments offers photometer controllers and electronic amplifiers that satisfy any combination of answers to these questions. The instruments range from simple analog amplifiers and hand held photometers, to multichannel computer-controllable laboratory instruments. Versions are available which suit most any budget.

UDT INSTRUMENTS
THE STANDARD OF MEASUREMENT

Laboratory Photometers

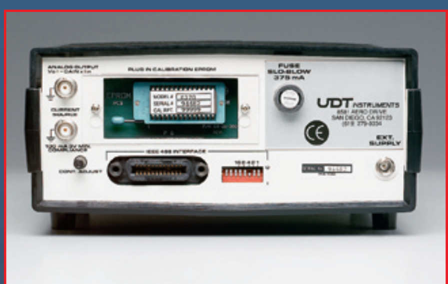
SYSTEM S370

Single-Channel IEEE-488 Compatible Power Meter

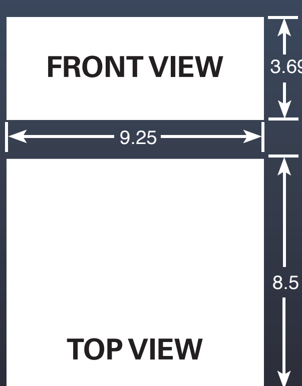
The System S370 Single-Channel Optometer is lightweight and compact for portability; yet, it has large controls and a convenient, easy-to-read, 16-character LCD screen. As the user programs each test parameter, its microprocessor provides step-by-step prompts via a LCD screen. Add any UDT Instruments Radiometric Sensor Head and the system becomes a versatile, simple-to-use photometric system.

The S370 can be controlled by a simple, 10-function keypad or from a host computer via the IEEE-488 interface. Functions such as sending and receiving data, viewing operational data on the host computer's monitor, and programming the S370 can be performed from a remote location.

UDT Instruments unique plug-in calibration module enables limitless calibration. The module is an EPROM that is pre-programmed by qualified technicians in a UDT Instruments calibration lab. All calibrations are NIST-traceable and multiple modules are also available.



The S370 has five functions that eliminate tedious calculations. In "Linear", the S370 can be used with any linear photodiode. "Log" permits attenuation measurements or measurements relative to a reference level. "Log Ratio" allows the user to set a measurement as a reference level to which other measurements may be compared. "Ratio" takes the ratio of a reference value to subsequent measurements. "Responsivity" permits the user to program the responsivity of any uncalibrated sensor head into the S370. The S370 also offers an analog output and an analog bar graph display on the front panel.



Dimensions shown in inches

Performance Specifications

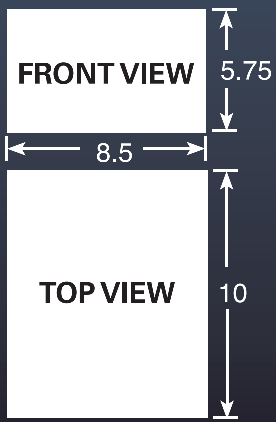
Accuracy	Linear Mode	Log Mode
	±0.2% + 1 count, 10^3 to 10^7 range	±0.2% + 1 count, 10^3 to 10^7 range
	±1.2% + 1 count 10^8 to 10^9 ranges	±1.2% + 1 count 10^8 to 10^9 ranges
Dynamic Range	10 decades.	9 decades
Calibration	*May be calibrated in multiple units*	
Temperature Drift		
10^3 to 10^7 range	±0.03% /C°	N/A
10^8 to 10^9 range	±0.06% /C°	N/A
dbm % of reading refered to input	N/A	None

General Specifications

Output	
Digital	IEEE-488 (drivers available for Lab Windows™)
Analog	±2.5 VDC
Output Connectors	
Digital	IEEE-488
Analog	BNC
Bandwidth	9.0Hz
Temperature Range	
Operating	0° to +45°C
Storage	-20° to +60 °C
Weight	3.1 pounds (1.41 Kg)
Accessories supplied	120/240V power supply, instruction manual, corrugated cardboard carrying case

Laboratory Photometers

SYSTEM S380



Dimensions shown in inches

System S380 Dual-Channel Photometer

The System S380 has all of the systems S370's convenient features: easy programming an IEEE-488 interface for host computer control and storage capacity for a large number of sensor head calibrations.

However an additional measurement channel is provided with the S380 to measure two light sources simultaneously, or perform real-time ratio measurements.

The second channel is as easy to program as the first, since it is prompted and controlled similarity. Additionally, the prompt menus and measurement data are displayed on a large, 2 x 16 –character LCD screen.

Performance Specifications

Accuracy	**Linear Mode**	**Log Mode**
	±0.2% + 1 count, 10^3 to 10^7 range	±0.2% + 1 count, 10^3 to 10^7 range
	±1.2% + 1 count 10^8 to 10^9 range	±1.2% + 1 count 10^8 to 10^9 range
Dynamic Range	10 decades	9 decades
Calibration	*Two selectable channels may be calibrated in multiple units*	*Available on both channels*
Temperature Drift		
10^3 to 10^7 range	±0.03% /C°	N/A
10^8 to 10^9 range	±0.06% /C°	N/A
dBm, % of reading, referred to input	N/A	None
Bandwidth	9.0 Hz	

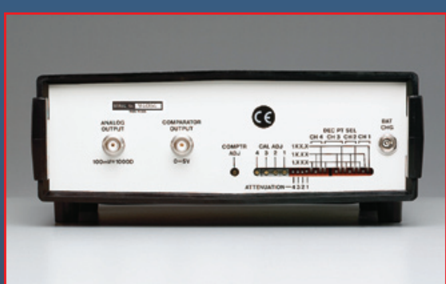
General Specifications

Display	Liquid crystal, with two lines of 16 characters
Display Range	0000 to 9999
Range Control	Automatic or manual
Output	
Digital	IEEE-488 (driver available for Lab Windows™)
Analog	±2.5 V DC Both channels
Output Connectors	
Digital	IEEE-488
Analog	BNC
Temperature Range	
Operating	0° to +45°C
Storage	-20° to +60 °C
Weight	5.1 pounds (2.31 Kg)
Accessories supplied	CE Approved Power Supply, instruction manual corrugated cardboard carrying case

UDT INSTRUMENTS
THE STANDARD OF MEASUREMENT

Laboratory Photometers

SYSTEM S350



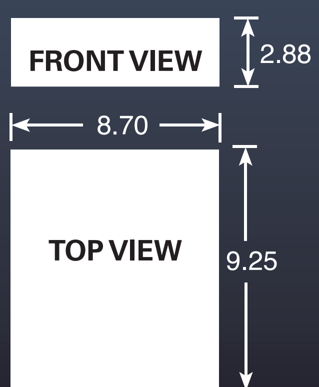
Photometer

The S350 provides both radiometric/photometric and log measurements. Measurement modes are selected with a front panel switch. As a photometer, the S350 makes power and energy measurements. A front panel "Multiplier" control provides seven full-scale decades of power and five full-scale decades of energy measurement capability.

Data is displayed on a large LCD monitor. Four calibration channels are selectable from the front panel.

System S350 Specifications

	Linear Mode	Log Mode
Accuracy	±1.2% ±2 counts,	5%(referred to input)
Stability	$\leq$ 1%	$\leq$ 1%
Dynamic Range		
Power	9 decades	
Energy	7 decades	
Log		9 1/2 decades
Temperature Drift		
10^{-1} to 10^{3} range	±0.03% /C°	
10^{-3} to 10^{-2} range	±0.06% /C°	
dBm, %of reading, referred to input		0.1%/ºC@ dBmA* 0.1%/ºC@ -30dBmA* 2.0%/ºC@ -60dBmA*
Battery	NiCad rechargeable	NiCad rechargeable
Battery Life		
LCD backlight off	25 hours	25 hours
LCD backlight on	8 hours	8 hours
LCD powered	8 hours	8 hours
Temperature Range		
Operating	0° to 45ºC	
Storage	-20° to 60ºC	
Analog Output	0-100 mV	
Display	3 1/2 digit LCD	
Weight	3.75 pounds (1/8 kg)	
Accessories supplied	CE Approved Power Supply, instruction manual, corrugated cardboard carrying case	



Dimensions shown in inches

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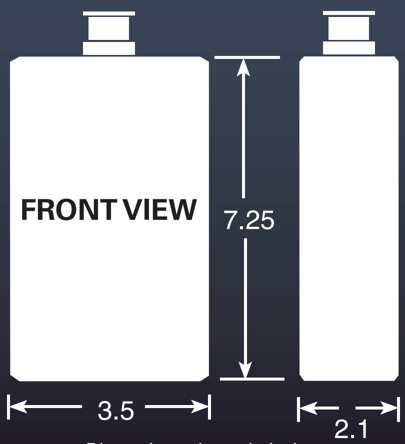
UDT INSTRUMENTS

THE STANDARD OF MEASUREMENT

Portable Photometer

SYSTEM S371R



Dimensions shown in inches

Autoranging Handheld Power Meter

The System S371 is a rugged, microprocessor-controlled handheld optometer that puts the capabilities of a benchtop model in the palm of your hand. It accepts all UDT Instruments photometric sensor heads. One meter can be programmed for 13 selectable calibration settings.

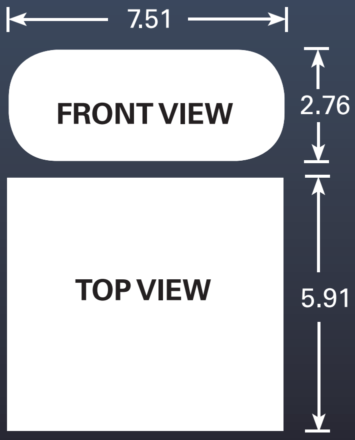
Controls for the S371 are limited to seven buttons for added convenience: select proper calibrations, choose between linear and logarithmic measurements, set ranges manually or automatically, zero the unit to compensate for ambient light, and set a reference level as a standard for comparison measurements. Values are displayed on a 16-character LCD screen.

System S371 Specifications

Controls	On/Off, Calibration/Select, Log/Linear, Zero/Logarithmic Reference, Auto/Manual, Step Range
Display	16-character, Dot Matrix LCD
Electrical Accuracy	±1% and ±2 counts
Bandwidth	3.0 Hz
Operating Temperature	0 to 45°C
Battery Life Before Recharge	Greater than 8 hours
Battery	5 AA V NiCad Rechargeable
Weight	16 ounces (454 gm)
Accessories supplied	CE Approved Power Supply, instruction manual, corrugated cardboard carrying case

Amplifier

TRAMP MODEL



Dimensions shown in inches

TRAMP Model

The UDT TRAMP is a (AC coupled) transimpedance (current-to-voltage) instrument which provides a low input impedance to accurately measure the short circuit current of phototransducers, such as silicon and germanium photodetectors, vacuum photodiodes and photomultiplier tubes.

This model provides multiple gain selection and utilizes common BNC connectors for all input and output connections for user convenience. A voltmeter, oscilloscope, chart recorder or any other voltage sensitive instrument may be used to monitor the amplifier output.

TRAMP Features

- Rugged metal case for superior 60 Hz rejection
- Computer interface
- Over 10 hrs. of battery life per charge
- LED display of gain range, overload, and low battery
- Low noise ≤5m V rms.

TRAMP Specifications

Gain	10^3 - 10^{10}
Current Range	10^{-2} - 10^{-13}
Bandwidth	
10^3	160 kHz
10^4	45 kHz
10^5	12 kHz
10^6	12 kHz
10^7	550 Hz
10^8	550 Hz
10^9	5 Hz
10^{10}	5 Hz
Noise (MV RMS)	0.5
Overall Accuracy	±2%
Offset Drift vs. Temperature	50 μV/°C
Input Impedance	0.001 ohms
Output Impedance	1 ohm
Output Voltage	±5V
Battery Life	Greater than10 hours
Type	10 AA NiCad
Accessories supplied	CE Approved Power Supply, instruction manual, corrugated cardboard carrying case

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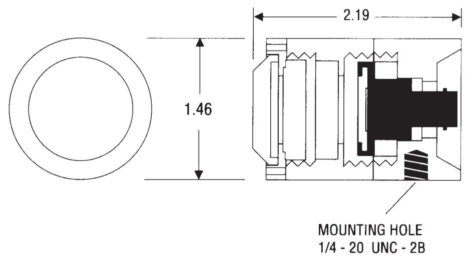
Photometric Sensors

ILLUMANANCE MEASUREMENT HEADS

Each of these sensor heads is provided with a photometric filter and cosine diffuser. The Model 211 is UDT Instruments' "universal" photometric head, as it adapts for use with most accessories. The Model 263 is a scaled-down version of the 211 suited for field measurements. And for applications with limited mechanical clearance, we offer the low-profile Model 268P.

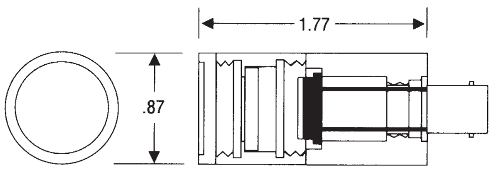
MODEL 211



Illuminance Sensor Head

Calibrations	lux, footcandles
Photometric filter accuracy	≤ 1% total area error
CIE Vl function	$F_1 l \leq 3\%$
Sensor active area	$1\ cm^2$
Measurement range	10^{-3} to 10^{5} lux 10^{-4} to 10^{4} footcandles
Compatible accessories	Models 116, 124, 114, 1153, 1120, 2525, 105, 106, & 107

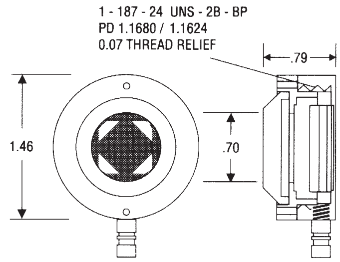
MODEL 263



Illuminance Sensor Head

Calibrations	lux, footcandles
Photometric filter accuracy	≤ 1% total area error
CIE Vl function	$F_1 l \leq 3\%$
Sensor active area	$0.34\ cm^2$
Measurement range	10^{-2} to 10^{6} lux 10^{-3} to 10^{5} footcandles

MODEL 268P



Low-profile Illuminance Sensor Head

Calibrations	lux, footcandles
Photometric filter accuracy	≤ 1% total area error
CIE Vl function	$F_1 l \leq 3\%$
Sensor active area	$1\ cm^2$
Measurement range	10^{-3} to 10^{5} lux 10^{-4} to 10^{4} footcandles

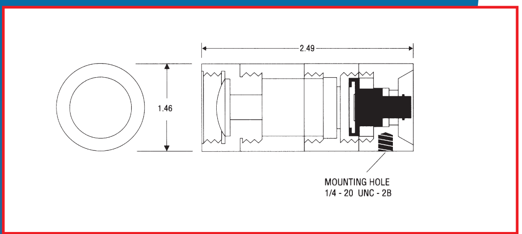
UDT INSTRUMENTS

THE STANDARD OF MEASUREMENT

Photometric Sensors

LUMINANCE MEASUREMENT HEADS AND ACCESSORIES

MODEL 2153

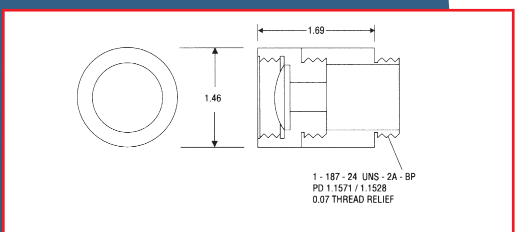


Brightness Sensor

This luminance head is analogous to the Model 211, except that a lens attaches to the photometric filter in place of the cosine diffuser. In this way, the field-of-view of the sensor is fixed at 15° for measurements of diffuse surfaces, or uniform light sources such as display panels or LCDs. The 2153 is designed for measurement areas greater than 19.05mm.

Calibrations	footlamberts, cd/m^2, nits
Photometric filter accuracy	≤ 1% total area error
CIE Vλ function	$F_1' \leq 3\%$
Sensor active area	1 cm^2
Measurement range	10^{-3} to 10^5 fL or cd/m^2

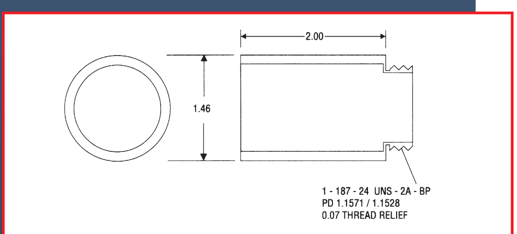
MODEL 1153



Lumilens

When substituted for the cosine diffuser of the Model 211, the Model 1153 mimics the look and specifications of the 2153 above. It is intended for users who make illuminance and luminance measurements. It may be calibrated in footlamberts or cd/m^2.

MODEL 114

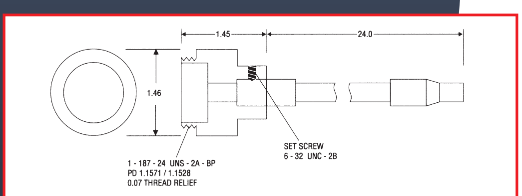


Steradian Shade

When used with the Model 211 head, the Model 114 forms a 0.155-steradian field-of-view. It is calibrated in footlamberts or cd/m^2.

Measurement range	10^{-3} to 10^5 cd/m^2
	10^{-4} to 10^4 fL

MODEL 116



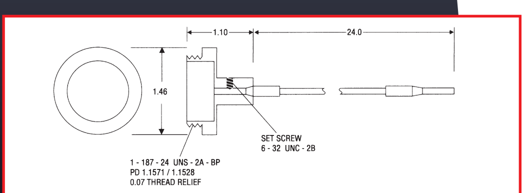
Luminance Probes

For luminance measurements in difficult-to-reach places, such as in photocopiers or photolithography systems, UDT Instruments offers two luminance probes. Both are fiberoptic bundles, two feet long, which affix to the Model 211 sensor head. They may be calibrated in footlamberts or cd/m^2. The Model 116 provides a 6.35-mm entrance aperture, while the Model 124's is 1.50 mm.

Measurement range

Model 116	10^{-2} to 10^6 cd/m^2
	10^{-3} to 10^5 fL
Model 124	10^{-1} to 10^7 cd/m^2
	10^{-2} to 10^6 fL

MODEL 124



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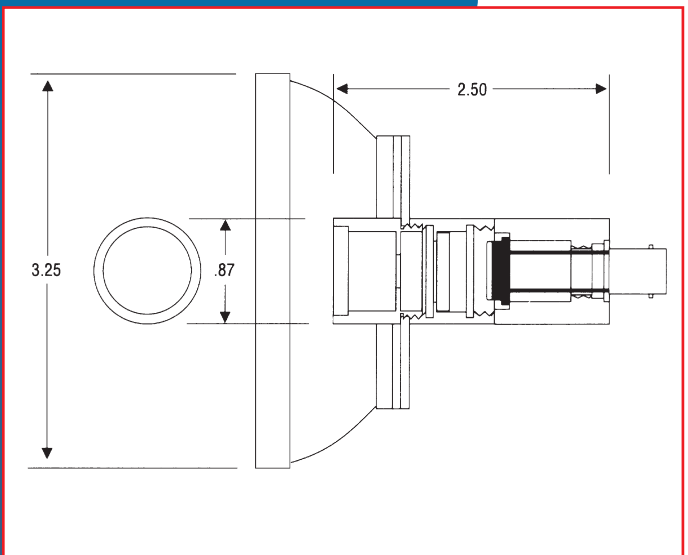
INSTRUMENTS

THE STANDARD OF MEASUREMENT

Photometric Sensors

LUMINANCE MEASUREMENT HEADS

MODEL 265

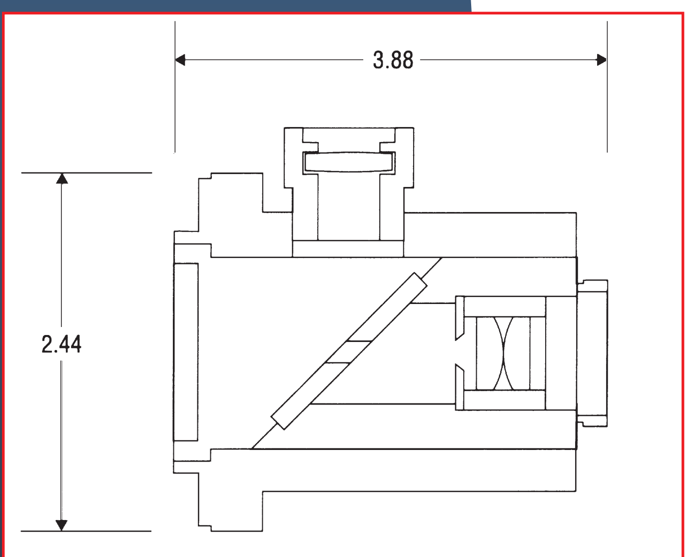


CRT Brightness Sensor

This luminance head was specifically designed for measuring CRTs. Its integral lens provides a fixed field-of-view of 13°; and a soft rubber light shade eliminates errors due to ambient light, and keeps the CRT from being scratched during measurements. The 265 is designed for measurement areas greater than 19.05mm.

Calibrations	footlamberts, cd/m^2, nits
Photometric filter accuracy	≤ 1% total area error
CIE VI function	$F_1 I \leq 3\%$
Measurement range	10^{-3} to 10^5 fL or cd/m^2

MODEL 1120



Reflex Viewing Module

Since the Model 1120 provides a direct view of the measurement field, it is ideal for CRT measurements of a single pixel, small pixel cluster, or narrow scan line. But it also enables users to measure distant objects, small light sources, or to survey the distribution of light across luminous surfaces.

This accessory operates like a camera viewing system, since it splits the measurement and viewing fields. When attached to the front of the 1120, a camera lens or microscope objective focuses an object at the center of the internal 45° mirror. The user sees the object as an upright image in the eyepiece. A small hole in the center of the mirror allows a portion of the image to pass through. Then, it is imaged by a relay lens onto the 211 sensor. To the user, the hole appears as a black spot on the object, corresponding to the actual area measured.

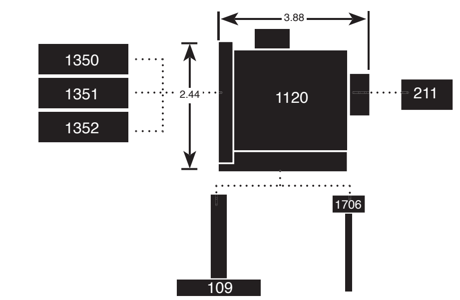
The Model 1120's field-of-view is established by the focal length of the lens affixed to it. Adapters are available to accept camera lenses or microscope objectives, converting the 1120 into a microphotometer or a telephotometer. Since UDT offers a variety of lens accessories, a system can be constructed to fit most any working-distance versus measurement-field-size requirement.

To ensure accuracy, the Model 1120 must be calibrated with each lens/aperture with which it is used. These calibrations are expressed in footlamberts or cd/m^2.

THE STANDARD OF MEASUREMENT

Photometric Sensors

LUMINANCE MEASUREMENT HEADS



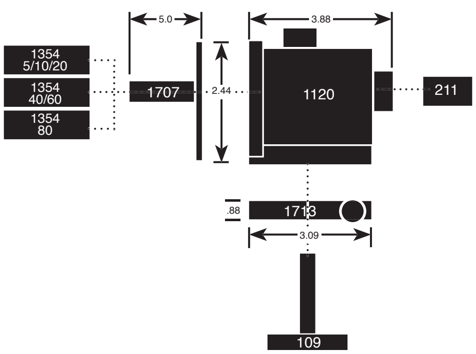
Model 1120 Reflex Viewing Module in Telephotometer Configuration

Telephotometer Configuration List

1120	Reflex viewing module
211	Photometric sensor head
1350	Lens, 50 mm
1351	Lens, 55 mm Macro
1352	Lens, 135 mm
1706	Tabletop Tripod
109	Heavy-duty lab stand

Telephotometer Lens Performance Specifications

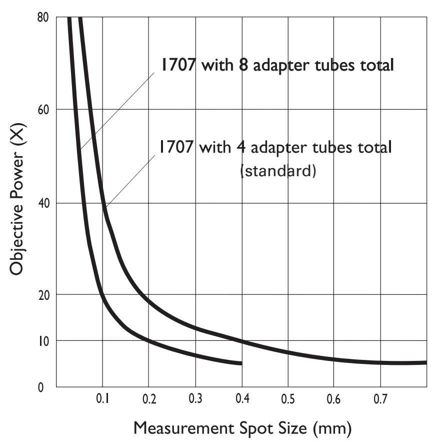
Model #	focal length	f/#	minimum focal distance(m)	internal limiting measurement field-of-view	aperture size (mm)	typical sensitivity (A/fl)
1350	50 mm	f/1.8	0.4	3.3 °	4.0	10^{-10}
1351	55 mm Macro	f/2.8+	0.2 for 1:1 conjugates	3.3 °	1.6	1.8×10^{-10}
1352	135 mm	f/2.8	2.1	1.3 °	4.0	1.2×10^{-10}



Model 1120 Reflex Viewing Module in Microphotometer Configuration

Microphotometer Configuration List

1120	Reflex viewing module
211	Photometric sensor head
1713	Rack and pinion focus mount
1707	Micro-adapter tube (includes 4 1-inch adapter tubes)
1354-5/10/20	5x, 10x, or 20x microscope objectives
1354-40/60	40x or 60x microscope objectives
109	Heavy-duty lab stand



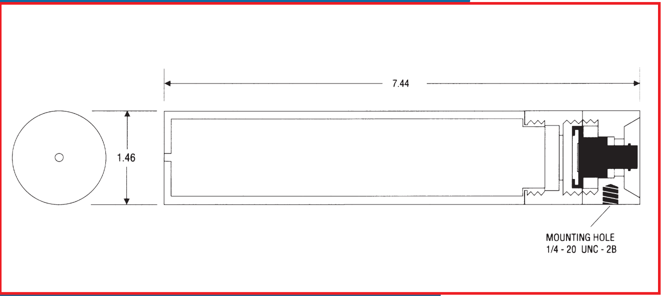
Microphotometer Lens Performance Specifications

Microscope Objective Lens					Measurement Spot Size			
Model #	**Power**	**focal length**	**NA**	**working distance**	**1707 with 4 adapter tubes**	**typical sensitivity (A/fl)**	**1707 with 8 adapter tubes**	**typical sensitivity (A/fl)**
1354-1	1x	1.36mm			2.60mm		1.30mm	
1354-5	5x	30mm	10	20mm	0.8mm	9.8×10^{-12}	0.4mm	3.7×10^{-12}
1354-10	10x	16mm	3	6mm	0.4mm	8.7×10^{-12}	0.2mm	3.4×10^{-12}
1354-20	20x	9mm	2	3.2mm	0.25mm	6.0×10^{-12}	0.1mm	2.5×10^{-12}
1354-40	40x	5mm	1.5	0.3mm	0.1mm	3.7×10^{-12}	0.06mm	1.6×10^{-12}
1354-60	60x	3mm	1.2	< 0.3mm	0.07mm	2.3×10^{-12}	0.04mm	9.8×10^{-12}

Photmetric Sensors

LED AND POINT-SOURCE MEASUREMENT HEADS

MODEL 224

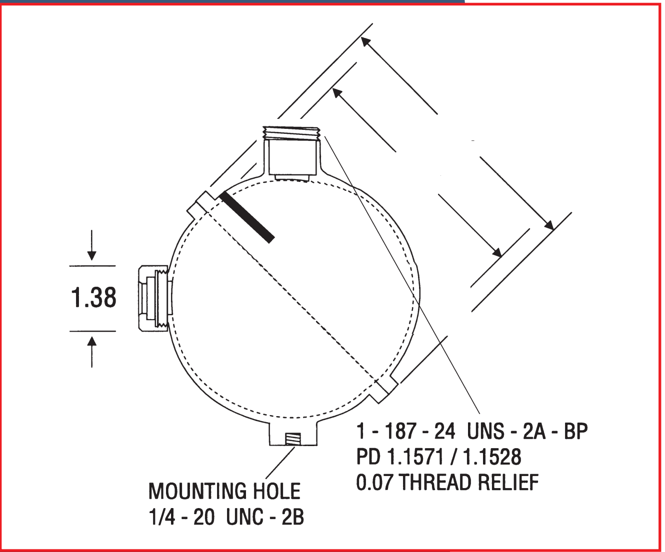


LED Measurement Head

This sensor head makes use of a special fixture to measure lensed LEDs. This attachment fixes the distance and angle between the LED and the detector, so that measurement accuracy and repeatability are ensured.

Calibrations	candela @ 565, 585, & 665 nm typical (other wavelengths available)
Photometric filter accuracy	≤ 1% total area error
CIE VI function	F1[1] ≤ 3%
Measurement range	10^{-5} to 10^{3} cd @ 565 nm 10^{-5} to 10^{3} cd @ 585 nm 10^{-6} to 10^{2} cd @ 665 nm

MODEL 2525



Integrating Sphere

A six-inch integrating sphere with an attenuation of 600:1, the Model 2525 is used with the Model 211 sensor head to determine the luminous flux of LEDs.

The sphere has an internal baffle which makes it ideal for diverging light sources. The 2525 includes an input aperture plate with a 5 mm port, and a blank adapter which can be drilled for other aperture sizes. Because an LED can be positioned right at the input aperture, 100% of the flux is collected.

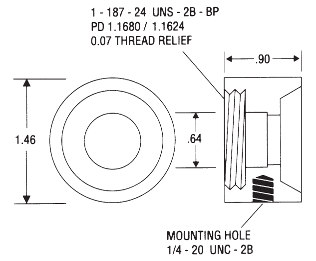
Calibrations	lumens @ specified wavelength between 400 and 700 nm
Photometric filter accuracy	≤ 1% total area error
CIE VI function	F1[1] ≤ 3%
Measurement range	10^{-6} to 10^{2} lumens @ 400nm 10^{-6} to 10^{2} lumens @ 550nm 10^{-6} to 10^{2} lumens @ 700nm

Accessories

HOUSING, STANDS AND ADAPTERS

MODEL 101-1

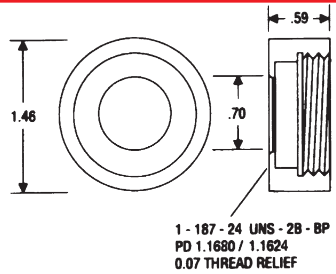
Universal Sensor Housing



This Universal Sensor Housing holds a standard 1-cm^2 BNC detector package. It is part of sensor head models 211, 2153, and 224. The male threads connect directly to UDT Instruments' filters, attenuators, and integrating spheres.

MODEL 102

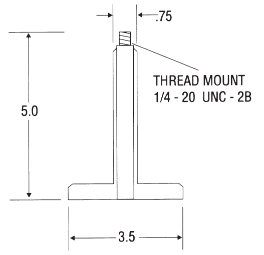
Filter Holder



The model 102 Filter Holder holds any 25-mm-diameter filter. It is female-threaded on one side for connection to the Model 211 sensor head.

MODEL 103

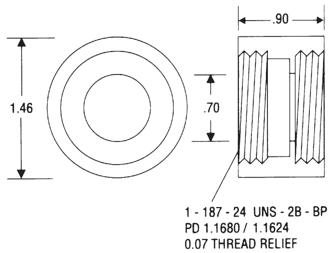
Standard Lab Stand



This lab stand has a 1/4-20 threaded post for holding the Models 211, 2153, and 224.

MODEL 104

Filter Holder and Coupler

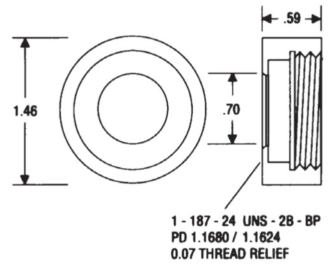


Designed to hold standard 25-mm-diameter filters, the Model 104 connects to standard threads of the Model 211 sensor head. In contrast to the Model 102, both sides of the Model 104 are threaded. As such, it may be attached to other accessories.

Accessories

HOUSING, STANDS AND ADAPTERS

MODEL 105, 106, OR 107

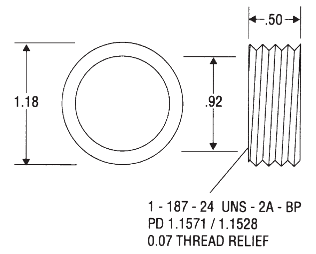


ND Filters

The filters extend the illuminance measurement range of the 211.

Model 105	10:1	Attenuation
Model 106	100:1	Attenuation
Model 107	1000:1	Attenuation

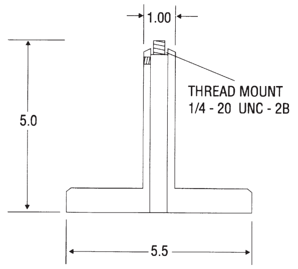
MODEL 108



Male Coupler

The model 108 male coupler is designed to connect two UDT Instruments accessories when both are female threaded.

MODEL 109



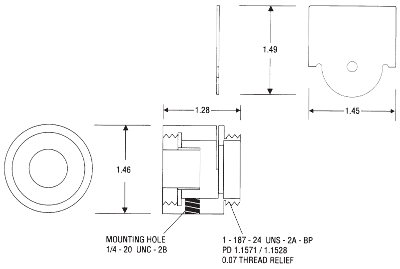
Heavy-Duty Lab Stand

This lab stand features a 1/4-20 thread mount post and is compatible with the Models 211, 2153, and 224. Its extra-heavy base makes it especially useful with the Model 1120 reflex viewing module.

1706 Tabletop Tripod

Intended for use in CRT-, microphotometry-, and telephotometry- applications, the Model 1706 provides tip, tilt, and pan capabilities for accurate pointing and alignment. It attaches to any sensor head with a 1/4-20 thread mount, and is especially intended for the Model 1120.

MODEL 110



Sensor Holder and Aperture Set

This accessory holds UDT's standard 1-cm^2 silicon photosensors. It is provided with five interchangeable apertures of 5, 6, 7, 8, and 9 mm.

Accessories

COMPUTER-CONTROLLED PHOTOMETRIC MEASUREMENTS

It's easy for you to take advantage of the IEEE-488 interface on our Model S370 and S380 photometers, because National Instruments offers LabWindows® drivers for these instruments. These drivers enable you to write computer-control programs, and analyze and display data in a Windows-like environment.

To help get you up and running with the drivers, we offer a fully- operational application software model that works with all of our IEEE-488 photometers. This software provides complete control in a clear, graphic format that simulates each instrumentÍs front panel. The software - SFW370 and SFW380 - is available in DOS format.

If you would like to further increase the software capabilities of our power meters, UDT offers a free DOS version of the LabWindows Driver. If you desire a different LabWindows Driver (such as CVI), it is available from National Instruments. With LabWindows extensive analysis library, a wide variety of array manipulation, complex arithmetic, and statistical functions are available for customizing your application. Or you can synchronize measurements with other computer-controlled measurements you make, and so perform fully automated experiments.

Driver Requirements:

- IBM PC AT, EISA, PS/2 or compatible computer with at least 2M memory (4M recommended); 10M free hard disk space
- 80286 processor or better
- EGA, VGA, Super VGA, or Hercules graphics adapter
- National Instruments GPIB-II/IIA
- LabWindows®
- UDT's Instrument Drivers (SFW370 or SFW380)
- Working knowledge of BASIC or C

Application Model Requirements:

- IBM PC AT, EISA, PS/2 or compatible computer with at least 640K of memory.
- 80286 processor or better
- EGA, VGA, Super VGA, or Hercules graphics adapter
- National Instruments GPIB-II/IIA

LabWindows® is a registered trademark of National Instruments.

Labview is not available for the above instrumentation. For assistance with National Instruments products, please contact the following:

National Instruments Sales	512 794 0100
National Instruments Technical Support	512 795 8248

UDT INSTRUMENTS

THE STANDARD OF MEASUREMENT

Discover the Power of Light

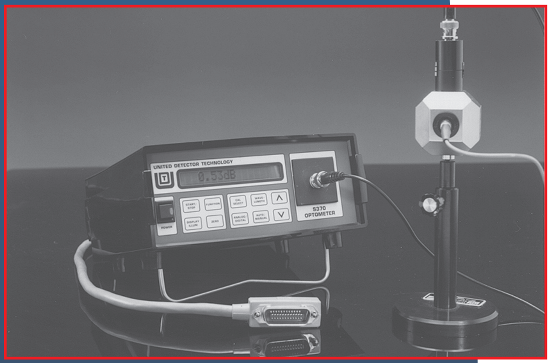
UDT Instruments provides a detailed guide for four other light-measurement product categories. Each guide contains sections on theory, applications, and on specifying an appropriate instrument or system. To request any of these guides, just contact UDT Instruments.

Position Sensing Instruments

These instruments incorporate advanced detectors that monitor the position of a light spot on their surface to within 0.0001 inches. Through the use of a unique optical accessories and electronics, the systems may be used for a variety of geometric measurements.

Applications

❏ Autocollimators ❏ Optical system alignment ❏ Straightness measurements, ❏ Movement and vibration measurements



Radiometers

UDT Instruments offer many optical accessories with our radiometers, for monitoring extremely powerful sources, or ones too dim to be detected by the eye. Single-and multi-channel instruments are available.

Applications

❏ Lasers ❏ Lamp systems ❏ Infrared emitting diodes (IREDs)

Fiber Optics

Measurements for fiberoptic applications can be made in either decibels or watts with our instruments. Both field-portable and laboratory versions are available.

Applications

Optical fiber and cable loss ❏ Connector and coupler attenuation
❏ Losses due to fiber breaks or splices

Colorimeters

UDT offers the first handheld tri-stimulus colorimeter to provide lab-grade accuracy and precision at an affordable price.

Applications

❏ Assists CRT manufacturers with production line quality control
❏ Incoming inspection of CRT's for TV and computer manufacturers
❏ Allows technicians in the broadcast industry to measure and.calibrate video walls for color accuracy, uniformity of brightness, and white balance
❏ Advertisers, computer animators, desktop publishers or anyone who requires absolute color accuracy of their monitors or televisions will find the SLS 9400 an invaluable tool

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