Linear Moving-Detector Photometer:
A New Design Concept

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Introduction

A photometer is used to measure the luminous flux and intensity of luminaires. Traditionally, the industry standard is to have the luminaire modeled as a point source[1,2], and therefore photometers are typically designed to comply with the so-called "five-time rule[3]". The result is that photometry is performed at a distance of at least five times greater distance than the maximum projected dimension of the luminaire[4].

There are several basic types of photometers that are currently used in the lighting profession. The first is the Moving-detector Photometer[1,5] where luminaire is located in the center of the photometer and the photo-detector moves around the test-luminaire at a fixed distance while collecting luminous intensity readings. The second is a Fixed Detector Photometer[6] . This piece of equipment is similar to the moving-detector photometer except that multiple photo-detectors are used with a single photo-detector installed at each vertical measurement angle of the photometric system. Finally, there is the Rotating Mirror Photometer[1,7] where, like the moving-detector photometer, a mirror travels around a test-luminaire and reflects the light to a single fixed photo-detector and records the data. The Rotating Mirror Photometer is the most common of the photometers used to measure the luminaire intensity distribution.

While these photometers offer great flexibility and speed in acquiring intensity data in the field around the luminaire, the fact that they use a predefined detector-distance with a fixed incident-angle has demonstrated to be a constraint for the real world applications. Some types of luminaires do not lend themselves to accurate photometry by the above-mentioned photometers. The photometric measurements of luminaire such as wall-washers, cove-lights, and the task-lights using these types of photometers are limited and the accuracy of measurement is sacrificed[8] because these photometers were not designed specifically for measurements of these types of luminaire applications. Recently, several other photometric techniques have been introduced such as Near-Field photometry[9,10,11], Luminance Field photometry[12], and Luminance Scans method[13]. While these approaches have great advantages over the traditional methods, there are still certain drawbacks such as ingrained assumptions and interpretations. Also there are some hardware and computer software limitations.

The purpose of this paper is to present a new design concept of a photometric acquisition system called a linear moving-detector photometer, and to describe its applications.

The Concept of the Linear Moving-Detector Photometer

The linear moving-detector photometer takes lighting measurements at various distances and at different incident-angles relative to the luminaire in three-dimensional space by using a computer controlled moving-detector system. The photo-detector travels a wide range of distances from a few inches to many feet in a three-dimensional field surrounding the luminaire. It then acquires photometry at the desired locations and orientations. In other words, the system performs the photometry at a series of actual application distances and incident-angles, which we refer to as near-field or application distance photometry[9]. For a typical application, thousands of measurement data can be collected and stored in the computer database. This allows luminous flux and intensity to be reported in both spherical and Cartesian coordinate systems as are required by the specific lighting applications. Actual illuminance distribution on any surfaces in this photometric field can be generated.

While linear moving-detector photometer system was not developed to replace existing photometry equipment, this automated equipment will supplement and enhance current photometry methodology. It accurately measures and reports the performance of the luminaires for the real lighting applications without applying the assumption of the "five-time rule". This photometer integrates measuring hardware and computer software into one lighting measurement system.

Description of the Mechanics of the Linear Moving-Detector Photometer

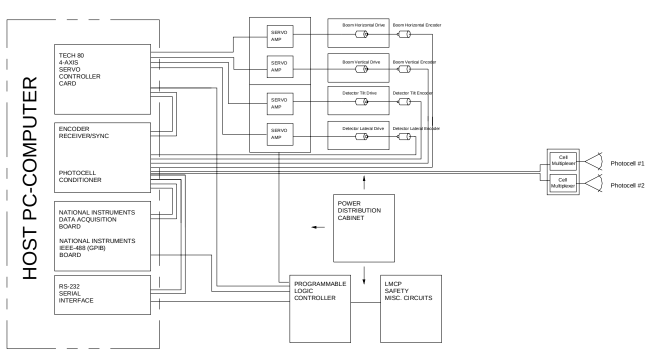
The ultimate goal of linear moving-detector photometer system is to accurately and effectively take the measurements of a light source at any angle and at any location just as the luminaire is used in real world application. To accomplish this task, the photometer system is developed to be an integration of a robot-boom, a photo-detectors/radiometer, and computer software. The system is made up of the following mechanisms:

- A luminaire mounting structure, allowing the light source to be mounted in the center of photometric system within geometry coordinate system, and rotated round the vertical-axis.
- Two photo-detectors, which are mounted at the end of rigid robot-boom while rotating around two-axes, allowing every possible incident angle relative to the light source. A photo-detector /radiometer system, giving high dynamic range readings with excellent linearity response and cosine correction.
- A robot-boom system, carrying the photo-detectors traveling horizontally and vertically across the photometric space. Built-in position and limit sensors with error and fault detection for automatic control and operation.
- Combined state-of-the-art motors and electronics, using off-the-shelf mechanical parts and electronic components including motors, precision bearings and timing chains, extrusions, controllers, IC board, and other electronic components.
- Fully automated photometer system with a personal computer control for photometric data acquisition. Computer software providing with interactive and user-friendly virtual instrument for large database capability.

Integration of Four Processes to Comprise the Linear Moving-detector Photometer

Figure 1 illustrates four major processes that comprise the linear moving-detector photometer system. The first portion is a four-axis motor controller that operates four individual motors. Two motors manage robot-boom system and two others are responsible for the rotation of the photo-detectors. The second portion manages the interface of photo-detector/multiplexer, whereby two photo-detectors are controlled by the computer interface and obtain the measurement data separately. The third portion is the data acquisition system, where the measurement data are collected, processed, and saved in the computer database. The fourth portion is the communication interface of programmable logic controller, an interconnection bridge between the light source and the linear moving-detector photometer system. This photometer is an integration of a computer-controlled robot-boom, photo-detectors/radiometer, and computer software system.

Figure 1



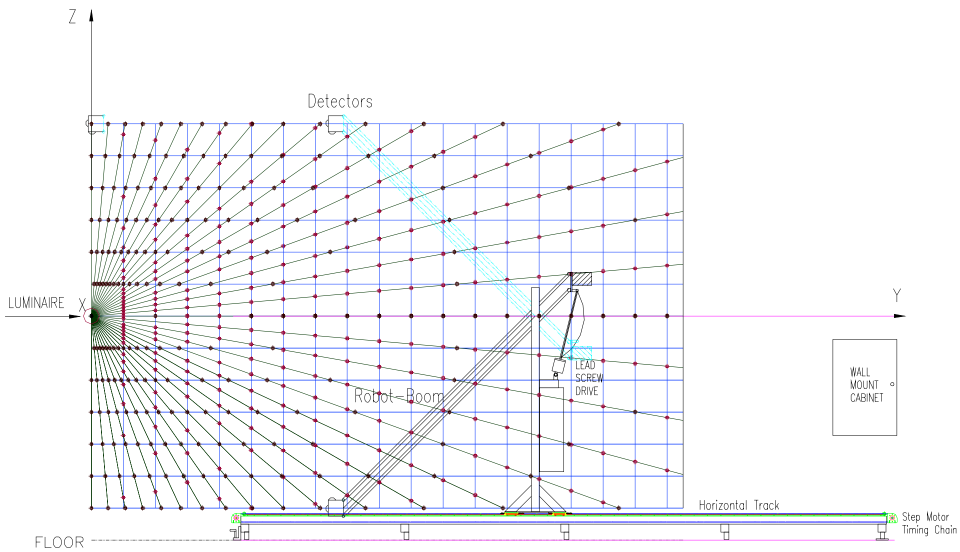
Explanation of the Computer-Controlled Robot-boom Structure

The linear moving-detector photometer is actually a robot system that integrates the photo-detectors with a robot-boom structure, which travels along two axes (Y-axis and Z-axis) in the photometric space. A picture of this photometer system is shown in Figure 2.

Figure 2

Figure 3 shows the section view of geometry coordinate system of the linear moving-detector photometer where the traveling range of photo-detector/robot-boom is illustrated. During the photometric measurement process, the maximum travel distance between the photo-detector and luminaire is set to be 3.05m (10ft) for both horizontal-axis (Y) and vertical-axis (Z).

Figure 3



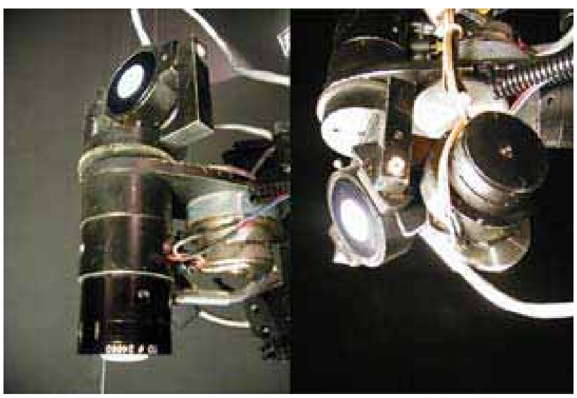
In order to obtain the precise linear movement and accurate measurement positions, the standard T-slotted aluminum extrusions and high-cycle linear bearings are used to construct the linear-motion of robot-boom system, which is lightweight, yet highly rigid structure. To ensure precise steps of linear movement, two hybrid-enhanced stepping motors are used to drive the vertical (Z-axis) and horizontal (Y-axis) movement respectively. With dual channel incremental optical rotary encoder, the motors provide extremely accurate linear-motion. These enhanced stepping motors have a higher torque output than the standard stepping motors and they are capable of withstanding high cycles with sudden acceleration/deceleration. To allow for precise horizontal motion, a 0.5 circle pitch timing chain is utilized along the horizontal track (Y-axis). In addition, a precision ball bearing screw assembly is used for the vertical movement of robot-boom structure. This movement, along with the stepping motor, allows a very smooth vertical rolling-motion with precise lead accuracy and no backlash.

One of the challenges to achieve precise linear-motion is having the ability to obtain repeatable positions while the robot-boom moves along the Y-axis and Z-axis. It is possible that the quality precision of materials and the tolerance of mechanical parts of this large-scale equipment can result in error of the linear-motion. To detect and correct possible position errors of the linear-motion, an array of sensors is used along the frame of robot-boom structure. Each time a laser beam collides with the individual sensor during the movement of robot-boom structure, the system will recalibrate the position index of linear-motion and correct the position errors. Combination of this laser/sensor detecting device with the optical encoder technology gives us confidence that precise positions can be accomplished within the system, throughout the entire range of linear movement.

Description of the Photo-detector/Radiometer

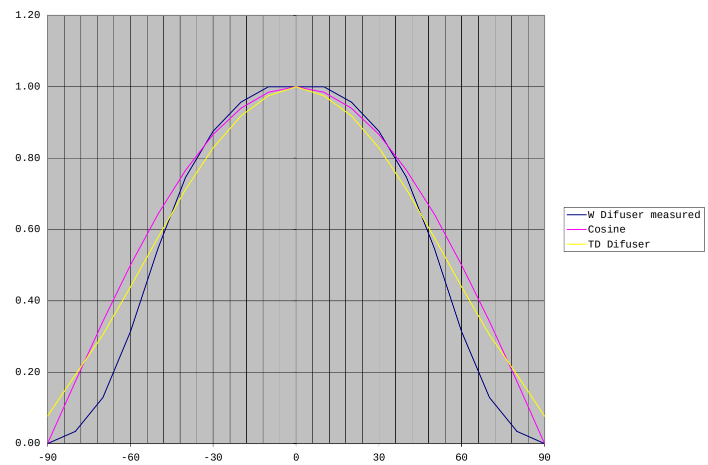
Due to the fact that multi-directional light measurements are required, two photo-detectors are selected and installed at the end of the robot-boom. One is facing horizontally downward/upward to perform the ceiling/floor light measurements, and the other is orientated to face any angle with the ability to rotate180° around both X-axis and Z-axis (Figure 4). Two stepper motors are used to drive this angular movement of the photo-detector. The combination of precise spur gears and gear-train reduction devices results in the ability to obtain a step-angle accuracy of 0.1°. When incorporated with two axes (Y-axis and Z-axis) of the robot-boom structure, this system enables the photo-detector to receive directional light in any position and any incident-angle within the field of spherical coordinate system.

Figure 4



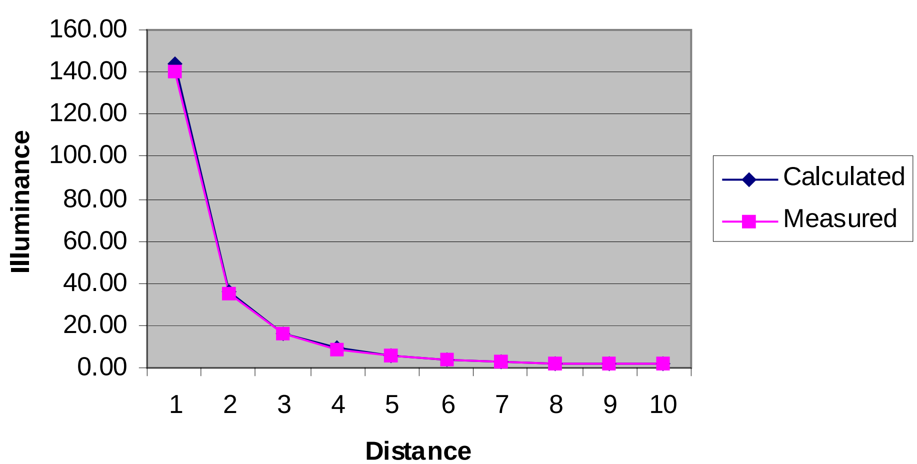
For light signal acquisition and processing, a research radiometer is used. With microprocessor controlled auto-range technology, light measurement can be obtained with the dynamic output range from 5.0×10^{-4} to 1.0×10^{6} lux (5×10^{-5} to 5×10^{5} fc). The photo-detector employs silicon photodiode with excellent color correction. Using composite filter design, Y filter matches the CIE V(λ) photopic response curve to be better than 1% at all wavelengths. The measurement results are traceable to the standard lamp defined by the National Institute of Standards and Technology, NIST. A quartz diffuser (W-diffuser) was originally used for cosine correction but was found to produce relatively large errors at incident angles greater than 60°. Since the cosine property is critical for the measurements of photometer, especially at large incident angles, a better correction diffuser was required. After conducting a series of researches, it was decided to use a modified Teflon diffuser (TD- diffuser), which provides a good cosine response and gives a highly linear response at all visible wavelengths. Figure 5 shows the measurement comparison of the spatial response of various incident-angles between standard cosine curve, modified TD- diffuser, and quartz W-diffuser.

Figure 5



The linearity response of the photo-detector/radiometer was also examined by performing a series of measurements. Figure 6 illustrates the comparison of the illuminance measurements and calculated values at a series of distances. The results show that the photo-detector provides excellent correlation relative to the curve of inverse square law. We found that having auto-range technology, the photo-detector/radiometer system gives highly linearity response of light measurements in a wide range of test distances. Note that the differences from the curve of inverse square law and the results of actual measurements are less than 1% at all the test distances. This excellent linearity response is critical for the photometry of the photometer system since the real measurements will be taken at a dynamic range of application distances.

Figure 6

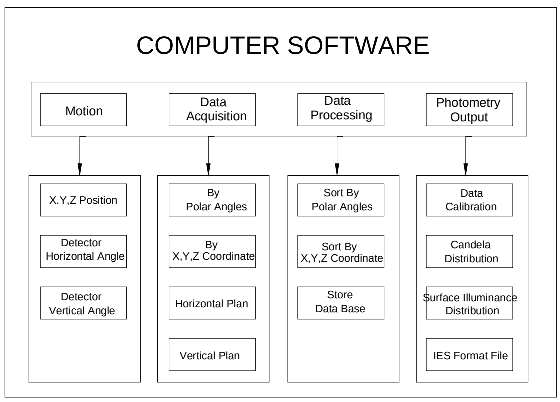


The standard interface enhances the communication between the photo-detector/radiometer and computer. With the multiple computer interfaces (RS232C and TTL) and an analog recorder output (0-1 volt), the photo-detector/radiometer provides a sophisticated communication interface for data acquisition and processing. When coupled with the photo-detector/Multiplexer, two photo-detectors are controlled, selected, and read remotely by computer.

Computer Software Structure

The overall computer software structure is illustrated in Figure 7. The computer program is written in Visual Basic and is divided into four major groups: motion control, measurement and acquisition, data processing, and photometry output. The computer software is a graphic interface designed for automatic instrumentation.

Figure 7



<u>Photometry of the Linear Moving-Detector Photometer and Its Applications</u>

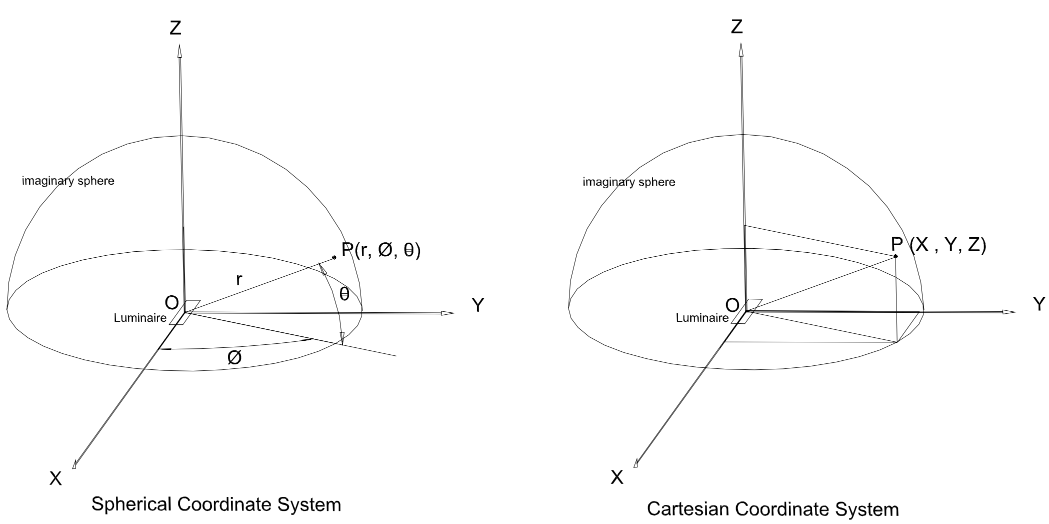
To ensure the accuracy of photometry and repeatability of measurements from using linear moving-detector photometer system, three sets of repeat-tests have been performed over a horizontal ceiling-plane with an indirect luminaire suspended 61cm (24”) away from the test surface. For each set of repeat-test, fifteen measurements are taken at a 5°-angle increment starting direct above the luminaire (0°) to the higher incident-angle (70°) across the ceiling-plane. Table 1 illustrates the results of three sets of repeat measurements. As we can see, the illuminance measurements of the same points on the ceiling-plane are extremely consistent for all three sets of repeat measurements. These results provide us with confidence that the measurements of the photometer system are repeatable and photometric results are reliable, as well as accurate for the real-world lighting applications.

Table 1

Angles	Test #1	Test #2	Test #3
0.0	228.0	227.0	227.0
5.0	226.0	225.0	225.0
10.0	221.0	221.0	221.0
15.0	211.0	211.0	211.0
20.0	195.6	196.4	195.3
25.0	179.1	180.2	178.9
30.0	161.2	160.9	161.0
35.0	140.1	141.3	140.1
40.0	120.3	119.8	120.0
45.0	97.9	97.8	98.0
50.0	76.7	76.6	76.7
55.0	56.4	56.3	56.4
60.0	37.4	37.4	37.5
65.0	22.5	22.5	22.5
70.0	10.8	10.7	10.8

The linear moving-detector photometer system performs and reports photometry using two coordinate systems - spherical coordinate and Cartesian coordinate systems (Figure 8). The spherical coordinate system involves the distance from the origin (O) and two angles. The position of point (P) is described as P(*r*, Ø, θ), where *r* = the distance from the origin, Ø = the lateral angle measured on the *XY*-plane from the *X*-axis in the counterclockwise direction, and θ = the vertical angle measured from the *Z*-axis. Cartesian coordinate system, however, is based on three perpendicular spatial axes designated *X*, *Y*, and *Z*. Starting from the origin (O), any point (P) can be represented by P (x, y, z), where the coordinate is the perpendicular distance from the plane formed by the other two axes. During a typical measurement process, the test-luminaire is set at the origin (O) with its photometric zero-axis coinciding with X-axis of the coordinate system. The photo-detector travels along Y-axis and the Z-axis to allocate a sequence of points, obtaining measurements across the vertical *YZ*-plane. Then the test-luminaire rotates to consequence *YZ*-planes around Z-axis, and a series of data are recorded. Photometry can be described using both of these coordinate systems, however one may be better suited than the other for specific lighting applications.

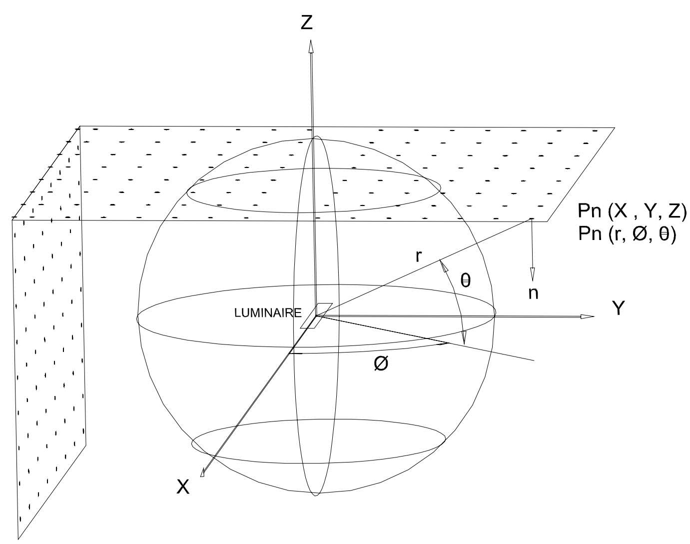
Figure 8



The spherical coordinate system is the most common coordinate system used for the traditional luminaire photometry. With a fixed test distance (r) based on "five-time rule", the measurements are performed at a series of points of different angles (Ø, θ) across the imaginary surface of the sphere. The photometry is taken commonly with a 5° vertical-angle (θ) increment for a multiple *YZ*-plane of every 22.5° lateral-angle (Ø).

Unlike the traditional photometry method, linear moving-detector photometer system performs measurements and reports the photometry at various test distances and different light incident angles, where both spherical coordinate and Cartesian coordinate systems are used for the geometry description of the photometry. Given the normal vector (ň) to any surface within the imaginary sphere, the point (P) on any plane can be represented as $P_{ň}(r, Ø, θ)$ in spherical coordinate system or $P_{ň}(x, y, z)$ in Cartesian coordinate system as shown in Figure 9. The normal vector (ň) of the surface determines the rotation angle of the photo-detector. For example, for a flat ceiling in a space (normal vector (ň) is pointing to the floor) the photo-detector will face downward during the measurement process. The same rule applies to any surface in these coordinate systems. For instance, for the measurements of a spherical surface the photo-detector is always facing toward the origin (O). It is interesting to note that the photometry on the surface of an imaginary sphere is the only special case of these coordinate systems that has been used in traditional photometry for many years.

Figure 9



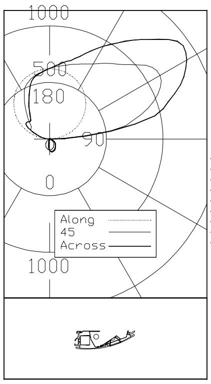
Because linear moving-detector photometer system works together with both these coordinate systems, this method of photometry is suitable for measuring lighting applications that specify uniformity and illuminance-distribution as the design criteria. This is especially correct when illuminated surfaces are close to the light source. For many lighting applications, photometrics with point-by-point luminance distribution are highly desired. This is true for wall-wash, cove-light, and task-light applications where precise lighting information is critical because of the close proximity of the luminaries to architectural surfaces. The linear moving-detector photometer system fulfills these criteria. It takes measurements at the actual locations and orientations of the specific application by moving and rotating the photo-detector to desired coordinates and orientations, and reports the photometry in either spherical or Cartesian coordinate system.

Of particular importance is the photometry of indirect luminaire. For cove-light indirect luminaire application, architectural surfaces are close to the installed luminaires. The luminance distribution on the architectural surfaces is simply the collection of actual measurements across the horizontal ceiling and vertical walls. Figure 10 shows the photometrics of a typical cove-light application generated from both traditional photometry method and linear moving-detector photometer system, where the cove-light is installed 46cm (18") from the ceiling next to the wall.

Figure 10

FAR–FIELD PHOTOMETRY
DATE: 2–5–2003
REPORT NUMBER: 123456

CATALOG NUMBER: XYZ–1–54WT5HO
LUMINAIRE: 7 1/2"W X 2 1/4"H ALUMINUM ASYMMETRIC INDIRECT/DIRECT LIGHT WITH WHITE PAINTED REFLECTOR AND SPECULAR BAFFLE
LAMP(S): FP54/835/HO RATED @ 5000 LUMENS
BALLAST: QT–1X54/120PHO
MOUNTING:
LUMEN TO CANDELA RATIO USED = 9.15
TOTAL INPUT WATTES = 58.4 AT 120 VOLTS
THE 0 DEGREE PLANE IS PARALLEL WITH THE LAMPS.



CANDELA DISTRIBUTION

	0.0	45.0	90.0	135.0	180.0	FLUX
0	98	98	98	98	98	
5	111	106	94	89	84	9
15	112	107	87	45	34	22
25	104	97	77	22	12	29
35	86	85	62	6	3	31
45	72	65	45	1	3	29
55	57	50	23	2	2	23
65	31	28	5	1	2	13
75	2	5	0	0	1	2
85	1	0	0	0	1	0
90	9	12	10	7	2	
95	321	343	24	26	22	154
105	1039	833	151	92	93	434
115	1306	1078	269	182	188	565
125	1437	1104	366	200	252	564
135	1244	931	449	275	237	464
145	1036	815	518	384	313	375
155	858	732	567	511	430	284
165	716	679	601	567	556	176
175	652	642	618	607	601	59
180	624	624	624	624	624	

ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0– 30	61	1.2	1.9
0– 40	92	1.9	2.9
0– 60	145	2.9	4.5
0– 90	161	3.2	5
90–120	1154	23.1	35.6
90–130	1718	34.4	53
90–150	2558	51.2	79
90–180	3078	61.6	95
0–180	3240	64.8	100.0

LUMINANCE DATA IN FOOTLAMBERTS

ANGLE IN DEG	AVERAGE 0–DEG	AVERAGE 45–DEG	AVERAGE 90–DEG
45	569	591	479
55	501	527	308
65	354	398	91
75	36	101	0
85	33	14	0

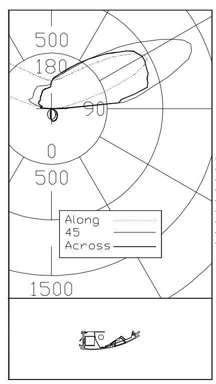
TOTAL LUMINAIRE EFFICIENCY = 64.8 %
CIE TYPE – INDIRECT

APPROVED BY:

TESTED IN ACCORDANCE WITH IES PROCEDURES, TEST DISTANCE EXCEEDS 25.0 FEET

APPLICATION DISTANCE PHOTOMETRY
DATE: 2–5–2003
REPORT NUMBER: 123456–12

CATALOG NUMBER: XYZ–1–54WT5HO
LUMINAIRE: 7 1/2"W X 2 1/4"H ALUMINUM ASYMMETRIC INDIRECT/DIRECT LIGHT WITH WHITE PAINTED REFLECTOR AND SPECULAR BAFFLE
LAMP(S): FP54/835/HO RATED @ 5000 LUMENS
BALLAST: QT–1X54/120PHO
MOUNTING:
LUMEN TO CANDELA RATIO USED = 9.15
TOTAL INPUT WATTES = 58.4 AT 120 VOLTS
THE 0 DEGREE PLANE IS PARALLEL WITH THE LAMPS.



CANDELA DISTRIBUTION

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25	104	97	77	22	12	29
35	86	85	62	6	3	31
45	72	65	45	1	3	29
55	57	50	23	2	2	23
65	31	28	5	1	2	13
75	2	5	0	0	1	2
85	1	0	0	0	1	0
90	9	12	10	7	2	
95	608	651	99	96	94	326
105	895	1076	327	157	95	544
115	932	1379	914	211	127	753
125	898	1061	852	200	126	589
135	697	739	594	220	142	382
145	528	522	424	234	158	239
155	411	390	330	226	182	143
165	331	315	279	215	185	75
175	281	272	257	215	192	23
180	243	243	243	243	243	

ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0– 30	61	1.2	1.9
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85	33	14	0

TOTAL LUMINAIRE EFFICIENCY = 64.8 %
CIE TYPE – INDIRECT

APPROVED BY:

The photometry of Figure 10 is reported in a graphic table form, which is a list of data at a 10° vertical-angle interval in the sphere of five lateral-angle planes. The graphic curves represent the luminaire intensity distribution in three lateral-angle planes (0°, 45°, and 90°). As can be seen, the luminous intensity curves from two reports of the same luminaire are very different. Since the measurements of linear moving-detector photometer system (photometry at right side of Figure 10) are performed at a series of actual points on the planes of ceiling and wall, we are certain that this system reports accurate luminous intensity distribution of the cove-light application. In contrast, the traditional photometry only offers an approximation of the point source since all the measurements are taken at a far-distance and it is impossible for the far-field measurements to accurately model the real performance of the cove-light in a close-distance application. It should be noted the luminous intensity distribution that reported from linear moving-detector photometer system is the equivalent intensity. The intensity distribution is dependent on both the measurement distances and light incident angles of application surfaces. The precise orientation and position of the photo-detector are extremely important. Using the measurements performed with the normal incident angle of photo-detector, and therefore intensity data calibrated with a cosine factor are not correct for the photometry of cove-light in this near-field application. A detailed description of the equivalent intensity is beyond the scope of this paper. For more information on the concept of the near-field photometry, please refer to reference #9.

As mentioned previously, photometry can be reported in spherical coordinates as well as in the Cartesian coordinate system. For example, it is to be expected that point-by-point illuminance distribution for wall-wash installations have the greatest benefit by using the Cartesian coordinate system.

Figure 11

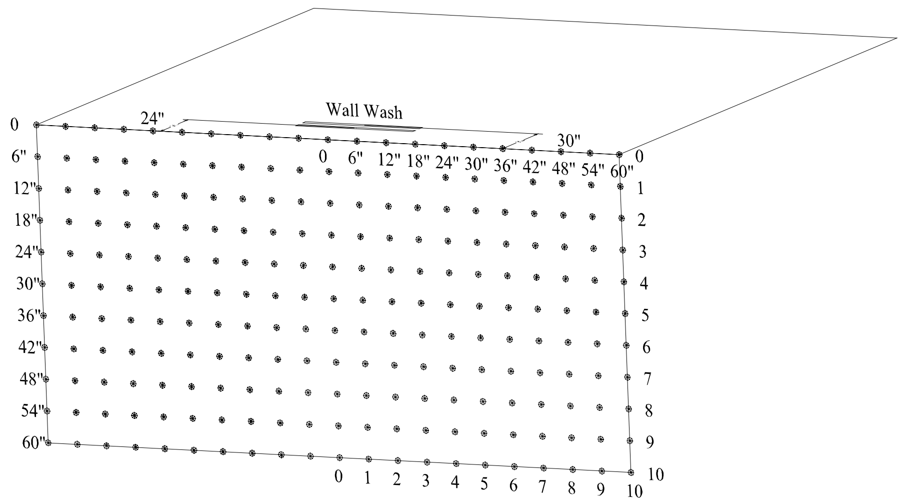

Figure 11 demonstrates the geometry relationship of a wall-wash luminaire and an architectural wall surface. In this example, a 1.2m(4ft) wall-wash luminaire is recessed in the ceiling with two typical application distances of 61cm(24") and 76cm(30") from the wall within the imaginary space. To obtain the illuminance distribution of the wall surface, linear moving-detector photometer system has performed a grid of 15.2cm(6") x 15.2cm(6") measurements. Tables 2 & 3 showing the results of illuminance distribution for both setups of the wall-wash applications. Examination of the photometry indicates that the 76cm(30") installation is a better choice since it gives a smoother illuminance distribution across the application wall. As anticipated, the photometrics use the Cartesian coordinate system providing a detailed illustration on the performance of wall-wash luminaire. This photometer system measures and reports the actual performance of the wall-wash luminaire, as it would be utilized in a real-world application. For the typical applications, a series of surface illuminance distributions is reported with five plane-data at 6" apart.

Table 2

Point-By-Pont Illuminance Distribution (61cm-24" from the wall)

Y/X	0	1	2	3	4	5	6	7	8	9	10
0	19.00	18.29	17.29	15.14	13.30	12.05	10.22	8.60	7.24	6.12	5.05
1	23.13	22.29	20.73	18.76	16.38	14.45	12.11	9.97	8.27	6.79	5.52
2	28.39	27.23	25.23	22.92	20.10	17.83	14.63	11.80	9.65	7.76	6.10
3	35.85	34.28	31.44	28.49	24.50	21.24	17.30	13.82	11.02	8.66	6.73
4	46.68	44.27	40.59	35.85	30.39	25.44	20.20	15.68	12.09	9.23	6.98
5	61.82	58.46	53.52	46.79	38.80	31.33	24.08	17.90	13.25	9.72	7.08
6	75.39	71.81	65.50	57.51	47.31	37.01	27.44	19.75	14.05	9.90	7.00
7	94.00	90.11	81.70	70.24	55.20	40.90	28.70	19.35	13.25	9.00	6.12
8	92.32	90.00	82.12	69.50	53.52	38.06	25.44	16.40	10.80	6.80	4.38
9	68.97	67.61	67.19	55.62	42.06	27.86	17.83	11.00	6.69	3.85	2.42
10	32.17	32.25	32.28	26.71	20.12	13.46	7.62	4.62	2.91	1.46	0.76

Table 3

Point-By-Pont Illuminance Distribution (76cm-30" from the wall)

Y/X	0	1	2	3	4	5	6	7	8	9	10
0	19.34	19.23	17.50	16.16	14.56	12.99	11.80	10.01	8.43	7.10	5.96
1	23.24	22.82	20.81	19.30	17.24	15.04	13.35	11.38	9.48	7.83	6.54
2	28.60	28.39	25.55	23.24	20.41	17.65	15.39	12.87	10.57	8.60	7.01
3	36.48	35.64	31.75	29.12	24.92	21.24	18.05	14.69	11.74	9.32	7.44
4	45.00	44.16	39.64	36.27	30.91	25.55	21.24	17.00	13.16	10.19	7.94
5	52.99	51.84	46.16	42.06	35.43	29.02	23.66	18.37	14.03	10.62	8.09
6	65.08	63.40	56.04	50.15	40.90	32.49	25.23	18.92	13.94	10.24	7.59
7	68.03	66.24	60.77	53.73	43.53	33.96	25.55	18.63	13.28	9.49	6.77
8	59.41	58.67	56.04	49.21	39.43	29.65	21.45	15.20	10.49	7.27	4.93
9	43.00	42.64	42.37	36.69	29.02	21.34	14.95	10.24	6.78	4.64	2.90
10	18.82	20.40	21.97	17.34	14.02	10.42	6.99	4.62	2.86	2.01	1.17

The photometry of linear moving-detector photometer system benefits other lighting applications as well. Reliable photometry is often required for task-light applications when illumination distribution is important for close task work. The photometry methodology is also appropriate for applications of tunnel lighting and roadway lighting where large surface illuminance distribution next to the light source is required. Using this photometer system, narrow-beam light sources such as spotlights and automotive headlamps can be precisely modeled and iso-candela diagrams generated at various application distances. The benefits can be extended to the applications of day-lighting where the accurate photometry of light-shelves and skylights are desirable. The linear moving-detector photometer system is also suitable for many special applications such as pipe-light and prism-light-guide luminaires. It is important to note that the photometry of a flat surface is not the only lighting application that can be benefited from this photometer system. The photometry for any type of surfaces such as sloped, stepped, or even curved surfaces can be accurately modeled by using this photometer system. Luminaire design can also benefit from this photometer system, which will aid in the optical design and help predict the striations on near-field surfaces that might be produced in the luminaire applications of prismatic lenses, specular and semi-specular reflectors.

Limitations of the Linear Moving-Detector Photometer System

Data acquisition of linear moving-detector photometer system using the radiometer/Multiplexer is relatively slow. With the current setup, a ½ second is required to obtain the next reading when switching the photo-detector from one to another. On average, two to four hours worth of measurement time are required for a typical photometry.

Due to the geometry limitations of the linear moving-detector photometer system and laboratory space, the maximum range for surface illuminance measurement is set to 3.05m(10') x 3.05m(10') over a two-dimensional plane. Fortunately, this dimension usually meets the requirement of the near-field lighting applications. As the application distances increase farther, far-field photometry becomes more appropriate for the most lighting applications.

The new design is not intended to replace current photometry equipment. The linear moving-detector photometer system can be used as stand-alone equipment to perform photometry; however it becomes more valuable when combined with traditional photometric equipment.

Conclusion

Linear moving-detector photometer is a new design concept of lighting measurement equipment that evaluates the performance of the luminaires using automatic control system, without applying the assumption of the “five-times rule”. By utilizing this photometer system, photometric measurements can be performed in the actual locations and real orientations that the luminaire is to be applied. The photometry obtained using this photometer system has been shown to be practical and accurate, and it can be performed and reported in both spherical and Cartesian coordinate systems. Many lighting installations using uniformity and illuminance-distribution as design criteria will benefit from photometry obtained using the linear moving-detector photometer system, especially those applications where the light source is close to the surface. It is conceivable that the photometry of this photometer system will be a powerful design tool for both lighting specifications and luminaire development when coupled with an advanced computer program.

The design concept of the linear moving-detector photometer system is new and can serve as an enhancement to the traditional photometry photometer. Further development should be continued to improve measurement speed, preferably with the instant data acquisition.

Acknowledgement

The development of linear moving-detector photometer is a joint venture by Peerless Lighting and LumiWork. The author would like to thank Jorge Darr for his vast contributions.

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