

Cold-Cathode Lighting and LED Lighting for Indirect Cove Applications: A Comparison

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Today's Lighting Environment

Considering the extensive publicity surrounding LEDs (light emitting diodes) as "the future of lighting", an argument could be made that some of the more traditional lamp technologies are being overlooked. Though the inertia behind the emerging technology of LEDs may continue to swell, the predictions that LEDs will eventually render all other light sources obsolete may be overstated.

While LED lighting is an exciting, rapidly-evolving technology, it may not be the best choice for all applications. A wide variety of mature and constantly-improving lamp technologies currently exist which may be better alternatives from a number of stand-points: light quality and quantity, energy consumption, reliability, simplicity, and cost. These are critical issues to consider when choosing the best application for indirect cove lighting.

Effective Cove Lighting

Selecting the proper light source for an indirect light cove can prove challenging. Many factors ultimately dictate what product is best suited for a particular application. Since cove lighting is almost always considered to be decorative, the foremost consideration should be the aesthetic quality of the lighting effect. If the intention of the cove lighting is to provide or contribute to illumination levels within the space, the requirements can shift dramatically. Generally, the designer must consider the following criteria:

- 1) Absolute uniformity of the lighting effect (no shadows, no striations, no bright or dark spots)
- 2) Color consistency from one lamp to the next
- 3) Color degradation or shift over lamp's operational life
- 4) Quantity of light produced (initial lumens and lumens over the life of the lamp)
- 5) How much light is produced per unit of energy consumed, or *efficacy* (lumens per watt)
- 6) Lamp life
- 7) Dimming performance
- 8) Future availability and cost of replacement lamps or components
- 9) Initial cost
- 10) Long-term cost

Cold Cathode Fluorescent Lighting

Background

Much like the fluorescent lamp, which is technically referred to as a *hot-cathode* lamp, the operation of a cold-cathode lamp is well-established technology. Lamp life can exceed 100,000 hours, and the unique design of the cold-cathode lamp allows for seamless lighting effects as lamp ends are fully illuminated. When installed end-to-end, an array of cold cathode lamps appear as one continuous, uninterrupted lamp, making it an ideal light source for shadowless indirect cove illumination. Cold cathode lamps are often made in curved and angled shapes allowing them to follow a variety of architectural details.

Some designers associate cold-cathode lighting with field-assembled component-based systems that have changed little since the 1940's. Bulky fixture profiles, large porcelain lampholders and heavy, inefficient, remotely-installed magnetic power supplies are the hallmarks of traditional cold-cathode lighting systems.

Cold Cathode Advancements

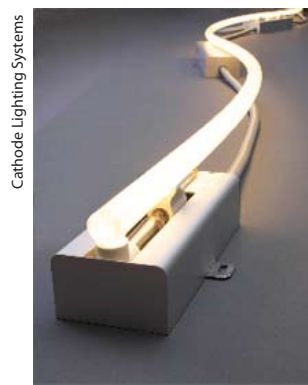
While some manufacturers still produce these antiquated systems, the advent of newer technology has brought remarkable change to this niche industry. Cold cathode lamps may now be powered by discrete, lightweight electric power supplies, allowing for a variety of new fixture types. Because these power supplies are small and silent, they can be integral to the fixture. Remote installation of noisy magnetic ballasts, transformers, and mandatory access panels are no longer necessary. Additionally, fixture heights have been reduced by up to 70%.

These new electronic ballasts also eliminate a problem that has plagued cold-cathode manufacturers for many years: power factor correction and dimmability. Historically, magnetic high-power-factor or *HPF* ($PF > .95$) ballasts and transformers were available, but could not be dimmed. Only low-power-factor or *LPF* ($PF < .60$) ballasts and transformers could be dimmed, with outstanding results. This high-quality dimming function, however, came at price: *double the number of circuits for a dimmable low-power factor system versus a non-dimmable high-power factor system*. The new electronic ballasts that are now available are revolutionary in that they are both high-power-factor ($PF > .95$) and dimmable, maximizing efficacies and minimizing the number of required circuits.

Newer cold-cathode technology also features high-efficiency tri-band lamp phosphors which produce higher brightness (equivalent to T5 fluorescent), higher color rendering (CRIs for most white lamps are >95 CRI), and improved lumen maintenance.



A contemporary, integrally ballasted "plug and play" cold cathode fixture (shown without lamp installed), which accepts a variety of lamp sizes and shapes



The same fixture with an "S" shape lamp installed.

LED Fixture Selection and Light Output

There are a variety of LED-based cove-lighting fixtures currently available. This paper has omitted the lower-cost LED cove systems which, because of their very low lumen outputs (45 lumens per foot¹ and below), do not represent a fair basis for comparison as they produce less than 6% (1/17th) of the light of a high-output cold cathode lamp.² The LED products selected for this comparison are far brighter and substantially more expensive than their lower-wattage counterparts. They produce more light, and through the use of sophisticated binning algorithms, attempt to remedy some of the color-consistency issues associated with LEDs. The fixtures chosen are all well-engineered, well-designed products, and are representative of what may be sourced in the specification-grade marketplace. They are designed for indirect cove illumination, and are supplied in sections as short as six inches, which are plugged or wired together. It should be noted that the higher wattage LED fixtures (referenced in this comparison) are now producing higher lumen outputs but still do not come close to the efficacies of linear fluorescent, which can be as high as 104 lumens per watt.³

RGB (red, blue and green) LEDs may be blended to generate a variety of white hues. However, this method of producing white light is not the most economical (it requires three LEDs to generate a white hue), this paper will focus on white LEDs only and, more specifically, those closest in color to incandescent light (2700°K).

¹ GE® Lighting Tetra® Minimax Data Sheet product code #75601 2700°K LED 45 lumens per foot 1.87 watts per foot system efficacy: 24.1 lumens per watt http://secure.ge-lightingsystems.com/gels01/r2/productcentral/htmls/13_37.html (accessed on 2/11/2010)

² Cathode Lighting Systems Model FCLS 28TC (2700°K) 772 lumens per foot 12 watts per foot system efficacy: 67 lumens per watt www.CathodeLightingSystems.com (accessed on 2/11/2010)

³ Osram Sylvania® Lumilux® T5 Fluorescent lamp data sheet lamp efficacy: 104 lumens per watt http://www.osram.com/osram_com/Professionals/General_Lighting/Fluorescent_lamps/Products/T5/LUMILUX_T5_HE_HIGH_EFFICIENCY/index.html (accessed on 2/11/2010)

LED Performance in Cove Lighting

Physical Characteristics

The small size of an LED fixture is appealing. Smaller fixtures mean smaller cove dimensional requirements. LED applications in which space for concealing the light source is limited are ideal for their very minimal dimensions and, as a solid-state light source, they are inaudible and do not need to be handled with the same care as a fluorescent or cold cathode lamp.

The Lighting Effect

LED is a point source rather than a true linear source. The best-performing LED fixtures incorporate features which attempt to reduce some of the inherent negative effects associated with point-source lighting. Closely-spaced LEDs, wider beam angles and diffusers (which can reduce efficacies) assist in softening the potential for striations, shadowing, and *cut off**. Color variations between batches of LEDs are addressed by binning (batching LEDs into groups of similar chromaticity and brightness). A significant percentage of the expense in the higher-performing, more color-consistent fixtures comes from this rigorous sorting process.

**Cut-off* is an undesirable lighting effect in which an obstruction (e.g., cove fascia) or beam-angle limitation prevents the light source from spreading evenly on critical adjacent areas, creating a defined shadow or demarcation between illuminated and unilluminated surfaces.



COLD CATHODE COVE

Cold cathode sources within coves are true linear sources and emit 360 degrees from the lamp body, allowing high brightnesses on surfaces directly above the lamp and a very gradual drop-off of light intensity and saturation on surfaces farther from the lamp. High lamp brightnesses and CRIs also contribute to overall footcandle levels and natural appearances of finished surfaces.



LED COVE

LED light cove example with a very sharp delineation between illuminated and un-illuminated surfaces, a function of the very directional nature of point-source based lighting, and restrictions created by narrow beam angles.

Energy Efficiency

As advancements in LED technology continue, efficacies will increase. Currently, the highest-lumen LED cove fixtures evaluated in this limited comparison produce approximately 44 lumens per each watt of electricity consumed.⁴ While this efficacy range is far better than incandescent, it is only roughly half of the best fluorescent products.⁵

LED Maintenance & Sustainability

Maintenance

Well-engineered LED fixtures with adequate heat management are expected to last their predicted life. However, the nature of rapidly advancing technology (especially in the case of LEDs) has significant implications that could drastically affect both short and long-term maintenance costs. There are currently hundreds of lighting manufacturers with LED-based products that can be used for indirect cove lighting. Construction methods vary, but for almost all manufacturers, the predominant design approach dictates that individual LEDs are not replaceable. These solid-state lighting fixtures are constructed in one of two different fashions:

⁴ Philips® / Color Kinetics® eW® Cove MX Powercore (2700°K white) 527 lumens per foot@ 12 watts per foot Efficacy: 43.9 lumens per watt CRI: 83 <http://www.colorkinetics.com/l/essentialwhite/ewcovemxpc> (accessed on 2/11/2010)

⁵ Osram® Sylvania® Lumilux® T5 Fluorescent lamp data sheet lamp efficacy: 104 lumens per watt http://www.osram.com/osram_com/Professionals/General_Lighting/Fluorescent_lamps/Products/T5/LUMILUX_T5_HE_HIGH_EFFICIENCY/index.html (accessed on 2/11/2010)

1. Either the fixtures are manufactured as unitized assemblies and are not made to be field-disassembled, and must be 100% replaced in the event of a single LED failure, or
2. The replaceable component in the fixture is an entire array of LEDs which, again, are generally not field-replaceable, but must be sent back to the original manufacturer to be repaired, and reinstalled into the fixture.

The above two items are inherent commonalities in LED fixture design. They have no counterpart in other types of specification-grade fixtures, in which fixture, light source, and power supply are separate, distinct and field-replaceable. By comparison, it would be difficult to accept that the failure of a fluorescent ballast on a costly linear fixture would require replacement of the entire fixture.

Sustainability

There is no doubt that the rate at which LEDs are advancing is impressive. While this makes for exciting press releases about astounding improvements in laboratory efficacies, it may not inspire confidence in the specification community. The potential for a fixture or LED modality to become obsolete a year or two after its introduction could be disastrous.⁶ Sourcing replacements or designing the second phase of a multi-phase project could prove very difficult if some LED fixtures become the equivalent of the latest PDA (Personal Digital Assistant), which becomes obsolete as soon as the next generation of the product is introduced. It may very well be prudent to plan for contingencies after the 50,000-hour life of the LED cove fixture (5.7 years at continuous operation). Unlike most fluorescent and cold cathode fixtures which, after six years of continuous operation, may only require new lamps or ballasts, the current generation of LED cove fixtures may require 100% replacement.

Summary

While no “perfect” product or solution exists for all lighting applications, it is the specifier’s responsibility to present informed, unbiased options to his/her client(s). With a firm understanding of the pros and cons of competing lighting technologies, the client will be empowered to make the best choice for their project.

In the case of specification-grade LED architectural cove lighting versus a more traditional light source like cold cathode, there is a tradeoff: the latest technology is exchanged for very high cost, relatively low efficacies and lumen outputs, color consistency issues, and potential product obsolescence well before useful life has ended.

Cold cathode is a well-established, reliable performer. Contemporary cold cathode technology overcomes a variety of deficits often associated with older versions of this type of lighting. Greatly reduced fixture dimensions, silent integral electronic ballasts, excellent energy efficiency, outstanding color consistency and lamp life, and contractor friendly “plug and play” connections make cold cathode a formidable tool for the designer. The advantage of cold cathode should always be considered when the highest quality cove lighting effects are desired.

⁶ Knisley, Joseph *The Fixture Piece of the LED Equation* Electrical Wholesaling Magazine 12/1/2008
http://ewweb.com/electrical/electric_fixture_piece_led/ (accessed on 2/11/2010)

The following tables have been prepared as a resource for quick comparison of the two light sources:

Table 1: Cost Comparison of LED and Cold Cathode for a Typical Cove Lighting Application

Table 2: Cold Cathode and LED Cove Fixture Features and Operational Characteristics

Table 3: Advantages and Potential Disadvantages of LED and Cold Cathode for Cove Applications

Table 1: Cost Comparison of LED and Cold Cathode for a Typical Cove Lighting Application

This table is based upon a typical application for three (3) rectangular coves 30' x 15' (90 feet each), for a total of 270 feet of cove lighting. For balanced comparison purposes, LED and Cold-Cathode fixtures of similar lumen values (both high-output and low output).

Fixture Type	Manufacturer	Model	Lumens per foot (2700°K)	Material Cost Per Foot*	Number of Feet	Total Cost (Material Only)	
High Lumen Output	Cold Cathode	Cathode Lighting Systems Inc.	Model FCLS (High Output)	772 ⁹	\$74 per foot	270	\$19,980
	LED	Philips® / Color Kinetics®	eW Cove MX Powercore	527 ⁷	\$182 per foot	270	\$49,140
Lower Lumen Output	Cold Cathode	Cathode Lighting Systems Inc.	Model H-FCLS (High Efficiency)	250 ¹⁰	\$68 per foot	270	\$18,360
	LED	I/O® Lighting	Line .75 (Standard Output)	68 ⁸	\$93 per foot	270	\$25,110

*Distributor-net pricing based on 2/17/2010 survey

⁷ Philips® / Color Kinetics® eW® Cove MX Powercore (2700°K white) 527 lumens per foot @ 12 watts per foot Efficacy: 43.9 lumens per watt CRI: 83 <http://www.colorkinetics.com/lc/essentialwhite/ewcovemxpc> (accessed on 2/11/2010)

⁸ I/O® Lighting Line .75® (2700°K white)
Standard output: 68 lumens per foot @ 2.92 watts per foot Efficacy: 23.3 lumens per watt
CRI: Not published <http://www.iolighting.com> (accessed on 2/11/2010)

⁹ Cathode Lighting System Inc. Model FCLS (2700°K white) 772 lumens per foot @ 12 watts per foot System efficacy (lamp + ballast): 67 lumens per watt CRI: 92 <http://www.cathodelightingsystems.com> (accessed on 3/10/2010)

¹⁰ Cathode Lighting System Inc. Model H-FCLS (2700°K white) 250 lumens per foot @ 4 watts per foot System efficacy (lamp + ballast): 67 lumens per watt CRI: 92 <http://www.cathodelightingsystems.com> (accessed on 3/10/2010)

Table 2: Cold Cathode and LED Cove Fixture Features and Operational Characteristics

FEATURES & OPERATIONAL CHARACTERISTICS	LED COVE LIGHTING	COLD CATHODE COVE LIGHTING
Lumen output	68-527 lumens per foot ¹¹	280 to 772 lumens per foot ¹²
Watt consumption per foot (system)	2.92 watts @ 68 lumens /ft. ¹¹ 12 watts @ 527 lumens/ft.	4 watts @ 257 lumens/ft. ¹² 12 watts @ 772 lumens/ft.
System efficacy (lumens per watt) for 2700°K white color temperature	23.3 - 45 lumens per watt ¹¹	67 lumens per watt ¹² (system: lamp + ballast)
Lamp life	Up to 50,000 hours ¹¹	100,000 hours @ 257 lumens/ft. ¹² 50,000 hours @ 760 lumens/ft.
CRI (color rendering index)	70-83 ¹¹	>92 ¹²
Power factor*	.6 (low voltage) to .99 (line voltage)	>.95
Fixture height	.75" to 2.5"	2.5"
Approximate Cost per foot (material only)	\$80 to \$190 per foot	\$68 to \$75 per foot
Low voltage or line voltage	Both	Line voltage only
Color shift or color degradation over lifetime of lamp	Yes	Negligible
Fully recyclable	Unknown	Yes
Dimmability	Yes, to 1% , but low levels may vary by manufacturer	Yes, to 1%
Light distribution (beam angle)	Narrow (up to 130 degrees)	Wide (360 degrees)
Temperature sensitivity	Reduced light output and lamp life at elevated temperatures.	Good tolerance at elevated temperatures. Reduced light output below 40°F
Light source type	Point source	Linear source
Color temperature tolerances	+/- 200°K	+/- 50°K
Color binning required?	Yes	No

*Power factor of an AC electric power system is defined as "the ratio of the real power to the apparent power", and is a number between 0 and 1 (or Unity). Low power-factor loads increase line losses in a power distribution system and result in increased energy costs for the utility. Although most residential and some commercial customers will only be charged for wattage consumed, the utility must deliver more power to the grid to make up for these losses. The additional fees for low power-factor device usage may show up as a surcharges on an electric bill.

¹¹ IO® Lighting Line .75° (2700°K white)

Standard output: 68 lumens per foot @ 2.92 watts per foot Efficacy: 23.3 lumens per watt
Medium output: 126 lumens per foot @ 5.34 watts per foot Efficacy: 23.6 lumens per watt
High output: 180 lumens per foot @ 7.62 watts per foot Efficacy: 23.6 lumens per watt
CRI: Not published <http://www.iolighting.com> (accessed on 2/11/2010)

¹¹ GE® LED Cove® (2700°K white) 290 lumens per foot @ 6.5 watts per foot Efficacy: 45 lumens per watt CRI: 70
http://www.gelighting.com/na/business_lighting/products/ledm (accessed on 2/11/2010)

¹² Philips® / Color Kinetics® eW® Cove MX Powercore (2700°K white) 527 lumens per foot @ 12 watts per foot Efficacy: 43.9 lumens per watt
CRI: 83 <http://www.colorkinetics.com/ls/essentialwhite/ewcovemxpc> (accessed on 2/11/2010)

¹² Cathode Lighting System Inc. Model FCLS (2700°K white) 772 lumens per foot @ 12 watts per foot 92 CRI
Cathode Lighting System Inc. Model H-FCLS (2700°K white) 250 lumens per foot @ 4 watts per foot 92 CRI
System efficacy (lamp + ballast): 67 lumens per watt CRI: 92 <http://www.cathodelightingsystems.com> (accessed on 3/10/2010)

Table 3: Advantages and Potential Disadvantages of LED and Cold Cathode for Cove Applications

Cold Cathode Cove Lighting Advantages	Cold Cathode Cove Lighting Disadvantages	LED Cove Lighting Advantages	LED Cove Lighting Disadvantages
<p>Contemporary versions of this type are low profile, have integrated electronic ballasts and are “plug & play”</p> <p>Reliable, well-established technology</p> <p>Moderately priced, in comparison with LED fixtures that approach cold cathode’s performance</p> <p>True linear source</p> <p>Field-proven lamp life of 50,000 to 100,000 hours</p> <p>Available in 11 different shades of white</p> <p>High CRI >92</p> <p>High power factor >.95</p> <p>Dimmable with 3-wire fluorescent dimmers</p> <p>Low replacement cost for lamps and ballasts</p> <p>Lamps can be made to effectively transition straight and curved coves seamlessly</p> <p>Minimal color shift over lamp life, and throughout dimming range</p>	<p>Lamps are glass and will break just as a standard fluorescent lamp will</p> <p>Larger fixture footprint and profile than many LED fixtures, requiring larger cove dimensions</p>	<p>Small fixture size, small cove dimensional requirements</p> <p>“Latest” technology</p> <p>50,000-hour predicted lamp life</p> <p>Not fragile</p> <p>Dimmable</p> <p>Small segmented fixture designs can transition straight and curved coves</p> <p>Available in six standard white colors</p> <p>High power factor on line-voltage systems</p>	<p>Lower efficacies than linear fluorescent and cold cathode</p> <p>Low CRI</p> <p>Expensive</p> <p>Rapidly changing technology may render fixtures obsolete prior to useful life</p> <p>High replacement cost - single LEDs cannot be replaced, only the entire module or fixture</p> <p>Directional nature of LEDs creates abrupt cessation of lighting effect on adjacent surfaces</p> <p>Color consistency issues</p> <p>Color shifting over the lifetime of the LED</p> <p>Point source and not a true linear source</p> <p>Low power factor on low-voltage systems</p> <p>Potential heat-management issues may shorten lamp life</p>

Additional resources

Mitchell, John *LED Street Lighting: Hope or Hype* Architect-Web Weekly 4/2009
<http://www.architechweb.com/PastIssues/emATWeeklyem/ArticleDetails/tabid/171/ArticleID/8210/Default.aspx>
 (accessed on 2/11/2010)

US Department of Energy CALiPER Program: <http://www1.eere.energy.gov/buildings/ssl/caliper.html>

LightingFacts.com (accessed on 2/11/2010)