Request for Reconsideration after Final Action

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MARK SECTION	
MARK	https://tmng-al.uspto.gov/resting2/api/img/79188560/large
LITERAL ELEMENT	CU-BEAM
STANDARD CHARACTERS	YES
USPTO-GENERATED IMAGE	YES
MARK STATEMENT	The mark consists of standard characters, without claim to any particular font style, size or color.
ARGUMENT(S)	

RESPONSE TO FINAL OFFICE ACTION AND REQUEST FOR RECONSIDERATION

Commissioner for Trademarks
2900 Crystal Drive
Arlington, VA 22202-3513

Dear Commissioner:

This communication is being filed in response to the final office action ("Final Office Action") mailed March 1, 2017. Pursuant to T.M.E.P. §715.03 and 37 C.F.R. § 2.64(b), Applicant Dyson Research Limited ("Applicant") respectfully submits this communication both as a Response to Office Action and as a Request for Reconsideration of the Office Action. Applicant requests that the Examining Attorney reconsider her refusal to register the mark based on the previously submitted office action response ("Office Action Response") and additional information submitted with this communication. Applicant is also filing a Notice of Appeal concurrently with this Response to Office Action and Request for Reconsideration.

THERE IS NO LIKELIHOOD OF CONFUSION BETWEEN APPLICANT'S MARK AND THE CITED MARK

The Examining Attorney has maintained her refusal to register Applicant's CU-BEAM mark under Section 2(d) on the grounds that the mark is confusingly similar to U.S. Registration No. 1,079,479 for the Q-BEAM mark for "portable electric lights and accessories therefor-namely, replacement lamps and filters," in Class 11, and U.S. Registration No. 2,600,421 for the mark Q-BEAM SPOT/FLOOD, for "Lighting apparatus and instruments - namely, a hand-held combination spotlight and floodlight," in Class 11, both owned by Viatek Consumer Products Group, Inc. ("the Registrant").
In support of her continued refusal, the Examining Attorney attached internet evidence to the Final Office Action, purportedly demonstrating "that the same entity commonly provides the relevant goods and markets the goods under the same mark and in the same general channels of trade. Therefore, applicant's and registrant's goods are considered related for likelihood of confusion purposes." For the reasons set forth below, Applicant believes that this evidence is unpersuasive. In addition, Applicant respectfully disagrees with the Examining Attorney's conclusion concerning the commercial impression created by the applied-for mark, and on these bases, believes that the refusal of registration for Applicant's mark should be withdrawn.

I. APPLICANT'S AMENDED GOODS ARE UNRELATED TO THOSE OF THE REGISTRANT

While Applicant believes that its current identification of "ceiling lights; suspended lights in the nature of lighting fixtures design to be suspended from a ceiling with uplighters and/or downlighters; parts and fittings for the aforesaid goods," creates a sufficient distinction from the Registrant's goods, Applicant herewith amends its identification to cover " suspended lights in the nature of LED lighting fixtures designed to be suspended from a ceiling with uplighters and/or downlighters, the aforesaid optimized to reduce eye strain and increase comfort and productivity; parts and fittings for the aforesaid goods," in Class 11.

These amendments limit Applicant's goods in a significant way. In particular, it is material that the identified lighting fixtures are LED lights. LED lighting is an increasingly popular alternative to both incandescent and fluorescent light sources. Namely, LED lights use less energy and have a longer lifetime than incandescent lights. (*Exhibit A.*) LED is also considered superior to fluorescent lighting, as it is more energy efficient and does not have the environmental disposal issues of fluorescent lighting. *Id.*
Critically, the light from fluorescent bulbs is non-directional. (*Exhibit B.*) This makes it inappropriate for commercial settings in which strong, directional lighting is necessary in order to provide adequate lighting for those reading, working at computers, or engaging in similar eye intensive tasks. Incandescent lighting is equally inappropriate for such settings, since it requires a whopping 85% more electricity than LED lighting. (*Exhibit C.*)

By contrast, LED lighting is highly flexible in its ability to be adjusted in strength, directionality, and color design. (*Exhibit D.*) In addition, the ability of LED lighting to mimic the warm light that emits from traditional incandescent lighting makes it appropriate for high-end office, conference, and library settings. (*See Exhibit E.*)

Finally, LED lighting has been celebrated for its ability to increase office employee productivity, and in particular, a Cornell University study showed that LED lighting led to a 3%-5% increase in worker productivity. (*Exhibit F.*) It is believed that this increase in productivity is due to the ability of LED lighting to emit light in specific directions, such that light is not "lost"' in other directions. The office worker receives strong directional light, thus reducing eyestrain.
These considerations are precisely what inform the design of the CU-BEAM light fixture, which allows light to be directionally placed (up, down, or both), as well as adjusted in strength, according to the necessity of various tasks and stages in the day (for example, for presenting, meeting, and out of hours). (*See Exhibit G.)* As discussed below, these characteristics, which are explicit in the amended goods identification, dictate the channels of trade and type of consumer to whom Applicant's goods are offered.

II. APPLICANT'S AMENDED GOODS AND THE REGISTRANT'S GOODS ARE OFFERED IN SEPARATE CHANNELS OF TRADE AND TO DISTINCT CONSUMERS

A. The Internet Evidence provided by the Examining Attorney Is Not Persuasive

In order to plausibly demonstrate that Applicant's and the Registrant's goods are commonly sold by the same entity, it must be shown that it is commonplace for a company to offer portable flashlights and spotlights on the one hand, and LED ceiling fixtures designed to optimize a user's experience, on the other. The internet evidence provided by the Examining Attorney simply does not do this.

First, the Examining Attorney provided a webpage for an incandescent floodlight lightbulb offered by Philips, along with a Philips webpage that offers flashlights and batteries therefor, and finally, a Philips webpage showing indoor suspension lights and ceiling lights. Applicant believes this evidence is of limited utility. Philips is one of the largest electronics companies in the world (*see Exhibit H*), and offers a product range of enormous breadth. In addition to the lighting products that the Examining Attorney points to, Philips also offers molecular imaging systems (*Exhibit I*) and personal dictation devices (*Exhibit J*), and yet it would be ludicrous to assert, on this basis alone, that flashlights, molecular imaging systems, and personal dictation devices are each commonly offered by the same entities.

Second, the Examining Attorney pointed to webpages for the company Grainger, which show that it sells temporary job site floodlights, wet location ceiling fixture lights, and a decorative ceiling fixture. But, again, this evidence is not probative of the fact the goods described in Applicant's and the Registrant's identifications are offered by the same sources. Grainger describes itself as a supplier of maintenance, repair and operating ("MRO") products. (*See Exhibit K.*) MRO refers to " performing routine actions which keep devices, equipment, machinery, building infrastructure and supporting utilities in working order (known as scheduled maintenance) and prevent trouble from arising (preventive maintenance)." (*Exhibit L.*)

This fact is born out when looking at the product details for the 60W Wet Location Fixture, featured in the webpage that the Examining Attorney provides. The fluorescent fixture is intended for "wet and dusty locations" and it "helps prevent entry of airborne contaminants," making it appropriate for use in fabrication and machining areas, and welding and grinding environments. (*Exhibit M.*)

This type of product could not be further from the expensive fixtures (*see* the websites for Y Lighting and Lightology attached to the Final Office Action) offered by Applicant under the CU-BEAM mark and elaborated on in the marketing materials presented in *Exhibit G*.

The decorative light fixture featured in another Grainger webpage is similarly distinguishable. It uses fluorescent bulbs, has a retail price that ranges $35.42 to $46.80, and is not Energy Star compliant. (*Exhibit N*.) This lighting fixture has nothing in common with the goods described in Applicant's amended identification except that it is a light fixture. This is simply not enough. *See Electronic Data Sys. Corp. v. EDSA Micro Corp.*, 23 U.S.P.Q.2d 1460, 1463-64 (T.T.A.B. 1992) (holding the marks EDS and EDSA not likely to cause confusion despite the fact that both marks were used in connection with products that were broadly characterized as computer software). Moreover, the fact that Grainger happens to have a decorative light fixture in its catalog of over 3,000 pages of MRO products (*Exhibit O*), is an incidental fact at best, and certainly an insufficient basis to support the Examining Attorney's proposition that it is common for a single source to sell the type of products offered by Applicant and the Registrant.

Finally, the Examining Attorney attached webpages for Phoenix Lighting, which prove, rather than undercut, Applicant's point. The webpages show that Phoenix offers both portable floodlights and interior ceiling fixtures. Yet the nature and purpose of the ceiling fixture differentiates it from those described in the subject application in a material way. The webpage explains that the fixture is vibration-resistant for demanding applications, has UV-stabilized nylon housing that is corrosion-free, high impact, and glass reinforced, and that the fixture is UL listed as suitable for wet locations, saltwater, and emergency lighting equipment. (*Exhibit P.)* Accordingly, the point that this evidence supports is narrow—that it is common for a single source to offer lighting both for the outdoors and for wet, industrial environments because each product category requires the same high-performance construction that is resistant to the elements.

Indeed, as the evidence demonstrates, distinctions in the purpose and nature of various lighting products make a critical difference in the channels of trade where each light will be sold. And while the Examining Attorney observes that the Registrant's goods are not limited to the consumer types listed on its websites: outdoor hobbyists and military or industrial applications, this misses Applicant's point. Implicit in goods identifications for "portable electric lights" and a "hand-held combination spotlight and floodlight" are certain uses, certain consumers, and certain channels of trade. These consumers and channels of trade quite simply do not align with those for Applicant's amended goods.

B. Applicant's Goods Are Sold to Design Professionals

In its Office Action Response, Applicant explained that its CU-BEAM light fixtures "are not offered directly to the public, but are marketed towards architects, designers, and facilities managers who make institutional purchasing decisions." (Office Action Response at 3.) In rebuttal, the Examining Attorney pointed to two websites that offer the CU-BEAM light fixtures for sale. (Final Office Action at 4). Yet a review of these websites reveals that they support, rather than contradict, Applicant's point.

Y Lighting describes itself as offering "the best in modern furniture, accessories, and decorative plumbing," including many high-end and highly lauded lines. (*Exhibit Q.)* Indeed, the company's Trade Program is a buying program specifically for use by design professionals, not the general public. (*Id.)* Similarly, Lightology describes itself as North America's premier contemporary lighting showroom, which serves "the specialty needs of architects, designers, contractors, and other trade professionals." (*Exhibit R*.) The fact that these two large designer showrooms also permit online sales to end-users does not change the fact that Applicant's products (and all products of this nature) are offered through a very narrow number of outlets. Indeed, as a review of *Exhibit G* shows, unlike other of Applicant's products, there is no point of sale option on Applicant's website for the CU-BEAM light fixture.

The fact that the products in the subject application and the cited registrations are all lights, is not determinative. Moreover, the fact that third-party companies cited by the Examining Attorney offer lights for both indoor and outdoor use is equally undeterminative. The critical question is whether the goods described in the amended identification are likely to be sold by the same companies as those that sell floodlights and flashlights. They are not, and the Examining Attorney's evidence does not demonstrate otherwise.

III. DIFFERENCES IN THE MEANING OF THE MARKS MITIGATE AGAINST A LIKELIHOOD OF CONFUSION

In its Office Action Response, Applicant argues that consumers associate its CU-BEAM mark with the copper pipes used in its construction, therefore creating a distinct commercial impression from the Q-BEAM marks. (Office Action Response at 1.)

The Examining Attorney states that "Applicant's website does not reference copper." (Office Action at 4.) While the Applicant concedes that it failed to attach such evidence, it herewith attaches an excerpt from its webpage wherein it is explained that as part of its CU-BEAM fixture's heat pipe technology, a "copper wick draws the water back toward the LEDS." (*Exhibit G*.) Perhaps more critically, third-parties are discussing the role that copper pipes play in the CU-BEAM light fixtures. For example, an article by Wired explains that "[e]very Cu-Beam contains six copper heat pipes." (*Exhibit S*.) And an article on Cool Things describes how the CU-BEAM light fixture utilizes "one large high-power LED with a custom-engineered lens that's cooled by six copper heat pipes integrated into the rig." (*Exhibit T*.) These third-party references to the copper pipes that form a central aspect of the design of the CU-BEAM lighting fixture, are highly probative that consumers will understand that "CU" means copper, and thereby will differentiate Applicant's mark from the Registrant's Q-BEAM marks.

COMMENTS

Applicant believes that it has responded to all of the Examining Attorney's questions and objections and that the application is now in condition to go forward to publication.

If the Examining Attorney has any questions or wishes to discuss any of the information contained herein so as to expedite matters, the Examining Attorney is requested to telephone the undersigned at (415) 268-6538.

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DESCRIPTION OF EVIDENCE FILE	exhibits in support of Argument

GOODS AND/OR SERVICES SECTION (current)

INTERNATIONAL CLASS	011

DESCRIPTION

ceiling lights; suspended lights in the nature of lighting fixtures design to be suspended from a ceiling with uplighters and/or downlighters; parts and fittings for the aforesaid goods

GOODS AND/OR SERVICES SECTION (proposed)

INTERNATIONAL CLASS	011

TRACKED TEXT DESCRIPTION

~~ceiling lights~~; suspended lights in the nature of LED lighting fixtures designed to be suspended from a ceiling with uplighters and/or downlighters, the aforesaid optimized to reduce eye strain and increase comfort and productivity; ~~suspended lights in the nature of lighting fixtures design to be suspended from a ceiling with uplighters and/or downlighters~~; parts and fittings for the aforesaid goods

FINAL DESCRIPTION	
suspended lights in the nature of LED lighting fixtures designed to be suspended from a ceiling with uplighters and/or downlighters, the aforesaid optimized to reduce eye strain and increase comfort and productivity; parts and fittings for the aforesaid goods	
SIGNATURE SECTION	
RESPONSE SIGNATURE	/Jennifer Lee Taylor/
SIGNATORY'S NAME	Jennifer Lee Taylor
SIGNATORY'S POSITION	Attorney of Record, CA Bar member
DATE SIGNED	09/01/2017
AUTHORIZED SIGNATORY	YES
CONCURRENT APPEAL NOTICE FILED	YES
FILING INFORMATION SECTION	
SUBMIT DATE	Fri Sep 01 20:43:57 EDT 2017
TEAS STAMP	USPTO/RFR-XXX.XXX.X.X-201 70901204357414026-7918856 0-5101f25dfb7b0af8cea43fc e1ddd11a13f1cb49dcb937b26 3cab86b9a6774837d5-N/A-N/ A-20170901201316921881

Request for Reconsideration after Final Action

To the Commissioner for Trademarks:

Application serial no. **79188560** CU-BEAM(Standard Characters, see https://tmng-al.uspto.gov/resting2/api/img/79188560/large) has been amended as follows:

ARGUMENT(S)
In response to the substantive refusal(s), please note the following:

RESPONSE TO FINAL OFFICE ACTION AND REQUEST FOR RECONSIDERATION

Commissioner for Trademarks
2900 Crystal Drive
Arlington, VA 22202-3513

Dear Commissioner:

This communication is being filed in response to the final office action ("Final Office Action") mailed March 1, 2017.   Pursuant to T.M.E.P. §715.03 and 37 C.F.R. § 2.64(b), Applicant Dyson Research Limited ("Applicant") respectfully submits this communication both as a Response to Office Action and as a Request for Reconsideration of the Office Action. Applicant requests that the Examining Attorney reconsider her refusal to register the mark based on the previously submitted office action response ("Office Action Response") and additional information submitted with this communication. Applicant is also filing a Notice of Appeal concurrently with this Response to Office Action and Request for Reconsideration.

THERE IS NO LIKELIHOOD OF CONFUSION BETWEEN APPLICANT'S MARK AND THE CITED MARK

The Examining Attorney has maintained her refusal to register Applicant's CU-BEAM mark under Section 2(d) on the grounds that the mark is confusingly similar to U.S. Registration No. 1,079,479 for the Q-BEAM mark for "portable electric lights and accessories therefor-namely, replacement lamps and filters," in Class 11, and U.S. Registration No. 2,600,421 for the mark Q-BEAM SPOT/FLOOD, for "Lighting apparatus and instruments - namely, a hand-held combination spotlight and floodlight," in Class 11, both owned by Viatek Consumer Products Group, Inc. ("the Registrant").

In support of her continued refusal, the Examining Attorney attached internet evidence to the Final Office Action, purportedly demonstrating "that the same entity commonly provides the relevant goods and markets the goods under the same mark and in the same general channels of trade. Therefore, applicant's and registrant's goods are considered related for likelihood of confusion purposes." For the reasons set forth below, Applicant believes that this evidence is unpersuasive. In addition, Applicant respectfully disagrees with the Examining Attorney's conclusion concerning the commercial impression created by the applied-for mark, and on these bases, believes that the refusal of registration for Applicant's mark should be withdrawn.

I. APPLICANT'S AMENDED GOODS ARE UNRELATED TO THOSE OF THE REGISTRANT

While Applicant believes that its current identification of "ceiling lights; suspended lights in the nature of lighting fixtures design to be suspended from a ceiling with uplighters and/or downlighters; parts and fittings for the aforesaid goods," creates a sufficient distinction from the Registrant's goods, Applicant herewith amends its identification to cover " suspended lights in the nature of LED lighting fixtures designed to be suspended from a ceiling with uplighters and/or downlighters, the aforesaid optimized to reduce eye strain and increase comfort and productivity; parts and fittings for the aforesaid goods," in Class 11.

These amendments limit Applicant's goods in a significant way. In particular, it is material that the identified lighting fixtures are LED lights. LED lighting is an increasingly popular alternative to both incandescent and fluorescent light sources. Namely, LED lights use less energy and have a longer lifetime than incandescent lights. (*Exhibit A.*) LED is also considered superior to fluorescent lighting, as it is more energy efficient and does not have the environmental disposal issues of fluorescent lighting. *Id.*

Critically, the light from fluorescent bulbs is non-directional. (*Exhibit B.*) This makes it inappropriate for commercial settings in which strong, directional lighting is necessary in order to provide adequate lighting for those reading, working at computers, or engaging in similar eye intensive tasks. Incandescent lighting is equally inappropriate for such settings, since it requires a whopping 85% more electricity than LED lighting. (*Exhibit C.*)

By contrast, LED lighting is highly flexible in its ability to be adjusted in strength, directionality, and color design. (*Exhibit D.*) In addition, the ability of LED lighting to mimic the warm light that emits from traditional incandescent lighting makes it appropriate for high-end office, conference, and library settings. (*See Exhibit E.*)

Finally, LED lighting has been celebrated for its ability to increase office employee productivity, and in particular, a Cornell University study showed that LED lighting led to a 3%-5% increase in worker productivity. (*Exhibit F.*) It is believed that this increase in productivity is due to the ability of LED lighting to emit light in specific directions, such that light is not "lost"' in other directions. The office worker receives strong directional light, thus reducing eyestrain. These considerations are precisely what inform the design of the CU-BEAM light fixture, which allows light to be directionally placed (up, down, or both), as well as adjusted in strength, according to the necessity of various tasks and stages in the day (for example, for presenting, meeting, and out of hours). (*See Exhibit G.)* As discussed below, these characteristics, which are explicit in the amended goods identification, dictate the channels of trade and type of consumer to whom Applicant's goods are offered.

II. APPLICANT'S AMENDED GOODS AND THE REGISTRANT'S GOODS ARE OFFERED IN SEPARATE CHANNELS OF TRADE AND TO DISTINCT CONSUMERS

A. The Internet Evidence provided by the Examining Attorney Is Not Persuasive

In order to plausibly demonstrate that Applicant's and the Registrant's goods are commonly sold by the same entity, it must be shown that it is commonplace for a company to offer portable flashlights and spotlights on the one hand, and LED ceiling fixtures designed to optimize a user's experience, on the other. The internet evidence provided by the Examining Attorney simply does not do this.

First, the Examining Attorney provided a webpage for an incandescent floodlight lightbulb offered by Philips, along with a Philips webpage that offers flashlights and batteries therefor, and finally, a Philips webpage showing indoor suspension lights and ceiling lights. Applicant believes this evidence is of limited utility. Philips is one of the largest electronics companies in the world (*see Exhibit H*), and offers a product range of enormous breadth. In addition to the lighting products that the Examining Attorney points to, Philips also offers molecular imaging systems (*Exhibit I*) and personal dictation devices (*Exhibit J*), and yet it would be ludicrous to assert, on this basis alone, that flashlights, molecular imaging systems, and personal dictation devices are each commonly offered by the same entities.

Second, the Examining Attorney pointed to webpages for the company Grainger, which show that it sells temporary job site floodlights, wet location ceiling fixture lights, and a decorative ceiling fixture. But, again, this evidence is not probative of the fact the goods described in Applicant's and the Registrant's identifications are offered by the same sources. Grainger describes itself as a supplier of maintenance, repair and operating ("MRO") products. (*See Exhibit K*.) MRO refers to " performing routine actions which keep devices, equipment, machinery, building infrastructure and supporting utilities in working order (known as scheduled maintenance) and prevent trouble from arising (preventive maintenance)." (*Exhibit L*.)

This fact is born out when looking at the product details for the 60W Wet Location Fixture, featured in the webpage that the Examining Attorney provides. The fluorescent fixture is intended for "wet and dusty locations" and it "helps prevent entry of airborne contaminants," making it appropriate for use in fabrication and machining areas, and welding and grinding environments. (*Exhibit M*.) This type of product could not be further from the expensive fixtures (*see* the websites for Y Lighting and Lightology attached to the Final Office Action) offered by Applicant under the CU-BEAM mark and elaborated on in the marketing materials presented in *Exhibit G*.

The decorative light fixture featured in another Grainger webpage is similarly distinguishable. It uses fluorescent bulbs, has a retail price that ranges $35.42 to $46.80, and is not Energy Star compliant. (*Exhibit N*.) This lighting fixture has nothing in common with the goods described in Applicant's amended identification except that it is a light fixture. This is simply not enough. *See Electronic Data Sys. Corp. v. EDSA Micro Corp.*, 23 U.S.P.Q.2d 1460, 1463-64 (T.T.A.B. 1992) (holding the marks EDS and EDSA not likely to cause confusion despite the fact that both marks were used in connection with products that were broadly characterized as computer software). Moreover, the fact that Grainger happens to have a decorative light fixture in its catalog of over 3,000 pages of MRO products (*Exhibit O*), is an incidental fact at best, and certainly an insufficient basis to support the Examining Attorney's proposition that it is common for a single source to sell the type of products offered by Applicant and the Registrant.

Finally, the Examining Attorney attached webpages for Phoenix Lighting, which prove, rather than undercut, Applicant's point. The webpages show that Phoenix offers both portable floodlights and interior ceiling fixtures. Yet the nature and purpose of the ceiling fixture differentiates it from those described in the subject application in a material way. The webpage explains that the fixture is vibration-resistant for demanding applications, has UV-stabilized nylon housing that is corrosion-free, high impact, and glass reinforced, and that the fixture is UL listed as suitable for wet locations, saltwater, and emergency lighting equipment. (*Exhibit P.)* Accordingly, the point that this evidence supports is narrow—that it is common for a single source to offer lighting both for the outdoors and for wet, industrial environments because each product category requires the same high-performance construction that is resistant to the elements.

Indeed, as the evidence demonstrates, distinctions in the purpose and nature of various lighting products make a critical difference in the channels of trade where each light will be sold. And while the Examining Attorney observes that the Registrant's goods are not limited to the consumer types listed on its websites: outdoor hobbyists and military or industrial applications, this misses Applicant's point. Implicit in goods identifications for "portable electric lights" and a "hand-held combination spotlight and floodlight" are certain uses, certain consumers, and certain channels of trade. These consumers and channels of trade quite simply do not align with those for Applicant's amended goods.

B. Applicant's Goods Are Sold to Design Professionals

In its Office Action Response, Applicant explained that its CU-BEAM light fixtures "are not offered directly to the public, but are marketed towards architects, designers, and facilities managers who make institutional purchasing decisions." (Office Action Response at 3.) In rebuttal, the Examining Attorney pointed to two websites that offer the CU-BEAM light fixtures for sale. (Final Office Action at 4). Yet a review of these websites reveals that they support, rather than contradict, Applicant's point.

Y Lighting describes itself as offering "the best in modern furniture, accessories, and decorative plumbing," including many high-end and highly lauded lines. (*Exhibit Q.)* Indeed, the company's Trade Program is a buying program specifically for use by design professionals, not the general public. (*Id.)* Similarly, Lightology describes itself as North America's premier contemporary lighting showroom, which serves "the specialty needs of architects, designers, contractors, and other trade professionals." (*Exhibit R*.) The fact that these two large designer showrooms also permit online sales to end-users does not change the fact that Applicant's products (and all products of this nature) are offered through a very narrow number of outlets. Indeed, as a review of *Exhibit G* shows, unlike other of Applicant's products, there is no point of sale option on Applicant's website for the CU-BEAM light fixture.

The fact that the products in the subject application and the cited registrations are all lights, is not determinative. Moreover, the fact that third-party companies cited by the Examining Attorney offer lights for both indoor and outdoor use is equally undeterminative. The critical question is whether the goods described in the amended identification are likely to be sold by the same companies as those that sell floodlights and flashlights. They are not, and the Examining Attorney's evidence does not demonstrate otherwise.

III. DIFFERENCES IN THE MEANING OF THE MARKS MITIGATE AGAINST A LIKELIHOOD OF CONFUSION

In its Office Action Response, Applicant argues that consumers associate its CU-BEAM mark with the copper pipes used in its construction, therefore creating a distinct commercial impression from the Q-BEAM marks. (Office Action Response at 1.)

The Examining Attorney states that "Applicant's website does not reference copper." (Office Action at 4.) While the Applicant concedes that it failed to attach such evidence, it herewith attaches an excerpt from its webpage wherein it is explained that as part of its CU-BEAM fixture's heat pipe technology, a "copper wick draws the water back toward the LEDS." (*Exhibit G*.) Perhaps more critically, third-parties are discussing the role that copper pipes play in the CU-BEAM light fixtures. For example, an article by Wired explains that "[e]very Cu-Beam contains six copper heat pipes." (*Exhibit S*.) And an article on Cool Things describes how the CU-BEAM light fixture utilizes "one large high-power LED with a custom-engineered lens that's cooled by six copper heat pipes integrated into the rig." (*Exhibit T*.) These third-party references to the copper pipes that form a central aspect of the design of the CU-BEAM lighting fixture, are highly probative that consumers will understand that "CU" means copper, and thereby will differentiate Applicant's mark from the Registrant's Q-BEAM marks.

COMMENTS

Applicant believes that it has responded to all of the Examining Attorney's questions and objections and that the application is now in condition to go forward to publication.

If the Examining Attorney has any questions or wishes to discuss any of the information contained herein so as to expedite matters, the Examining Attorney is requested to telephone the undersigned at (415) 268-6538.

EVIDENCE

Evidence in the nature of exhibits in support of Argument has been attached.

Original PDF file:

evi_20413008-20170901201316921881_._Exhibits_A_to_G.pdf

Converted PDF file(s) (101 pages)

Evidence-1
Evidence-2
Evidence-3
Evidence-4
Evidence-5
Evidence-6
Evidence-7
Evidence-8
Evidence-9
Evidence-10
Evidence-11
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Original PDF file:
evi_20413008-20170901201316921881_._Exhibits_H_to_T.pdf
Converted PDF file(s) (88 pages)
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Evidence-88

CLASSIFICATION AND LISTING OF GOODS/SERVICES
Applicant proposes to amend the following class of goods/services in the application:
Current: Class 011 for ceiling lights; suspended lights in the nature of lighting fixtures design to be suspended from a ceiling with uplighters and/or downlighters; parts and fittings for the aforesaid goods
Original Filing Basis:
Filing Basis Section 66(a) , Request for Extension of Protection to the United States. Section 66(a) of the Trademark Act, 15 U.S.C. §1141f.

Proposed:
Tracked Text Description: ~~ceiling lights~~; suspended lights in the nature of LED lighting fixtures designed to be suspended from a ceiling with uplighters and/or downlighters, the aforesaid optimized to reduce eye strain and increase comfort and productivity; ~~suspended lights in the nature of lighting fixtures design to be suspended from a ceiling with uplighters and/or downlighters~~; parts and fittings for the aforesaid goods

Class 011 for suspended lights in the nature of LED lighting fixtures designed to be suspended from a ceiling with uplighters and/or downlighters, the aforesaid optimized to reduce eye strain and increase comfort and productivity; parts and fittings for the aforesaid goods

Filing Basis Section 66(a) , Request for Extension of Protection to the United States. Section 66(a) of the Trademark Act, 15 U.S.C. §1141f.

SIGNATURE(S)
Request for Reconsideration Signature
Signature: /Jennifer Lee Taylor/ Date: 09/01/2017
Signatory's Name: Jennifer Lee Taylor
Signatory's Position: Attorney of Record, CA Bar member

The signatory has confirmed that he/she is an attorney who is a member in good standing of the bar of the highest court of a U.S. state, which includes the District of Columbia, Puerto Rico, and other federal territories and possessions; and he/she is currently the owner's/holder's attorney or an associate thereof; and to the best of his/her knowledge, if prior to his/her appointment another U.S. attorney or a Canadian attorney/agent not currently associated with his/her company/firm previously represented the owner/holder in this matter: (1) the owner/holder has filed or is concurrently filing a signed revocation of or substitute power of attorney with the USPTO; (2) the USPTO has granted the request of the prior representative to withdraw; (3) the owner/holder has filed a power of attorney appointing him/her in this matter; or (4) the owner's/holder's appointed U.S. attorney or Canadian attorney/agent has filed a power of attorney appointing him/her as an associate attorney in this matter.

The applicant is filing a Notice of Appeal in conjunction with this Request for Reconsideration.

Serial Number: 79188560
Internet Transmission Date: Fri Sep 01 20:43:57 EDT 2017
TEAS Stamp: USPTO/RFR-XXX.XXX.X.X-201709012043574140
26-79188560-5101f25dfb7b0af8cea43fce1ddd
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EXHIBIT A

Light-emitting diode

From Wikipedia, the free encyclopedia

A **light-emitting diode** (**LED**) is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated.[5] When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. LEDs are typically small (less than 1 mm^2) and integrated optical components may be used to shape the radiation pattern.[6]

Appearing as practical electronic components in 1962, the earliest LEDs emitted low-intensity infrared light.[7] Infrared LEDs are still frequently used as transmitting elements in remote-control circuits, such as those in remote controls for a wide variety of consumer electronics. The first visible-light LEDs were also of low intensity and limited to red. Modern LEDs are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness.

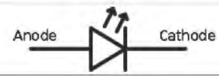
Early LEDs were often used as indicator lamps for electronic devices, replacing small incandescent bulbs. They were soon packaged into numeric readouts in the form of seven-segment displays and were commonly seen in digital clocks. Recent developments have produced LEDs suitable for environmental and task lighting. LEDs have led to new displays and sensors, while their high switching rates are useful in advanced communications technology.

Light-emitting diode

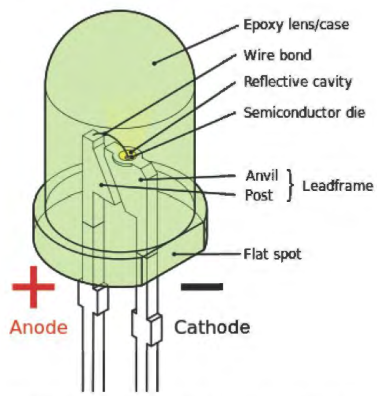
Blue, green, and red LEDs in 5 mm diffused case

Working principle	Electroluminescence
Invented	H. J. Round (1907)[1] Oleg Losev (1927)[2] James R. Biard (1961)[3] Nick Holonyak (1962)[4]
First production	October 1962
Pin configuration	Anode and cathode

Electronic symbol



LEDs have many advantages over incandescent light sources, including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching. Light-emitting diodes are used in applications as diverse as aviation lighting, automotive headlamps, advertising, general lighting, traffic signals, camera flashes, and lighted wallpaper. As of 2017, LED lights home room lighting are as cheap or cheaper than compact fluorescent lamp sources of comparable output.[8] They are also significantly more energy efficient and, arguably, have fewer environmental concerns linked to their disposal.[9][10]

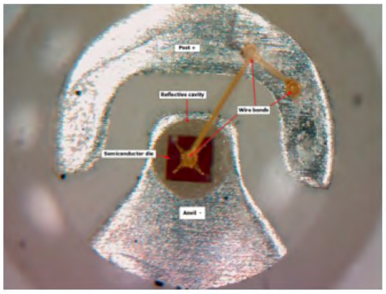


Parts of a conventional LED. The flat bottom surfaces of the anvil and post embedded inside the epoxy act as anchors, to prevent the conductors from being forcefully pulled out via mechanical strain or vibration.

Unlike a laser, the color of light emitted from an LED is neither coherent nor monochromatic, but the spectrum is narrow with respect to human vision, and for most purposes the light from a simple diode element can be regarded as functionally monochromatic.[11]

Contents

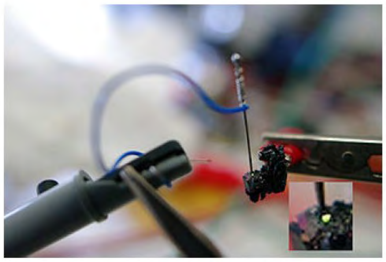
A bulb-shaped modern retrofit LED lamp with aluminium heat sink, a light diffusing dome and E27 screw base, using a built-in power supply working on mains voltage



Close up image of a surface mount LED

History

Discoveries and early devices



Green electroluminescence from a point contact on a crystal of SiC recreates Round's original experiment from 1907.

Electroluminescence as a phenomenon was discovered in 1907 by the British experimenter H. J. Round of Marconi Labs, using a crystal of silicon carbide and a cat's-whisker detector.[12][13] Russian inventor Oleg Losev reported creation of the first LED in 1927.[14] His research was distributed in Soviet, German and British scientific journals, but no practical use was made of the discovery for several decades.[15][16] Kurt Lehovec, Carl Accardo, and Edward Jamgochian explained these first light-emitting diodes in 1951 using an apparatus employing SiC crystals with a current source of battery or pulse generator and with a comparison to a variant, pure, crystal in 1953.[17][18]

Rubin Braunstein[19] of the Radio Corporation of America reported on infrared emission from gallium arsenide (GaAs) and other semiconductor alloys in 1955.[20] Braunstein observed infrared emission generated by simple diode structures using gallium antimonide (GaSb), GaAs, indium phosphide (InP), and silicon-germanium (SiGe) alloys at room temperature and at 77 Kelvin.

In 1957, Braunstein further demonstrated that the rudimentary devices could be used for non-radio communication across a short distance. As noted by Kroemer[21] Braunstein "…had set up a simple optical communications link: Music emerging from a record player was used via suitable electronics to modulate the forward current of a GaAs diode. The emitted light was detected by a PbS diode some distance away. This signal was fed into an audio amplifier and played back by a loudspeaker. Intercepting the beam stopped the music. We had a great deal of fun playing with this setup." This setup presaged the use of LEDs for optical communication applications.

A Texas Instruments SNX-100 GaAs LED contained in a TO-18 transistor metal case.

In September 1961, while working at Texas Instruments in Dallas, Texas, James R. Biard and Gary Pittman discovered near-infrared (900 nm) light emission from a tunnel diode they had constructed on a GaAs substrate.[7] By October 1961, they had demonstrated efficient light emission and signal coupling between a GaAs p-n junction light emitter and an electrically-isolated semiconductor photodetector.[22] On August 8, 1962, Biard and Pittman filed a patent titled "Semiconductor Radiant Diode" based on their findings, which described a zinc diffused p–n junction LED with a spaced cathode contact to allow for efficient emission of infrared light under forward bias. After establishing the priority of their work based on engineering notebooks predating submissions from G.E. Labs, RCA Research Labs, IBM Research Labs, Bell Labs, and Lincoln Lab at MIT, the U.S. patent office issued the two inventors the patent for the GaAs infrared (IR) light-emitting diode (U.S. Patent US3293513 (http://www.freepatentsonline.com/3293513.pdf)), the first practical LED.[7] Immediately after filing the patent, Texas Instruments (TI) began a project to manufacture infrared diodes. In October 1962, TI announced the first commercial LED product (the SNX-100), which employed a pure GaAs crystal to emit a 890 nm light output.[7] In October 1963, TI announced the first commercial hemispherical LED, the SNX-110.[23]

The first visible-spectrum (red) LED was developed in 1962 by Nick Holonyak, Jr. while working at General Electric. Holonyak first reported his LED in the journal *Applied Physics Letters* on December 1, 1962.[24][25] M. George Craford,[26] a former graduate student of Holonyak, invented the first yellow LED and improved the brightness of red and red-orange LEDs by a factor of ten in 1972.[27] In 1976, T. P. Pearsall created the first high-brightness, high-efficiency LEDs for optical fiber telecommunications by inventing new semiconductor materials specifically adapted to optical fiber transmission wavelengths.[28]

Initial commercial development

The first commercial LEDs were commonly used as replacements for incandescent and neon indicator lamps, and in seven-segment displays,[29] first in expensive equipment such as laboratory and electronics test equipment, then later in such appliances as TVs, radios, telephones, calculators, as well as watches (see list of signal uses). Until 1968, visible and infrared LEDs were extremely costly, in the order of US$200 per unit, and so had little practical use.[30] The Monsanto Company was the first organization to mass-produce visible LEDs, using gallium arsenide phosphide (GaAsP) in 1968 to produce red LEDs suitable for indicators.[30] Hewlett-Packard (HP) introduced LEDs in 1968, initially using GaAsP supplied by Monsanto. These red LEDs were bright enough only for use as indicators, as the light output was not enough to illuminate an area. Readouts in calculators were so small that plastic lenses were built over each digit to make them legible. Later, other colors became widely available and appeared in appliances and equipment. In the 1970s commercially successful LED devices at less than five cents each were produced by Fairchild Optoelectronics. These devices employed compound semiconductor chips fabricated with the planar process invented by Dr. Jean Hoerni at Fairchild Semiconductor.[31][32] The combination of planar processing for chip fabrication and innovative packaging methods enabled the team at Fairchild led by optoelectronics pioneer Thomas Brandt to achieve the needed cost reductions.[33] LED producers continue to use these methods.[34]

Most LEDs were made in the very common 5 mm T1¾ and 3 mm T1 packages, but with rising power output, it has grown increasingly necessary to shed excess heat to maintain reliability,[35] so more complex packages have been adapted for efficient heat dissipation. Packages for state-of-the-art high-power LEDs bear little resemblance to early LEDs.

LED display of a TI-30 scientific calculator (ca. 1978), which uses plastic lenses to increase the visible digit size

Blue LED

Blue LEDs were first developed by Herbert Paul Maruska at RCA in 1972 using gallium nitride (GaN) on a sapphire substrate.[36] SiC-types were first commercially sold in the United States by Cree in 1989.[37] However, neither of these initial blue LEDs were very bright.

The first high-brightness blue LED was demonstrated by Shuji Nakamura of Nichia Corporation in 1994 and was based on InGaN.[38][39] In parallel, Isamu Akasaki and Hiroshi Amano in Nagoya were working on developing the important GaN nucleation on sapphire substrates and the demonstration of p-type doping of GaN. Nakamura, Akasaki, and Amano were awarded the 2014 Nobel prize in physics for their work.[40] In 1995, Alberto Barbieri at the Cardiff University Laboratory (GB) investigated the efficiency and reliability of high-brightness LEDs and demonstrated a "transparent contact" LED using indium tin oxide (ITO) on (AlGaInP/GaAs).

In 2001[41] and 2002,[42] processes for growing gallium nitride (GaN) LEDs on silicon were successfully demonstrated. In January 2012, Osram demonstrated high-power InGaN LEDs grown on silicon substrates commercially.[43]

White LEDs and the illumination breakthrough

The attainment of high efficiency in blue LEDs was quickly followed by the development of the first white LED. In this device a $Y_3Al_5O_{12}$:Ce (known as "YAG") phosphor coating on the emitter absorbs some of the blue emission and produces yellow light through fluorescence. The combination of that yellow with remaining blue light appears white to the eye. However, using different phosphors (fluorescent materials) it also became possible to instead produce green and red light through fluorescence. The resulting mixture of red, green and blue is not only perceived by humans as white light but is superior for illumination in terms of color rendering, whereas one cannot appreciate the color of red or green objects illuminated only by the yellow (and remaining blue) wavelengths from the YAG phosphor.

The first white LEDs were expensive and inefficient. However, the light output of LEDs has increased exponentially, with a doubling occurring approximately every 36 months since the 1960s (similar to Moore's law). This trend is generally attributed to the parallel development of other semiconductor technologies and advances in optics and materials science and has been called Haitz's law after Dr. Roland Haitz.[44]

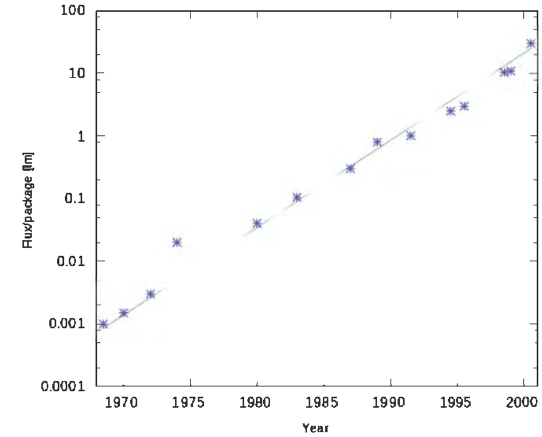


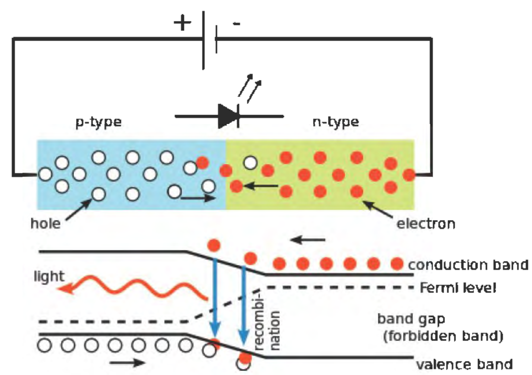
Illustration of Haitz's law, showing improvement in light output per LED over time, with a logarithmic scale on the vertical axis

Light output and efficiency of blue and near-ultraviolet LEDs rose as the cost of reliable devices fell. This led to relatively high-power white-light LEDs for illumination, which are replacing incandescent and fluorescent lighting.[45][46]

Experimental white LEDs have been demonstrated to produce over 300 lumens per watt of electricity; some can last up to 100,000 hours.[47] Compared to incandescent bulbs, this is not only a huge increase in electrical efficiency but – over time – a similar or lower cost per bulb.[48]

Working principle

A P-N junction can convert absorbed light energy into a proportional electric current. The same process is reversed here (i.e. the P-N junction emits light when electrical energy is applied to it). This phenomenon is generally called electroluminescence, which can be defined as the emission of light from a semiconductor under the influence of an electric field. The charge carriers recombine in a forward-biased P-N junction as the electrons cross from the N-region and recombine with the holes existing in the P-region. Free electrons are in the conduction band of energy levels, while holes are in the valence energy band. Thus the energy level of the holes is less than the energy levels of the electrons. Some portion of the energy must be dissipated to recombine the electrons and the holes. This energy is emitted in the form of heat and light.



The inner workings of an LED, showing circuit (top) and band diagram (bottom)

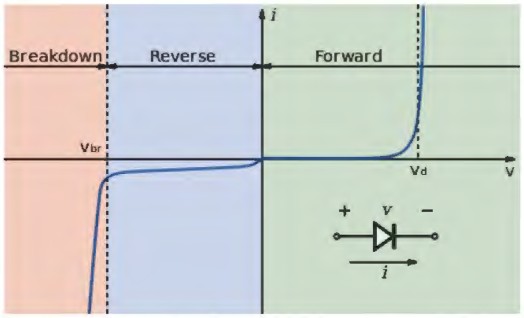
The electrons dissipate energy in the form of heat for silicon and germanium diodes but in gallium arsenide phosphide (GaAsP) and gallium phosphide (GaP) semiconductors, the electrons dissipate energy by emitting photons. If the semiconductor is translucent, the junction becomes the source of light as it is emitted, thus becoming a light-emitting diode. However, when the junction is reverse biased, the LED produces no light and—if the potential is great enough, the device is damaged.

Technology

Physics

The LED consists of a chip of semiconducting material doped with impurities to create a *p-n junction*. As in other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse direction. Charge-carriers—electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level and releases energy in the form of a photon.

The wavelength of the light emitted, and thus its color, depends on the band gap energy of the materials forming the *p-n junction*. In silicon or germanium diodes, the electrons and holes usually recombine by a *non-radiative transition*, which produces no optical emission, because these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible, or near-ultraviolet light.



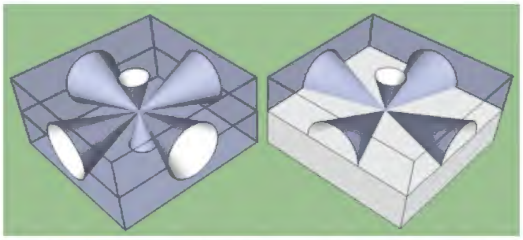
I-V diagram for a diode. An LED begins to emit light when more than 2 or 3 volts is applied. The reverse bias region uses a different vertical scale from the forward bias region to show that the leakage current is nearly constant with voltage until breakdown occurs. In forward bias, the current is small but increases exponentially with voltage.

LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have enabled making devices with ever-shorter wavelengths, emitting light in a variety of colors.

LEDs are usually built on an n-type substrate, with an electrode attached to the p-type layer deposited on its surface. P-type substrates, while less common, occur as well. Many commercial LEDs, especially GaN/InGaN, also use sapphire substrate.

Refractive index

Bare uncoated semiconductors such as silicon exhibit a very high refractive index relative to open air, which prevents passage of photons arriving at sharp angles relative to the air-contacting surface of the semiconductor due to total internal reflection. This property affects both the light-emission efficiency of LEDs as well as the light-absorption efficiency of photovoltaic cells. The refractive index of silicon is 3.96 (at 590 nm),[50] while air is 1.0002926.[51]


Idealized example of light emission cones in a simple square semiconductor, for a single point-source emission zone. The left illustration is for a translucent wafer, while the right illustration shows the half-cones formed when the bottom layer is opaque. The light is actually emitted equally in all directions from the point-source, but can only escape perpendicular to the semiconductor's surface and some degrees to the side, which is illustrated by the cone shapes. When the critical angle is exceeded, photons are reflected internally. The areas between the cones represent the trapped light energy wasted as heat.[49]

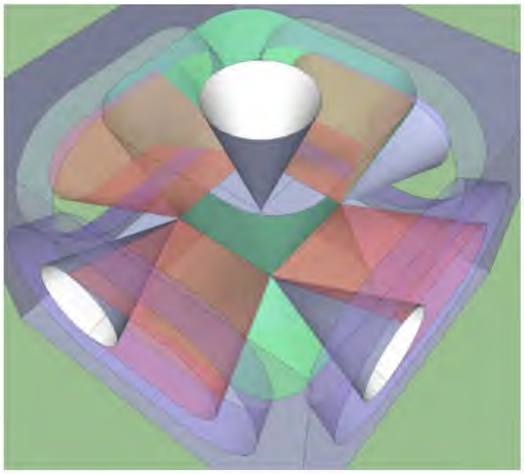
In general, a flat-surface uncoated LED semiconductor chip emits light only perpendicular to the semiconductor's surface, and a few degrees to the side, in a cone shape referred to as the *light cone*, *cone of light*,[52] or the *escape cone*.[49] The maximum angle of incidence is referred to as the critical angle. When this angle is exceeded, photons no longer escape the semiconductor but are instead reflected internally inside the semiconductor crystal as if it were a mirror.[49]

Internal reflections can escape through other crystalline faces if the incidence angle is low enough and the crystal is sufficiently transparent to not re-absorb the photon emission. But for a simple square LED with 90-degree angled surfaces on all sides, the faces all act as equal angle mirrors. In this case, most of the light can not escape and is lost as waste heat in the crystal.[49]

A convoluted chip surface with angled facets similar to a jewel or fresnel lens can increase light output by distributing light perpendicular to the chip surface and far to the sides of the photon emission point.[53]

The ideal shape of a semiconductor with maximum light output would be a microsphere with the photon emission occurring at the exact center, with electrodes penetrating to the center to contact at the emission point. All light rays emanating from the center would be perpendicular to the entire surface of the sphere, resulting in no internal reflections. A hemispherical semiconductor would also work, with the flat back-surface serving as a mirror to back-scattered photons.[54]

Transition coatings



Most materials used for LED production have very high refractive indices. This means that much of the light is reflected back into the material at the material/air surface interface. Thus, light extraction in LEDs is an important aspect of LED production, subject to much research and development. The light emission cones of a real LED wafer are far more complex than a single point-source light emission. The light emission zone is typically a two-dimensional plane between the wafers. Every atom across this plane has an individual set of emission cones. Drawing the billions of overlapping cones is impossible, so this is a simplified diagram showing the extents of all the emission cones combined. The larger side cones are clipped to show the interior features and reduce image complexity; they would extend to the opposite edges of the two-dimensional emission plane.

After the doping of the wafer, it is cut apart into individual dies. Each die is commonly called a chip.

Many LED semiconductor chips are encapsulated or potted in clear or colored molded plastic shells. The plastic shell has three purposes:

1. Mounting the semiconductor chip in devices is easier to accomplish.
2. The tiny fragile electrical wiring is physically supported and protected from damage.
3. The plastic acts as a refractive intermediary between the relatively high-index semiconductor and low-index open air.[55]

The third feature helps to boost the light emission from the semiconductor by acting as a diffusing lens, emitting light at a much higher angle of incidence from the light cone than the bare chip would alone.

Efficiency and operational parameters

Typical indicator LEDs are designed to operate with no more than 30–60 milliwatts (mW) of electrical power. Around 1999, Philips Lumileds introduced power LEDs capable of continuous use at one watt. These LEDs used much larger semiconductor die sizes to handle the large power inputs. Also, the semiconductor dies were mounted onto metal slugs to allow for heat removal from the LED die.

One of the key advantages of LED-based lighting sources is high luminous efficacy. White LEDs quickly matched and overtook the efficacy of standard incandescent lighting systems. In 2002, Lumileds made five-watt LEDs available with luminous efficacy of 18–22 lumens per watt (lm/W). For comparison, a conventional incandescent light bulb of 60–100 watts emits around 15 lm/W, and standard fluorescent lights emit up to 100 lm/W.

As of 2012, Philips had achieved the following efficacies for each color.[56] The efficiency values show the physics – light power out per electrical power in. The lumen-per-watt efficacy value includes characteristics of the human eye and is derived using the luminosity function.

	Color	Wavelength range (nm)	Typical efficiency coefficient	Typical efficacy (lm/W)
	Red	$620 < \lambda < 645$	0.39	72
	Red-orange	$610 < \lambda < 620$	0.29	98
	Green	$520 < \lambda < 550$	0.15	93
	Cyan	$490 < \lambda < 520$	0.26	75
	Blue	$460 < \lambda < 490$	0.35	37

In September 2003, a new type of blue LED was demonstrated by Cree that consumes 24 mW at 20 milliamperes (mA). This produced a commercially packaged white light giving 65 lm/W at 20 mA, becoming the brightest white LED commercially available at the time, and more than four times as efficient as standard incandescents. In 2006, they demonstrated a prototype with a record white LED luminous efficacy of 131 lm/W at 20 mA. Nichia Corporation has developed a white LED with luminous efficacy of 150 lm/W at a forward current of 20 mA.[57] Cree's XLamp XM-L LEDs, commercially available in 2011, produce 100 lm/W at their full power of 10 W, and up to 160 lm/W at around 2 W input power. In 2012, Cree announced a white LED giving 254 lm/W,[58] and 303 lm/W in March 2014.[59] Practical general lighting needs high-power LEDs, of one watt or more. Typical operating currents for such devices begin at 350 mA.

These efficiencies are for the light-emitting diode only, held at low temperature in a lab. Since LEDs installed in real fixtures operate at higher temperature and with driver losses, real-world efficiencies are much lower. United States Department of Energy (DOE) testing of commercial LED lamps designed to replace incandescent lamps or CFLs showed that average efficacy was still about 46 lm/W in 2009 (tested performance ranged from 17 lm/W to 79 lm/W).[60]

Efficiency droop

Efficiency droop is the decrease in luminous efficiency of LEDs as the electric current increases above tens of milliamperes.

This effect was initially theorized to be related to elevated temperatures. Scientists proved the opposite is true: though the life of an LED would be shortened, the efficiency droop is less severe at elevated temperatures.[61] The mechanism causing efficiency droop was identified in 2007 as Auger recombination, which was taken with mixed reaction.[62] In 2013, a study confirmed Auger recombination as the cause of efficiency droop.[63]

In addition to being less efficient, operating LEDs at higher electric currents creates higher heat levels, which can compromise LED lifetime. Because of this increased heat at higher currents, high-brightness LEDs have an industry standard of operating at only 350 mA, which is a compromise between light output, efficiency, and longevity.[62][64][65][66]

Possible solutions

Instead of increasing current levels, luminance is usually increased by combining multiple LEDs in one bulb. Solving the problem of efficiency droop would mean that household LED light bulbs would need fewer LEDs, which would significantly reduce costs.

Researchers at the U.S. Naval Research Laboratory have found a way to lessen the efficiency droop. They found that the droop arises from non-radiative Auger recombination of the injected carriers. They created quantum wells with a soft confinement potential to lessen the non-radiative Auger processes.[67]

Researchers at Taiwan National Central University and Epistar Corp are developing a way to lessen the efficiency droop by using ceramic aluminium nitride (AlN) substrates, which are more thermally conductive than the commercially used sapphire. The higher thermal conductivity reduces self-heating effects.[68]

Lifetime and failure

Solid-state devices such as LEDs are subject to very limited wear and tear if operated at low currents and at low temperatures. Typical lifetimes quoted are 25,000 to 100,000 hours, but heat and current settings can extend or shorten this time significantly.[69]

The most common symptom of LED (and diode laser) failure is the gradual lowering of light output and loss of efficiency. Sudden failures, although rare, can also occur. Early red LEDs were notable for their short service life. With the development of high-power LEDs, the devices are subjected to higher junction temperatures and higher current densities than traditional devices. This causes stress on the material and may cause early light-output degradation. To quantify useful lifetime in a standardized manner, some suggest using L70 or L50, which are runtimes (typically in thousands of hours) at which a given LED reaches 70% and 50% of initial light output, respectively.[70]

Whereas in most previous sources of light (incandescent lamps, discharge lamps, and those that burn combustible fuel, e.g. candles and oil lamps) the light results from heat, LEDs only operate if they are kept cool enough. The manufacturer commonly specifies a maximum junction temperature of 125 or 150 °C, and lower temperatures are advisable in the interests of long life. At these temperatures, relatively little heat is lost by radiation, which means that the light beam generated by an LED is cool.

The waste heat in a high-power LED (which as of 2015 can be less than half the power that it consumes) is conveyed by conduction through the substrate and package of the LED to a heat sink, which gives up the heat to the ambient air by convection. Careful thermal design is, therefore, essential, taking into account the thermal resistances of the LED's package, the heat sink and the interface between the two. Medium-power LEDs are often designed to solder directly to a printed circuit board that contains a thermally conductive metal layer. High-power LEDs are packaged in large-area ceramic packages that attach to a metal heat sink—the interface being a material with high thermal conductivity (thermal grease, phase-change material, thermally conductive pad, or thermal adhesive).

If an LED-based lamp is installed in an unventilated luminaire, or a luminaire is located in an environment that does not have free air circulation, the LED is likely to overheat, resulting in reduced life or early catastrophic failure. Thermal design is often based on an ambient temperature of 25 °C (77 °F). LEDs used in outdoor applications, such as traffic signals or in-pavement signal lights, and in climates where the temperature within the light fixture gets very high, could experience reduced output or even failure.[71]

Since LED efficacy is higher at low temperatures, LED technology is well suited for supermarket freezer lighting.[72][73][74] Because LEDs produce less waste heat than incandescent lamps, their use in freezers can save on refrigeration costs as well. However, they may be more susceptible to frost and snow buildup than incandescent lamps,[71] so some LED lighting systems have been designed with an added heating circuit. Additionally, research has developed heat sink technologies that transfer heat produced within the junction to appropriate areas of the light fixture.[75]

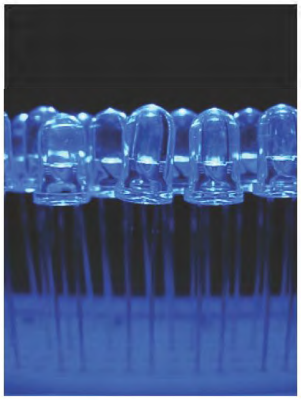
Colors and materials

Conventional LEDs are made from a variety of inorganic semiconductor materials. The following table shows the available colors with wavelength range, voltage drop, and material:

	Color	Wavelength [nm]	Voltage drop [ΔV]	Semiconductor material
	Infrared	$\lambda > 760$	$\Delta V < 1.63$	Gallium arsenide (GaAs) Aluminium gallium arsenide (AlGaAs)
	Red	$610 < \lambda < 760$	$1.63 < \Delta V < 2.03$	Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
	Orange	$590 < \lambda < 610$	$2.03 < \Delta V < 2.10$	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
	Yellow	$570 < \lambda < 590$	$2.10 < \Delta V < 2.18$	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
	Green	$500 < \lambda < 570$	1.9[76] $< \Delta V < 4.0$	**Traditional green:** Gallium(III) phosphide (GaP) Aluminium gallium indium phosphide (AlGaInP) Aluminium gallium phosphide (AlGaP) **Pure green:** Indium gallium nitride (InGaN) / Gallium(III) nitride (GaN)
	Blue	$450 < \lambda < 500$	$2.48 < \Delta V < 3.7$	Zinc selenide (ZnSe) Indium gallium nitride (InGaN) Silicon carbide (SiC) as substrate Silicon (Si) as substrate—under development
	Violet	$400 < \lambda < 450$	$2.76 < \Delta V < 4.0$	Indium gallium nitride (InGaN)
	Ultraviolet	$\lambda < 400$	$3 < \Delta V < 4.1$	Indium gallium nitride (InGaN) (385-400 nm) Diamond (235 nm)[77] Boron nitride (215 nm)[78][79] Aluminium nitride (AlN) (210 nm)[80] Aluminium gallium nitride (AlGaN) Aluminium gallium indium nitride (AlGaInN)—down to 210 nm[81]
	Pink	Multiple types	$\Delta V \approx 3.3$[82]	Blue with one or two phosphor layers, yellow with red, orange or pink phosphor added afterwards, white with pink plastic, or white phosphors with pink pigment or dye over top.[83]
	Purple	Multiple types	$2.48 < \Delta V < 3.7$	Dual blue/red LEDs, blue with red phosphor, or white with purple plastic
	White	Broad spectrum	$2.8 < \Delta V < 4.2$	**Cool / Pure White:** Blue/UV diode with yellow phosphor **Warm White:** Blue diode with orange phosphor

Blue and ultraviolet

The first blue-violet LED using magnesium-doped gallium nitride was made at Stanford University in 1972 by Herb Maruska and Wally Rhines, doctoral students in materials science and engineering.[84][85] At the time Maruska was on leave from RCA Laboratories, where he collaborated with Jacques Pankove on related work. In 1971, the year after Maruska left for Stanford, his RCA colleagues Pankove and Ed Miller demonstrated the first blue electroluminescence from zinc-doped gallium nitride, though the subsequent device Pankove and Miller built, the first actual gallium nitride light-emitting diode, emitted green light.[86][87] In 1974 the U.S. Patent Office awarded Maruska, Rhines and Stanford professor David Stevenson a patent for their work in 1972 (U.S. Patent US3819974 A (http://www.google.co m/patents/US3819974)) and today, magnesium-doping of gallium nitride remains the basis for all commercial blue LEDs and laser diodes. In the early 1970s, these devices were too dim for practical use, and research into gallium nitride devices slowed. In August 1989, Cree introduced the first commercially available blue LED based on the indirect bandgap semiconductor, silicon carbide (SiC).[88] SiC LEDs had very low efficiency, no more than about 0.03%, but did emit in the blue portion of the visible light spectrum.



Blue LEDs

In the late 1980s, key breakthroughs in GaN epitaxial growth and p-type doping[89] ushered in the modern era of GaN-based optoelectronic devices. Building upon this foundation, Theodore Moustakas at Boston University patented a method for producing high-brightness blue LEDs using a new two-step process.[90] Two years later, in 1993, high-brightness blue LEDs were demonstrated again by Shuji Nakamura of Nichia Corporation using a gallium nitride growth process similar to Moustakas's.[91] Both Moustakas and Nakamura were issued separate patents, which confused the issue of who was the original inventor (partly because although Moustakas invented his first, Nakamura filed first). This new development revolutionized LED lighting, making high-power blue light sources practical, leading to the development of technologies like Blu-ray, as well as allowing the bright high-resolution screens of modern tablets and phones.

External video

"The Original Blue LED" (https://vimeo.com/109205062), Chemical Heritage Foundation

Nakamura was awarded the 2006 Millennium Technology Prize for his invention.[92] Nakamura, Hiroshi Amano and Isamu Akasaki were awarded the Nobel Prize in Physics in 2014 for the invention of the blue LED.[93][94][95] In 2015, a US court ruled that three companies (i.e. the litigants who had not previously settled out of court) that had licensed Nakamura's patents for production in the United States had infringed Moustakas's prior patent, and ordered them to pay licensing fees of not less than 13 million USD.[96]

By the late 1990s, blue LEDs became widely available. They have an active region consisting of one or more InGaN quantum wells sandwiched between thicker layers of GaN, called cladding layers. By varying the relative In/Ga fraction in the InGaN quantum wells, the light emission can in theory be varied from violet to amber. Aluminium gallium nitride (AlGaN) of varying Al/Ga fraction can be used to manufacture the cladding and quantum well layers for ultraviolet LEDs, but these devices have not yet reached the level of efficiency and technological maturity of InGaN/GaN blue/green devices. If un-alloyed GaN is used in this case to form the active quantum well layers, the device emits near-ultraviolet light with a peak wavelength centred around 365 nm. Green LEDs manufactured from the InGaN/GaN system are far more efficient and brighter than green LEDs produced with non-nitride material systems, but practical devices still exhibit efficiency too low for high-brightness applications.

With nitrides containing aluminium, most often AlGaN and AlGaInN, even shorter wavelengths are achievable. Ultraviolet LEDs in a range of wavelengths are becoming available on the market. Near-UV emitters at wavelengths around 375–395 nm are already cheap and often encountered, for example, as black light lamp replacements for inspection of anti-counterfeiting UV watermarks in some documents and paper currencies. Shorter-wavelength diodes, while substantially more expensive, are commercially available for wavelengths down to 240 nm.[97] As the photosensitivity of microorganisms approximately matches the absorption spectrum of DNA, with a peak at about 260 nm, UV LED emitting at 250–270 nm are to be expected in prospective disinfection and sterilization devices. Recent research has shown that commercially available UVA LEDs (365 nm) are already effective disinfection and sterilization devices.[98] UV-C wavelengths were obtained in laboratories using aluminium nitride (210 nm),[80] boron nitride (215 nm)[78][79] and diamond (235 nm).[77]

RGB

RGB LEDs consist of one red, one green, and one blue LED.[99] By independently adjusting each of the three, RGB LEDs are capable of producing a wide color gamut. Unlike dedicated-color LEDs, however, these obviously do not produce pure wavelengths. Moreover, such modules as commercially available are often not optimized for smooth color mixing.

RGB-SMD-LED

White

There are two primary ways of producing white light-emitting diodes (WLEDs), LEDs that generate high-intensity white light. One is to use individual LEDs that emit three primary colors[100]—red, green, and blue—and then mix all the colors to form white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light, much in the same way a fluorescent light bulb works. It is important to note that the 'whiteness' of the light produced is essentially engineered to suit the human eye, and depending on the situation it may not always be appropriate to think of it as white light.

There are three main methods of mixing colors to produce white light from an LED:

- blue LED + green LED + red LED (color mixing; can be used as backlighting for displays, extremely poor for illumination due to gaps in spectrum)
- near-UV or UV LED + RGB phosphor (an LED producing light with a wavelength shorter than blue's is used to excite an RGB phosphor)
- blue LED + yellow phosphor (two complementary colors combine to form white light; more efficient than first two methods and more commonly used)[101]

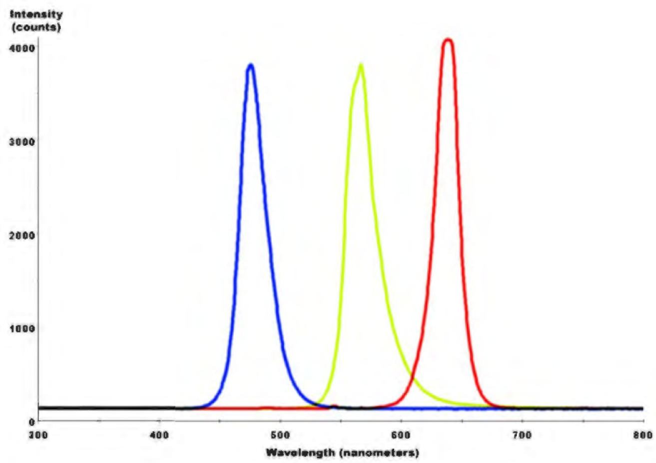
Because of metamerism, it is possible to have quite different spectra that appear white. However, the appearance of objects illuminated by that light may vary as the spectrum varies, this is the issue of Colour rendition, quite separate from Colour Temperature, where a really orange or cyan object could appear with the wrong colour and much darker as the LED or phosphor does not emit the wavelength it reflects. The best colour rendition CFL and LEDs use a mix of phosphors, resulting in less efficiency but better quality of light. Though incandescent halogen lamps have a more orange colour temperature, they are still the best easily available artificial light sources in terms of colour rendition.

RGB systems

White light can be formed by mixing differently colored lights; the most common method is to use red, green, and blue (RGB). Hence the method is called multi-color white LEDs (sometimes referred to as RGB LEDs). Because these need electronic circuits to control the blending and diffusion of different colors, and because the individual color LEDs typically have slightly different emission patterns (leading to variation of the color depending on direction) even if they are made as a single unit, these are seldom used to produce white lighting. Nonetheless, this method has many applications because of the flexibility of mixing different colors,[102] and in principle, this mechanism also has higher quantum efficiency in producing white light.

There are several types of multi-color white LEDs: di-, tri-, and tetrachromatic white LEDs. Several key factors that play among these different methods include color stability, color rendering capability, and luminous efficacy. Often, higher efficiency means lower color rendering, presenting a trade-off between the luminous efficacy and color rendering. For example, the dichromatic white LEDs have the best luminous efficacy (120 lm/W), but the lowest color rendering capability. However, although tetrachromatic white LEDs have excellent color rendering capability, they often have poor luminous efficacy. Trichromatic white LEDs are in between, having both good luminous efficacy (>70 lm/W) and fair color rendering capability.

One of the challenges is the development of more efficient green LEDs. The theoretical maximum for green LEDs is 683 lumens per watt but as of 2010 few green LEDs exceed even 100 lumens per watt. The blue and red LEDs get closer to their theoretical limits.



Combined spectral curves for blue, yellow-green, and high-brightness red solid-state semiconductor LEDs. FWHM spectral bandwidth is approximately 24–27 nm for all three colors.

Multi-color LEDs offer not merely another means to form white light but a new means to form light of different colors. Most perceivable colors can be formed by mixing different amounts of three primary colors. This allows precise dynamic color control. As more effort is devoted to investigating this method, multi-color LEDs should have profound influence on the fundamental method that we use to produce and control light color. However, before this type of LED can play a role on the market, several technical problems must be solved. These include that this type of LED's emission power decays exponentially with rising temperature,[103] resulting in a substantial change in color stability. Such problems inhibit and may preclude industrial use. Thus, many new package designs aimed at solving this problem have been proposed and their results are now being reproduced by researchers and scientists. However multi-colour LEDs without phosphors can never provide good quality lighting because each LED is a narrow band source (see graph). LEDs without phosphor while a poorer solution for general lighting are the best solution for displays, either backlight of LCD, or direct LED based pixels.

RGB LED

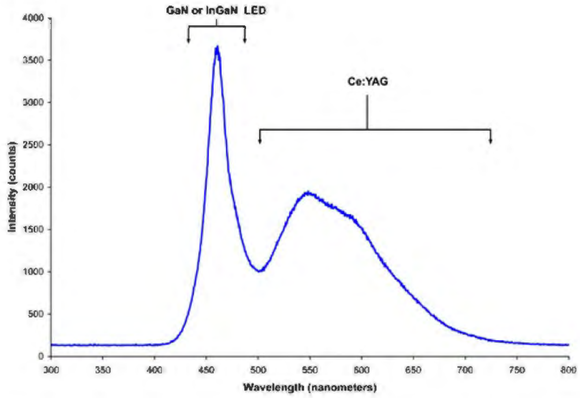
Correlated color temperature (CCT) dimming for LED technology is regarded as a difficult task since binning, age and temperature drift effects of LEDs change the actual color value output. Feedback loop systems are used for example with color sensors, to actively monitor and control the color output of multiple color mixing LEDs.[104]

Phosphor-based LEDs

This method involves coating LEDs of one color (mostly blue LEDs made of InGaN) with phosphors of different colors to form white light; the resultant LEDs are called phosphor-based or phosphor-converted white LEDs (pcLEDs).[105] A fraction of the blue light undergoes the Stokes shift being transformed from shorter wavelengths to longer. Depending on the color of the original LED, phosphors of different colors can be employed. If several phosphor layers of distinct colors are applied, the emitted spectrum is broadened, effectively raising the color rendering index (CRI) value of a given LED.[106]

Phosphor-based LED efficiency losses are due to the heat loss from the Stokes shift and also other phosphor-related degradation issues. Their luminous efficacies compared to normal LEDs depend on the spectral distribution of the resultant light output and the original wavelength of the LED itself. For example, the luminous efficacy of a typical YAG yellow phosphor based white LED ranges from 3 to 5 times the luminous efficacy of the original blue LED because of the human eye's greater sensitivity to yellow than to blue (as modeled in the luminosity function). Due to the simplicity of manufacturing, the phosphor method is still the most popular method for making high-intensity white LEDs. The design and production of a light source or light fixture using a monochrome emitter with phosphor conversion is simpler and cheaper than a complex RGB system, and the majority of high-intensity white LEDs presently on the market are manufactured using phosphor light conversion.

Among the challenges being faced to improve the efficiency of LED-based white light sources is the development of more efficient phosphors. As of 2010, the most efficient yellow phosphor is still the YAG phosphor, with less than 10% Stokes shift loss. Losses attributable to internal optical losses due to re-absorption in the LED chip and in the LED packaging itself account typically for another 10% to 30% of efficiency loss. Currently, in the area of phosphor LED development, much effort is being spent on optimizing these devices to higher light output and higher operation temperatures. For instance, the efficiency can be raised by adapting better package design or by using a more suitable type of phosphor. Conformal coating process is frequently used to address the issue of varying phosphor thickness.



Spectrum of a white LED showing blue light directly emitted by the GaN-based LED (peak at about 465 nm) and the more broadband Stokes-shifted light emitted by the Ce^{3+}:YAG phosphor, which emits at roughly 500–700 nm

Some phosphor-based white LEDs encapsulate InGaN blue LEDs inside phosphor-coated epoxy. Alternatively, the LED might be paired with a remote phosphor, a preformed polycarbonate piece coated with the phosphor material. Remote phosphors provide more diffuse light, which is desirable for many applications. Remote phosphor designs are also more tolerant of variations in the LED emissions spectrum. A common yellow phosphor material is cerium-doped yttrium aluminium garnet (Ce^{3+}:YAG).

White LEDs can also be made by coating near-ultraviolet (NUV) LEDs with a mixture of high-efficiency europium-based phosphors that emit red and blue, plus copper and aluminium-doped zinc sulfide (ZnS:Cu, Al) that emits green. This is a method analogous to the way fluorescent lamps work. This method is less efficient than blue LEDs with YAG:Ce phosphor, as the Stokes shift is larger, so more energy is converted to heat, but yields light with better spectral characteristics, which render color better. Due to the higher radiative output of the ultraviolet LEDs than of the blue ones, both methods offer comparable brightness. A concern is that UV light may leak from a malfunctioning light source and cause harm to human eyes or skin.

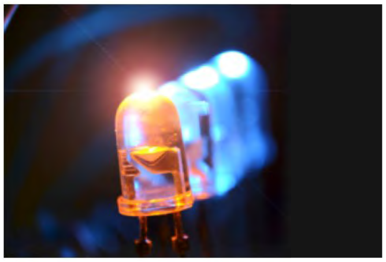
Other white LEDs

Another method used to produce experimental white light LEDs used no phosphors at all and was based on homoepitaxially grown zinc selenide (ZnSe) on a ZnSe substrate that simultaneously emitted blue light from its active region and yellow light from the substrate.[107]

A new style of wafers composed of gallium-nitride-on-silicon (GaN-on-Si) is being used to produce white LEDs using 200-mm silicon wafers. This avoids the typical costly sapphire substrate in relatively small 100- or 150-mm wafer sizes.[108] The sapphire apparatus must be coupled with a mirror-like collector to reflect light that would otherwise be wasted. It is predicted that by 2020, 40% of all GaN LEDs will be made with GaN-on-Si. Manufacturing large sapphire material is difficult, while large silicon material is cheaper and more abundant. LED companies shifting from using sapphire to silicon should be a minimal investment.[109]

Organic light-emitting diodes (OLEDs)

In an organic light-emitting diode (OLED), the electroluminescent material comprising the emissive layer of the diode is an organic compound. The organic material is electrically conductive due to the delocalization of pi electrons caused by conjugation over all or part of the molecule, and the material therefore functions as an organic semiconductor.[110] The organic materials can be small organic molecules in a crystalline phase, or polymers.[111]


Orange light-emitting diode

The potential advantages of OLEDs include thin, low-cost displays with a low driving voltage, wide viewing angle, and high contrast and color gamut.[112] Polymer LEDs have the added benefit of printable and flexible displays.[113][114][115] OLEDs have been used to make visual displays for portable electronic devices such as cellphones, digital cameras, and MP3 players while possible future uses include lighting and televisions.[111][112]

Quantum dot LEDs

Quantum dots (QD) are semiconductor nanocrystals with optical properties that let their emission color be tuned from the visible into the infrared spectrum.[116][117] This allows quantum dot LEDs to create almost any color on the CIE diagram. This provides more color options and better color rendering than white LEDs since the emission spectrum is much narrower, characteristic of quantum confined states.

There are two types of schemes for QD excitation. One uses photo excitation with a primary light source LED (typically blue or UV LEDs are used). The other is direct electrical excitation first demonstrated by Alivisatos et al.[118]

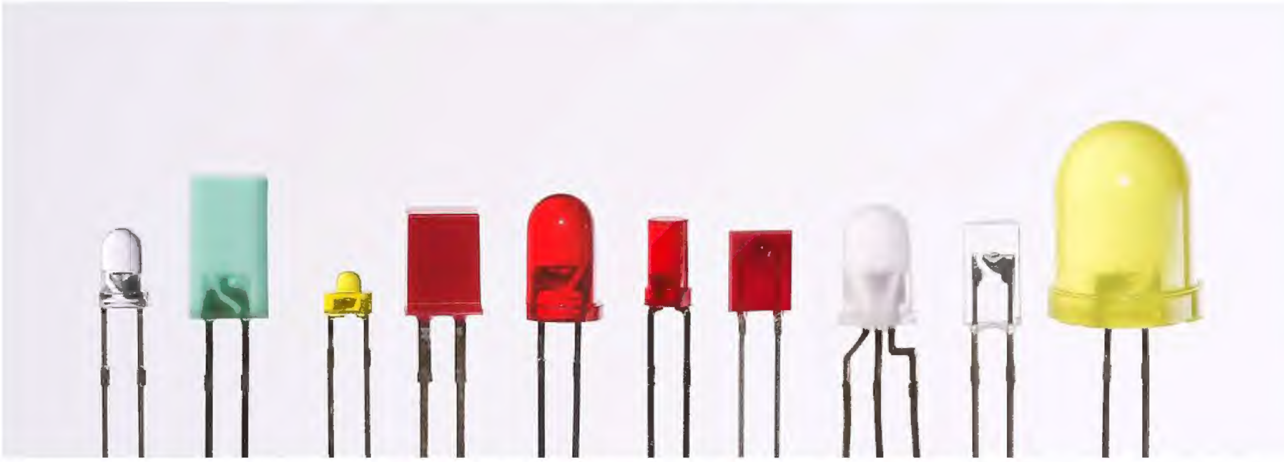
One example of the photo-excitation scheme is a method developed by Michael Bowers, at Vanderbilt University in Nashville, involving coating a blue LED with quantum dots that glow white in response to the blue light from the LED. This method emits a warm, yellowish-white light similar to that made by incandescent light bulbs.[119] Quantum dots are also being considered for use in white light-emitting diodes in liquid crystal display (LCD) televisions.[120]

In February 2011 scientists at PlasmaChem GmbH were able to synthesize quantum dots for LED applications and build a light converter on their basis, which was able to efficiently convert light from blue to any other color for many hundred hours.[121] Such QDs can be used to emit visible or near infrared light of any wavelength being excited by light with a shorter wavelength.

The structure of QD-LEDs used for the electrical-excitation scheme is similar to basic design of OLEDs. A layer of quantum dots is sandwiched between layers of electron-transporting and hole-transporting materials. An applied electric field causes electrons and holes to move into the quantum dot layer and recombine forming an exciton that excites a QD. This scheme is commonly studied for quantum dot display. The tunability of emission wavelengths and narrow bandwidth is also beneficial as excitation sources for fluorescence imaging. Fluorescence near-field scanning optical microscopy (NSOM) utilizing an integrated QD-LED has been demonstrated.[122]

In February 2008, a luminous efficacy of 300 lumens of visible light per watt of radiation (not per electrical watt) and warm-light emission was achieved by using nanocrystals.[123]

Types



LEDs are produced in a variety of shapes and sizes. The color of the plastic lens is often the same as the actual color of light emitted, but not always. For instance, purple plastic is often used for infrared LEDs, and most blue devices have colorless housings. Modern high-power LEDs such as those used for lighting and backlighting are generally found in surface-mount technology (SMT) packages (not shown).

The main types of LEDs are miniature, high-power devices and custom designs such as alphanumeric or multi-color.[124]

Miniature

These are mostly single-die LEDs used as indicators, and they come in various sizes from 2 mm to 8 mm, through-hole and surface mount packages. They usually do not use a separate heat sink.[125] Typical current ratings range from around 1 mA to above 20 mA. The small size sets a natural upper boundary on power consumption due to heat caused by the high current density and need for a heat sink. Often daisy chained as used in LED tapes.

Photo of miniature surface mount LEDs in most common sizes. They can be much smaller than a traditional 5 mm lamp type LED, shown on the upper left corner.

Common package shapes include round, with a domed or flat top, rectangular with a flat top (as used in bar-graph displays), and triangular or square with a flat top. The encapsulation may also be clear or tinted to improve contrast and viewing angle.

Researchers at the University of Washington have invented the thinnest LED. It is made of two-dimensional (2-D) flexible materials. It is three atoms thick, which is 10 to 20 times thinner than three-dimensional (3-D) LEDs and is also 10,000 times smaller than the thickness of a human hair. These 2-D LEDs are going to make it possible to create smaller, more energy-efficient lighting, optical communication and nano lasers.[126][127]

There are three main categories of miniature single die LEDs:

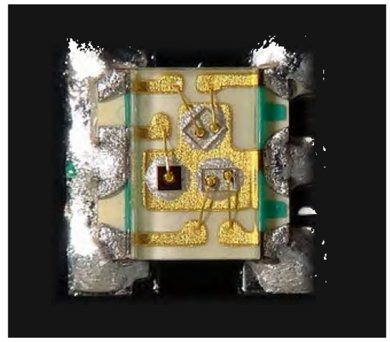
Low-current
: Typically rated for 2 mA at around 2 V (approximately 4 mW consumption)

Standard
: 20 mA LEDs (ranging from approximately 40 mW to 90 mW) at around:

- 1.9 to 2.1 V for red, orange, yellow, and traditional green
- 3.0 to 3.4 V for pure green and blue
- 2.9 to 4.2 V for violet, pink, purple and white

Ultra-high-output
: 20 mA at approximately 2 or 4–5 V, designed for viewing in direct sunlight

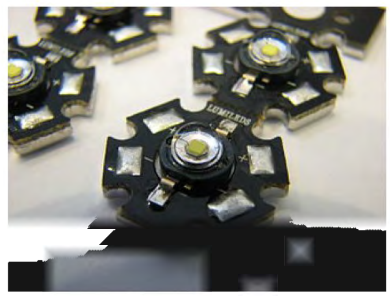
5 V and 12 V LEDs are ordinary miniature LEDs that incorporate a suitable series resistor for direct connection to a 5 V or 12 V supply.



Very small (1.6x1.6x0.35 mm) red, green, and blue surface mount miniature LED package with gold wire bonding details.

High-power

High-power LEDs (HP-LEDs) or high-output LEDs (HO-LEDs) can be driven at currents from hundreds of mA to more than an ampere, compared with the tens of mA for other LEDs. Some can emit over a thousand lumens.[128][129] LED power densities up to 300 W/cm^2 have been achieved.[130] Since overheating is destructive, the HP-LEDs must be mounted on a heat sink to allow for heat dissipation. If the heat from an HP-LED is not removed, the device fails in seconds. One HP-LED can often replace an incandescent bulb in a flashlight, or be set in an array to form a powerful LED lamp.



High-power light-emitting diodes attached to an LED star base (Luxeon, Lumileds)

Some well-known HP-LEDs in this category are the Nichia 19 series, Lumileds Rebel Led, Osram Opto Semiconductors Golden Dragon, and Cree X-lamp. As of September 2009, some HP-LEDs manufactured by Cree now exceed 105 lm/W.[131]

Examples for Haitz's law—which predicts an exponential rise in light output and efficacy of LEDs over time—are the CREE XP-G series LED, which achieved 105 lm/W in 2009[131] and the Nichia 19 series with a typical efficacy of 140 lm/W, released in 2010.[132]

AC driven

LEDs developed by Seoul Semiconductor can operate on AC power without a DC converter. For each half-cycle, part of the LED emits light and part is dark, and this is reversed during the next half-cycle. The efficacy of this type of HP-LED is typically 40 lm/W.[133] A large number of LED elements in series may be able to operate directly from line voltage. In 2009, Seoul Semiconductor released a high DC voltage LED, named as 'Acrich MJT', capable of being driven from AC power with a simple controlling circuit. The low-power dissipation of these LEDs affords them more flexibility than the original AC LED design.[134]

Application-specific variations

Flashing

Flashing LEDs are used as attention seeking indicators without requiring external electronics. Flashing LEDs resemble standard LEDs but they contain an integrated multivibrator circuit that causes the LED to flash with a typical period of one second. In diffused lens LEDs, this circuit is visible as a small black dot. Most flashing LEDs emit light of one color, but more sophisticated devices can flash between multiple colors and even fade through a color sequence using RGB color mixing.

Bi-color

Bi-color LEDs contain two different LED emitters in one case. There are two types of these. One type consists of two dies connected to the same two leads antiparallel to each other. Current flow in one direction emits one color, and current in the opposite direction emits the other color. The other type consists of two dies with separate leads for both dies and another lead for common anode or cathode so that they can be controlled independently. The most common bi-color combination is red/traditional green, however, other available combinations include amber/traditional green, red/pure green, red/blue, and blue/pure green.

Tri-color

Tri-color LEDs contain three different LED emitters in one case. Each emitter is connected to a separate lead so they can be controlled independently. A four-lead arrangement is typical with one common lead (anode or cathode) and an additional lead for each color.

RGB

RGB LEDs are tri-color LEDs with red, green, and blue emitters, in general using a four-wire connection with one common lead (anode or cathode). These LEDs can have either common positive leads in the case of a common anode LED, or common negative leads in the case of a common cathode LED. Others, however, have only two leads (positive and negative) and have a built-in tiny electronic control unit.

Decorative-multicolor

Decorative-multicolor LEDs incorporate several emitters of different colors supplied by only two lead-out wires. Colors are switched internally by varying the supply voltage.

Alphanumeric

Alphanumeric LEDs are available in seven-segment, starburst, and dot-matrix format. Seven-segment displays handle all numbers and a limited set of letters. Starburst displays can display all letters. Dot-matrix displays typically use 5x7 pixels per character. Seven-segment LED displays were in widespread use in the 1970s and 1980s, but rising use of liquid crystal displays, with their lower power needs and greater display flexibility, has reduced the popularity of numeric and alphanumeric LED displays.

Digital-RGB

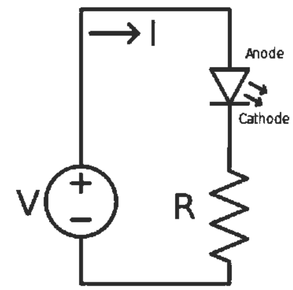
Digital-RGB LEDs are RGB LEDs that contain their own "smart" control electronics. In addition to power and ground, these provide connections for data-in, data-out, and sometimes a clock or strobe signal. These are connected in a daisy chain, with the data in of the first LED sourced by a microprocessor, which can control the brightness and color of each LED independently of the others. They are used where a combination of maximum control and minimum visible electronics are needed such as strings for Christmas and LED matrices. Some even have refresh rates in the kHz range, allowing for basic video applications.

Filament

An LED filament consists of multiple LED chips connected in series on a common longitudinal substrate that forms a thin rod reminiscent of a traditional incandescent filament.[135] These are being used as a low-cost decorative alternative for traditional light bulbs that are being phased out in many countries. The filaments require a rather high voltage to light to nominal brightness, allowing them to work efficiently and simply with mains voltages. Often a simple rectifier and capacitive current limiting are employed to create a low-cost replacement for a traditional light bulb without the complexity of the low voltage, high current converter that single die LEDs need.[136] Usually, they are packaged in a sealed enclosure with a shape similar to lamps they were designed to replace (e.g. a bulb) and filled with inert nitrogen or carbon dioxide gas to remove heat efficiently.

Considerations for use

Power sources



Simple LED circuit with resistor for current limiting

The current–voltage characteristic of an LED is similar to other diodes, in that the current is dependent exponentially on the voltage (see Shockley diode equation). This means that a small change in voltage can cause a large change in current.[137] If the applied voltage exceeds the LED's forward voltage drop by a small amount, the current rating may be exceeded by a large amount, potentially damaging or destroying the LED. The typical solution is to use constant-current power supplies to keep the current below the LED's maximum current rating. Since most common power sources (batteries, mains) are constant-voltage sources, most LED fixtures must include a power converter, at least a current-limiting resistor. However, the high resistance of three-volt coin cells combined with the high differential resistance of nitride-based LEDs makes it possible to power such an LED from such a coin cell without an external resistor.

Electrical polarity

As with all diodes, current flows easily from p-type to n-type material.[138] However, no current flows and no light is emitted if a small voltage is applied in the reverse direction. If the reverse voltage grows large enough to exceed the breakdown voltage, a large current flows and the LED may be damaged. If the reverse current is sufficiently limited to avoid damage, the reverse-conducting LED is a useful noise diode.

Safety and health

The vast majority of devices containing LEDs are "safe under all conditions of normal use", and so are classified as "Class 1 LED product"/"LED Klasse 1". At present, only a few LEDs—extremely bright LEDs that also have a tightly focused viewing angle of 8° or less—could, in theory, cause temporary blindness, and so are classified as "Class 2".[139] The opinion of the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) of 2010, on the health issues concerning LEDs, suggested banning public use of lamps in the moderate Risk Group 2, especially those with a high blue component, in places frequented by children.[140] [141]

In general, laser safety regulations—and the "Class 1", "Class 2", etc. system—also apply to LEDs.[142]

While LEDs have the advantage over fluorescent lamps that they do not contain mercury, they may contain other hazardous metals such as lead and arsenic. Regarding the toxicity of LEDs when treated as waste, a study published in 2011 stated: "According to federal standards, LEDs are not hazardous except for low-intensity red LEDs, which leached Pb [lead] at levels exceeding regulatory limits (186 mg/L; regulatory limit: 5). However, according to California regulations, excessive levels of copper (up to 3892 mg/kg; limit: 2500), lead (up to 8103 mg/kg; limit: 1000), nickel (up to 4797 mg/kg; limit: 2000), or silver (up to 721 mg/kg; limit: 500) render all except low-intensity yellow LEDs hazardous."[143]

In 2016 a statement of the American Medical Association (AMA) concerning the possible influence of blueish street lighting on the sleep-wake cycle of city-dwellers led to some controversy. So far high-pressure sodium lamps (HPS) with an orange light spectrum were the most efficient light sources commonly used in street-lighting. Now many modern street lamps are equipped with Indium gallium nitride LEDs (InGaN). These are even more efficient and mostly emit blue-rich light with a higher *correlated color temperature (CCT)*. Since light with a high CCT resembles daylight it is thought that this might have an effect on the normal circadian physiology by suppressing melatonin production in the human body. There have been no relevant studies as yet and critics claim exposure levels are not high enough to have a noticeable effect. [144]

Advantages

- **Efficiency:** LEDs emit more lumens per watt than incandescent light bulbs.[145] The efficiency of LED lighting fixtures is not affected by shape and size, unlike fluorescent light bulbs or tubes.
- **Color:** LEDs can emit light of an intended color without using any color filters as traditional lighting methods need. This is more efficient and can lower initial costs.
- **Size:** LEDs can be very small (smaller than 2 mm^2[146]) and are easily attached to printed circuit boards.
- **Warmup time:** LEDs light up very quickly. A typical red indicator LED achieves full brightness in under a microsecond.[147] LEDs used in communications devices can have even faster response times.
- **Cycling:** LEDs are ideal for uses subject to frequent on-off cycling, unlike incandescent and fluorescent lamps that fail faster when cycled often, or high-intensity discharge lamps (HID lamps) that require a long time before restarting.
- **Dimming:** LEDs can very easily be dimmed either by pulse-width modulation or lowering the forward current.[148] This pulse-width modulation is why LED lights, particularly headlights on cars, when viewed on camera or by some people, appear to be flashing or flickering. This is a type of stroboscopic effect.
- **Cool light:** In contrast to most light sources, LEDs radiate very little heat in the form of IR that can cause damage to sensitive objects or fabrics. Wasted energy is dispersed as heat through the base of the LED.
- **Slow failure:** LEDs mostly fail by dimming over time, rather than the abrupt failure of incandescent bulbs.[69]
- **Lifetime:** LEDs can have a relatively long useful life. One report estimates 35,000 to 50,000 hours of useful life, though time to complete failure may be longer.[149] Fluorescent tubes typically are rated at about 10,000 to 15,000 hours, depending partly on the conditions of use, and incandescent light bulbs at 1,000 to 2,000 hours. Several DOE demonstrations have shown that reduced maintenance costs from this extended lifetime, rather than energy savings, is the primary factor in determining the payback period for an LED product.[150]
- **Shock resistance:** LEDs, being solid-state components, are difficult to damage with external shock, unlike fluorescent and incandescent bulbs, which are fragile.
- **Focus:** The solid package of the LED can be designed to focus its light. Incandescent and fluorescent sources often require an external reflector to collect light and direct it in a usable manner. For larger LED packages total internal reflection (TIR) lenses are often used to the same effect. However, when large quantities of light are needed many light sources are usually deployed, which are difficult to focus or collimate towards the same target.

Disadvantages

- **Initial price:** LEDs are currently slightly more expensive (price per lumen) on an initial capital cost basis, than other lighting technologies. As of March 2014, at least one manufacturer claims to have reached $1 per kilolumen.[151] The additional expense partially stems from the relatively low lumen output and the drive circuitry and power supplies needed.
- **Temperature dependence:** LED performance largely depends on the ambient temperature of the operating environment – or thermal management properties. Overdriving an LED in high ambient temperatures may result in overheating the LED package, eventually leading to device failure. An adequate heat sink is needed to maintain long life. This is especially important in automotive, medical, and military uses where devices must operate over a wide range of temperatures, which require low failure rates. Toshiba has produced LEDs with an operating temperature range of −40 to 100 °C, which suits the LEDs for both indoor and outdoor use in applications such as lamps, ceiling lighting, street lights, and floodlights.[108]
- **Voltage sensitivity:** LEDs must be supplied with a voltage above their threshold voltage and a current below their rating. Current and lifetime change greatly with a small change in applied voltage. They thus require a current-regulated supply (usually just a series resistor for indicator LEDs).[152]
- **Color rendition:** Most cool-white LEDs have spectra that differ significantly from a black body radiator like the sun or an incandescent light. The spike at 460 nm and dip at 500 nm can cause the color of objects to be perceived differently under cool-white LED illumination than sunlight or incandescent sources, due to metamerism,[153] red surfaces being rendered particularly poorly by typical phosphor-based cool-white LEDs.
- **Area light source:** Single LEDs do not approximate a point source of light giving a spherical light distribution, but rather a lambertian distribution. So LEDs are difficult to apply to uses needing a spherical light field; however, different fields of light can be manipulated by the application of different optics or "lenses". LEDs cannot provide divergence below a few degrees. In contrast, lasers can emit beams with divergences of 0.2 degrees or less.[154]

- **Electrical polarity:** Unlike incandescent light bulbs, which illuminate regardless of the electrical polarity, LEDs only light with correct electrical polarity. To automatically match source polarity to LED devices, rectifiers can be used.
- **Blue hazard:** There is a concern that blue LEDs and cool-white LEDs are now capable of exceeding safe limits of the so-called blue-light hazard as defined in eye safety specifications such as ANSI/IESNA RP-27.1–05: Recommended Practice for Photobiological Safety for Lamp and Lamp Systems.[155][156]
- **Light pollution:** Because white LEDs, especially those with high color temperature, emit much more short wavelength light than conventional outdoor light sources such as high-pressure sodium vapor lamps, the increased blue and green sensitivity of scotopic vision means that white LEDs used in outdoor lighting cause substantially more sky glow.[134][157][158][159][160] The American Medical Association warned on the use of high blue content white LEDs in street lighting, due to their higher impact on human health and environment, compared to low blue content light sources (e.g. High-Pressure Sodium, PC amber LEDs, and low CCT LEDs).[161]
- **Efficiency droop:** The efficiency of LEDs decreases as the electric current increases. Heating also increases with higher currents, which compromises LED lifetime. These effects put practical limits on the current through an LED in high power applications.[62][64][65][162]
- **Impact on insects:** LEDs are much more attractive to insects than sodium-vapor lights, so much so that there has been speculative concern about the possibility of disruption to food webs.[163][164]
- **Use in winter conditions:** Since they do not give off much heat in comparison to incandescent lights, LED lights used for traffic control can have snow obscuring them, leading to accidents.[165][166]

Applications

LED uses fall into four major categories:

- Visual signals where light goes more or less directly from the source to the human eye, to convey a message or meaning
- Illumination where light is reflected from objects to give visual response of these objects
- Measuring and interacting with processes involving no human vision[167]
- Narrow band light sensors where LEDs operate in a reverse-bias mode and respond to incident light, instead of emitting light[168][169][170][171]

Indicators and signs

The low energy consumption, low maintenance and small size of LEDs has led to uses as status indicators and displays on a variety of equipment and installations. Large-area LED displays are used as stadium displays, dynamic decorative displays, and dynamic message signs on freeways. Thin, lightweight message displays are used at airports and railway stations, and as destination displays for trains, buses, trams, and ferries.

One-color light is well suited for traffic lights and signals, exit signs, emergency vehicle lighting, ships' navigation lights or lanterns (chromacity and luminance standards being set under the Convention on the International Regulations for Preventing Collisions at Sea 1972, Annex I and the CIE) and LED-based Christmas lights. In cold climates, LED traffic lights may remain snow-covered.[172] Red or yellow LEDs are used in indicator and alphanumeric displays in environments where night vision must be retained: aircraft cockpits, submarine and ship bridges, astronomy observatories, and in the field, e.g. night time animal watching and military field use.

Red and green LED traffic signals

Because of their long life, fast switching times, and visibility in broad daylight due to their high output and focus, LEDs have been used in brake lights for cars' high-mounted brake lights, trucks, and buses, and in turn signals for some time. However, many vehicles now use LEDs for their rear light clusters. The use in brakes improves safety, due to a great reduction in the time needed to light fully, or faster rise time, up to 0.5 second faster than an incandescent bulb. This gives drivers behind more time to react. In a dual intensity circuit (rear markers and brakes) if the LEDs are not pulsed at a fast enough frequency, they can create a phantom array, where ghost images of the LED appear if the eyes quickly scan across the array. White LED headlamps are beginning to appear. Using LEDs has styling advantages because LEDs can form much thinner lights than incandescent lamps with parabolic reflectors.

Automotive applications for LEDs continue to grow.

Due to the relative cheapness of low output LEDs, they are also used in many temporary uses such as glowsticks, throwies, and the photonic textile Lumalive. Artists have also used LEDs for LED art.

Weather and all-hazards radio receivers with Specific Area Message Encoding (SAME) have three LEDs: red for warnings, orange for watches, and yellow for advisories and statements whenever issued.

Lighting

With the development of high-efficiency and high-power LEDs, it has become possible to use LEDs in lighting and illumination. To encourage the shift to LED lamps and other high-efficiency lighting, the US Department of Energy has created the L Prize competition. The Philips Lighting North America LED bulb won the first competition on August 3, 2011, after successfully completing 18 months of intensive field, lab, and product testing.[173]

LEDs are used as street lights and in other architectural lighting. The mechanical robustness and long lifetime are used in automotive lighting on cars, motorcycles, and bicycle lights. LED light emission may be efficiently controlled by using nonimaging optics principles.

LED street lights are employed on poles and in parking garages. In 2007, the Italian village of Torraca was the first place to convert its entire illumination system to LEDs.[174]

LEDs are used in aviation lighting. Airbus has used LED lighting in its Airbus A320 Enhanced since 2007, and Boeing uses LED lighting in the 787. LEDs are also being used now in airport and heliport lighting. LED airport fixtures currently include medium-intensity runway lights, runway centerline lights, taxiway centerline and edge lights, guidance signs, and obstruction lighting.

LEDs are also used as a light source for DLP projectors, and to backlight LCD televisions (referred to as LED TVs) and laptop displays. RGB LEDs raise the color gamut by as much as 45%. Screens for TV and computer displays can be made thinner using LEDs for backlighting.[175]

The lack of IR or heat radiation makes LEDs ideal for stage lights using banks of RGB LEDs that can easily change color and decrease heating from traditional stage lighting, as well as medical lighting where IR-radiation can be harmful. In energy conservation, the lower heat output of LEDs also means air conditioning (cooling) systems have less heat in need of disposal.

LEDs are small, durable and need little power, so they are used in handheld devices such as flashlights. LED strobe lights or camera flashes operate at a safe, low voltage, instead of the 250+ volts commonly found in xenon flashlamp-based lighting. This is especially useful in cameras on mobile phones, where space is at a premium and bulky voltage-raising circuitry is undesirable.

LEDs are used for infrared illumination in night vision uses including security cameras. A ring of LEDs around a video camera, aimed forward into a retroreflective background, allows chroma keying in video productions.

LEDs are used in mining operations, as cap lamps to provide light for miners. Research has been done to improve LEDs for mining, to reduce glare and to increase illumination, reducing risk of injury to the miners.[176]

LEDs are now used commonly in all market areas from commercial to home use: standard lighting, AV, stage, theatrical, architectural, and public installations, and wherever artificial light is used.

LEDs are increasingly finding uses in medical and educational applications, for example as mood enhancement, and new technologies such as AmBX, exploiting LED versatility. NASA has even sponsored research for the use of LEDs to promote health for astronauts.[177]

LED for miners, to increase visibility inside mines

Data communication and other signalling

Light can be used to transmit data and analog signals. For example, lighting white LEDs can be used in systems assisting people to navigate in closed spaces while searching necessary rooms or objects.[178]

Assistive listening devices in many theaters and similar spaces use arrays of infrared LEDs to send sound to listeners' receivers. Light-emitting diodes (as well as semiconductor lasers) are used to send data over many types of fiber optic cable, from digital audio over TOSLINK cables to the very high bandwidth fiber links that form the Internet backbone. For some time, computers were commonly equipped with IrDA interfaces, which allowed them to send and receive data to nearby machines via infrared.

Because LEDs can cycle on and off millions of times per second, very high data bandwidth can be achieved.[179]

Sustainable lighting

Efficient lighting is needed for sustainable architecture. In 2009, US Department of Energy testing results on LED lamps showed an average efficacy of 35 lm/W, below that of typical CFLs, and as low as 9 lm/W, worse than standard incandescent bulbs. A typical 13-watt LED lamp emitted 450 to 650 lumens,[180] which is equivalent to a standard 40-watt incandescent bulb.

However, as of 2011, there are LED bulbs available as efficient as 150 lm/W and even inexpensive low-end models typically exceed 50 lm/W, so that a 6-watt LED could achieve the same results as a standard 40-watt incandescent bulb. The latter has an expected lifespan of 1,000 hours, whereas an LED can continue to operate with reduced efficiency for more than 50,000 hours.

See the chart below for a comparison of common light types:

	LED	CFL	Incandescent
Lightbulb Projected Lifespan	50,000 hours	10,000 hours	1,200 hours
Watts Per Bulb (equiv. 60 watts)	10	14	60
Cost Per Bulb	$2.00	$7.00	$1.25
kWh of Electricity Used Over 50,000 Hours	500	700	3000
Cost of Electricity (@ 0.10 per kWh)	$50	$70	$300
Bulbs Needed for 50,000 Hours of Use	1	5	42
Equivalent 50,000 Hours Bulb Expense	$2.00	$35.00	$52.50
TOTAL Cost for 50,000 Hours	$52.00	$105.00	$352.50

Energy consumption

In the US, one kilowatt-hour (3.6 MJ) of electricity currently causes an average 1.34 pounds (610 g) of CO_2 emission.[181] Assuming the average light bulb is on for 10 hours a day, a 40-watt bulb causes 196 pounds (89 kg) of CO_2 emission per year. The 6-watt LED equivalent only causes 30 pounds (14 kg) of CO_2 over the same time span. A building's carbon footprint from lighting can, therefore, be reduced by 85% by exchanging all incandescent bulbs for new LEDs—if a building previously used only incandescent bulbs.

In practice, most buildings that use a lot of lighting use fluorescent lighting, which has 22% luminous efficiency compared with 5% for filaments, so changing to LED lighting would still give a 34% reduction in electrical power use and carbon emissions.

The reduction in carbon emissions depends on the source of electricity. Nuclear power in the United States produced 19.2% of electricity in 2011, so reducing electricity consumption in the U.S. reduces carbon emissions more than in France (75% nuclear electricity) or Norway (almost entirely hydroelectric).

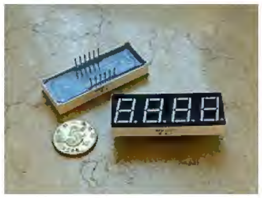
Replacing lights that spend the most time lit results in the most savings, so LED lights in infrequently used locations bring a smaller return on investment.

Light sources for machine vision systems

Machine vision systems often require bright and homogeneous illumination, so features of interest are easier to process. LEDs are often used for this purpose, and this is likely to remain one of their major uses until the price drops low enough to make signaling and illumination uses more widespread. Barcode scanners are the most common example of machine vision, and many low-cost products use red LEDs instead of lasers.[182] Optical computer mice are an example of LEDs in machine vision, as it is used to provide an even light source on the surface for the miniature camera within the mouse. LEDs constitute a nearly ideal light source for machine vision systems for several reasons:

- The size of the illuminated field is usually comparatively small and machine vision systems are often quite expensive, so the cost of the light source is usually a minor concern. However, it might not be easy to replace a broken light source placed within complex machinery, and here the long service life of LEDs is a benefit.
- LED elements tend to be small and can be placed with high density over flat or even-shaped substrates (PCBs etc.) so that bright and homogeneous sources that direct light from tightly controlled directions on inspected parts can be designed. This can often be obtained with small, low-cost lenses and diffusers, helping to achieve high light densities with control over lighting levels and homogeneity. LED sources can be shaped in several configurations (spot lights for reflective illumination; ring lights for coaxial illumination; backlights for contour illumination; linear assemblies; flat, large format panels; dome sources for diffused, omnidirectional illumination).
- LEDs can be easily strobed (in the microsecond range and below) and synchronized with imaging. High-power LEDs are available allowing well-lit images even with very short light pulses. This is often used to obtain crisp and sharp "still" images of quickly moving parts.
- LEDs come in several different colors and wavelengths, allowing easy use of the best color for each need, where different color may provide better visibility of features of interest. Having a precisely known spectrum lets tightly matched filters be used to separate informative bandwidth or to reduce disturbing effects of ambient light. LEDs usually operate at comparatively low working temperatures, simplifying heat management, and dissipation. This allows using plastic lenses, filters, and diffusers. Waterproof units can also easily be designed, allowing use in harsh or wet environments (food, beverage, oil industries).[182]

A large LED display behind a disc jockey



LED digital display that can display four digits and points

Traffic light using LED

LED daytime running lights of Audi A4

LED panel light source used in an experiment on plant growth. The findings of such experiments may be used to grow food in space on long duration missions.

LED lights reacting dynamically to video feed via AmBX

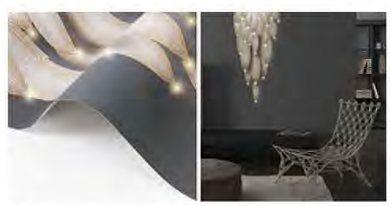
Different sized LEDs. 8 mm, 5 mm and 3 mm, with a wooden match-stick for scale.

A green surface-mount colored LED mounted on an Arduino circuit board

Other applications

LED costume for stage performers

The light from LEDs can be modulated very quickly so they are used extensively in optical fiber and free space optics communications. This includes remote controls, such as for TVs, VCRs, and LED Computers, where infrared LEDs are often used. Opto-isolators use an LED combined with a photodiode or phototransistor to provide a signal path with electrical isolation between two circuits. This is especially useful in medical equipment where the signals from a low-voltage sensor circuit (usually battery-powered) in contact with a living organism must be electrically isolated from any possible electrical failure in a recording or monitoring device operating at potentially dangerous voltages. An optoisolator also lets information be transferred between circuits that don't share a common ground potential.



LED wallpaper by Meystyle

Many sensor systems rely on light as the signal source. LEDs are often ideal as a light source due to the requirements of the sensors. LEDs are used as motion sensors, for example in optical computer mice. The Nintendo Wii's sensor bar uses infrared LEDs. Pulse oximeters use them for measuring oxygen saturation. Some flatbed scanners use arrays of RGB LEDs rather than the typical cold-cathode fluorescent lamp as the light source. Having independent control of three illuminated colors allows the scanner to calibrate itself for more accurate color balance, and there is no need for warm-up. Further, its sensors only need be monochromatic, since at any one time the page being scanned is only lit by one color of light. Since LEDs can also be used as photodiodes, they can be used for both photo emission and detection. This could be used, for example, in a touchscreen that registers reflected light from a finger or stylus.[183] Many materials and biological systems are sensitive to, or dependent on, light. Grow lights use LEDs to increase photosynthesis in plants,[184] and bacteria and viruses can be removed from water and other substances using UV LEDs for sterilization.[98]

LEDs have also been used as a medium-quality voltage reference in electronic circuits. The forward voltage drop (e.g. about 1.7 V for a normal red LED) can be used instead of a Zener diode in low-voltage regulators. Red LEDs have the flattest I/V curve above the knee. Nitride-based LEDs have a fairly steep I/V curve and are useless for this purpose. Although LED forward voltage is far more current-dependent than a Zener diode, Zener diodes with breakdown voltages below 3 V are not widely available.

The progressive miniaturization of low-voltage lighting technology, such as LEDs and OLEDs, suitable to incorporate into low-thickness materials has fostered experimentation in combining light sources and wall covering surfaces for interior walls.[185] The new possibilities offered by these developments have prompted some designers and companies, such as Meystyle,[186] Ingo Maurer,[187] Lomox[188] and Philips,[189] to research and develop proprietary LED wallpaper technologies, some of which are currently available for commercial purchase. Other solutions mainly exist as prototypes or are in the process of being further refined.

See also

- History of display technology
- Laser diode
- LEAD (diode), a light-emitting and absorbing diode
- LED circuit
- LED lamp
- LED tattoo
- Li-Fi
- Light-emitting electrochemical cell
- List of LED failure modes
- Nixie tube
- OLED
- Photovoltaics
- Seven-segment display
- SMD LED Module
- Solar lamp
- Solid-state lighting
- Thermal management of high-power LEDs
- UV curing

References

1. "HJ Round Started It All By Discovering Electroluminescence." (http://www.myledpassion.com/History/hj-round.htm). *www.myledpassion.com*.
2. "The life and times of the LED — a 100-year history" (http://holly.orc.soton.ac.uk/fileadmin/downloads/100_years_of_optoelectronics__2_.pdf) (PDF). The Optoelectronics Research Centre, University of Southampton. April 2007. Retrieved September 4, 2012.
3. US Patent 3293513 (http://www.freepatentsonline.com/3293513.pdf), "Semiconductor Radiant Diode", James R. Biard and Gary Pittman, Filed on Aug. 8th, 1962, Issued on Dec. 20th, 1966.
4. "Inventor of Long-Lasting, Low-Heat Light Source Awarded $500,000 Lemelson-MIT Prize for Invention" (https://web.archive.org/web/20111009111042/http://web.mit.edu/invent/n-pressreleases/n-press-04LMP.html). Washington, D.C. Massachusetts Institute of Technology. April 21, 2004. Archived from the original (http://web.mit.edu/invent/n-pressreleases/n-press-04LMP.html) on October 9, 2011. Retrieved December 21, 2011.
5. "LED". *The American heritage science dictionary*. Houghton Mifflin Company. 2005. led (https://dictionary.reference.com/browse/led) and LED (http://www.thefreedictionary.com/LED).
6. Moreno, Ivan; Sun, Ching-Cherng (2008-02-04). "Modeling the radiation pattern of LEDs" (https://www.osapublishing.org/abstract.cfm?uri=oe-16-3-1808). *Optics Express*. **16** (3): 1808–1819. ISSN 1094-4087 (https://www.worldcat.org/issn/1094-4087). doi:10.1364/oe.16.001808 (https://doi.org/10.1364%2Foe.16.001808).
7. Thomas M. Okon; James R. Biard (2015). "The First Practical LED" (http://edisontechcenter.org/lighting/LED/TheFirstPracticalLED.pdf) (PDF). *EdisonTechCenter.org*. Edison Tech Center. Retrieved 2016-02-02.
8. Savov, Vlad. "LED light bulbs are a smart upgrade whether or not they're 'smart'" (http://www.theverge.com/circuitbreaker/2017/2/4/14507712/led-light-bulbs-good-idea). *The Verge*. Retrieved 2017-02-08.

9. "Cleaning Up a Broken CFL" (https://www.epa.gov/cfl/cleaning-broken-cfl). *www.epa.gov*. United States Environmental Protection Agency.
10. Carlessi, F., MO Oliveira2 HO Ando Junior, J. M. Neto, A. D. Spacek, V. L. Coelho, L. Schaeffer, H. Bordon, O. E. Perrone, and A. S. Bretas. "Evaluation of Alternative Disposal and Replacement of Fluorescent Lamps" (http://www.ufrgs.br/ldtm/publicacoes/Evaluation%20of%20Alternative%20Disposal%20and%20Replacement%20of%20Fluorescent%20Lamps.pdf) (PDF). *International Conference on Renewable Energies and Power Quality (ICREPQ'13)*.
11. "LED Spectral Distribution" (https://optiwave.com/resources/applications-resources/optical-system-led-spectral-distribution/). *optiwave.com*. Retrieved 20 June 2017.
12. Round, H. J. (1907). "A note on carborundum" (https://books.google.com/books?id=TAZRAAAAYAAJ&pg=PA309#v=onepage&q&f=false). *Electrical World*. **19**: 309.
13. Margolin J. "*The Road to the Transistor*" (http://www.jmargolin.com/history/trans.htm). *jmargolin.com*.
14. Losev, O. V. (1927). "Telegrafiya i Telefoniya bez Provodov". **44**: 485–494.
15. Zheludev, N. (2007). "The life and times of the LED: a 100-year history" (http://www.nanophotonics.org.uk/niz/publications/zheludev-2007-ltl.pdf) (free-download PDF). *Nature Photonics*. **1** (4): 189–192. Bibcode:2007NaPho...1..189Z (http://adsabs.harvard.edu/abs/2007NaPho...1..189Z). doi:10.1038/nphoton.2007.34 (https://doi.org/10.1038%2Fnphoton.2007.34).
16. Lee, Thomas H. (2004). *The design of CMOS radio-frequency integrated circuits*. Cambridge University Press. p. 20. ISBN 0-521-83539-9.
17. K. Lehovec; C. A. Accardo; AND E. Jamgochian (1951). "Injected Light Emission of Silicon Carbide Crystals" (https://web.archive.org/web/20141211015103/http://www.campevans.org/_CE/html/tpr-08-01-1951p604-lehovec.html). *Physical Review*. **83** (3): 603–607. doi:10.1103/PhysRev.83.603 (https://doi.org/10.1103%2FPhysRev.83.603). Archived from the original (http://www.campevans.org/_CE/html/tpr-08-01-1951p604-lehovec.html) (free-download HTML) on December 11, 2014.
18. K. Lehovec; C. A. Accardo; AND E. Jamgochian (1953). "Injected Light Emission of Silicon Carbide Crystals" (http://journals.aps.org/pr/abstract/10.1103/PhysRev.89.20). *Physical Review*. **89**: 20–25. doi:10.1103/PhysRev.89.20 (https://doi.org/10.1103%2FPhysRev.89.20).
19. Rubin Braunstein (http://personnel.physics.ucla.edu/directory/faculty/braunstein/) Archived (https://web.archive.org/web/20120204092217/http://personnel.physics.ucla.edu/directory/faculty/braunstein) February 4, 2012, at the Wayback Machine.. physics.ucla.edu
20. Braunstein, Rubin (1955). "Radiative Transitions in Semiconductors". *Physical Review*. **99** (6): 1892–1893. Bibcode:1955PhRv...99.1892B (http://adsabs.harvard.edu/abs/1955PhRv...99.1892B). doi:10.1103/PhysRev.99.1892 (https://doi.org/10.1103%2FPhysRev.99.1892).
21. Kroemer, Herbert (Sep 16, 2013). "The Double-Heterostructure Concept: How It Got Started". *Proceedings of the IEEE*. **101** (10): 2183–2187. doi:10.1109/JPROC.2013.2274914 (https://doi.org/10.1109%2FJPROC.2013.2274914).
22. W. T. Matzen, Ed., "Semiconductor Single-Crystal Circuit Development," Texas Instruments Inc., Contract No. AF33(616)-6600, Rept. No ASD-TDR-63-281; March, 1963.
23. Carr, W. N.; G. E. Pittman (November 1963). "One-watt GaAs p-n junction infrared source" (http://scitation.aip.org/content/aip/journal/apl/3/10/10.1063/1.1753837). *Applied Physics Letters*. **3** (10): 173–175. doi:10.1063/1.1753837 (https://doi.org/10.1063%2F1.1753837).
24. Holonyak Nick; Bevacqua, S. F. (December 1962). "Coherent (Visible) Light Emission from Ga(As_{1-x} P_x) Junctions" (https://web.archive.org/web/20121014035733/http://apl.aip.org/resource/1/applab/v1/i4). *Applied Physics Letters*. **1** (4): 82. Bibcode:1962ApPhL...1...82H (http://adsabs.harvard.edu/abs/1962ApPhL...1...82H). doi:10.1063/1.1753706 (https://doi.org/10.1063%2F1.1753706). Archived from the original (http://apl.aip.org/resource/1/applab/v1/i4) on October 14, 2012.
25. Wolinsky, Howard (February 5, 2005). "U. of I.'s Holonyak out to take some of Edison's luster" (https://web.archive.org/web/20060328001535/http://findarticles.com/p/articles/mi_qn4155/is_20050202/ai_n9504926). *Chicago Sun-Times*. Archived from the original (http://findarticles.com/p/articles/mi_qn4155/is_20050202/ai_n9504926) on March 28, 2006. Retrieved July 29, 2007.
26. Perry, T.S. (1995). "M. George Craford [biography]". *IEEE Spectrum*. **32** (2): 52–55. doi:10.1109/6.343989 (https://doi.org/10.1109%2F6.343989).

27. "Brief Biography — Holonyak, Craford, Dupuis" (https://web.archive.org/web/20070809062214/http://www.technology.gov/Medal/2002/bios/Holonyak_Craford_Dupuis.pdf) (PDF). Technology Administration. Archived from the original (http://www.technology.gov/Medal/2002/bios/Holonyak_Craford_Dupuis.pdf) (PDF) on August 9, 2007. Retrieved May 30, 2007.
28. Pearsall, T. P.; Miller, B. I.; Capik, R. J.; Bachmann, K. J. (1976). "Efficient, Lattice-matched, Double Heterostructure LEDs at 1.1 mm from GaxIn1-xAsyP1-y by Liquid-phase Epitaxy". *Appl. Phys. Lett.* **28** (9): 499. Bibcode:1976ApPhL..28..499P (http://adsabs.harvard.edu/abs/1976ApPhL..28..499P). doi:10.1063/1.88831 (https://doi.org/10.1063%2F1.88831).
29. Rostky, George (March 1997). "LEDs cast Monsanto in Unfamiliar Role" (http://www.datamath.org/Display/Monsanto.htm). *Electronic Engineering Times (EETimes)* (944).
30. Schubert, E. Fred (2003). "1". *Light-Emitting Diodes*. Cambridge University Press. ISBN 0-8194-3956-8.
31. US 3025589 (https://worldwide.espacenet.com/textdoc?DB=EPODOC&IDX=US3025589), "Method of Manufacturing Semiconductor Devices", issued Mar 20, 1962
32. Patent number: 3025589 (http://www.google.com/patents/US3025589) Retrieved May 17, 2013
33. Bausch, Jeffrey (December 2011). "The Long History of Light Emitting Diodes" (http://www.electronicproducts.com/Optoelectronics/LEDs/The_long_history_of_light-emitting_diodes.aspx). Hearst Business Communications.
34. Park, S. -I.; Xiong, Y.; Kim, R. -H.; Elvikis, P.; Meitl, M.; Kim, D. -H.; Wu, J.; Yoon, J.; Yu, C. -J.; Liu, Z.; Huang, Y.; Hwang, K. -C.; Ferreira, P.; Li, X.; Choquette, K.; Rogers, J. A. (2009). "Printed Assemblies of Inorganic Light-Emitting Diodes for Deformable and Semitransparent Displays". *Science*. **325** (5943): 977–981. PMID 19696346 (https://www.ncbi.nlm.nih.gov/pubmed/19696346). doi:10.1126/science.1175690 (https://doi.org/10.1126%2Fscience.1175690).
35. LED Thermal Management (http://www.lunaraccents.com/educational-LED-thermal-management.html). Lunaraccents.com. Retrieved on March 16, 2012.
36. Patel, Neel V. (9 Oct 2014). "Nobel Shocker: RCA Had the First Blue LED in 1972" (http://spectrum.ieee.org/tech-talk/geek-life/history/rcas-forgotten-work-on-the-blue-led). *IEEE Spectrum*. Institute of Electrical and Electronics Engineers. Retrieved June 21, 2016.
37. "History & Milestones" (http://www.cree.com/About-Cree/History-and-Milestones). *Cree.com*. Cree. Retrieved 2015-09-14.
38. Nakamura, S.; Mukai, T.; Senoh, M. (1994). "Candela-Class High-Brightness InGaN/AlGaN Double-Heterostructure Blue-Light-Emitting-Diodes". *Appl. Phys. Lett.* **64** (13): 1687. Bibcode:1994ApPhL..64.1687N (http://adsabs.harvard.edu/abs/1994ApPhL..64.1687N). doi:10.1063/1.111832 (https://doi.org/10.1063%2F1.111832).
39. Nakamura, Shuji. "Development of the Blue Light-Emitting Diode" (http://spie.org/x115688.xml). SPIE Newsroom. Retrieved 28 September 2015.
40. "The Nobel Prize in Physics 2014 Isamu Akasaki, Hiroshi Amano, Shuji Nakamura" (https://www.nobelprize.org/nobel_prizes/physics/laureates/2014/press.html). *nobelprize.org*. The Royal Swedish Academy of Sciences. Retrieved 17 March 2015.
41. Dadgar, A.; Alam, A.; Riemann, T.; Bläsing, J.; Diez, A.; Poschenrieder, M.; Strassburg, M.; Heuken, M.; Christen, J.; Krost, A. (2001). "Crack-Free InGaN/GaN Light Emitters on Si(111)". *Physica status solidi (a)*. **188**: 155–158. doi:10.1002/1521-396X(200111)188:1<155::AID-PSSA155>3.0.CO;2-P (https://doi.org/10.1002%2F1521-396X%28200111%29188%3A1%3C155%3A%3AAID-PSSA155%3E3.0.CO%3B2-P).
42. Dadgar, A.; Poschenrieder, M.; BläSing, J.; Fehse, K.; Diez, A.; Krost, A. (2002). "Thick, crack-free blue light-emitting diodes on Si(111) using low-temperature AlN interlayers and in situ Si\sub x]N\sub y] masking". *Applied Physics Letters*. **80** (20): 3670. Bibcode:2002ApPhL..80.3670D (http://adsabs.harvard.edu/abs/2002ApPhL..80.3670D). doi:10.1063/1.1479455 (https://doi.org/10.1063%2F1.1479455).
43. "Success in research: First gallium-nitride LED chips on silicon in pilot stage" (https://web.archive.org/web/20120915034646/http://www.osram-os.de/osram_os/EN/Press/Press_Releases/Company_Information/2012/_documents/OSRAM_PI_Production_GaNonSi_e.pdf) (PDF). Archived from the original (http://www.osram-os.de/osram_os/EN/Press/Press_Releases/Company_Information/2012/_documents/OSRAM_PI_Production_GaNonSi_e.pdf) (PDF) on September 15, 2012. Retrieved 2012-09-15.. www.osram.de, January 12, 2012
44. "Haitz's law". *Nature Photonics*. **1** (1): 23. 2007. Bibcode:2007NaPho...1...23. (http://adsabs.harvard.edu/abs/2007NaPho...1...23.). doi:10.1038/nphoton.2006.78 (https://doi.org/10.1038%2Fnphoton.2006.78).
45. Nick, Morris. "LED there be light, Nick Morris predicts a bright future for LEDs" (http://www.electrooptics.com/features/junjul06/junjul06leds.html). *Electrooptics.com*. Retrieved 17 March 2015.

46. "The LED Illumination Revolution" (http://www.forbes.com/2008/02/27/incandescent-led-cfl-pf-guru_in_mm_0227energy_inl.html). *Forbes*. February 27, 2008.
47. Press Release (https://www.nobelprize.org/nobel_prizes/physics/laureates/2014/press.html), Official Nobel Prize website, 7 October 2014
48. https://www.eia.gov/todayinenergy/detail.cfm?id=15471 2016-06-11
49. Mueller, Gerd (2000) Electroluminescence I (https://books.google.com/books?id=2plxAU3tPj4C&lpg=PA67), Academic Press, ISBN 0-12-752173-9, p. 67, "escape cone of light" from semiconductor, illustrations of light cones on p. 69
50. "Optical Properties of Silicon" (https://web.archive.org/web/20090605222316/http://pvcdrom.pveducation.org/APPEND/OPTICAL.HTM). *PVCDROM.PVEducation.org*. Archived from the original (http://pvcdrom.pveducation.org/APPEND/OPTICAL.HTM) on 2009-06-05.
51. Refraction — Snell's Law (http://interactagram.com/physics/optics/refraction/). Interactagram.com. Retrieved on March 16, 2012.
52. Lipták, Bela G. (2005) Instrument Engineers' Handbook: Process control and optimization (https://books.google.com/books?id=TxKynbyaIAMC&lpg=PA537), CRC Press, ISBN 0-8493-1081-4 p. 537, "cone of light" in context of optical fibers
53. Capper, Peter; Mauk, Michael (2007). *Liquid phase epitaxy of electronic, optical, and optoelectronic materials* (https://books.google.com/books?id=IfLGPRJDfqgC&lpg=PA389). Wiley. p. 389. ISBN 0-470-85290-9. "faceted structures are of interest for solar cells, LEDs, thermophotovoltaic devices, and detectors in that nonplanar surfaces and facets can enhance optical coupling and light-trapping effects, [with example microphotograph of a faceted crystal substrate]."
54. Dakin, John and Brown, Robert G. W. (eds.) Handbook of optoelectronics, Volume 2 (https://books.google.com/books?id=3GmcgL7Z-6YC&lpg=PA356), Taylor & Francis, 2006 ISBN 0-7503-0646-7 p. 356, "Die shaping is a step towards the ideal solution, that of a point light source at the center of a spherical semiconductor die."
55. Schubert, E. Fred (2006) Light-emitting diodes (https://books.google.com/books?id=0H4bWIpaXb0C&lpg=PA97), Cambridge University Press, ISBN 0-521-86538-7 p. 97, "Epoxy Encapsulants", "The light extraction efficiency can be enhanced by using dome-shaped encapsulants with a large refractive index."
56. "All in 1 LED Lighting Solutions Guide" (https://web.archive.org/web/20130314111003/http://www.philipslumileds.com/uploads/221/PG01-pdf). *PhilipsLumileds.com*. Philips. 2012-10-04. p. 15. Archived from the original (http://www.philipslumileds.com/uploads/221/PG01-pdf) (PDF) on March 14, 2013. Retrieved 2015-11-18.
57. "Nichia Unveils White LED with 150 lm/W Luminous Efficiency" (http://techon.nikkeibp.co.jp/english/NEWS_EN/20061221/125713/). Tech-On!. December 21, 2006. Retrieved August 13, 2007.
58. "Cree Sets New Record for White LED Efficiency" (http://techon.nikkeibp.co.jp/english/NEWS_EN/20120423/214494/), Tech-On, April 23, 2012.
59. "Cree First to Break 300 Lumens-Per-Watt Barrier" (http://www.cree.com/News-and-Events/Cree-News/Press-Releases/2014/March/300LPW-LED-barrier), Cree news
60. *DOE Solid-State Lighting CALiPER Program Summary of Results: Round 9 of Product Testing.* (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_round-9_summary.pdf) (PDF). U.S. Department of Energy. October 2009.
61. Identifying the Causes of LED Efficiency Droop (http://www.digikey.com/us/en/techzone/lighting/resources/articles/identifying-the-causes-of-led-efficiency-droop.html) Archived (https://web.archive.org/web/20131213073051/http://www.digikey.com/us/en/techzone/lighting/resources/articles/identifying-the-causes-of-led-efficiency-droop.html) December 13, 2013, at the Wayback Machine., By Steven Keeping, Digi-Key Corporation Tech Zone
62. Stevenson, Richard (August 2009) The LED's Dark Secret: Solid-state lighting won't supplant the lightbulb until it can overcome the mysterious malady known as droop (http://www.spectrum.ieee.org/semiconductors/optoelectronics/the-leds-dark-secret). *IEEE Spectrum*
63. Iveland, Justin; Martinelli, Lucio; Peretti, Jacques; Speck, James S.; Weisbuch, Claude. "Cause of LED Efficiency Droop Finally Revealed" (http://www.sciencedaily.com/releases/2013/04/130423102328.htm). *Physical Review Letters, 2013*. Science Daily. Retrieved 23 April 2013.
64. The LED's dark secret (http://www.energy-daily.com/reports/The_LED_Dark_Secret_999.html). EnergyDaily. Retrieved on March 16, 2012.
65. Smart Lighting: New LED Drops The 'Droop' (http://www.sciencedaily.com/releases/2009/01/090113123718.htm). Sciencedaily.com (January 13, 2009). Retrieved on March 16, 2012.

66. Efremov, A. A.; Bochkareva, N. I.; Gorbunov, R. I.; Lavrinovich, D. A.; Rebane, Y. T.; Tarkhin, D. V.; Shreter, Y. G. (2006). "Effect of the joule heating on the quantum efficiency and choice of thermal conditions for high-power blue InGaN/GaN LEDs". *Semiconductors*. **40** (5): 605–610. doi:10.1134/S1063782606050162 (https://doi.org/10.1134%2FS1063782606050162).
67. A Roadmap to Efficient Green-Blue-Ultraviolet Light-Emitting Diodes (http://www.nrl.navy.mil/media/news-releases/2014/a-roadmap-to-efficient-green-blue-ultraviolet-light-emitting-diodes), U.S. Naval Research Laboratory, 19 February 2014, Donna McKinney
68. Enabling high-voltage InGaN LED operation with ceramic substrate (http://www.semiconductor-today.com/news_items/2014/FEB/EPISTAR_110214.shtml), //Semiconductor Today//, 11 February 2014, Mike Cooke
69. "Lifetime of White LEDs" (https://web.archive.org/web/20090410145015/http://www1.eere.energy.gov/buildings/ssl/lifetime.html). Archived from the original (http://www1.eere.energy.gov/buildings/ssl/lifetime.html) on April 10, 2009. Retrieved 2009-04-10., US Department of Energy
70. Narendran, N.; Y. Gu (2005). "Life of LED-based white light sources". *IEEE/OSA Journal of Display Technology*. **1** (1): 167–171. Bibcode:2005JDisT...1..167N (http://adsabs.harvard.edu/abs/2005JDisT...1..167N). doi:10.1109/JDT.2005.852510 (https://doi.org/10.1109%2FJDT.2005.852510).
71. Conway, K. M. and J. D. Bullough. 1999. Will LEDs transform traffic signals as they did exit signs? (http://www.lrc.rpi.edu/resources/pdf/57-1999.pdf) Proceedings of the Illuminating Engineering Society of North America Annual Conference (pp. 1–9), New Orleans, Louisiana, August 9–11. New York, NY: Illuminating Engineering Society of North America.
72. Narendran, N., J. Brons, and J. Taylor. 2006. Energy-efficient Alternative for Commercial Refrigeration (http://www.lrc.rpi.edu/programs/solidstate/cr_freezers.asp). Project report prepared for the New York State Energy Research and Development Authority.
73. ASSIST. 2008. Recommendations for Testing and Evaluating Luminaires for Refrigerated and Freezer Display Cases (http://www.lrc.rpi.edu/programs/solidstate/assist/pdf/AR-FreezerCaseTesting-Nov2008.pdf). Vol. 5, Issue 1. Troy, N.Y.: Lighting Research Center.
74. Narendran, N. 2006. Field Test DELTA Snapshots: LED Lighting In Freezer Cases (http://www.lrc.rpi.edu/programs/delta/pdf/FTDeltaFreezer.pdf). Troy, N.Y.: Lighting Research Center.
75. Gu, Y., A. Baker, and N. Narendran. 2007. Investigation of thermal management technique in blue LED airport taxiway fixtures (http://www.lrc.rpi.edu/programs/solidstate/cr_blueTaxiway.asp). Seventh International Conference on Solid State Lighting, Proceedings of SPIE 6669: 66690U.
76. OSRAM: green LED (http://catalog.osram-os.com/media/_en/Graphics/00041987_0.pdf). osram-os.com. Retrieved on March 16, 2012.
77. Koizumi, S.; Watanabe, K.; Hasegawa, M.; Kanda, H. (2001). "Ultraviolet Emission from a Diamond pn Junction". *Science*. **292** (5523): 1899–1901. PMID 11397942 (https://www.ncbi.nlm.nih.gov/pubmed/11397942). doi:10.1126/science.1060258 (https://doi.org/10.1126%2Fscience.1060258).
78. Kubota, Y.; Watanabe, K.; Tsuda, O.; Taniguchi, T. (2007). "Deep Ultraviolet Light-Emitting Hexagonal Boron Nitride Synthesized at Atmospheric Pressure". *Science*. **317** (5840): 932–934. PMID 17702939 (https://www.ncbi.nlm.nih.gov/pubmed/17702939). doi:10.1126/science.1144216 (https://doi.org/10.1126%2Fscience.1144216).
79. Watanabe, K.; Taniguchi, T.; Kanda, H. (2004). "Direct-bandgap properties and evidence for ultraviolet lasing of hexagonal boron nitride single crystal". *Nature Materials*. **3** (6): 404–409. Bibcode:2004NatMa...3..404W (http://adsabs.harvard.edu/abs/2004NatMa...3..404W). PMID 15156198 (https://www.ncbi.nlm.nih.gov/pubmed/15156198). doi:10.1038/nmat1134 (https://doi.org/10.1038%2Fnmat1134).
80. Taniyasu, Y.; Kasu, M.; Makimoto, T. (2006). "An aluminium nitride light-emitting diode with a wavelength of 210 nanometres". *Nature*. **441** (7091): 325–328. PMID 16710416 (https://www.ncbi.nlm.nih.gov/pubmed/16710416). doi:10.1038/nature04760 (https://doi.org/10.1038%2Fnature04760).
81. "LEDs move into the ultraviolet" (http://physicsworld.com/cws/article/news/24926). physicsworld.com. May 17, 2006. Retrieved August 13, 2007.
82. How to Wire/Connect LEDs (http://www.llamma.com/xbox360/mods/How%20to%20use%20an%20LED.htm) Archived (https://web.archive.org/web/20120302033005/http://www.llamma.com/xbox360/mods/How%20to%20use%20an%20LED.htm) March 2, 2012, at the Wayback Machine.. Llamma.com. Retrieved on March 16, 2012.
83. LED types by Color, Brightness, and Chemistry (http://donklipstein.com/ledc.html). Donklipstein.com. Retrieved on March 16, 2012.
84. "Nobel Shocker: RCA Had the First Blue LED in 1972" (http://spectrum.ieee.org/tech-talk/geek-life/history/rcas-forgotten-work-on-the-blue-led). *IEEE Spectrum*. October 9, 2014

85. "Oregon tech CEO says Nobel Prize in Physics overlooks the actual inventors" (http://www.oregonlive.com/silicon-forest/index.ssf/2014/10/oregon_tech_ceo_says_nobel_pri.html). *The Oregonian*. October 16, 2014
86. Schubert, E. Fred *Light-emitting diodes 2nd ed.*, Cambridge University Press, 2006 ISBN 0-521-86538-7 pp. 16–17
87. Maruska, H. (2005). "A Brief History of GaN Blue Light-Emitting Diodes" (http://www.sslighting.net/news/features/maruska_blue_led_history.pdf). *LIGHTimes Online – LED Industry News*. Archived (https://web.archive.org/web/20120611224723/http://www.sslighting.net/news/features/maruska_blue_led_history.pdf) June 11, 2012, at the Wayback Machine.
88. Major Business and Product Milestones (http://www.cree.com/about/milestones.asp). Cree.com. Retrieved on March 16, 2012. Archived (https://web.archive.org/web/20110413031614/http://www.cree.com/about/milestones.asp) April 13, 2011, at the Wayback Machine.
89. "GaN-based blue light emitting device development by Akasaki and Amano" (http://www.takeda-foundation.jp/en/award/takeda/2002/fact/pdf/fact01.pdf) (PDF). *Takeda Award 2002 Achievement Facts Sheet*. The Takeda Foundation. April 5, 2002. Retrieved November 28, 2007.
90. Moustakas, Theodore D. U.S. Patent 5,686,738A (https://www.google.com/patents/US5686738A) "Highly insulating monocrystalline gallium nitride thin films " Issue date: Mar 18, 1991
91. Iwasa, Naruhito; Mukai, Takashi and Nakamura, Shuji U.S. Patent 5,578,839 (https://www.google.com/patents/US5578839) "Light-emitting gallium nitride-based compound semiconductor device" Issue date: November 26, 1996
92. 2006 Millennium technology prize awarded to UCSB's Shuji Nakamura (http://www.ia.ucsb.edu/pa/display.aspx?pkey=1475). Ia.ucsb.edu (June 15, 2006). Retrieved on March 16, 2012.
93. Overbye, Dennis (7 October 2014). "Nobel Prize in Physics" (https://www.nytimes.com/2014/10/08/science/isamu-akasaki-hiroshi-amano-and-shuji-nakamura-awarded-the-nobel-prize-in-physics.html). *New York Times*. Retrieved 7 October 2014.
94. "The Nobel Prize in Physics 2014 – Press release" (https://www.nobelprize.org/nobel_prizes/physics/laureates/2014/press.html). *www.nobelprize.org*. Retrieved October 7, 2014.
95. Jonathan Webb (7 October 2014). "Invention of blue LEDs wins physics Nobel" (http://www.bbc.co.uk/news/science-environment-29518521). BBC News.
96. Brown, Joel (7 December 2015). "BU Wins $13 Million in Patent Infringement Suit" (http://www.bu.edu/today/2015/bu-wins-13-million-in-patent-infringement-suit/). *BU Today*. Retrieved 7 December 2015.
97. Cooke, Mike (April–May 2010). "Going Deep for UV Sterilization LEDs" (https://web.archive.org/web/20130515030549/http://www.semiconductor-today.com/features/SemiconductorToday%20-%20Going%20deep%20for%20UV%20sterilization%20LEDs.pdf) (PDF). *Semiconductor Today*. **5** (3): 82. Archived from the original (http://www.semiconductor-today.com/features/SemiconductorToday%20-%20Going%20deep%20for%20UV%20sterilization%20LEDs.pdf) (PDF) on May 15, 2013.
98. Mori, M.; Hamamoto, A.; Takahashi, A.; Nakano, M.; Wakikawa, N.; Tachibana, S.; Ikehara, T.; Nakaya, Y.; Akutagawa, M.; Kinouchi, Y. (2007). "Development of a new water sterilization device with a 365 nm UV-LED". *Medical & Biological Engineering & Computing*. **45** (12): 1237–1241. PMID 17978842 (https://www.ncbi.nlm.nih.gov/pubmed/17978842). doi:10.1007/s11517-007-0263-1 (https://doi.org/10.1007%2Fs11517-007-0263-1).
99. Ting, Hua-Nong (2011-06-17). *5th Kuala Lumpur International Conference on Biomedical Engineering 2011: BIOMED 2011, 20-23 June 2011, Kuala Lumpur, Malaysia* (https://books.google.com/books?id=qk1hmpEQVxIC&pg=PA349&dq=rgb+led+consists+of+one+red,+green,+and+blue+leds&hl=en&sa=X&ved=0ahUKEwjki4z8jIDUAhUE2WMKHaz2C7IQ6AEIUDAH#v=onepage&q=rgb%20led%20consists%20of%20one%20red,%20green,%20and%20blue%20leds&f=false). Springer Science & Business Media. ISBN 9783642217296.
100. Wold, J. H.; Valberg, A. (2000). "The derivation of XYZ tristimulus spaces: A comparison of two alternative methods". *Color Research & Application*. **26** (S1): S222. doi:10.1002/1520-6378(2001)26:1+<::AID-COL47>3.0.CO;2-4 (https://doi.org/10.1002%2F1520-6378%282001%2926%3A1%2B%3C%3A%3AAID-COL47%3E3.0.CO%3B2-4).
101. Bessho, M; Shimizu, K (2012). "Latest trends in LED lighting". *Electronics and Communications in Japan*. **95** (1): 1–7. doi:10.1002/ecj.10394 (https://doi.org/10.1002%2Fecj.10394).
102. Moreno, I.; Contreras, U. (2007). "Color distribution from multicolor LED arrays". *Optics Express*. **15** (6): 3607–3618. PMID 19532605 (https://www.ncbi.nlm.nih.gov/pubmed/19532605). doi:10.1364/OE.15.003607 (https://doi.org/10.1364%2FOE.15.003607).

103. Schubert, E. Fred; Kim, Jong Kyu (2005). "Solid-State Light Sources Getting Smart" (http://www.ecse.rpi.edu/~schubert/Reprints/2005%20Schubert%20and%20Kim%20%28Science%29%20Solid-state%20light%20sources%20getting%20smart.pdf) (PDF). *Science*. **308** (5726): 1274–1278. Bibcode:2005Sci...308.1274S (http://adsabs.harvard.edu/abs/2005Sci...308.1274S). PMID 15919985 (https://www.ncbi.nlm.nih.gov/pubmed/15919985). doi:10.1126/science.1108712 (https://doi.org/10.1126%2Fscience.1108712).
104. Nimz, Thomas; Hailer, Fredrik; Jensen, Kevin (November 2012). *Sensors and Feedback Control of Multi-Color LED Systems* (https://web.archive.org/web/20140429162806/http://www.mazet.de/en/english-documents/english/featured-articles/sensors-and-feedback-control-of-multi-color-led-systems-1/download#.UX7VXYIcUZI). LED Professional. pp. 2–5. ISSN 1993-890X (https://www.worldcat.org/issn/1993-890X). Archived from the original (http://www.mazet.de/en/english-documents/english/featured-articles/sensors-and-feedback-control-of-multi-color-led-systems-1/download#.UX7VXYIcUZI) (PDF) on 2014-04-29.
105. Tanabe, S.; Fujita, S.; Yoshihara, S.; Sakamoto, A.; Yamamoto, S. (2005). "YAG glass-ceramic phosphor for white LED (II): luminescence characteristics" (https://web.archive.org/web/20110511182527/http://lib.semi.ac.cn:8080/tsh/dzzy/wsqk/SPIE/vol5941/594112.pdf) (PDF). *Proc. of SPIE*. Fifth International Conference on Solid State Lighting. **5941**: 594112. doi:10.1117/12.614681 (https://doi.org/10.1117%2F12.614681). Archived from the original (http://lib.semi.ac.cn:8080/tsh/dzzy/wsqk/SPIE/vol5941/594112.pdf) (PDF) on 2011-05-11.
106. Ohno, Y. (2004). "Color rendering and luminous efficacy of white LED spectra" (https://web.archive.org/web/20110511182632/http://lib.semi.ac.cn:8080/tsh/dzzy/wsqk/SPIE/vol5530/5530-88.pdf) (PDF). *Proc. SPIE*. Fourth International Conference on Solid State Lighting. **5530**: 89. doi:10.1117/12.565757 (https://doi.org/10.1117%2F12.565757). Archived from the original (http://lib.semi.ac.cn:8080/tsh/dzzy/wsqk/SPIE/vol5530/5530-88.pdf) (PDF) on 2011-05-11.
107. Whitaker, Tim (December 6, 2002). "Joint venture to make ZnSe white LEDs" (http://optics.org/cws/article/research/16534). Retrieved January 3, 2009.
108. Next-Generation GaN-on-Si White LEDs Suppress Costs (http://electronicdesign.com/europe-news/next-generation-gan-si-white-leds-suppress-costs), Electronic Design, 19 November 2013
109. GaN-on-Silicon LEDs Forecast to Increase Market Share to 40 Percent by 2020 (http://www.isuppli.com/Semiconductor-Value-Chain/News/Pages/GaN-on-Silicon-LEDs-Forecast-to-Increase-Market-Share-to-40Percent-by-2020.aspx), iSuppli, 4 December 2013
110. Burroughes, J. H.; Bradley, D. D. C.; Brown, A. R.; Marks, R. N.; MacKay, K.; Friend, R. H.; Burns, P. L.; Holmes, A. B. (1990). "Light-emitting diodes based on conjugated polymers". *Nature*. **347** (6293): 539–541. Bibcode:1990Natur.347..539B (http://adsabs.harvard.edu/abs/1990Natur.347..539B). doi:10.1038/347539a0 (https://doi.org/10.1038%2F347539a0).
111. Kho, Mu-Jeong; Javed, T.; Mark, R.; Maier, E.; David, C (March 4, 2008). *Final Report: OLED Solid State Lighting*. Kodak European Research. Cambridge Science Park, Cambridge, UK.
112. Bardsley, J. N. (2004). "International OLED Technology Roadmap". *IEEE Journal of Selected Topics in Quantum Electronics*. **10**: 3–4. doi:10.1109/JSTQE.2004.824077 (https://doi.org/10.1109%2FJSTQE.2004.824077).
113. Hebner, T. R.; Wu, C. C.; Marcy, D.; Lu, M. H.; Sturm, J. C. (1998). "Ink-jet printing of doped polymers for organic light emitting devices". *Applied Physics Letters*. **72** (5): 519. Bibcode:1998ApPhL..72..519H (http://adsabs.harvard.edu/abs/1998ApPhL..72..519H). doi:10.1063/1.120807 (https://doi.org/10.1063%2F1.120807).
114. Bharathan, J.; Yang, Y. (1998). "Polymer electroluminescent devices processed by inkjet printing: I. Polymer light-emitting logo". *Applied Physics Letters*. **72** (21): 2660. Bibcode:1998ApPhL..72.2660B (http://adsabs.harvard.edu/abs/1998ApPhL..72.2660B). doi:10.1063/1.121090 (https://doi.org/10.1063%2F1.121090).
115. Gustafsson, G.; Cao, Y.; Treacy, G. M.; Klavetter, F.; Colaneri, N.; Heeger, A. J. (1992). "Flexible light-emitting diodes made from soluble conducting polymers". *Nature*. **357** (6378): 477–479. Bibcode:1992Natur.357..477G (http://adsabs.harvard.edu/abs/1992Natur.357..477G). doi:10.1038/357477a0 (https://doi.org/10.1038%2F357477a0).
116. Quantum-dot LED may be screen of choice for future electronics (http://web.mit.edu/newsoffice/2002/dot.html) Massachusetts Institute of Technology News Office, December 18, 2002
117. Neidhardt, H.; Wilhelm, L.; Zagrebnov, V. A. (February 2015). "A New Model for Quantum Dot Light Emitting-Absorbing Bevices: Proofs and Supplements" (http://nanojournal.ifmo.ru/en/articles-2/volume6/6-1/invited-speakers/paper01/). *Nanosystems: Physics, Chemistry, Mathematics*. **6** (1): 6–45. doi:10.17586/2220-8054-2015-6-1-6-45 (https://doi.org/10.17586%2F2220-8054-2015-6-1-6-45). Retrieved 2015-10-31.
118. Colvin, V. L.; Schlamp, M. C.; Alivisatos, A. P. (1994). "Light-emitting diodes made from cadmium selenide nanocrystals and a semiconducting polymer". *Nature*. **370** (6488): 354–357. doi:10.1038/370354a0 (https://doi.org/10.1038%2F370354a0).

119. "Accidental Invention Points to End of Light Bulbs" (http://www.livescience.com/technology/051021_nano_light.html). LiveScience.com. October 21, 2005. Retrieved January 24, 2007.
120. Nanoco Signs Agreement with Major Japanese Electronics Company (http://www.nanocogroup.com/content/Library/NewsandEvents/articles/Nanoco_Signs_Agreement_with_Major_Japanese_Electronics_Company/136.aspx), September 23, 2009
121. Nanotechnologie Aktuell, pp. 98–99, v. 4, 2011, ISSN 1866-4997 (https://www.worldcat.org/search?fq=x0:jrnl&q=n2:1866-4997)
122. Hoshino, K.; Gopal, A.; Glaz, M. S.; Vanden Bout, D. A.; Zhang, X. (2012). "Nanoscale fluorescence imaging with quantum dot near-field electroluminescence". *Applied Physics Letters*. **101** (4): 043118. Bibcode:2012ApPhL.101d3118H (http://adsabs.harvard.edu/abs/2012ApPhL.101d3118H). doi:10.1063/1.4739235 (https://doi.org/10.1063%2F1.4739235).
123. Inman, Mason (February 1, 2008). "Crystal Coat Warms up LED Light" (http://technology.newscientist.com/channel/tech/dn13266-crystal-coat-warms-up-led-light.html). newscientist.com. Retrieved January 30, 2012.
124. What is the difference between 3528 LEDs and 5050 LEDs |SMD 5050 SMD 3528 (http://www.flexfireleds.com/pages/Comparison-between-3528-LEDs-and-5050-LEDs.html). Flexfireleds.com. Retrieved on March 16, 2012.
125. LED-design (http://www.elektor.com/magazines/2008/february/power-to-the-leds.350167.lynkx). Elektor.com. Retrieved on March 16, 2012. Archived (https://web.archive.org/web/20120831112624/http://www.elektor.com/magazines/2008/february/power-to-the-leds.350167.lynkx) August 31, 2012, at the Wayback Machine.
126. Researchers build thinnest-known LED (http://www.washington.edu/news/2014/03/10/scientists-build-thinnest-possible-leds-to-be-stronger-more-energy-efficient/), UW Today, 10 March 2014, Michelle Ma
127. Electrically tunable excitonic light-emitting diodes based on monolayer WSe_2 p–n junctions (http://www.nature.com/nnano/journal/v9/n4/full/nnano.2014.26.html), Nature Nanotechnology vol 9, pp 268–272 (2014)
128. "Luminus Products" (https://web.archive.org/web/20080725033952/http://www.luminus.com/content1044). Luminus Devices. Archived from the original (http://www.luminus.com/content1044) on 2008-07-25. Retrieved October 21, 2009.
129. "Luminus Products CST-90 Series Datasheet" (https://web.archive.org/web/20100331100545/http://www.luminus.com/stuff/contentmgr/files/0/7c8547b3575bcecc577525b80d210ac7/misc/pds_001314_rev_03__cst_90_w_product_datasheet_illumination.pdf) (PDF). Luminus Devices. Archived from the original (http://www.luminus.com/stuff/contentmgr/files/0/7c8547b3575bcecc577525b80d210ac7/misc/pds_001314_rev_03__cst_90_w_product_datasheet_illumination.pdf) (PDF) on 2010-03-31. Retrieved October 25, 2009.
130. Poensgen, Tobias (January 22, 2013) InfiniLED MicroLEDs achieve Ultra-High Light Intensity (http://www.infiniled.com/news/infiniledmicroledsachieveultra-highlightintensity). infiniled.com Archived (https://web.archive.org/web/20130506034212/http://www.infiniled.com/news/infiniledmicroledsachieveultra-highlightintensity) May 6, 2013, at the Wayback Machine.
131. "Xlamp Xp-G Led" (https://web.archive.org/web/20120313082324/http://www.cree.com/products/xlamp_xpg.asp). *Cree.com*. Cree, Inc. Archived from the original (http://www.cree.com/products/xlamp_xpg.asp) on March 13, 2012. Retrieved March 16, 2012.
132. High Power Point Source White Led NVSx219A (http://www.nichia.co.jp/en/about_nichia/2010/2010_110201.html). Nichia.co.jp, November 2, 2010.
133. "Seoul Semiconductor launches AC LED lighting source Acrich" (http://www.ledsmagazine.com/news/3/11/14). LEDS Magazine. November 17, 2006. Retrieved February 17, 2008.
134. *Visibility, Environmental, and Astronomical Issues Associated with Blue-Rich White Outdoor Lighting* (https://web.archive.org/web/20130116003035/http://darksky.org/assets/documents/Reports/IDA-Blue-Rich-Light-White-Paper.pdf) (PDF). International Dark-Sky Association. May 4, 2010. Archived from the original (http://www.darksky.org/assets/documents/Reports/IDA-Blue-Rich-Light-White-Paper.pdf) (PDF) on January 16, 2013.
135. "The Next Generation of LED Filament Bulbs" (http://www.ledinside.com/knowledge/2015/2/the_next_generation_of_led_filament_bulbs). *LEDInside.com*. Trendforce. Retrieved October 26, 2015.
136. "LED Filaments" (https://www.youtube.com/watch?v=H_XiunR-cAQ). Retrieved October 26, 2015.
137. *Elektrotechnik Gesamtband Technische Mathematik Kommunikationselektronik* (in German) (1st ed.). Westermann. 1997. p. 171. ISBN 3142212515.
138. Schubert, E. Fred (2005). "Chapter 4". *Light-Emitting Diodes*. Cambridge University Press. ISBN 0-8194-3956-8.
139. "Visible LED Device Classifications" (https://web.archive.org/web/20120125033254/http://www.datasheetarchive.com:80/datasheet-pdf/054/DSA0017490.html). Datasheetarchive.com. Retrieved on January 25, 2012.

140. Opinion of the French Agency for Food, Environmental and Occupational Health & Safety (http://www.anses.fr/Documents/AP2008sa0408EN.pdf), ANSES Opinion, October 19, 2010. Archived (https://web.archive.org/web/20140429161553/http://www.anses.fr/Documents/AP2008sa0408EN.pdf) April 29, 2014, at the Wayback Machine.
141. Opinion of the French Agency for Food, Environmental and Occupational Health & Safety (https://www.anses.fr/en/content/led-%E2%80%93-light-emitting-diodes), ANSES Opinion update, September 21, 2016.
142. "Eye Safety and LED (Light Emitting Diode) diffusion" (http://www.beadlight.com/pages/health_and_safety.asp) Archived (https://web.archive.org/web/20100108160138/http://www.beadlight.com/pages/health_and_safety.asp) January 8, 2010, at the Wayback Machine.: "The relevant standard for LED lighting is EN 60825-1:2001 (Safety of laser products) ... The standard states that throughout the standard "light emitting diodes (LED) are included whenever the word "laser" is used." "Archived copy" (https://web.archive.org/web/20100108160138/http://www.beadlight.com/pages/health_and_safety.asp). Archived from the original (http://www.beadlight.com/pages/health_and_safety.asp) on January 8, 2010. Retrieved 2010-03-08.
143. Lim, S. R.; Kang, D.; Ogunseitan, O. A.; Schoenung, J. M. (2011). "Potential Environmental Impacts of Light-Emitting Diodes (LEDs): Metallic Resources, Toxicity, and Hazardous Waste Classification". *Environmental Science & Technology*. **45** (1): 320–327. PMID 21138290 (https://www.ncbi.nlm.nih.gov/pubmed/21138290). doi:10.1021/es101052q (https://doi.org/10.1021%2Fes101052q).
144. The reactions to the recommendations of the American Medical Association are cited in an article (http://www.lightnowblog.com/2016/07/ama-issues-led-streetlighting-guidance-controversy-ensues/) on LightNowBlog.com. The comments note that the AMA slogan "cool it and dim it" leads to some confusion, since this refers to lighting with *cooler* color temperatures, which is commonly perceived as having a *warmer* color.
145. "Solid-State Lighting: Comparing LEDs to Traditional Light Sources" (https://web.archive.org/web/20090505080533/http://www1.eere.energy.gov/buildings/ssl/comparing.html). *eere.energy.gov*. Archived from the original (http://www1.eere.energy.gov/buildings/ssl/comparing.html) on 2009-05-05.
146. "Dialight Micro LED SMD LED "598 SERIES" Datasheet" (https://web.archive.org/web/20090205040334/http://www.dialight.com/Assets/Brochures_And_Catalogs/Indication/MDEI5980603.pdf) (PDF). *Dialight.com*. Archived from the original (http://www.dialight.com/Assets/Brochures_And_Catalogs/Indication/MDEI5980603.pdf) (PDF) on 2009-02-05.
147. "Data Sheet — HLMP-1301, T-1 (3 mm) Diffused LED Lamps" (http://www.avagotech.com/docs/AV02-1555EN). Avago Technologies. Retrieved May 30, 2010.
148. Narra, Prathyusha; Zinger, D.S. (2004). "An effective LED dimming approach". *Industry Applications Conference, 2004. 39th IAS Annual Meeting. Conference Record of the 2004 IEEE*. **3**: 1671–1676. ISBN 0-7803-8486-5. doi:10.1109/IAS.2004.1348695 (https://doi.org/10.1109%2FIAS.2004.1348695).
149. Lifetime of White LEDs (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lifetime_white_leds_aug16_r1.pdf). US Department of Energy. (PDF) . Retrieved on March 16, 2012.
150. "In depth: Advantages of LED Lighting" (http://energy.ltgovernors.com/in-depth-advantages-of-led-lighting.html). *energy.ltgovernors.com*.
151. "Philips Lumileds" (http://www.philipslumileds.com/uploads/news/id228/PR211.pdf) (PDF). *Philipslumileds.com*. March 25, 2014.
152. The Led Museum (http://www.ledmuseum.org/). The Led Museum. Retrieved on March 16, 2012.
153. Worthey, James A. "How White Light Works" (http://www.jimworthey.com/jimtalk2006feb.html). *LRO Lighting Research Symposium, Light and Color*. Retrieved October 6, 2007.
154. Hecht, E. (2002). *Optics* (4 ed.). Addison Wesley. p. 591. ISBN 0-19-510818-3.
155. "Blue LEDs: A health hazard?" (http://texyt.com/bright+blue+leds+annoyance+health+risks). texyt.com. January 15, 2007. Retrieved September 3, 2007.
156. Raloff, Janet (May 27, 2006). "Light Impacts: Science News" (https://web.archive.org/web/20070501051125/http://www.sciencenews.org/articles/20060527/bob9.asp). Sciencenews.org. Archived from the original (http://www.sciencenews.org/articles/20060527/bob9.asp) on 2007-05-01.
157. Luginbuhl, C. (2014). "The impact of light source spectral power distribution on sky glow" (http://www.sciencedirect.com/science/article/pii/S0022407313004792). *Journal of Quantitative Spectroscopy and Radiative Transfer*. **139**: 21–26. doi:10.1016/j.jqsrt.2013.12.004 (https://doi.org/10.1016%2Fj.jqsrt.2013.12.004).
158. Aubé, M.; Roby, J.; Kocifaj, M. (2013). "Evaluating Potential Spectral Impacts of Various Artificial Lights on Melatonin Suppression, Photosynthesis, and Star Visibility" (http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0067798). *PLOS ONE*. **8** (7): e67798. PMC 3702543 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3702543). PMID 23861808 (https://www.ncbi.nlm.nih.gov/pubmed/23861808). doi:10.1371/journal.pone.0067798 (https://doi.org/10.1371%2Fjournal.pone.0067798).

159. Crawford, Mark. "LED light pollution: Can we save energy and save the night?" (http://spie.org/newsroom/technical-articles/1015-led-light-pollution?highlight=x2408&ArticleID=x115768). SPIE Newsroom. Retrieved 5 October 2015.
160. Flagstaff Dark Skies Coalition. "Lamp Spectrum and Light Pollution" (http://www.flagstaffdarkskies.org/for-wonks/lamp-spectrum-light-pollution/). *Lamp Spectrum and Light Pollution*. Retrieved 10 April 2016.
161. "AMA Adopts Community Guidance to Reduce the Harmful Human and Environmental Effects of High Intensity Street Lighting" (http://www.ama-assn.org/ama/pub/news/news/2016/2016-06-14-community-guidance-street-lighting.page?). *www.ama-assn.org*. Retrieved 2016-08-01.
162. Efremov, A. A.; Bochkareva, N. I.; Gorbunov, R. I.; Lavrinovich, D. A.; Rebane, Y. T.; Tarkhin, D. V.; Shreter, Y. G. (2006). "Effect of the joule heating on the quantum efficiency and choice of thermal conditions for high-power blue InGaN/GaN LEDs". *Semiconductors*. **40** (5): 605–610. doi:10.1134/S1063782606050162 (https://doi.org/10.1134%2FS1063782606050162).
163. "LEDs: Good for prizes, bad for insects" (http://news.sciencemag.org/plants-animals/2014/10/leds-good-prizes-bad-insects). *news.sciencemag.org*. 7 October 2014. Retrieved 7 October 2014.
164. Pawson, S. M.; Bader, M. K.-F. (2014). "LED Lighting Increases the Ecological Impact of Light Pollution Irrespective of Color Temperature" (http://www.esajournals.org/doi/full/10.1890/14-0468.1). *Ecological Applications*. **24** (7): 1561–1568. doi:10.1890/14-0468.1 (https://doi.org/10.1890%2F14-0468.1). Retrieved 22 January 2015.
165. "Stoplights' Potentially Deadly Winter Problem" (http://abcnews.go.com/GMA/ConsumerNews/led-traffic-lights-unusual-potentially-deadly-winter-problem/story?id=9506449). ABC News. January 8, 2010.
166. "LED Traffic Lights Can't Melt Snow, Ice" (https://www.cars.com/articles/2009/12/led-traffic-lights-cant-melt-snow-ice/).
167. European Photonics Industry Consortium (EPIC). This includes use in data communications over fiber optics as well as "broadcast" data or signaling.
168. Forrest M. Mims III. "An Inexpensive and Accurate Student Sun Photometer with Light-Emitting Diodes as Spectrally Selective Detectors" (http://www.instesre.org/papers/Snowmass/MimsSnowmass.htm).(1998 ?)
169. "Water Vapor Measurements with LED Detectors" (https://www.cs.drexel.edu/~dbrooks/globe/special_measurements/water_vapor.htm). cs.drexel.edu (2002).
170. Dziekan, Mike (February 6, 2009) "Using Light-Emitting Diodes as Sensors" (http://www.soamsci.org/tcs/weeklyIssues_2009/2009-02-06/feature1/index.html). soamsci.or. Archived (https://web.archive.org/web/20130531090631/http://www.soamsci.org/tcs/weeklyIssues_2009/2009-02-06/feature1/index.html) May 31, 2013, at the Wayback Machine.
171. Ben-ezra, Moshe; Wang, Jiaping; Wilburn, Bennett; Li, Xiaoyang and Ma, Le. "An LED-only BRDF Measurement Device" (https://web.archive.org/web/20140224023057/http://130.203.133.150/viewdoc/summary?doi=10.1.1.165.484)
172. LED advantages outweigh potential snow hazards in traffic signals (http://www.ledsmagazine.com/news/7/1/4), LEDs magazine January 7, 2010
173. "L-Prize U.S. Department of Energy" (http://www.lightingprize.org/), L-Prize Website, August 3, 2011
174. LED There Be Light (http://www.scientificamerican.com/article.cfm?id=led-there-be-light), Scientific American, March 18, 2009
175. Eisenberg, Anne (June 24, 2007). "In Pursuit of Perfect TV Color, With L.E.D.'s and Lasers" (https://www.nytimes.com/2007/06/24/business/yourmoney/24novel.html). New York Times. Retrieved April 4, 2010.
176. "CDC – NIOSH Publications and Products – Impact: NIOSH Light-Emitting Diode (LED) Cap Lamp Improves Illumination and Decreases Injury Risk for Underground Miners" (http://www.cdc.gov/niosh/docs/2011-192/). cdc.gov. Retrieved May 3, 2013.
177. "LED Device Illuminates New Path to Healing" (http://www.sti.nasa.gov/tto/Spinoff2008/hm_3.html) (Press release). nasa.gov. Retrieved January 30, 2012.
178. M. S. Fudin; K. D. Mynbaev; K. E. Aifantis; H. Lipsanen; V. E. Bougrov; A. E. Romanov (2014). "Frequency characteristics of modern LED phosphor materials" (http://ntv.ifmo.ru/en/article/11192/chastotnye_harakteristiki_sovremennyh_svetodiodnyh_lyuminofornyh_materialov.htm). *Scientific and Technical Journal of Information Technologies, Mechanics and Optics*. **14** (6).
179. Green, Hank (October 9, 2008). "Transmitting Data Through LED Light Bulbs" (https://web.archive.org/web/20081212050729/http://www.ecogeek.org/content/view/2194/74/). EcoGeek. Archived from the original (http://www.ecogeek.org/content/view/2194/74/) on December 12, 2008. Retrieved February 15, 2009.

180. *DOE Solid-State Lighting CALiPER Program Summary of Results: Round 7 of Product Testing* (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_round_7_summary_final.pdf) (PDF). U.S. Department of Energy. February 2009.
181. US DOE EIA: Electricity Emission Factors (http://www.eia.doe.gov/oiaf/1605/emission_factors.html). Eia.doe.gov. Retrieved on March 16, 2012.
182. Administrator. "Application of LED Lighting" (http://www.abengroup.com/index.php/general-info/49-application-of-led-lighting). *www.abengroup.com*. Retrieved 2016-02-12.
183. Dietz, P. H.; Yerazunis, W. S.; Leigh, D. L. (2004). "Very Low-Cost Sensing and Communication Using Bidirectional LEDs" (http://www.merl.com/publications/TR2003-035/).
184. Goins, G. D.; Yorio, N. C.; Sanwo, M. M.; Brown, C. S. (1997). "Photomorphogenesis, photosynthesis, and seed yield of wheat plants grown under red light-emitting diodes (LEDs) with and without supplemental blue lighting". *Journal of Experimental Botany*. **48** (7): 1407–1413. doi:10.1093/jxb/48.7.1407 (https://doi.org/10.1093%2Fjxb%2F48.7.1407).
185. Schubert, E. Fred (2003). *Light-emitting Diodes*. Cambridge: Cambridge University Press. ISBN 0521823307.
186. "Winner of Maison & Objet Projects award 2014" (https://web.archive.org/web/20160329164250/http://meystyle.com/about/about.html). *Meystyle.com*. Meystyle. Archived from the original (http://www.meystyle.com/about/about.html) on March 29, 2016. Retrieved 31 March 2016.
187. "LED Wallpaper" (https://www.ingo-maurer.com/en/products/led-wallpaper). *Ingo-maurer.com*. Ingo Maurer. Retrieved 31 March 2016.
188. "LOMOX OLED Innovation" (http://www.lomox.co.uk/articles/technology). *Lomox.co.uk*. Lomox. Retrieved 31 March 2016.
189. "Philips Announces Partnership with Kvadrat Soft Cells to Bring Spaces Alive with luminous textile" (http://www.newscenter.philips.com/main/standard/news/press/2011/20110704_luminous_textile.wpd#.Vvunp3qwV_o). *Philips.com*. Philips. 2011. Retrieved 31 March 2016.

Further reading

- Shuji Nakamura; Gerhard Fasol; Stephen J Pearton (2000). *The Blue Laser Diode: The Complete Story* (https://books.google.com/books?id=AHyMBJ_LMykC&printsec=frontcover). Springer Verlag. ISBN 3-540-66505-6.

External links

- Light-emitting diode (https://dmoztools.net/Business/Electronics_and_Electrical/Optoelectronics_and_Fiber/Vendors/) at DMOZ
- Educational video on LEDs (https://www.youtube.com/watch?v=4y7p9R2No-4) on YouTube

EXHIBIT B

HOVEY COMPANIES

LED vs Fluorescent: 10 Problems To Consider With Fluorescent Lighting

Posted by Jimmy Hovey on Mon, Sep 09, 2013 @ 16:09 PM

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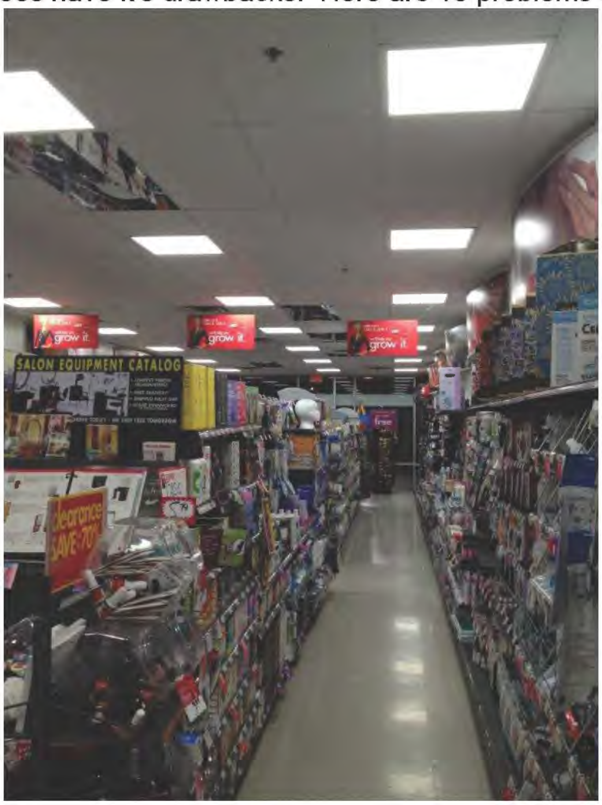
Which Way To Go...LED vs Fluorescent

Fluorescent is still an inexpensive option for retrofitting old T12 fixtures, but Fluorescent lighting does have it's drawbacks. Here are 10 problems that people run into with Fluorescent Lighting:



1. Frequent Switching Causes Early Failures

If the lamp is installed where it is frequently switched on and off, it will age rapidly.

Under extreme conditions, its lifespan may be much shorter than a cheap incandescent lamp.

Each start cycle slightly erodes the electron-emitting surface of the cathodes; when all the emission material is gone, the lamp cannot start with the available ballast voltage.

Fixtures intended for flashing of lights (such as for advertising) will use a ballast that maintains cathode temperature when the arc is off, preserving the life of the lamp.

The extra energy used to start a fluorescent lamp is equivalent to a few seconds of normal operation; it is more energy-efficient to switch off lamps when not required for several minutes.

2. Fluorescent Bulbs Contain Mercury

If a fluorescent lamp is broken, a very small amount of mercury can contaminate the surrounding environment. About 99% of the mercury is typically contained in the phosphor, especially on lamps that are near the end of their life.

The broken glass is usually considered a greater hazard than the small amount of spilled mercury.The EPA recommends airing out the location of a fluorescent tube break and using wet paper towels to help pick up the broken glass and fine particles.

Any glass and used towels should be disposed of in a sealed plastic bag. Vacuum cleaners can cause the particles to become airborne, and should not be used.

3. Fluorescent Lights Give Off Ultraviolet Light

Ultraviolet emission Fluorescent lamps emit a small amount of ultraviolet (UV) light. A 1993 study in the US found that ultraviolet exposure from sitting under fluorescent lights for eight hours is equivalent to only one minute of sun exposure.

Very sensitive individuals may experience a variety of health problems relating to light sensitivity that is aggravated by artificial lighting.

Ultraviolet light can affect sensitive paintings, especially watercolors and many textiles. Valuable art work must be protected from light by additional glass or transparent acrylic sheets put between the fluorescent lamp(s) and the painting.

4. The "Buzz" On the Fluorescent Ballast

Magnetic single-lamp ballasts have a low power factor. Fluorescent lamps require a ballast to stabilize the current through the lamp, and to provide the initial striking voltage required to start the arc discharge.

This increases the cost of fluorescent light fixtures, though often one ballast is shared between two or more lamps. Electromagnetic ballasts with a minor fault can produce an audible humming or buzzing noise.

Magnetic ballasts are usually filled with a tar-like potting compound to reduce emitted noise. Hum is eliminated in lamps with a high-frequency electronic ballast. Energy lost in magnetic ballasts can be significant, on the order of 10% of lamp input power.

Electronic ballasts reduce this loss. Small lamps may use an incandescent lamp as a ballast if the supply voltage is high enough to allow the lamp to start.

5. Power Quality and Radio Interference

Inductive ballasts include power factor correction capacitors. Simple electronic ballasts may also have low power factor due to their rectifier input stage.

Fluorescent lamps are a non-linear load and generate harmonic currents in the electrical power supply. The arc within the lamp may generate radio frequency noise, which can be conducted through power wiring. Suppression of radio interference is possible.

Good suppression is possible, but adds to the cost of the fluorescent fixtures.

6. Not As Efficient At High and Low Temperatures

Fluorescent lamps operate best around room temperature. At much lower or higher temperatures, efficiency decreases.

At below-freezing temperatures standard lamps may not start. Special lamps may be needed for reliable service outdoors in cold weather.

In applications such as road and railway signaling, fluorescent lamps which do not generate as much heat as incandescent lamps may not melt snow and ice build up around the lamp, leading to reduced visibility.

7. Fluorescent Lamp Shape Cause Retrofit Problems

Fluorescent tubes are long, low-luminance sources compared with high pressure arc lamps and incandescent lamps. However, low luminous intensity of the emitting surface is useful because it reduces glare.

Lamp fixture design must control light from a long tube instead of a compact globe. The compact fluorescent lamp (CFL) replaces regular incandescent bulbs.

However, some CFLs will not fit some lamps, because the harp (heavy wire shade support bracket) is shaped for the narrow neck of an incandescent lamp, while CFLs tend to have a wide housing for their electronic ballast close to the lamp's base.

8. Most Fluorescents Are Not Able To Be Dimmed

Fluorescent light fixtures cannot be connected to dimmer switches intended for incandescent lamps.

Two effects are responsible for this:

1. The waveform of the voltage emitted by a standard phase-control dimmer interacts badly with many ballasts.

2. It becomes difficult to sustain an arc in the fluorescent tube at low power levels.

Dimming installations require a compatible dimming ballast. These systems keep the cathodes of the fluorescent tube fully heated even as the arc current is reduced, promoting easy thermionic emission of electrons into the arc stream.

Now, before you go off and write me a note telling me I am wrong, here is the exception...

This would not apply to some CFLs as they are available to be used with with suitable dimmers.

9. Contaminants Cause Disposal and Recycling Issues

The disposal of phosphor and particularly the toxic mercury in the tubes is an environmental issue.

Governmental regulations in many areas require special disposal of fluorescent lamps separate from general and household wastes.

For large commercial or industrial users of fluorescent lights, recycling services are available in many nations, and may be required by regulation. In some areas, recycling is also available to consumers.

But even though recycling is available, it can be expensive which leads to a bigger issue. If it is too expensive to dispose of the lamps, people are not encouraged to recycle and dispose of the lamps in ways that are harmful to our environment.

10. Light From Fluorescent Bulb Is Non-Directional

The Light from fluorescent bulbs is non-directional light source. When a fluorescent bulb is lit, it gives off lighting all the way around the bulb or otherwise 360 degrees.

This means that only about 60-70% of the actual light being given off by the fluorescent lamps is being used. The other 30-40% is wasted.

This wasted light tends to lead to over lighting certain areas, especially offices. Most offices we go into will not qualify for The Energy Policy Act of 2005 because the wattage per square foot is too high.

What About Considering T8 LED Bulbs?

In the article above, LED is the best replacement to solve most of those problems that are listed, but they can be a little pricey. Because of the reach of our blog, we have set up a special direct relationship with a LED manufacturer and now have LED T8 Bulbs, LED Parking Fixtures, LED Wall Packs and LED Troffers.

If you are looking for a better alternative to Fluorscent lighting, then check out our deal on T8 LED bulbs, just click on the blue box below. Thanks, Jimmy

Click Here To Learn More About T8 LED Bulbs

Topics: fluorescent ballasts, led replacement bulbs, led vs fluorescent, LED Lighting, fluorescent lighting, fluorescent bulbs vs led bulbs

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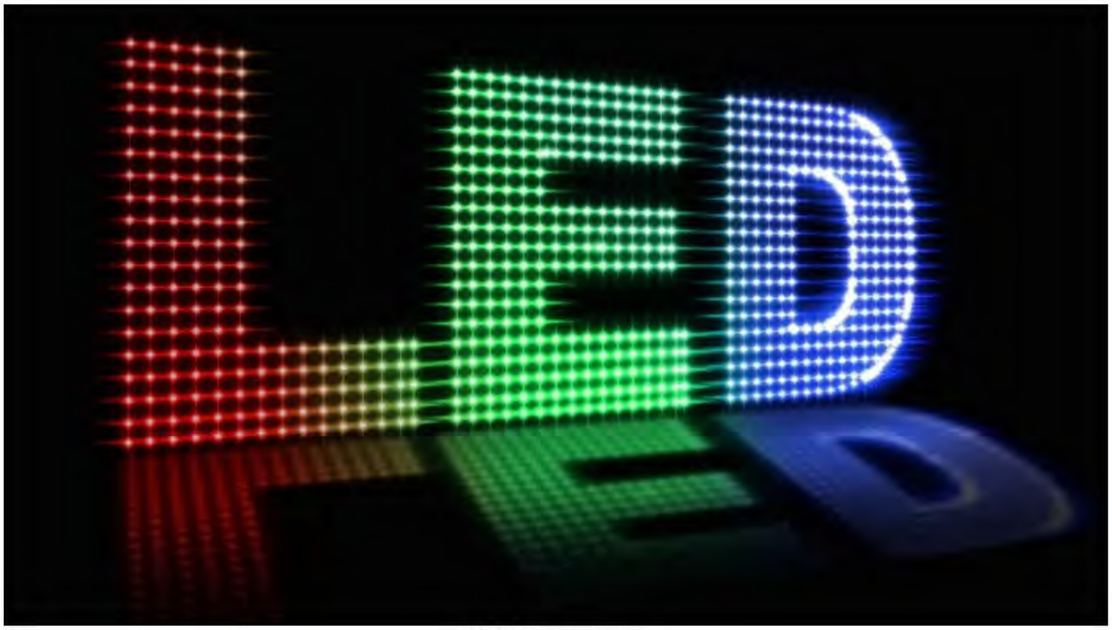
EXHIBIT C

5 Charts That Illustrate The Remarkable LED Lighting Revolution

JOE ROMM
AUG 2, 2016, 4:09 PM



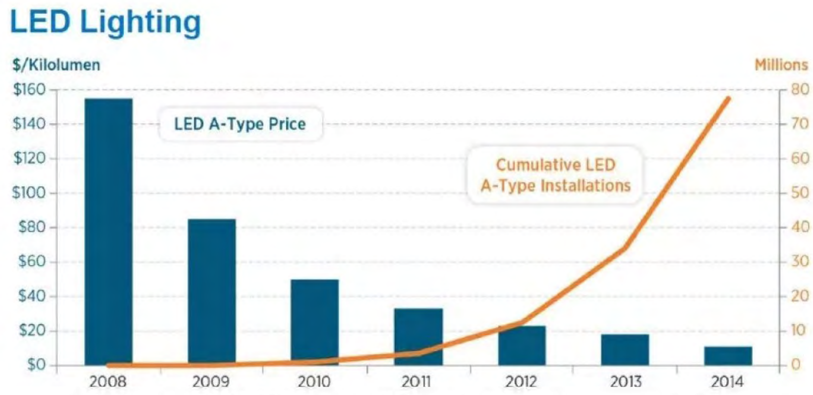
CREDIT: SHUTTERSTOCK

"The rapid adoption of LEDs in lighting marks one of the fastest technology shifts in human history," Goldman Sachs stated in a new report.

The accelerated deployment of light-emitting diode (LED) bulbs is on track to save U.S. consumers and businesses $20 billion a year in electricity costs within a decade, which would lower U.S. CO_2 emissions by some 100 million metric tons a year! The growing global effort to speed up LED adoption could ultimately cut global energy costs and carbon pollution 5 times as much.

Let's look at some key charts and facts that illustrate the LED lighting "miracle," which is every bit as remarkable—and every bit as unheralded by the major media—as the solar miracle, the battery miracle, and the electric vehicle miracle.

As recently as 2009, this country didn't have even 400,000 installations of common home LED bulbs, according to the November 2015 Department of Energy report "Revolution… Now The Future Arrives for Five Clean Energy Technologies." And yet by 2012, we had 14 million—and by 2014 we had whopping 78 million installations.



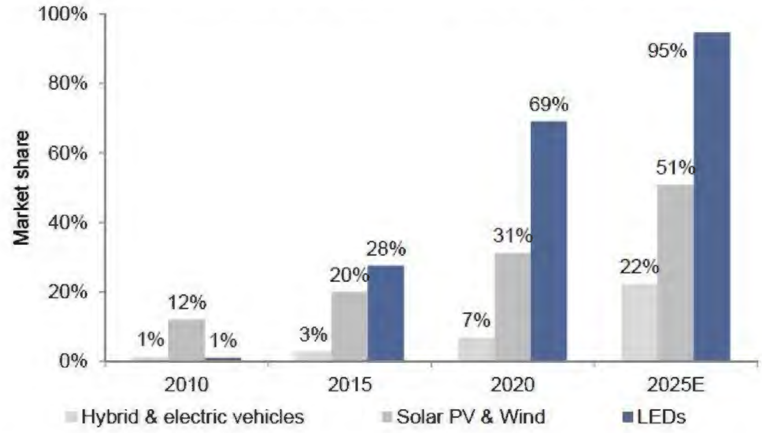
NOTE: KILOLUMEN IS A MEASURE OF VISIBLE LIGHT OUTPUT BY A SOURCE. PRICE DATA IS IN NOMINAL DOLLARS. VIA DOE.

This revolution has been driven by "sharp cost reductions and performance improvements, relatively short replacement cycles for incumbent technologies, and aggressive policy support (including bans on incandescent technology in major markets such as the U.S., the E.U. and China)," as Goldman Sachs has detailed in its recent reports on "The Low Carbon Economy."

Since 2008 alone, prices for LED lightbulbs have dropped a remarkable 90 percent, and you can now buy a 60-watt-equivalent LED bulb for a little more than $3.

Goldman forecasts "that LEDs will account for 69 percent of light bulbs sold and over 60 percent of the installed global base by 2020." This chart of where LEDs have been and where Goldman Sachs projects they are going in the near term is from their July 20 report, "The Low Carbon Economy: Our Thesis In 60 CHARTS." It compares LED adoption with the adoption of hybrid and electric vehicles and solar PV and wind.

Exhibit 19: The rapid adoption of LEDs in lighting marks one of the fastest technology shifts in human history.
LEDs for general lighting were commercialized only recently, but will dominate sales by the end of this decade



Source: IHS, Company data, IEA, IRENA, BP, Goldman Sachs Global Investment Research.

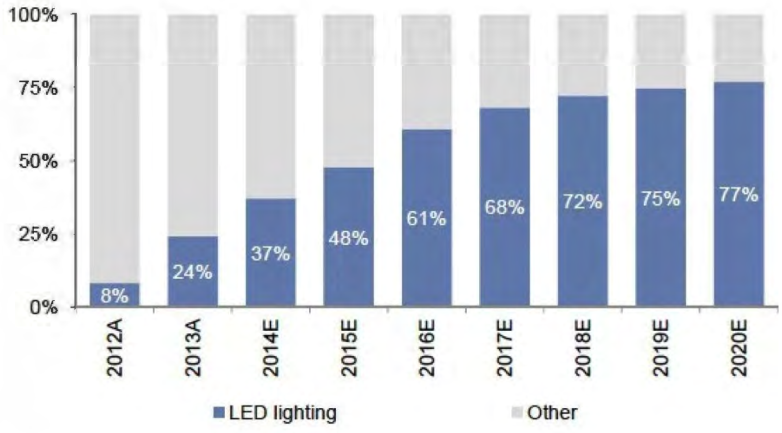
Currently the best LED bulbs cut electricity use by 85 percent compared to incandescent light bulbs and by 40 percent compared to fluorescent lights. By 2020, Goldman expects those savings to increase to over 90 percent and 50 percent respectively.

At the same time, LEDs can last for up to 5 years of nonstop use—or a few *decades* if used just a few hours a day. This is 50 times longer than incandescents and some 3 to 7 times longer than fluorescents. At the same time, LED bulbs provide superior light quality than compact fluorescent lights (CFLs). For all these reasons and more, GE announced earlier this year it would stop making CFLs "for the U.S. market and instead focus its consumer lighting efforts on LED lamps."

With the initial price dropping sharply while the ultra-low lifecycle costs also keep dropping, you end up with a revolution—one that is happening even faster in the United States:

Exhibit 53: ...and LEDs now account for over half of US lighting sales...

LEDs for residential lighting are seeing over 1000 basis points in market share gain per annum.

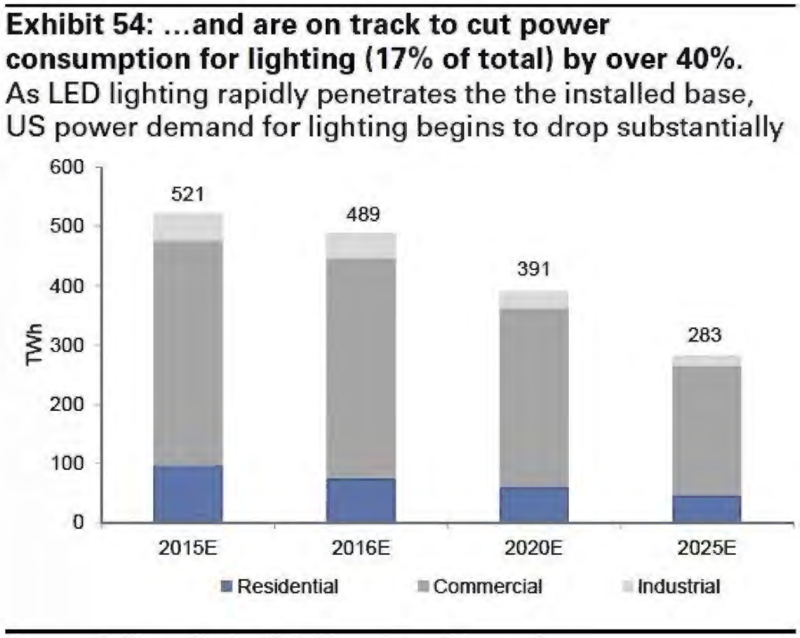


Source: DOE, Goldman Sachs Global Investment Research.

With such an unprecedented technology revolution, it's no wonder that, in 2014, the Nobel Committee awarded the Physics Prize to three scientists for their 1990s invention of "efficient blue light-emitting diodes [LEDs], which has enabled a bright, energy-saving white light source."

And in case you think that one small product you can hold in the palm of your hand can't be a game-changer in the arena of energy and climate solutions, think again. The nation's total electricity bill for residential and commercial customers is now more than $320 billion. Of that about 15 percent is lighting—nearly $50 billion a year.

Goldman Sachs projected last month that LED lights "are on track to cut power consumption for lighting... by over 40 percent." That would provide annual savings of more than $20 billion for consumers and businesses within a decade. And that in turn would reduce U.S. CO2 emissions by some 100 million metric tons a year.



Source: Goldman Sachs Global Investment Research.

I have previously noted that electricity sales in this country have been flat for nearly a decade even as the economy has kept growing. This shift has been driven federal energy efficiency standards for appliances (including lighting) and a growing embrace of policies to promote efficiency at the state level.

Clearly, the LED lighting revolution will help ensure that trend continues for at least one more decade. Indeed, the only plausible way the United States could return to an era of significant electricity demand growth is if the electric vehicle revolution takes off in the 2020s, which as we've seen is entirely possible, if not likely.

The energy and climate benefits of LEDs are so large, it's no wonder the U.S. Department of Energy has been working to advance the technology and promote their deployment for over 15 years. And it's no surprise the DOE has worked with countries like India on technical and analytic approaches to rapidly accelerate their adoption of LED lights.

Indeed, most of the major countries in the world have adopted policies that have sped up the adoption of LEDs, the most important of which have been the mandatory phaseout of inefficient incandescent lights:

Exhibit 20: Aggressive policy support in all major jurisdictions has been a key catalyst for growth...
Mandatory phase-outs of incandescent lighting in all major markets played a key role in boosting investment in LEDs

Source: Goldman Sachs Global Investment Research.

On top of all that, in 2015, the world's energy ministers embraced a Global Lighting Challenge, which is "a global race to accelerate phase-in of high efficiency, high-quality and affordable advanced lamps and lighting systems with a target of achieving cumulative global sales of 10 billion such units as fast as possible." LED lighting will be a central focus.

As with solar energy, advanced batteries, and electric vehicles, the LED lighting revolution may not be televised by the major media, but it is happening at a torrid pace nonetheless—with a big boost from government deployment policies.

#CLIMATE, **#CLIMATE CHANGE**

EXHIBIT D

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Top 5 Reasons to Choose LED Light Bulbs

Posted by Maria Tenningas in LED Technology, LED Wholesale on January 31, 2013 .
8 Comments.

Top Reasons Why You Should Choose Energy-Saving LED Light Bulbs

LED light bulbs are currently about to take over the lighting technology market by storm. And this with good reasons, because as you know, LED bulbs are a far more energy efficient, more environmentally friendly and also a cost-saving alternative to the old conventional incandescent and CFL light bulbs.

These are also the main reasons for both private and public transformations and upgrading of residential and commercial lighting technology systems to LED illumination. But are you aware of just how much of a difference LED light bulbs can make to energy saving, sustainability and financial spending?

Well, apparently both Bill Clinton and Los Angeles Mayor Antonio Villaraigosa are highly aware of just this:

Already back in February 2009, the Clinton Climate Initiative replaced 140,000 streetlights in Los Angeles with energy-saving LED fixtures. This investment into energy efficient LED lighting solutions is now saving the city of Los Angeles more than US$ 5 million annually, a number that is to reach $7.5 million per year once the entire LED upgrade has been made. Saving US$ 5 million per year by switching over to LED light bulbs, imagine that!

Clearly, LED lights are a revolutionary, cost-saving and energy efficient lighting solution - but just how different is the LED technology when compared to incandescent and compact fluorescent light bulbs, the CFLs?

So let's take a closer look at the top 5 reasons LED lighting clearly outshines its alternatives and leaves the other conventional lighting technologies left behind and in the dark.

1. LED light bulbs are more energy efficient

The main argument of course refers to the clear advantage LED lighting technologies have with regards to energy efficiency. With increasing costs of electricity, the cost factor of electricity is becoming more and more relevant. For example, up to 40% of a city's electricity costs are spent on street lighting only!

By applying energy efficient LED light bulbs these costs can be reduced by 70-90% and generate significant cost-savings for urban communities and municipal governments.

2. LED light bulbs have a longer life span

When looking at the average life span of LED, conventional incandescent and CFL light bulbs, it is crystal clear to anyone why LED lighting is by far the best solution. An average CFL's lifespan is approximately 8,000 hours, whereas incandescent light bulbs only light for about 1,200 hours. LED technology, on the other hand, has an average lifespan of an impressive up 50,000 hours or more! That means, an LED light bulb is an investment you make to last for many years or even decades of sustainable illumination in your personal home residence or on your commercial business premises and other public venues or buildings.

For urban lighting, this long life span also pays back in form of substantial cost-savings in maintenance:

Instead of having to replace conventional light bulbs regularly and thereby generating high maintenance costs especially in a large-scale urban municipality setting, LED light bulbs with their exceptional long life time expectancy lead to significant cost-savings in regards to maintenance and replacement workloads.

3. LED light bulbs helps you save money on your electricity bills

LED lights use less power (watts) per unit of light (lumen) generated. Therefore, they are not only much longer-lasting in lifespan but also lower your electricity bill providing 100 or even up to 200 lumen per watt. CFLs, in contrast use about twice the amount of watts and incandescent light bulbs around 10x as much power with only ca. 18-20 lumen per watts.

In a home or residential setting, this difference in lifespan and efficiency between incandescent lighting and LED lighting helps you to significantly reduce your electricity bill.

In conclusion, a LED light bulb is therefore almost 50 times more efficient in lifespan, and ca. 70-80% more energy-efficient than a conventional incandescent option. Impressed yet? It gets better!

4. LED lights are non-toxic and greener than other alternatives

Apart from the compelling differences in efficiency, lifespan and therefore also electricity cost, LED lighting is also the greenest solution available on today's markets. For one, LEDs, in contrast to CFLs, do not contain the highly toxic mercury, which is harmful not only to the environment but also to your personal health.

LED lights are free of toxic materials and are 100% recyclable, and besides this they will help you to reduce your carbon footprint by up to a third:

The long operational life time span mentioned above means also that one LED light bulb can save material and production of 25 incandescent light bulbs. A big step towards a greener future!

Most important for issues regarding global warming and environmental change, LED light bulbs release substantially less CO_2, sulfur oxide and nuclear waste. Where 30 incandescent light bulbs release about 2500 kg's of these emissions a year, LEDs only produce about 200 kg's annually. Taking into consideration the increasing threats of global warming and the effects of CO_2 emissions on our planet and personal health, it goes without saying that LED bulbs are by far the greenest lighting solution so far.

5. LED lighting is flexible in color and design

LED lights can easily be combined in various shapes and designs in order to produce highly efficient solutions for both residential and commercial illumination. Individual LEDs can be dimmed and both light, color and distribution can be dynamic controlled and adjusted either via timers or also remote and even via the internet or your home WLAN. A well-designed LED illumination system can achieve some amazing lighting effects that influence not only the eye but also for the mood and the mind of human beings.

LED mood illumination is already being used in airplanes to bridge jet-lags allow for more natural sleep patterns, and also in classrooms where the right lighting has proven to improve students learning abilities.

You can expect to see a lot more LED mood illumination that are being dynamically controlled depending on settings, moods and so on in our daily lives within the next few years.

LEDs are the way to a bright green future

Mostly, when thinking about personal and individual benefits and comforts of LED bulbs, one considers factors such as the non-effect of on/off cycling in LED bulbs which means lifespan doesn't decrease.

Additionally, the much lower output of heat which ensures that the bulbs typically do not overheat is also an important factor to consider. Besides these benefits, it is clear that with the efficiency, lifespan and ecological factors mentioned, the advantages of LED light bulbs range far beyond these simple comforts.

LED technology is substantially more efficient, longer lasting and far more sustainable than other lighting alternatives, especially in comparison to incandescent bulbs - which, in our opinion and also in that of many regulators should be removed entirely from the market because of their massive environmental impact.

If you want to learn more about the advantages of LED technology and digital illumination, feel free to also read our article Top 10 Benefits of Using LED Lighting to find out more about the benefits of LED lighting.

It is high time to start saving money, benefit from longer-lasting lighting systems and sustainable illumination - and most importantly, you can also do your part and start to help saving our planet:

You can now shop your LED light bulbs wholesale in the LEDLuxor online shop, where you'll have the choice of a wide range of high quality products to suit your LED lighting needs.

Feel free to contact our customer service for a wholesale quote and assistance!

Tags: LED Technology, Reasons for LED, LED Benefits Last update: May 03, 2013

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LED Global Market Penetration of 50% Expected by 2015

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Ridley
July 12, 2017 12:16
I really like the idea of LED lights. Just the fact that they use less watts and can save me money is great! We need to start replacing all of the bulbs in our home with LED ones, for sure.

Reply

David Wei
April 03, 2017 03:58
Thanks for these messages.Led lights is the trend to replace the incandescent bulb and CFL bulb

Reply

Sansak
July 27, 2016 00:28
The Basic Advantages of LED's are that they are Long Operational,Great Energy Saver. But White LED's Must be ignored as they are more Power Consuming. Nice Post Buddy!

Reply

Monica Weiss
January 26, 2016 11:16
I am a member of the environmental group 350NYC, a local affiliate of 350.org We are launching a lightbulb project and are looking for partners. and suppliers. I can send you the information. Whose attention and which email address would I send it to?
Also, would someone be able to help calculate the savings in CO_2 from changing one CFL to one LED? Thank you. Monica

Reply

Susan Karppala

July 03, 2014 11:13
Add to this article:

#6 Health benefits of LED mood lighting per your own page! https://www.ledluxor.com/led-innovation/led-mood-lighting-increases-well-being-mood-health

Reply

Susan
July 03, 2014 11:15
PS. Love your website and eMagazine.

okledlights
August 08, 2013 18:36
Most people prefer to buy LED lights in comparison of traditional bulbs because led lights produce less heat and saves energy. LED lights are cost effective and energy efficient diode. The installation of light emitting diodes is also very easy.

Reply

Tom Smith
April 15, 2013 04:13
Nice post LED lights are used 70% less energy than an incandescent light and because they required less energy, we need to spend less money on our energy bills. If you are using old traditional light strings then you are wasting energy and money. By purchasing new LED lights you can save the energy resources and make the environment green.

Reply

sebb
February 14, 2013 18:58
LED rocks and has helped us cut our electricity bill by 50 procent or so!

Reply

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EXHIBIT E

What is Color Temperature? Choosing a Proper Color Temperature for your next LED Bulb

Posted by EarthLED News on Mar 18, 2015

Color temperature is a description of the warmth or coolness of a light source. When a piece of metal is heated, the color of light it emits will change. This color begins as red in appearance and graduates to orange, yellow, white, and then blue-white to deeper colors of blue. The temperature of this metal is a physical measure in degrees Kelvin or absolute temperature. While lamps other than incandescent such as LEDs do not exactly mimic the output of this piece of metal, we utilize the correlated color temperature (or Kelvins) to describe the appearance of that light source as it relates to the appearance of the piece of metal (specifically a black body radiator).

By convention, yellow-red colors (like the flames of a fire) are considered warm, and blue-green colors (like light from an overcast sky) are considered cool. Confusingly, higher Kelvin temperatures (3600–5500 K) are what we consider cool and lower color temperatures (2700–3000 K) are considered warm. Cool light is preferred for visual tasks because it produces higher contrast than warm light. Warm light is preferred for living spaces because it is more flattering to skin tones and clothing. A color temperature of 2700–3600 K is generally recommended for most indoor general and task lighting applications. Color Temperature is not an indicator of lamp heat.

Newly created vintage and filament LED bulbs offer color temperatures below 2700K, some even as low as 1900K! These color temperatures are suited for those looking to mimic the ambience created by traditional carbon filament bulbs. These bulbs produce a lower number of lumens than traditional incandescent bulbs as do their LED counterparts. Only chose this level of color temperature if you are willing to sacrifice lumens for a more ambience that demands the extremely soft light these bulbs create.

Need Help? Let Us Find The Right LED Bulb For You!

Find the Right Bulb for Me!

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Tags: color temperature, what is color temperature

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I am interested in the TCP Elite Deco – G16.5 – E12 Candelabra Base – 4 Watts – 25 Watt Equal. I would like to know if these are available in the daylight bulbs.
Thank you

Lynn on Mar 12, 2016

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A big thank you for your blog.Thanks Again. Fantastic.

Marlin Colvert** on **Aug 04, 2015

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EXHIBIT F

The Productivity Benefits of LED Lighting in Offices

Published by Scott Enfield at February 4, 2016

Tags

LED indoor lighting
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Office Employee Productivity

We talk a lot about the energy and cost savings and environmental benefits of LED lights (and will continue to do so), however something not often considered is the range of other business benefits that quality LED lighting can achieve.

Several reports in the U.S. Library of Medicine National Institutes of Health reveal the positive effects of 'light' and its influence on human vitality, energy, mood, alertness, psychomotor vigilance and work performance.

Workers surveyed by the Kensington Technology Group listed eyestrain as a leading cause of physical stress in the workplace. According to a study sponsored by the American Society of Interior Designers, 68% of all office workers were concerned about lighting. Office workers consistently rated poor lighting as the first or second work environment concern.

A study by Cornell University found 24% of office workers claimed poor lighting as a causal factor in loss of work due to eyestrain and discomfort. The study revealed a 2% loss of productivity per year for each individual surveyed, which equates to about one week of paid annual leave for each employee.

The Cornell University study demonstrated that a 3% to 5% gain in worker productivity could be obtained with commercial LED lighting.

We have a strong view that proper illumination is essential for comfort and productivity in office environments. Lighting in offices impacts upon quality of perception, mood and performance of employees.

LED lighting can have this positive impact on employees – on their physical, physiological, and psychological health and well-being, enhancing their general performance and potentially reducing absenteeism.

Conversely, dim or harsh lighting, often associated with traditional fluorescent and incandescent lights, can cause eye strain, as your eyes work harder to see, and associated ailments. Fluorescent and 'bulb'-shaped incandescent lamps emit light in all directions, with the result that much of the light they produce is lost within the fixture or escapes in a direction not useful for the intended application.

One of the defining benefits of LEDs is that they emit light in a specific direction, which reduces the need for reflectors and diffusers that can lower efficiency. LEDs do not flicker and are free from toxic substances and UV emissions.

While natural light through windows provides the optimal lighting outcome, LEDs are the next best alternative and beautifully complement natural lighting, particularly when combined with modern control systems, which include wireless control (see our blog post on Zigbee control systems).

MatrixLED offers a large range of office LED lighting solutions, including Zigbee wireless controlled systems. Please visit our website to learn more about LED lights and contact us for a free consultation.

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- May 2017
- March 2017
- February 2017
- January 2017
- December 2016
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RT @toolboxaus: Top 5 Useful Hand Tools for #Electricians https://t.co/Oc9aA3p1KC #electrician #electrical #handtools
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We'll see you tomorrow, yes? Confirm your attendance here: #SwitchToLED @DubboCouncil #DubboCity… https://t.co/Rccb1iuEsS
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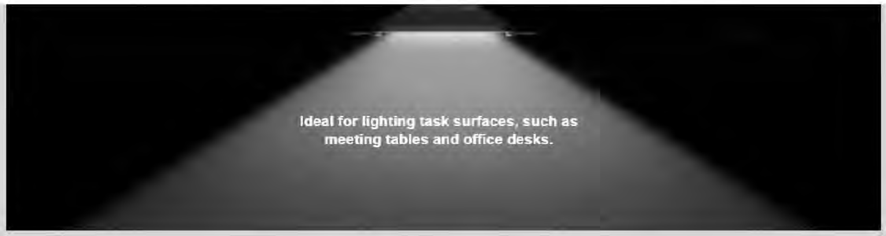

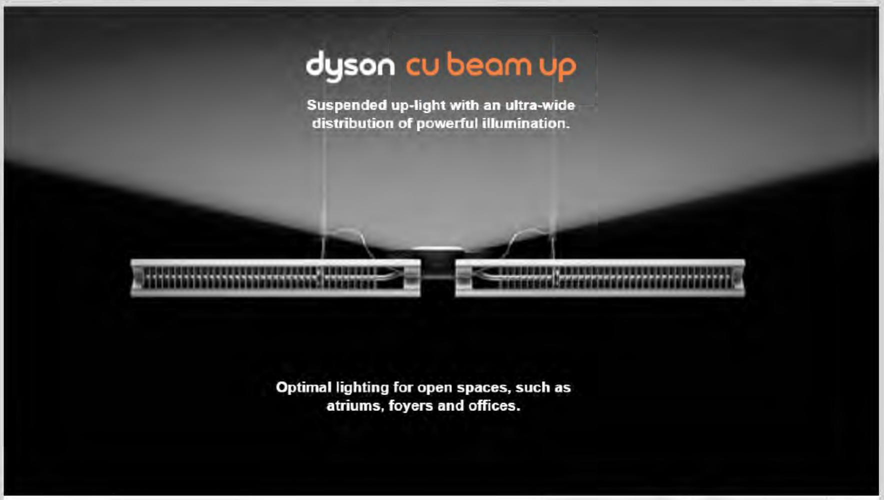

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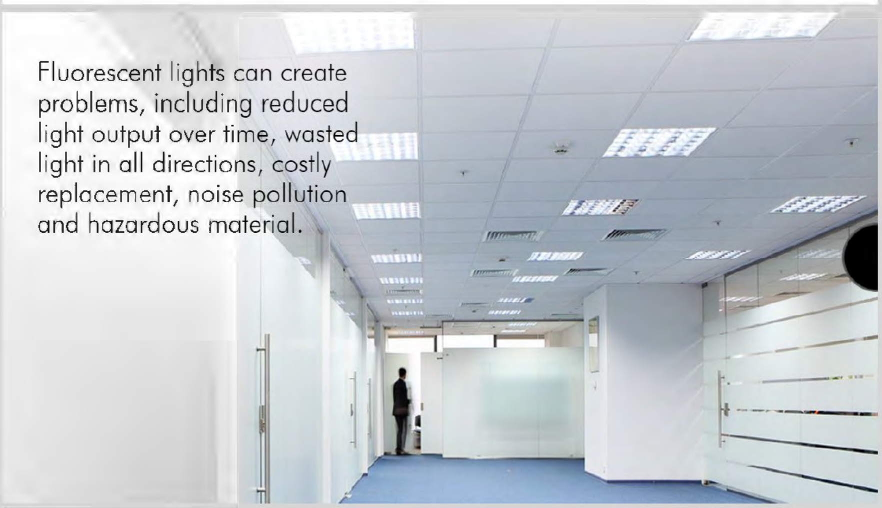

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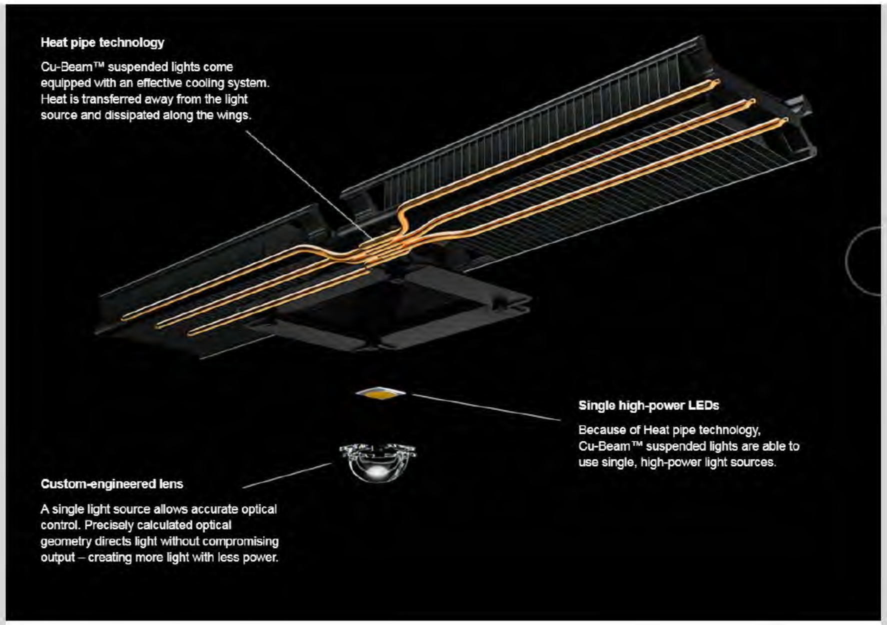

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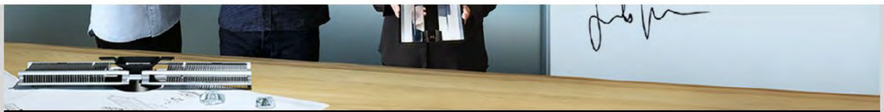

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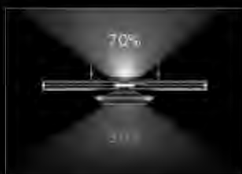
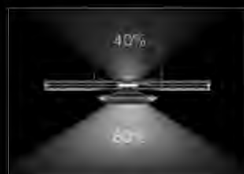




Presenting

With more light upward and less light downward, the presenter's screen can become the focal point.

Meeting

More light directed downward illuminates the table, to aid note-taking and discussions across the table.

Out of hours

Full up-light provides a blanket of ambient illumination across the space – ideal for maintenance staff.

Presenting

With more light upward and less light downward, the presenter's screen can become the focal point.

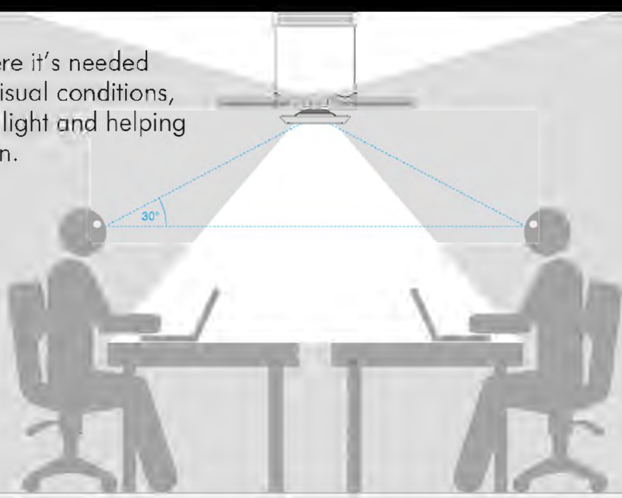
Meeting

More light directed downward illuminates the table, to aid note-taking and discussions across the table.

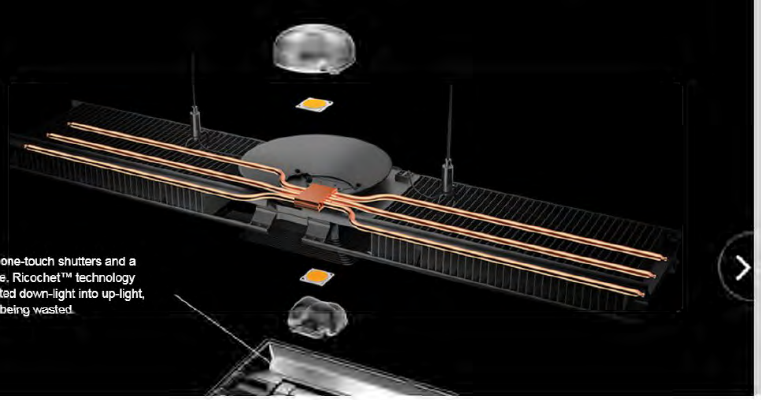
Out of hours

Full up-light provides a blanket of ambient illumination across the space – ideal for maintenance staff.

Directing light where it's needed provides optimal visual conditions, preventing wasted light and helping to reduce eye strain.



Ricochet™ technology maximizes the output of every lumen.



With adjustable one-touch shutters and a reflective surface, Ricochet™ technology converts unwanted down-light into up-light, preventing light being wasted.

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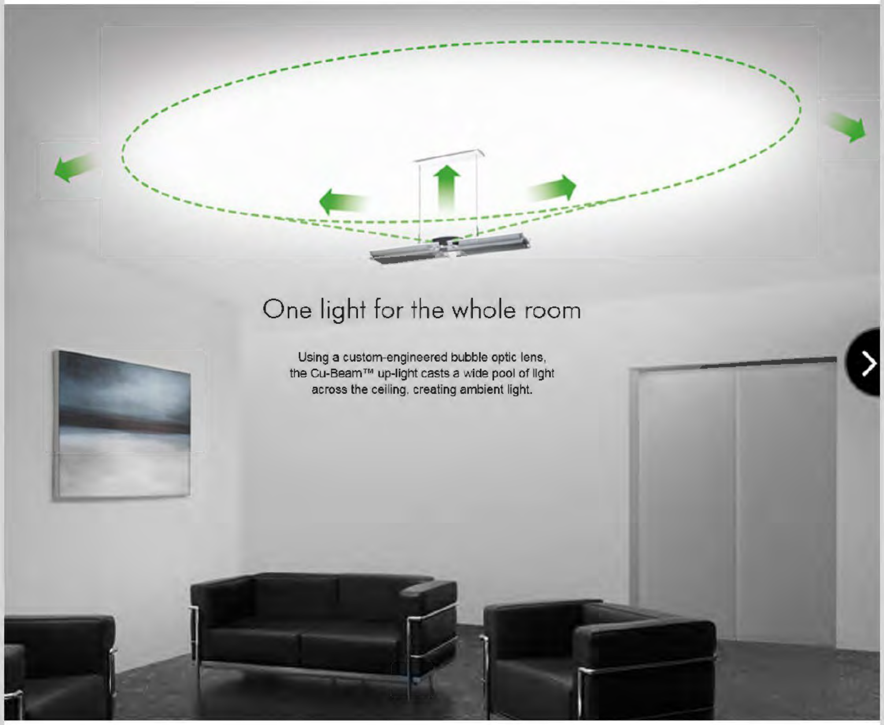

Wide distribution of light

Wide distribution of light

When mounted at 400mm / 15.75in from the ceiling, Cu-Beam™ up-light projects light evenly over an area of 4m / 13ft wide.

Useful resources

Download manuals, installation guides and technical specifications.

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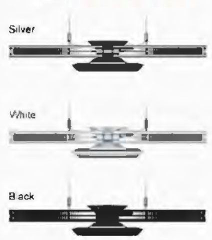

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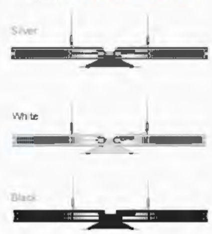
- Installation guide

dyson cu beam down



- Range brochure
- Operations manual
- Technical specification

dyson cu beam up

- Range brochure
- Operations manual
- Technical specification

Products	Shopping info	Support	Community	General
Vacuum cleaners	Store	Get expert help	About Dyson	Contact us
Air treatment	Browse vacuum cleaners	Register your warranty	Press	Privacy
Hair Care	Browse air treatment	Register your hand dryer	Careers	Terms and conditions
Hand dryers	Browse lighting	Service centers	James Dyson Foundation	Sign up for Dyson emails
Parts	Browse tools and accessories	Your account		Corporate Social Responsibility
Tools	Shop special offers	Safety recall		California Transparency declaration
Asthma & Allergy	Delivery details			Sitemap
Pets	Warranty details			
	Returns policy			
	Store locator			

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‡Suction tested to ASTM F558 at the cleaner head, dust-loaded against upright market.

*Suction testing based on ASTM F558, dust-loaded against robot market.

[1]Historically, manufacturers based "no loss of suction" claims on a single test that can be completed before a vacuum's bin is full. We repeat that test to bin full 100s of times consecutively, amounting to 10 years' worth of test dust, to ensure vacuums containing Dyson Cinetic™ science maintain constant suction

[2]AM06 is 75% quieter than AM01; AM07 60% than AM02; AM08 35% than AM03.

[3]AM09 is 75% quieter than AM05.

[4]Calculated using PE International GaBi software and method developed with Carbon Trust based on 5 years use and dry times measured using Dyson test method 769 based on NSF P335 with a measurement of 0.1g residual moisture.

[5]Suction tested to ASTM F558 at the cleaner head, dust-loaded. Lightweight market defined by machines weighing less than 14.55 lbs.

[6]Usage based on 2 paper towels per dry (data from Dyson internal research –Sept 2008). Calculations include standby power. Cost based on average paper towel cost of $0.01 and an electricity charge of $0.10 per kWh (source: US Department of Energy). Paper towel dispenser, warm air hand dryer, and Dyson Airblade™ hand dryer purchase costs are excluded from comparison. Dry times calculated using Dyson test method 769 based on NSF protocol P335 using a measurement of 0.1g residual moisture.

[7]Dry time measured using Dyson test method 769 based on NSF P335 using a measurement of 0.1g residual moisture.

[8]For calculations, visit http://www.dyson.com/hand-dryers/calculator/savings-calculator.aspx

[9]Compared to the original Dyson Airblade™ hand dryer.

[10]Research carried out by Accugen Laboratory Chicago and SGS Laboratory New Jersey in 2015.

[11]Gendron LMc, Trudel L, Moineau S, Duchaine C. Evaluation of bacterial contaminants found on unused paper towels and possible postcontamination after handwashing: A pilot study. American Journal of Infection Control 40; 2012: e5-e9

[12]www.cdc.gov/features/handwashing/index.html

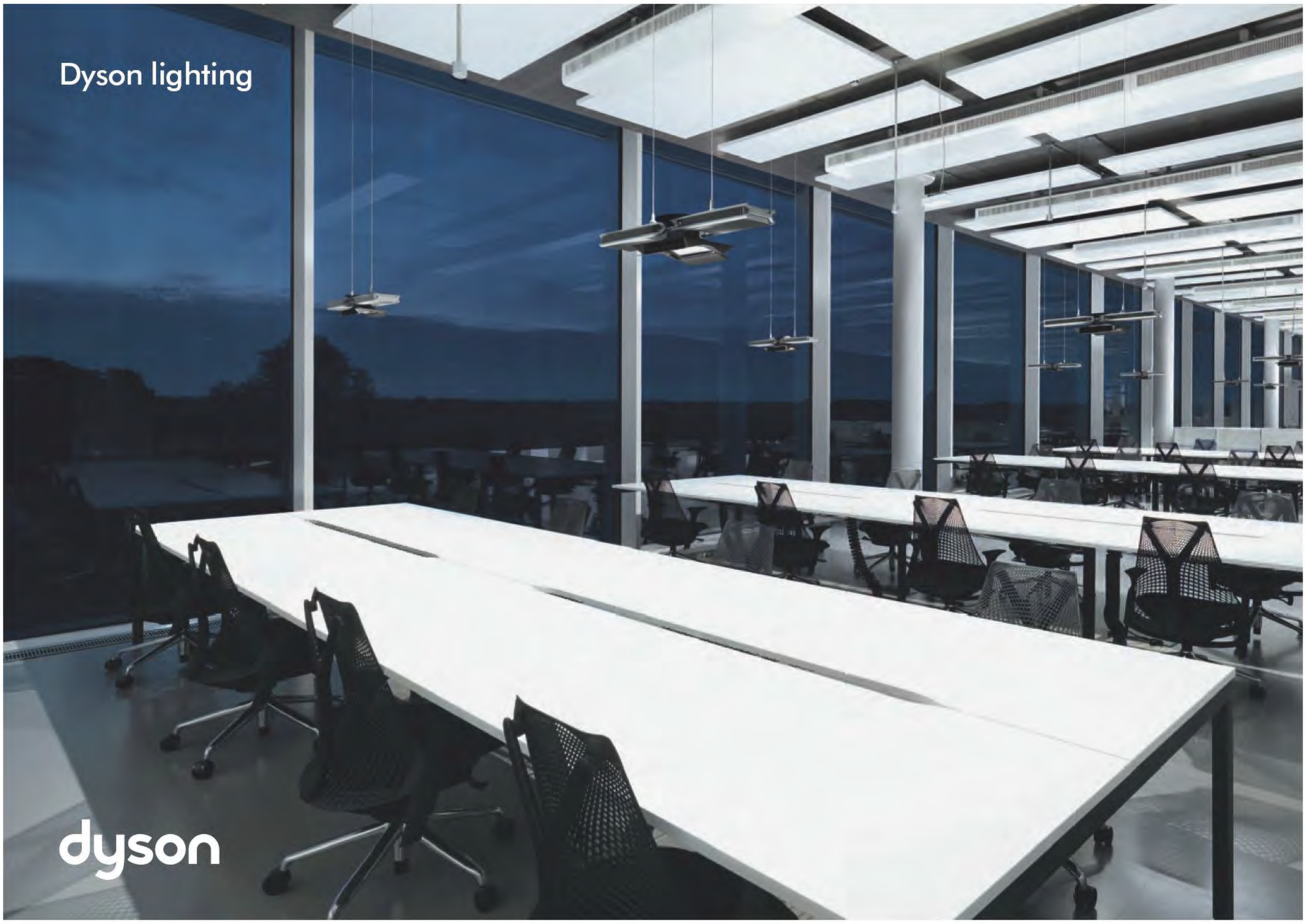
*Tested using test method DTM 961, based on IEC 60675.

**Assumes up to 6% savings in air conditioning costs for every degree Fahrenheit that thermostat is raised. (See U.S. EPA and D.O.E. Energy Savings Calculator). Also assumes elevated air speed may offset increase in air temperature by up to five degrees (See ASHRAE Standard 55-2004-Thermal Environmental Conditions for Human Occupancy). Air multiplier must be used in conjunction with and in close proximity to air conditioning ventilation output in each room to recognize savings benefit. Actual savings may vary based on use and other factors.

***Calculated lifetime based on LED L70.

****Based on Tolomeo lettura halo aluminium reading lamp using a 70W halogen bulb at a cost of $3.55 electricity cost of $0.15 per kWh and 144,000 hours duration.

o Dyson received the highest numerical score among canister and stick vacuums in the J.D. Power 2017 Vacuum Satisfaction Study, based on 6,965 total responses and measures the opinions of consumers who purchased a canister or stick vacuum in the previous 12 months surveyed February-March 2017. Your experiences may vary. Visit jdpower.com.


Dyson lighting
dyson

Jake Dyson
Director and Chief Lighting Engineer


Powerful light, precisely where you need it.
Neglecting to protect LEDs from heat can damage their phosphorus coating, degrading brightness. That's why Jake Dyson introduced Heat pipe technology to direct heat away from the LEDs to sustain their brightness.

Dyson lighting works differently

Designed from the inside out.
Dyson lighting has
all this technology.

1 Heat pipe technology

+

2 High power LEDs for powerful light

+

3 Precise optical control

=

Heat pipe technology to cool LEDs.
For powerful light, precisely
where you need it.

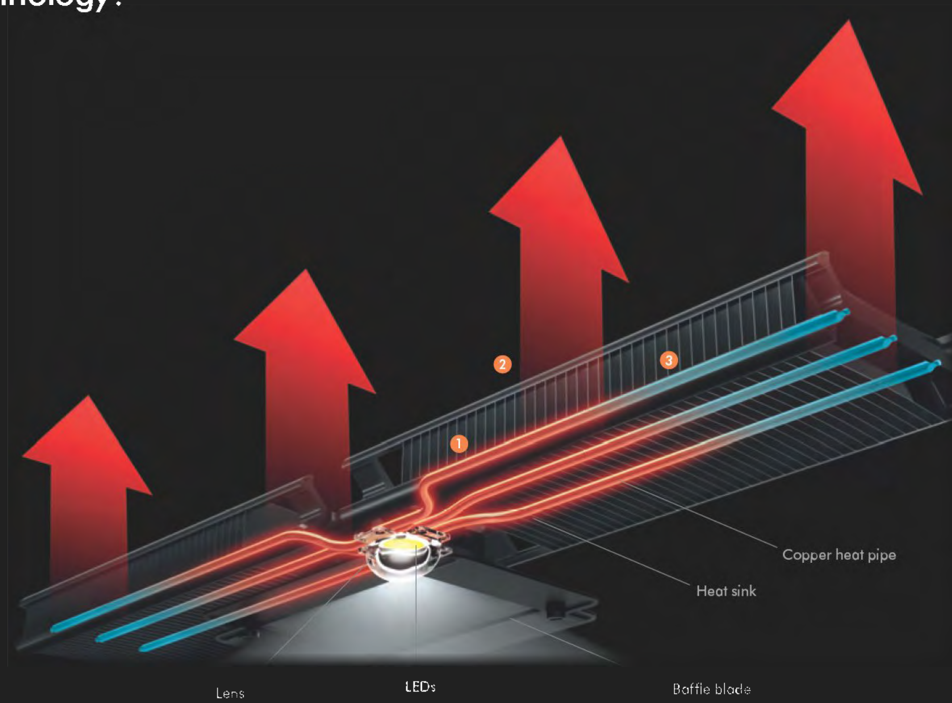
What is Heat pipe technology?

Heat pipe technology cools the LEDs:

Stage 1
When the light is switched on, the heat generated by the LEDs turns the water inside the tubes into vapor. The vapor begins moving along the tubes due to the difference in pressure.

Stage 2
As soon the vapor reaches a cool area of the tube, it condenses back into water. The remaining heat energy is dissipated through the finned aluminum heat sinks that form the light's wings.

Stage 3
A copper wick draws the water back towards the LEDs via capillary action, and the cycle begins again.



dyson cu beam duo

Combined up and down light with full flexible control.

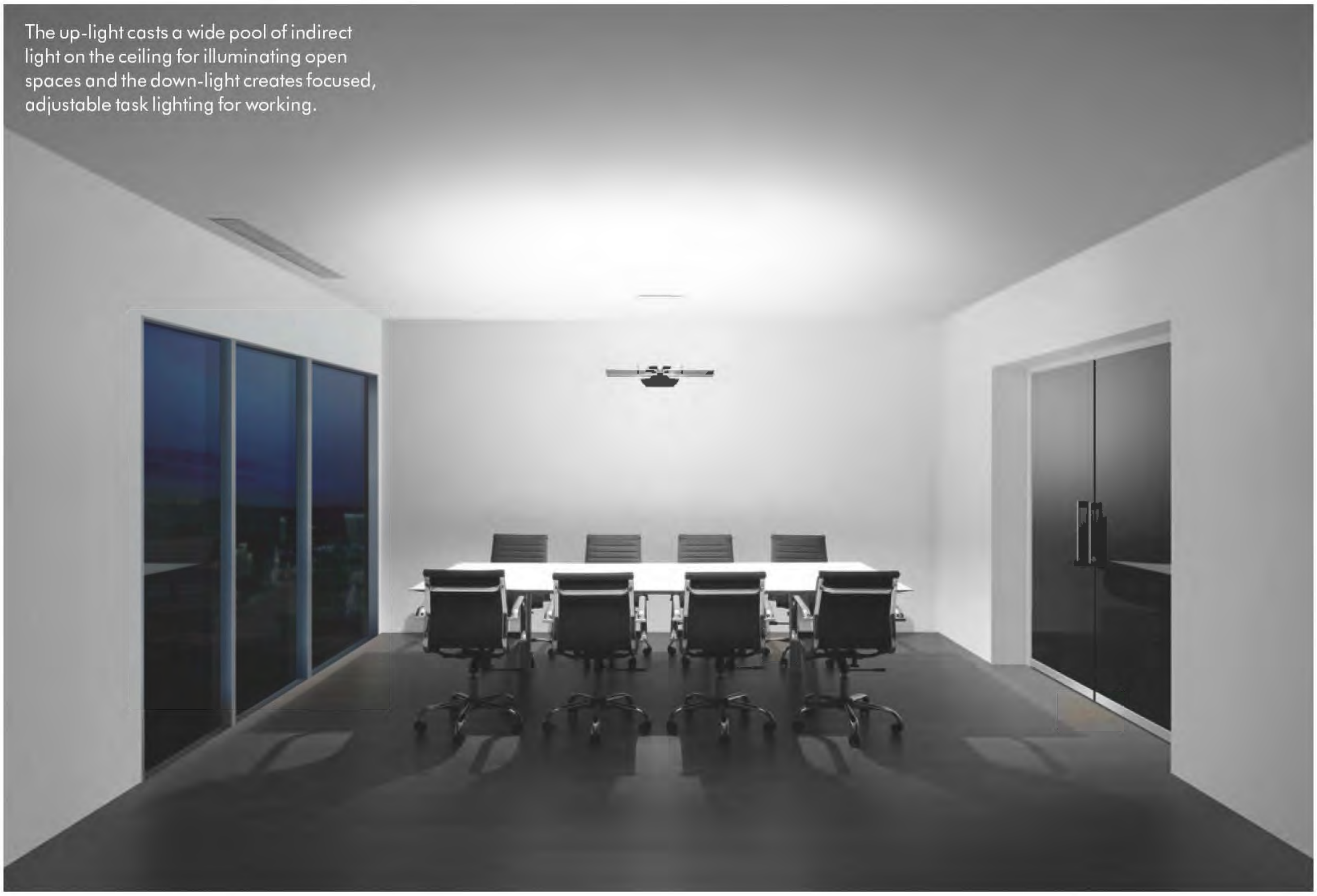
- Powerful up and down light from one product.
- Custom-engineered lens and trim blades project direct light precisely where you need it.
- The down-light projects up to 722lx at 4000K evenly over an area of 10.5ft x 5.3ft / 3.2m x 1.6m when mounted 4.3ft / 1.3m above the task area.[1]
- The up-light projects up to 733lx at 4000K evenly over an area of 13ft / 4m wide when mounted at a 15.8in /400 mm drop height from the ceiling.[1]
- High efficacy with up to 113 lm/W at 4000K.
- Weighs only 7lb / 3.2kg.
- 5 year warranty (parts only).


Silver


Black


White

[1]Based on 50/50 split of up and down light.

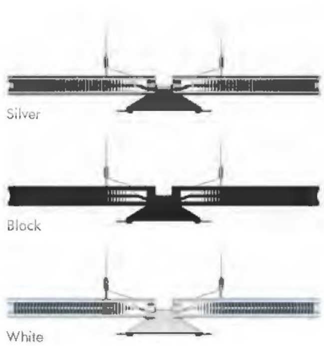


The up-light casts a wide pool of indirect light on the ceiling for illuminating open spaces and the down-light creates focused, adjustable task lighting for working.

dyson cu beam down

Suspended down-light with a controlled pool of powerful illumination.

Powerful LED light (5350lm at 4000K).
Custom-engineered lens and trim blades project direct light precisely where you need it.
LEDs stay bright for up to 180,000 hours.[2]
Projects up to 674lx at 4000K evenly over an area of 10.5ft x 5.3ft / 3.2m x 1.6m when mounted 4.3ft / 1.3m above the task area.
High efficacy with up to 94 lm/W at 4000K.
Weighs only 6lb 6oz / 2.9kg.
5 year warranty (parts only).



[2]Calculated lifetime based on LED L70.

Cu-Beam™ down-light is perfect for task surfaces such as meeting tables, reception desks, office and dining areas.

dyson cu beam up

Suspended up-light with an ultra-wide distribution of powerful illumination.

Powerful LED light (7800lm at 4000K).
Custom-engineered lens projects wide beam of ambient light precisely where you need it.
Stays bright for up to 180,000 hours.[2]
Projects up to 690lx at 4000K evenly over an area of 13ft / 4m wide when mounted at 15.8in / 400 mm drop height from the ceiling.
High efficacy with up to 92 lm/W at 4000K.
Weighs only 6lb 6oz / 2.9kg.
5 year warranty (parts only).

Silver

Black

White

[2]Calculated lifetime based on LED L70.

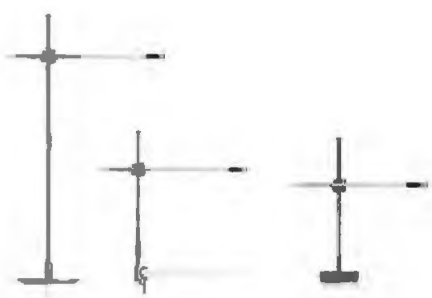
Cu-Beam™ up-light makes indirect lighting possible, creating ambient lighting for open spaces like atriums, foyers, circulation areas and general office lighting.

dyson csys

Powerful warm white task light.
Engineered for use in a relaxing space.

Powerful LED light (648lx). Measured from 1.9ft / 0.6m distance over 10.7ft² / 1m² task area.
Stays precisely where you need it.
Touch sensitive continuous dimming.
Conical reflectors help to reduce glare.
LEDs stay bright for up to 144,000 hours[2] due to Heat pipe technology.
2 year warranty (parts only).

Colorways – Floor and Clamp: Black/Silver, Black/Black.
Desk: Black/Silver, Black/Black or White/Silver.



[2]Calculated lifetime based on LED L70.

CSYS™ task lights give hotel guests powerful warm white light. They can position it precisely where it's needed, to suit working and reading.

dyson csys 4k

Powerful cool white task light.
Engineered for the office environment.

Powerful LED light (808lx). Measured from 1.9ft / 0.6m distance over $10.7ft^2$ / $1m^2$ task area.
High-efficiency LEDs provide 30% more lumens per watt than our original model.
Stays precisely where you need it.
Touch sensitive continuous dimming.
Conical reflectors help to reduce glare.
LEDs stay bright for up to 144,000 hours[2] due to Heat pipe technology.
2 year warranty (parts only).

Colorways – Clamp: Black/Silver, Black/Black.
Desk: Black/Silver, Black/Black or White/Silver.

[2]Calculated lifetime based on LED L70.

Cool white light can create an office-like environment. CSYS™ 4K task lights provide 25% more light on the task plane than the original CSYS™ task light (2700K).

dyson cu beam duo

Visit website for full downloadable technical specifications.
wwww.dyson.com/lighting
www.dysoncanada.ca/lighting

Luminaire dimensions

H 3.5in (89 mm)
W 28.5in (725 mm) D 8.1in (206 mm)

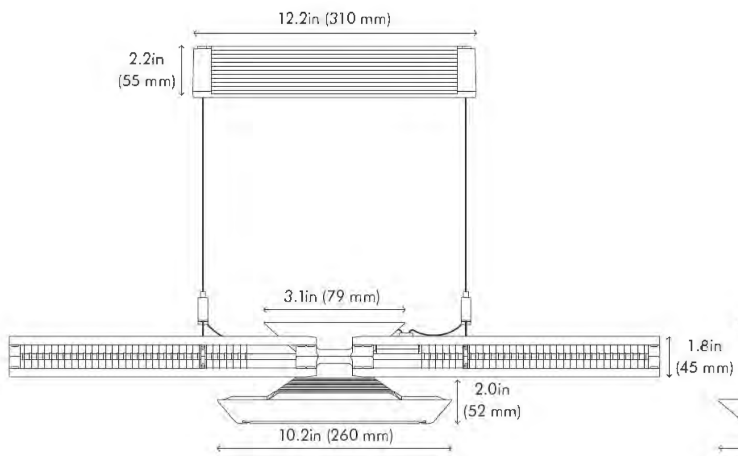
Driver dimensions

H 2.2in (55 mm)
W 12.2in (310 mm) D 4.3in (110 mm)

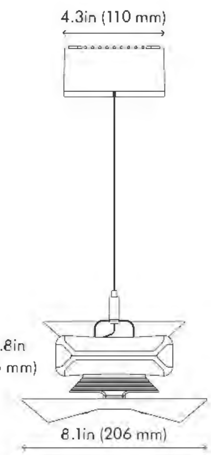
Minimum clearance from ceiling

15.7in (400 mm)
Dimmable: DALI, PWM, 0-10V, 1-10V
Factory pre-set light split ratio:
50% down-light / 50% up-light
(available with 0-10 & 1-10V controls)

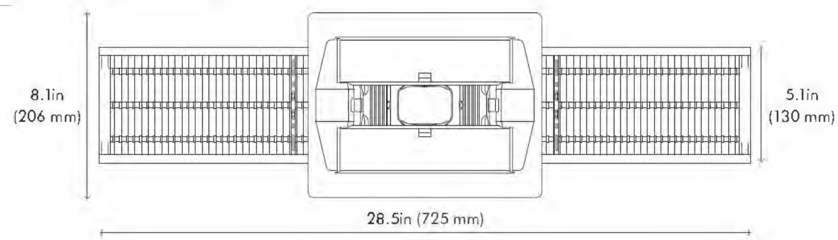
FRONT ELEVATION



SIDE ELEVATION



UNDER ELEVATION



dyson cu beam down

Visit website for full downloadable technical specifications.
wwww.dyson.com/lighting
www.dysoncanada.ca/lighting

Luminaire dimensions

H 3.3in (83 mm)
W 28.3in (720 mm) D 5.1in (130 mm)

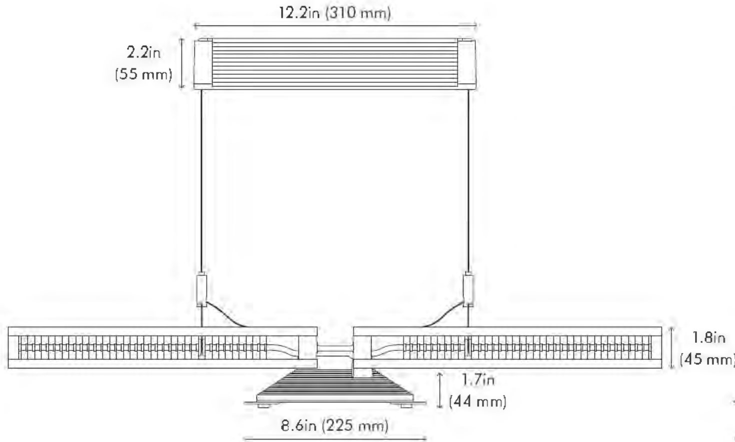
Driver dimensions

H 2.2in (55 mm)
W 12.2in (310 mm) D 4.3in (110 mm)

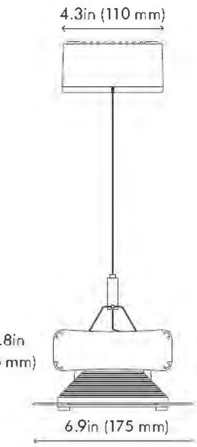
Minimum clearance from ceiling

15.7in (400 mm)

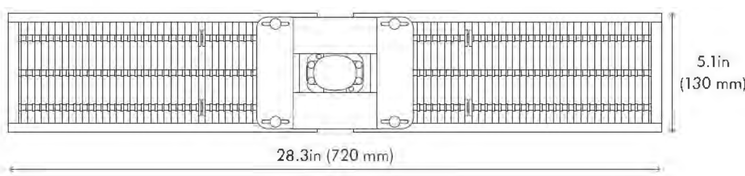
FRONT ELEVATION



SIDE ELEVATION



UNDER ELEVATION



dyson cu beam up

Visit website for full downloadable technical specifications.
wwww.dyson.com/lighting
www.dysoncanada.ca/lighting

Luminaire dimensions

H 2.3in (60 mm)
W 28.3in (720 mm) D 5.1in (130 mm)

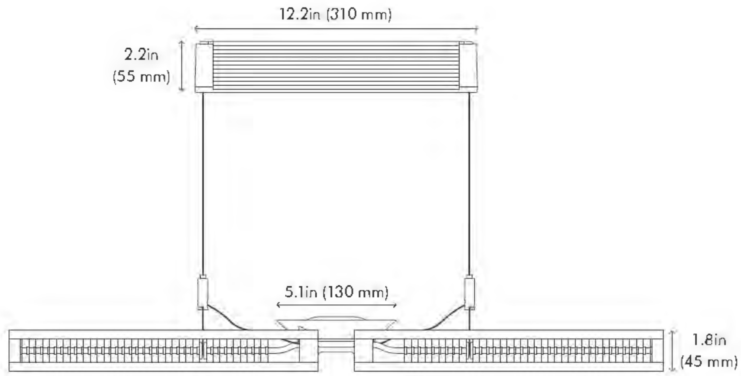
Driver dimensions

H 2.2in (55 mm)
W 12.2in (310 mm) D 4.3in (110 mm)

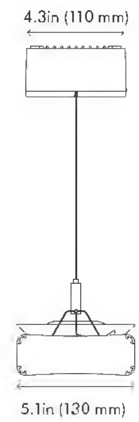
Minimum clearance from ceiling

15.7in (400 mm)

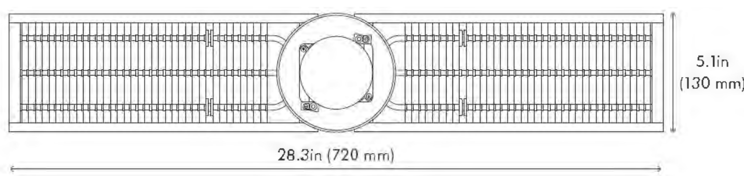
FRONT ELEVATION



SIDE ELEVATION



TOP ELEVATION



dyson csys desk

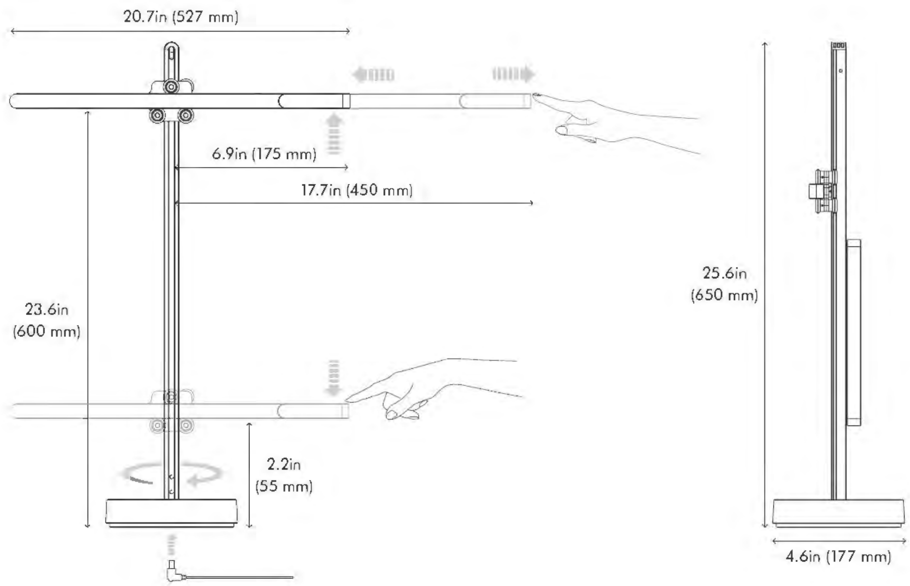
Visit website for full downloadable technical specifications.
wwww.dyson.com/lighting
www.dysoncanada.ca/lighting

Luminaire dimensions

H 25.6in (650 mm)
W 20.7in (527 mm) D 4.6in (177 mm)

FRONT ELEVATION

SIDE ELEVATION



dyson csys clamp

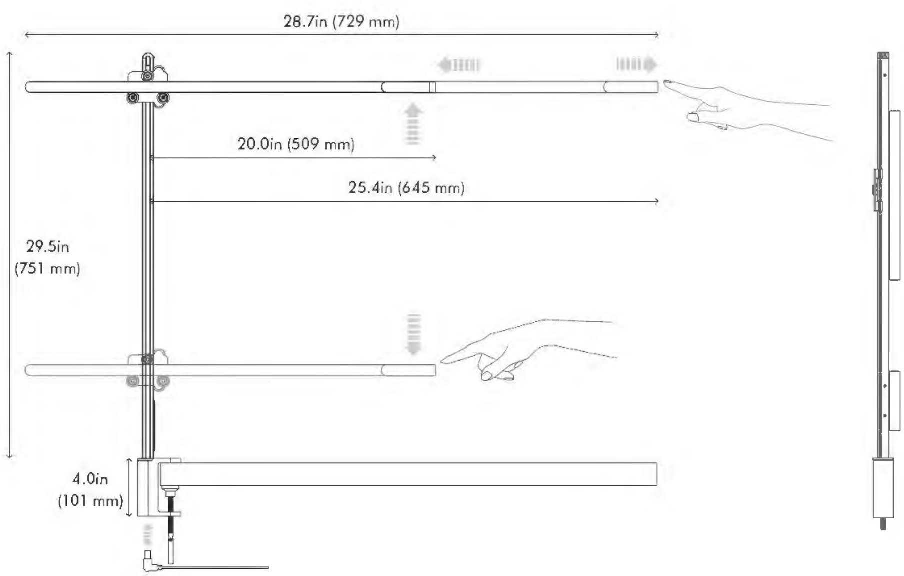
Visit website for full downloadable technical specifications.
wwww.dyson.com/lighting
www.dysoncanada.ca/lighting

Luminaire dimensions

H 29.5in (751 mm)
W 28.7in (729 mm) D 1.5in (38 mm)

FRONT ELEVATION

SIDE ELEVATION



dyson csys floor

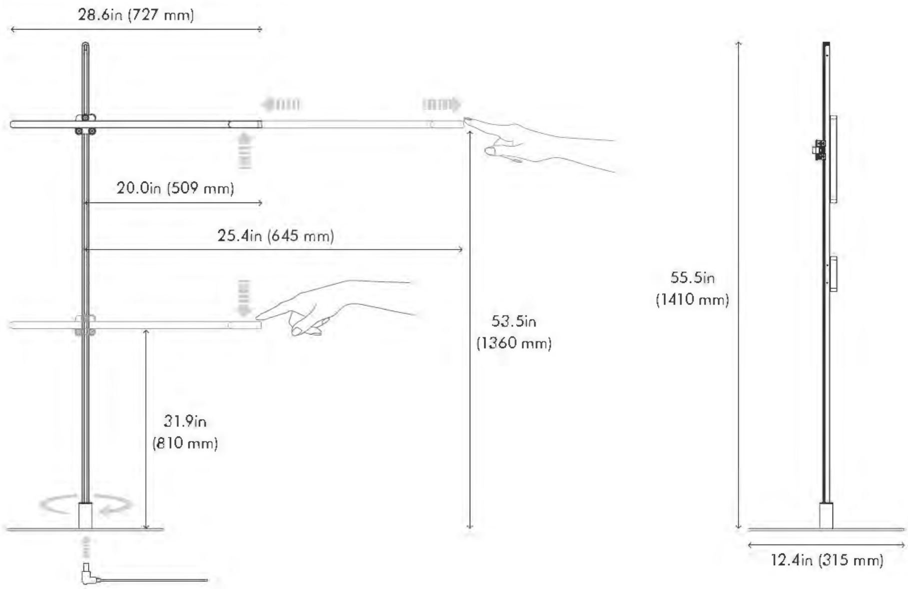
Visit website for full downloadable technical specifications.
wwww.dyson.com/lighting
www.dysoncanada.ca/lighting

Luminaire dimensions

H 55.5in (1410 mm)
W 28.6in (727 mm) D 12.4in (315 mm)

FRONT ELEVATION

SIDE ELEVATION



[redacted]

For more information
please contact:

USA
855-720-6377
www.dyson.com/lighting
lighting@dyson.com

CANADA
877-397-6622
www.dysoncanada.ca/lighting
commercial.sales@dyson.com

dyson

EXHIBIT H

Philips

From Wikipedia, the free encyclopedia

Koninklijke Philips N.V. (**Koninklijke Philips N.V. of the Netherland, Philips**), (stylized as **PHILIPS**) is a Dutch technology company headquartered in Amsterdam with primary divisions focused in the areas of electronics, healthcare and lighting. It was founded in Eindhoven in 1891, by Gerard Philips and his father Frederik. It is one of the largest electronics companies in the world and employs around 105,000 people across more than 60 countries.[1]

Philips is organized into three main divisions: Philips Consumer Lifestyle (formerly Philips Consumer Electronics and Philips Domestic Appliances and Personal Care), Philips Healthcare (formerly Philips Medical Systems) and Philips Lighting. As of 2012, Philips was the largest manufacturer of lighting in the world measured by applicable revenues.[2] In 2013, the company announced the sale of the bulk of its remaining consumer electronics to Japan's Funai Electric Co,[3] but in October 2013, the deal to Funai Electric Co was broken off and the consumer electronics operations remain under Philips. Philips said it would seek damages for breach of contract in the US$200-million sale.[4] In April 2016, the International Court of Arbitration ruled in favour of Philips, awarding compensation of €135 million in the process.[5]

Philips has a primary listing on the Euronext Amsterdam stock exchange and is a component of the Euro Stoxx 50 stock market index.[6] It has a secondary listing on the New York Stock Exchange.

Koninklijke Philips N.V.

PHILIPS

World headquarters in Amsterdam, Netherlands

Type	Naamloze vennootschap
Traded as	Euronext: PHIA (https://euronext.com/products/equities/NL0000009538-XAMS/quotes), NYSE: PHG (https://www.nyse.com/quote/XNYS:PHG)
Industry	Consumer electronics Lighting Healthcare
Founded	15 May 1891 Eindhoven, Netherlands
Founders	Gerard Philips Frederik Philips
Headquarters	Amsterdam, Netherlands
Area served	Worldwide
Key people	Jeroen van der Veer (Chairman) Frans van Houten (CEO)
Products	Home appliances Lighting Medical equipment Audio equipment
Revenue	€24.51 billion (2016)[1]

Contents

Operating income	€1.855 billion (2016)[1]
Profit	€1.448 billion (2016)[1]
Total assets	€32.30 billion (2016)[1]
Total equity	€12.60 billion (2016)[1]
Number of employees	114,188 (2016)[1]
Divisions	Philips Consumer Lifestyle Philips Healthcare Philips Lighting
Website	www.philips.com/global/ (http://www.philips.com/global/)

History


Gerard Philips

The Philips Company was founded in 1891, by Gerard Philips and his father Frederik. Frederik, a Jewish banker based in Zaltbommel, financed the purchase and setup of a modest, empty factory building in Eindhoven, where the company started the production of carbon-filament lamps and other electro-technical products in 1892. This first factory has been adapted and is used as a museum.[7]

In 1895, after a difficult first few years and near bankruptcy, the Philipses brought in Anton, Gerard's younger brother by sixteen years. Though he had earned a degree in engineering, Anton started work as a sales representative; soon, however, he began to contribute many important business ideas. With Anton's arrival, the family business began to expand rapidly, resulting in the founding of Philips Metaalgloeilampfabriek N.V. (Philips Metal Filament Lamp Factory Ltd.) in Eindhoven in 1908, followed in 1912, by the foundation of Philips Gloeilampenfabrieken N.V. (Philips Lightbulb Factories Ltd.). After Gerard and Anton Philips changed their family business by founding the Philips corporation, they laid the foundations for the later electronics multinational.

In the 1920s, the company started to manufacture other products, such as vacuum tubes. In 1939, they introduced their electric razor, the *Philishave* (marketed in the US using the Norelco brand name). The "Chapel" is a radio with built-in loudspeaker, which was designed during the early 1930s.

Philips Radio

On 11 March 1927, Philips went on the air with shortwave radio station PCJJ (later PCJ) which was joined in 1929 by sister station PHOHI (Philips Omroep Holland-Indië). PHOHI broadcast in Dutch to the Dutch East Indies (now Indonesia) while PCJJ broadcast in English, Spanish and German to the rest of the world.

The international program on Sundays commenced in 1928, with host Eddie Startz hosting the *Happy Station* show, which became the world's longest-running shortwave program. Broadcasts from the Netherlands were interrupted by the German invasion in May 1940. The Germans commandeered the transmitters in Huizen to use for pro-Nazi broadcasts, some originating from Germany, others concerts from Dutch broadcasters under German control.

Philips Radio was absorbed shortly after liberation when its two shortwave stations were nationalised in 1947 and renamed Radio Netherlands Worldwide, the Dutch International Service. Some PCJ programs, such as *Happy Station*, continued on the new station.

Philips chapel radio model 930A, 1931

Stirling engine

Philips was instrumental in the revival of the Stirling engine when, in the early 1930s, the management decided that offering a low-power portable generator would assist in expanding sales of its radios into parts of the world where mains electricity was unavailable and the supply of batteries uncertain. Engineers at the company's research lab carried out a systematic comparison of various power sources and determined that the almost forgotten Stirling engine would be most suitable, citing its quiet operation (both audibly and in terms of radio interference) and ability to run on a variety of heat sources (common lamp oil – "cheap and available everywhere" – was favored).[8] They were also aware that, unlike steam and internal combustion engines, virtually no serious development work had been carried out on the Stirling engine for many years and asserted that modern materials and know-how should enable great improvements.[9]

Encouraged by their first experimental engine, which produced 16 W of shaft power from a bore and stroke of 30 mm × 25 mm,[10] various development models were produced in a program which continued throughout World War II. By the late 1940s, the 'Type 10' was ready to be handed over to Philips' subsidiary Johan de Witt in Dordrecht to be produced and incorporated into a generator set as originally planned. The result, rated at 180/200 W electrical output from a bore and stroke of 55 mm × 27 mm, was designated MP1002CA (known as the "Bungalow set"). Production of an initial batch of 250 began in 1951, but it became clear that they could not be made at a competitive price, besides with the advent of transistor radios with their much lower power requirements meant that the original rationale for the set was disappearing. Approximately 150 of these sets were eventually produced.[11]

In parallel with the generator set Philips developed experimental Stirling engines for a wide variety of applications and continued to work in the field until the late 1970s, though the only commercial success was the 'reversed Stirling engine' cryocooler. However, they filed a large number of patents and amassed a wealth of information, which they later licensed to other companies.[12]

Shavers

The first Philips shaver was introduced in the 1930s, and was simply called “The Philishave”. In the USA, it was called the “Norelco”, which remains a part of their product line today.[13]

World War II

On 9 May 1940, the Philips directors learned that the German invasion of the Netherlands was to take place the following day. Having prepared for this, Anton Philips and his son in law Frans Otten, as well as other Philips family members, fled to the United States, taking a large amount of the company capital with them. Operating from the US as the **North American Philips Company,** they managed to run the company throughout the war. At the same time, the company was moved (on paper) to the Netherlands Antilles to keep it out of American hands.

On 6 December 1942, The British No. 2 Group RAF led an air raid which heavily damaged the Philips Radio factory in Eindhoven with few casualties among the Dutch workers and civilians.[14] The Philips works in Eindhoven was bombed again by the RAF on 30 March 1943.[15][16]

Frits Philips, the son of Anton, was the only Philips family member to stay in the Netherlands. He saved the lives of 382 Jews by convincing the Nazis that they were indispensable for the production process at Philips.[17] In 1943 he was held at the internment camp for political prisoners at Vught for several months because a strike at his factory reduced production. For his actions in saving the hundreds of Jews, he was recognized by Yad Vashem in 1995 as a "Righteous Among the Nations".[18]

1945 to 2001

After the war the company was moved back to the Netherlands, with their headquarters in Eindhoven.

In 1949, the company began selling television sets.[20] In 1950, it formed Philips Records, which eventually formed part of PolyGram.

The Philips Light Tower in Eindhoven, originally a light bulb factory and later the company headquarters[19]

Philips introduced the audio Compact Audio Cassette tape in 1963, and it was wildly successful. Compact cassettes were initially used for dictation machines for office typing stenographers and professional journalists. As their sound quality improved, cassettes would also be used to record sound and became the second mass media alongside vinyl records used to sell recorded music.

Philips introduced the first combination portable radio and cassette recorder, which was marketed as the "radiorecorder", and is now better known as the boom box. Later, the cassette was used in telephone answering machines, including a special form of cassette where the tape was wound on an endless loop. The C-cassette was used as the first mass storage device for early personal computers in the 1970s and 1980s. Philips reduced the cassette size for the professional needs with the Mini-Cassette, although it would not be as successful as the Olympus Microcassette. This became the predominant dictation medium up to the advent of fully digital dictation machines.

In 1972, Philips launched the world's first home video cassette recorder, in the UK, the N1500. Its relatively bulky video cassettes could record 30 minutes or 45 minutes. Later one-hour tapes were also offered. As competition came from Sony's Betamax and the VHS group of manufacturers, Philips introduced the N1700 system which allowed double-length recording. For the first time, a 2-hour movie could fit onto one video cassette. In 1977, the company unveiled a special promotional film for this system in the UK, featuring comedian Denis Norden.[21] The concept was quickly copied by the Japanese makers, whose tapes were significantly cheaper. Philips made one last attempt at a new standard for video recorders with the Video 2000 system, with tapes that could be used on both sides and had 8 hours of total recording time. As Philips only sold its systems on the PAL standard and in Europe, and the Japanese makers sold globally, the scale advantages of the Japanese proved insurmountable and Philips withdrew the V2000 system and joined the VHS Coalition.

Philips had developed a LaserDisc early on for selling movies, but delayed its commercial launch for fear of cannibalizing its video recorder sales. Later Philips joined with MCA to launch the first commercial LaserDisc standard and players. In 1982, Philips teamed with Sony to launch the Compact Disc; this format evolved into the CD-R, CD-RW, DVD and later Blu-ray, which Philips launched with Sony in 1997 and 2006 respectively.

In 1984, Philips split off its activities on the field of photolithographic integrated circuit production equipment, the so-called wafer steppers, into a joint venture with ASM International, located in Veldhoven under the name ASML. Over the years, this new company has evolved into the world's leading manufacturer of chip production machines at the expense of competitors like Nikon and Canon.

In 1991, the company's name was changed from N.V. Philips Gloeilampenfabrieken to Philips Electronics N.V. At the same time, North American Philips was formally dissolved, and a new corporate division was formed in the US with the name Philips Electronics North America Corp.

In 1991-1992, Philips along with their subsidiary Magnavox, released the Philips CD-i, a combined CD player and home video game console. It sold one million units and was discontinued in 1998 after being heavily criticized amongst the gaming community.[22]

In 1997, the company officers decided to move the headquarters from Eindhoven to Amsterdam along with the corporate name change to Koninklijke Philips Electronics N.V. The move was completed in 2001. Initially, the company was housed in the Rembrandt Tower, but in 2002 they moved again, this time to the Breitner Tower. Philips Lighting, Philips Research, Philips Semiconductors (spun off as NXP in September 2006) and Philips Design, are still based in Eindhoven. Philips Healthcare is headquartered in both Best, Netherlands (near Eindhoven) and Andover, Massachusetts, United States (near Boston).

In 2000, Philips bought Optiva Corporation, the maker of Sonicare electric toothbrushes. The company was renamed Philips Oral Healthcare and made a subsidiary of Philips DAP.

In 2001, Philips acquired Agilent Technologies' Healthcare Solutions Group (HSG) for EUR 2 billion.[23]

2001 to 2011

In 2004, Philips abandoned the slogan "Let's make things better" in favour of a new one: "Sense and simplicity".

In December 2005 Philips announced its intention to sell or demerge its semiconductor division. On 1 September 2006, it was announced in Berlin that the name of the new company formed by the division would be NXP Semiconductors. On 2 August 2006, Philips completed an agreement to sell a controlling 80.1% stake in NXP Semiconductors to a consortium of private equity investors consisting of Kohlberg Kravis Roberts & Co. (KKR), Silver Lake Partners and AlpInvest Partners. On 21 August 2006, Bain Capital and Apax Partners announced that they had signed definitive commitments to join the acquiring consortium, a process which was completed on 1 October 2006.

In 2006 Philips bought out the company Lifeline Systems headquartered in Framingham, Massachusetts in a deal valued at $750 million, its biggest move yet to expand its consumer-health business (M).[24]

In August 2007, Philips acquired the company Ximis, Inc. headquartered in El Paso, Texas for their Medical Informatics Division.[25] In October 2007, it purchased a Moore Microprocessor Patent (MPP) Portfolio license from The TPL Group.

On 21 December 2007, Philips and Respironics, Inc. announced a definitive agreement pursuant to which Philips acquired all of the outstanding shares of Respironics for US$66 per share, or a total purchase price of approximately €3.6 billion (US$5.1 billion) in cash.[26]

On 21 February 2008, Philips completed the acquisition of VISICU Baltimore, Maryland through the merger of its indirect wholly owned subsidiary into VISICU. As a result of that merger, VISICU has become an indirect wholly owned subsidiary of Philips. VISICU was the creator of the eICU concept of the use of Telemedicine from a centralized facility to monitor and care for ICU patients.[27]

The Philips physics laboratory was scaled down in the early 21st century, as the company ceased trying to be innovative in consumer electronics through fundamental research.[28]

2011 to present

In January 2011, Philips agreed to acquire the assets of Preethi, a leading India-based kitchen appliances company.[29]

On 27 June 2011, Philips acquired Sectra Mamea AB, the mammography division of Sectra AB, together with the MicroDose brand.[30]

Because net profit slumped 85 percent in Q3 2011, Philips announced a cut of 4,500 jobs to match part of an €800 million ($1.1 billion) cost-cutting scheme to boost profits and meet its financial target.[31]

In March 2012, Philips announced its intention to sell, or demerge its television manufacturing operations to TPV Technology.[32]

In 2011, the company posted a loss of €1.3 billion, but earned a net profit in Q1 and Q2 2012, however the management wanted €1.1 billion cost-cutting which was an increase from €800 million and may cut another 2,200 jobs until end of 2014.[33]

On 5 December 2012, the antitrust regulators of the European Union fined Philips and several other major companies for fixing prices of TV cathode-ray tubes in two cartels lasting nearly a decade.[34]

On 29 January 2013, it was announced that Philips had agreed to sell its audio and video operations to the Japan-based Funai Electric for €150 million, with the audio business planned to transfer to Funai in the latter half of 2013, and the video business in 2017.[35][36] As part of the transaction, Funai was to pay a regular licensing fee to Philips for the use of the Philips brand.[35] The purchase agreement was terminated by Philips in October because of breach of contract.[37]

In April 2013, Philips announced a collaboration with Paradox Engineering for the realization and implementation of a “pilot project” on network-connected street-lighting management solutions. This project was endorsed by the San Francisco Public Utilities Commission (SFPUC).[38]

In 2013, Philips omitted the word "Electronics" from its name, which is now Royal Philips N.V.[39]

On 13 November 2013, Philips unveiled its new brand line “Innovation and You” and a new design of its shield mark. The new brand positioning is cited by Philips to signify company’s evolution and emphasize that innovation is only meaningful if it is based on an understanding of people’s needs and desires.[40]

On 28 April 2014, Philips agreed to sell their Woox Innovations subsidiary (consumer electronics) to Gibson Brands for $US135 million.

On 23 September 2014, Philips announced a plan to split the company into two, separating the lighting business from the healthcare and consumer lifestyle divisions.[41] it moved to complete this in March 2015 to an investment group for $3.3 billion[42]

On February 2015, Philips acquired Volcano Corporation to strengthen its position in non-invasive surgery and imaging.[43]

In June 2016, Philips spun off its lighting division to focus on the healthcare division[44]

In June 2017, Philips announce it would acquire US-based Spectranetics Corp, a manufacturer of devices to treat heart disease, for €1.9 billion (£1.68 billion) expanding its current image-guided therapy business.[45]

Corporate affairs

CEOs

Past and present CEOs:

- 1891–1922: Gerard Philips
- 1922–1939: Anton Philips
- 1939–1961: Frans Otten
- 1961–1971: Frits Philips
- 1971–1977: Henk van Riemsdijk
- 1977–1981: Nico Rodenburg
- 1981-1982: Cor Dillen
- 1982–1986: Wisse Dekker
- 1986–1990: Cor van der Klugt
- 1990–1996: Jan Timmer
- 1996–2001: Cor Boonstra
- 2001–2011: Gerard Kleisterlee
- 2011–present: Frans van Houten

CEOs lighting

- 2003-2008: Theo van Deursen
- 2012-2015: Erik Rondolat

CFOs

Past CFO (Chief Financial Officer)

- 1960–1968: Cor Dillen

Acquisitions

Companies acquired by Philips through the years include ADAC Laboratories, Agilent Healthcare Solutions Group, Amperex, ATL Ultrasound, EKCO, Lifeline Systems, Magnavox, Marconi Medical Systems, Mullard, Optiva, Preethi, Pye, Respironics, Inc., Sectra Mamea AB, Signetics, VISICU, Volcano, VLSI, Ximis, portions of Westinghouse and the consumer electronics operations of Philco and Sylvania. Philips abandoned the Sylvania trademark which is now owned by Havells Sylvania except in Australia, Canada, Mexico, New Zealand, Puerto Rico and the USA where it is owned by Osram. Formed in November 1999 as an equal joint venture between Philips and Agilent Technologies, the light-emitting diode manufacturer Lumileds became a subsidiary of Phillips Lighting in August 2005 and a fully owned subsidiary in December 2006.[46][47] An 80.1 percent stake in Lumileds was sold to Go Scale in early 2015.[48]

Operations

Philips is registered in the Netherlands as a naamloze vennootschap and has its global headquarters in Amsterdam.[1] At the end of 2013 Philips had 111 manufacturing facilities, 59 R&D Facilities across 26 countries and sales and service operations in around 100 countries.[49]

Philips is organized into three main divisions: Philips Consumer Lifestyle (formerly Philips Consumer Electronics and Philips Domestic Appliances and Personal Care), Philips Healthcare (formerly Philips Medical Systems) and Philips Lighting.[1] Philips achieved total revenues of €22.579 billion in 2011, of which €8.852 billion were generated by Philips Healthcare, €7.638 billion by Philips Lighting, €5.823 billion by Philips Consumer Lifestyle and €266 million from group activities.[1] At the end of 2011 Philips had a total of 121,888 employees, of whom around 44% were employed in Philips Lighting, 31% in Philips Healthcare and 15% in Philips Consumer Lifestyle.[1]

Philips invested a total of €1.61 billion in research and development in 2011, equivalent to 7.1% of sales.[1] Philips Intellectual Property and Standards is the group-wide division responsible for licensing, trademark protection and patenting.[50] Philips currently holds around 54,000 patent rights, 39,000 trademarks, 70,000 design rights and 4,400 domain name registrations.[1]

Asia

Thailand

Philips Thailand was established since 1952. It is a branch of Royal Philips Electronics of the Netherlands which is a healthcare, lifestyle and lighting. Philips started manufacturing in Thailand in 1960 with an incandescent lamp factory. Philips has diversified its production facilities to include a fluorescent lamp factory and a luminaries factory, serving Thai's and worldwide markets.[51]

Hong Kong

Philips Hong Kong began operation in 1948. Philips Hong Kong houses the global headquarters of Philips' Audio Business Unit. It also house Philips' Asia Pacific regional office and headquarters for its Design Division, Domestic Appliances & Personal Care Products Division, Lighting Products Division and Medical System Products Division.[52]


The Philips building in the Hong Kong Science Park

In 1974, Philips opened a lamp factory in Hong Kong. This has a capacity of 200 million pieces a year and is certified with ISO 9001:2000 and ISO 14001. Its product portfolio includes prefocus, lensend and E10 miniature light bulbs.[52]

China

Philips established in Zhuhai, Guangdong in 1990. The site mainly manufactures Philishaves and healthcare products.[53] In early 2008, Philips Lighting, a division of Royal Philips Electronics, opened a small engineering center in Shanghai to adapt the company's products to vehicles in Asia.[54]

India

Philips began operations in India in 1930, with the establishment of **Philips Electrical Co. (India) Pvt Ltd** in Kolkata as a sales outlet for imported Philips lamps. In 1938, Philips established its first Indian lamp-manufacturing factory in Kolkata. In 1948, Philips started manufacturing radios in Kolkata. In 1959, a second radio factory was established near Pune. This was closed and sold around 2006. In 1957, the company converted into a public limited company, renamed "Philips India Ltd". In 1970 a new consumer electronics factory began operations in Pimpri near Pune. This is now called the 'Philips Healthcare Innovation Centre'. Also, a manufacturing facility 'Philips Centre for Manufacturing Excellence' was set up in Chakan, Pune in 2012. In 1996, the Philips Software Centre was established in Bangalore, later renamed the Philips Innovation Campus.[55] In 2008, Philips India entered the water purifier market. In 2014, Philip's was ranked 12th among India's most trusted brands according to the Brand Trust Report, a study conducted by Trust Research Advisory.[56]

Israel

Philips has been active in Israel since 1948 and in 1998, set up a wholly owned subsidiary, Philips Electronics (Israel) Ltd. The company has over 700 employees in Israel and generated sales of over $300 million in 2007.[57]

Philips Medical Systems Technologies Ltd. (Haifa) is a developer and manufacturer of Computerized Tomography (CT), diagnostic and Medical Imaging systems. The company was founded in 1969 as Elscint by Elron Electronic Industries and was acquired by Marconi Medical Systems in 1998, which was itself acquired by Philips in 2001.

Philips Semiconductors formerly had major operations in Israel; these now form part of NXP Semiconductors.

Pakistan

Philips has been active in Pakistan since 1948 and has a wholly owned subsidiary, Philips Pakistan Limited (Formerly Philips Electrical Industries of Pakistan Limited).[58]

The head office is in Karachi with regional sales offices in Lahore and Rawalpindi.

Europe

France

Philips France has its headquarters in Suresnes. The company employs over 3600 people nationwide.

Philips Lighting has manufacturing facilities in Chalon-sur-Saône (fluorescent lamps), Chartres (automotive lighting), Lamotte-Beuvron (architectural lighting by LEDs and professional indoor lighting), Longvic (lamps), Miribel (outdoor lighting), Nevers (professional indoor lighting).

The headquarters of Philips France in Suresnes

Germany

Philips Germany was founded in 1926 in Berlin. Now its headquarters is located in Hamburg. Over 4900 people are employed in Germany.[59]

- Hamburg
  - Distribution center of the divisions Healthcare, Consumer Lifestyle, and Lighting.
  - Philips Medical Systems DMC.
  - Philips Innovative Technologies, Research Laboratories.
- Aachen
  - Philips Innovative Technologies.
  - Philips Innovation Services.
- Böblingen
  - Philips Medical Systems, patient monitoring systems.
- Herrsching
  - Philips Respironics.
- Ulm
  - Philips Photonics, development and manufacture of vertical laser diodes (VCSELs) and photodiodes for sensing and data communication.

Greece

Philips' Greece is headquartered in Halandri, Attica. As of 2012 Philips has no manufacturing plants in Greece, although there have been in the past.

Italy

Philips founded its Italian headquarter in 1918, basing it in Monza (Milan) where it still operates, for commercial activities only.

Poland

Philips' operations in Poland include: a European financial and accounting centre in Łódź; Philips Lighting facilities in Bielsko-Biała, Pabianice, Piła, and Kętrzyn; and a Philips Domestic Appliances facility in Białystok.

Portugal

Philips started business in Portugal in 1927, as "Philips Portuguesa S.A.R.L.".[60][61] Currently, Philips Portuguesa S.A. is headquartered in Oeiras near Lisbon.[62] There were three Philips factories in Portugal: the FAPAE lamp factory in Lisbon;[61][63][64] the Carnaxide magnetic-core memory factory near Lisbon, where the Philips Service organization was also based; and the Ovar factory in northern Portugal making camera components and remote control devices.[63] The company still operates in Portugal with divisions for commercial lighting, medical systems and domestic appliances.[65]

Sweden

Philips Sweden has two main sites, Kista, Stockholm County, with regional sales, marketing and a customer support organization and Solna, Stockholm County, with the main office of the mammography division.

United Kingdom

Philips UK has its headquarters[66] in Guildford. The company employs over 2500 people nationwide.[67]

- Philips Healthcare Informatics, Belfast develops healthcare software products.
- Philips Consumer Products, Guildford provides sales and marketing for televisions, including High Definition televisions, DVD recorders, hi-fi and portable audio, CD recorders, PC peripherals, cordless telephones, home and kitchen appliances, personal care (shavers, hair dryers, body beauty and oral hygiene).
- Philips Dictation Systems, Colchester.
- Philips Lighting: sales from Guildford and manufacture in Hamilton.
- Philips Healthcare, Reigate. Sales and technical support for X-ray, ultrasound, nuclear medicine, patient monitoring, magnetic resonance, computed tomography, and resuscitation products.
- Philips Research Laboratories, Cambridge (Until 2008 based in Redhill, Surrey. Originally these were the Mullard Research Laboratories.)

In the past, Philips UK also included:

- Consumer product manufacturing in Croydon
- Television Tube Manufacturing Mullard Simonstone
- Philips Business Communications, Cambridge: offered voice and data communications products, specialising in Customer Relationship Management (CRM) applications, IP Telephony, data networking, voice processing, command and control systems and cordless and mobile telephony. In 2006 the business was placed into a 60/40 joint venture with NEC. NEC later acquired 100% ownership and the business was renamed NEC Unified Solutions.

- Philips Electronics Blackburn; vacuum tubes, capacitors, delay-lines, Laserdiscs, CDs.
- Philips Domestic Appliances Hastings: Design and Production of Electric kettles, Fan Heaters plus former EKCO brand "Thermotube" Tubular Heaters and "Hostess" Domestic Food Warming Trolleys.
- Philips Semiconductors, Hazel Grove, Stockport and Southampton, both also earlier part of Mullard. These became part of NXP.
- London Carriers, logistics and transport division.
- Mullard Equipment Limited (MEL) which produced products for the military
- Pye Telecommunications Ltd of Cambridge
- TMC Limited of Malmesbury
- Pye TVT Ltd of Cambridge

North America

Canada

Philips Canada was founded in 1934. It is well known in medical systems for diagnosis and therapy, lighting technologies, shavers, and consumer electronics.

The Canadian headquarters are located in Markham, Ontario.

For several years, Philips manufactured lighting products in two Canadian factories. The London, Ontario, plant opened in 1971. It produced A19 lamps (including the "Royale" long life bulbs), PAR38 lamps and T19 lamps (originally a Westinghouse lamp shape). Philips closed the factory in May 2003. The Trois-Rivières, Quebec plant was a Westinghouse facility which Philips continued to run it after buying Westinghouse's lamp division in 1983. Philips closed this factory a few years later, in the late 1980s.

Mexico

Philips Mexicana SA de CV is headquartered in Mexico City. Philips Lighting has manufacturing facilities in: Monterrey, Nuevo León; Ciudad Juárez, Chihuahua; and Tijuana, Baja California. Philips Consumer Electronics has a manufacturing facility in Ciudad Juárez, Chihuahua. Philips Domestic Appliances formerly operated a large factory in the Industrial Vallejo sector of Mexico City but this was closed in 2004.

United States

Philips' North American headquarters in Andover, Massachusetts

Philips' Electronics North American headquarters is in Andover, Massachusetts. Philips Lighting has its corporate office in Somerset, New Jersey, with manufacturing plants in Danville, Kentucky, Dallas, Salina, Kansas and Paris, Texas and distribution centers in Mountain Top, Pennsylvania El Paso, Texas, Ontario, California and Memphis, Tennessee. Philips Healthcare is headquartered in Andover, Massachusetts. The North American sales organization is based in Bothell, Washington. There are also manufacturing facilities in Andover, Massachusetts, Bothell, Washington, Baltimore, Maryland, Cleveland, Ohio, Foster City, California, Gainesville, Florida, Milpitas, California and Reedsville, Pennsylvania. Philips Healthcare also formerly had a factory in Knoxville, Tennessee. Philips Consumer Lifestyle has its corporate office in Stamford, Connecticut. Philips Lighting has a Color Kinetics office in Burlington, Massachusetts. Philips Research North American headquarters is in Cambridge, Massachusetts.

In 2007, Philips entered into a definitive merger agreement with North American luminaires company Genlyte Group Incorporated, which provides the company with a leading position in the North American luminaires (also known as "lighting fixtures"), controls and related products for a wide variety of applications, including solid state lighting. The company also acquired Respironics, which was a significant gain for its healthcare sector. On 21 February 2008 Philips completed the acquisition of VISICU Baltimore, Maryland. VISICU was the creator of the eICU concept of the use of Telemedicine from a centralized facility to monitor and care for ICU patients.

Oceania

Australia and New Zealand

Philips Australia was founded in 1927 and is headquartered in North Ryde, New South Wales and also manages the New Zealand operation from there. The company currently employs around 800 people. Regional sales and support offices are located in Melbourne, Brisbane, Adelaide, Perth and Auckland.

Current activities include: Philips Healthcare (also responsible for New Zealand operations); Philips Lighting (also responsible for New Zealand operations); Phillips Oral Healthcare, Phillips Professional Dictation Solutions, Phillips Professional Display Solutions, Phillips AVENT Professional, Philips Consumer Lifestyle (also responsible for New Zealand operations); Philips Sleep & Respiratory Care (formerly Respironics), with its ever-increasing national network of Sleepeasy Centres ; Philips Dynalite (Lighting Control systems, acquired in 2009, global design and manufacturing centre) and Philips Selecon NZ (Lighting Entertainment product design and manufacture).

South America

Brazil

Philips do Brasil (Portuguese: *Philips do Brasil*) was founded in 1924 in Rio de Janeiro.[68] In 1929, Philips started to sell radio receivers. In the 1930s, Philips was making its light bulbs and radio receivers in Brazil. From 1939 to 1945, World War II forced Brazilian branch of Philips to sell bicycles, refrigerators and insecticides. After the war, Philips had a great industrial expansion in Brazil, and was among the first groups to establish in Manaus Free Zone. In the 1970s, Philips Records was a major player in Brazil recording industry. Nowadays, Philips do Brasil is one of the largest foreign-owned companies in Brazil. Philips uses the brand Walita for domestic appliances in Brazil.

Former operations

Philips subsidiary *Philips-Duphar* manufactured pharmaceuticals for human and veterinary use and products for crop protection. Duphar was sold to Solvay in 1990. In subsequent years Solvay sold off all divisions to other companies (crop protection to UniRoyal, now Chemtura, the veterinary division to Fort Dodge, a division of Wyeth, and the pharmaceutical division to Abbott Laboratories).

PolyGram, Philips' music television and movies division, was sold to Seagram in 1998; merged into Universal Music Group. Philips Records continues to operate as record label of UMG, its name licensed from its former parent.

Origin, now part of Atos Origin, is a former division of Philips.

ASM Lithography is a spin-off from a division of Philips.

Hollandse Signaalapparaten was a manufacturer of military electronics. The business was sold to Thomson-CSF in 1990 and is now Thales Nederland.

NXP Semiconductors, formerly known as Philips Semiconductors, was sold a consortium of private equity investors in 2006. On 6 August 2010, NXP completed its IPO, with shares trading on NASDAQ.

Philips used to sell major household appliances (whitegoods) under the name **Philips**. After selling the Major Domestic Appliances division to Whirlpool Corporation it changed from **Philips Whirlpool** to **Whirlpool Philips** and finally to just **Whirlpool**. Whirlpool bought a 53% stake in Philips' major appliance operations to form Whirlpool International. Whirlpool bought Philips' remaining interest in Whirlpool International in 1991.

Philips Cryogenics was split off in 1990 to form the Stirling Cryogenics BV, Netherlands. This company is still active in the development and manufacturing of Stirling cryocoolers and cryogenic cooling systems.

North American Philips distributed AKG Acoustics products under the AKG of America, Philips Audio/Video, Norelco and AKG Acoustics Inc. branding until AKG set up its North American division in San Leandro, California in 1985. (AKG's North American division has since moved to Northridge, California.)

Polymer Vision was a Philips spin-off that manufactured a flexible e-ink display screen. The company closed in 2009.[69][70]

Products

Philips' core products are consumer electronics and electrical products, including small domestic appliances, shavers, beauty appliances, mother and childcare appliances, electric toothbrushes and coffee makers (products like Smart Phones, audio equipment, Blu-ray players, computer accessories and televisions are sold under license); healthcare products (including CT scanners, ECG equipment, mammography equipment, monitoring equipment, MRI scanners, radiography equipment, resuscitation equipment, ultrasound equipment and X-ray equipment);[71]

Lighting products

LED bulbs made by Philips.[72]

- Professional indoor luminaires[73]
- Professional outdoor luminaires[74]
- Professional lamps[75]
- Lighting controls and control systems[76]
- Digital projection lights[77]
- Horticulture lighting[78]
- Solar LED lights[79]
- Smart office lighting systems[80]
- Smart retail lighting systems[81]
- Smart city lighting systems[82]
- Home lamps[83]
- Home fixtures[84]
- Home systems (branded as Philips Hue) [85]

Audio products

- Hi-fi systems
- Wireless speakers
- Radio systems
- Docking stations

- Headphones
- DJ mixers
- Alarm clocks


The Philips A5-PRO headphones

Healthcare products

Philips healthcare products include:

- CT scan

Clinical informatics

- Cardiology informatics (IntelliSpace Cardiovascular, Xcelera)
- Enterprise Imaging Informatics (IntelliSpace PACS, XIRIS)
- IntelliSpace family of solutions

Imaging systems

- Cardio/Vascular X-Ray
- Computed tomography (CT)
- Fluoroscopy
- Magnetic resonance imaging (MRI)
- Mammography
- Mobile C-Arms
- Nuclear medicine
- PET (Positron emission tomography)
- PET/CT
- Radiography
- Radiation oncology Systemsroots
- Ultrasound

Diagnostic monitoring

- Diagnostic ECG

Defibrillators

- Accessories
- Equipment
- Software

Consumer

- Philips AVENTil

Patient care and clinical informatics

64-slice CT scanner originally developed by Elscint, now a Philips product[86]

- Anesthetic gas monitoring
- Blood pressure
- Capnography
- D.M.E.
- Diagnostic sleep testing
- ECG
- Enterprise patient informatics solutions

  OB TraceVue
  Compurecord
  ICIP
  eICU program
  Emergin

- Hemodynamic
- IntelliSpace Cardiovascular
- IntelliSpace PACS (http://www.usa.philips.com/healthcare/solutions/clinical-informatics/enterprise-imaging-pacs)
- IntelliSpace portal
- Multi-measurement servers
- Neurophedeoiles
- Pulse oximetry

A typical Phillips Magnavox VCR

- Tasy (http://www.philips.com.br/healthcare/product/HCNOCTN306/tasy)
- Temperature
- Transcutaneous gases
- Ventilation
- ViewForum
- Xcelera
- XIRIS
- Xper Information Management

Coat of arms/logotype

Original Philips shield introduced in 1938

Philips shield in use from 1968 until March 2008[87]

The Philips logo in use until March 2008

The current Philips logo

Philips Shield in use until November 2013

Philips shield design introduced in November 2013

Sponsorships

In 1913, in celebration of the 100th anniversary of the independence of the Netherlands, Philips founded *Philips Sport Vereniging* (Philips Sports Club, now commonly known as PSV). The club is active in numerous sports, but is now best known for its football team, PSV Eindhoven, and swimming team. Philips owns the naming rights to Philips Stadion in Eindhoven, which is the home ground of PSV Eindhoven.

Outside of the Netherlands, Philips sponsors and has sponsored numerous sport clubs, sport facilities and events. In November 2008 Philips renewed and extended its F1 partnership with AT&T Williams. Philips owns the naming rights to the Philips Arena in Atlanta, Georgia and to the *Philips Championship*, the premier basketball league in

Australia, traditionally known as the National Basketball League. From 1988 to 1993 Philips was the principal sponsor of the Australian rugby league team The Balmain Tigers.And Indonesian football club side Persiba Balikpapan

Outside of sports Philips sponsors the international *Philips Monsters of Rock festival*.

Environmental record

Green initiatives

Philips is running the EcoVision4 initiative in which it committed to a number of environmentally positive improvements by 2012.[88]

Also Philips marks its "green" products with the Philips Green Logo, identifying them as products that have a significantly better environmental performance than their competitors or predecessors.[89]

L-Prize competition

In 2011, Philips won a $10 million cash prize from the US Department of Energy for winning its L-Prize competition, to produce a high-efficiency, long operating life replacement for a standard 60-W incandescent lightbulb.[90] The winning LED lightbulb, which was made available to consumers in April 2012, produces slightly more than 900 lumens at an input power of only 10 W.[91]

Greenpeace ranking

In Greenpeace's 2012 Guide to Greener Electronics, that ranks electronics manufacturers on sustainability, climate and energy and how green their products are, Philips ranks 10th place with a score of 3.8/10.[92] The company was the top scorer in the Energy section due to its energy advocacy work calling upon the EU to adopt a 30% reduction for greenhouse gas emissions by 2020. It is also praised for its new products which are free from PVC plastic and BFRs. However, the guide criticizes Phillips' sourcing of fibres for paper, arguing it must develop a paper procurement policy which excludes suppliers involved in deforestation and illegal logging.[93]

Philips have made some considerable progress since 2007 (when it was first ranked in this guide), in particular by supporting the Individual Producer Responsibility principle, which means that the company is accepting the responsibility for the toxic impacts of its products on e-waste dumps around the world.[94]

Publications

- A. Heerding: *The origin of the Dutch incandescent lamp industry*. (Vol. 1 of *The history of N.V. Philips gloeilampenfabriek*). Cambridge, Cambridge University Press, 1986. ISBN 0-521-32169-7
- A. Heerding: *A company of many parts*. (Vol. 2 of *The history of N.V. Philips' gloeilampenfabrieken*). Cambridge, Cambridge University Press, 1988. ISBN 0-521-32170-0
- I.J. Blanken: *The development of N.V. Philips' Gloeilampenfabrieken into a major electrical group*. Zaltbommel, European Library, 1999. (Vol. 3 of *The history of Philips Electronics N.V.*). ISBN 90-288-1439-6
- I.J. Blanken: *Under German rule*. Zaltbommel, European Library, 1999. (Vol. 4 of *The history of Philips Electronics N.V*). ISBN 90-288-1440-X

References

1. "Annual Report 2014" (https://www.google.com/finance?q=NYSE%3APHG&fstype=ii&ei=aX5ZVergDMPGugSJo4DoBg). Philips. Retrieved 19 August 2012.
2. "Lighting maker Philips warns fourth quarter earnings hurt by weakness in European market" (http://www.washingtonpost.com/business/philips-warns-fourth-quarter-earnings-were-worse-than-expected/2012/01/10/gIQAd9FQnP_story.html). The Washington Post. 10 January 2012. Retrieved 13 January 2012.
3. Van, Robert. (29 January 2013) Philips Exits Consumer Electronics - The Source - WSJ (https://blogs.wsj.com/source/2013/01/29/philips-exits-consumer-electronics/). Blogs.wsj.com. Retrieved on 2013-08-16.
4. Sterling, Toby; Mari Yamaguchi. "Philips Breaks off Deal With Funai" (https://web.archive.org/web/20131102130812/http://abcnews.go.com/Technology/wireStory/philips-breaks-off-deal-funai-20679628). *ABC News*. Amsterdam. Associated Press. Archived from the original (http://abcnews.go.com/Technology/wireStory/philips-breaks-off-deal-funai-20679628) on 2 November 2013. Retrieved 22 June 2014.
5. "Philips announces decision by ICC International Court of Arbitration in Funai arbitration case" (http://www.philips.com/a-w/about/news/archive/standard/news/press/2016/20160426-philips-announces-decision-by-icc-international-court-of-arbitration-in-funai-arbitration-case.html). *Philips Electronics*. 2016-04-26. Retrieved 2016-07-23.
6. Frankfurt Stock Exchange (http://www.boerse-frankfurt.de/en/equities/indices/euro+stoxx+50+EU0009658145/constituents)
7. "Philips Museum" (http://www.philips-museum.com/uk/). Retrieved 30 December 2016.
8. C.M. Hargreaves (1991). *The Philips Stirling Engine*. Elsevier Science. ISBN 0-444-88463-7. pp.28–30
9. *Philips Technical Review* Vol.9 No.4 page 97 (1947)
10. C.M. Hargreaves (1991), Fig. 3
11. C.M. Hargreaves (1991), p.61
12. C.M. Hargreaves (1991), p.77
13. "Philips Shavers: Innovation and You - Shaver Reviews" (https://www.shaver-reviews.com/philips-electric-shavers/). *Shaver Reviews*. 2015-05-03. Retrieved 2016-05-16.
14. "BBC - WW2 People's War - Operation Oyster, Part 1" (http://www.bbc.co.uk/history/ww2peopleswar/stories/61/a3537461.shtml). Retrieved 30 December 2016.
15. Everitt, Chris; Middlebrook, Martin (2 April 2014). "The Bomber Command War Diaries: An Operational Reference Book" (https://books.google.com/books?id=eDoRBQAAQBAJ&pg=PA140&lpg=PA140&dq=philips%20+%20eindhoven%20+%20bombed%20+%20march%20+%201943&source=bl&ots=lwJXrwkLt0&sig=5Wox2HGZBpbCSuObMHDnL4uymBs&hl=en&sa=X&ved=0ahUKEwjMmcec4c7NAhXIKyYKHVKIBpQQ6AEINDAE#v=onepage&q=philips%20+%20eindhoven%20+%20bombed%20+%20march%20+%201943&f=false). Pen and Sword. Retrieved 30 December 2016 – via Google Books.
16. Bruce, Mr A I. "30th March 1943 WWII Timeline" (http://www.wehrmacht-history.com/timeline/1943/30th-march-1943-wwii-timeline.htm). Retrieved 30 December 2016.
17. "Frits Philips celebrates 100th birthday" (http://www.newscenter.philips.com/main/standard/about/news/news/archive/news2005/article-14959.wpd). Philips. 15 April 2005. Retrieved 10 January 2015.
18. *The Encyclopedia of the Righteous Among the Nations: Rescuers of Jews during the Holocaust: The Netherlands*, Jerusalem: Yad Vashem, 2004, pp. 596–597
19. "PHILIPS Light Tower Complex - The Netherlands" (https://web.archive.org/web/20120120021100/https://www.reynaers-solutions.com/ru/getpage.asp?i=6), *www.reynaers-solutions.com*, Reynaers Aluminium, archived from the original (http://www.reynaers-solutions.com/ru/getpage.asp?i=6) on 20 January 2012, retrieved 12 September 2011
20. "Waarom stopt Philips met zelf televisies maken?" (http://www.volkskrant.nl/vk/nl/2680/Economie/article/detail/1876925/2011/04/18/Waarom-stopt-Philips-met-zelf-televisies-maken.dhtml). *de Volkskrant*. 18 April 2011. Retrieved 18 April 2011.
21. "BFI – Film & TV Database – The Philips Time Machine (1977)" (http://ftvdb.bfi.org.uk/sift/title/105150). *The British Film Institute Web Database*. Retrieved 16 February 2010.
22. Snow, Blake (May 5, 2007). "The 10 Worst-Selling Consoles of All Time" (https://web.archive.org/web/20070508035815/http://www.gamepro.com/gamepro/domestic/games/features/111823.shtml). GamePro.com. Archived from the original (http://www.gamepro.com/gamepro/domestic/games/features/111823.shtml) on May 8, 2007. Retrieved November 1, 2016.

23. "Philips Completes Acquisition Agilent Technologies' Healthcare Solutions Group" (https://www.thefreelibrary.com/Philips+Completes+Acquisition+Agilent+Technologies'+Healthcare...-a076902583). www.thefreelibrary.com. Retrieved 6 January 2017.
24. "Philips electronics to buy lifeline to expand in consumer health" (https://www.wsj.com/articles/SB113765652747250681).
25. 16 August 2007, Philips to Acquire Healthcare Informatics Company XIMIS Inc. to Strengthen Presence in the Healthcare Information Technology Market (http://www.finanznachrichten.de/nachrichten-2007-08/8833411-philips-to-acquire-healthcare-informatics-company-ximis-inc-to-strengthen-presence-in-the-healthcare-information-technology-market-004.htm)
26. NewsCenter.philips.com (http://arquivo.pt/wayback/20160516125532/http://www.newscenter.philips.com/about/news/press/20071221_pressrelease_respironics.page_20071221_pressrelease_respironics)
27. "Philips completes acquisition of US-based VISICU" (http://www.newscenter.philips.com/main/standard/about/news/press/20080221_completion_visicu.wpd). Newscenter.philips.com. 21 February 2008. Retrieved 24 November 2012.
28. NRC Handelsblad, 4 September 2010 *Het nieuwe Philips wordt blij van een iPad-hoesje/The new Philips becomes happy from an iPad cover*, Dutch original:" 'We zijn geen high-tech bedrijf meer, het gaat erom dat de technologieën introduceren die breed gedragen worden door de consument', zegt Valk [..] Consumer Lifestyle is nu zodanig ingericht dat er geen jaren meer gewerkt wordt aan uitvindingen die weinig kans van slagen hebben. [..]De Philips staf windt er geen doekjes om dat het bedrijf niet altijd voorop loopt bij de technologische ontwikkelingen in consumentengoederen."
29. "Philips to merge Preethi biz in future" (http://www.moneycontrol.com/news/business/philips-to-merge-preethi-bizfuture_753834.html). www.moneycontrol.com. 5 September 2012. Retrieved 6 January 2017.
30. "Sectra news and press releases - Sectra and Philips sign large mammography modality acquisition deal" (http://www.sectra.com/medical/press/press_releases/en/medical/2016/2011/item/Sectra-and-Philips-sign-large-mammography-modality-acquisition-deal(631887)). *www.sectra.com*. Retrieved 2016-04-08.
31. "Philips to cut 4,500 jobs" (https://www.theguardian.com/business/2011/oct/17/philips-cut-4500-jobs-profits). 17 October 2011.
32. Lezhnev, Sasha; Alex Hellmuth (August 2012). "Taking Conflict Out of Consumer Gadgets: Company Rankings on Conflict Minerals 2012" (http://www.enoughproject.org/files/CorporateRankings2012.pdf) (PDF). Enough Project. Retrieved 17 August 2012.
33. "Philips Electronics cuts another 2,200 jobs" (http://www.bbc.co.uk/news/business-19554444). 11 September 2012.
34. "Philips, LG Electronics, 4 others fined 1.47 billion Euros for EU cartel" (http://economictimes.indiatimes.com/news/international-business/philips-lg-electronics-4-others-fined-1-47-billion-euros-for-eu-cartel/articleshow/17493208.cms). The Economic Times. 5 December 2012. Retrieved 5 December 2012.
35. "Philips to exit hi-fis and DVD players" (http://www.bbc.co.uk/news/business-21242127). BBC News. 29 January 2013. Retrieved 2 February 2013.
36. "Philips exits shrinking home entertainment business" (http://uk.reuters.com/article/2013/01/29/uk-philips-idUKBRE90S0C820130129). Reuters. 29 January 2013. Retrieved 2 February 2013.
37. Philips to take legal action against Funai (http://www.broadbandtvnews.com/2013/10/25/philips-to-take-legal-action-against-funai/). Broadbandtvnews.com (25 October 2013). Retrieved on 2013-12-09.
38. "Paradox Engineering and Philips Lighting working together on smart city solutions." (http://www.startupticker.ch/en/news/april-2013/paradox-engineering-and-philips-lighting-working-together-on-smart-city-solutions#.Uh8LgNL0HKM). startupticker.ch. Retrieved on September 2013.
39. "Koninklijke Philips Electronics N.V.: Name change" (http://www.eurexchange.com/blob/exchange-en/4060-497582/497578/2/data/er13096e.pdf) (PDF). eurex. 15 May 2013. Retrieved 10 July 2013.
40. "Philips unveils new brand direction centered around innovation and people" (http://www.newscenter.philips.com/us_en/standard/news/press/2013/20131113-Philips-unveils-new-brand-direction-centered-around-innovation-and-people.wpd#.UoyCXOKgS9g). Retrieved 20 November 2013.
41. "Dutch electronics giant Philips plans to split business" (http://www.bbc.com/news/business-29324406). Retrieved 23 September 2014.
42. Tartwijk, Maarten Van (31 March 2015). "Philips Sells Majority Stake in LED Components, Automotive Business" (https://www.wsj.com/articles/philips-sells-lighting-business-to-consortium-1427780362). Retrieved 30 December 2016 – via Wall Street Journal.

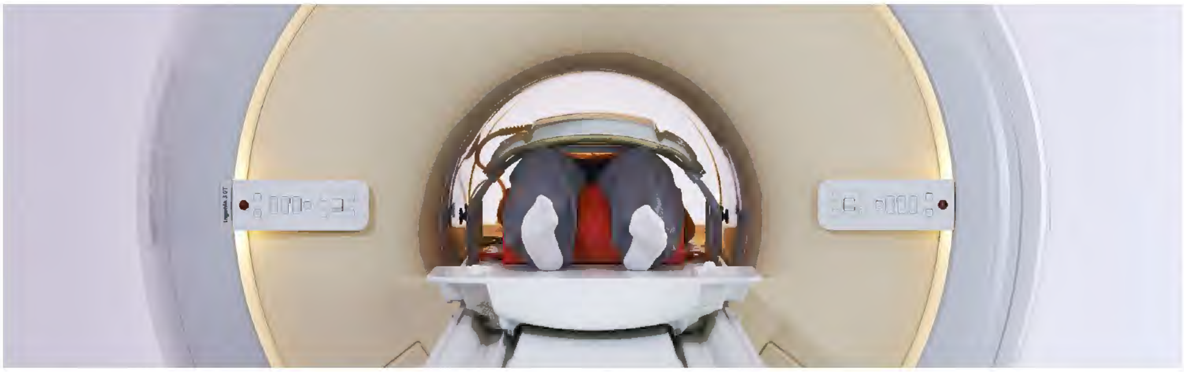
43. https://www.reuters.com/article/2014/12/17/us-volcano-m-a-philips-idUSKBN0JV0G120141217
44. "Subscribe to read" (http://www.ft.com/cms/s/0/33f5fa4e-1121-11e6-91da-096d89bd2173.html#axzz4E5CZB2Pp). Retrieved 30 December 2016.
45. http://uk.reuters.com/article/uk-spectranetics-m-a-philips-idUKKBN19J0MZ
46. PennWell Corporation (19 August 2005). "LedsMagazine.com" (http://www.ledsmagazine.com/news/2/8/23). LedsMagazine.com. Retrieved 27 January 2011.
47. PennWell Corporation (1 January 2007). "LedsMagazine.com" (http://www.ledsmagazine.com/news/4/1/1). LedsMagazine.com. Retrieved 27 January 2011.
48. Go Scale to fund Philips lighting components buy with $1.93 billion in debt, Reuters, 27 May 2015 (https://www.reuters.com/article/2015/05/27/us-philips-goscale-lighting-idUSKBN0OC0XZ20150527,)
49. "Interactive world maps" (http://www.annualreport2013.philips.com/content/interactive_worldmap/index_en.html#global_presence-1). Retrieved 30 December 2016.
50. Nieuwhof, Marc (15 November 2010). "IP.Philips.com" (http://www.ip.philips.com). IP.Philips.com. Retrieved 27 January 2011.
51. http://www.ntccthailand.org/job-webboard/thai-graduate-program/241-philips-electronics-thailand-ltd
52. "(Company profile – Philips Hong Kong)" (http://www.philips.com.hk/about/company/local/index.page). Philips.com.hk. Retrieved 27 January 2011.
53. "珠海经济特区飞利浦家庭电器有限公司" (http://www.qixin.com/company/72a62d25-5108-4ef1-b9f0-8ed7816f8612?token=6634d44741ea2a3640fcc99c4f9032c6&from=bkdt).
54. Philips opens lighting center in China (http://www.autonews.com/article/20080501/ANE02/748157025/philips-opens-lighting-center-in-china) Automotive News Report – 1 May 2008
55. "Bangalore.philips.com" (http://www.bangalore.philips.com/). Bangalore.philips.com. Retrieved 24 November 2012.
56. "India's Most Trusted Brands 2014" (https://web.archive.org/web/20150502221904/http://www.trustadvisory.info/allindia_2014.html). Archived from the original (http://www.trustadvisory.info/allindia_2014.html) on 2 May 2015.
57. "Philips Israel- Company Overview" (http://www.philips.co.il/). Retrieved 1 May 2010
58. "Philips Pakistan - Company Overview" (http://www.philips.com.pk/). Retrieved 17 October 2011
59. "Philips Deutschland - Philips" (http://www.philips.de/a-w/about-philips/unternehmensprofil/philips-deutschland.html). Retrieved 30 December 2016.
60. http://restosdecoleccao.blogspot.pt/2013/09/philips-portuguesa.html
61. "História Local - Philips" (http://www.philips.pt/a-w/about-philips/perfil-da-empresa/historia.html). Retrieved 30 December 2016.
62. */philips%20em%20portugal/@38.712024,-9.3119793,233m/data=!3m1!1e3!4m8!4m7!1m0!1m5!1m1!1s0xd1ecec52fd7fd77:0xd4be2a9cca5551b9!2m2!1d-9.311267!2d38.712061 "Google Maps"* (https://www.google.pt/maps/dir/). Retrieved 30 December 2016.
63. Portugal, Philips. "Philips Portugal manufacturer in P, radio technology from Po" (http://www.radiomuseum.org/dsp_hersteller_detail.cfm?company_id=5544). Retrieved 30 December 2016.
64. http://www.pardalmonteiro.com/atelier/imag/ARTIGOS/Tese/Para%20o%20projeto%20global%20-%20Volume%20I.pdf
65. "Philips - Portugal" (http://www.philips.pt/). Retrieved 30 December 2016.
66. "philips uk - Google Maps" (http://maps.google.co.uk/maps?f=q&source=s_q&hl=en&geocode=&q=philips+uk&sll=51.246446,-0.586755&sspn=0.00135,0.003484&g=Guildford,+Surrey+GU2+8XH,+United+Kingdom&layer=t&ie=UTF8&hq=philips+uk&hnear=Guildford,+GU2+8XH,+UK&ll=51.246524,-0.586755&spn=0.001308,0.003484&t=h&z=19&iwloc=B). Maps.google.co.uk. Retrieved 24 November 2012.
67. Official website (http://philips.co.uk)
68. [1] (https://web.archive.org/web/19961230143035/http://www.philips.com.br/)
69. John Biggs, Tech Crunch. "Welcome To The Future: Polymer Vision Demos SVGA Rollable Screen (https://techcrunch.com/2011/05/27/welcome-to-the-future-polymer-vision-demos-svga-rollable-screen/)." 27 May 2011. Retrieved 27 May 2011.
70. Lewis, Gareth (15 July 2009). "50 jobs go at Polymer Vision" (http://www.dailyecho.co.uk/news/4492908.display/). *Southern Daily Echo*. Retrieved 6 January 2016.
71. "Products & Solutions" (http://www.healthcare.philips.com/gb_en/products/index.wpd). Philips Healthcare. Retrieved 28 January 2012.

72. "LED 12.5W A19 Soft White 12.5W (60W) Dimmable A19" (http://www.usa.philips.com/c/energy-saving-light-bulbs/led-soft-white-12.5w-60w-dimmable-a19-046677422158/prd/en/?t=specifications). *Energy-saving light bulbs*. Philips.
73. "Indoor Luminaires" (http://www.lighting.philips.com/main/prof/indoor-luminaires#pfpath=0-CINDOOR_GR). Philips Lighting. Retrieved 4 March 2016.
74. "Outdoor Luminaires" (http://www.lighting.philips.com/main/prof/outdoor-luminaires#pfpath=0-OCOUTD_GR). Philips Lighting. Retrieved 4 March 2016.
75. "Lamps" (http://www.lighting.philips.com/main/prof/lamps). Philips Lighting. Retrieved 4 March 2016.
76. "Lighting Controls" (http://www.lighting.philips.com/main/products/lighting-controls.html). Philips Lighting. Retrieved 27 June 2016.
77. "Digital projection lighting" (http://www.lighting.philips.com/main/products/digital-projection.html). Philips Lighting. Retrieved 27 June 2016.
78. "Horticulture" (http://www.lighting.philips.com/main/products/horticulture.html). Philips Lighting. Retrieved 27 June 2016.
79. "Solar" (http://www.lighting.philips.com/main/products/solar.html). Philips Lighting. Retrieved 27 June 2016.
80. "Lighting systems for office & industry" (http://www.lighting.philips.com/main/systems/packaged-offerings/office-and-industry). Philips Lighting. Retrieved 4 March 2016.
81. "Retail and hospitality systems" (http://www.lighting.philips.com/main/systems/packaged-offerings/retail-and-hospitality). Philips Lighting. Retrieved 4 March 2016.
82. "Lighting systems: for public spaces" (http://www.lighting.philips.com/main/systems/packaged-offerings/public-spaces). Philips Lighting. Retrieved 4 March 2016.
83. "Choose a bulb" (http://www.philips.co.uk/c-m-li/choose-a-bulb/need-help). Philips Lighting. Retrieved 27 June 2016.
84. "Choose a lamp" (http://www.philips.co.uk/c-m-li/choose-a-lamp). Philips Lighting. Retrieved 27 June 2016.
85. "Philips Hue homepage" (http://www.meethue.com). Philips Lighting. Retrieved 27 June 2016.
86. "The 64 Slice CT Scanner" (https://web.archive.org/web/20160310172530/http://www.ct-scan-info.com/64slicect.html). Archived from the original (http://www.ct-scan-info.com/64slicect.html) on 10 March 2016. Retrieved 30 December 2016.
87. http://www.philips.com/consumerfiles/newscenter/main/standard/resources/corporate/press/2013/Brand/Phili
88. "Philips – EcoVision4" (http://www.philips.com/sites/philipsglobal/about/sustainability/environmentalresponsibility/ecovision4program/index.page). Philips. Retrieved 7 January 2011.
89. "Philips – Our Green Products" (http://www.philips.com/about/sustainability/ourgreenproducts/index.page). Philips. Retrieved 7 January 2011.
90. Margery Conner, EE Times. "$10M L Prize goes to Philips for 60W replacement LED bulb (http://eetimes.com/electronics-news/4218485/-10M-L-Prize-goes-to-Philips-for-60W-replacement-LED-bulb)." 3 August 2011. Retrieved 5 August 2011.
91. "DOE Announces Philips as First Winner of the L Prize Competition" (http://www.webcitation.org/60jS9wT6Q?url=http://www.lightingprize.org/philips-winner.stm). US Department of Energy. Archived from the original (http://www.lightingprize.org/philips-winner.stm) on 6 August 2011. Retrieved 6 August 2011.
92. "Guide to Greener Electronics | Greenpeace International" (http://www.greenpeace.org/international/en/campaigns/toxics/electronics/how-the-companies-line-up/). Greenpeace.org. Retrieved 24 November 2012.
93. "Guide to Greener Electronics – Greenpeace International" (http://www.greenpeace.org/international/en/campaigns/climate-change/cool-it/Guide-to-Greener-Electronics/). Greenpeace International. Retrieved 14 November 2011.
94. "Philips Greenpeace International" (http://www.greenpeace.org/international/en/campaigns/toxics/electronics/Guide-to-Greener-Electronics/companies/Philips/). Greenpeace International. Retrieved 7 January 2011.

External links

- Official website (http://www.philips.com/global/)

EXHIBIT I



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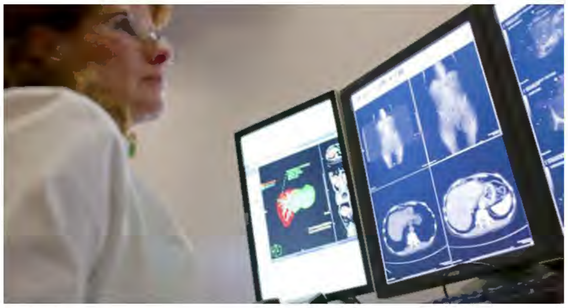

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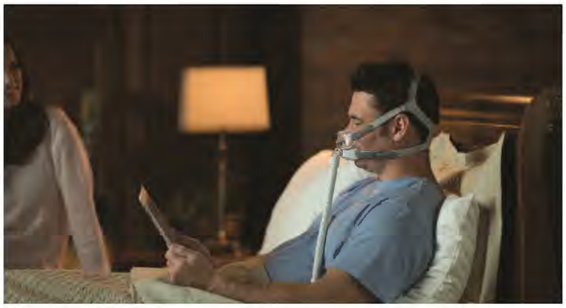

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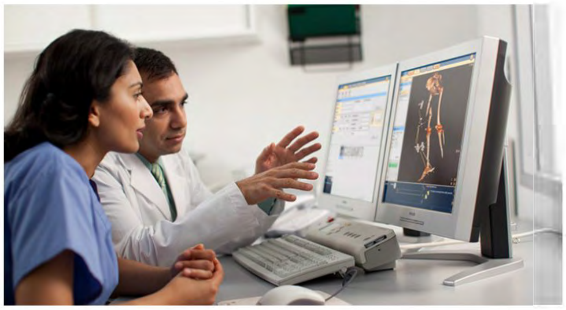

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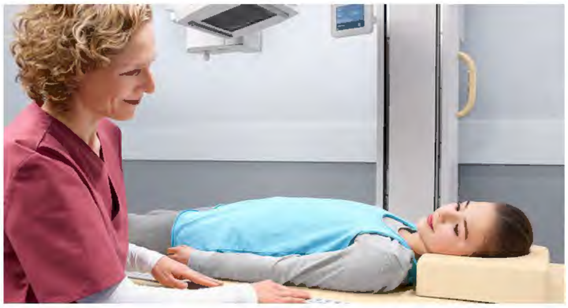

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EXHIBIT J

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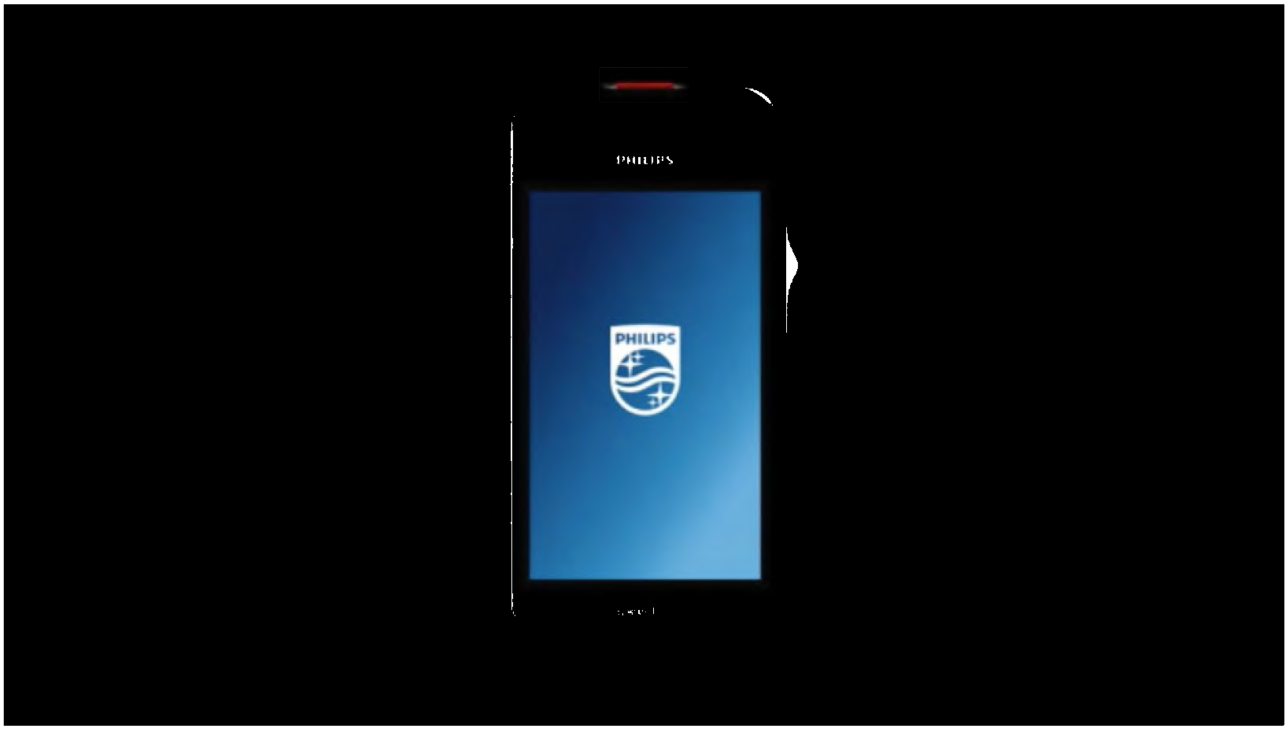
How does it work

The Philips SpeechAir fits perfectly into your daily workflow. Record your voice from your office or on the road and securely send it off for transcription. You can send your recordings to your assistant or use the Philips SpeechLive transcription service, where trained professionals will quickly type up your documents for you. You can also use speech recognition for almost instant transcription results.


01 Record your voice
02 Select your transcription option
03 Receive finished text file
Speech recognition software
Your assistant
SpeechLive transcription service

Highlights



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Camera

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Dictation app

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Company Size
10,001+ employees

Founded
1927

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Grainger 15% of all accidental workplace deaths per year are caused by a slip, trip, or fall. These 6 tips can help you prevent one of the biggest workplace hazards http://bit.ly/2griaNe

6 Tips to Help Prevent Slips, Trips and Falls

bit.ly It's probably happened to most of us. That momentary lapse of attention, thinking about a personal problem or distraction by an activity that ends in a slip, trip or fall. A stumble down a stairway. A trip over an uneven surface. Slipping on the ice. It can lead to a variety of regrettable events...

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bit.ly Even though safety management systems (SMS) in the workplace have a lot of benefits, many small to medium-sized business owners shy away from SMS because of some persistent myths. Let's debunk a few of the big ones. Myth #1: Safety management systems are only for big companies. Fact: Safety...

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bit.ly Every fall, the Occupational Safety and Health Administration releases a list of the 10 most frequently cited safety and health standards for the fiscal year. It is compiled from more than 30,000 workplace inspections by Federal OSHA. The list rarely changes from year to year. In fact, the top...

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Food Terrorism and Intentional Adulteration

bit.ly An act of terrorism directed at the food supply could be devastating, and the industry has a legal and moral responsibility to safeguard consumers. The FSMA Final Rule on Intentional Adulteration was written with the explicit goal of preventing acts of terror. The new law codifies producers' obligation to develop a food defense plan to deter potential attacks.

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Grainger Learn the 4 industry best practices that will help you comply with the CMS final rule on emergency preparedness during this 8/29 webinar. Register now: http://bit.ly/2wCPsPX

CMS' Final Rule on Emergency Preparedness

bit.ly Tuesday, August 29, 2017 at 01:00 PM Central Daylight Time.

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Grainger See why now, more than ever, collaboration and effective communication between the Sterile Processing Department (SPD) and the Operating Room (OR) are critical to improve patient safety http://bit.ly/2hoDOJS

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to know where ingredients come from for specific products, they expect answers within hours, not days. This is especially critical in cases of food contamination http://bit.ly/2i9QUTQ

Good Data Management Is Critical in the Food Industry

bit.ly There are many aspects of the food industry that require good data management, whether it's recipe and formulations development, the management of raw ingredients, manufacturing and process control or post-market feedback. The reasons for good data management are diverse -- typically, drivers are...

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EXHIBIT L

Maintenance, repair and operations

From Wikipedia, the free encyclopedia

Mechanical repair

Field repair of aircraft engine (1915-1916 yy)

Maintenance, repair and operations [1] (**MRO**) involves fixing any sort of mechanical, plumbing, or electrical device should it become out of order or broken (known as repair, unscheduled, casualty or corrective maintenance). In the aircraft maintenance market sector, **maintenance, repair and overhaul**[2] (**MRO**) services also include inspection, rebuilding, alteration and the supply of spare parts, accessories, raw materials, adhesives, sealants, coatings and consumables for aircraft manufacturing and MRO.

In all sectors, effective MRO involves performing routine actions which keep devices, equipment, machinery, building infrastructure and supporting utilities in working order (known as scheduled maintenance) and prevent trouble from arising (preventive maintenance).[3]

The marine transportation,[4] offshore structures,[5] industrial plant/equipment and commercial facilities market sectors depend on scheduled or preventive paint maintenance programmes to maintain and restore coatings applied to steel,[6] and also concrete and masonry assets in environments subject to attack from erosion, corrosion and environmental pollution.

MRO can be categorised by whether the product remains the property of the customer (i.e. a service is being offered), or whether the product is bought by the reprocessing organisation and sold to any customer wishing to make the purchase (Guadette, 2002). In the former case it may be a backshop operation within a larger organization or smaller operation.

The former of these represents a closed loop supply chain and usually has the scope of maintenance, repair, or overhaul. The latter of the categorisations is an open loop supply chain and is typified by refurbishment and remanufacture. The main characteristic of the closed loop system is that the demand for a product is matched with the supply of a used product. Neglecting asset write-offs and exceptional activities the total population of the product between the customer and the service provider remains constant.

Contents

Engineering

In telecommunication, commercial real estate, and engineering in general, the term maintenance has the following meanings:


Road repair

- Any activity – such as tests, measurements, replacements, adjustments, and repairs — intended to retain or restore a functional unit in or to a specified state in which the unit can perform its required functions.[7]
- For material – all action taken to retain material in a serviceable condition or to restore it to serviceability. It includes inspection, testing, servicing, classification as to serviceability, repair, rebuilding, and reclamation.[7]
- For material – all supply and repair action taken to keep a force in condition to carry out its mission.[7]
- For material – the routine recurring work required to keep a facility (plant, building, structure, ground facility, utility system, or other real property) in such condition that it may be continuously used, at its original or designed capacity and efficiency for its intended purpose.[7]

Manufacturers and industrial-supply companies often refer to MRO as opposed to original equipment manufacturer (OEM). OEM includes any activity related to the direct manufacture of goods, where MRO refers to any maintenance, repair or overhaul activity to keep a manufacturing plant or facility running. Maintenance is strictly connected to the stage of ideation, in which the concept of maintainability must be included. In this scenario, maintainability is considered as the ability of an item, under stated conditions of use, to be retained in or restored to a state in which it can perform its required functions, using prescribed procedures and resources.[8][9] Overhaul extends to the concept of improving performance over and above original design specification.

Maintenance types

Generally speaking, there are two types of maintenance in use:

- Preventive or scheduled maintenance, where equipment or facilities are inspected, maintained and protected before break down or other problems occur.
- Corrective maintenance where equipment is repaired or replaced after wear, malfunction or break down.

Architectural conservation is another type of maintenance involving the preservation, rehabilitation, restoration or reconstruction of historical structures made from stone, brick, glass, metal, and wood with MRO materials which match the original constituent materials where possible, or with suitable polymer technologies.[10]

Preventive maintenance

Preventive maintenance is maintenance performed with the intent of avoiding failures, safety violations, unnecessary production costs and losses, and to conserve original materials of fabrication. The effectiveness of a preventive maintenance schedule depends on the RCM analysis which it was based on, and the ground rules used for cost efficacy.[11]

Corrective maintenance

Corrective maintenance of equipment after equipment break down or malfunction is often most expensive – not only can worn equipment damage other parts and cause multiple damage, but consequential repair/replacement costs and loss of revenues due to down time during overhaul can be significant. Rebuilding and resurfacing of equipment and infrastructure damaged by erosion and corrosion as part of corrective or preventive maintenance programmes involves conventional processes such as welding and metal flame-spraying, as well as engineered solutions with thermoset polymeric materials.[12]

Predictive maintenance

More recently, advances in sensing and computing technology have given rise to 'predictive maintenance'. This maintenance strategy uses sensors to monitor key parameters within a machine or system, and uses this data in conjunction with analysed historical trends to continuously evaluate the system health and predict a breakdown before it happens. [13] This strategy allows maintenance to be performed more efficiently, since more up-to-date data is obtained about how close the product is to failure. [14]

See also

- Auto maintenance
- Darning
- Design for repair
- Do it yourself
- Kludge
- Logistics center
- Maintainability
- MRO Software
    - Oracle Complex MRO
    - MRO Software, later called Maximo
- Product Lifecycle Management
- RAMS
- Reliability engineering
- Remanufacturing
- Scheduled maintenance
- Total productive maintenance

No to be confused with

- Reparation (legal)
- Reparations (transitional justice), measures taken by the state to redress gross and systematic violations of human rights law or humanitarian law
- Reparations for slavery

References

1. "Defense Logistics Agency" (http://www.dla.mil). www.dla.mil. Retrieved 5 August 2016.
2. United States Code of Federal Regulations Title 14, Part 43 - Maintenance, Preventive Maintenance, Rebuilding, and Alteration
3. "All actions which have the objective of retaining or restoring an item in or to a state in which it can perform its required function. The actions include the combination of all technical and corresponding administrative, managerial, and supervision actions.""European Federation of National Maintenance Societies" (http://www.efnms.org/). www.efnms.org. Retrieved 5 August 2016.
4. Marine Painting Manual Paperback (softcover reprint of original 1st ed. 1989 edition), A. M. Berendsen, Springer, 2013, ISBN 978-90-481-8244-2
5. ISO 20340 - Performance requirements for protective paint systems for offshore and related structures
6. ISO 12944 – Corrosion protection of steel structures by protective paint systems

7. Federal Standard 1037C and from MIL-STD-188 and from the Department of Defense Dictionary of Military and Associated Terms
8. North Atlantic Treaty Organization, Nato Standardization Agency AAP-6 - Glossary of terms and definitions, p 158.
9. "Commercial Electrical Contractor and Domestic Electrician Leeds" (http://www.247electricalservices.co.uk/). *247 Electrical Services Leeds*. Retrieved 2017-01-26.
10. Materials for Conservation: Organic Consolidants, Adhesives and Coatings by C.V. Horie, Butterworth-Heinemann, 2nd ed., 2010, ISBN 978-0-75-066905-4
11. "RCM Reliability Centered Maintenance Analysis" (http://www.mtain.com/logistics/logrcm.htm). www.mtain.com. Retrieved 5 August 2016.
12. Industrial Polymer Applications: Essential Chemistry and Technology, Royal Society of Chemistry, UK, 1st edition, 2016, ISBN 978-1782628149
13. Garcia, Mari Cruz; Sanz-Bobi, Miguel A.; Del Pico, Javier (August 2006), "SIMAP: Intelligent System for Predictive Maintenance: Application to the health condition monitoring of a windturbine gearbox" (http://www.sciencedirect.com/science/article/pii/S0166361506000534), *Computers in Industry*, **57** (6): 552–568, doi:10.1016/j.compind.2006.02.011 (https://doi.org/10.1016%2Fj.compind.2006.02.011)
14. Kaiser, Kevin A.; Gebraeel, Nagi Z. (12 May 2009), "Predictive Maintenance Management Using Sensor-Based Degradation Models" (http://ieeexplore.ieee.org/abstract/document/4914831/), *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, IEEE, **39** (4): 840–849, doi:10.1109/TSMCA.2009.2016429 (https://doi.org/10.1109%2FTSMCA.2009.2016429)

EXHIBIT M

Lighting | Indoor Fixtures | Wet Location Fluorescent Fixtures

Search Feedback

Wet Location Fluorescent Fixtures

6 results found that include 28 products

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Search within these results

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PREVIOUSLY PURCHASED

- [ ] View Previously Purchased Products

BRANCH AVAILABILITY

Select a pickup branch to see products in stock now.

ITEM

- [ ] Dust Resistant Fixture (12)
- [ ] Wet Location Fixture (16)

LAMP QUANTITY

- [ ] 1 (3)
- [ ] 2 (18)
- [ ] 4 (5)
- [ ] 6 (2)

LAMP TYPE

- [ ] T8 (10)
- [ ] F17T8 (2)
- [ ] F32T8 (4)
- [ ] T5HO (7)

Sort Results By: Top Sellers

List | Table | Results per page: 16 | 32 | 48

Dust Resistant Fixtures

These fluorescent light fixtures are designed for wet or dusty locations. They help to prevent entry of airborne contaminants. The impact-resistant acrylic diffuser is also secured to housing with cam latches for a positive seal. Suitable for use in fabrication and machining areas, welding, grinding, or any nonhazardous environments.

Brands

ACUITY LITHONIA and LUMAPRO

Lamp Type	Fixture Wattage	Length	Height	Width	Brand	Item #	Price
Lamp Quantity 1							
F17T8	17	26-3/8"	4-5/16"	4"	LUMAPRO	6GAL4	$73.48 /Each
F32T8	32	50-3/16"	4-5/16"	4"	LUMAPRO	6GAL5	$114.05 /Each
Lamp Quantity 2							
T8	56W	48"	4"	5-3/4"	ACUITY LITHONIA	4LUW4	$106.13 /Each
T8	56W	50"	4-3/4"	8-1/8"	ACUITY LITHONIA	3YA23	$142.56 /Each
T8	108W	98"	5-5/8"	8-1/8"	ACUITY LITHONIA	3YA24	$232.10 /Each

- T8HO (3)
- F54T5HO (2)

BALLAST TYPE

- Electronic (4)
- Electronic Instant Start (9)
- Electronic Program Start (11)
- Instant Start (2)
- Programmed Rapid Start (2)

AMBIENT TEMP. RANGE

- -20 Degrees to 104 Degrees F (10)
- -18 Degrees to 104 Degrees F (1)
- 0 Degrees to 104 Degrees F (11)
- 0 Degrees to 131 Degrees F (4)
- 32 Degrees to 104 Degrees F (1)
- 50 Degrees to 104 Degrees F (1)

FIXTURE WATTAGE

Type here to refine filters

- 17 (1)
- 32 (1)
- 34 (1)
- 64 (1)
- 56W (4)
- 58W (2)

View More

REPLACEMENT LENS

- 31C005 (2)
- 31C006 (2)

Lamp Type	Fixture Wattage	Length	Height	Width	Brand	Item #	Price
F17T8	34	26-3/8"	4-5/16"	6-3/8"	LUMAPRO	6GAL3	$79.68 /Each
F32T8	64	50-3/16"	4-5/16"	6-3/8"	LUMAPRO	6GAL2	$131.08 /Each
T5HO	120W	48"	4"	5-3/4"	ACUITY LITHONIA	4VDD1	$120.69 /Each
T5HO	120W	50"	4-3/4"	8-1/8"	ACUITY LITHONIA	1VNU5	$184.58 /Each
T8HO	98W	50"	5-5/8"	8-1/8"	ACUITY LITHONIA	6HHG4	$280.50 /Each
T8HO	185W	98"	5-5/8"	8-1/8"	ACUITY LITHONIA	2LYX9	$326.70 /Each
Lamp Quantity 4							
T8	112W	98"	5-5/8"	8-1/8"	ACUITY LITHONIA	5YA12	$239.14 /Each

60W Wet Location Fixture, Instant Start Ballast Type, F32T8 Lamp Type

Wet Location Fixture, Wet Location, 2 Lamp Quantity, F32T8 Lamp Type, 32 Lamp Watts, 60W Fixture Wattage, 120 to 277 Voltage, Description/Special Features Wet Locations, Gasketed Fixture,IP65, 31C006 Replacement Lens, Instant Start Ballast Type, Polycarbonate Housing Material, Gray Housing Finish, Suggested Lamp Item No. 2ETU3, No Lamp Included, 0 Degrees to 131 Degrees F Ambient Temp. Range, Surface or Suspended Mounting, 50-13/16" Length, 3-13/16 In. Height, 6-45/64 In. Width

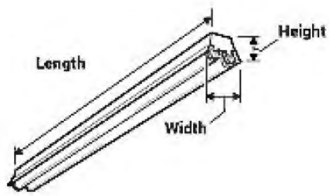
Lamp Type	Fixture Wattage	Length	Height	Width	Item #	Price
F32T8	60W	50-13/16"	3-13/16"	6-45/64"	31C003	$141.46 /Each

118W Wet Location Fixture, Programmed Rapid Start Ballast Type, F54T5HO Lamp Type

- 6EKP6 (1)
- 6EKP7 (1)
- 6EKP8 (1)
- 6EKP9 (1)

View More

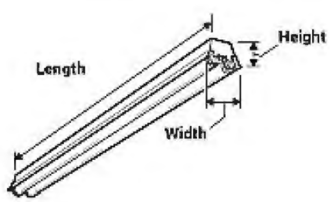
LENGTH



- 26-3/8" (2)
- 48" (3)
- 49-3/4" (1)
- 50" (4)
- 50-3/16" (2)
- 51-3/4" (3)

View More

HEIGHT



- 3-3/4" (1)
- 3-13/16" (2)
- 4" (6)
- 4-13/64" (2)
- 4-5/16" (4)
- 4-3/4" (2)

View More

WIDTH

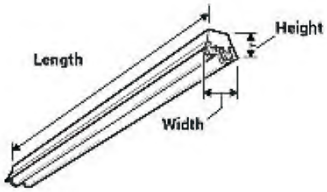
Wet Location Fixture, Wet Location, 2 Lamp Quantity, F54T5HO Lamp Type, 54 Lamp Watts, 118W Fixture Wattage, 120 to 277 Voltage, Description/Special Features Wet Locations, Gasketed Fixture,IP65, 31C005 Replacement Lens, Programmed Rapid Start Ballast Type, Polycarbonate Housing Material, Gray Housing Finish, Suggested Lamp Item No. 5AE35, No Lamp Included, 0 Degrees to 131 Degrees F Ambient Temp. Range, Surface or Suspended Mounting, 50" Length, 4-13/64 In. Height, 6 In. Width

Lamp Type	Fixture Wattage	Length	Height	Width	Item #	Price
F54T5HO	118W	50"	4-13/64"	6"	31C002	$157.96 /Each

60W Wet Location Fixture, Instant Start Ballast Type, F32T8 Lamp Type

Wet Location Fixture, Wet Location, 2 Lamp Quantity, F32T8 Lamp Type, 32 Lamp Watts, 60W Fixture Wattage, 120 to 277 Voltage, Description/Special Features Wet Locations, Gasketed Fixture,IP65, 31C005 Replacement Lens, Instant Start Ballast Type, Polycarbonate Housing Material, Gray Housing Finish, Suggested Lamp Item No. 2ETU3, No Lamp Included, 0 Degrees to 131 Degrees F Ambient Temp. Range, Surface or Suspended Mounting, 50" Length, 4-13/64 In. Height, 6 In. Width, Standards cULus Listed

Lamp Type	Fixture Wattage	Length	Height	Width	Item #	Price



- 4" (3)
- 5-3/4" (2)
- 6" (2)
- 6-3/8" (2)
- 6-1/2" (2)
- 6-45/64" (2)

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- DMW (5)
- EFS (1)
- EFT (2)
- FEM (3)
- FEN (1)
- FHE (4)

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SUGGESTED LAMP ITEM NO.

- 2F964 (2)
- 21GR04 (2)
- 38L993 (1)
- 5AE35 (8)
- 3CA64 (1)
- 2EAF8 (1)

View More

BRAND

- ACUITY LITHONIA (20)
- LUMAPRO (8)

F32T8	60W	50"	4-13/64"	6"	31C001	$136.84 /Each

Wet Location Fixtures

These special application fluorescent fixtures feature high-impact acrylic lenses and are intended for low to medium mounting heights.They are designed for wet or dusty locations, and can help to provide bright light cost effectively in areas where moisture may be prevalent. Completely enclosed and gasketed, the multi-purpose fixtures feature fiberglass-reinforced polyester housings that resist oxidization and corrosion.

Brands

ACUITY LITHONIA

Lamp Type	Fixture Wattage	Length	Height	Width	Item #	Price
Lamp Quantity 1						
T5HO	58W	51-3/4"	4"	4"	16U242	$165.00 /Each
Lamp Quantity 2						
T8	56W	49-3/4"	6"	9-3/4"	5YA99	$518.76 /Each
T8	56W	50"	7-1/4"	6-1/2"	1BP87	$517.88 /Each
T8	58W	51-3/4"	4"	7"	16U241	$154.66 /Each
T5HO	117W	51-3/4"	4"	7"	16U243	$179.96 /Each
T8HO	160W	98"	7-1/4"	6-1/2"	2LYX8	$866.36 /Each
Lamp Quantity 4						
T8	112W	48"	3-3/4"	24"	3XY80	$224.62 /Each
T8	128W	51-7/8"	6"	14-5/8"	4VDC3	$333.30 /Each
T5HO	216W	51-7/8"	6"	14-5/8"	4VDC4	$327.58 /Each
T5HO	234W	100"	4"	7"	16U240	$332.42 /Each
Lamp Quantity 6						

PRICE

- $70-$80 (2)
- $100-$200 (13)
- $200-$300 (4)
- $300-$400 (6)
- $500-$600 (2)
- $800-$900 (1)

SHOP BY

- Country Of Origin: US (11)
- Grainger Choice (8)

RATINGS

- 3 Stars ★★★☆☆ (1)
- 1 Stars ★☆☆☆☆ (1)

Lamp Type	Fixture Wattage	Length	Height	Width	Item #	Price
T8	192W	51-7/8"	6"	14-5/8"	4VDC5	$368.94 /Each
T5HO	324W	51-7/8"	6"	14-5/8"	4VDC6	$369.82 /Each

118W Wet Location Fixture, Programmed Rapid Start Ballast Type, F54T5HO Lamp Type

Wet Location Fixture, Wet Location, 2 Lamp Quantity, F54T5HO Lamp Type, 54 Lamp Watts, 118W Fixture Wattage, 120 to 277 Voltage, Description/Special Features Wet Locations, Gasketed Fixture,IP65, 31C006 Replacement Lens, Programmed Rapid Start Ballast Type, Polycarbonate Housing Material, Gray Housing Finish, Suggested Lamp Item No. 5AE35, No Lamp Included, 0 Degrees to 131 Degrees F Ambient Temp. Range, Surface or Suspended Mounting, 50-13/16" Length, 3-13/16 In. Height, 6-45/64 In. Width

Lamp Type	Fixture Wattage	Length	Height	Width	Item #	Price
F54T5HO	118W	50-13/16"	3-13/16"	6-45/64"	31C004	$164.56 /Each

List | Table | Results per page: 16 | **32** | 48

EXHIBIT N

Email

Lighting > Indoor Fixtures > Decorative Fixtures

Decorative Light Fixture

GRAINGER CHOICE

1 product found with these common attributes:

Brand	LUMAPRO	Item	Decorative Light Fixture
Fixture Type	Ceiling	Lamp Quantity	2
Housing Finish	White	Lens Type	Acrylic Mushroom
Lamp Type	FC8T9/FC12T9	Energy Star Compliant	No
Mounting	Flush	Suggested Lamp Item No.	1V776/1V860
Fixture Wattage	54W	Length	14"
Height	4"		

Price

$45-$50 Clear All

Select items to compare View Previously Purchased +Add to List ADD TO CART

Compare / Item #	Mfr. Model #	Price	Ship To 07101 Pick Up	Qty

2ZE29

2ZE29

$46.20 / each

Expected to arrive **Tue. Sep 05**

⚠ Hurricane Harvey is impacting shipments in TX and LA which may impact delivery date estimates.

Qty

Note: Product availability is real-time basis and adjusted continuously. The product will be reserved for you when you complete your order. More

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1 of 2 PREV | NEXT

Ceiling Fixture,54W,Circular,White

ITEM # **2ZE25**

LUMAPRO

Web Price **$44.88** / each

1 ADD TO CART

Ceiling Fixture,26W,Compact Fluorescent

ITEM # **2ZE32**

LUMAPRO

Web Price **$35.42** / each

1 ADD TO CART

Carpet Protection Film, 200 ft. Length x

ITEM # **2NYH7**

PLASTICOVER

Web Price **$46.80** / each

1 ADD TO CART

18.0 Watts LED Lamp, Cylindrical, Medium Screw

ITEM # **45PC25**

LIGHT EFFICIENT DESIGN

Web Price **$74.72** / each

1 ADD TO CART

Nylon Straight Union, 1/4" Tube Size

ITEM # **40L314**

PARKER

Web Price **$18.92** / pkg. of 1

1 ADD TO CA

EXHIBIT O

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PHOENIX® DURABILITY X DESIGN™

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Home / Products / ReadiLED™ Series | LED Snaplight® & Retrofit Kit

Get Spec Sheets: Product name

ReadiLED™ Series | LED Snaplight® & Retrofit Kit

Designed to replace linear fluorescent fixtures

Vibration-resistant for demanding applications

Superior corrosion resistance

LED technology increases efficiency, eliminates maintenance and supports green initiatives

Where to Buy ›

Specification Sheet › | Installation Instructions ›

ReadiLED™ Additional Installation Instructions | ReadiLED™ Spec Sheet - Spanish

4 foot fixture - 38W, 3617 lumens

CRI > 80

CCT 5000K

50,000 hour rated life

stabilized nylon housing

Power source

120-277V, 50/60Hz

0-10V dimming option (DIM)

Compliances

UL/cUL Listed to:

- UL 1598 Suitable for Wet Locations
- UL 1598C LED Retrofit Conversion (retrofit kits only)
- CSA C22.2 No. 250.0-08

UL Listed to:

- UL 1598A Marine Outside Type (Saltwater)
- UL 924 Emergency Lighting Equipment

ABS

IP65

EXHIBIT Q

Your life.
Your design.

Helping people bring great design into the spaces they live, work and play.

WHO WE ARE

Helping people bring great design into the spaces they live, work and play.

YDesign Group is an online-led retailer offering the best in modern and contemporary lighting, furnishings, and decorative plumbing to design driven consumers and trade professionals.

YLighting, our flagship brand that launched in 2001, is the leading modern lighting retailer in the US and offers more than 10,000 designs from top international brands. We launched YLiving in 2009 to provide our customers access to exceptional modern furniture and accessories. In 2014, we expanded into the decorative plumbing category.

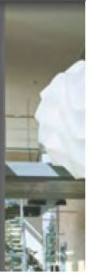
YDesign Group inspires our customers to confidently fulfill their interior design visions with us by providing them an incomparable experience: a combination of products, advice, inspiration, site design and services that no competitor can match.

2001

YLighting is founded by Jeff Zwelling and David Feldman to serve the high-end, modern-lighting space online

2002

Illuminating Experiences becomes first European importer/distributor to partner with YLighting



OUR BRANDS

YLIGHTING
The Best in Modern Lighting

(http://www.ylighting.com)Founded in 2001, YLighting is the leading retailer dedicated to the best in modern and contemporary lighting. We offer design driven consumers and trade professionals a premier selection of more than 15,000 products from top international brands, such as Artemide, FLOS, Nelson Bubble Lamps, and Louis Poulsen. Our curated collection ranges from iconic mid-century modern works to today's most innovative, contemporary lighting. Our difference is our commitment to an incomparable customer experience including an extensive assortment of the best in modern and contemporary lighting, expert advice and service, inspiration and support throughout our customers' projects.

(http://www.lumens.com)Lumens was founded in 2004 with a goal in mind: to be the best place to shop for lighting, fans, modern furniture and accessories for people who love modern design. Cofounded by Ken Plumlee and Peter Weight, Lumens team is comprised of lighting and design enthusiasts servicing residential, trade professional, retail showroom, and commercial customers. Its team of product specialists is certified by the American Lighting Association. YDesign Group acquired Lumens in July, 2016.

(http://www.yliving.com)Launched in 2009, YLiving offers design-driven consumers and trade professionals the best in modern furniture, accessories, and decorative plumbing. We carry thousands of exceptional products from renowned brands, including Herman Miller, Knoll, and Kartell, as well as from up-and-coming companies. Our curated collection ranges from midcentury-modern classics to today's most cutting-edge, contemporary designs. Our difference is our commitment to an incomparable customer experience including an extensive assortment of the best in modern and contemporary home furnishings, expert advice and service, inspiration and support throughout our customers' projects.

MEET THE TEAM

Sean Callahan

Chief Executive Officer

Sean Callahan joined the company as CEO in September 2008. Prior to YDesign Group, Sean was an Executive in Residence at the private equity firm Alpine Investors and led the operational diligence on the YLighting investment. Previous to this he was based in London as the Senior Vice President and GM of EMEA for Business Engine, an enterprise software company backed by Morgan Stanley, Oak Investment Partners, and Technology Crossover Ventures. Business Engine was acquired in early 2007 by Planview, following a successful turnaround. Previous experiences include Director level roles in product management, product marketing and business development at Oracle and NONSTOP Solutions (now part of Manhattan Associates).

Sean holds a BS in Manufacturing Systems Engineering from the Pennsylvania State University, an MBA from Northwestern's Kellogg School of Business and Masters of Engineering from Northwestern's McCormick School of Engineering. He lives with his wife and three children in the San Francisco Bay Area.

Next: Donnat Lettman

Brand Partners + Product Designers

YDesign Group is committed to bringing customers the best in modern and contemporary design. Our seasoned merchandising team searches worldwide for products and partners who share this commitment to great design and an incomparable customer experience. Our merchants emphasize accurately representing and communicating our partners' brand story. Each brand and product page is overseen by a dedicated merchandiser. In addition, YDesign Group's sales team averages more than 15 years of retail and commercial furnishings experience. Finally, we have the best marketing team in the space to make sure we reach the design community to introduce them to our product partners in a compelling way.

If you are interested in partnering with YDesign Group, please contact us. We look forward to hearing from you.

Lighting: products@ylighting.com (mailto:products@ylighting.com)

Home furnishings: products@yliving.com (mailto:products@yliving.com)

Trade Program

Apply Now: YLighting (http://www.ylighting.com/trade-program.html) | YLiving (http://www.yliving.com/trade-program.html)

Our Trade Program offers exclusive benefits and support for design professionals. Once you are registered, you are automatically enrolled to receive Trade Program benefits on both YLighting and YLiving.

Our Trade Program benefits and resources include:

- Trade discount pricing
- Project and account management support
- Complimentary quotes and design consultation
- Dedicated technical and customer service support
- Trade newsletters with exclusive previews to sales and new products
- Free swatches, delivered directly to you or your clients
- Customized specifications sheets

Partnerships

YDesign Group continuously looks for ways to raise awareness of great design and contribute to the design community. When we get the chance to work with like-minded people, we jump at the opportunity. On occasion, we expand our horizons to work with individuals and organizations supporting causes in-line with our corporate values and that share our passion to make the world a better place.

If you have a passion for modern design and are exploring new and exciting ways to put people in touch with the best modern design has to offer, we would like to hear from you. Please reach out to us at marketing@ylighting.com (mailto:marketing@ylighting.com).

Featured Partner: Be Original Americas

Compelled by powerful data that highlights the negative impact of the knock-off trade, Be Original Americas is committed to informing, educating, and influencing manufacturers, design professionals, and individuals on the economic, ethical, and environmental value of authentic design while preserving and investing in its future.

YDesign Group and other charter members believe that the value of authenticity can't be underestimated or taken for granted in the marketplace. YDesign Group has long supported this concept and works with partner brands who believe in supporting creativity and authenticity in order to invest in the future of design, and give back to the industry and the people it serves.

EXHIBIT R

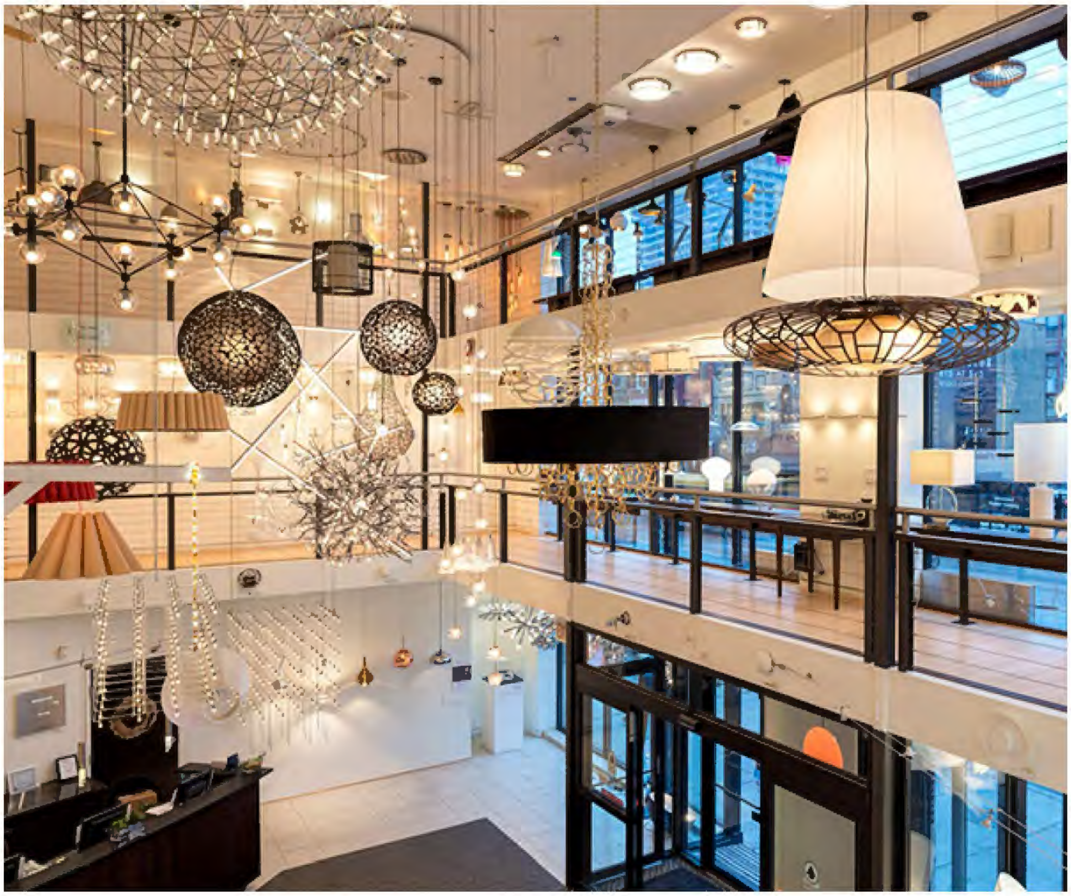
WELCOME TO LIGHTOLOGY

215 W. Chicago Ave.
Chicago IL 60654
(312) 944-1000

NORTH AMERICA'S PREMIER CONTEMPORARY LIGHTING SHOWROOM

Featuring a highly-trained and dynamic staff of American Lighting Association-Certified Lighting Consultants, Lightology is an award-winning showcase of the latest and greatest in luxury contemporary lighting from around the world.

Lightology howroom is designed from the ground up to serve the specialty needs of architects, designers, contractors, and other trade professionals. The 20,000 square foot glass-enclosed space flows around a central atrium featuring catwalks filled with high-end fixtures as well as permanent exhibits on light color, temperature, the history of electric lighting, and anything else inquisitive customers need to know about creating their ideal lighting environment. Our three-story showroom is topped off with a lush roof garden for meetings and events, providing a dramatic vantage point to Chicago's magnificent architecture.



BIRTH OF AN INSTITUTION

Lightology is the product of the combined skills and expertise of our dedicated staff.

Since opening its doors in 2001, Lightology has been home to the most talented and knowledgeable lighting experts, most with Lighting Specialist certifications from the American Lighting Association. From fitting individual lighting fixtures to designing large-scale projects for retail and commercial spaces, our lighting consultants help make the entire Lightology experience simple, satisfying and enjoyable. Confident navigators of limitless lighting possibilities, Lightology staff can guide retail, trade, and commercial customers through projects from start to finish.

Lightology site has fast become a cornerstone of the Lightology experience. Our newly redesigned, mobile-friendly site allows customers from around the country to explore our thousands of lighting products, learn everything they need to know about contemporary lighting design, and purchase online. Our website is staffed by constantly growing sales and customer service teams who ensure all customers' needs are met, near and far.

THE EARLY DAYS

Lightology is the culmination of the three-decade career of founder Greg Kay.

A Detroit native, Kay had an interest in design from an early age. He completed his training as a master electrician in the 1970s, and soon spotted an entrepreneurial niche in the cultural climate of the day, as a roller disco lighting specialist.

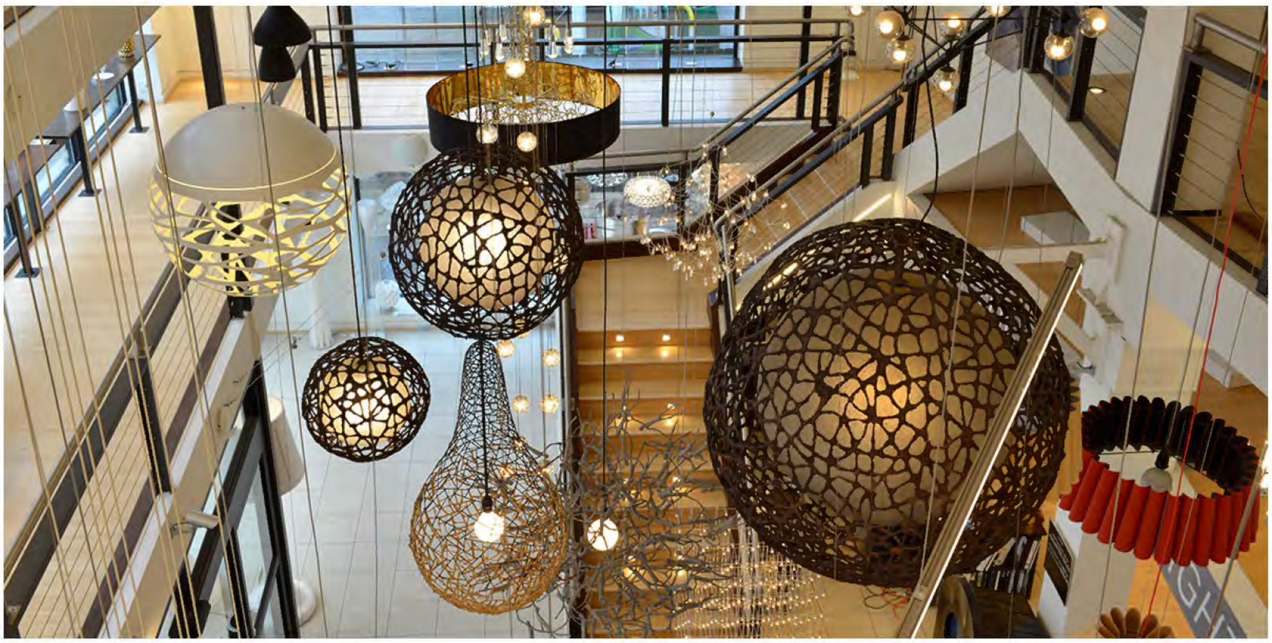
In 1983, Kay opened Tech Lighting in Chicago's River North gallery district. It was the city's first all-contemporary lighting showroom, and was a hit from the start. Kay has won dozens of awards in lighting and product design, as well as for the Lightology showroom itself. Notable awards include the prestigious Edwin F. Guth Award of Excellence in

Lightology

nd Lighting Showroom of the Year (2016).

Kay surprised many in 2001 by selling Tech Lighting to focus on his biggest project to date: Lightology, the finest contemporary lighting showroom in the world.

Visit The Lightology Showroom



Lightology

Visit our showroom located at:
215 W. Chicago Avenue, Chicago, IL 60654

Directions

DESIGN ACCLAIM

// Residential Lighting Showroom of the Year Award (2016) \\

Lightology tial Lighting Showroom of the Year Award for Merchandising (2010) \\

// ASID-Illinois Design Excellence Award for "Stratus" Wall Grazer (2008) \\

// ESNA International Illumination Design Award of Merit (1997) \\

// Chicago Lighting Institute Award of Merit for Lighting Excellence (1994) \\

// Chicago Athenaeum Good Design Award for Johnny and Wishbone KableLite fixtures (1992) \\

// Edwin F. Guth Award of Excellence in Lighting Design (1989) \\

CLIENT TESTIMONIALS

Xavier,

Thank you for taking care of this! Great connecting with you today - you are my kind of people. :)

// Karen K

Lightology

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EXHIBIT S

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DYSON'S CU-BEAM DUO IS A RADICALLY NEW OFFICE LAMP —SERIOUSLY

MIKE COOPER/DYSON

JAKE DYSON, SON of inventor and noted vacuum-maker Sir James Dyson, is taking on the lighting industry. Specifically, he's on a crusade for change in office lighting. His means to that end is the Cu-Beam Duo, a new suspension lamp that looks like a satellite, runs for decades, and gives you ample control over the direction and intensity of both up- and down-light.

If one expensive suspension lamp seems like an unlikely change agent in the world of office lighting, consider the light in most offices. If you're in one, look around. It's probably really bright—far brighter than it needs to be. Government regulations require a minimum level out light output in the workplace, so a building's architect will often install a surplus of equally very bright lights into the ceiling. It's a blanket approach, not a personalized one.

light in specific directions—could help solve that problem.

"Lighting an office effectively is really difficult," says lighting designer Naomi Miller, a researcher at the Department of Energy's Pacific Northwest National Laboratory. She says it's particularly challenging to balance the quality, quantity, and placement of light. If any of these variables is off, the result is poor lighting conditions. And remember, an office's lighting needs usually change throughout the day. The ideal lighting solution produces adjustable, high quality light.

Miller says the Cu-Beam Duo is impressive on that front. "What draws me to this new product is the ability to change the light distribution. That's pretty nifty." She's referring to the lamp's driver which lets users adjust the output ratio between the upward light and the downward-facing task light throughout the day. This allows the Duo to suit a range of needs. If you host a brainstorming meeting, for instance, you can choose to pour more light onto the table, so people can take notes. Need to interview a job candidate? Bathe the ceiling in light. It'll help diffuse the light, like a photographer's soft box, so your interviewee doesn't feel like they're under an interrogation lamp.

DYSON

Office buildings rarely support such options. A typical workplace ceiling has recessed lighting fixtures known as troffers, which blast a uniform blanket of light onto a space. The LEDs inside them are actually several small LEDs arranged together on one module. These are called chip-on-board LEDs, and while they emit light less effectively than large LEDs, casting shadows on each other that make it difficult to generate a focused beam, they disperse heat more effectively than larger diodes.

"Everyone else gets more light out by using lots of little LEDs, because they don't want to engineer or invest in the cooling of them," Dyson says. Not him. He wanted a big LED that could also shed heat quickly. A few years ago, he realized he could use heat transfer to do it. Every Cu-Beam contains six copper heat pipes. Each pipe contains a small volume of water that wicks heat from the LED by vaporizing. The vapor then migrates to the end of the pipe, where it condenses back into liquid water, and repeats the cycle. This system allows the Cu-Beam Duo to keep two powerful, single LEDs running at low temperature. And because the lights emanates from a single source, they focus like a dream.

impressive engineering will convince office managers with budgets. Miller says decisions about workplace lighting mostly come down to cost and convenience. Dyson hasn't assigned a price to the Cu-Beam Duo yet, but the Cu-Beam Up and Cu-Beam Down, which cast light up and down, respectively, cost $1,999 apiece.

That's a hefty price tag, but its sheer existence could affect the industry. "It might change lighting as we know it, because it's creating awareness that you can do something besides put troffers in the ceiling," Miller says. For those who do opt in, Dyson says the Cu-Beam Duo stays lit at peak brightness for 180,000 hours, or up to 37 years of working hours. "It's future proof," he says. OK, maybe not future proof—it'll only be so long before someone else tries to revolutionize office lighting.

VIEW COMMENTS

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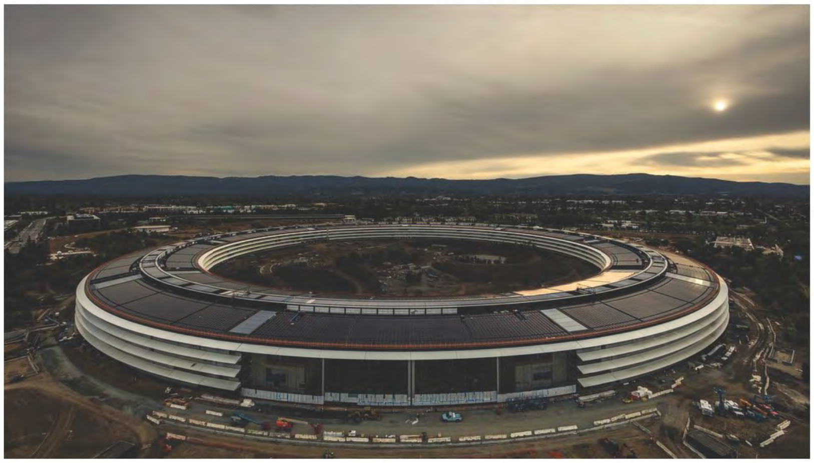

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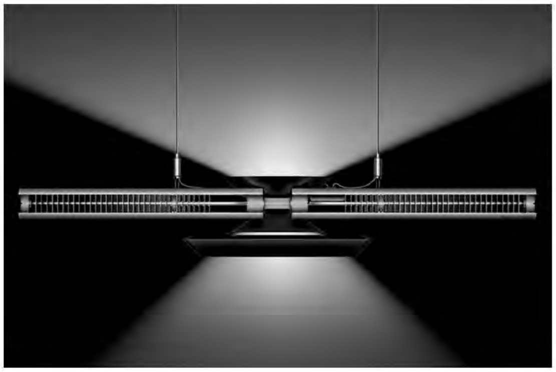
EXHIBIT T

Dyson Cu-Beam Duo Offers A Unique Twist To Office Lighting

DECEMBER 13, 2016



Most offices use either fluorescent lighting or LED troffers for illumination. And they're perfectly fine. Except for the fact that there's no way to personalize the kind of lighting you get in the room. Simply put, you either get high levels of brightness or none of it. The Dyson Cu-Beam Duo offers a customizable alternative.

Unlike conventional office lighting solutions, the lamp doesn't just throw down a bright white light to keep every inch of the office well-illuminated. Instead, it can shine its light either upward or downward, with the upward light being diffused through the ceiling and the downward light providing the necessary illumination to get work done.

The Dyson Cu-Beam Duo doesn't just deliver the same level of lighting throughout the day, as it comes with a custom driver that lets you easily adjust the ratio between the upward and downward light, allowing you to tailor the exact amount of light in the room. You can, for instance, maximize the amount of light shining down on the table to make sure people see everything they're reading and writing clearly, all while shining more light upward when someone's doing a presentation to ensure the giant screen on the wall becomes the focal point of the room.

Unlike LED troffers, by the way, Dyson's lamp doesn't use an array of small LEDs for its light. Instead, they use one large high-power LED with a custom-engineered lens that's cooled by six copper heat pipes integrated into the rig.

No pricing has been announced yet for the Dyson Cu-Beam Duo, but it's slated to come out next year.

Check It Out

COOL LIGHTING

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