Custom Garage Door

- **Considering Decorative Hardware for Visual Appeal**
  Considering Decorative Hardware for Visual Appeal Evaluating Window Inserts to Increase Light Exploring Color Matching Options for Unique Exteriors Understanding Methods for Personalizing Door Panels Identifying Materials that Complement Architectural Themes Balancing Function and Form in Customized Designs Approaches to Incorporating Artistic Elements in Door Surfaces Observing Trends in Personalized Garage Door Styles Selecting Subtle Accents to Enhance Appearance Assessing Long Term Impact of Design Modifications Steps for Coordinating Garage Doors with Surrounding Landscaping Recognizing the Value of Expert Guidance in Aesthetic Decisions
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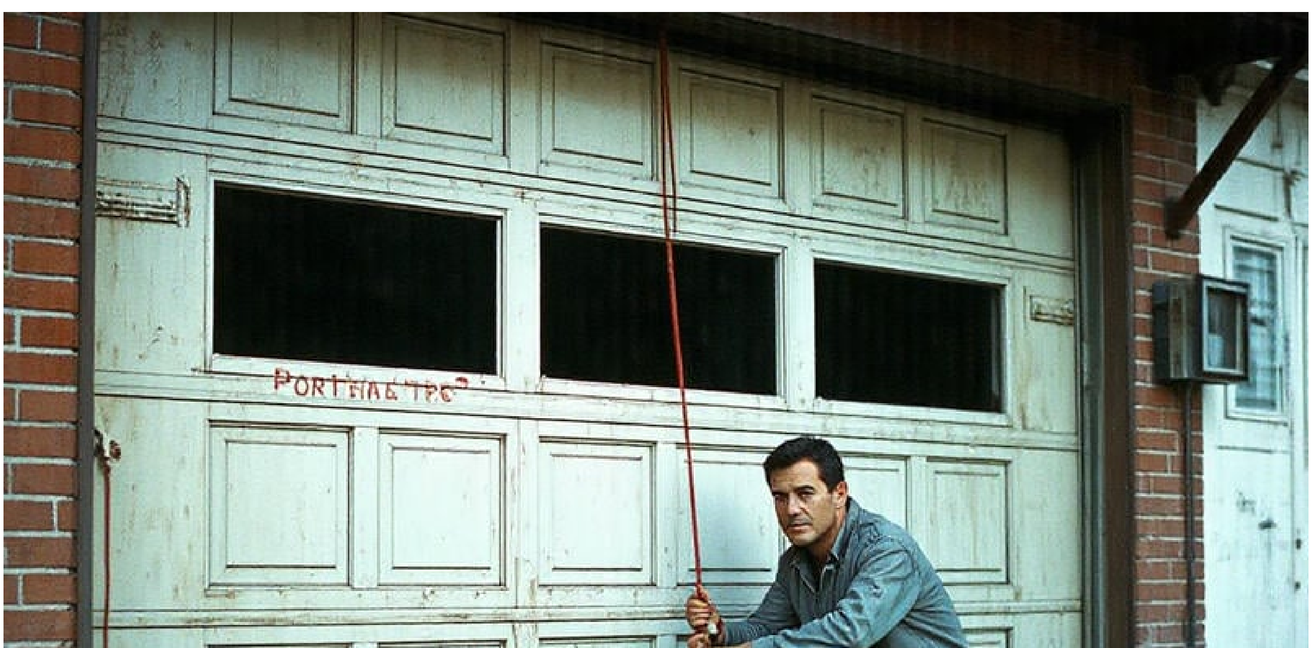
- **About Us**



When considering garage door installations, understanding the pricing structures can be as intricate as the mechanisms of the doors themselves. Vinyl garage doors are resistant to dents and scratches, making them low-maintenance **garage door openner repair** attention. Several key factors influence these costs, and asking the right questions can help you navigate this often complex process to ensure you get the best value for your investment.

Firstly, it's essential to inquire about the types of materials used in constructing the garage door. Materials such as steel, wood, aluminum, and fiberglass each come with their own set of benefits and price points. For instance, while wooden doors might offer a classic aesthetic appeal, they typically require more maintenance and can be more expensive compared to steel doors which are known for their durability and cost-effectiveness. Asking what materials are available and why one might be favored over another can provide insight into both immediate costs and long-term implications.

Another crucial factor is the size and design of the garage door. Customizations like windows or unique panel designs can significantly alter pricing. Therefore, it's wise to ask how different sizes or styles impact overall costs. You may also want to explore whether there are standard models that could offer savings without compromising on quality or functionality.

Installation fees themselves should not be overlooked when discussing prices. It's important to understand if installation is included in the quoted price or if it incurs an additional fee. Inquiring about any potential hidden charges will prevent unexpected surprises later on. Furthermore, asking about warranties provided by both manufacturers and installers can give peace of mind regarding future repairs or replacements.

Labor costs vary depending on geographic location and company reputation; hence it's beneficial to question how these elements affect pricing in your specific area. Some companies might offer package deals that include installation at a reduced rate a detail worth exploring during discussions.

Finally, energy efficiency is becoming an increasingly popular consideration among homeowners looking for long-term savings on utility bills. Energy-efficient doors may have higher upfront costs but could lead to significant savings down the line. Asking about insulation options and their effect on energy efficiency could lead you to make a more informed decision that balances initial expenditure with future cost reductions.

In conclusion, delving into these questions not only aids in comprehending current market rates but also empowers you to make an educated choice tailored to your needs and budget constraints when installing a new garage door. By addressing these aspects proactively with potential suppliers or contractors, you ensure transparency in pricing structures while maximizing value from your purchase decision-making process.

Types of Decorative Hardware for Garage Doors —

- **Discuss the role of decorative hardware in enhancing the visual appeal of garage doors.**
- **Types of Decorative Hardware for Garage Doors**
- **Explore different styles and materials, such as handles, hinges, and clavos.**
- **Choosing the Right Style for Your Home**
- **Consider architectural styles and how they influence hardware selection.**
- **Material Considerations for Durability and Aesthetics**
- **Review popular materials like wrought iron, stainless steel, and aluminum.**

In the complex world of business, pricing models play a crucial role in determining the success and sustainability of any enterprise. As organizations strive to optimize their revenue streams while meeting consumer demands, understanding various pricing structures becomes imperative. This essay delves into some common types of pricing models used across industries and suggests pertinent questions that one might consider asking about these structures to ensure they align with strategic goals.

One prevalent pricing model is cost-plus pricing, where a fixed percentage markup is added to the production cost of a product or service. While straightforward and easy to implement, this method often overlooks competitive dynamics and consumer willingness to pay. To evaluate its effectiveness, it's essential to ask: How does this markup compare with industry standards?

Does this model allow us to remain competitive in our target market?

Value-based pricing stands out as another significant approach, where prices are set based on the perceived value to the customer rather than the cost of production. This model necessitates a deep understanding of customer needs and preferences. Key questions here include: What unique value does our product offer compared to competitors? How can we quantify this perceived value for different customer segments?

Dynamic pricing has gained traction, particularly in industries like airlines and hospitality, where prices fluctuate based on demand and supply conditions. While potentially maximizing profits, dynamic pricing can alienate customers if not managed carefully. Therefore, businesses should consider: What data do we need to effectively implement dynamic pricing? How do we communicate price changes transparently to maintain customer trust?

Subscription-based models have revolutionized sectors such as software and media by offering continuous access for a recurring fee. This approach fosters long-term customer relationships but requires ongoing engagement strategies. Questions worth exploring include: How do we ensure consistent value delivery over time? What metrics will help us assess subscription churn rates and customer lifetime value?

Finally, freemium models provide basic services for free while charging for advanced features or functionalities. Common in digital products, this model helps build user bases but poses challenges in converting free users into paying customers. Critical questions might be: Which features should remain free versus paid? What conversion strategies will best incentivize upgrades without compromising user satisfaction?

In conclusion, selecting an appropriate pricing model involves more than just setting numbers; it requires strategic thinking aligned with market conditions and consumer behavior insights. By asking insightful questions tailored to each model's nuances, businesses can refine their approaches and achieve better financial outcomes while enhancing customer satisfaction.

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Explore different styles and materials, such as handles, hinges, and clavos.

When delving into the complex landscape of labor costs and fees, understanding pricing structures becomes paramount. Whether you're a consumer navigating service options or a business owner strategizing for profitability, asking the right questions can unveil crucial insights. Essential questions about labor costs and fees not only clarify financial expectations but also enhance negotiation efficacy and budget planning.

First and foremost, it's vital to ask, "What components are included in the labor cost?" This question helps distinguish between direct wages paid to employees and other associated expenses such as benefits, overtime pay, or training costs. Understanding these components allows you to assess whether the quoted prices align with industry standards or if there are hidden charges that might inflate the overall cost unexpectedly.

Another critical inquiry is, "How does your pricing structure account for fluctuations in demand or project complexity?" Labor costs can significantly vary depending on factors like peak seasons, urgent deadlines, or specialized skills required for complex tasks. By addressing this question upfront, you ensure transparency in how potential price adjustments are handled and whether they follow a reasonable methodology.

Furthermore, consider asking, "Are there any additional fees I should be aware of?" This encompasses potential surcharges for expedited services, administrative fees, or penalties that might apply under specific conditions. Identifying these upfront prevents unpleasant surprises down the line and aids in making accurate budget forecasts.

For businesses hiring contractors or freelancers, it's prudent to inquire about payment terms: "What is your billing cycle and payment policy?" Understanding when payments are due and what methods are acceptable ensures smooth cash flow management while maintaining amicable business relationships.

Moreover, exploring the experience behind the numbers is beneficial: "How do your labor costs reflect employee expertise and efficiency?" Higher rates may correlate with skilled workers who deliver superior results more swiftly than their less experienced counterparts. Gauging this balance can inform whether higher initial costs might ultimately result in greater value and efficiency.

Finally, an often overlooked yet insightful question is: "Can you provide references from previous clients regarding pricing satisfaction?" Testimonials or case studies from past engagements offer not just validation of fair pricing but also insights into how well a service provider adheres to their stated policies over time.

In conclusion, by posing these essential questions about labor costs and fees within different pricing structures, both consumers and businesses gain clarity that empowers informed decision-making. It fosters transparency between parties involved while ensuring that financial commitments align with expectations-ultimately supporting sustainable economic practices.

Choosing the Right Style for Your Home

When delving into the intricacies of pricing structures, particularly in relation to material and equipment expenses, it's crucial to approach the subject with a strategic mindset. This approach not only stimulates insightful discussions but also ensures that one comprehensively understands the financial underpinnings of any project or purchase. To effectively engage with this topic, consider suggesting questions that probe deeper into the components and justifications of these costs.

First and foremost, it's essential to inquire about how material expenses are calculated. Ask whether there's a standardized formula or method that suppliers use to determine these costs. Understanding if they factor in raw material prices, transportation fees, or even market fluctuations can provide clarity on why prices may vary or seem inflated at times.

Another critical question revolves around the transparency of cost breakdowns. It's beneficial to ask if detailed invoices can be provided that outline individual material and equipment costs. Such transparency not only aids in budget planning but also builds trust between parties involved. It allows for an open dialogue where potential discrepancies can be addressed promptly.

Furthermore, consider questioning the longevity and durability of materials and equipment being proposed. Often, cheaper materials might seem attractive initially but could lead to higher costs over time due to frequent replacements or repairs. By understanding the lifecycle cost rather than just the upfront expense, decision-makers can make more informed choices that align with long-term financial strategies.

Additionally, it's worth exploring potential discounts or bulk purchasing options when discussing pricing structures related to materials and equipment. Asking suppliers if they offer reduced rates for larger orders or if there are seasonal promotions can lead to significant savings.

Engage in queries about market trends as well-how do current geopolitical events or economic conditions influence these material and equipment prices? Are there anticipated changes on the horizon that could affect future budgets? Being aware of such factors enables better preparedness and negotiation positions.

Lastly, don't shy away from asking about alternative materials or technologies that could serve similar purposes at different price points. With rapid advancements in technology and sustainable practices gaining traction, newer options might offer both cost-efficiency and environmental benefits.

In conclusion, approaching inquiries regarding material and equipment expenses with a comprehensive set of questions not only enhances one's understanding but also cultivates a proactive stance towards managing finances effectively. By fostering transparent communication channels through such inquiries, one lays down a foundation for successful negotiations and sound financial planning aligned with both immediate needs and future goals.

Consider architectural styles and how they influence hardware selection.

When navigating the often complex landscape of purchasing goods and services, understanding extra charges and hidden fees is crucial for making informed financial decisions. All too often, consumers find themselves blindsided by additional costs that were not explicitly stated upfront. These surprise fees can significantly inflate the final price of a product or service, leading to frustration and financial strain. To mitigate such unpleasant surprises, it is essential to delve into pricing structures with a critical eye and ask pointed questions that unravel the layers of potential hidden costs.

One of the first questions to pose is: What exactly does the advertised price include? This fundamental inquiry helps clarify whether the initial price encompasses all necessary components or if there are essential features or services that come at an additional cost. For instance, when booking a hotel room, it's important to determine if amenities like Wi-Fi, parking, or breakfast are covered in the quoted rate. Similarly, in subscription-based services, understanding what constitutes a basic package versus premium enhancements can prevent unexpected expenses.

Another pivotal question concerns any potential surcharges: Are there seasonal rates or peak-time fees that apply? Vendors may implement variable pricing models based on demand fluctuations throughout the year. By asking about these variations upfront, consumers can make strategic decisions about timing their purchases to avoid higher costs during peak periods.

Additionally, it's prudent to inquire about cancellation policies and associated fees: What are the terms if I need to cancel or modify my purchase? Understanding these conditions can save both money and hassle should plans change unexpectedly. Many businesses impose penalties for last-minute cancellations or modifications; knowing these details allows consumers to weigh their options more effectively.

Moreover, asking about taxes and service charges is another critical step: Are taxes and service charges included in the quoted price? In many regions, sales tax is added at checkout rather than being included in advertised prices. Service charges might also apply in industries like hospitality and dining. By clarifying this aspect early on, buyers can better anticipate their total outlay.

Finally, one should not overlook loyalty programs or discounts: Are there any available discounts or loyalty programs I could benefit from? Businesses frequently offer promotions that reduce costs for members or repeat customers. Being aware of these opportunities enables consumers to capitalize on savings they might otherwise miss.

In conclusion, taking a proactive role by asking targeted questions about pricing structures empowers consumers to sidestep hidden fees and extra charges effectively. By seeking comprehensive information regarding what is included in prices, potential surcharges during high-demand periods, cancellation policies and associated fees, as well as taxes and service charge inclusions-and exploring available discounts-consumers position themselves strategically within market transactions. This diligence transforms purchasing experiences from potential pitfalls into satisfying endeavors rooted in transparency and trust between buyers and sellers alike.

Material Considerations for Durability and Aesthetics

When navigating the intricate waters of pricing structures, one must not overlook the pivotal roles played by warranties and maintenance costs. These elements can significantly impact the overall value and cost-effectiveness of a purchase, whether it be a piece of technology, a vehicle, or any long-term investment. To gain clarity on these aspects and make informed decisions, it is essential to ask targeted questions that uncover hidden implications.

Firstly, understanding the scope and limitations of warranties is crucial. A warranty serves as a seller's promise to stand behind their product; however, not all warranties are created equal. It is important to ask specific questions such as: What exactly does the warranty cover? Are there any parts or repairs excluded from this coverage? How long does the warranty last? Is there an option to extend it for additional protection? These inquiries help reveal whether the warranty provides comprehensive coverage or if significant exceptions might lead to unexpected expenses down the line.

Furthermore, exploring who bears responsibility for shipping costs in case of repairs can also prevent unpleasant surprises. Some warranties may require you to cover these expenses, which could add up depending on the nature of the product and its location.

Equally important is addressing maintenance cost implications. While initial pricing might seem attractive, ongoing maintenance can dramatically alter total ownership costs. Questions like: What routine maintenance will be required over time? Are there recommended service providers or can any qualified technician perform necessary upkeep without voiding the warranty? Should I expect consumables or replacement parts that are not covered under warranty but are essential for continued operation?

Additionally, evaluating potential price fluctuations in spare parts or consumable supplies ensures that you're financially prepared throughout your ownership journey. This foresight aids in comparing different products not just based on upfront cost but considering total expenditure across their lifecycle.

Lastly, inquire about any service contracts offered alongside your purchase. Service contracts may provide extended support beyond standard warranties; however, they often come with additional costs themselves. Understanding what these contracts entail-including terms around cancellation policies or transferability-will further enhance your ability to gauge true value versus projected expense.

In conclusion, clarifying warranties and assessing maintenance cost implications should form an integral part of discussions when examining pricing structures. By asking pointed questions about coverage details within warranties as well as diving deep into likely ongoing expenditures related to maintenance needs-you empower yourself with knowledge leading towards more prudent purchasing decisions framed by comprehensive awareness rather than surface-level appeal alone.

Review popular materials like wrought iron, stainless steel, and aluminum.

When navigating the labyrinth of selecting a service provider, one quickly realizes that comparing quotes is not as simple as it might initially seem. Whether you're looking for a contractor to renovate your home, an IT company to handle your business's digital needs, or a caterer for an upcoming event, understanding the nuances of pricing structures is crucial. Asking the right questions can unravel complexities and ensure you make an informed decision that aligns with both your needs and budget.

To begin with, clarity on what exactly is included in the quoted price can save you from unexpected expenses later on. Ask providers what specific services are covered under their quote. Are there any services you might assume are standard but are actually additional? For instance, if you're hiring a construction firm, does their quote include permits and materials, or just labor costs? An IT service provider may offer software installation in their package but charge extra for ongoing maintenance.

Another important question revolves around potential hidden fees or charges. It's not uncommon for service providers to have additional costs that aren't immediately apparent in the initial quote. Inquire about circumstances that could lead to extra charges: What happens if there's a delay beyond your control? Will there be any fees for canceling or rescheduling services? Understanding these contingencies upfront allows you to prepare financially and avoid unpleasant surprises.

The structure of payment is also crucial when evaluating quotes. Is there a requirement for an upfront deposit? If so, how much? Are payments structured in milestones, upon completion of certain phases of work? Or is it all due at once upon completion? Knowing this helps you manage cash flow more effectively and ensures there are no misunderstandings down the line.

Additionally, ask about discounts or promotions that may apply. Service providers often have seasonal offers or package deals that can significantly reduce costs. Don't hesitate to ask whether they offer discounts for referrals or long-term contracts if applicable.

An inquiry into price adjustments over time is equally vital, especially if you're entering into a long-term agreement. Clarify whether prices are fixed or subject to change based on market conditions. Some service agreements include clauses allowing periodic adjustments; understanding these terms beforehand helps maintain financial predictability.

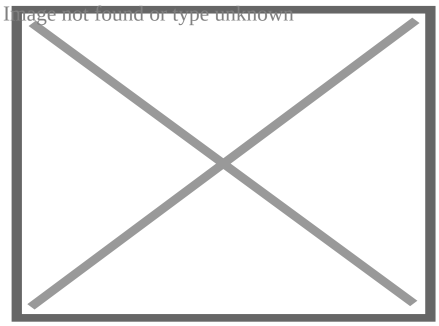
Finally, consider asking about their refund policy should the service not meet expectations. While everyone hopes for flawless execution, it's practical to know what recourse you have should issues arise post-payment.

In conclusion, when comparing quotes from different service providers, asking detailed questions about pricing structures provides transparency and aids in making well-informed decisions. With clarity comes confidence-not only in understanding what you're paying for but also in knowing you've chosen the best fit among available options. As consumers become savvier and markets more competitive, these inquiries aren't just beneficial-they're essential tools in navigating today's complex service landscapes.

About light-emitting diode

This article is about the electronic device. For specific use in lighting, see LED lamp. "LED" and "Led" redirect here. For other uses, see LED (disambiguation).

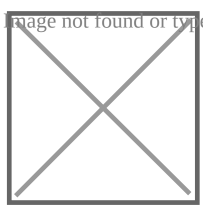
Light-emitting diode

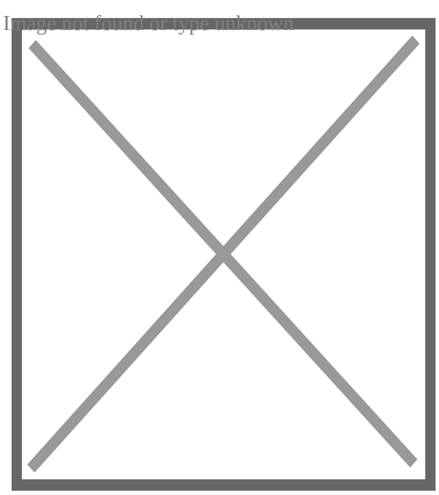


Blue, green, and red LEDs in 5 mm diffused cases. There are many different variants of LEDs.

Working principle	Electroluminescence
Inventor	○ H. J. Round (1907)[1] ○ Oleg Losev (1927)[2] ○ James R. Biard (1961)[3] ○ Nick Holonyak (1962)[4]
First production	October 1962; 62 years ago
Pin names	Anode and cathode

Electronic symbol





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.

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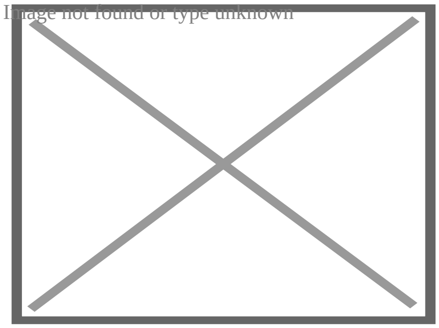

Close-up image of a surface-mount LED

Close-up of an LED with the voltage being increased and decreased to show a detailed view of its operation

Modern LED retrofit with E27 screw in base

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

A **light-emitting diode** (**LED**) is a semiconductor device that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor.[5] White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.[6]

Appearing as practical electronic components in 1962, the earliest LEDs emitted low-intensity infrared (IR) light.[7] Infrared LEDs are used in remote-control circuits, such as those used with a wide variety of consumer electronics. The first visible-light LEDs were of low intensity and limited to red.

Early LEDs were often used as indicator lamps, replacing small incandescent bulbs, and in seven-segment displays. Later developments produced LEDs available in visible, ultraviolet (UV), and infrared wavelengths with high, low, or intermediate light output, for instance, white LEDs suitable for room and outdoor lighting. LEDs have also given rise to new types of displays and sensors, while their high switching rates are useful in advanced communications technology with applications as diverse as aviation lighting, fairy lights, strip lights, automotive headlamps, advertising, general lighting, traffic signals, camera flashes, lighted wallpaper, horticultural grow lights, and medical devices.[8]

LEDs have many advantages over incandescent light sources, including lower power consumption, a longer lifetime, improved physical robustness, smaller sizes, and faster switching. In exchange for these generally favorable attributes, disadvantages of LEDs include electrical limitations to low voltage and generally to DC (not AC) power, the inability to provide steady illumination from a pulsing DC or an AC electrical supply source, and a lesser maximum operating temperature and storage temperature.

LEDs are transducers of electricity into light. They operate in reverse of photodiodes, which convert light into electricity.

History

[edit]
Main article: History of LEDs

The first LED was created by Soviet inventor Oleg Losev[9] in 1927, but electroluminescence was already known for 20 years, and relied on a diode made of silicon carbide.

Commercially viable LEDs only became available after Texas Instruments engineers patented efficient near-infrared emission from a diode based on GaAs in 1962.

From 1968, commercial LEDs were extremely costly and saw no practical use. Monsanto and Hewlett-Packard led the development of LEDs to the point where, in the 1970s, a unit cost less than five cents.[10]

Physics of light production and emission

[edit]
Main article: Light-emitting diode physics

In a light-emitting diode, the recombination of electrons and electron holes in a semiconductor produces light (be it infrared, visible or UV), a process called "electroluminescence". The wavelength of the light depends on the energy band gap of the semiconductors used. Since these materials have a high index of refraction, design features of the devices such as special optical coatings and die shape are required to efficiently emit light.[11]

Unlike a laser, the light emitted from an LED is neither spectrally coherent nor even highly monochromatic. Its spectrum is sufficiently narrow that it appears to the human eye as a pure (saturated) color.[12][13] Also unlike most lasers, its radiation is not spatially coherent, so it cannot approach the very high intensity characteristic of lasers.

Single-color LEDs

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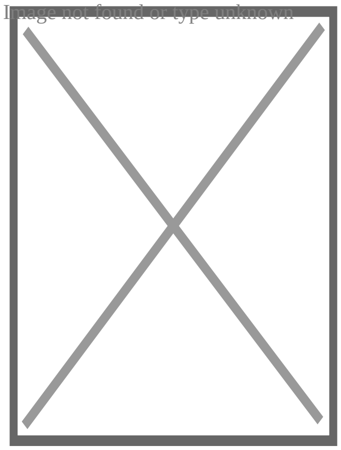
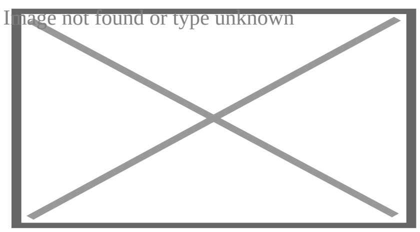


Blue LEDs

External videos



video icon "The Original Blue LED", Science History Institute

By selection of different semiconductor materials, single-color LEDs can be made that emit light in a narrow band of wavelengths from near-infrared through the visible spectrum and into the ultraviolet range. The required operating voltages of LEDs increase as the emitted wavelengths become shorter (higher energy, red to blue), because of their increasing semiconductor band gap.

Blue LEDs 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 unalloyed 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.[*citation needed*]

With AlGaN and AlGaInN, even shorter wavelengths are achievable. Near-UV emitters at wavelengths around 360–395 nm are already cheap and often encountered, for example, as black light lamp replacements for inspection of anti-counterfeiting UV watermarks in documents and bank notes, and for UV curing. Substantially more expensive, shorter-wavelength diodes are commercially available for wavelengths down to 240 nm.[14] 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 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.[15] UV-C wavelengths were obtained in laboratories using aluminium nitride (210 nm),[16] boron nitride (215 nm)[17][18] and diamond (235 nm).[19]

White LEDs

[edit]

There are two primary ways of producing white light-emitting diodes. One is to use individual LEDs that emit three primary colors—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, similar to a fluorescent lamp. The yellow phosphor is cerium-doped YAG crystals suspended in the package or coated on the LED. This YAG phosphor causes white LEDs to appear yellow when off, and the space between the crystals allow some blue light to pass through in LEDs with partial phosphor conversion. Alternatively, white LEDs may use other phosphors like manganese(IV)-doped potassium fluorosilicate (PFS) or other engineered phosphors. PFS assists in red light generation, and is used in conjunction with conventional Ce:YAG phosphor.

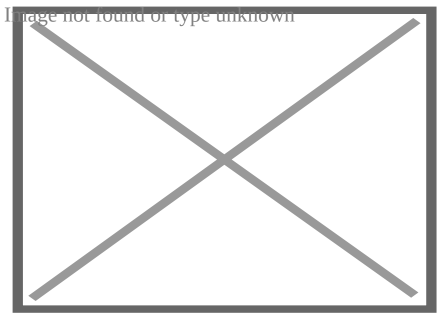
In LEDs with PFS phosphor, some blue light passes through the phosphors, the Ce:YAG phosphor converts blue light to green and red (yellow) light, and the PFS phosphor converts blue light to red light. The color, emission spectrum or color temperature of white phosphor converted and other phosphor converted LEDs can be controlled by changing the concentration of several phosphors that form a phosphor blend used in an LED package.[20][21][22][23]

The 'whiteness' of the light produced is engineered to suit the human eye. Because of metamerism, it is possible to have quite different spectra that appear white. The appearance of objects illuminated by that light may vary as the spectrum varies. This is the issue of color rendition, quite separate from color temperature. An orange or cyan object could appear with the wrong color and much darker as the LED or phosphor does not emit the wavelength it reflects. The best color rendition LEDs use a mix of phosphors, resulting in less efficiency and better color rendering.[*citation needed*]

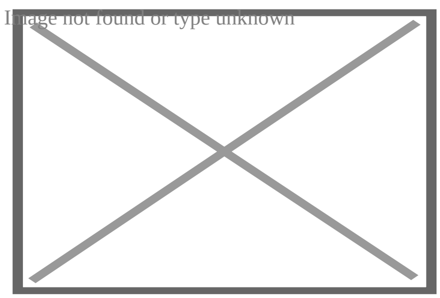
The first white light-emitting diodes (LEDs) were offered for sale in the autumn of 1996.[24] Nichia made some of the first white LEDs which were based on blue LEDs with Ce:YAG phosphor.[25] Ce:YAG is often grown using the Czochralski method.[26]

RGB systems

[edit]



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.



An RGB LED projecting red, green, and blue onto a surface

Mixing red, green, and blue sources to produce white light needs electronic circuits to control the blending of the colors. Since LEDs have slightly different emission patterns, the color balance may change depending on the angle of view, even if the RGB sources are in a single package, so RGB diodes are seldom used to produce white lighting. Nonetheless, this method has many applications because of the flexibility of mixing different colors,[27] and in principle, this mechanism also has higher quantum efficiency in producing white light.[28]

There are several types of multicolor 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. 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.[29]

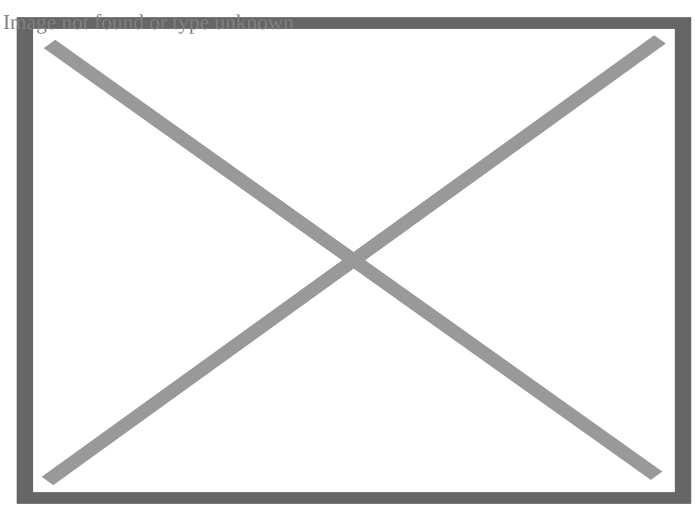
One of the challenges is the development of more efficient green LEDs. The theoretical maximum for green LEDs is 683 lumens per watt but as of 2010 few green LEDs exceed even 100 lumens per watt. The blue and red LEDs approach their theoretical limits.[*citation needed*]

Multicolor LEDs offer a 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. Their emission power decays exponentially with rising temperature,[30] resulting in a substantial change in color stability. Such problems inhibit industrial use. Multicolor LEDs without phosphors cannot provide good color rendering because each LED is a narrowband source. 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.

Dimming a multicolor LED source to match the characteristics of incandescent lamps is difficult because manufacturing variations, age, and temperature change the actual color value output. To emulate the appearance of dimming incandescent lamps may require a feedback system with color sensor to actively monitor and control the color.[31]

Phosphor-based LEDs

[edit]

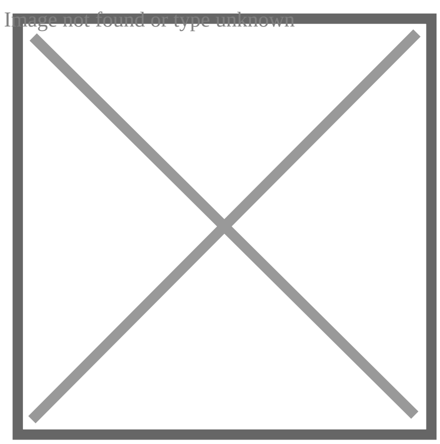


Spectrum of a white LED showing blue light directly emitted by the GaN-based LED (peak at about 465 nm) and the more broadband Stokes-shifted light emitted by the Ce^{3+}:YAG phosphor, which emits at roughly 500–700 nm

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).[32] A fraction of the blue light undergoes the Stokes shift, which transforms it from shorter wavelengths to longer. Depending on the original LED's color, various color phosphors are used. Using several phosphor layers of distinct colors broadens the emitted spectrum, effectively raising the color rendering index (CRI).[33]

Phosphor-based LEDs have efficiency losses due to heat loss from the Stokes shift and also other phosphor-related 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.[*citation needed*]



1 watt 9 volt three chips SMD phosphor based white LED

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.[*citation needed*]

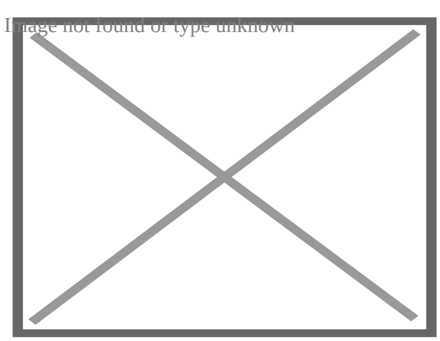
Some phosphor-based white LEDs encapsulate InGaN blue LEDs inside phosphor-coated epoxy. Alternatively, the LED might be paired with a remote phosphor, a preformed polycarbonate piece coated with the phosphor material. Remote phosphors provide more diffuse light, which is desirable for many applications. 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).[*citation neede*

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.[*citation needed*]

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.[34] The sapphire apparatus must be coupled with a mirror-like collector to reflect light that would otherwise be wasted. It was predicted that since 2020, 40% of all GaN LEDs are 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.[35]

Mixed white LEDs

[edit]



Tunable white LED array in a floodlight

There are RGBW LEDs that combine RGB units with a phosphor white LED on the market. Doing so retains the extremely tunable color of RGB LED, but allows color rendering and efficiency to be optimized when a color close to white is selected.[36]

Some phosphor white LED units are "tunable white", blending two extremes of color temperatures (commonly 2700K and 6500K) to produce intermediate values. This feature allows users to change the lighting to suit the current use of a multifunction room.[37] As illustrated by a straight line on the chromaticity diagram, simple two-white blends will have a pink bias, becoming most severe in the middle. A small amount of green light, provided by another LED, could correct the problem.[38] Some products are RGBWW, i.e. RGBW with tunable white.[39]

A final class of white LED with mixed light is dim-to-warm. These are ordinary 2700K white LED bulbs with a small red LED that turns on when the bulb is dimmed. Doing so makes the color warmer, emulating an incandescent light bulb.[39]

Other white LEDs

[edit]

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.[40]

Organic light-emitting diodes (OLEDs)

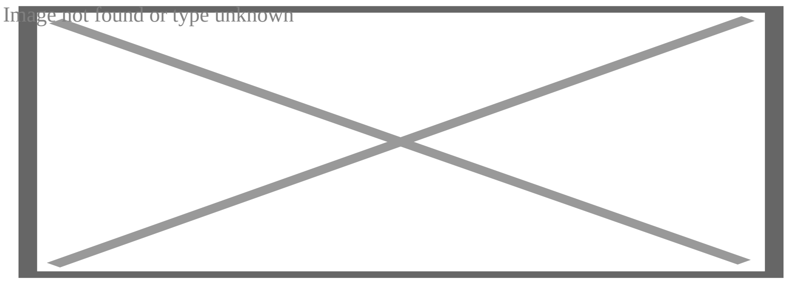
[edit]
Main article: OLED

In an organic light-emitting diode (OLED), the electroluminescent material composing 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.[41] The organic materials can be small organic molecules in a crystalline phase, or polymers.[42]

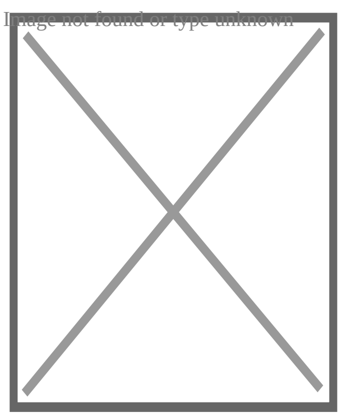
The potential advantages of OLEDs include thin, low-cost displays with a low driving voltage, wide viewing angle, and high contrast and color gamut.[43] Polymer LEDs have the added benefit of printable and flexible displays.[44][45][46] OLEDs have been used to make visual displays for portable electronic devices such as cellphones, digital cameras, lighting and televisions.[42][43]

Types

[edit]



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).



A variety of different diffused 5 mm THT-LEDs

- Red, 650 – 625nm
- Orange, 600 – 610nm
- Yellow, 587 – 591nm
- Green, 570 – 575nm
- Blue, 465 – 467nm
- Purple, 395 – 400nm

LEDs are made in different packages for different applications. A single or a few LED junctions may be packed in one miniature device for use as an indicator or pilot lamp. An LED array may include controlling circuits within the same package, which may range from a simple resistor, blinking or color changing control, or an addressable controller for RGB devices. Higher-powered white-emitting devices will be mounted on heat sinks and will be used for illumination. Alphanumeric displays in dot matrix or bar formats are widely available. Special packages permit connection of LEDs to optical fibers for high-speed data communication links.

Miniature

[edit]

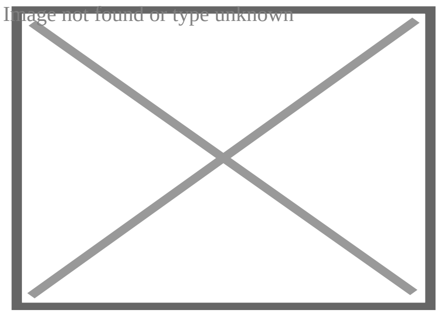
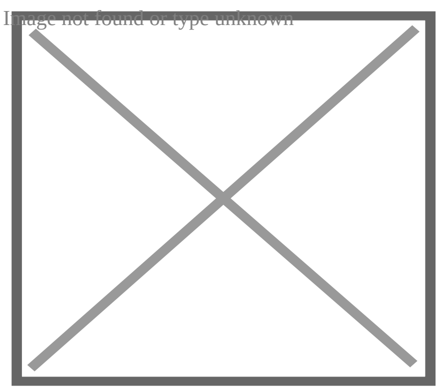


Image of miniature surface mount LEDs in most common sizes. They can be much smaller than a traditional 5 mm lamp type LED, shown on the upper left corner.



Very small (1.6×1.6×0.35 mm) red, green, and blue surface mount miniature LED package with gold wire bonding details

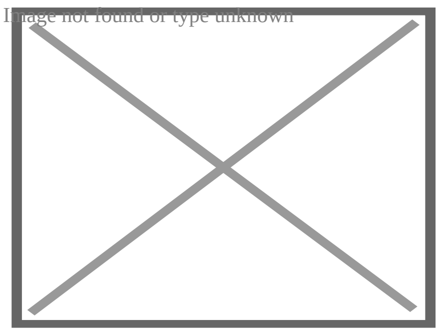
These are mostly single-die LEDs used as indicators, and they come in various sizes from 1.8 mm to 10 mm, through-hole and surface mount packages.[47] Typical current ratings range from around 1 mA to above 20 mA. LED's can be soldered to a flexible PCB strip to form LED tape popularly used for decoration.

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. Infrared devices may have a black tint to block visible light while passing infrared radiation, such as the Osram SFH 4546.[48]

5 V and 12 V LEDs are ordinary miniature LEDs that have a series resistor for direct connection to a 5 V or 12 V supply.[49]

High-power

[edit]



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

See also: Solid-state lighting, LED lamp, and Thermal management of high-power LEDs

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.[50][51] LED power densities up to 300 W/cm^2 have been achieved. 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.

Some 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 exceed 105 lm/W.[52]

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[52] and the Nichia 19 series with a typical efficacy of 140 lm/W, released in 2010.[53]

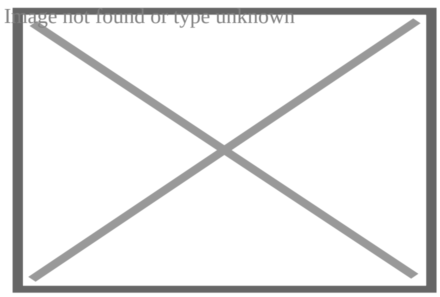
AC-driven

[edit]

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 efficiency of this type of HP-LED is typically 40 lm/W.[54] 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 '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.[55]

Strip

[edit]
This section is an excerpt from LED strip light.[edit]

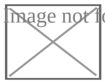


Several LED spots being reflected as continuous lighting strip

An LED strip, tape, or ribbon light is a flexible circuit board populated by surface-mount light-emitting diodes (SMD LEDs) and other components that usually comes with an adhesive backing. Traditionally, strip lights had been used solely in accent lighting, backlighting, task lighting, and decorative lighting applications, such as cove lighting. LED strip lights originated in the early 2000s. Since then, increased luminous efficacy and higher-power SMDs have allowed them to be used in applications such as high brightness task lighting, fluorescent and halogen lighting fixture replacements, indirect lighting applications, ultraviolet inspection during manufacturing processes, set and costume design, and growing plants.

Application-specific

[edit]



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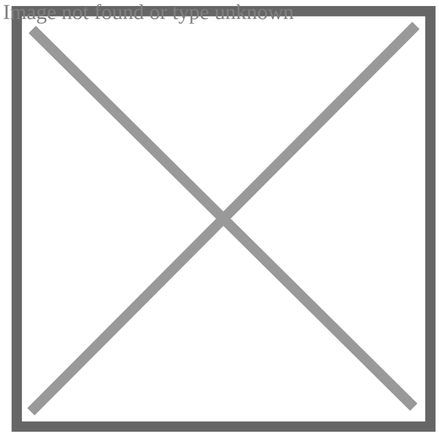
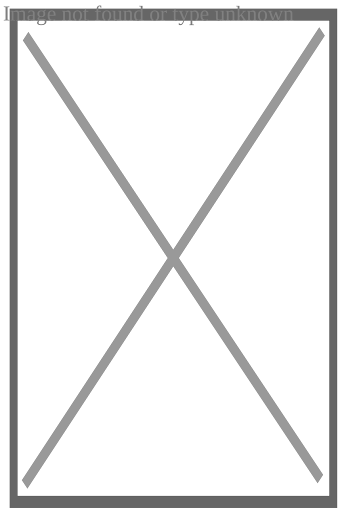
Find sources: "Light-emitting diode" – news · newspapers · books · scholar · JSTOR *(October 2020) (Learn how and when to remove this message)*



RGB-SMD-LED



Composite image of an 11 × 44 LED matrix lapel name tag display using 1608/0603-type SMD LEDs. Top: A little over half of the 21 × 86 mm display. Center: Close-up of LEDs in ambient light. Bottom: LEDs in their own red light.

Flashing

Flashing LEDs are used as attention seeking indicators without requiring external electronics. Flashing LEDs resemble standard LEDs but they contain an integrated voltage regulator and a 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. Flashing SMD LEDs in the 0805 and other size formats have been available since early 2019.

Flickering

Integrated electronics Simple electronic circuits integrated into the LED package have been around since at least 2011 which produce a random LED intensity pattern reminiscent of a flickering candle.[56] Reverse engineering in 2024 has suggested that some flickering LEDs with automatic sleep and wake modes might be using an integrated 8-bit microcontroller for such functionally.[57]

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. Others include amber/traditional green, red/pure green, red/blue, and blue/pure green.

RGB 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. Others have only two leads (positive and negative) and have a built-in electronic controller. RGB LEDs consist of one red, one green, and one blue LED.[58] By independently adjusting each of the three, RGB LEDs are capable of producing a wide color gamut. Unlike dedicated-color LEDs, these do not produce pure wavelengths. Modules may not be optimized for smooth color mixing.

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 5×7 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 addressable LEDs contain their own "smart" control electronics. In addition to power and ground, these provide connections for data-in, data-out, clock and sometimes a strobe signal. These are connected in a daisy chain, which allows individual LEDs in a long LED strip light to be easily controlled by a microcontroller. Data sent to the first LED of the chain 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. These devices are known by their part number (WS2812 being common) or a brand name such as NeoPixel.

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.[59] These are being used as a low-cost decorative alternative for traditional light bulbs that are being phased out in many countries. The filaments use a rather high voltage, allowing them to work efficiently 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.[60] Usually, they are packaged in bulb similar to the lamps they were designed to replace, and filled with inert gas at slightly lower than ambient pressure to remove heat efficiently and prevent corrosion.

Chip-on-board arrays

Surface-mounted LEDs are frequently produced in chip on board (COB) arrays, allowing better heat dissipation than with a single LED of comparable luminous output.[61] The LEDs can be arranged around a cylinder, and are called "corn cob lights" because of the rows of yellow LEDs.[62]

Considerations for use

[edit]

- Efficiency: LEDs emit more lumens per watt than incandescent light bulbs.[63] The efficiency of LED lighting fixtures is not affected by shape and size, unlike fluorescent light bulbs or tubes.
- Size: LEDs can be very small (smaller than 2 mm^2[64]) and are easily attached to printed circuit boards.

Power sources

[edit]

Main article: LED power sources

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Simple LED circuit with resistor for current limiting

The current in an LED or other diodes rises exponentially with the applied voltage (see Shockley diode equation), so a small change in voltage can cause a large change in current. Current through the LED must be regulated by an external circuit such as a constant current source to prevent damage. Since most common power supplies are (nearly) constant-voltage sources, LED fixtures must include a power converter, or at least a current-limiting resistor. In some applications, the internal resistance of small batteries is sufficient to keep current within the LED rating.[*citation needed*]

LEDs are sensitive to voltage. They 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).[65]

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.[66]

Electrical polarity

[edit]
Main article: Electrical polarity of LEDs

Unlike a traditional incandescent lamp, an LED will light only when voltage is applied in the forward direction of the diode. No current flows and no light is emitted if voltage is applied in the reverse direction. If the reverse voltage exceeds the breakdown voltage, which is typically about five volts, a large current flows and the LED will be damaged. If the reverse current is sufficiently limited to avoid damage, the reverse-conducting LED is a useful noise diode.[*citation needed*]

By definition, the energy band gap of any diode is higher when reverse-biased than when forward-biased. Because the band gap energy determines the wavelength of the light emitted, the color cannot be the same when reverse-biased. The reverse breakdown voltage is sufficiently high that the emitted wavelength cannot be similar enough to still be visible. Though dual-LED packages exist that contain a different color LED in each direction, it is not expected that any single LED element can emit visible light when reverse-biased.[*citation needed*]

It is not known if any zener diode could exist that emits light only in reverse-bias mode. Uniquely, this type of LED would conduct when connected backwards.

Appearance

[edit]

- 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.
- 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.
- 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 make the color of objects appear differently under cool-white LED illumination than sunlight or incandescent sources, due to metamerism,[67] red surfaces being rendered particularly poorly by typical phosphor-based cool-white LEDs. The same is true with green surfaces. The quality of color rendition of an LED is measured by the Color Rendering Index (CRI).
- Dimming: LEDs can be dimmed either by pulse-width modulation or lowering the forward current.[68] This pulse-width modulation is why LED lights, particularly headlights on cars, when viewed on camera or by some people, seem to flash or flicker. This is a type of stroboscopic effect.

Light properties

[edit]

- Switch on time: LEDs light up extremely quickly. A typical red indicator LED achieves full brightness in under a microsecond.[69] LEDs used in communications devices can have even faster response times.
- 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. When large quantities of light are needed, many light sources such as LED chips are usually deployed,

which are difficult to focus or collimate on the same target.

- 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. Different fields of light can be manipulated by the application of different optics or "lenses". LEDs cannot provide divergence below a few degrees.[70]

Reliability

[edit]

- Shock resistance: LEDs, being solid-state components, are difficult to damage with external shock, unlike fluorescent and incandescent bulbs, which are fragile.[71]
- Thermal runaway: Parallel strings of LEDs will not share current evenly due to the manufacturing tolerances in their forward voltage. Running two or more strings from a single current source may result in LED failure as the devices warm up. If forward voltage binning is not possible, a circuit is required to ensure even distribution of current between parallel strands.[72]
- Slow failure: LEDs mainly fail by dimming over time, rather than the abrupt failure of incandescent bulbs.[73]
- 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 shorter or longer.[74] Fluorescent tubes typically are rated at about 10,000 to 25,000 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.[75]
- 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 to warm up to full output and to cool down before they can be lighted again if they are being restarted.
- 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, and require low failure rates.

Manufacturing

[edit]

LED manufacturing involves multiple steps, including epitaxy, chip processing, chip separation, and packaging.[76]

In a typical LED manufacturing process, encapsulation is performed after probing, dicing, die transfer from wafer to package, and wire bonding or flip chip mounting,[77] perhaps using indium tin oxide, a transparent electrical conductor. In this case, the bond wire(s) are attached to the ITO film that has been deposited in the LEDs.

Flip chip circuit on board (COB) is a technique that can be used to manufacture LEDs.[78]

Colors and materials

[edit]

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 (V)	Semiconductor material
	Infrared	*?* > 760	?*V* < 1.9	Gallium arsenide (GaAs) Aluminium gallium arsenide (AlGaAs)
	Red	610 < *?* < 760	1.63 < ?*V* < 2.03	Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
	Orange	590 < *?* < 610	2.03 < ?*V* < 2.10	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
	Yellow	570 < *?* < 590	2.10 < ?*V* < 2.18	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)

	Green	500 < ? < 570	1.9[79] < ?V < 4.0	Indium gallium nitride (InGaN) / Gallium(III) nitride (GaN) Gallium(III) phosphide (GaP) Aluminium gallium indium phosphide (AlGaInP) Aluminium gallium phosphide (AlGaP)
	Blue	450 < ? < 500	2.48 < ?V < 3.7	Zinc selenide (ZnSe) Indium gallium nitride (InGaN) Silicon carbide (SiC) as substrate Silicon (Si) as substrate — (under development)
	Violet	400 < ? < 450	2.76 < ?V < 4.0	Indium gallium nitride (InGaN)
	Purple	multiple types	2.48 < ?V < 3.7	Dual blue/red LEDs, blue with red phosphor, or white with purple plastic
	Ultraviolet	? < 400	3.1 < ?V < 4.4	Diamond (235 nm)[80] Boron nitride (215 nm)[81][82] Aluminium nitride (AlN) (210 nm)[16] Aluminium gallium nitride (AlGaN) Aluminium gallium indium nitride (AlGaInN) — (down to 210 nm)[83]
	White	Broad spectrum	2.7 < ?V < 3.5	Blue diode with yellow phosphor or violet/UV diode with multi-color phosphor

Applications

[edit]

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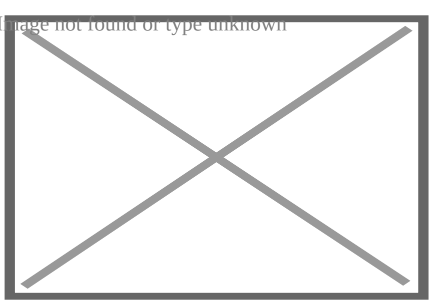

Daytime running light LEDs of an automobile

LED uses fall into five 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[84]
- Narrow band light sensors where LEDs operate in a reverse-bias mode and respond to incident light, instead of emitting light[85][86][87][88]
- Indoor cultivation, including cannabis.[89]

The application of LEDs in horticulture has revolutionized plant cultivation by providing energy-efficient, customizable lighting solutions that optimize plant growth and development.[90] LEDs offer precise control over light spectra, intensity, and photoperiods, enabling growers to tailor lighting conditions to the specific needs of different plant species and growth stages. This technology enhances photosynthesis, improves crop yields, and reduces energy costs compared to traditional lighting systems. Additionally, LEDs generate less heat, allowing closer placement to plants without risking thermal damage, and contribute to sustainable farming practices by lowering carbon footprints and extending growing seasons in controlled environments.[91] Light spectrum affects growth, metabolite profile, and resistance against fungal phytopathogens of *Solanum lycopersicum* seedlings.[92] LEDs can also be used in micropropagation.[93]

Indicators and signs

[edit]

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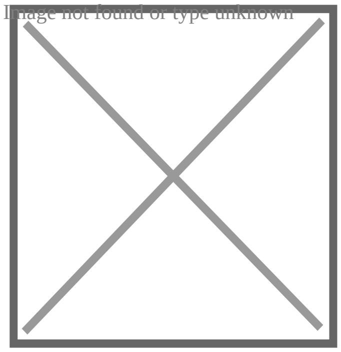
The low energy consumption, low maintenance and small size of LEDs has led to uses as status indicators and displays on a variety of equipment and installations. Large-area LED displays are used as stadium displays, dynamic decorative displays, and dynamic message signs on freeways. Thin, lightweight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



Red and green LED traffic signals

One-color light is well suited for traffic lights and signals, exit signs, emergency vehicle lighting, ships' navigation lights, and LED-based Christmas lights

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 automotive brake lights and turn signals. The use in brakes improves safety, due to a great reduction in the time needed to light fully, or faster rise time, about 0.1 second faster[*citation needed*] 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.

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

Lighting

[edit]
Main article: LED lamp

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, in 2008 the US Department of Energy 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.[94]

Efficient lighting is needed for sustainable architecture. As of 2011, some LED bulbs provide up to 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 lower heat output of LEDs also reduces demand on air conditioning systems. Worldwide, LEDs are rapidly adopted to displace less effective sources such as incandescent lamps and CFLs and reduce electrical energy consumption and its associated emissions. Solar powered LEDs are used as street lights and in architectural lighting.

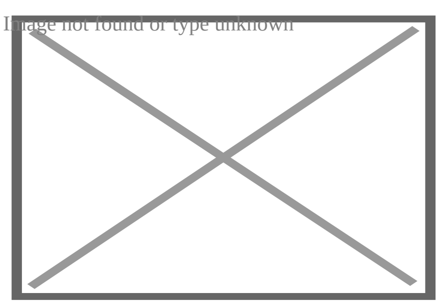
The mechanical robustness and long lifetime are used in automotive lighting on cars, motorcycles, and bicycle lights. LED street lights are employed on poles and in parking garages. In 2007, the Italian village of Torraca was the first place to convert its street lighting to LEDs.[95]

Cabin lighting on recent[*when?*] Airbus and Boeing jetliners uses LED lighting. LEDs are also being used 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.

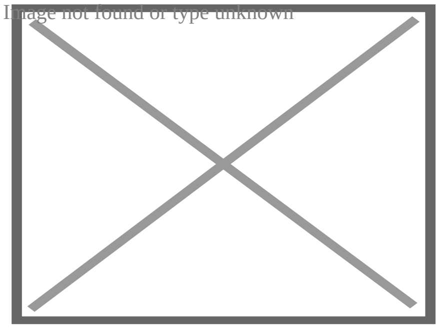
LEDs are also used as a light source for DLP projectors, and to backlight newer LCD television (referred to as LED TV), computer monitor (including laptop) and handheld device LCDs, succeeding older CCFL-backlit LCDs although being superseded by OLED screens. RGB LEDs raise the color gamut by as much as 45%. Screens for TV and computer displays can be made thinner using LEDs for backlighting.[96]

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.



LED for miners, to increase visibility inside mines



Los Angeles Vincent Thomas Bridge illuminated with blue LEDs

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.[97]

LEDs are increasingly finding uses in medical and educational applications, for example as mood enhancement.[98] NASA has even sponsored research for the use of LEDs to promote health for astronauts.[99]

Data communication and other signalling

[edit]
See also: Li-Fi, fibre optics, Visible light communication, and Optical disc

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.[100]

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.[101] For that reason, visible light communication (VLC) has been proposed as an alternative to the increasingly competitive radio bandwidth.[102] VLC operates in the visible part of the electromagnetic spectrum, so data can be transmitted without occupying the frequencies of radio communications.

Machine vision systems

[edit]
Main article: Machine vision

Machine vision systems often require bright and homogeneous illumination, so features of interest are easier to process. LEDs are often used.

Barcode scanners are the most common example of machine vision applications, and many of those scanners use red LEDs instead of lasers. Optical computer mice use LEDs as a light source for the miniature camera within the mouse.

LEDs are useful for machine vision because they provide a compact, reliable source of light. LED lamps can be turned on and off to suit the needs of the vision system, and the shape of the beam produced can be tailored to match the system's requirements.

Biological detection

[edit]

The discovery of radiative recombination in aluminum gallium nitride (AlGaN) alloys by U.S. Army Research Laboratory (ARL) led to the conceptualization of UV light-emitting diodes (LEDs) to be incorporated in light-induced fluorescence sensors used for biological agent detection.[103][104][105] In 2004, the Edgewood Chemical Biological Center (ECBC) initiated the effort to create a biological detector named TAC-BIO. The program capitalized on semiconductor UV optical sources (SUVOS) developed by the Defense Advanced Research Projects Agency (DARPA).[105]

UV-induced fluorescence is one of the most robust techniques used for rapid real-time detection of biological aerosols.[105] The first UV sensors were lasers lacking in-field-use practicality. In order to address this, DARPA incorporated SUVOS technology to create a low-cost, small, lightweight, low-power device. The TAC-BIO detector's response time was one minute from when it sensed a biological agent. It was also demonstrated that the detector could be operated unattended indoors and outdoors for weeks at a time.[105]

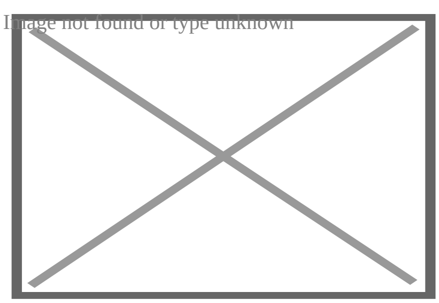
Aerosolized biological particles fluoresce and scatter light under a UV light beam. Observed fluorescence is dependent on the applied wavelength and the biochemical fluorophores within the biological agent. UV induced fluorescence offers a rapid, accurate, efficient and logistically practical way for biological agent detection. This is because the use of UV fluorescence is reagentless, or a process that does not require an added chemical to produce a reaction, with no consumables, or produces no chemical byproducts.[105]

Additionally, TAC-BIO can reliably discriminate between threat and non-threat aerosols. It was claimed to be sensitive enough to detect low concentrations, but not so sensitive that it would cause false positives. The particle-counting algorithm used in the device converted raw data into information by counting the photon pulses per unit of time from the fluorescence and scattering detectors, and comparing the value to a set threshold.[106]

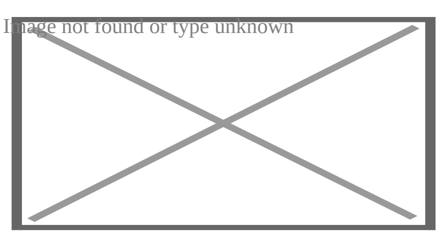
The original TAC-BIO was introduced in 2010, while the second-generation TAC-BIO GEN II, was designed in 2015 to be more cost-efficient, as plastic parts were used. Its small, light-weight design allows it to be mounted to vehicles, robots, and unmanned aerial vehicles. The second-generation device could also be utilized as an environmental detector to monitor air quality in hospitals, airplanes, or even in households to detect fungus and mold.[107][108]

Other applications

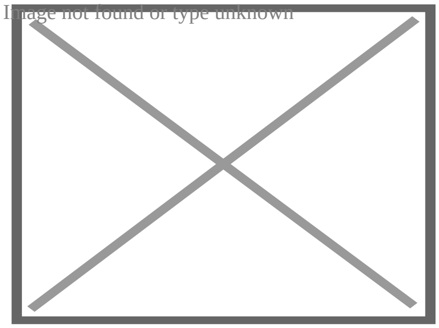
[edit]



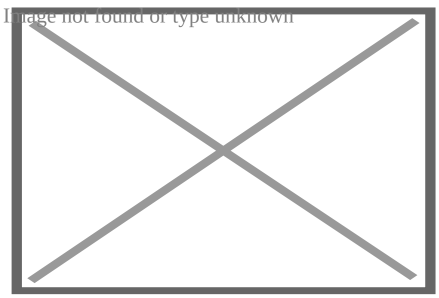
LED costume for stage performers



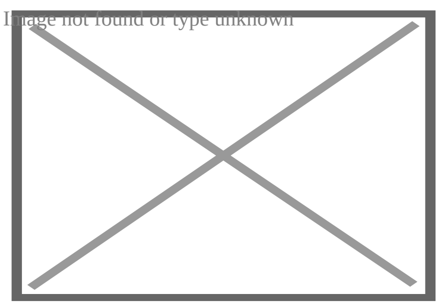
LED wallpaper by Meystyle



A large LED display behind a disc jockey



Seven-segment display that can display four digits and points



LED panel light source used in an early experiment on potato growth during Shuttle mission STS-73 to investigate the potential for growing food on future long duration missions

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 television sets, 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 do not share a common ground potential.

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. 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.[109] Many materials and biological systems are sensitive to, or dependent on, light. Grow lights use LEDs to increase photosynthesis in plants,[110] and bacteria and viruses can be removed from water and other substances using UV LEDs for sterilization.[15] LEDs of certain wavelengths have also been used for light therapy treatment of neonatal jaundice and acne.[111]

UV LEDs, with spectra range of 220 nm to 395 nm, have other applications, such as water/air purification, surface disinfection, glue curing, free-space non-line-of-sight communication, high performance liquid chromatography, UV curing dye printing, phototherapy (295nm Vitamin D, 308nm Excimer lamp or laser replacement), medical/ analytical instrumentation, and DNA absorption.[104][112]

LEDs have also been used as a medium-quality voltage reference in electronic circuits. The forward voltage drop (about 1.7 V for a red LED or 1.2V for an infrared) 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 in the form of LED wallpaper.

Research and development

[edit]

Key challenges

[edit]

LEDs require optimized efficiency to hinge on ongoing improvements such as phosphor materials and quantum dots.[113]

The process of down-conversion (the method by which materials convert more-energetic photons to different, less energetic colors) also needs improvement. For example, the red phosphors that are used today are thermally sensitive and need to be improved in that aspect so that they do not color shift and experience efficiency drop-off with temperature. Red phosphors could also benefit from a narrower spectral width to emit more lumens and becoming more efficient at converting photons.[114]

In addition, work remains to be done in the realms of current efficiency droop, color shift, system reliability, light distribution, dimming, thermal management, and power supply performance.[113]

Early suspicions were that the LED droop was caused by elevated temperatures. Scientists showed that temperature was not the root cause of efficiency droop.[115] The mechanism causing efficiency droop was identified in 2007 as Auger recombination, which was taken with mixed reaction.[66] A 2013 study conclusively identified Auger recombination as the cause.[116]

Potential technology

[edit]

A new family of LEDs are based on the semiconductors called perovskites. In 2018, less than four years after their discovery, the ability of perovskite LEDs (PLEDs) to produce light from electrons already rivaled those of the best performing OLEDs.[117] They have a potential for cost-effectiveness as they can be processed from solution, a low-cost and low-tech method, which might allow perovskite-based devices that have large areas to be made with extremely low cost. Their efficiency is superior by eliminating non-radiative losses, in other words, elimination of recombination pathways that do not produce photons; or by solving outcoupling problem (prevalent for thin-film LEDs) or balancing charge carrier injection to increase the EQE (external quantum efficiency). The most up-to-date PLED devices have broken the performance barrier by shooting the EQE above 20%.[118]

In 2018, Cao et al. and Lin et al. independently published two papers on developing perovskite LEDs with EQE greater than 20%, which made these two papers a mile-stone in PLED development. Their device have similar planar structure, i.e. the active layer (perovskite) is sandwiched between two electrodes. To achieve a high EQE, they not only reduced non-radiative recombination, but also utilized their own, subtly different methods to improve the EQE.[118]

In the work of Cao *et al.*,[119] researchers targeted the outcoupling problem, which is that the optical physics of thin-film LEDs causes the majority of light generated by the semiconductor to be trapped in the device.[120] To achieve this goal, they demonstrated that solution-processed perovskites can spontaneously form submicrometre-scale crystal platelets, which can efficiently extract light from the device. These perovskites are formed via the introduction of amino acid additives into the perovskite precursor solutions. In addition, their method is able to passivate perovskite surface defects and reduce nonradiative recombination. Therefore, by improving the light outcoupling and reducing nonradiative losses, Cao and his colleagues successfully achieved PLED with EQE up to 20.7%.[119]

Lin and his colleague used a different approach to generate high EQE. Instead of modifying the microstructure of perovskite layer, they chose to adopt a new strategy for managing the compositional distribution in the device—an approach that simultaneously provides high luminescence and balanced charge injection. In other words, they still used flat emissive layer, but tried to optimize the balance of electrons and holes injected into the perovskite, so as to make the most efficient use of the charge carriers. Moreover, in the perovskite layer, the crystals are perfectly enclosed by MABr additive (where MA is CH_3NH_3). The MABr shell passivates the nonradiative defects that would otherwise be present perovskite crystals, resulting in reduction of the nonradiative recombination. Therefore, by balancing charge injection and decreasing nonradiative losses, Lin and his colleagues developed PLED with EQE up to 20.3%.[121]

Health and safety

[edit]

Certain blue LEDs and cool-white LEDs can exceed 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".[122] One study showed no evidence of a risk in normal use at domestic illuminance,[123] and that caution is only needed for particular occupational situations or for specific populations.[124] In 2006, the International Electrotechnical Commission published *IEC 62471 Photobiological safety of lamps and lamp systems*, replacing the application of early laser-oriented standards for classification of LED sources.[125]

While LEDs have the advantage over fluorescent lamps, in that they do not contain mercury, they may contain other hazardous metals such as lead and arsenic.[126]

In 2016 the American Medical Association (AMA) issued a statement concerning the possible adverse influence of blueish street lighting on the sleep-wake cycle of city-dwellers. Critics in the industry claim exposure levels are not high enough to have a noticeable effect.[127]

Environmental issues

[edit]

- Light pollution: Because white LEDs emit more short wavelength light than 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.[55]
- Impact on wildlife: 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.[128][129] LED lighting near beaches, particularly intense blue and white colors, can disorient turtle hatchlings and make them wander inland instead.[130] The use of "turtle-safe lighting" LEDs that emit only at narrow portions of the visible spectrum is encouraged by conservancy groups in order to reduce harm.[131]
- 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.[132][133]

See also

[edit]

- icon Image not found or type unknown Electronics portal
- icon Image not found or type unknown Energy portal
- LED tattoo
- High-CRI LED lighting
- List of light sources
- MicroLED
- Superluminescent diode
- Perovskite light-emitting diode

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- Building a do-it-yourself LED
- Color cycling LED in a single two pin package,
- Educational video on LEDs on YouTube

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Lighting

Concepts	○ Accent lighting
	○ Color rendering index
	○ Color temperature
	○ Electric light
	○ Glare
	○ Light fixture
	○ Light pollution
	    ○ Hawaii
	    ○ Hong Kong
	○ Lightbulb socket
	    ○ Bi-pin lamp base
	    ○ Edison screw
	○ Luminous efficacy
	○ Task lighting

Methods of generation

- Incandescent
  - Regular
  - Edison
  - Halogen
  - Nernst
- Luminescent
  - Cathodoluminescent
    - Electron-stimulated
  - Chemiluminescent
  - Electrochemiluminescence
  - Electroluminescent
    - field-induced polymer
  - Fluorescent
    - Fluorescent lamp (compact)
    - Fluorescent induction
  - Photoluminescent
    - Laser headlamp
  - Radioluminescence
  - Solid-state
    - LED lamp
- Combustion
  - Acetylene/Carbide
  - Argand
  - Campfire
  - Candle
  - Carcel
  - Diya
  - Flare
  - Gas
  - Kerosene
    - Petromax
  - Lantern
    - Fanous
    - Paper
  - Limelight
  - Luchina
  - Magnesium torch
  - Oil
    - Qulliq
  - Rushlight
  - Safety
  - Tilley
  - Torch
- Electric arc
  - Carbon arc
  - Klieg light
  - Yablochkov candle
- Gas discharge
  - Deuterium arc
  - Neon
    - Neon lamp
  - Plasma
    - Sulfur

Stationary	◦ Reflector
	    ◦ Ellipsoidal reflector
	    ◦ Multifaceted reflector
	    ◦ Parabolic aluminized reflector (PAR)
	◦ Aviation obstruction
	◦ Balanced-arm lamp
	◦ Chandelier
	◦ Emergency light
	◦ Gas lighting
	◦ Gooseneck lamp
	◦ Intelligent street lighting
	◦ Light tube
	◦ Nightlight
	◦ Neon lighting
	◦ Pendant light
	◦ Recessed light
	◦ Sconce
	◦ Street light
	    ◦ in the US
	◦ Torchère
	◦ Track lighting
	◦ Troffer

Portable	◦ Bicycle lighting
	◦ Flashlight
	    ◦ Mechanically powered
	    ◦ Tactical
	◦ Glow stick
	◦ Headlamp
	    ◦ outdoor
	◦ Lantern
	◦ Laser pointer
	◦ Navigation light
	◦ Searchlight
	◦ Solar lamp

Automotive	○ Automotive light bulb types
	○ Daytime running lamp
	○ Headlamp
	    ○ hidden
	    ○ high-intensity discharge
	    ○ sealed beam
	○ Rear position lights
	○ Reversing lights
	○ Safety reflector
	    ○ retroreflector
	○ Stop lights
	○ Turn signals
	    ○ trafficators

○ **Display** ○ **Decorative**	○ Aroma lamp ○ Blacklight ○ Bubble light ○ Christmas lights ○ Crackle tube ○ DJ lighting ○ Electroluminescent wire ○ Lava lamp ○ Marquee ○ Plasma globe ○ Strobe light
○ **Theatrical** ○ **Cinematic**	○ Floodlight ○ Footlight ○ Gobo ○ Scoop ○ Spotlight ○ ellipsoidal reflector ○ Stage lighting instrument
○ **Industrial** ○ **Scientific**	○ Germicidal ○ Grow light ○ Infrared lamp ○ Stroboscope ○ Tanning
Related topics	○ Battlefield illumination ○ Bioluminescence ○ Laser ○ Light art ○ Luminous gemstones ○ Signal lamp ○ Sources ○ Reflected

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Display technology

Video displays	**Past generation**	◦ Eidophor ◦ Cathode-ray tube (CRT) ◦ Jumbotron ◦ Electroluminescent display (ELD) ◦ Rear-projection display ◦ Plasma display panel (PDP) ◦ ALiS

	Current generation	◦ Quantum dot display (QLED)
		◦ Electronic paper
		    ◦ E Ink
		    ◦ Gyricon
		◦ Light-emitting diode display (LED)
		    ◦ Organic light-emitting diode (OLED)
		        ◦ Active-Matrix Organic light-emitting diode (AMOLED)
		◦ Liquid-crystal display (LCD)
		    ◦ TFT
		        ◦ TN
		        ◦ IPS
		    ◦ LED-backlit
		    ◦ Blue Phase
		◦ Digital Light Processing (DLP)
		◦ Liquid crystal on silicon (LCoS)

	Next generation	◦ microLED
		◦ Electroluminescent Quantum Dots (ELQD/QD-LED)
		◦ Organic light-emitting transistor (OLET)
		◦ Surface-conduction electron-emitter display (SED)
		◦ Field-emission display (FED)
		◦ Laser TV
		    ◦ Quantum dot
		    ◦ Liquid crystal
		◦ MEMS display
		    ◦ IMoD
		    ◦ TMOS
		◦ Ferroelectric liquid crystal display (FLCD)
		◦ Thick-film dielectric electroluminescent technology (TDEL)
		◦ Laser-powered phosphor display (LPD)

Non-video	◦ Electromechanical
	  ◦ Flip-dot
	  ◦ Split-flap
	◦ Eggcrate
	◦ Fiber-optic
	◦ Nixie tube
	◦ Vacuum fluorescent display (VFD)
	◦ Light-emitting electrochemical cell (LEC)
	◦ Lightguide display
	◦ Dot-matrix display
	◦ Seven-segment display (SSD)
	◦ Eight-segment display
	◦ Nine-segment display
	◦ Fourteen-segment display (FSD)
	◦ Sixteen-segment display (SISD)

3D display	◦ Stereoscopic
	◦ Autostereoscopic
	◦ Multiscopic
	◦ Hologram
	  ◦ Holographic display
	  ◦ Computer-generated holography
	◦ Volumetric
	◦ Fog display

Static media	◦ Monoscope ◦ Movie projector ◦ Neon sign ◦ Slide projector ◦ Transparency ◦ Laser beam
Display capabilities	◦ EDID ◦ CEA-861 ◦ DisplayID ◦ Always-on display ◦ See-through display
Related articles	◦ Scan line ◦ History of display technology ◦ Large-screen television technology ◦ Optimum HDTV viewing distance ◦ High Dynamic Range (HDR) ◦ Color Light Output ◦ Flexible display ◦ Comparison of CRT, LCD, plasma, and OLED displays

Comparison of display technology

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Electronic components

Semiconductor devices

MOS transistors

- Transistor
- NMOS
- PMOS
- BiCMOS
- BioFET
- Chemical field-effect transistor (ChemFET)
- Complementary MOS (CMOS)
- Depletion-load NMOS
- Fin field-effect transistor (FinFET)
- Floating-gate MOSFET (FGMOS)
- Insulated-gate bipolar transistor (IGBT)
- ISFET
- LDMOS
- MOS field-effect transistor (MOSFET)
- Multi-gate field-effect transistor (MuGFET)
- Power MOSFET
- Thin-film transistor (TFT)
- VMOS
- UMOS

Other transistors

- Bipolar junction transistor (BJT)
- Darlington transistor
- Diffused junction transistor
- Field-effect transistor (FET)
  - Junction Gate FET (JFET)
  - Organic FET (OFET)
- Light-emitting transistor (LET)
  - Organic LET (OLET)
- Pentode transistor
- Point-contact transistor
- Programmable unijunction transistor (PUT)
- Static induction transistor (SIT)
- Tetrode transistor
- Unijunction transistor (UJT)

Diodes

- Avalanche diode
- Constant-current diode (CLD, CRD)
- Gunn diode
- Laser diode (LD)
- Light-emitting diode (LED)
- Organic light-emitting diode (OLED)
- Photodiode
- PIN diode
- Schottky diode
- Step recovery diode
- Zener diode

- Printed electronics
- Printed circuit board
- DIAC
- Heterostructure barrier varactor

Voltage regulators

- Linear regulator
- Low-dropout regulator
- Switching regulator
- Buck
- Boost
- Buck–boost
- Split-pi
- ÃƒÆ’Ã†â€™Ãƒâ€ Ã¢â‚¬â„¢ÃƒÆ’Ã‚Â¢ÃƒÂ¢Ã¢â‚¬Å¡Ã‚Â¬Ãƒâ€¦Ã‚Â¾ÃƒÆ
- SEPIC
- Charge pump
- Switched capacitor

Vacuum tubes

- Acorn tube
- Audion
- Beam tetrode
- Barretter
- Compactron
- Diode
- Fleming valve
- Neutron tube
- Nonode
- Nuvistor
- Pentagrid (Hexode, Heptode, Octode)
- Pentode
- Photomultiplier
- Phototube
- Tetrode
- Triode

Vacuum tubes (RF)

- Backward-wave oscillator (BWO)
- Cavity magnetron
- Crossed-field amplifier (CFA)
- Gyrotron
- Inductive output tube (IOT)
- Klystron
- Maser
- Sutton tube
- Traveling-wave tube (TWT)
- X-ray tube

Cathode-ray tubes	○ Beam deflection tube ○ Charactron ○ Iconoscope ○ Magic eye tube ○ Monoscope ○ Selectron tube ○ Storage tube ○ Trochotron ○ Video camera tube ○ Williams tube
Gas-filled tubes	○ Cold cathode ○ Crossatron ○ Dekatron ○ Ignitron ○ Krytron ○ Mercury-arc valve ○ Neon lamp ○ Nixie tube ○ Thyratron ○ Trigatron ○ Voltage-regulator tube
Adjustable	○ Potentiometer ○ digital ○ Variable capacitor ○ Varicap

Passive	○ Connector
	    ○ audio and video
	    ○ electrical power
	    ○ RF
	○ Electrolytic detector
	○ Ferrite
	○ Antifuse
	○ Fuse
	    ○ resettable
	    ○ eFUSE
	○ Resistor
	○ Switch
	○ Thermistor
	○ Transformer
	○ Varistor
	○ Wire
	    ○ Wollaston wire

Reactive

- Capacitor
  - types
- Ceramic resonator
- Crystal oscillator
- Inductor
- Parametron
- Relay
  - reed relay
  - mercury relay

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About Overhead Door Company of Joliet

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Illinois State Museum-Lockport Gallery

4.7 (105)

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Gemini Giant

3.5 (27)

Photo

Lincoln Landing

4.6 (134)

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Joliet Iron Works Park

4.6 (148)

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Lake Renwick Heron Rookery Nature Preserve

4.6 (87)

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Knoch Knolls Nature Center

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Isle A La Cache Museum Pavilion

5 (1)

Driving Directions in Will County

Driving Directions From Al's Steak House Restaurant to Overhead Door Company of Joliet

Driving Directions From Chillin' Products to Overhead Door Company of Joliet

Driving Directions From Joliet West High School to Overhead Door Company of Joliet

Driving Directions From The Haley Mansion to Overhead Door Company of Joliet

Driving Directions From Honorable Edward A Burmila Jr to Overhead Door Company of Joliet

Driving Directions From Rockdale to Overhead Door Company of Joliet

Driving Directions From Will County Sheriff Department to Overhead Door Company of Joliet

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Driving Directions From Joliet Iron Works Park to Overhead Door Company of Joliet

Driving Directions From Knoch Knolls Nature Center to Overhead Door Company of Joliet

Driving Directions From Lincoln Landing to Overhead Door Company of Joliet

Driving Directions From Joliet Iron Works Historic Site to Overhead Door Company of Joliet

Driving Directions From Fox Museum to Overhead Door Company of Joliet

Driving Directions From Illinois State Museum-Lockport Gallery to Overhead Door Company of Joliet

Driving Directions From Isle A La Cache Museum Pavilion to Overhead Door Company of Joliet

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Reviews for Overhead Door Company of Joliet

Overhead Door Company of Joliet

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Hector Melero

(5)

Had a really great experience with Middleton Overhead Doors. My door started to bow and after several attempts on me fixing it I just couldn’t get it. I didn’t want to pay on something I knew I could fix. Well, I gave up and they came out and made it look easy. I know what they are doing not to mention they called me before hand to confirm my appointment and they showed up at there scheduled appointment. I highly recommend Middleton Overhead Doors on any work that needs to be done

Overhead Door Company of Joliet

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Owen McCarthy

(5)

I called the office just by chance to see if there was an available opening for a service call to repair a busted spring. Unfortunately I didn’t catch the name of the person who answere, but she couldn’t have been more pleasant and polite. She was able to get a tech to my house in an hour. I believe the tech’s name was Mike and he too was amazing. He quickly resolved my issue and even corrected a couple of things that he saw that weren’t quite right. I would recommend to anyone and will definitely call on Middleton for any future needs. Thank you all for your great service.

Overhead Door Company of Joliet

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Kelley Jansa

(5)

We used Middleton Door to upgrade our garage door. We had three different companies come out to quote the job and across the board Middleton was better. They were professional, had plenty of different options and priced appropriately. The door we ordered came with a small dent and they handled getting a new panel ordered and reinstalled very quickly.

Overhead Door Company of Joliet

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Andrea Nitsche

(4)

Scheduling was easy, job was done quickly. Little disappointed that they gave me a quote over email (which they confirmed was for labor and materials), but when they finished it was just over $30 more. Not a huge deal, but when I asked why, I was told they gave me an approx cost and it depends on what is needed. I get that in general, however, they installed the door and I gave them my address and pics of the existing prior to getting a quote. I feel like they could have been more upfront with pricing. And just a heads up, it was pricey... Had them change the weather stripping, from ringing my doorbell to pulling out my driveway when done was literally 20 mins, cost was just over $260 ?

Overhead Door Company of Joliet

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Jim Chuporak

(5)

Received a notice the morning of telling me when to expect the men to come and put the door in. he was on time, answered all my questions, worked diligently in the cold. And did an absolutely awesome job. Everything was cleaned up, hauled away from the old door. I am extremely happy with the service I received from the first phone call I made through having the door put in. My wife and I are very, very happy with the door.

Suggesting Questions to Ask About Pricing Structures**View GBP**

Frequently Asked Questions

What factors influence the overall cost of garage door installation?

The cost is influenced by several factors, including the type and material of the door (e.g., steel, wood, aluminum), size and custom features, labor costs, removal of old doors if needed, and any additional accessories like openers or insulation.

Are there any hidden fees or additional charges I should be aware of?

Typically, costs can include delivery fees, disposal fees for old doors, permits if required by local regulations, and sales tax. Its important to ask your installer for a detailed quote that outlines all possible charges.

Do you offer any discounts or financing options for garage door installation?

Many companies offer seasonal promotions or discounts for first-time customers. Additionally, some provide financing options to help spread out payments over time. Its advisable to inquire directly with the company about current deals or payment plans available.

Overhead Door Company of Joliet

Phone : +18157256077

City : Joliet

State : IL

Zip : 60436

Address : Unknown Address

Google Business Profile

Company Website : **https://overheaddoorjoliet.com/garage-door-repair-romeoville.aspx**