Li-Fi: Quantum Dots for LCD Screens
New Business Models for LED Adoption
A Brighter Solution to High-speed Internet Access
Mentor Embedded support other tool chains like Keil, IAR and developers to use the full capability. We also got a free Code Composer Studio Integrated Community,” Folkens said. “Along with this, you monitor the Engineering-to-Engineering (or E2E) as assembled an online support team to cloud-based applications. “We have are well equipped to begin creating user guides, and ample online support comes complete with quick start and other Ethernet-ready kits. The LaunchPad $19.99 USD, it is less than half the price of is shipping now and the price is right; at The Tiva C Series Connected LaunchPad you are across the globe,” Folkens explained. “Remotely with this product and a user even if it is basically showing how you can interact a serial port from a terminal while someone supports a basic game by enabling someone to active and plugged-in to Exosite. “In addition, it other connected LaunchPad owners if they are the assigned IP address and display a map of all approximate geographic location based on reported temperature as well. It can also display and off remotely from the website and see the Internet and do things like turn an LED on and you can immediately interact with it across the globe. “We have the expansion of ingenious IoT applications in those ideas launched into the cloud.” As Folkens concluded, “The target audience actually are the hobbyists, students and professional engineers. A better way of looking at it is that we are targeting people with innovative ideas and trying to help them get the cloud.”
GreenPeak Launches Next-generation Wireless LED Lighting Solution

GreenPeak Technologies, the industry-leading low-power RF semiconductor company for Smart Home and IoT applications, has launched its wireless LED lighting solution, a low-cost ambient lighting application based on the new GreenPeak GP651 communication chip that can support various ZigBee and IEEE 802.15.4 communication protocols.

GreenPeak’s wireless LED lighting solution can combine LED lights with smart ambient applications, giving residents the creative freedom to create lighting scenes that match mood and function. The solution supports 1-, 2- or 4-channel LED bulbs, allowing bulb manufacturers to build products which will give residents the ability to dim a bright LED bulb into warm white or to create a more vivid colorful scene. Settings and time schedules can be controlled by a Smart Home system, a smartphone or even a basic wireless switch.

Controlling your home with a wireless LED lighting solution makes it smarter, more secure, more comfortable and even more fun. Lights can intensify gradually when waking up or can gracefully dim in the evenings. Light can be bright at the dining table when working from home and can be switched to a more relaxed and cozy atmosphere during dinner. The wireless LED lighting solution will help support the body’s biorhythm and help to focus on work, study and reading. For security, while on vacation, the system can switch lights on and off, giving the impression of residents being home while nobody is there.

Controlled LED lighting market into a new era of mass adoption.

GreenPeak’s wireless LED lighting solution is built on the GP651 chip, supporting the IEEE 802.15.4 ZigBee wireless communication standards. “The GP651 chip enables the support of multiple protocols making it a future-proof and protocol-agnostic solution,” says Cees Links, founder and CEO of GreenPeak Technologies.

"GreenPeak’s wireless LED lighting solution will seamlessly fit existing Smart Home systems, originating from different sources. The GP651 silicon, in combination with our partner’s LED driver that controls the power, will allow the LED light bulb manufacturers to produce light bulbs at very low cost, which will move the controlled LED lighting market into a new era of mass adoption.”

The GP651 is a low-cost, small footprint (QFN32), single chip solution. Additional cost savings can be achieved because of its 125°C (257°F) spec, reducing the size of a heat sink, enabling a compact and creative product design, and reducing the complexity of manufacturing resulting in a low total BOM.
Break the LED Adoption Logjam

How New Business Models Can Increase LED Installations

Shifts in technology and society have changed customer behavior, leading to an on-demand culture where convenience and instant access to information have blurred the lines between digital and brick-and-mortar retail. Advances in technology have also led to the upending of long-established business models, ranging from Uber and Lyft in the taxi industry to Teladoc and TouchCare in telemedicine, and Tesla and TrueCar in automotive retailing to VRBO and Airbnb in vacation and room rentals.

All of these shifts have an underlying theme—a new business model is as important as the product or service in accelerating adoption and customer acceptance.
At the same time, the avalanche of new technologies, marketing models and sales strategies is overwhelming many companies’ abilities to review and assess, let alone implement, potentially beneficial options. So, how does a technology pioneer break through this noise, and gain traction for accelerated adoption?

Some of the disruptions in technology, marketing and sales have caused, not unexpectedly, resistance from well-entrenched players who have been using traditional models for decades. The challenge of new business models is more pronounced in markets where current distribution needs to be supplemented with a creative approach designed to reach currently unserved customers. So how do companies move beyond existing models without alienating traditional partners?

The lighting market has reached this exact crossroads. LED technology’s performance, reliability and viability has been proven to be far superior to traditional light sources, but while LED lighting has made inroads (more than quadrupling installations from 2012 to 2014), overall adoption remains at a paltry 3 percent. Achieving 100 percent adoption requires the use of inventive models that challenge and expand how lighting is sold and deployed today, especially since the bulk of the market is adopting at an even slower rate—upgrades. The upgrade market is fragmented and riddled with complexities, and most customers are not even thinking about new lighting as a potential investment, even though the returns are attractive. For example, by implementing a lighting service agreement (LSA), LED lighting as a service can often produce positive cash flow. Yet, due to many complexities, organizations are missing out on the undeniable benefits that LED can bring their bottom line.

Cree set out to tackle this problem head on. We took the first step by building our brand via reaching the consumer and motivating the industry with a better light bulb. And now, we are redefining the commercial category with Cree Solutions, offering lighting as a turn-key service, i.e., a comprehensive solution rather than a product alone, in order to activate a dormant market segment.

Cree Solutions has established a comprehensive team, including external firms, with the ability to simplify the lighting supply chain to facilitate quicker

**“THE UPGRADE MARKET IS FRAGMENTED AND RIDDLED WITH COMPLEXITIES, AND MOST CUSTOMERS ARE NOT EVEN THINKING ABOUT NEW LIGHTING AS A POTENTIAL INVESTMENT, EVEN THOUGH THE RETURNS ARE ATTRACTIVE.”**
and wider adoption of LED lighting. It expands the channel with turnkey solutions, from assessment of lighting needs to project design and management to engineering, financing, installation and the assignment of utility rebates. Thermo Fisher Scientific, in Asheville, N.C. recently became the latest global organization to adopt this new model.

Impacts of this new solutions model going forward include:

- **LED becomes truly accessible for all applications:** With Solutions, we are creating an opportunity for LED lighting that did not exist before. We are giving customers who face complex lighting challenges, need a comprehensive design offering, or are looking for an all-in solution that includes financing, access to the full power and benefits of Cree LED Lighting.

- **Balance sheet options:** A lighting service agreement (LSA) is characterized as a services agreement for accounting purposes—not a "lease" but still off the balance sheet. Fiscally, this means that lighting as a service can deliver positive cash flow from inception and become an operational expense, rather than a capital expense, avoiding the often lengthy and competitive capital approval process.

- **LED Lighting delivers broader business benefits, not just a replacement for bad lighting:** Many business leaders aren’t thinking about their lighting, nor are they shopping for new lights. Cree designed a program approach that overcomes this barrier by connecting lighting to critical business objectives ranging from sustainability and carbon footprint goals to cost reduction and operational targets. With Cree managing and delivering projects from start to finish, businesses can focus on their business, not their lighting.

With this solutions approach, our distributors are able to grow and expand their business by catering to the needs of the customers they have always served while Cree directly addresses an unserved market segment. The collaboration of both new and traditional models will help drive increased LED lighting adoption.
Maximizing LCD COLOR Performance with Quantum Dot Integration

With quantum dots, LCD screens finally have the capability to rival OLED products

By Nigel Pickett, CTO, and Steve Reinhard, Vice President of Business Development, Nanoco
www.nanocotechnologies.com

Quantum dots have quickly become the next big advancement in the display industry, with a growing number of electronic display manufacturers incorporating these brilliant tiny semiconductors into their backlight unit (BLU), offering improved color purity compared to conventional phosphor-based light-emitting diode (LED) backlit liquid crystal displays (LCDs). The excitement is driven by quantum dots’ unique ability to efficiently absorb and convert light, typically that of a blue LED, into very specific reds and greens—offering more beautiful, vibrant and true-to-life color performance than traditional LCD technology.
With quantum dots, LCD screens finally have the capability to rival OLED products. Quantum dots also present an easy solution for display manufacturers to integrate into their products. Unlike OLED, which requires a complete and expensive overhaul of a production line, quantum dots take advantage of the existing LCD infrastructure, helping manufacturers bring innovative new technologies to consumers without exceptional expense or complexity.

Furthermore, the flexible nature of quantum dot technology (as these particles are easily tunable simply by changing their size) is applicable to all sizes of displays—from large HDTVs to smaller devices like tablets and mobile phones.

Overcoming the Traditional Color Triangle Dilemma

Reds and greens have traditionally been difficult to mimic on displays due to color gamut constraints, which limit saturation levels. A wider color gamut gives manufacturers the ability to better match color according to how the eye sees it, so images on screen appear more real.

Today, the average gamut is about 72% of the DCI-P3 color triangle—meaning red more often looks closer to orange. At 100% gamut, viewers enjoy a true, precise red. However, achieving 100% color gamut via established technologies comes hand-in-hand with a trade off in brightness or efficiency. The method involves heavy use of color filters, which ultimately leads to increasing efficiency losses.

Quantum dots offer a solution to this problem. Their highly saturated emission can pass through the color filters with fewer losses, enabling high color purity with 100% of the DCI color triangle without any sacrifices in brightness.

Three Approaches to Integrating Quantum Dots into LCD Screens

To achieve the near-perfect color quantum dots deliver to LCD display screens, there are three different approaches to consider:

- **On-chip**, where the quantum dots are deposited directly into the LED package
- **On-edge**, where the quantum dots are integrated within a component, such as a thin glass tube, that is positioned remotely from, but in close proximity to, the LEDs
- **On-surface**, where the configuration utilizes a remote quantum dot film that covers the surface area of the display.

Though it has the highest material consumption, the on-surface geometry offers the advantage of operating near room temperature and is more easily and cost-effectively incorporated into the encasing display architecture.

Using the on-surface method, cadmium-free quantum dots, incorporated into a film located in between the LED light source and the LCD panel, are ‘excited’ by light emitted from blue LEDs, transforming some of it into very pure green and red light. As a result, the LCD panel receives a richer white light and expands the range of color the display can reproduce.

Using the on-surface method, quantum dots, incorporated into a film located in between the LED light source and the LCD panel, are ‘excited’ by light emitted from blue LEDs, transforming some of it into very pure green and red light.
Getting Beyond the Cadmium Concerns

It’s important to note that not all quantum dots are created equal. To date, a number of the suppliers of quantum dot products seeding the display market have contained cadmium. Cadmium is a toxic heavy metal and its use is restricted under European and other environmental legislation due to the threat it presents to both human health and the environment. For example, the European Union’s Restriction of the use of certain Hazardous Substances (RoHS) Directive limits the amount of cadmium, lead and mercury that can be included in electrical and electronic equipment placed in the European market. Cadmium is restricted to 100 ppm in homogeneous material, a figure 10 times less than that for mercury and lead.

The presence of cadmium has hindered the broad adoption of quantum dots in devices, keeping display manufacturers from realizing the benefits of the technology and products out of consumers’ hands. However, research into the synthesis and mass manufacture of heavy metal-free quantum dots is of growing interest. Cadmium-free quantum dots offer a safer and more sustainable option for manufacturers and consumers, giving them all of the color benefit associated with the technology without the risks associated with toxicity or potential regulatory limitations.

Moving Beyond Cadmium-based Quantum Dots

Research into visible light-emitting, Cadmium-free quantum dots for display applications has predominantly focused on indium phosphide. However, one of the shortcomings of indium phosphide for backlighting applications is that the full width at half-maximum (FWHM) of the emitted light is somewhat broader than that of II-VI materials such as cadmium. In part, this originates from the quantum confinement effects in indium phosphide being stronger than those in cadmium, leading to a relatively larger change in emission wavelength from a given change in particle size.

This means that much narrower particle size distributions are required to obtain the same FWHM as that of cadmium-based quantum dots. For display applications, using quantum dots with a broader FWHM makes maximizing the color gamut a challenge.

To overcome this problem, Nanoco has developed a unique, quantum dot matrix of semiconductor alloy that is free from cadmium. By tailoring the structure of the quantum dot and allowing the strength of the bonding interactions to be manipulated, the quantum confinement effects are reduced. The result is that Nanoco has made considerable advances in narrowing the FWHM and improving the phospholuminescence quantum yield of its cadmium-free quantum dots, making them perform nearly identically in a LCD display as their cadmium counterparts.

Research Demonstrates High Performance of Cadmium-free Quantum Dots

Nanoco has developed a versatile molecular seeding methodology that enables good control of the quantum dot growth process. Further, the process allows the substitution of precursors containing the required elements at specific times, which along with precursor ligand design enables the mechanism of precursor decomposition to be controlled, maximizing alloying when needed.

To demonstrate the efficacy of cadmium free quantum dots in the on-surface configuration, a BLU was prepared using a film comprising Nanoco’s red and green cadmium-free quantum dots in a resin matrix, illuminated by blue LEDs. The film was optimized for Digital Cinema Initiatives P3 (DCI-P3) color space, with the color triangle displaying 95-98% coverage (depending on the filters used) and a white point close to the Commission Internationale de l’Eclairage (CIE) Standard Illuminant D65 after applying color filters.

The research results showed the color gamut of the film comprising the cadmium-free quantum dots was significantly larger than that of the conventional yellow phosphor Ce:YAG BLU, and comparable to that of the...
Lighting Electronics

cadmium-based quantum dot television. This demonstrates that despite the technical challenges, excellent optical performance can be achieved with cadmium-free quantum dots and films.

As further advancements are made in the molecular seeding process, we envision that even narrower FWHM values will be achieved in the future. The color gamut will be further improved not only by using quantum dots with a narrower FWHM but also, as the technology becomes more widely adopted, by tuning the color filters for use with quantum dots rather than for use with conventional rare earth phosphors.

Research also assessed the lifetime of a BLU prepared using cadmium-free quantum dots. During 3,000 hours of testing, the photoluminescence intensity remained stable. Using a logarithmic extrapolation of the data, this gives a projected lifetime of at least 30,000 hours, which is sufficient for electronic display devices.

The results show that the company’s cadmium-free quantum dots offer a viable alternative for LCD BLU applications to commercially available displays using cadmium-based quantum dots, without the use of toxic heavy metals.

As legislation restricting the use of heavy-metals gets ever tighter, cadmium-free quantum dots are uniquely positioned as the future-proof quantum dot display technology on the market. Thanks to this innovative technology, the future indeed looks more colorful (and safer) for both manufacturers and consumers.
Professor Harald Haas coined the term “Li-Fi” to mean ‘light fidelity.’ However, Li-Fi is rather distinct in a far more fascinating approach; it is distinguished as new, groundbreaking technology that aims to provide ubiquitous wireless access for indoor communications, or indeed any, illuminated area. Li-Fi uses the light waves from LED light bulbs to transmit data, simultaneously providing a home or area with both illumination and wireless communication.
With the demand for mobile wireless access ever growing, mobile cellular and Wi-Fi networks will continue to become increasingly congested—to a limit where adding additional radio frequency (RF) resources will be ineffective. This is referred to as the spectrum crunch. However, a brighter solution is manifesting; with over 70% of mobile traffic originating indoors, Li-Fi is ideally poised to resolve this spectrum crunch by supplying complementary (non-interfering) bandwidth in LED illuminated areas, and, its enormous data density capability will substantially reduce the burden on existing RF networks.

What Constitutes Li-Fi?

Li-Fi is well defined as the networked, mobile, high-speed visible light communication (VLC) solution for wireless communications. To facilitate pervasive indoor wireless access, each Li-Fi system requires:

**High Speed** – the exponential growth of wireless data demand is not only due to the growing number of users, but also the availability of high-rate downlink services, such as video streaming and file download—both of which require large amounts of bandwidth. Li-Fi systems, therefore, must be high speed to maintain currently offered network services and user expectations.

**Bi-directionality** – to provide modest Internet access, there must be a reverse link from the device to the network, which allows the device to request and/or modify information—and in a large data-crazed world—upload photos and videos. Thus, bi-directional communication is essential for full network operation and a user-friendly experience.

**Multiple Access** – for RF networks to serve an abundant volume of users, each cellular base station (BS) (100s of mobile users) and each Wi-Fi access point (AP) (10s of user devices) shares its time and/or frequency resources among the connected parties. Given that a defined area, theoretically housing multiple users/devices, could be illuminated by a single luminaire, adding Li-Fi to the light will necessitate a similar sharing of resources. This is called multiple access, it is needed to extend wireless access to all desired users within the illuminated space, and hence the network.

**Mobility/Handover** – finally, due to the inherent directionality of light (as opposed to RF signals), any space (generally indoor, but also outdoor) that is to be illuminated needs several light fixtures to sufficiently cover the area. Since every light source is a wireless AP in a Li-Fi network, it is essential for network operation that the communications link is unbroken while a user is moving: the network must hand-over the user from one AP to the next. Without such functionality, a mobile user will need to constantly re-establish connection with each network AP, and re-start its running information transfer on the device.

While some of these features are more important than others, all are fundamental to the operation of Li-Fi for wireless communications networks. Each contributes for less disturbance and difficulty and influences higher efficiency with an overall improved user experience.

The Dangers of ‘Quasi-Li-Fi’

Even in its early period there are already a few commercial Li-Fi products available. As an emerging technology, developing Li-Fi products will have very limited capabilities.
The lure is that “first mover advantage” harbors many pitfalls for all but a few well defined applications in a specific market segments. Rushing to products (i.e., missing one or more of the core features) potentially dead-ends those products in a technological niche.

Bi-directionality is, perhaps, the easiest feature of Li-Fi to overlook. However, that would essentially eliminate the possibility for a true Li-Fi system. With broadcast-only technology, the system is limited to just offloading the RF network downlink, and an uplink connection must be established. This leaves the product applicable to only a handful of use cases (e.g., sensor networks, data showers). If high-speed communication is disregarded, the Li-Fi network degrades to a basic control information distributor, which may enable a few applications such as indoor positioning and mobile app content update. Moreover, the network will be reliant on existing RF infrastructures for content delivery and will in fact accelerate the inevitable spectrum crunch.

In order to serve the high extent of indoor users requesting traffic, each Li-Fi AP must be able to provide multiple-access to facilitate multiple users. Such application areas include underwater communications, some sensor networks, and hospital patient monitoring. Yet, even in these areas the ability to communicate with many devices would greatly enhance the product functionality.

Finally, the principal requirement to achieving ubiquitous wireless access is the ability for a mobile device to transfer from one AP to another without its connection faltering, and its information transferal being interrupted. Imagine if, in an office space, a user is downloading important documents while moving around the room, and whenever they leave the illumination of one luminaire and enters the next, the downloads need to be restarted. This eliminates the possibility of mobile wireless access, because the user is not being handed-over from one AP to the next. The result would be a static-user wireless access scheme. This denies the very ubiquity of wireless access that has become a part of everyday life, depriving the illuminated space of proper-networked communication.

The Value of ‘True’ Li-Fi
Due to the immense challenges of developing a full Li-Fi system, it can be very easy to be drawn into the simpler solutions in an attempt to get to an early product and revenue stream. However, the development of a ‘true’ Li-Fi solution will provide vast benefits for the developing company, both in the short/medium term, and especially the long term. Among these benefits, the main are:

- In order to serve the high extent of indoor users requesting traffic, each Li-Fi AP must be able to provide multiple-access to facilitate multiple users.
The elaboration of a ‘true’ Li-Fi solution will allow products to be derived from this solution that can be utilized in (almost) all VLC applications and use cases. ‘True’ Li-Fi is supremely competent to provide indoor communications. All other VLC offerings are only a small part of a ‘true’ Li-Fi system. Location-based services can be implemented through unidirectional, low-speed Li-Fi. Point-to-point applications (e.g., underwater, transportation) can be achieved without the need for multiple access, and Augmented Entertainment for the television market can use non-networked Li-Fi. Therefore, during the development of full Li-Fi, not only can products be spun out for niche areas, but the final solution will allow the developer access to every aspect of the VLC market.

While there have been various markets identified for the proliferation of VLC/Li-Fi technology, the primary target market is indoor networked communications. The discovery that a substantial portion (> 70%) of wireless traffic originates indoors, identifies this environment as the place where Li-Fi will be indispensable in the future. The conception of a ‘true’ Li-Fi solution will preferably position the developer to command this market.

The second largest area of interest is that of location-based services, which utilize a unique method to deliver data to standard smartphones and tablets. By delivering precise positional information to users, retailers and service providers can transmit location-based advertising and messages to substantially enhance consumer interaction. Ultimately, as mentioned above, the ‘true’ Li-Fi solution allows the developer to dominate all market segments and establish themselves as market leaders for VLC and Li-Fi solutions.

Dictating the VLC market through cutting-edge Li-Fi technology holds other values than just market share and revenue: principally, the power to drive and influence VLC standardization. The established Li-Fi market leader will have the unique position to develop a new standard that defines the operation of VLC for indoor communications and content delivery. By liaising with major handset and tablet manufacturers, the integration of Li-Fi technology into such devices can begin—with the market leader at the helm of this collaboration. All in all, the development of the ‘true’ Li-Fi solution will ultimately guarantee the developing company not only the market leadership, but also the continued strength to secure and bolden this position.

Li-Fi networks can, and will, provide the perfect complement to today’s RF infrastructure and further enhance mobile communications. However, the lack of ‘true Li-Fi’ products can lead to limited application, that ultimately do not constitute Li-Fi (as it has been defined) solutions. The spectrum crunch is coming, and indoor communications will be in sore need of bolstering; given that the current rate of wireless data growth is unceasing. The only solution to this is a high-speed, bi-directional, fully mobile wireless network: a Li-Fi system.
Sierra Circuits: A Complete PCB Resource

PLUS: The “Ground” Myth in Printed Circuits

Moving Towards a Clean Energy Future

How Cree reinvented the light bulb

New LED Filament Tower

Low-Power Design Techniques

From Concept to Reality

View more EEWeb magazines—Click Here