Peter Palomaki on Quantum Dots: Challenges and Possibilities

Developments in quantum dot technology are moving quickly. The challenges and possibilities posed by mass adoption are different than they were even a year ago, so we spoke to internationally recognized quantum dots scientist Peter Palomaki, PhD, owner and chief scientist at Palomaki Consulting to understand current developments, challenges and opportunities for the display industry.

What is the promise of quantum dot technology for the TV market and why should consumers care?

The benefit of the quantum dot technology is two-fold: it's a combination of higher efficiency and enhanced color. Current display technology wastes a lot of generated white light, whereas quantum dot displays use light more efficiently resulting in more energy-efficient solutions. At the same time, QD-enabled devices are providing a much higher quality of color that better represents all the colors we can actually see in nature.

Because of a more accurate and realistic color representation, quantum dot displays generate a more immersive viewing experience.

How do quantum dot displays compare with White-OLEDs? What are the pros and cons?

OLED is known for its very deep black levels—so, if you want a really dark black, OLED is the winner. If you are looking for better color, quantum dots deliver better performance.

Also, OLED has difficulty with large areas and is very expensive. With two screens of identical size, quantum dot technology will typically be cheaper than OLED because of manufacturing costs. A 75-inch OLED panel is incredibly expensive. This is one of the reasons quantum dots have had more success in large TVs and displays, while OLED has done well in the cell phone market.

What are some roadblocks to QD adoption for the mass consumer market?

One of the original big roadblocks for quantum dots was their stability. They used to degrade very rapidly, especially when exposed to air. Within the display, quantum dots particles are in this pretty harsh environment of relatively high temperature, high light flux, and exposure to atmosphere—all things that quantum dots don't really like.

But in the last five years QDs have been highly engineered to hold up in that environment—to the point where there is really no concern in its current form factor, which is a film in the back of the TV. As the industry matures and improves on the other form factors, that issue of reliability may crop back in. It may have to be dealt with in a different way, depending on what the form factor is. Again, this is something that any company that works with quantum dots is thinking about and taking action on regularly to continue to enhance and improve stability of the materials.

Then there is always the cost concern with any new technology in the display space, and quantum dots are no exception. They are a premium product at a premium price.

However, the price of the quantum dot film component within the TV has reduced. A few years ago, it cost around $100 a square meter, and is now closer to $30 a square meter. As the price continues to drop with economies of scale, and more people adopt quantum dot technology, the price barrier will become easier to handle. Instead of being only in the premium $1,500 or $2,000 displays, the technology will become available in the displays priced below $1,000 too.

What developments in QD research are you most excited about and why?

In terms of display technologies and how quantum dots are implemented, there are a lot of developments that will enhance the benefits of quantum dots even further, such as:

Color filters

QLEDs currently use quantum dot film within the backlight unit. To further improve on display efficiency, researchers are looking into bringing this color converting layer to the front of the screen and using quantum dots as a replacement to the existing color filters. If this form factor is implemented, it will enhance the efficiency potentially up to two and a half times.

This further enhancement in efficiency would maintain the great color that quantum dots are known for and add additional benefits, such as improved viewing angles. This development would eliminate the current advantage that OLED has in terms of viewing angles. This is because light would be emitting in all directions from the quantum dot layer at the front of the display.

However, this implementation is not without its challenges. The polarizers within the display need to be reengineered. The quantum dot layers also need to be highly absorbing and prevent blue light from leaking through in order to maintain high color quality. Despite these potential roadblocks, the technology is likely to mature and become adopted in displays within the next few years.

Quantum dots on-chip

Another implementation method that people are researching is quantum dots on chips. This is where the quantum dots are placed directly on the LED. This requires quantum dots specifically engineered to survive this harsh environment and has not yet been commercialized for displays.

However, there is progress in this area. The first commercial quantum dot on-chip product was launched last year by Lumileds. This was for lighting, which only requires a red quantum dot, not green—but it still shows that the approach is viable.

In theory, you could purchase LED chips that already have quantum dots on top of them. You could then arrange the green, blue and red however you want your pixels.If this comes to fruition, it would be very easy for large LED signage installers and creators to implement.

What are some substitutes to QD technology that you think may place a challenge?

Quantum dots are always competing with phosphors and OLED.

Phosphors

The traditional LCD TVs used phosphors – commonly a YAG phosphor, which is a broad white emitter. Color filters are then applied to take that white light and make it red, green and blue. These phosphors are very cheap and are incredibly stable but they don't give the high efficiency or color quality that quantum dots do. There have been recent advancements to some phosphors to make them more narrow, for example GE's KSF/PFS phosphor which has seen high adoption across many different display types. As the incumbent technology, QDs will be competing with phosphors for a long time.

OLED

With the high-end technology though, OLED is the main competitor. One advantage of OLED is that you can potentially make flexible material and screens, which you can't currently achieve with quantum dots in LCDs.

However, although people compare these technologies, they also have their own roles to play. OLED is good for small areas; quantum dots are good for large areas. Right now I view them as complementing technologies rather than competing.

There is also talk of incorporating the two together. There is potential for an OLED backlight unit with a quantum dot color filter in the front. This would give the benefits of both technologies in one device – the dark blacks of OLED and the enhanced color of quantum dots.

Looking at the QD value chain today, what are some challenges you foresee in the near future?

Cost remains a challenge. End-users want the price to continue to drop.

The other concern is scale. Although there are sufficient capabilities to meet demands now and into the foreseeable future, how much quantum dot manufacturing is required will depend on the form factors that are adopted.

If the dominant form factor becomes quantum dots on-LEDs, very little quantum dot material will be needed and the usage amount could actually decrease despite increased adoption.

Whereas with quantum dot color filters, very high concentrations of quantum dots are required. This method can also result in a significant amount of waste due to the lithography process. However, there is potential to do it via printing techniques, such as inkjet printing, which would reduce the amount of waste.

What do you know about QDs today that you did not one year ago?

The community has learned that quantum dots on-chip are a real possibility. People were skeptical that quantum dots on LEDs would be commercialized but now that it's been achieved for lighting, there is renewed hope.

The clarity of the different options for implementing QDs in displays has greatly improved. If you had asked anyone to give you at least four different implementation strategies a year ago, they wouldn't have been able to—but there's currently film, QD color filters, QDs on-chip, and electroluminescent QD approaches. The different ways you can implement QDs is now better understood.

What is your vision for the future of display technology?

In five or ten years, most off-the-shelf displays will have quantum dots incorporated into them. The way in which they're implemented will vary, depending on the quality of display and the price point.

Cheaper displays will probably use the film that high-end displays currently do. The high-end displays will upgrade to use either the QD color filters or electroluminescent QDs.

We are going to see continued adoption of quantum dot technology in the display field. It will broaden beyond TVs and monitors and expand into other display sizes, possibly including large scale signage and potentially the mobile market.

We are going to continue to see it expand and be adopted widely, because the benefits are hard to argue with.

What are some of your go-to resources to learn about quantum dots?

I read academic literature regularly. That's a great resource for people in the industry who want to learn more.

There are conferences such as the very educational Display Week which is held by SID—the Society for Information Display—in Los Angeles. Over the last few years, quantum dots have been a big component of that. There is also the Quantum Dots Forum in California held over two days – I continue to learn something every time I go.

I have a blog where I write about different quantum dot and nanotechnologies and I keep track of the Samsung PID site – it has many good resources about the basics of quantum dots, especially for people that are not highly technical.

This is the first part of a three part series looking at quantum dots. Sign up to our newsletter to get Part II: The Evolution of Quantum Dots Implementation and Part III: MicroLEDs and Quantum Dots.

As well as visiting his blog, follow Peter on LinkedIn.

To find out more about quantum dots read our whitepaper on quantum dot fundamentals.

Additional content on display technology:

- Advantages of PIDs
- What is color gamut and how displays can achieve wider color gamut
- What is the difference between VA and IPS display technologies