The Story of Edge-X: The Origins of a Major Optical Innovation in Lighting

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Gaia Photonics is a small design and consulting firm specializing in solid-state lighting located in Sidney, on Vancouver Island in British Columbia. Gaia Photonics was a key part of a team of innovators that developed Edge-X, an optical system for LED lighting that has the potential to revolutionize how lighting fixtures are designed and manufactured. By focusing on application efficiency or in other words on how to get the most useful light out of the entire system (LED, optics, and fixture) rather than only on highly efficient LEDs, the team accomplished an important shift in thinking about lighting technology.

In early 2011 deep tech lighting technology company Quarkstar convened a team to look at different solutions in solid-state lighting that could use the inherent qualities of LEDS to take lighting in new directions. I spoke to Gaia Photonics founder Ingo Speier about the genesis of the idea for Edge- X and how it came to be integrated into the lighting for one of the most prominent architectural museum projects in recent years.

"It was January 2011 and Bob Gardner, another Quarkstar team member and I met in Victoria, B.C. and were looking at novel ways to use LED technology, which was just then beginning to be widely commercialized in general lighting.

We considered light sheet technologies, but due to my previous engagement with focus on micro LEDs in this area, we decided to look in a slightly different direction to avoid conflicts. We looked at previous solutions and challenges, then brainstormed and sketched out concepts that would take advantage of the capabilities and promises of LEDs," recalled Speier.

According to Bob Gardner "Early on we thought about creating a new platform based on reinventing LED-based lighting systems as we understood them. Any proper R&D always starts with first principles – with the early LED work, it was a game of single digit efficiency increases. We looked at some of the ways things had been done before, and we thought we saw some ways that would preserve that principle. In fact we ended up also focusing on another first principle which is just as important as source efficiency – light extraction.

"I had worked in the early days with Roland Winston on the first automotive taillights, which used the concept of a compound parabolic concentrator or CPC, which he invented in 1974. In 1986 our goal was to put light in a particular pattern for the Center High Mount Stop Light, controlled by the Society of Automotive Engineering and enforced by the DOT. This work resulted in quantifying the light requirement to a fixed lumen value. In a subsequent discussion with solid state lighting pioneer Roland Haitz, we determined that if we could make a taillight with fewer lamps, we would win because our cost would be lower than our competitors. It then became a question of dollars per lumen – in fact dollars per useful lumen – to meet the quantified specification. And that kind of thinking was sort of folded into our DNA early on. One of the reasons Ingo and I got along so well was that we were kindred spirits in that sense."

Speier continued, "As Bob explained in his work with Roland Winston, the CPC was originally developed for solar energy applications, and is still used for that today. The CPC collects all light within the entrance aperture and acceptance angle of the optic and concentrates it onto a small exit aperture. As etendue (the product of solid angle and source area) is at best conserved in an optical system this concentration into a small area is also accompanied with a corresponding increase in solid angle. Applying the Principle of Reversibility of Light it follows that using a CPC in the reverse direction will allow collimation of light emitted by a tiny source with wide spatial angle, basically an LED. We already knew that we needed a CPC like optic close to the LED to gather as much light as possible but we were still struggling with the thermal and mechanical constraints in vicinity to the LED and also the lack of light control from conventional light-guide technologies as a light delivery platform when it all of a sudden clicked and we said, why don't we do this – we use a CPC, a lightguide, and a beam shaper, in one system? This system, which we eventually called Edge-X, was very different and superior to the typical LED package replacing an incandescent bulb in a luminaire."

"We now can bring the optic very close to the LED light source, where the CPC collects substantially all the light and pre-shapes the beam from the broad distribution emitted from the LED light source. The light guide mixes and transmits the light away from the source and its heat and mechanical constraints. This provides much more freedom for the optical design of the final optical component in the system, the extractor. The optical design of the extractor is determined by the requirements of the final application and distributes the light to wherever it needs to go. From a manufacturing point of view the system becomes extremely simple as the entire optic can be molded integrally in a single piece or as in our initial production tooling in two pieces and assembled. All critical tolerances that allow high optical efficiency and superb beam control are taking care of by the highly accurate optical molding process and the interface to the LEDs that is controlled. This leaves the industrial designers a lot of freedom to wrap a fixture around the Edge-X light engine using known and existing processes.

"With this approach, the light distribution pattern is our real product, not the fixture. Starting with this premise we saw that we could take a given distribution geometry as input and work down through the extractor to the light guide to the injector to the broad angular distribution emitting from the LED." The team was literally thinking outside the box, streamlining the different layers in the system – separate housings, diffusers, and reflectors – and integrating all of their functions directly into the optic," said Gardner.

Cascading Benefits

Edge–X opened up unexpected possibilities and delivered many complimentary benefits to manufacturers, designers, and end users: new light distributions; improved thermal management; glare elimination; customization and improved design for manufacturing. Edge-X gives the lighting industry a design language with which to realize new innovations, without sacrificing light extraction efficiency.

The Museum of Fine Arts in Houston Project

The Kinder Building, an expansion project for the Museum of Fine Arts Houston, was the largest budget museum expansion in the U.S. in 2020 at 164,000 ft2 ,with a $470M construction budget. Throughout the interior of the building, lighting is integrated into the wall structure to create a harmonious whole. Lighting designers L'Observatoire International worked closely with Steven Holl Architects to balance the physical nature of the built space with the ephemeral nature of light and creativity, to present an inspiring and optimal atmosphere for the enjoyment of art. The gallery spaces balance natural and artificial light, concealed within the building's reveals, walls, and ceilings where possible. The project has won a number of prestigious design awards.

Wall wash luminaires for museums present particularly demanding technical challenges for luminaire designers. L'Observatoire specified QuarkStar's Q-Wall with the Edge-X platform to light 20,000 ft2 of exhibit wall space. Edge-X's unprecedented beam control was demonstrated in the specification of the Q-Wall luminaire, which illuminate 16 foot walls with a two to one ratio of uniformity from top to bottom. Also, the optic is only about 1" wide, allowing the luminaire to be easily hidden in the ceiling."

Separating the Edge-X lightguide from the extractor allows manufacturers to stock the basic assembled lightguide units and order different extractor configurations with distinct distribution patterns as orders get closer to fulfillment. This efficient, modular approach allowed the luminaires for the MFAH project to be produced as a custom project in record time by the engineering and manufacturing team around Ingo Speier in Sidney, B.C. The team finished the design, secured UL approval, set up manufacturing and delivered and installed 1,500 linear feet of product in the space of six months.

Summary

Historically technology developments and transitions do not proceed in linear fashion and are very difficult to predict, especially when considering combinations of technologies. Early solid-state lighting technology gained ground at first entirely because of energy efficiency, and in the process other important considerations, such as application efficiency, light quality, power electronics, and optical distribution were not prioritized. While there is still much room for improvement, especially with affordable product offerings, many gains have been made in light quality and power distribution in the past decade, but we're just beginning to consider application efficiency and optimized optical systems. When we reach optimal levels of system performance in all these areas, we'll begin to fully realize the potential of solid-state lighting. With Edge-X, the Gaia Photonics and Quarkstar teams have made a crucial contribution to the transition to better lighting technology.

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