The Advantages of Using LBS in AR

The laser is now over 60 years old, and progress in laser-based display technology continues to accelerate.

This has especially been the case in recent years. Products today range from laser-illuminated flat-panel TVs, to pico-projectors, to head-mounted augmented reality displays and glasses. For AR in particular, good laser-based display candidates include such compact laser sources as edge-emitting diodes, vertical-cavity surface-emitting lasers (VCSEL), and optically pumped semiconductor lasers.

Laser beam scanning (LBS) modules coupled with reflective, refractive, and diffractive waveguides are an integral part of laser displays, where the specific requirements depend on the source specifications, modulation technique, and the scanning method being employed in the display.

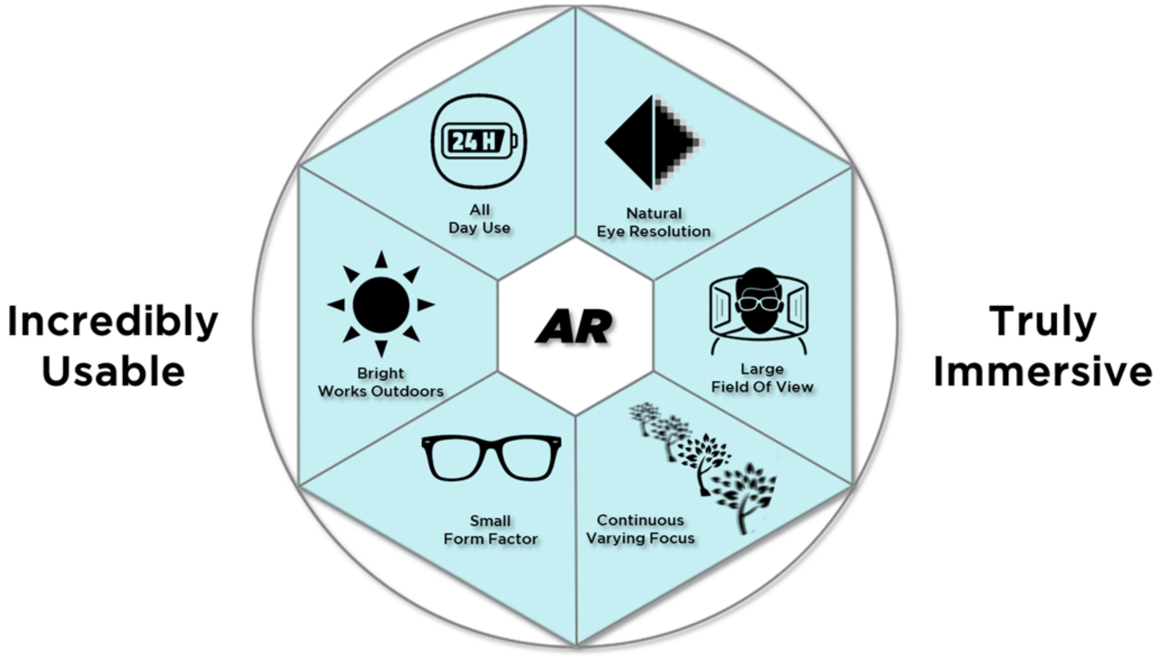
When coupled with compact, fast, reliable technologies such as MEMS mirrors, a scanning-based laser system can accurately render laser-sharp images with a broad color gamut that are then displayed to users using beam-combiner technology.

Threshold of an AR Revolution

We are, today, at threshold of the next revolution in laser beam scanning (LBS) technologies.

Digital information and other content can now be directly overlaid onto the physical world, allowing users, thanks to an AR wearable device, to simultaneously experience both. Comingling the digital and physical worlds has some critical implications. For one, images must be seamlessly integrated. That is, they must look natural, and the users must be able to interact with images and digital objects intuitively. For additional rich content (beyond text, symbols, and other informatics) and a truly immersive experience, the digital images must be photo-realistic and "world-locked." This is another way of saying that the digital object must occupy the physical space with the correct size, depth perception, and placement. The effect demands perceptually pixel-less stereo images with wide color gamut, a large field-of-view (FoV), large eyebox, high dynamic range that matches the real world illumination – even in bright ambient conditions – and, of course, natural adjustment of focus.

And even with all that accomplished, merely having a perfect image isn't sufficient for the task at hand. To achieve a great user experience, modern AR systems must in addition be lightweight, deliver high brightness, consume low power, enable fashionable designs, provide an intuitive user interface, and supports full day use.



Challenges to Achieving Great AR Experiences

While all these cited requirements must exist at the same time, some are still considered mutually exclusive in the AR industry.

It is unfortunately the case that when developing products, we all live in a system that demands tradeoffs. There is a price we pay when attempting to increase one facet of the user's experience (brightness, for example); we pay it by decreasing another feature (power, for example). Increasing the field of view usually comes at the expense of reducing resolution.

The key question we should ask ourselves is: *What is the way to best optimize the way we use light in AR systems so that we minimize tradeoffs as much as possible?*

One answer comes in the form of laser based scanning technology, which has the potential to help us overcome many of these challenges to enhance user experience with augmented reality devices. What follows is a discussion of architectural and color representation benefits of LBS systems.

Architectural Advantages of Using LBS in AR

In any projection system, the light source used has a fundamental effect on image quality (and experience). In this respect, using lasers as light sources holds several distinct advantages that contribute to achieving a significantly better image quality.

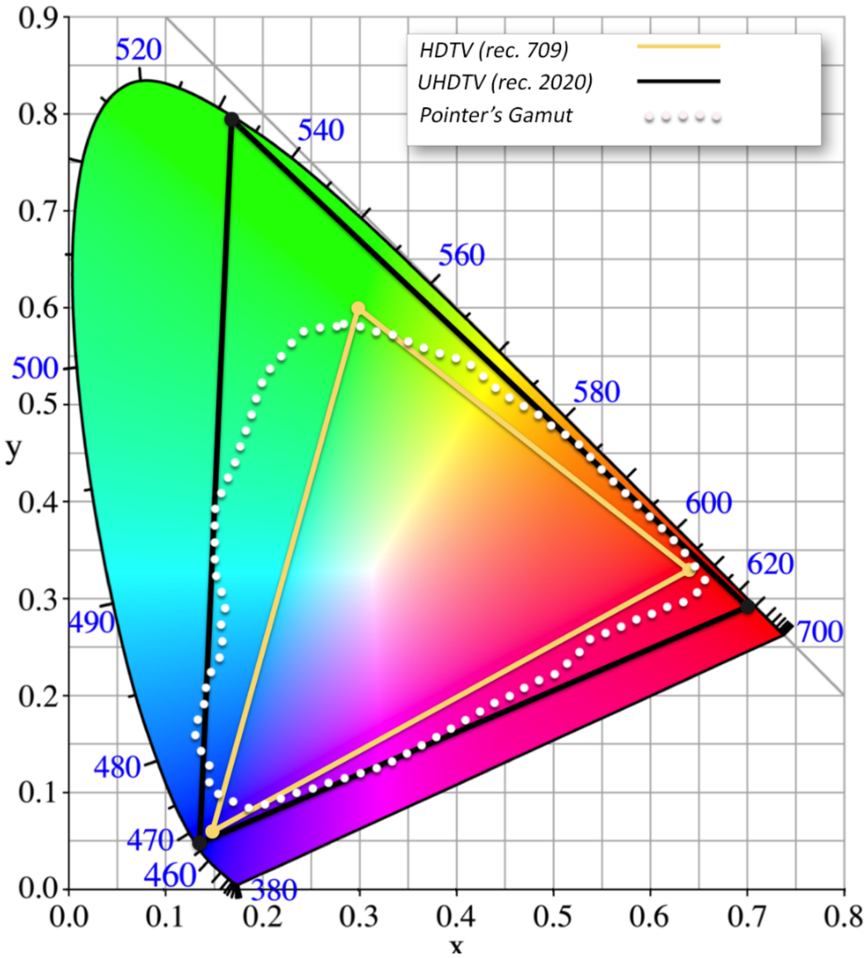
In addition to the light source, a key consideration is the display technology using the illumination source. LBS scanning works quite differently from traditional fixed pixel display technologies such as DLP, LCoS, micro-OLED, and micro-LED devices (even the CRT). LBS relies on MEMS micromirrors that scan the laser pixel across a given field-of-view and through a per-pixel modulation schema. In this regard, one can conceive of the LBS system as a “flying spot” display. The advantages of LBS include: compact form factor, very high brightness, low weight, low power, scalability (resolution, FoV, power etc.), all within a given design or architecture.

Fixed pixel technologies, on the other hand, generally suffer from brightness (or in some cases brightness at the sacrifice of power), as well as size and very limited scalability. In fixed pixel devices, as the name implies, the device has a fixed array of pixels that, in the case of DLP and LCoS panels, are illuminated by an external light source through additional optics (also called a reflective display panel). In such a configuration, the resolution is fixed and cannot be changed for a given device.

Typical AR content contains only a fraction of simultaneously active pixels out of the full display resolution. The illumination is a significant factor for the total display power consumption, regardless of the selected technology. One significant implication is that power consumption is generally higher for fixed pixel devices, since the entire display must be illuminated regardless of the number of pixels to be shown, whereas the way LBS systems operate manages this intrinsically. In LBS systems, each pixel is pre-modulated so that as the brightness of each pixel varies with the content, the laser power also follows. That is, when the pixels in a region are black (or there is no content in the region), the laser diode is turned off. Likewise, when the content has lower brightness in one region compared to other regions, the laser diode power lowered appropriately.

Secondly, for higher resolutions of fixed pixel devices, the device size increases because increasing the number of pixels results in larger panel size, which further requires larger illumination optics to display the full panel, as well as larger optics to collimate the exiting beam. Clearly there is a strong trade-off between achievable image source form factor and brightness. Fundamentally, the heart of the LBS imaging system relies on ultra-small MEMS mirrors (typically in 1-3mm range), which can be combined with ultracompact laser diode modules and a very simple optics to collimate the lasers, thus enabling extremely small size optical light engines. **Figure 1** shows such a design, one in which the optical light engine is ~0.7 cc. Even the addition of optics to drive performance, such as relay optics for waveguide displays, does not sacrifice the form factor or brightness benefits.

Self-emissive devices, such as micro-OLED and micro-LED, though not constrained by illumination sources, are either low brightness and limited in device reliability, as in the case of micro-OLED, or still many years away from commercial realization, as in the case of full-color micro-LED. Today, LBS offers the best overall architecture that provides the necessary performance, tradeoffs, flexibility, and scalability to meet the demanding needs of the AR market.



Enhanced Colors: Color Range, High Dynamic Range, and Contrast

Any conventional display has challenges to mimic real-world colors due to limited dynamic range and contrast in respect to what human eye is capable of observing. This means that colors represented by a display will lack tones (i.e., adjusting for the higher brightness washes away the darkest tones — imagine the colors of a sunset, for instance).

Moreover, typical selection of available display colors is limited by selected light sources that do not generally allow full representation of natural colors. LBS systems, however, have some advantages to address these limitations.

As discussed above, LBS systems are adaptable for local content brightness, allowing them to deliver high contrast and high dynamic range, significantly contributing to users' color experience.

One common way to represent a set of colors that a display is capable of producing is the CIE 1931 chromaticity diagram (see image below). The curved edge represents monochromatic, single wavelength, or spectral colors. The colored area inside represents a full set of colors that humans can see. The area outside contains either colors that do not exist (left, right, and above the curved line) or colors that humans cannot see (under the straight line, limiting the curved area from below). Not all colors that humans can see exist in nature — the curved dotted line on the diagram, called Pointer's gamut, represents the colors you see in nature. The orange line, or Rec. 709, represents a standard set of color that all HDTVs should be able to present. You can see that it fails to represent many colors that exist in nature, as well as a large number of colors that can be created artificially, especially saturated colors.

The recent emergence of HDR cinematic standards, specifically the BT Rec. 2020 HDR standard for wide color range (gamut) displays, elevated the requirements for display technology. This has been a giant step after the popular high definition (Rec. 709) standard, and it covers at least twice the area of possible colors a display could produce.

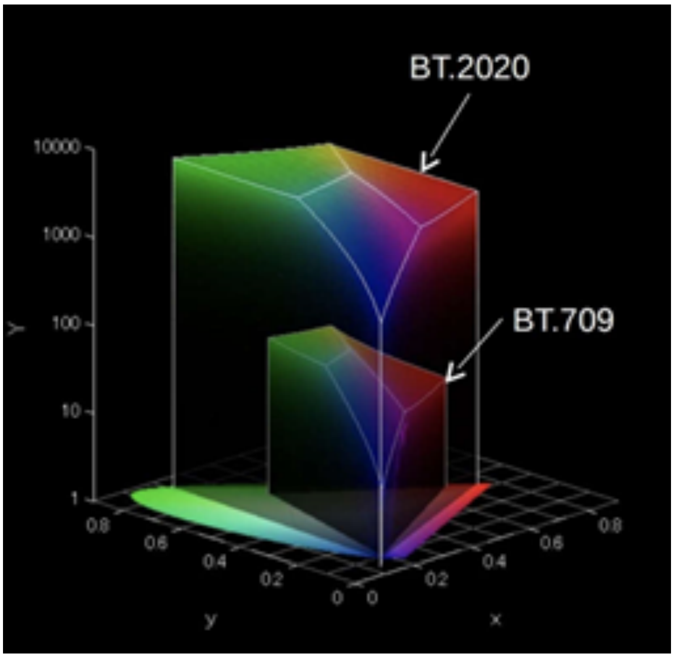
In order to meet these requirements, we must use monochromatic light sources, such as lasers. Choosing the frequencies of lasers that coincide with Rec. 2020 vertices allow full coverage of the BT Rec. 2020 standard. This means that RGB pure lasers can better project natural, real-world colors (see Pointer's gamut on the diagram below), as well as branded colors — think Ferrari red.

Observer Metameric Failure Mitigation

One of potential issues with high-end displays is so-called observer metameric failure of wide color gamut displays. Two colors (one natural and one created with lasers or other narrow bandwidth light sources) that appear similar to one observer may appear different to another observer.

But despite the fact that this may become an issue for movies, where a number of people share the display, this may be calibrated for an individual, wearing an AR system, thus achieving even better image consistency. [How is this done better by LBS system?]

Finally, as alluded to above, LBS systems are scalable where the product designer can make the appropriate tradeoffs to achieve their desired performance. In designs where power is not as demanding but where performance, such as higher FoV or higher resolution is required, the designer can sacrifice low power for the higher performance.



Smart AR approaches enabled by LBS

If display has a small exit pupil (requires fast and robust Eye Tracking) then this brings additional advantages to LBS

- High brightness and contrast, since most photons will enter the eye
- Much larger 3D color gamut than conventional displays

- Better security and privacy - light is scattered only on retina - no image escapes the system, unlike with commercial displays
- Higher efficiency - large percent of emitted photons reach retina

Summary

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