Magic Leap

Four Optics Breakthroughs to Power Enterprise AR

To create Magic Leap's next-generation augmented reality (AR) headset, Magic Leap 2, our engineering team was tasked with solving four of the toughest challenges in AR optics.

Taking into account customer feedback and our better understanding of the current limitations of augmented reality and its applications, we built Magic Leap 2 based on what we learned from our first-generation device.

What we discovered led us to four major optics advances that you will see on Magic Leap 2:

- Doubled the field of view and halved the size
- Added dynamic dimming to bring AR into bright conditions
- Simplified the optical system to offer more comfortable viewing and extended wear
- Enhanced our in-house manufacturing capabilities to ensure precision at scale and enable high performance from a diffractive eyepiece

Twice the Field of View, Half the Size

Customers told us that field of view (FOV) was critical to their use cases, especially for cooperative work, so expanding the FOV was a design priority for Magic Leap 2. But we also wanted to decrease the size of the projector by half — leading to a major optics challenge.

Through years of rigorous research, we concluded that the currently available projector options (uLED arrays, laser-scan-based systems, LCoS panels) were either too large, consumed too much power, or led to a Pandora's box of image artifacts. Adapting the eyepiece for a larger FOV also presented a design hurdle. If we simply enlarged Magic Leap 1's eyepiece, its surface area would have to increase by over 50% — or, as big as a hand, making the headset too big for practical use.

To solve the challenges around FOV and the size of the headset, we invented a new projector architecture and eyepiece design. Magic Leap 2's advanced architecture enables more immersive AR solutions. It offers twice the FOV (44.6 x 53.6 x 66 degrees) in a smaller form factor, with 2x image quality, 2-3x color uniformity, and 100x reduction in front rainbows, compared to our first-generation device. And using modeling software developed in-house at Magic Leap, we designed new 2D pupil expansion, double-sided, and spatial varying grating thicknesses to achieve a 70-degree FOV eyepiece with high efficiency, large eye box, and exceptional uniformity.

The larger FOV, especially its larger vertical direction, will provide direct benefits to businesses and end users. For example, two or more colleagues could comfortably view and collaborate on virtual content from different viewing angles, an engineer could see and modify a full-scale CAD model, and an analyst could visualize data at room-scale. Doubling the FOV in a smaller device could enable physicians to visualize a full person for health applications. With excellent image quality and better stability, they can avoid turning their bodies for a full horizontal view, and simply look up and down instead. And a contractor, architect, or property developer could simply walk through a building site and see plumbing, electricity, and other construction elements.

Solid Digital Content in Brighter Conditions, Even Outdoors

Virtual content tends to get washed out in bright environments, which has limited where and how you can use AR devices. We designed Magic Leap 2 to work across a huge range of ambient light conditions—including bright areas like outdoors or operating rooms.

Magic Leap 2 can reach up to an impressive 2,000 nits of brightness, but this still isn't enough to compete with direct sunlight. And making the display even brighter would have required consuming more power, in a bigger form factor.

To solve for this, we turned to a unique solution: dynamic dimming capabilities. Magic Leap 2 is the first AR headset to feature dimmers integrated into the optical stack.

This enables two types of dimming capabilities:

- ✓ **Global dimming, which automatically dims the environment to ensure clear, solid, and vibrant digital content in bright areas**
- ✓ **Segmented dimming, which enables applications to locally dim just the part of the display with virtual content**

Magic Leap 2 can dim the entire area for use in brighter environments and automatically adjust the dimming feature based on the brightness of the area and the brightness of the projector.

Currently, this happens automatically, but we're also exploring how to give end users control of this capability. Users can also use dimming selectively, so that only the part of the display with the virtual content is brighter or in a lighter view than the surrounding area.

This segmented dimmer results in excellent virtual image quality, as background light is eliminated. The segmented dimmer also enables the rendering of black, which is impossible without a dimmer, and also allows for a minimum amount of virtual light leakage into the real world.

Dynamic dimming will improve the user experience and allow Magic Leap to work in more environments, and there are several possible use cases for this technology. For example, workers could see solid virtual content outdoors, like construction sites or outdoor facilities, and surgeons could bring immersive AR solutions with dynamic dimming into brightly lit operating rooms, where it could help with surgery and related medical needs. Global and segmented dimming capabilities will provide a better AR experience for people next to windows, in brightly lit conference rooms, or bright industrial spaces, and could even ensure easy text and image legibility for stationary blocks of content, such as menus, interfaces, and instructions.

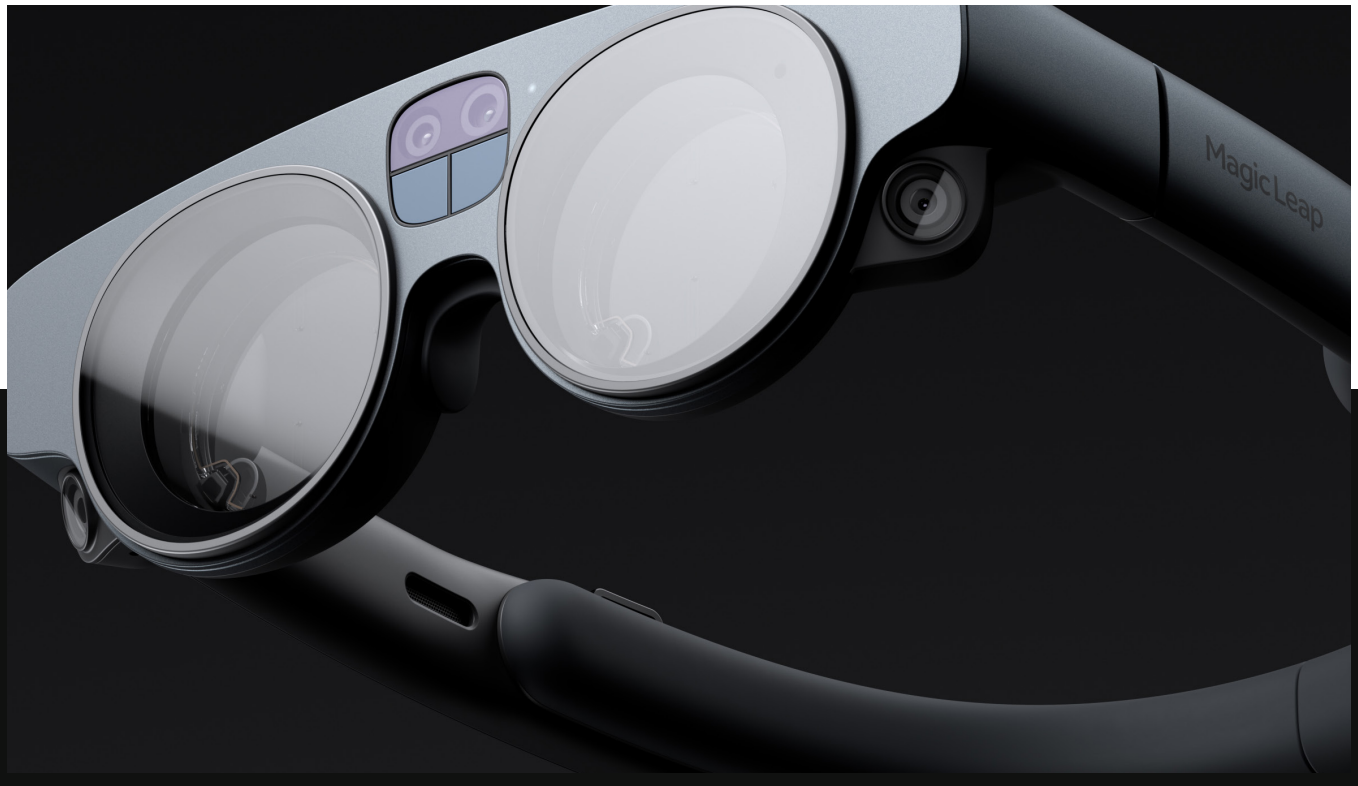
Comfortable Viewing, Extended Wear with a Simplified Optical System

When viewing virtual content, several issues can cause visual discomfort. Vergence-accommodation conflict, for example, occurs when your visual system senses that your eyes' focus and rotation don't match. And incorrect render perspective can occur when the AR device misperceives the location of your eyes and renders incorrectly. Additionally, bionicle misalignment can occur when the virtual image in your right eye doesn't match your left eye.

Our first-generation Magic Leap headset addressed the vergence-accommodation conflict by using two focal planes, but this required larger, more complex hardware. To still enable a smaller form factor and a larger viewing volume for Magic Leap 2, we needed to ensure comfortable viewing of near and far objects on a single focal plane.

We therefore developed a suite of solutions that addresses these common causes of discomfort, enabling users to view content at near (37cm) and far (infinite) distances. This suite includes combining robust eye-tracking with a smart choice of focal plane, as well as automatic display calibration. Magic Leap 2 tracks each eye with two unobstructed cameras, together with 6 LEDs to illuminate and generate eye "glints," thereby improving rendering, image quality, and comfort. Having a smarter choice for focal plane minimizes discomfort and the 37cm clip plane is just the right distance to avoid negative effects. Magic Leap 2 also automatically calibrates the display to correct for any bionicle misalignment or color separation. Users can also run a diagnostic test to make corrections for a better immersive experience.

Comfort is essential for real-world usage. Together with the smaller, lighter form factor, solutions for near and far viewing will make Magic Leap 2 a practical tool for all types of workers and roles. For example, workers could comfortably view virtual content both close up and at a distance on Magic Leap 2 for extended periods while minimizing eye strain, thereby enabling them to use enterprise AR applications for longer, throughout the day. And Magic Leap 2's clip plane will prevent discomfort, nausea, or headaches from content that appears too close to the user.



Precision at Scale and High Performance from a Diffractive Eyepiece

Optics technologies are only viable if they can be produced with high-quality at scale. To provide an AR platform that enterprises and end users can rely on to get work done, we needed to reproduce our optics advances at industrial scale, while always maintaining image quality — fabricating tens of thousands of eyepieces, quickly, reliably, and without defects.

Magic Leap, with our unmatched, in-house manufacturing capability, controls 100% of the eyepiece fabrication process, imprint, and manufacturing and metrology equipment, which enables us to achieve an impressive yield rate (currently >90%).

Our proprietary, high-value processes and equipment include:

- ✓ **Unique jet and flash imprint lithography for optimal display performance**
- ✓ **Versatile nanostructure fabrication**
- ✓ **In-house metrology and innovative quality control**

With our unique jet and flash imprint lithography, Magic Leap owns every aspect of this nano-patterning technology — a key enabler of display performance.

By precisely controlling the volume of resin across the waveguide, this nano-imprint process achieves higher uniformity and efficiency performance. Our nano-imprint process opens many options for the structure of waveguides. We can develop 1D, 2D, and 3D nanostructures and combine different types of structures within a single waveguide element. Our team of experts at Magic Leap has also developed innovative solutions to detect defects and ensure quality. These include machine-vision-based inspection of transparent substrates, a stack and layer inspection system, and automated, in-line stack metrology.

Such manufacturing expertise and IP adds value to our products and positions Magic Leap to meet growing demand. We estimate the capacity to produce more than 100,000 units each year, with the space, best practices, and machinery for further growth. This enables immersive AR solutions and incredible user experience, with Magic Leap 2's 2x sharpness, 2-3x color uniformity, 12x efficiency, and 100x reduction of rainbows. It also means reliable products for large enterprise deployments, based on Magic Leap's 37 critical-to-quality parameters, including dimensional and optical KPIs. And, we can provide ongoing scaling and innovation by tapping our expert in-house teams and proprietary equipment to move quickly from R&D to manufacturing at scale.

Looking Ahead

By solving four critical optics challenges, Magic Leap 2 is designed to be a best-in-class device for the most immersive enterprise AR applications. These proprietary solutions deliver real-world advantages. Doubling the FOV while shrinking the form factor by 50% enables more immersive experiences and a more comfortable headset. Developing a global and segmented dimmer enables solid virtual content across a huge range of ambient light conditions. By minimizing render perspective errors, we made a device with one focal plane that still has a 37cm to infinite range of depth for virtual content. This results in a better form factor and a more simplified device. And finally, Magic Leap 2 features huge improvements in eyepiece performance enabled by our design and unique, in-house manufacturing process and large improvements to sharpness, brightness, efficiency, and rainbows—all while maintaining a high-yield manufacturing process.

Solving the numerous challenges and customizing the platform to support enterprise use cases has poised Magic Leap 2 to become the leading enterprise AR platform. We look forward to collaborating with developers, enterprises, and the ecosystem to deliver on that potential.

Magic Leap 2 vs. our first-generation device

200% Field of View	**2X** Image Quality	**3** LEDs
~50% Smaller	**100X** Reduction in Rainbows	**12X** Efficiency
20% Lighter	**14X** Brightness	**2-3X** Color Uniformity

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