WHITEPAPER

Luna

illuminating LCoS into the future of augmented reality



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Abstract

Augmented Reality (AR) glasses need displays that are bright, efficient, and compact, a combination which Light-Emitting Diodes (LEDs) and discrete laser optics solutions cannot deliver. LEDs lack radiance and étendue match while lasers produce a concentrated beam that must be reshaped into uniform area illumination. Using discrete optics to do so results in products which are too bulky and alignment-sensitive for wearable form factors.

This paper presents Luna, a laserchip illumination engine that integrates flip-chip Laser Diodes (LDs), a Photonic Integrated Circuit (PIC), and a metasurface into a single compact stack: the LDs provide bright, etendue-efficient and polarized light, which the PIC splits, routes, and conditions using Y-branch splitters, directional couplers, Total Internal Reflection (TIR) mirrors, and Numerical Aperture (NA) control, while the metasurface converts the resulting beam array into a smooth, uniform, polarized illumination field matched to the exact requirements of a Liquid Crystal on Silicon (LCoS) panel.

We present Luna: a compact, semiconductor-scale illuminator delivering a uniform Red, Green and Blue (RGB) field. This paper describes its performance, its architecture and its place within the broader shift towards metasurface optics, which simplifies the conventional LCoS light engine.

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Key takeaways

01 AR displays need laser-grade brightness, high efficiency and a wearable form factor for broad consumer market adoption. Today's LCoS display technology does not meet the threshold to spur adoption.

02 Luna will simplify the projector architecture by reducing the number of components and matching the source etendue to the LCoS panel specifications.

03 The Luna PIC handles on-chip light distribution and beam-conditioning through four building blocks: splitters, directional couplers, TIR mirrors, and NA control.

04 The metasurface takes over where the PIC leaves off, turning the sparse beam grid into a single uniform, top-hat profile, 100% transverse electric (TE) polarized illumination field.

05 Co-designing the PIC and metasurface results in optimal efficiency: on-chip functions allow to maximize the metasurface capabilities for better efficiency, uniformity and size.

06 Depending on the integrated building blocks, Luna measures 5.0 × 4.2 × 1.5 mm to 7.0 × 7.0 × 1.5 mm, a volume of 0.030 to 0.074 cubic centimetres (cc), with further reductions possible through future optimization.

07 Simulations show Luna achieves a 90%-uniform, rectangular RGB illumination field at an optical efficacy of 17 lm/W.

08 Luna is a platform: currently both generations of the laserchip are being fabricated to match a 2.5 x 2.5 mm LCoS panel. Customization on both PIC and metasurface level is possible to match different system requirements.

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Introduction

AR glasses place fundamentally different demands on display illumination than conventional display systems. An AR display must generate a bright, high-quality image while operating within strict constraints on size, weight, power consumption, and thermal dissipation. Moreover, it must do so while remaining clearly visible outdoors and lasting through extended use on battery power. Illumination is therefore not a peripheral enabling component but a primary driver of an AR device's performance, form factor, and usability.

LCOS

Liquid Crystal on Silicon: a reflective spatial light modulator built on a CMOS backplane.

LCoS remains an attractive display technology in this context, offering high resolution and image quality on a mature semiconductor manufacturing base. But using LCoS in a wearable system requires an illumination source that delivers sufficient optical power at high efficiency and small size. Conventional LED illumination is simple and mature, but its limited radiance and wide étendue make it hard to hit the brightness and efficiency targets that compact, high-performance AR systems demand. Therefore, LED illumination pushes up power consumption, optics size, and reduces the battery life.

Laser illumination is the natural alternative: high radiance lets it deliver optical power efficiently within a constrained volume, and its narrow spectrum allows for a high dynamic range of colours. Its output is also intrinsically polarized, which suits a polarization-modulating panel such as LCoS and removes the polarization-conversion optics and pre-polarizer losses of LED engines [1, 2]. The laser alone does not solve the problem since it produces a highly localized, directional beam, whereas the LCoS panel needs to be filled uniformly across its two-dimensional area with the right angular characteristics. Therefore, the real challenge is transforming a concentrated beam into efficient area illumination.

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Traditionally, this transformation relies on discrete collimation optics, beam-shaping elements, and homogenizers, for example fly eye homogenizers. These can deliver excellent optical performance, but add significant volume and cost to the overall system and demand precise active alignment between multiple components. Consequently, such architectures are a poor fit for AR devices where space is scarce and every added interface or alignment step is a source of optical loss and manufacturing variability. The challenge is not just building a brighter source, it is building a laser-based area illuminator that is simultaneously efficient, compact, integrated, affordable and manufacturable.

TWO DIRECTIONS

LED: light-guide plates and front-lit optics. Laser: large-scale visible PICs.

Efforts are ongoing to reduce the size of an LCoS engine. On the LED side, thin light-guide plates and front-lit optics are replacing the bulky polarizing beam splitter (PBS) cube, bringing illumination optics and panel together from roughly 4 cc down to about 0.25 cc while keeping 36-41% optical efficiency for polarized input [3]. On the laser side, Meta Reality Labs reported in Nature a 2-mm-thick flat-panel laser display in which a centimeter-scale visible PIC, which integrates thousands of optical components, replaces the free-space illumination module of a conventional LCoS engine. It reaches 211% of the colour gamut and more than 80% volume reduction compared with traditional LCoS displays [4].

Additionally, Photonics Spectra's "LCOS 2.0" presents a roadmap of the next generation of LCoS-based AR projectors, showcasing Laser PIC with LCOS as part of an architecture evolution for LCOS display engines [5].

We believe Luna is a crucial element of this architecture evolution, offering a complementary route to laser-based LCoS that addresses the area-illumination challenge directly. It combines flip-chip LDs, a PIC, and a metasurface into a single compact illumination engine. All these components are wafer-level fabricated, enabling cost effective and capable manufacturing at high volume, as well as opening the possibility to future hybrid integration. With that, it replaces a chain of discrete bulk optics with a photonic architecture purpose-built for illuminating an LCoS display. Figure 1 showcases a conventional LED-based LCoS engine, in which a colour combiner, homogenizer, pre-polarizer and relay optics sit between source and panel, and a folded Luna-based

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engine, in which most of that chain moves onto the laserchip.

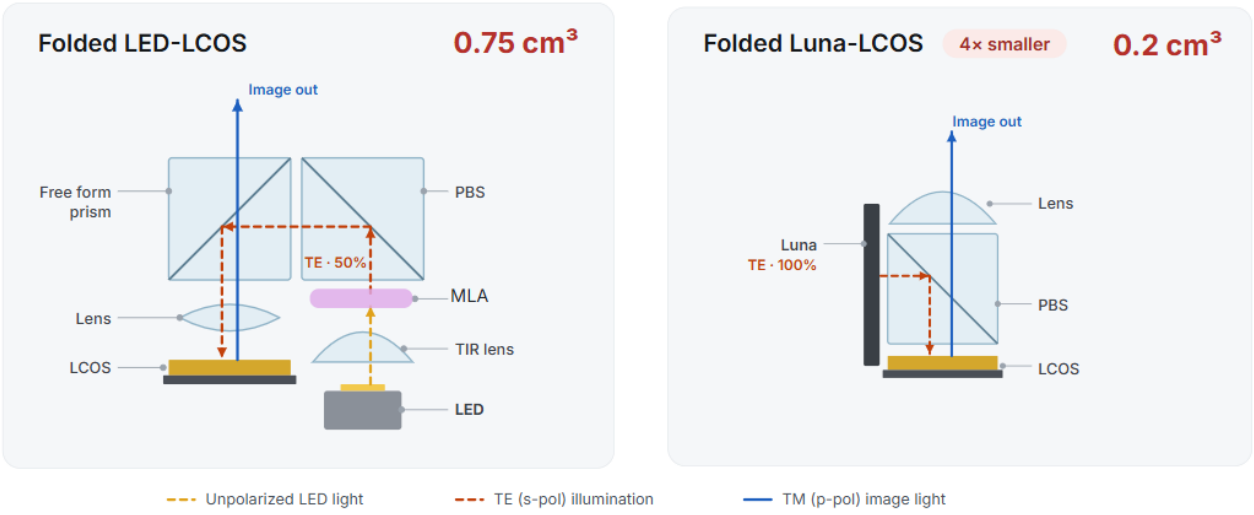


FIGURE 01 LCoS architectures based on two different optical sources: conventional LED-LCoS (left) vs. folded Luna-LCoS (right). Volumes are estimated for a 20° field of view (FOV) and a 4 µm pixel pitch.

ÉTENDUE

Area × angular spread of the light. Conserved along the optical chain.

Splitting the work between the PIC and the metasurface is what gives Luna its design freedom: efficiency and form factor stop being a trade-off and become parameters we can design for. Routing, splitting and NA control are defined on the PIC, which allows to maximize the metasurface capabilities for uniformity and efficiency while the whole stack stays at semiconductor scale. The same combination lets us tailor the étendue of the illumination, its area and angular spread, to the active area and acceptance angle of a specific LCoS panel. Because étendue is conserved along the optical chain, illumination matched this way can fill both the panel and the limited entrance pupil of a waveguide combiner with little loss [6].

In this work, we describe Luna's architecture and operating principles, and show how combining laser sources, integrated photonics, and metasurface optics addresses the core illumination challenges of LCoS-based AR displays.

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PIC

USD 14 bn

Global PIC market, 2024 [7]

USD 26 bn

Projected PIC market, 2030 [7]

~11%

PIC market growth per year [7]

~30%

Silicon photonics growth per year [8]

The global PIC market was valued at approximately USD 14 billion in 2024 and is projected to reach USD 26 billion by 2030, growing at around 11% annually [7]. Silicon photonics is growing even faster, with estimates approaching 30% annually [8]. This rapid shift toward integrated photonics is particularly relevant for AR, where optical performance must be achieved within millimeter-scale volumes while maintaining low power consumption and high efficiency.

For AR display architectures based on LCoS, this integration challenge is especially pronounced. As established in the previous section, an LCoS panel requires illumination that is distributed uniformly across a two-dimensional area matching the active surface of the panel, while also meeting specific angular requirements. The fundamental challenge is therefore not simply generating sufficient optical power, but transforming the concentrated output of laser sources into controlled, efficient, and spatially uniform area illumination.

This is where a PIC-based approach has an inherent advantage. As outlined in the introduction, because laser light has a much lower etendue than LED light, it can be shaped to closely match the active area and angular acceptance of the LCoS panel, so very little light is lost outside them. Combined with low-loss waveguide routing, this means a larger share of the generated light reaches the panel. The Luna PIC is therefore more efficient by default, before any form of dynamic control

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is applied.

ZONAL ILLUMINATION

A 4 × 4 grid of eventually independently addressable zones.

Zonal illumination builds on this baseline to increase efficiency further. By independently controlling illumination across multiple regions of the LCoS panel, optical power can be directed only where the displayed content requires it, reducing wasted light even more. Zonal illumination is not unique to lasers, LED-based systems use it as well. Combined with the efficient baseline of the PIC, however, its benefit is even greater. To support this future development, the Luna PIC architecture divides the illumination area into a 4 × 4 grid of eventually independently addressable zones. This provides a scalable foundation for implementing zonal illumination without requiring a fundamental redesign of the optical engine.

SILICON NITRIDE

Transparent across the full visible spectrum.

The Luna PIC is built on a silicon nitride (SiN) platform. SiN waveguides are fabricated on a silicon wafer, separated from the substrate by a silicon oxide layer that serves as the cladding. This choice is driven by the requirements of AR illumination: SiN is transparent across the full visible spectrum, enabling low-loss guiding of RGB laser light on a single chip.

Within this platform, the Luna PIC acts as the optical distribution and control layer between the laser sources and the metasurface. It takes the output of the LDs and distributes, combines, redirects, and controls the light to generate the required illumination pattern. These functions are implemented through four key building blocks: splitters, directional couplers, TIR mirrors, and NA control. Together, these elements form the core of the Luna optical architecture, enabling the conversion of concentrated laser light into precisely controlled two-dimensional illumination while providing a path toward future zonal illumination.

PIC building blocks

The benefit of PIC technology is that once the light is coupled into the waveguide of the chip, many functions can be created on-chip, without increasing the size or complexity of assembly.

A traditional electronic chip has a library of building blocks manipulating

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the electrons, such as analog-to-digital (AD) converters, power supplies, multipliers etc. In a similar way, for PICs we have building blocks manipulating the photons on our chip.

The most relevant building blocks for Luna are presented in Figure 2.

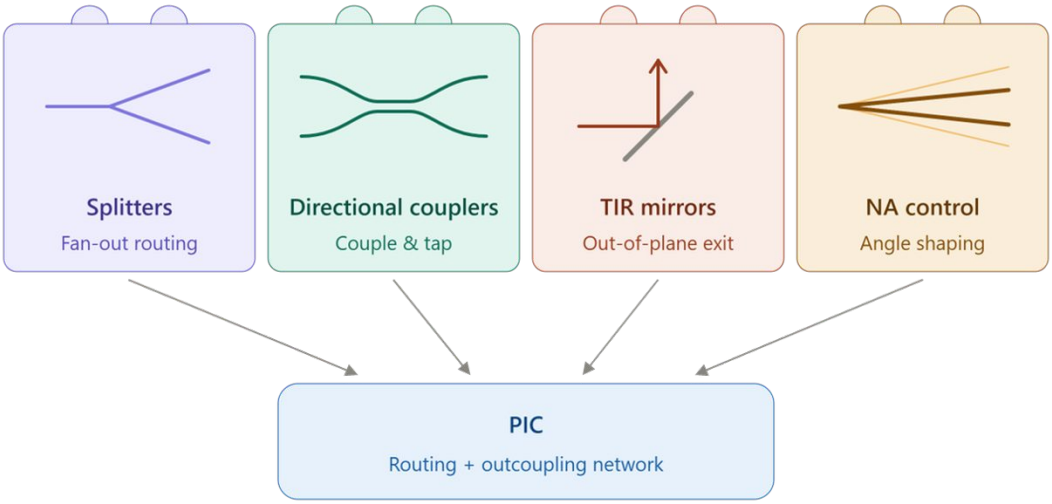


FIGURE 02 Building blocks which together create the Luna PIC.

BUILDING BLOCK 01
Fan-out routing

Splitters

The first building block of the Luna PIC is the splitter. Zonal illumination is on the Luna roadmap, and it requires light from a single laser source to be distributed across multiple locations in the illumination grid. By including this splitting network in the second generation, Luna demonstrates that power distribution works on our platform ahead of full zonal control.

This distribution is implemented using Y-branch splitters. A Y-branch splitter divides the guided optical power in one input waveguide between two output waveguides, typically with a 50/50 power split. By cascading multiple splitters, a single input can therefore be expanded into many individual optical channels while remaining within a single waveguide layer.

The number of available outputs scales as a power of two with the number of splitting stages: a single splitter produces two outputs, two stages produce four, and so on. For the 4 × 4 illumination grid, the

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optical power from each laser source must ultimately be distributed across 16 individual output channels, requiring four stages of 1-to-2 splitting. An example of such a splitting tree is shown in Figure 3.

BUILDING BLOCK 02

Couple & tap

Directional couplers

For optimal optical performance, it is often necessary to couple a controlled portion of the light into or out of a waveguide. Depending on the application, this may require a specific splitting ratio, or the selective coupling of light at a particular wavelength. Directional couplers provide a compact and versatile way of achieving both.

A directional coupler consists of two parallel or closely spaced waveguides in which light is transferred from one waveguide to the other through evanescent-field coupling. The amount of power transferred can be controlled by adjusting the waveguide separation distance and the interaction length, enabling extracted power ratios from 0% to 100%.

Directional couplers are used to extract a defined fraction of the optical power from a waveguide. Such a connection, commonly referred to as a power tap, can route a small portion of the light to an output location or to a photodiode for monitoring the optical power. This allows optical power to be measured or monitored without significantly affecting the main optical path.

The coupling is also wavelength dependent, which provides an additional degree of control. By designing the coupler appropriately, light at different wavelengths can be selectively transferred between waveguides. This enables multiple wavelengths to be combined into a single waveguide, for example to create an RGB combiner or RGB splitter. An example of such a wavelength dependent splitter is shown in Figure 3.

These capabilities are particularly important for the 4 × 4 illumination architecture of Luna. Because the waveguides that route the light are implemented in a single SiN layer, light cannot simply be branched independently to every location in the grid. Instead, multiple wavelengths must be selectively combined and separated again downstream at their respective destinations. Directional couplers provide the wavelength-selective coupling required to perform this routing within a single waveguide layer, eliminating the need for a

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second routing layer while maintaining independent control of the different wavelength channels.

BUILDING BLOCK 03

Out-of-plane exit

TIR mirrors

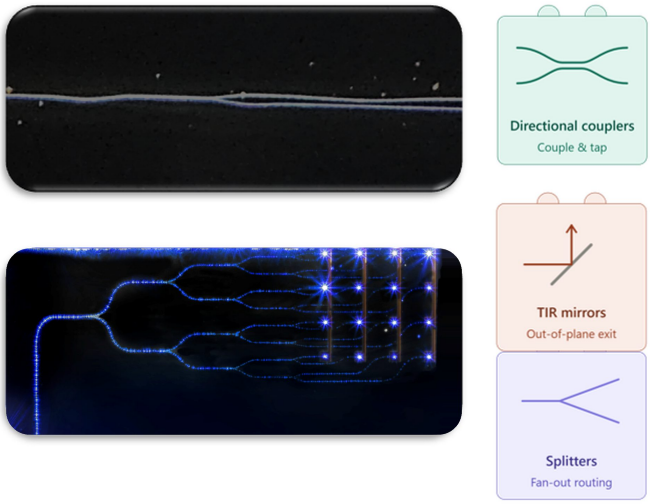
Compactness is one of the key design requirements for Luna. To minimize the footprint of the optical engine, it is therefore advantageous to couple light vertically out of the PIC rather than exiting it within the plane of the chip. Vertical outcoupling allows additional optical components to be positioned directly above the PIC, enabling a stacked architecture instead of requiring additional length along the PIC's routing direction.

TIR mirrors are used to achieve this vertical outcoupling. These structures are formed by removing PIC material under an angle. The resulting interface between the PIC material and the surrounding air gap creates a refractive-index contrast that enables TIR, redirecting the light out of the plane of the PIC.

The geometry and optical properties of the TIR mirror determine the characteristics of the outcoupled beam. In particular, the mirror angle, typically close to 45°, defines the direction in which the light is redirected, while the surface roughness determines the outcoupling efficiency. Both parameters must be controlled accurately and reproduced consistently across all illumination sites to ensure uniform and predictable performance.

In Luna, dedicated TIR mirrors are therefore implemented across the 4 × 4 grid site. An example of a 4 × 4 grid with TIR mirrors is displayed in Figure 3. This implementation provides precise control over the position and direction of each output beam while allowing the optical components above the PIC to be arranged in a compact, vertically stacked architecture.

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Directional coupler: splitting light of two different wavelengths into two waveguides.

Splitter tree with splitting ratio 1x 16 followed by TIR mirrors: splitting light and coupling it out perpendicularly of the chip.

FIGURE 03 Two test chips (actual pictures), where the top one shows a directional coupler splitting two wavelengths into their own exit path, and the bottom one shows a 1x16 splitter tree followed by a grid of 4x4 TIR mirrors.

BUILDING BLOCK 04

Angle shaping

NA control

The design of the optical system following the PIC depends strongly on the characteristics of the beam exiting the chip. One of the key beam parameters that can be tuned on-PIC is the opening angle of the emitted light, typically expressed as the NA, defined as:

$$NA = n \cdot \sin(\theta)$$

where n is the refractive index of the medium in which the light propagates, and θ is the half angle of the light cone.

This opening angle is set by the degree of confinement of light within the waveguide, and this in turn is dictated by the waveguide geometry, as illustrated in Figure 4. Tighter confinement produces a larger divergence angle at the PIC–air interface, while looser confinement yields a smaller one; the waveguide geometry therefore acts as a direct handle on the resulting NA.

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FIGURE 04 Waveguide geometry dictates the confinement of light, which in turn dictates the NA.

As an example, Figure 5 shows NA experimental data for a wavelength of 520 nm. By tuning certain parameters of the waveguide geometry such as the widths, different NA values can be achieved.

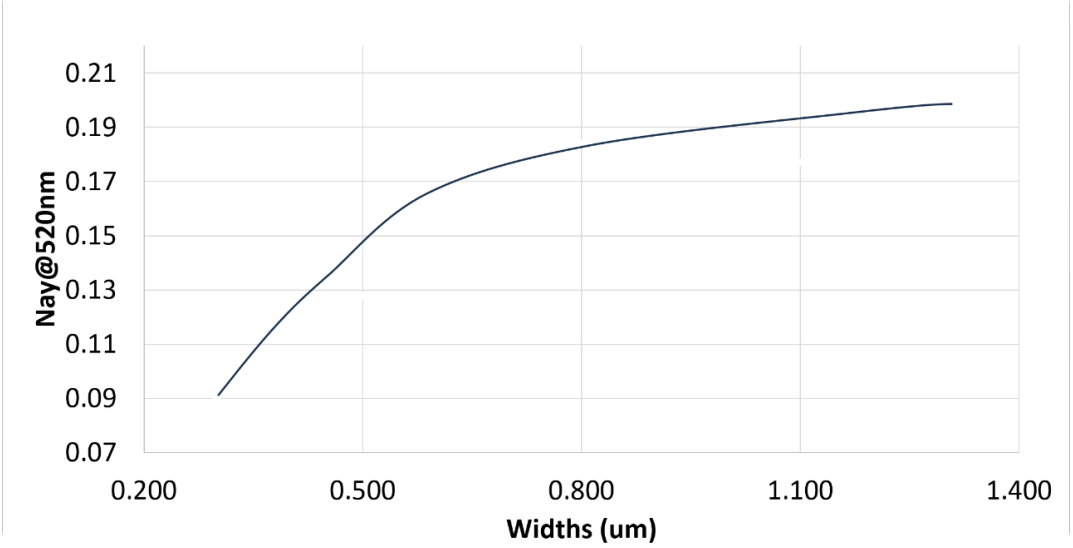


FIGURE 05 Measured NA at 520 nm as a function of waveguide width.

In Luna, the waveguide confinement is chosen such that the emitted NA matches the acceptance of the optical components positioned directly after the PIC, ensuring efficient coupling into the downstream optical path.

The PIC's output, however, is still not directly usable for LCoS panel

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illumination. What exits the PIC is a grid of discrete, NA-controlled beams, which are unusable as-is. Converting this into the uniform illumination that an LCoS panel requires means shaping and combining these individual beams into a coherent area-fill pattern, ideally without discarding the compactness the PIC was designed to deliver. This is the job of the optical element between the PIC and the display. It must turn a sparse array of small, well-defined beams into smooth, uniform illumination across the panel's active area, while matching the PIC's scale and level of integration.

> This raises the natural question of which optical technology is best suited to that job. As it turns out, the choice has significant implications not just for Luna, but for where the broader photonics industry is heading.

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Metasurface

In the previous section, we discussed the building blocks placed on the Luna PIC in-depth. In this section, we will investigate the second optical element of Luna: the metasurface.

ORIGIN

Capasso group, Harvard University, 2011.

Metasurfaces trace back to Federico Capasso's group (2011). At Harvard, they demonstrated meta-lenses with superior aberration control compared to conventional diffractive optics, while shrinking the footprint by orders of magnitude [9]. That work pushed the industry to converge complementary metal-oxide-semiconductor (CMOS) technology and lens fabrication, taking advantage of the large-scale fabrication techniques of the semiconductor industry (deep ultraviolet (DUV) lithography).

Three families, one job

Three families of optical elements are used in light-manipulation technology, shown in Figure 6: discrete optics, diffractive optical elements (DOEs) and metasurfaces. By definition:

Discrete optics	Macroscopic, standard refractive or reflective bulk components, such as mirrors, prisms and glass lenses, that bend and manipulate light via Snell's law.
DOEs	Flat elements like metasurfaces; however, they use diffraction to shape light, relying on microscale step-height profiles to manipulate the phase of light via scalar diffraction.

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Metasurfaces Planar/flat micro-nano structures designed at the sub-wavelength level, that can locally modify various optical parameters of an electromagnetic wave — polarization, phase and amplitude — through vector electromagnetic resonance.

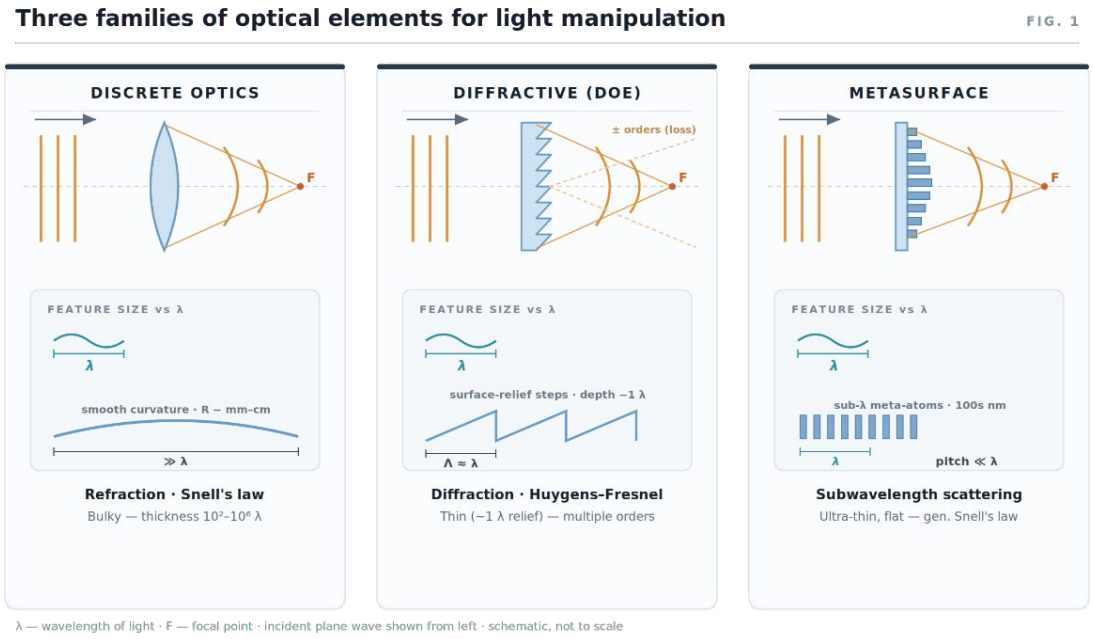


FIGURE 06 Three families of optics for light manipulation.

Why metasurfaces?

USD 170 m

Metasurface market, 2025 [10]

USD 875 m

Projected metasurface market, 2035 [10]

~18%

Annual metasurface market growth [10]

Metasurfaces play a different game compared to DOEs and discrete optics. For example, they act primarily through extreme miniaturization and semiconductor-fab integration. The metasurface market is the smallest of the three today but the fastest growing: from USD 170 million in 2025 to an expected USD 875 million by 2035. That is a compound annual growth rate (CAGR) of about 18%, compared with 10% for DOEs and 7% for discrete optics [10]. Much of that growth rides

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on AR, virtual reality (VR) and light detection and ranging (LiDAR) adoption, as rising headset miniaturisation requirements accelerate metasurface deployment for next-generation wearable optical systems.

The flexibility and freedom of metasurfaces

The desired wavefront is set by the design parameters: the shape of each pillar (its height, radius and cross-section) and where the pillars are placed across the surface. Figure 7 shows an example: a metasurface designed to turn an incoming green beam into a top-hat profile. In a refractive lens, the phase profile is bound to the surface curvature. In a metasurface, the curvature no longer matters.

Moving from one macroscale parameter to per-pillar control opens new, specific design freedoms:

- **Wavefront specified pillar by pillar,** at a resolution finer than the wavelength. Any phase profile (aspheric, off-axis, freeform, vortex or holographic) is simply a different arrangement of the same pillars.
- **Multiple phase mechanisms per meta-atom:** propagation/waveguide phase by tuning pillar widths or diameters, resonant phase from Mie or plasmonic resonances, and geometric Pancharatnam-Berry phase (equal to twice the rotation angle for circular polarization). Because these mechanisms are partly independent, combining them can control two orthogonal polarizations separately.
- **Simultaneous, decoupled control** of phase, amplitude and polarization.
- **Multiplexing,** multifunctionality in one flat element.
- **Cost that lives in the mask:** the patterns are written with semiconductor lithography, so as long as pillar height stays constant, added complexity costs essentially nothing.
- **Dispersion as a design variable,** since group delay and group-delay dispersion can be controlled at each point through meta-atom geometry.

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- **Freedom on a fixed budget,** where every degree of freedom draws from a shared budget: achromatic performance trades against the NA product and aperture size, while wide field of view, efficiency and polarization all compete for the same energy and information capacity.

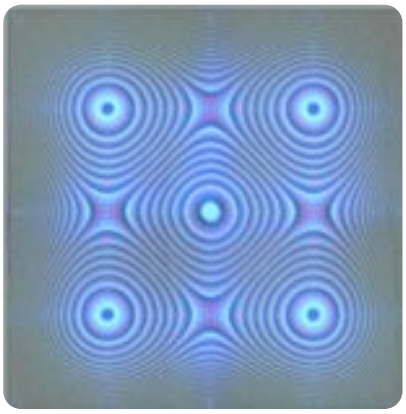


FIGURE 07 Example of metasurface for green top hat profile.

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Luna

NEPTUNE

RGB point illuminator in a 0.028 cc package.

Considering everything said in the previous sections, it is intuitive to imagine where this whitepaper is heading:

PIC + Metasurface = Luna

Both are fields of optics that have gained popularity in recent years across a wide range of applications, and both are defined by integration. PICs let us integrate and route light on a single platform, a substrate where different components can be hybrid-integrated. RGB point illuminator product family Neptune was a first step: a fully integrated RGB laserchip, and the first hybrid integration of visible-domain lasers flip-chipped onto a SiN PIC platform. It combines RGB on a single die to address the full visible gamut, delivering a highly circular beam (>90% circularity) at an NA which can be controlled by design in a 0.028 cc package.

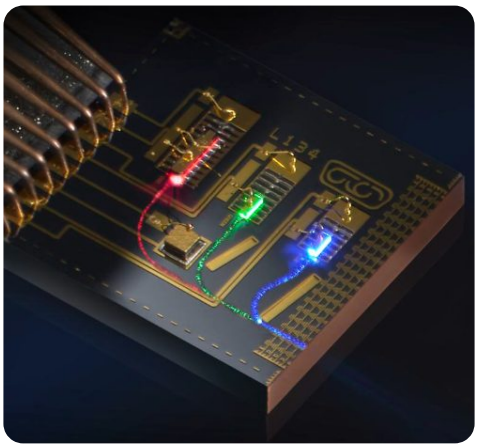


FIGURE 08 Neptune: a fully integrated RGB laserchip point illuminator on a SiN platform for laser beam scanning (LBS) and holographic applications.

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LUNA

RGB area illuminator: PIC building blocks plus a metasurface.

Luna goes one step further. Alongside the RGB lasers, it integrates the PIC building blocks, such as splitters, directional couplers and TIR mirrors, and couples them to a metasurface designed for the RGB wavelengths. This turns a point source into an area illuminator.

Inside of Luna

Luna is where the PIC + Metasurface combination stops being just a theory and turns into reality. How? By tuning waveguide geometry and optimizing it per wavelength. In this case, we keep the SiN waveguides as distinct inputs and with precise routing we designed the metasurface to overcome the strong effect of chromatic dispersion. As previously stated, freedom is on a fixed budget, and by taking more functionalities and control on PIC level, we leave more room on the budget imposed by the metasurface to play with other trade-offs, improving parameters such as efficiency. Since NA control is possible on PIC, this allows control over the angular spread of the light which exits the PIC and reaches the metasurface, contributing directly to parameters such as uniformity and efficiency.

Figure 9 below shows a schematic of the Luna design. The top-hat profile shown in Figure 9 is the simulation result from the three wavelengths: [450, 520, 639] nm.

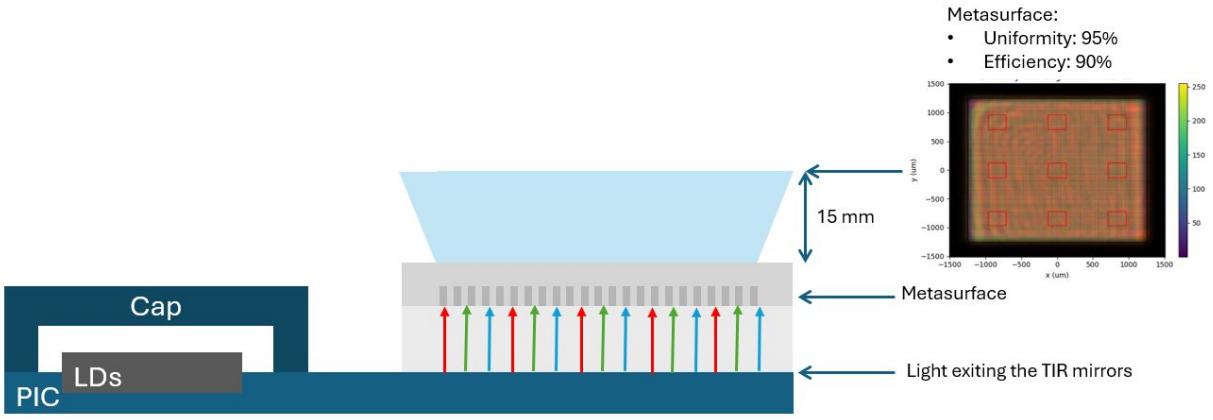


FIGURE 09 Schematic of Luna laserchips – cross section.

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Luna delivers a rectangular, uniform RGB field from one of the smallest packages currently available on the market. The specifications are:

1:1
Square pattern; aspect ratio at FWHM

15 mm
Focal-plane* distance

2.5 × 2.5
Illuminated area at focal plane (mm)

450 / 520 / 639 nm
Wavelengths

17 lm/W**
Luminous efficacy at focal plane

90%**
Global uniformity at focal plane

TE
Polarization

** Focal plane refers to the plane where the best overlap and uniformity among the 3 wavelengths is achieved.*
*** Simulated values.*
FWHM = full width at half maximum.

The Luna family

GEN 1 / GEN 2
5.0 × 4.2 × 1.5 mm (0.030 cc) for generation 1, up to 7.0 × 7.0 × 1.5 mm (0.074 cc) for generation 2.

Since the PIC and metasurface design options are so versatile, this opens the possibility to create multiple versions of the PIC for different purposes or customizations. This is why we see Luna as a product family, all part of a platform with the end goal to provide a top-hat profile.

Based on current and future market needs, we have defined two generations of Luna. In generation 1, the light is redirected from the LDs directly to the exit facets, where NA control is incorporated. After that, the light exits vertically by TIR mirror and enters the metasurface where the uniform top-hat output is created. This laserchip demonstrates the miniaturization capabilities of PIC's by achieving a total chip volume of 0.030 cc.

The second generation already incorporates additional functionality for coupling, splitting and routing, which lays the foundation for future zonal illumination in a 0.074 cc package.

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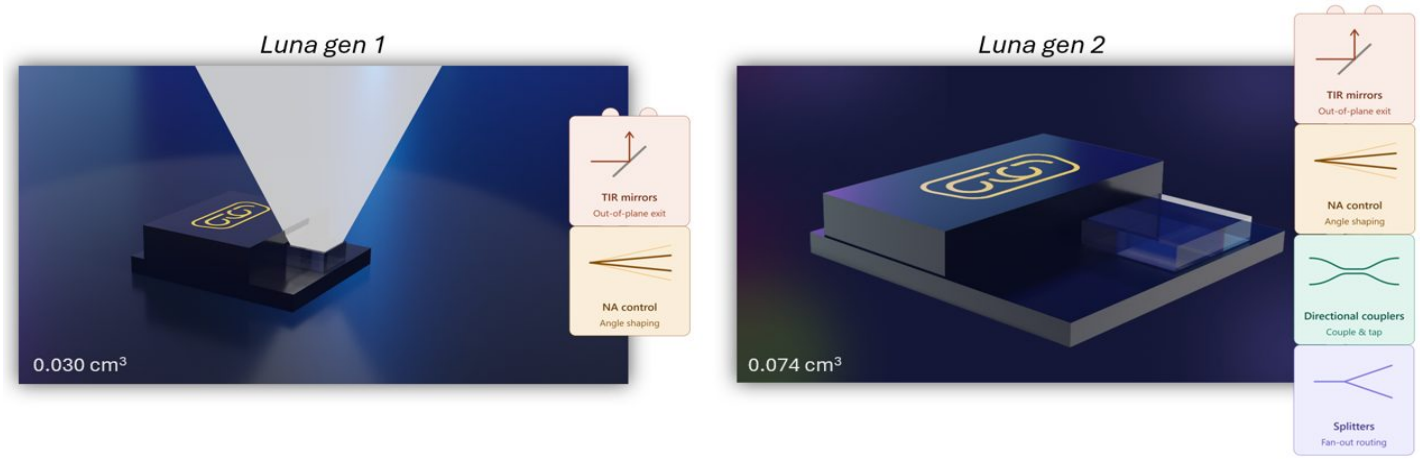


FIGURE 10 Luna gen 1 and Luna gen 2, with the PIC building blocks each generation integrates.

Discussion

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Luna's core value is integration. Splitting, routing, wavelength combination, vertical outcoupling and NA control all happen on the PIC, and a metasurface performs the final beam-shaping step. Together they replace a chain of discrete, individually aligned optical components with a single photonic stack.

For the AR engineer, this changes how the system is designed. There is no need to source, align and qualify a string of separate collimators, beam shapers and homogenizers. Instead, the engineer works with one pre-integrated optical engine. Because the optical functions are defined lithographically at wafer level rather than aligned component by component on the bench, much of the manual assembly disappears. With fewer components, less alignment work and fewer chances for yield loss, overall system cost drops compared with an equivalent bulk-

optic design. Integration also improves performance: with fewer interfaces and no free-space coupling between discrete elements, Luna avoids much of the Fresnel reflection, absorption and alignment loss that builds up in a conventional optical chain.

The two Luna generations show this from two sides. Generation 1 shows the first proofs of miniaturization. Light is routed from the LDs directly to NA-controlled exit facets, redirected vertically by TIR mirrors, and turned by the metasurface into a uniform top-hat field, all within 0.030 cc. Generation 2 adds the full set of PIC building blocks. Splitters and wavelength-selective directional couplers distribute RGB light across a 4 × 4 grid of illumination sites. Test chips have already demonstrated the key elements of this architecture on our SiN platform: a 1 × 16 splitter tree feeding a 4 × 4 TIR mirror grid, and a directional coupler that separates wavelengths into their own paths.

> “ Every function moved onto the chip makes the system simpler to build.

From here, the roadmap builds on what is already in place

01

Unlocking zonal illumination

The 4 × 4 grid of generation 2 is the physical foundation for zonal illumination. Today, all zones are driven together. The next step is making each zone independently addressable, which requires on-chip actuators that combine high efficiency, a small footprint, fast switching and compatibility with visible wavelengths. Once these are in place, optical power can be sent only where the displayed content needs it. Because the routing network already exists, this is an extension of the current design rather than a redesign of the optical engine.

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02

Scaling to volume

Luna's TIR mirrors are currently made by focused ion beam milling. This precise and flexible process is ideal for prototyping and low-volume production. Wafer-level fabrication methods for these mirrors are in active development. They would bring the mirrors in line with the wafer-scale processes used for the rest of the PIC and take Luna from demonstrator to high-volume manufacturing.

03

Gaining efficiency from the laser ecosystem

Wall-plug efficiency (WPE) of visible LDs, especially green ones, is a challenge across the whole industry. Brilliance RGB is working closely with LD suppliers to push it forward. Because the PIC and metasurface do not depend on the source, each gain in laser efficiency carries straight through to Luna without any redesign. The simulated 17 lm/W is therefore a starting point: as visible LDs improve, Luna's efficacy improves with them.

04

Integrating more on-chip functions

The platform can take on more functions. De-speckling is a strong candidate. Building it into the illumination engine would improve image quality without adding downstream optics, which follows the same principle that defines Luna: every function moved onto the chip makes the system simpler to build.

Generation 1 shows that a laser-based LCoS illuminator can be extremely small. Generation 2 brings the full PIC building-block architecture together on a single chip. The next steps turn Luna into a dynamic, volume-manufacturable illumination engine for the next generation of AR displays.

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Conclusion

Luna demonstrates that achieving the major benefits of laser-based area illumination for AR displays no longer needs to rely on a chain of discrete, fragile and expensive bulk optics. By integrating splitting, routing, vertical outcoupling, and NA control on a single PIC, and pairing it with a metasurface that converts the resulting beam array into a uniform, polarized illuminated area, significant gains in efficiency, maximum brightness and size reduction are achieved.

The core PIC technology is mature, proven and high-volume ready by now. Significant progress will be made by adding zonal switching, improving laser WPE values and implementing mass manufacturable mirrors. When connected to the progress in PIC-based actuators and on-chip de-speckling, we have all the ingredients for the ultimate miniature LCoS illuminator, powering all-day wearable everywhere-use AR glasses.

Luna is a platform rather than a single chip. Generation 1 shows how far the illuminator can be miniaturized, at 0.030 cc. Generation 2 brings together the full PIC building-block architecture within 0.074 cc. Together they offer a scalable, manufacturable path toward compact, efficient LCoS-based AR projectors. More broadly, Luna shows how combining PICs with metasurfaces can replace bulky optical systems with semiconductor-scale integration.

> “ Combining PICs with metasurfaces can replace bulk optical systems with semiconductor-scale integration.

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Abbreviations

AD	analog-to-digital
AR	augmented reality
CAGR	compound annual growth rate
cc	cubic centimeter
CMOS	complementary metal-oxide-semiconductor
DOE	diffractive optical element
DUV	deep ultraviolet
FOV	field of view
FWHM	full width at half maximum
HUD	head-up display
LBS	laser beam scanning
LCoS	liquid crystal on silicon
LD	laser diode
LED	light-emitting diode
LiDAR	light detection and ranging
NA	numerical aperture
PBS	polarizing beam splitter
PIC	photonic integrated circuit
RGB	red, green and blue
SiN	silicon nitride
TE	transverse electric
TIR	total internal reflection
VR	virtual reality
WPE	wall-plug efficiency

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About Brilliance RGB

Brilliance B.V. develops and manufactures miniature integrated RGB laserchips for next-generation AR glasses, automotive head-up displays (HUDs), and other advanced laser display applications. Its patented SiN PIC platform and proprietary laser integration technology enable compact, highly efficient, and scalable optical solutions. Brilliance's mission is to redefine the standards of photonic integration by solving the problems of today's bulky and complex projectors with fully integrated laserchips.

More information is available at www.brilliancergb.com.

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Cristina Cunha joined Brilliance driven by a curiosity for integrated photonics. Today, she helps push our laserchips into new territory. With a background in physics engineering and optics, she bridges customer collaboration and the development of new on-chip functionality.



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Kyra de Bree is a Development Engineer at Brilliance RGB, working on the integrated RGB laserchips behind the Luna and Neptune product families. Kyra is also a technical support for customers, enabling integration of laserchips into compact optical systems.

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