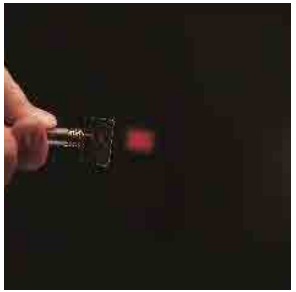
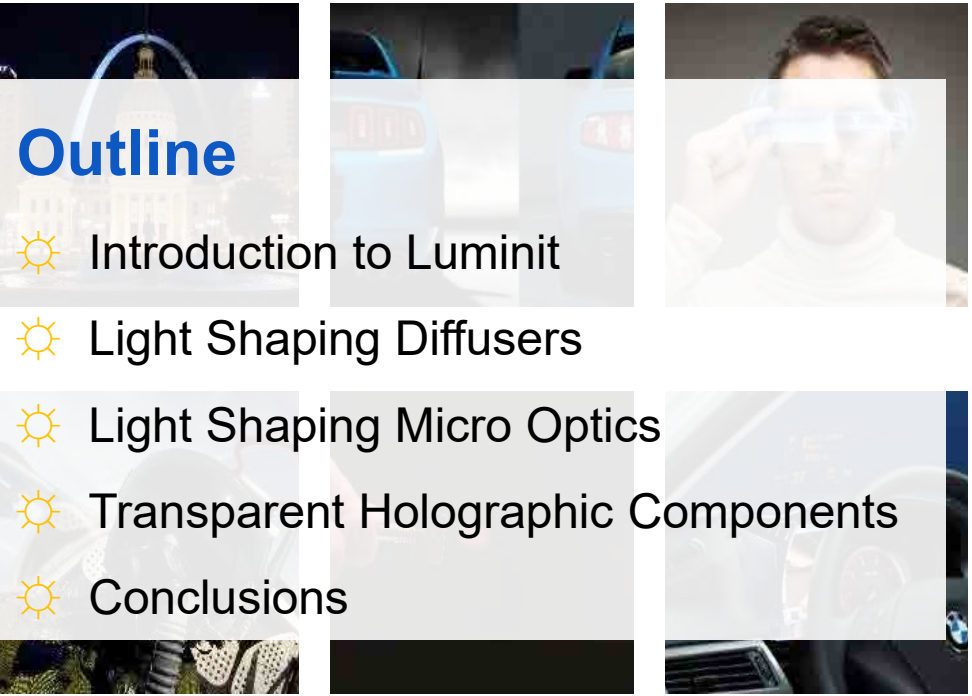
Luminit®
SHAPING LIGHT AS NEEDED





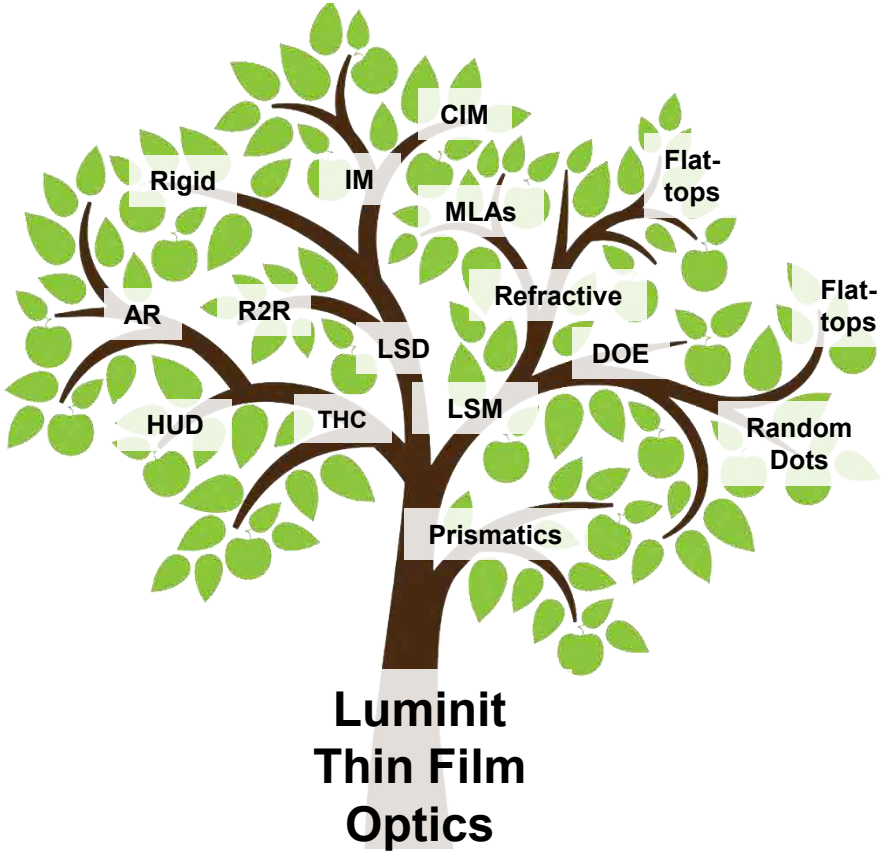



Next-Generation Optics for the Display and Lighting Industries



Outline

- Introduction to Luminit
- Light Shaping Diffusers
- Light Shaping Micro Optics
- Transparent Holographic Components
- Conclusions

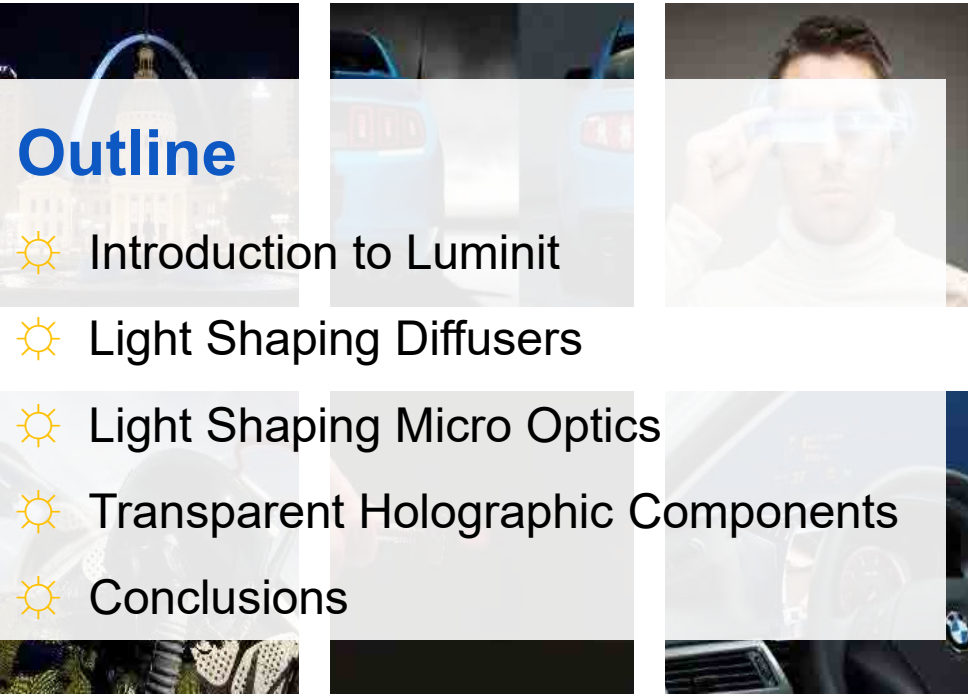


Luminit's Background

Spun out of Physical Optics Corp in 2006, Luminit is a global provider of innovative light management solutions for the lighting, display, automotive, aerospace, biomedical, and machine vision industries.

- Privately held, profitable business
- >$100M in cumulative revenue
- ~100 employees, US manufacturing
- Diversity in both customers and markets
- Differentiated high performance product
- Holography is our core technology

"Luminit wants to solve your most challenging light management problems!"



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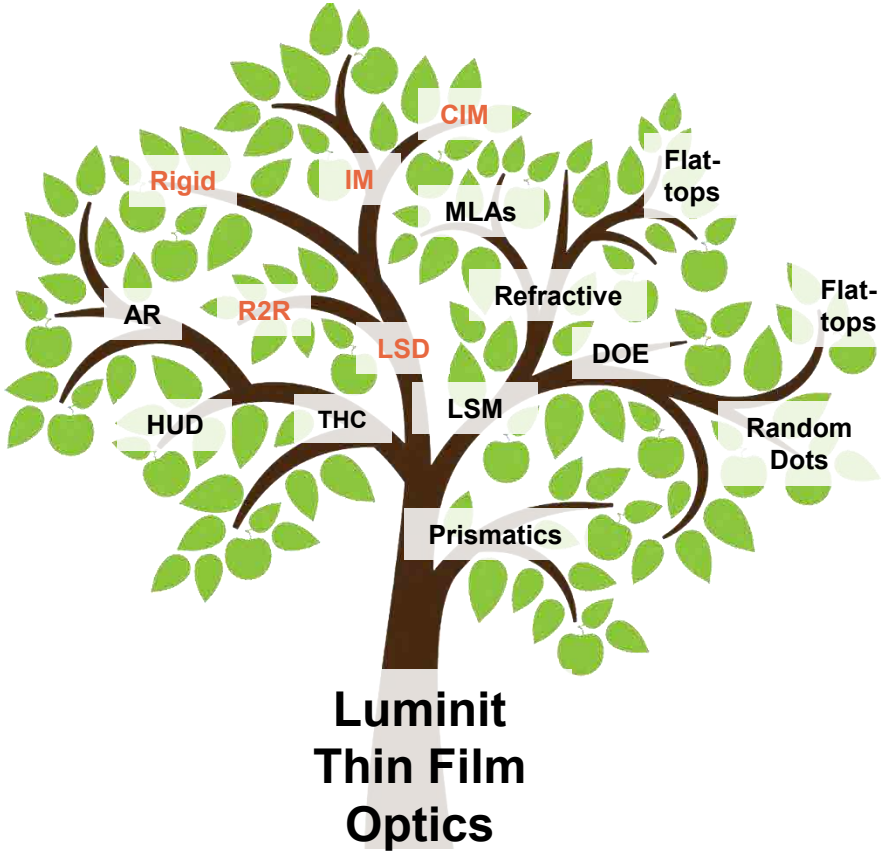


The Need for Diffuse Light

- The need for diffuse lighting has always existed
- LED point sources made it a more valuable point of differentiation.

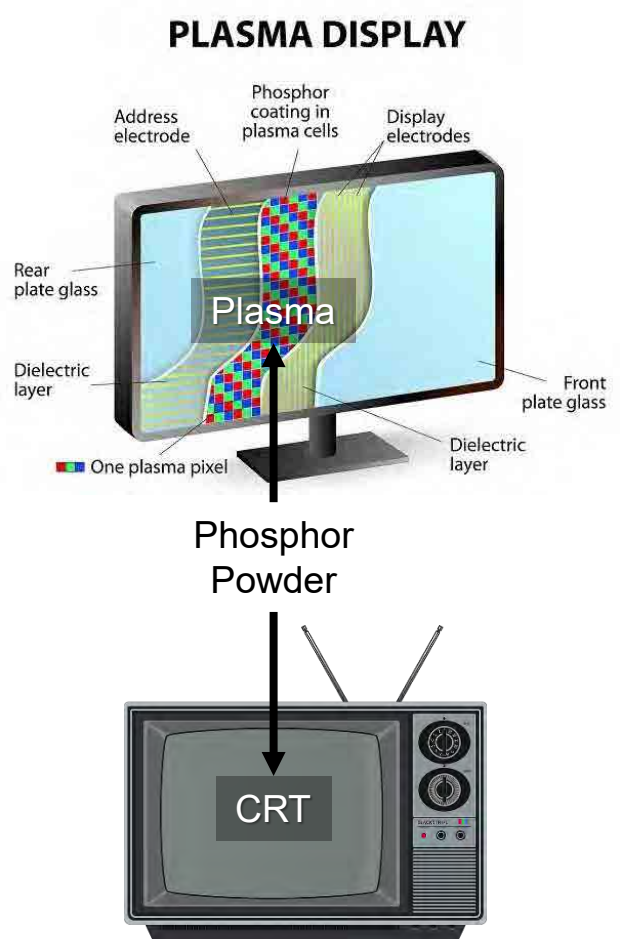
Ground Glass

Phosphor Powder

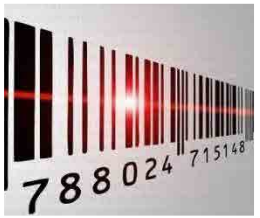
Light Shaping Diffuser

The Need for Diffuse Light – in Displays

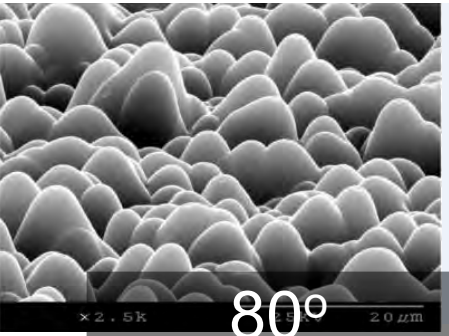
- The need for diffuse displays has always existed.
- LCD backlights made it a necessary and separate component.



Light Shaping Diffusers (LSDs®) Enhance and Improve Light Sources



LSD Diffuses Light in a Single Pass

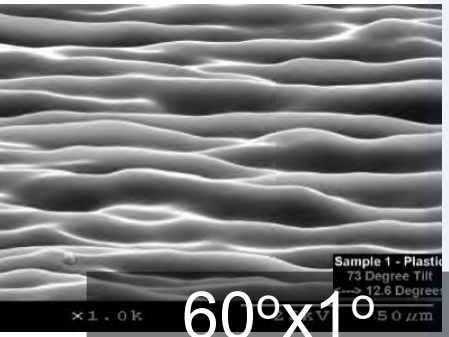


80°

Mimic Diffuser Function with Surface Relief

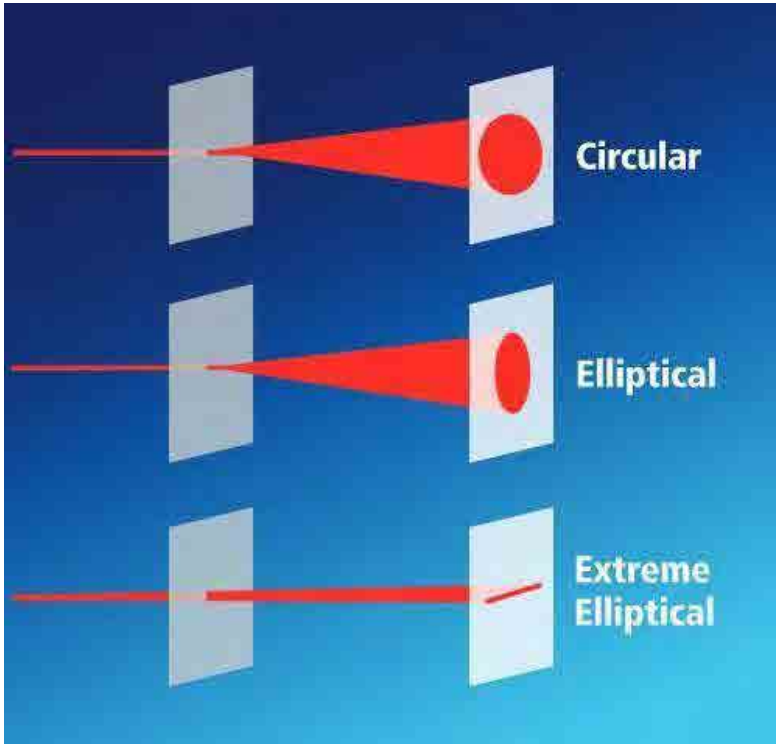
Light is refracted by lenslets

- All light goes ‘forward’
- Transmission >>90%



60°x1°

- No loss from scattering sites
- No wavelength dependence
- Gaussian output profiles



LSD Is Manufactured by Four Methodologies

1. Hand Replication

- Low volume, custom, development

2. Roll to Roll

- High volume, thin film, largest area

3. Sheet to Sheet

- Rigid parts, LCD fab-like capacity

4. Injection Molding

- Highest volume, small 3D parts
- Monolithic plastic

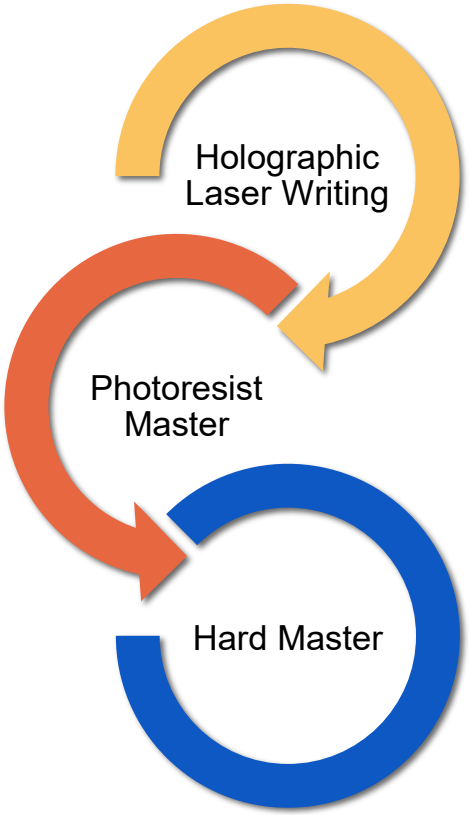
All Manufacturing Methods Start with Seamless Holographic Mastering

What Is Holographic Mastering?

High Volume replication requires creation of an original ‘master’ pattern on a hard surface.

Luminit creates these masters at very large area with very low cost using our patented Holographic Recording:

- Interference of multiple optical wavefronts creates pseudo-random intensity profile
- Intensity profile is mapped into surface relief
- Spot size can be <1mm or >>1cm
- Can use conventional optics to ‘stretch’ pattern
  - Symmetrical or asymmetrical
  - Fine grain or coarse grain
- Directly written onto large area, and even curved, surfaces



LSD Outperforms All Other Diffuser Technologies

Attribute	Bulk Diffuser	Mechanically Roughened	Light Shaping Diffuser®
Circular Small Angle			
Circular Large Angle			
Elliptical Diffuser			
Transmission			
High Temperature			
Hiding Power			
Price			

Lighting Case Study

Challenge

A school district converted to LED lighting in all classrooms; however, students were being blinded by the glare on their tablets and glossy text book pages.

Solution

Medium spread LSD that widened the beam and significantly reduced the glare.

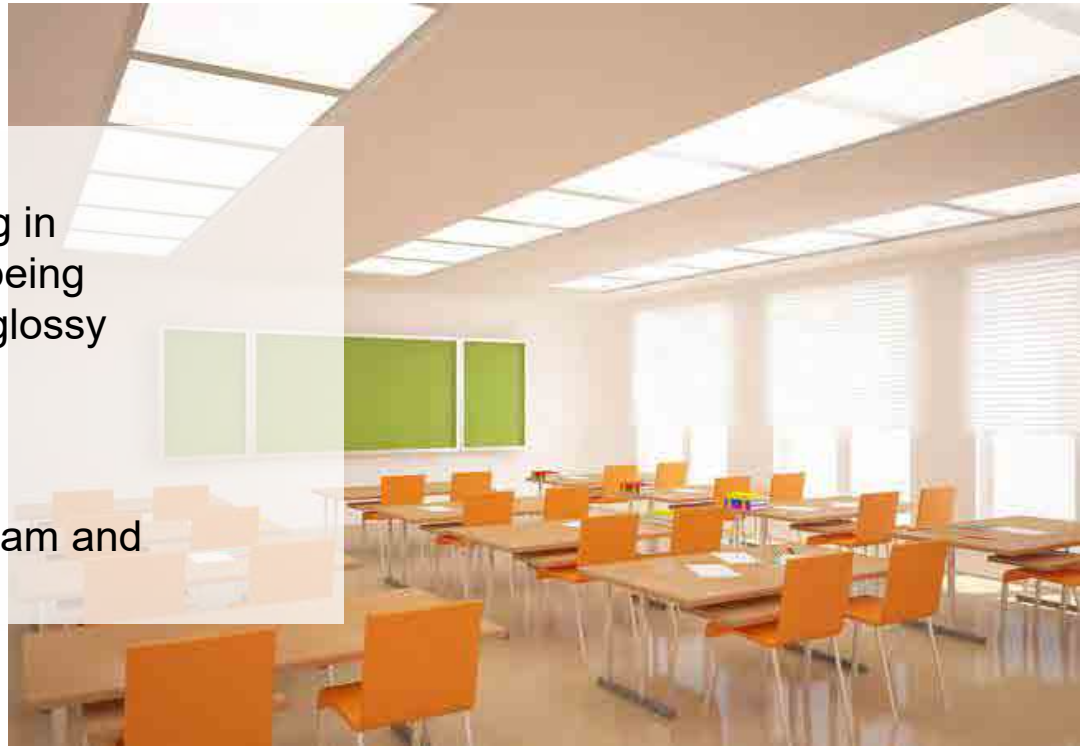
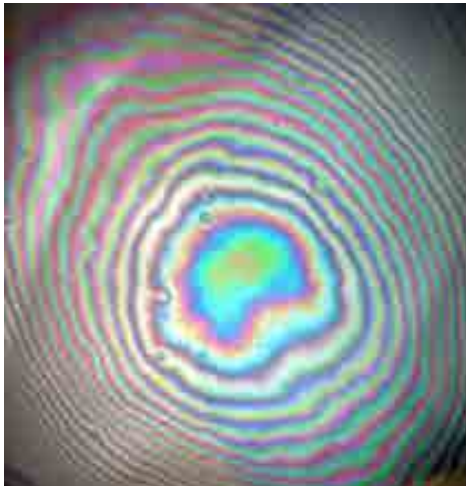


Photo Courtesy of Acuity Brands

Display Case Study



Challenge

Newton Rings or “wetting” effect on LCD displays caused by a micron-sized gap between two glossy surfaces (plastic film and the glass).

Solution

A double-sided thin film LSD. One had a large beam angle to homogenize the LED array. The other side had a small beam angle to prevent optical wetting to other materials in the optical stack.

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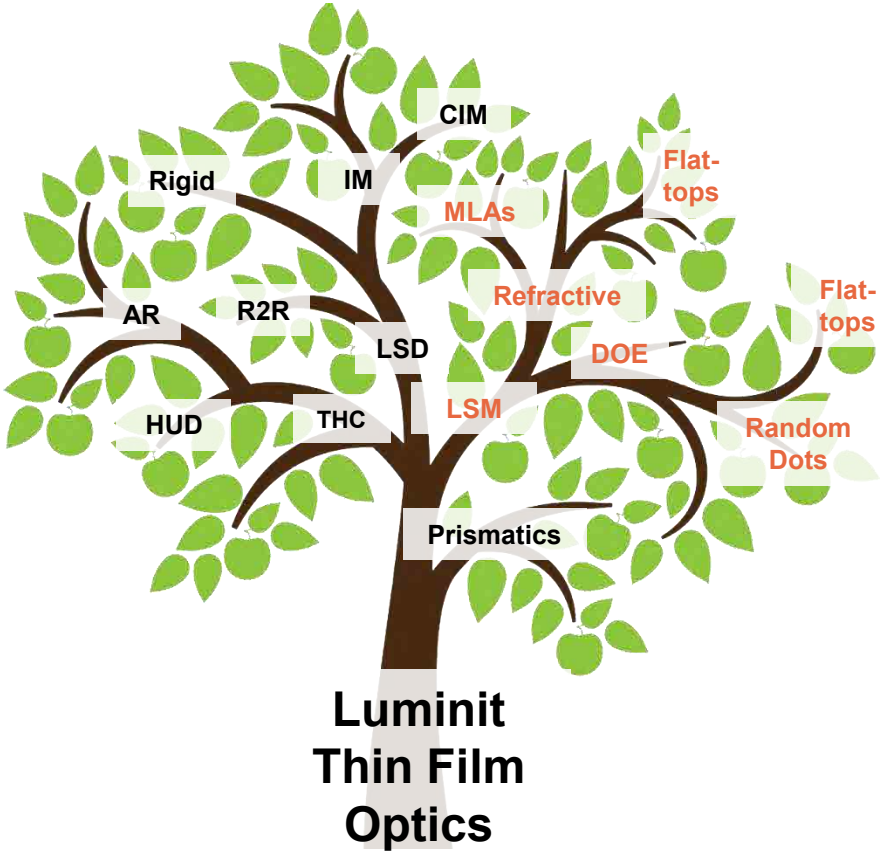
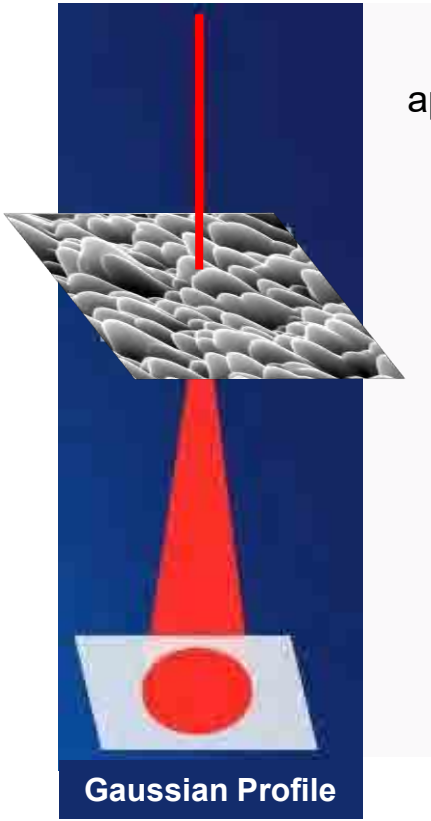


Light Shaping Is More than Just Gaussian Profiles

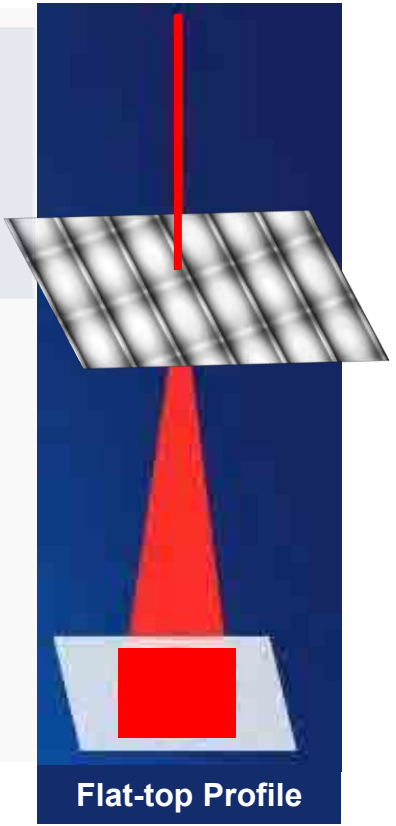


New applications require modified intensity profiles:

- Flat-top Diffusers
- Random Dots
- Grid Arrays
- Focusing Power
- Logo Projection

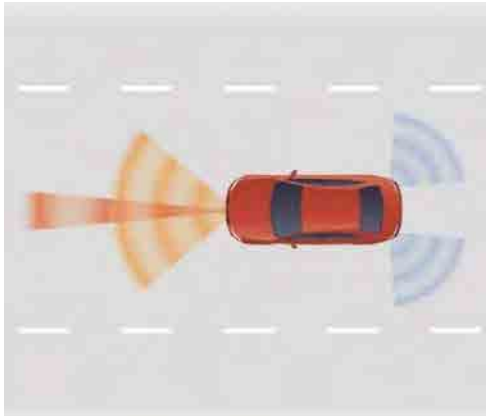
How can we extend our capabilities to serve broader markets and leverage our core competencies?
Design surfaces in x, y, z

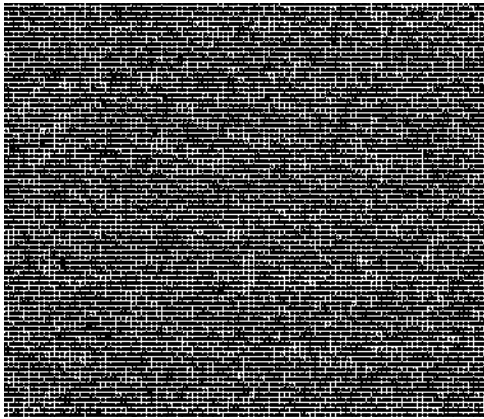
Light Shaping Microoptics (LSM)

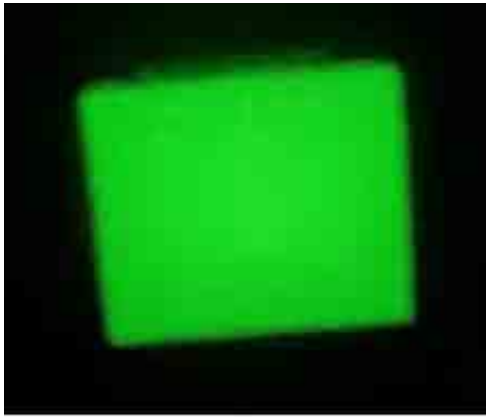


LSM Applications

LIDAR	Branding Projection	Facial Recognition
Iris Recognition	Time of Flight	Hand Tracking
Beam Shaping	Structured Lighting	3D Sensing

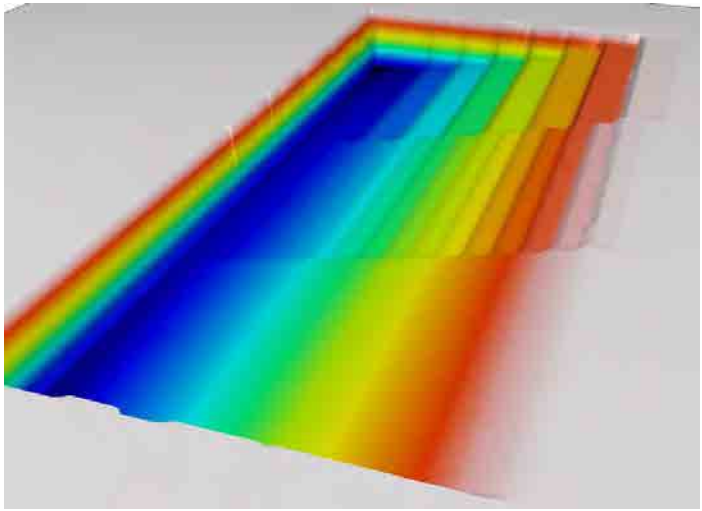






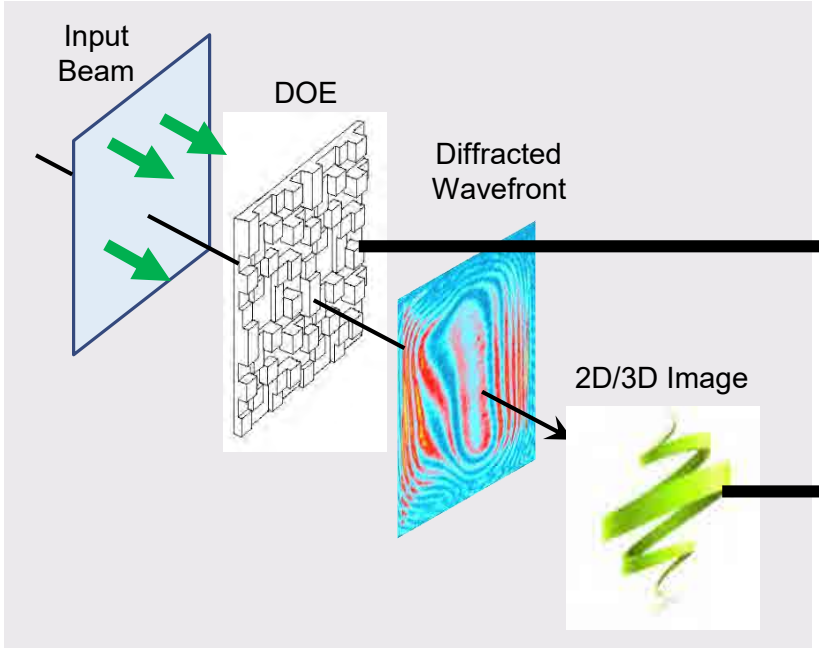
LSM Solution – Direct Laser Writing

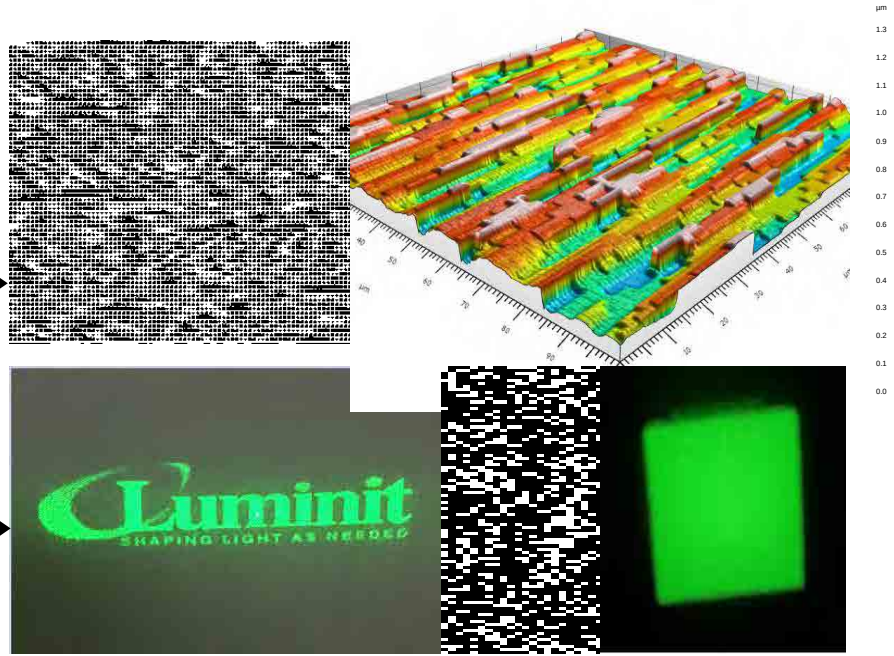
Identical materials, processing, equipment to LSD except for the laser writing step.
Rastering x, y position (20nm step size) while varying laser dosage to achieve z height.
Slower than holographic mastering, still orders of magnitude faster than other methods.



Greyscale Laser Writing → Photoresist Master → Hard Master

Diffractive Optical Elements (DOEs)





Branding, Structured Lighting, Flat-top diffusers

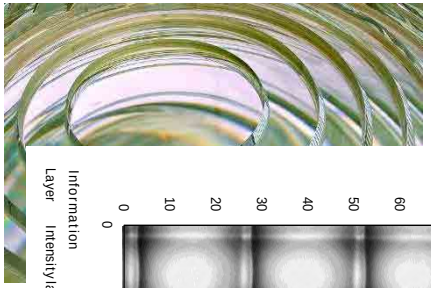
Refractive Optics

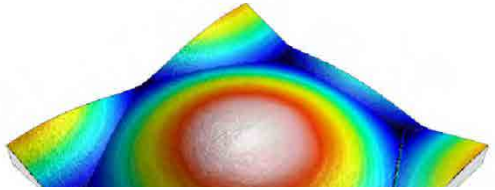
Structures such as:

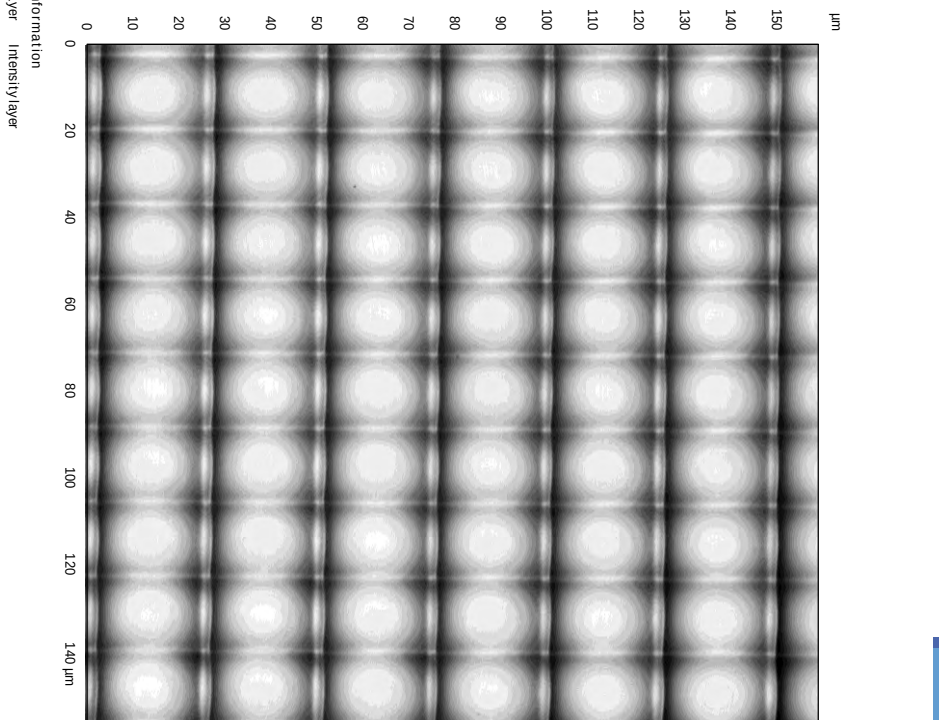
- Multi-lens Arrays
- Fresnel Lenses
- Prismatics

Serving applications such as:

- Flat-top diffusers
- Holographic displays
- LED Collimators
- VCSEL Collimators
- LIDAR



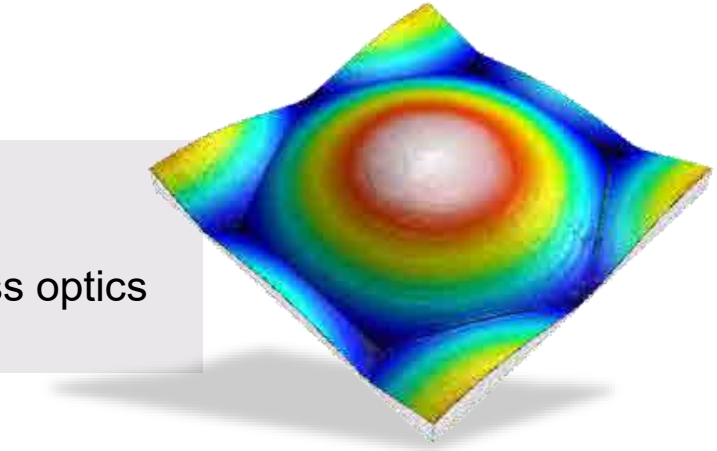




LSM Outperforms All Other Mastering Technologies

Attribute	E-Beam	Diamond Turning	LSM
Feature Size			
Throughput			
Area			
Write Speed			
Works with Roll-to-Roll			
Works w/ Sheet to Sheet			
Price			

LSM Case Study

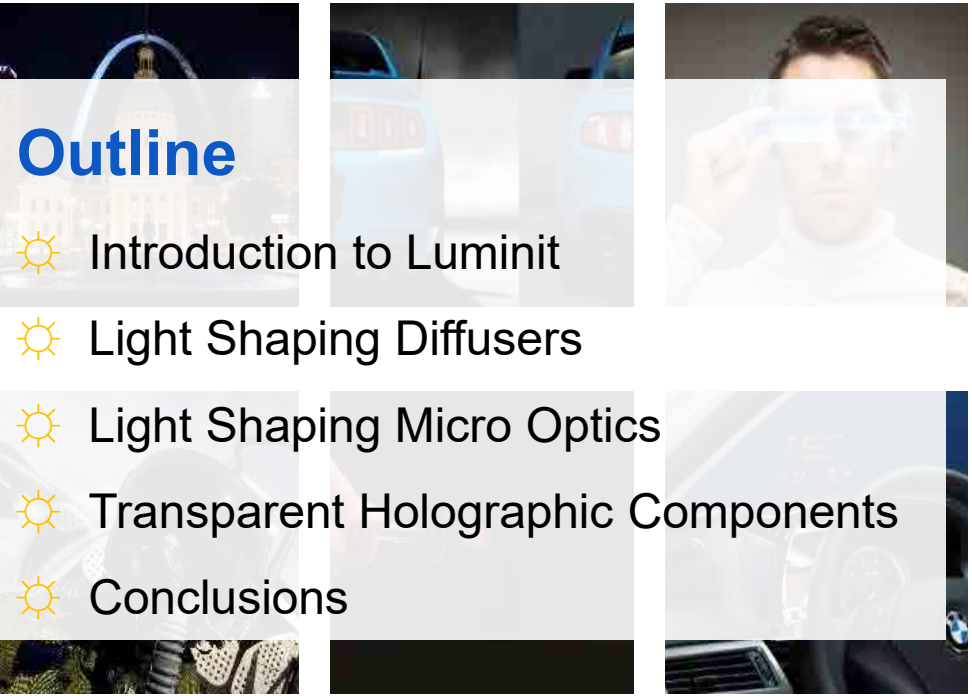


Challenge

A holographic display company wants to move from glass optics in demos to cost-effective volume production.

Solution

LSM large-area mastering, combined with Luminit's high volume sheet-to-sheet and roll-to-roll production, allow conversion to plastic optics that meet cost targets, while maintaining or improving on specification and performance.



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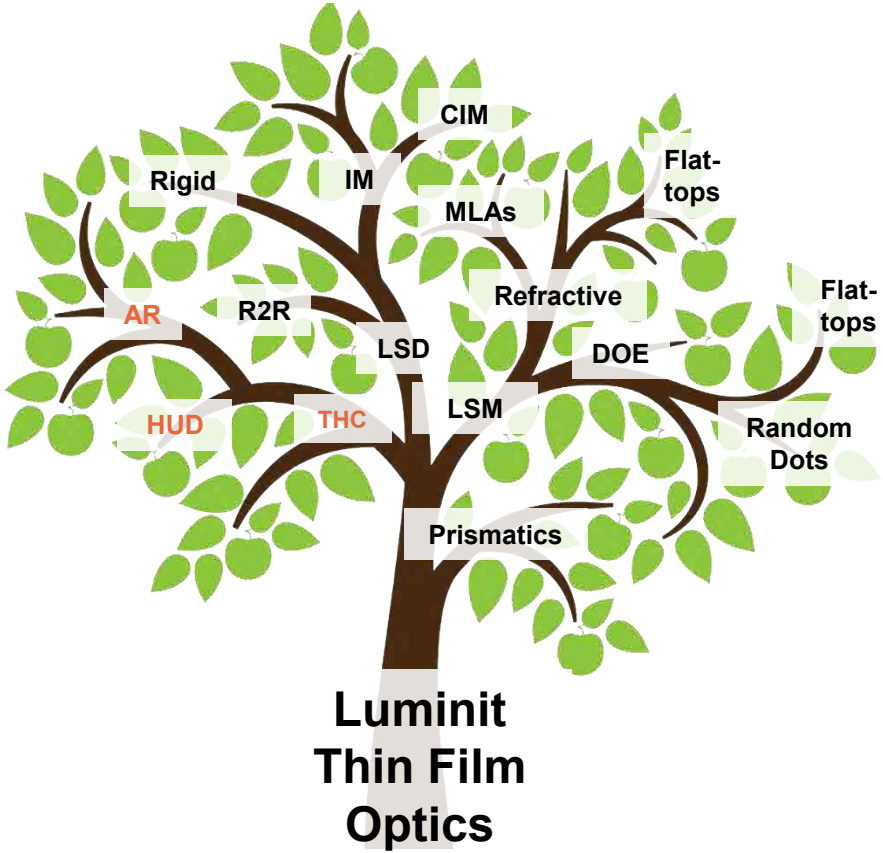


Light Shaping Can't Always Tolerate Haze – See-Through Optics

Augmented Reality, Smart Glasses, and Head-Up Displays require truly transparent optics:

- Need unobstructed view of reality
- Conventional optics too bulky
- Surface relief micro-optics too hazy
- Nano-optics too costly to manufacture at consumer volumes or prices

Requires a diffractive optic with lower index contrast and higher thickness

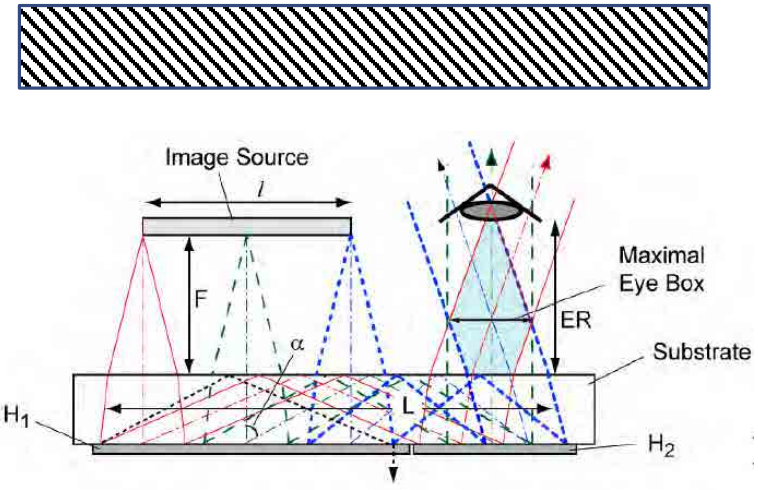
Solution

Transparent Holographic Components (THC)

Photo courtesy of REYDER

THCs Are Volumetric, Index Modulated, Polymer Films

Periodic index modulation(s) creates distributed Bragg gratings.



One example of a waveguide design using THC.

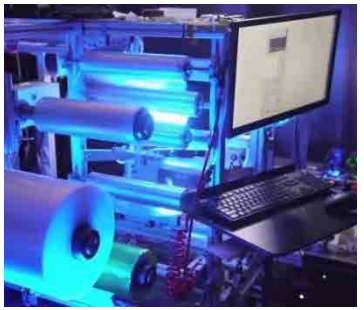
- No surface relief
- Highly efficient Holographic Optical Elements direct light beams without the need for conventional optics
- Recorded on thin (10-30 micron) holographic photopolymer film
- The holograms have thick Bragg properties that are wavelength and angle selective
- Very low scattering, low haze
- Transparency above 90%
- Diffraction efficiency above 90% at peak
- Can form linear gratings
- Can form ‘lenses’ with optical power

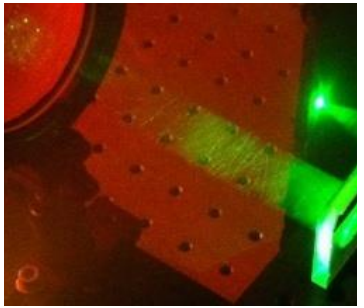
THC Has the Best Trade-offs

+ High transparency with high efficiency (diffractive)
+ Thin (10's of micron active layer) and lightweight
+ Thermoformable – photopolymer based
+ Roll-to-roll manufacturable
+ RGB performance in a single component/layer

Transparent Holographic Components (THCs) from **Luminit** address these problems

- Requires expensive tools/lasers
- Requires extensive customization
- No manufacturing capacity in the world





How To: Master with Two Beams → Replicate with One

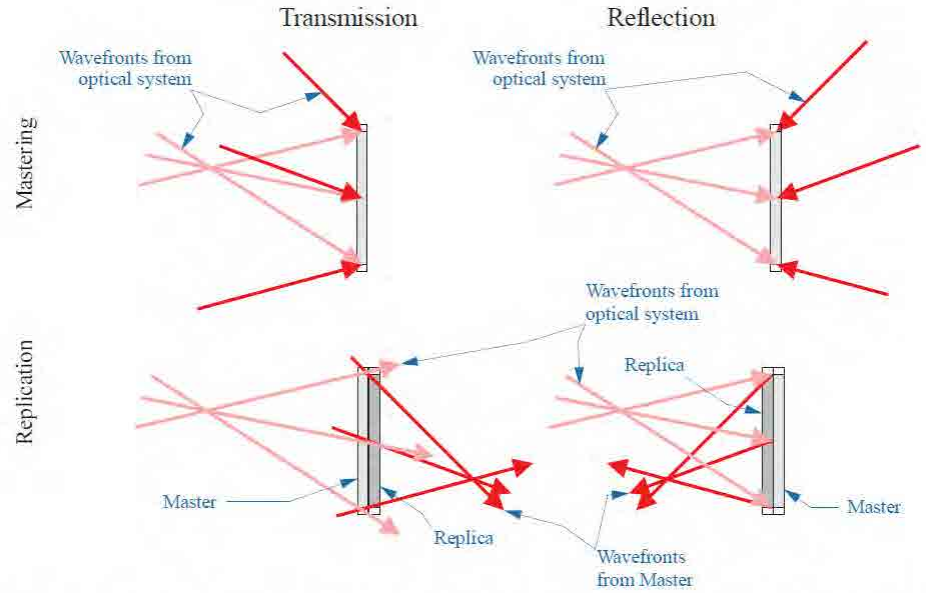


Figure 9. Mastering (top) and replication (bottom) shown for transmission (left) and reflection (right) hologram manufacturing. The interference pattern is provided by the overlap of two wavefronts in both cases.

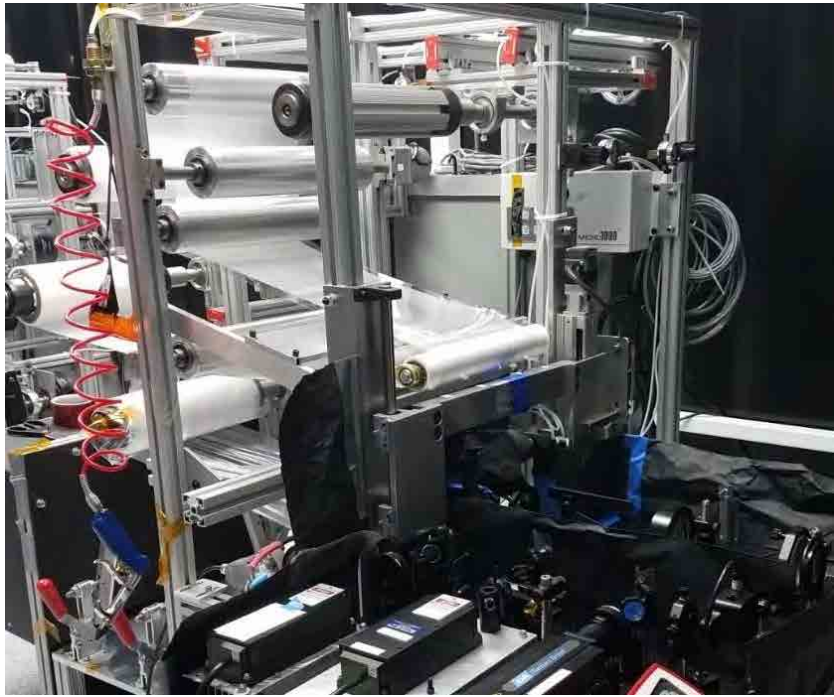
- Replication allows for lower cost, less vibration sensitive, rapid recording of optical copies of a pristine master.
- Replication is compatible with roll-to-roll manufacturing techniques.
- Only Luminit has installed and operating capacity of roll-to-roll holographic replication machines.

Active material ‘learns’ the function you write into it.

THC Mass Production

- Worldwide capability to mass produce volume HOEs was negligible until today
- Luminit is currently manufacturing THCs to meet AR industry's needs:
  - Current capacity 50,000 AR units/mo.
  - Mfg. Plan to support >5M units/year
- R2R thermal and optical post-processing
- R2R in-line barcoding and inspection

Combined expertise in roll-to-roll manufacturing and holography are required.



THC Outperforms All Other Combiner Technologies

Attribute	SRG (WG)	H-PDLC (WG)	THC (Reflective)
Eyebox			
Efficiency			
RGB (1-layer)			
Thinness			
Roll-to-Roll Mfg			
Curvable			
Color Shift			
Price Potential			

But we could also compare FoV, large-area compatible, stray light reflections, etc.

Case-study – Miko-san

Challenge

A man wants to marry a virtual human.

OR

Need a transparent, efficient diffusor screen to form real images on, for the personal digital assistant market.

Solution

Match.com

OR

We record an image of LSD into THC. This renders a diffuser effect for on-wavelength, on-angle light, while being largely transparent for all other photons.

Note: Gatebox does not use THC.

Case-study – Auto-HUD Volume Reduction

Challenge

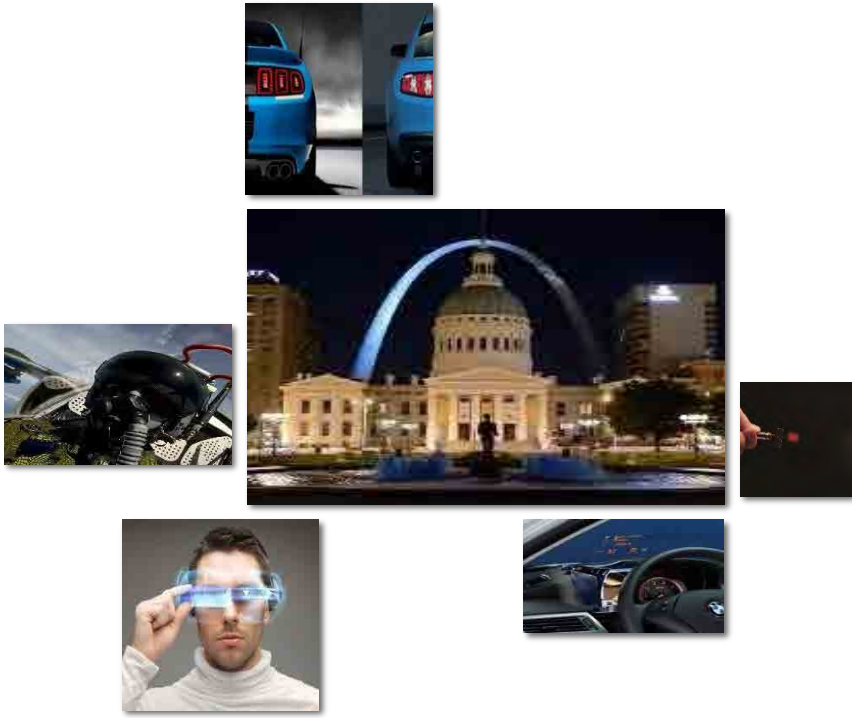
Current Auto-HUD is low efficiency, low FoV, and high-volume – need a highly transparent, highly efficient combiner that can be large-area.

Solution

We are exploring design options with various Tier 1 automotive partners to put THC 1) in the windshield, 2) as a separate combiner, or 3) as an under-dash component, with different trade-offs in volume vs efficiency, eyebox, and supply-chain complexity. In the case of #1, volume is reduced to <1.5 liters.

Conclusions

- **Light Shaping Diffuser** is an industry standard wherever Gaussian light distribution is required
- Where more detailed control over light shaping is required, **Light Shaping Micro-optics** are now available
- **Transparent Holographic Components** are appearing on the market now in Augmented Reality applications and wherever high transparency is a requirement
- Come talk to us about your unique thin-optic challenges!



Any Questions?

Thank you for your time!

www.luminitco.com
www.luminitholography.com