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Holography Group Leader
Research and Development

Light Shaping Diffusers for OLED Light Extraction

U.S. DOE SSL Workshop
2018-01-30 Nashville, Tennessee






Outline

- Luminit's Background
  - **Luminit Growth Businesses**
- OLED Light Extraction: Motivation
- LESO: Light Extraction System for OLED
  - Team
  - Description
  - Introduction to LSD
  - Manufacturing
- Conclusions






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Company Background

Growth businesses within Luminit

LUMINIT'S BACKGROUND

Luminit's Background

Founded 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 small business
- 80+ employees, U.S. manufacturing
- Diversity in both customers and market segments
- Differentiated high performance product
- Holography is our core technology

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Luminit Growth Businesses

- LSD → Growth in LED lighting and as Photonics finds new applications (OLED, LIDAR, ToF sensors)
- Government contracts → Advanced Technology development with USG and Prime Contractors
- 3D-Curved Injection Molding (of LSD)
  - Automotive interior and exterior lighting
  - Working with innovative OEMs and Tier 1 suppliers world-wide
- Crystal Screens (Reflective LSD)
  - Pro A/V, CEDIA, and Cinema Markets
  - Partnership model to address Asian (high growth) cinema market
- Transparent Holographic Components
  - Deep pipeline of direct-sales customers
  - Automotive HUD and Consumer Electronic Augmented Reality Markets

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OLED Light Extraction: Motivation

- OLED devices have great potential for large-area extended light sources luminaire applications that are flexible in construction and operation.
- OLED internal quantum efficiency can reach near 100%
- The external quantum efficiency limited to 20-40% hampered by low extraction efficiencies due to waveguiding and trapping of the light that either gets reabsorbed or exits the device in directions other than viewing.

Program Info

Team

Holography for Lighting and Displays

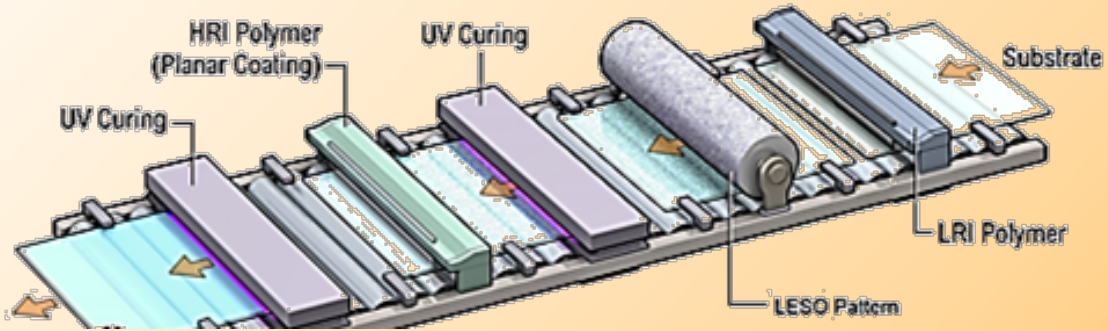
LSD Introduction and Metrics

Results

Manufacturing

Conclusions

LESO



LESO: Light Extraction System for OLED

Luminit, LLC | 1850 West 205th Street, Torrance, CA 90501-1526

Topic/Subtopic: **DOE 2017 R2 10b. Innovations in Solid-State Lighting for Buildings**

Principal Investigator: **Dr. Juan Russo**

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LESO: Phase I Team

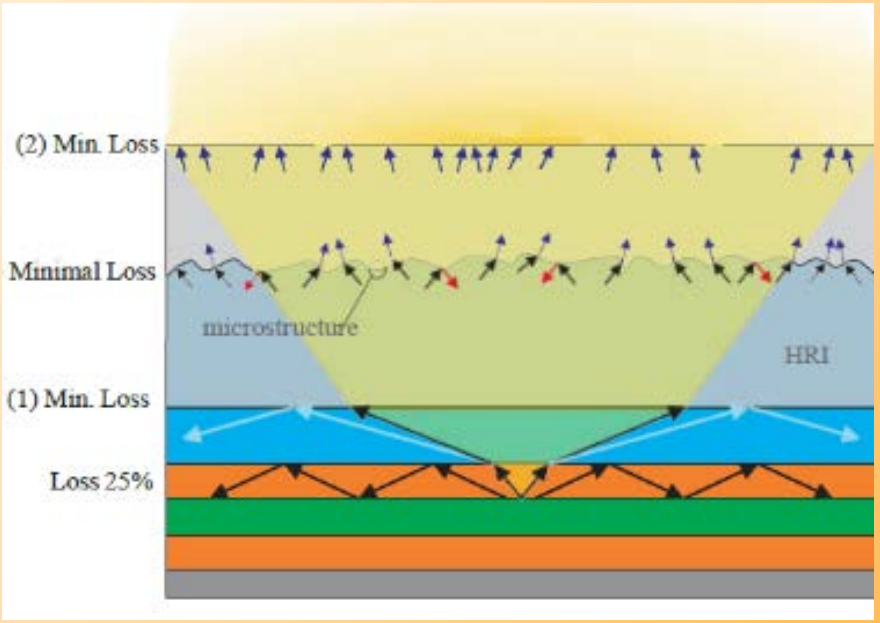
Dr. Juan M. Russo, **Research Scientist (PI)**, is the leader of holographic optical development within Luminit. He received his Ph.D. in Electrical and Computer Engineering from the University of Arizona, Tucson, AZ. He worked as a researcher at Prism Solar Tech., Inc. where he developed holographic optical elements both for energy collection and illumination. Dr. Russo's recent achievements include photopolymers nanocomposites with silica and titania nanoparticles. His research has also been focused on manufacturability. Dr. Russo is a Panamanian and Italian citizen, and a U.S. Permanent Resident.

Matthew Stevenson, Sr. Optoelectronic Engineer, received his M.S. in Materials Engineering from the University of California, Santa Barbara. His professional career has centered on the development of novel emissive technologies for displays, including polymer organic light emitting diode displays at DuPont Displays and both electro- and photo-luminescent quantum dots for display applications at QD Vision. Mr. Stevenson is a U.S. citizen.

Mr. Anthony Ang, Mastering Manager, will bring to the project expertise in statistical modeling and fabrication of diffuser characteristics to improve the targeted angular specifications for beam shaping and light extraction. Specifically, he will be responsible for the modeling of the microstructure light extraction capabilities to maximize light utilization. Mr. Ang is a U.S. citizen.

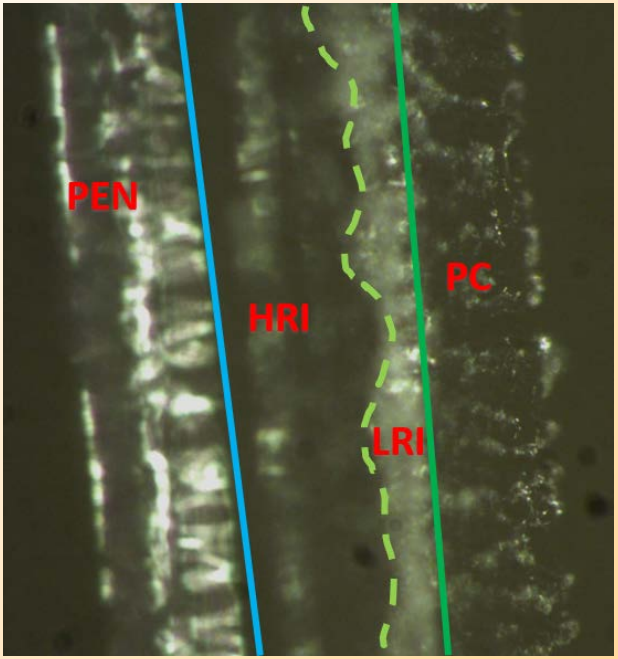
LESO: Luminit's Solution

- Advanced surface structure that increases light extraction in OLEDs
- Surface patterning in the interface between high and low refractive index layers
- Reduces the waveguide losses using resins

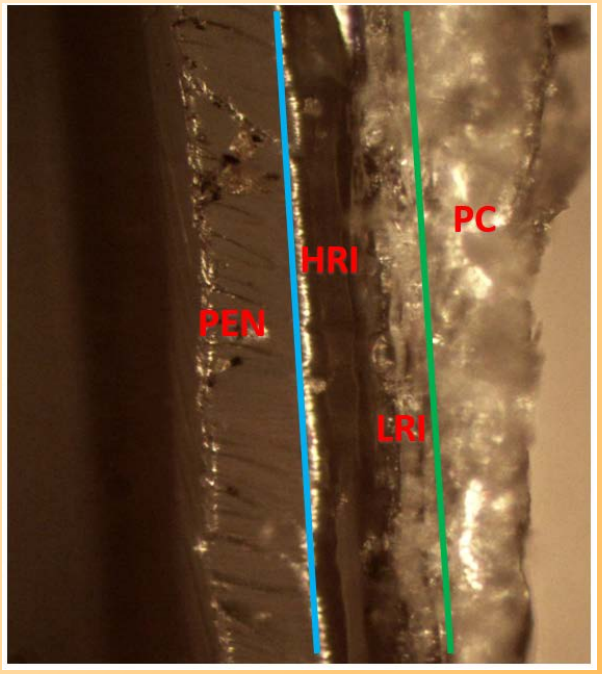


Compatible with Luminit's ISO certified diffuser manufacturing line

LESO Stack



0.5 deg LSD



100 deg LSD

Optical microscope 10x

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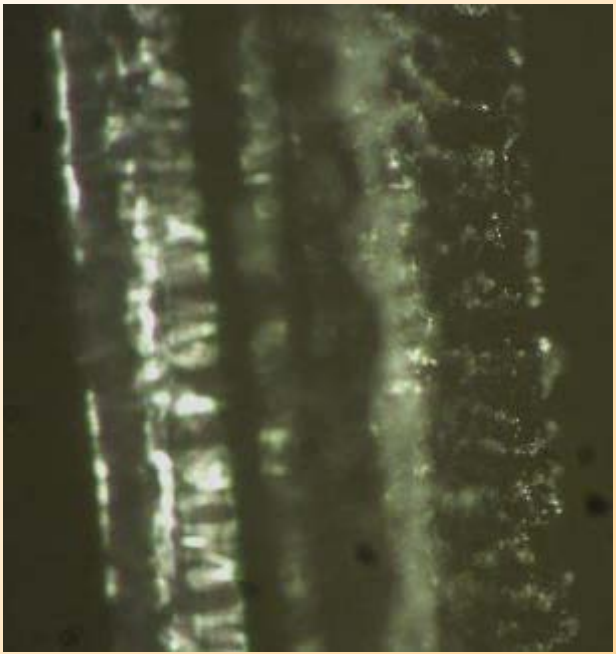
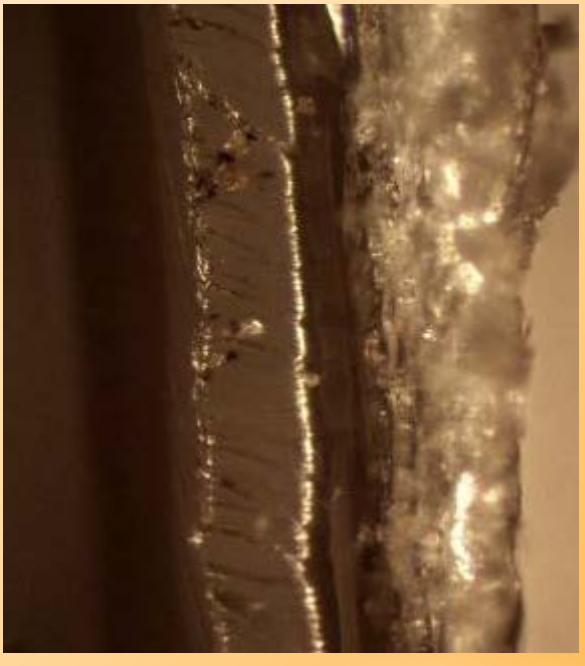
LESO Stack



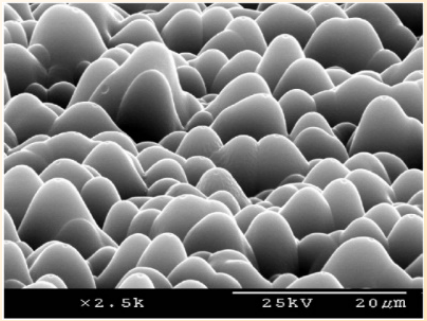
0.5 deg LSD



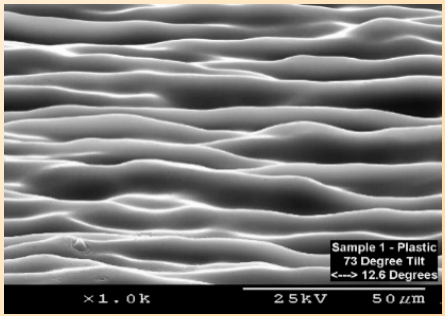
100 deg LSD

Optical microscope 10x

Holography for Lighting and Displays



80^0



$60x1^0$

Light Shaping Diffuser (LSD)

Mimic Diffuser Function with Surface Relief

Holographic Recording:

- Creates pseudo-random pattern
- Can be symmetrical or asymmetrical

Surface Relief:

- No loss from scattering sites
- No particles = no wavelength dependence

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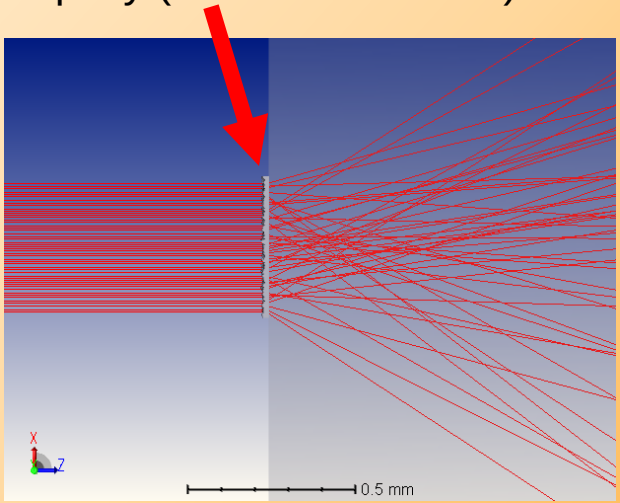
LSD: Definition of Diffuser Angle

- The Light Shaping Diffuser at Luminit consist of
  - An epoxy layer with an embedded surface relief pattern.
  - A substrate as a carrier for the epoxy.
- The surface relief pattern effectively acts to scatter the direction of the light such that the overall distribution is controlled to a specified envelope.
- The angular size of the envelope is known as the Full Width Half Maximum (fwhm) of the LSD, and is the primary functional specification of the product.

LESO: Introduction to LSD

- Measurement to determine the LSD Angle
- A collimated HeNe beam strikes the patterned side of the LSD first.

LSD = Epoxy (with surface relief) on PC



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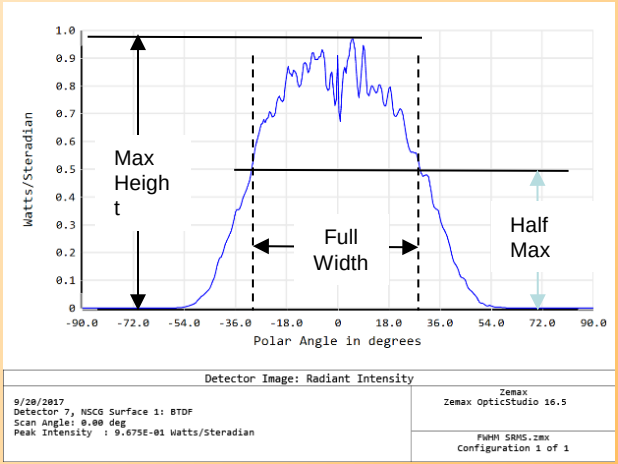
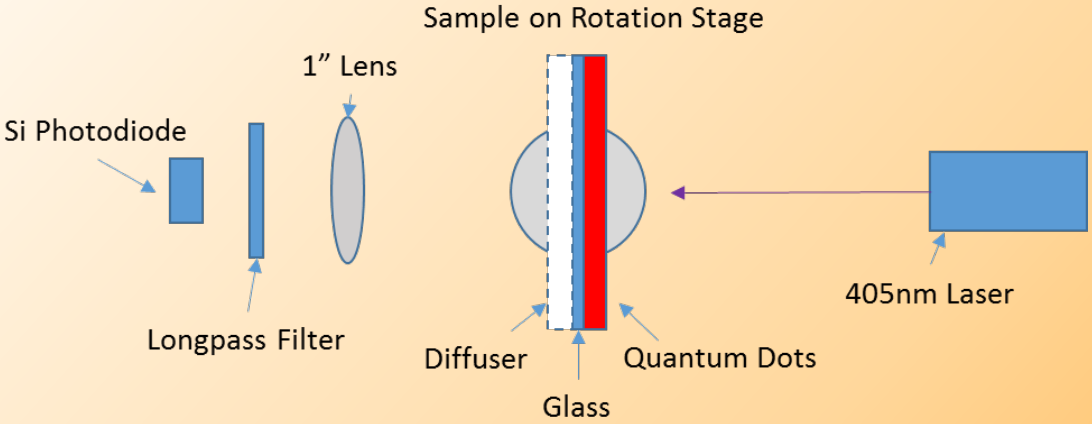
Light Transmitting through LSD

- To the right is the simulated output of a 60 deg LSD.
- The Goniometer captures the angular distribution of the scattered light.
- The software finds the maximum height of the profile.
- Then the width of the profile at half the maximum height is calculated.



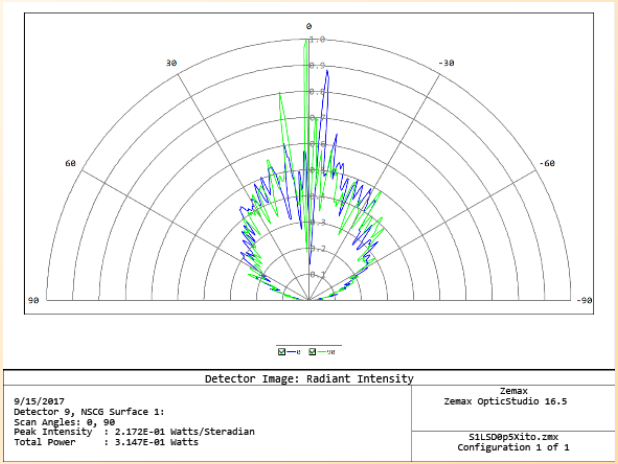
Preliminary Results

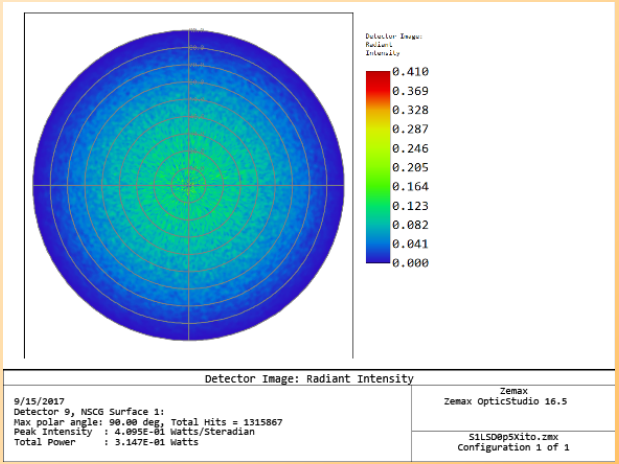


Up to 3.8x improvement of a QD photoluminescent layer

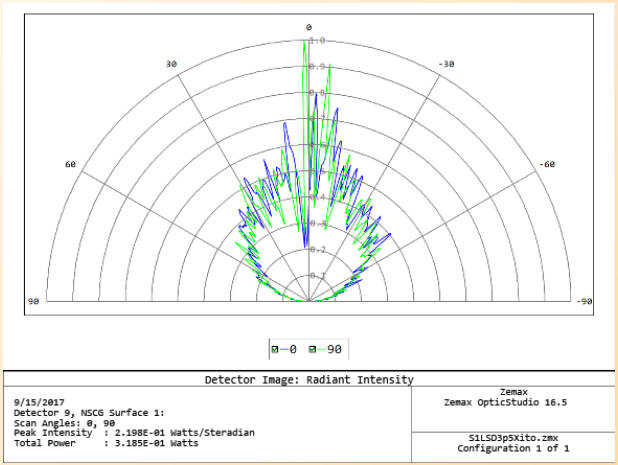
- As an external extraction layer
- QD device analogous to HRI/LRI (air) transition in OLED

Results
LSD 0 deg



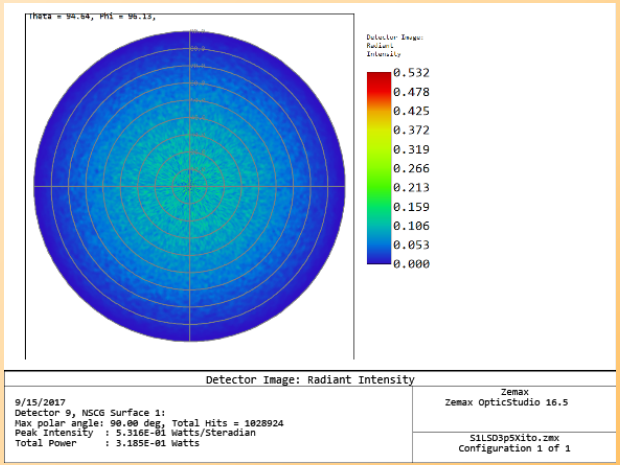


Results
LSD 3.5 deg



Detector Image: Radiant Intensity

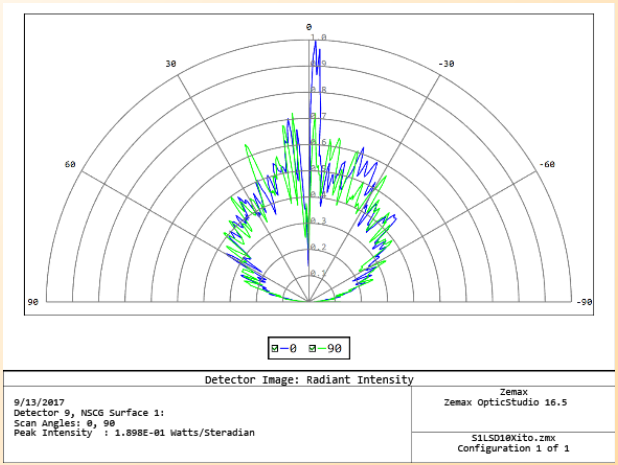
9/15/2017 Detector 9, NSC6 Surface 1: Scan Angles: 0, 90 Peak Intensity : 2.198E-01 Watts/Steradian Total Power : 3.185E-01 Watts	Zemax Zemax OpticStudio 16.5 S1LSD3p5Xito.zmx Configuration 1 of 1

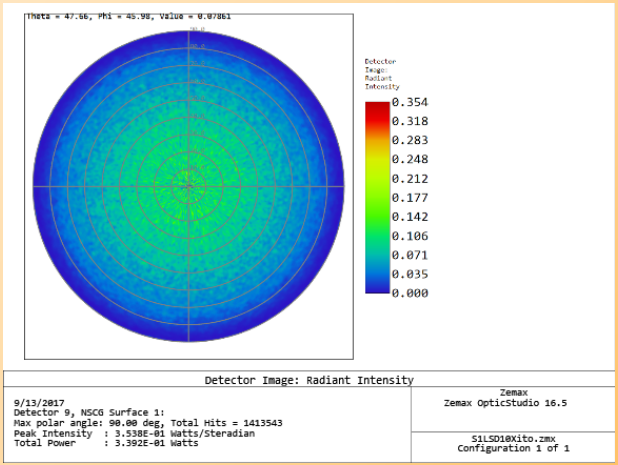


Detector Image: Radiant Intensity

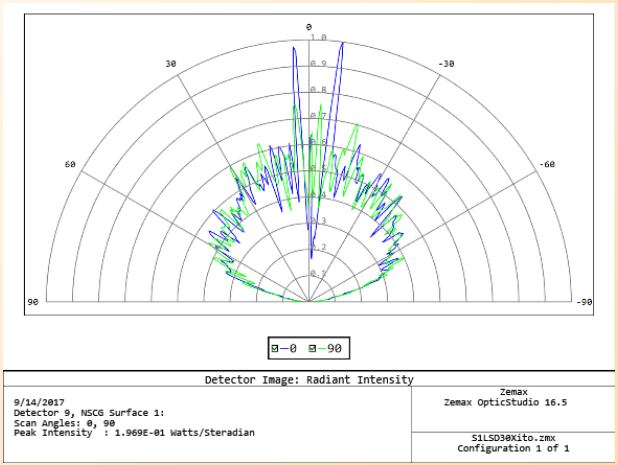
9/15/2017 Detector 9, NSC6 Surface 1: Max polar angle: 90.00 deg, Total Hits = 1028924 Peak Intensity : 5.316E-01 Watts/Steradian Total Power : 3.185E-01 Watts	Zemax Zemax OpticStudio 16.5 S1LSD3p5Xito.zmx Configuration 1 of 1

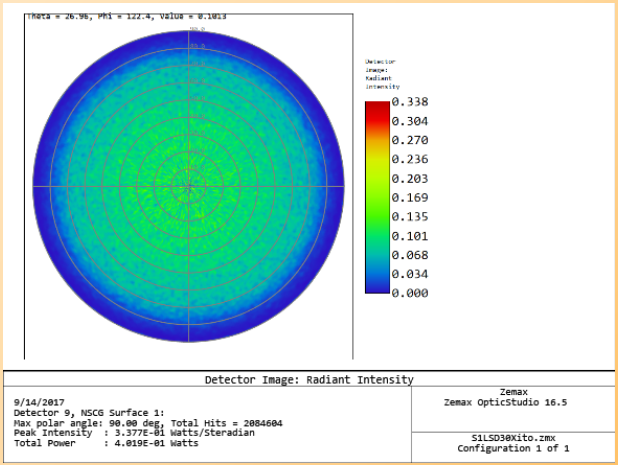
Results
LSD 10 deg



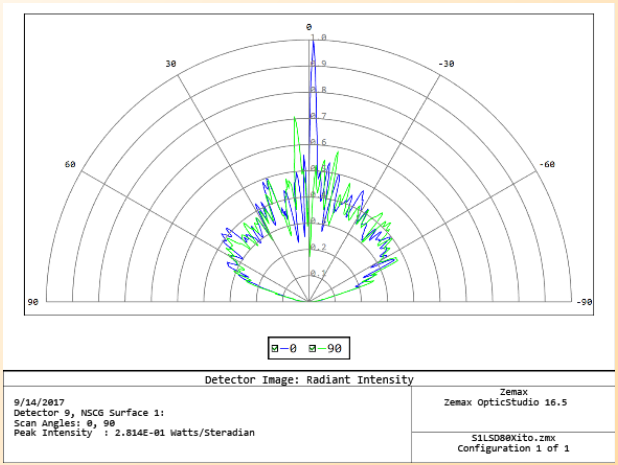


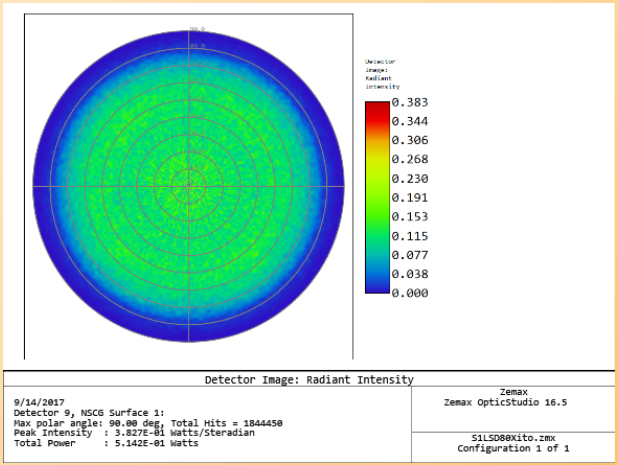
Results
LSD 30 deg



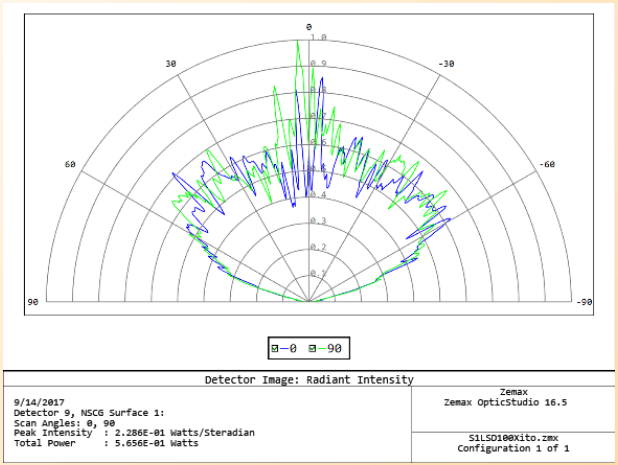


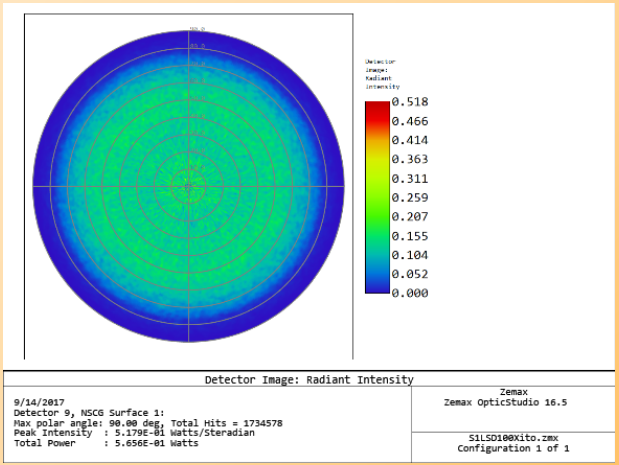
Results
LSD 80 deg





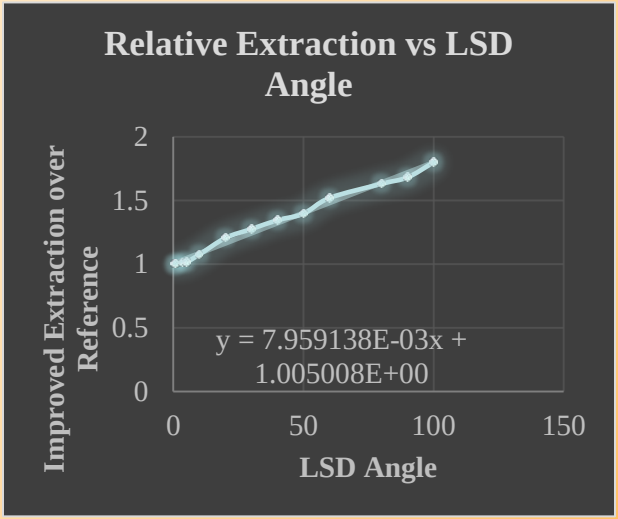
Results
LSD 100 deg





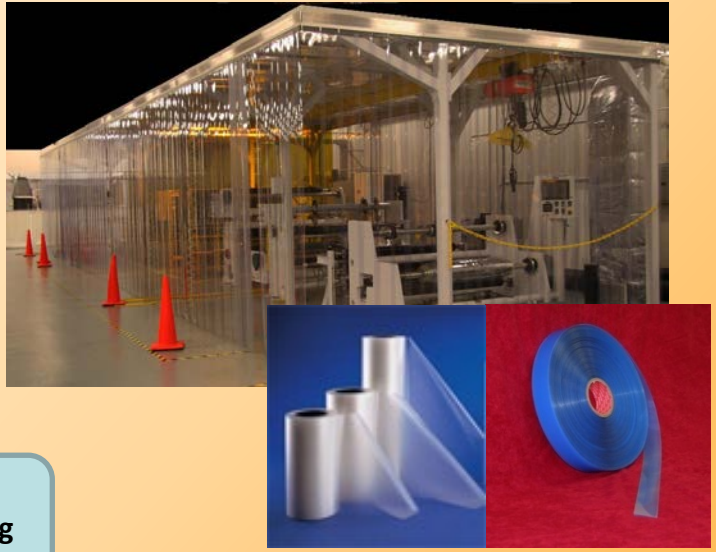
Results
Relative Light Extraction vs LSD Angle

- The amount of light extraction is fairly linear with the LSD angle.
- Approximately 80% more light is extracted with a 100 degree LSD vs no LSD pattern.



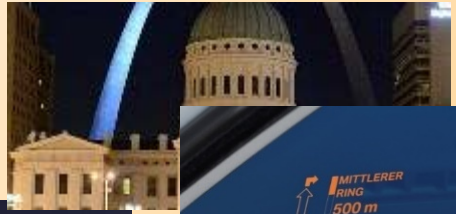
LSD is Manufactured by Four Methodologies

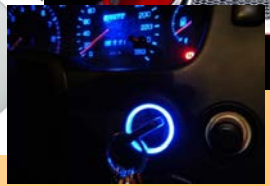
- Hand Replication
  - Low Volume, custom, development
- Roll-to-Roll
  - High volume, thin film, largest area
- Roll-to-Sheet
  - Rigid parts, LCD fab-like capacity
- Injection Molding
  - Highest volume, small 3D parts
  - Monolithic plastic



Shipping >100k linear ft/month R2R to LED lighting applications

Holography and LSD is Pervasive





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Conclusion Slide

- Market penetration benefit by increasing OLED light extraction
- Luminit makes LSD in the U.S. for LED lighting applications.
- LESO: Luminit uses LSD to improve OLED light extraction by 80%
- Luminit can manufacture in the U.S. to supply to OLED lighting and marginal additional cost increasing efficacy, reducing driving current (for same lumen output)
- LSD can also control uniformity and light utilization

Thank You!

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