Diffuse Thin-sheet Light Sources

Using LED-illuminated Waveguides

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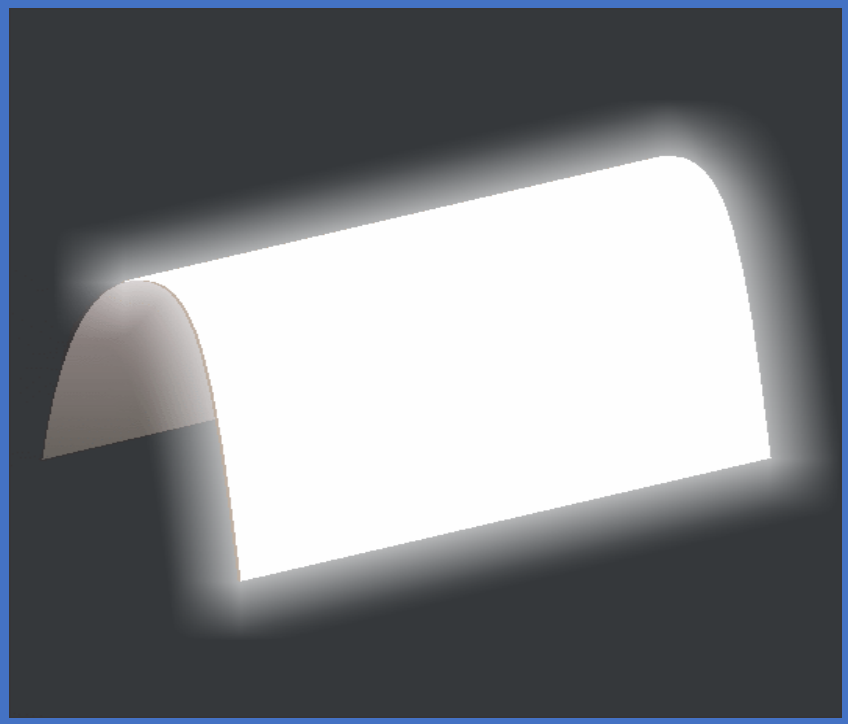
Thin & flexible wide-area light sources

- ✓ Highest levels of glare control
- ✓ Reduced complexity & raw materials intake
- ✓ Sustainable manufacturing with the lowest cost per luminaire's area ?
- ✓ Unique, previously unavailable form factor
- ✓ New luminaire design opportunities: superior aesthetics & visual differentiation
- ✓ Curved shapes, transparency, custom emission distribution
- ✓ New ways for building integration
  - Ceiling/walls/partitions, incl. curved surfaces
  - Furniture & interior design elements
  - Windows & daylighting integration?
  - Rollable & foldable light panels?



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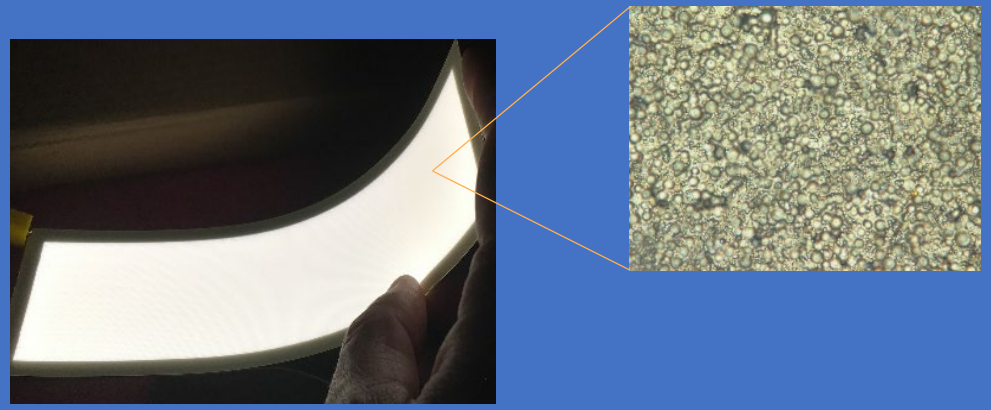
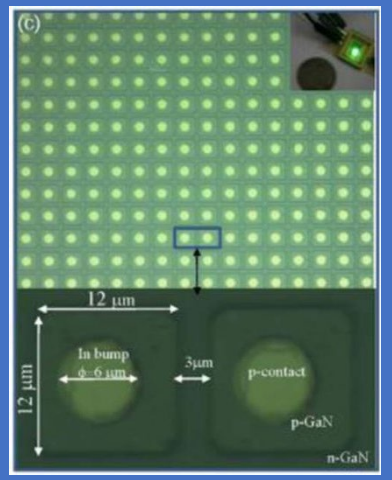
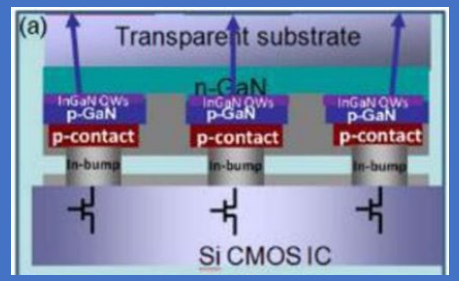
Thin & flexible wide-area light sources

OLEDs on film substrate



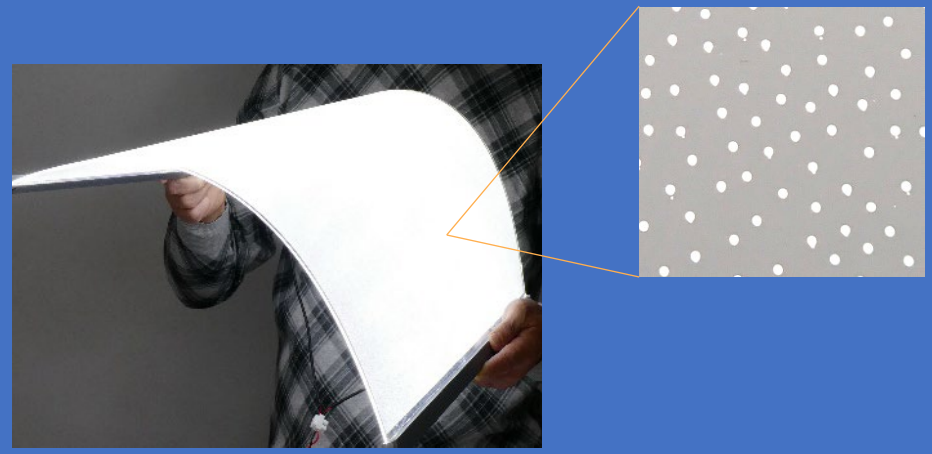
Micro LED array on flexible substrate





Jacob Day *et al.* Appl. Phys. Lett. **99**, 031116 (2011)

LEDs with flexible waveguide



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Lighting industry newcomer: ultra-thin LED waveguide panels

CoreGLO™ technology

inorganic LEDs

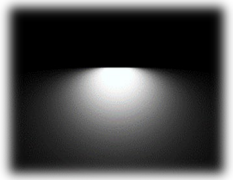
+

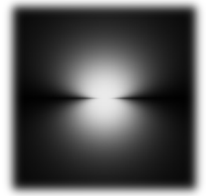
Thin/flexible substrate (optical waveguide)

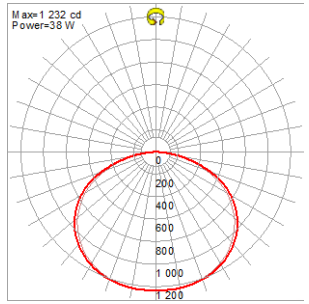
=

lighting panel

- ~1mm thickness
- Flexible with ~100mm bend radius
- Lambertian angular distribution
- Single-sided or two-sided output

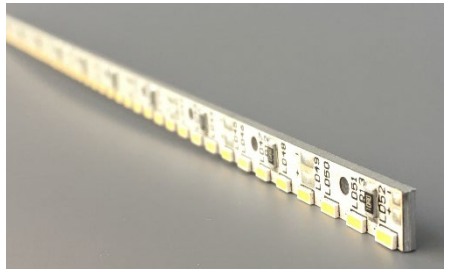






- ~90% emission uniformity
- 100-120 lm/W wall-plug efficacy (>160 lm/W next goal)

Low-profile LED engine



- Automated industrial manufacturing using common components
- Custom length, power density, color, CRI, and control/dimming options

“Microprinting” flexible waveguides

- Low-cost plastic substrates
- Automated additive manufacturing (“microprinting”)
- On-demand production
- Custom sizes and patterns

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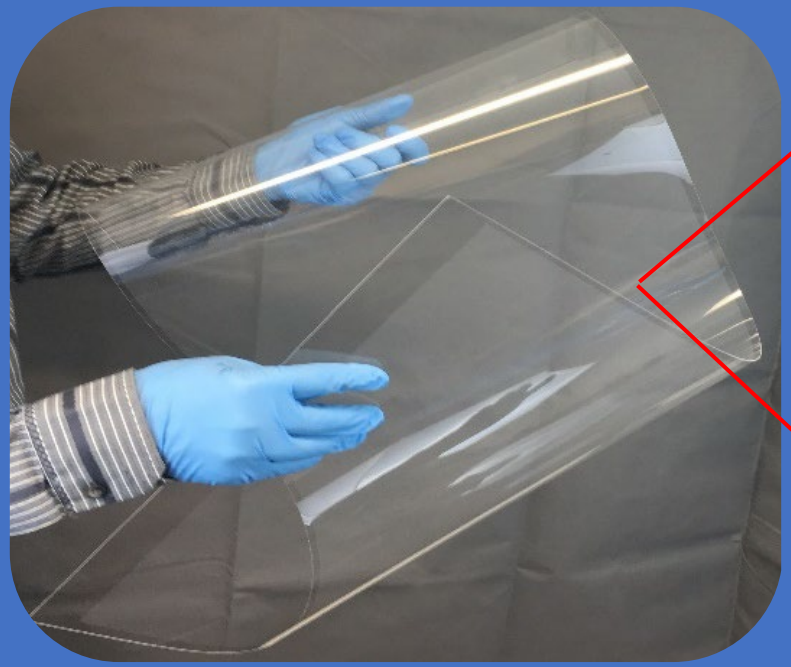
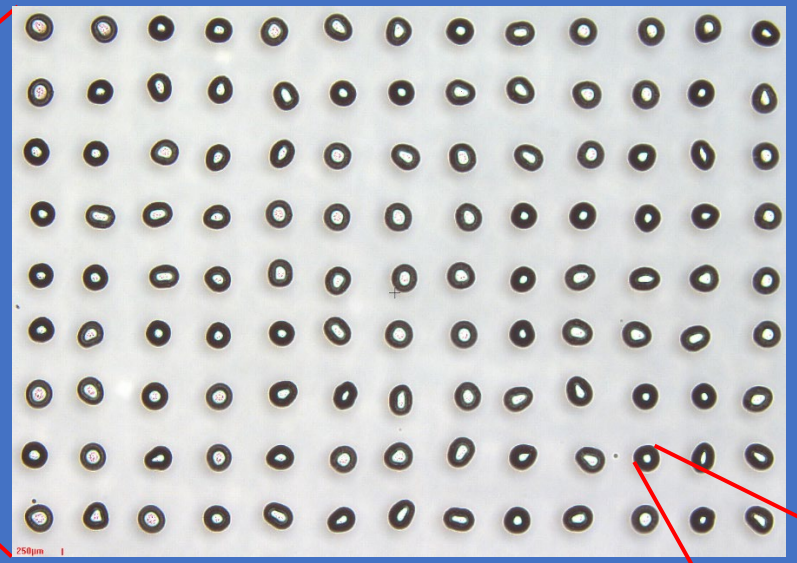
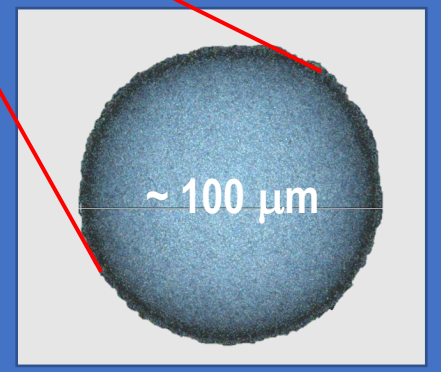
“Microprinted” light extraction







- Micro-droplets of light-scattering ink
- UV cured and made integral to waveguide’s body
- Individually placed using drop-on-demand technology
- ~ 2-3 million individual “emitters”
- ~ 0.1 ml of UV ink for 2’ x 2’ panel

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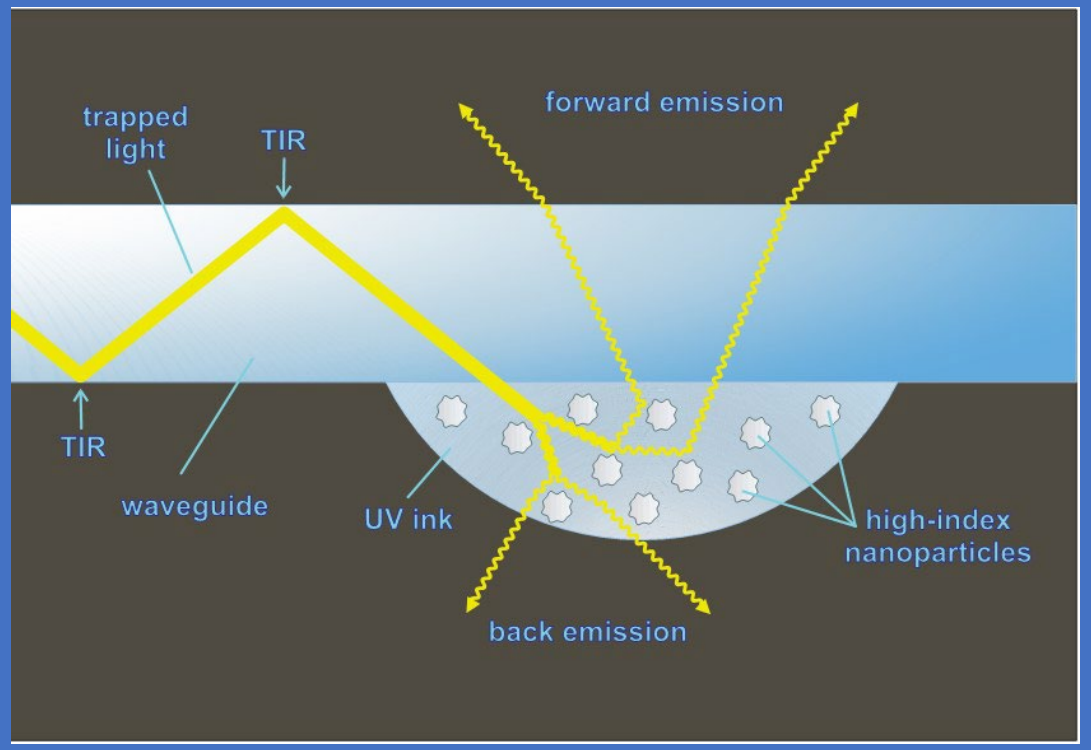
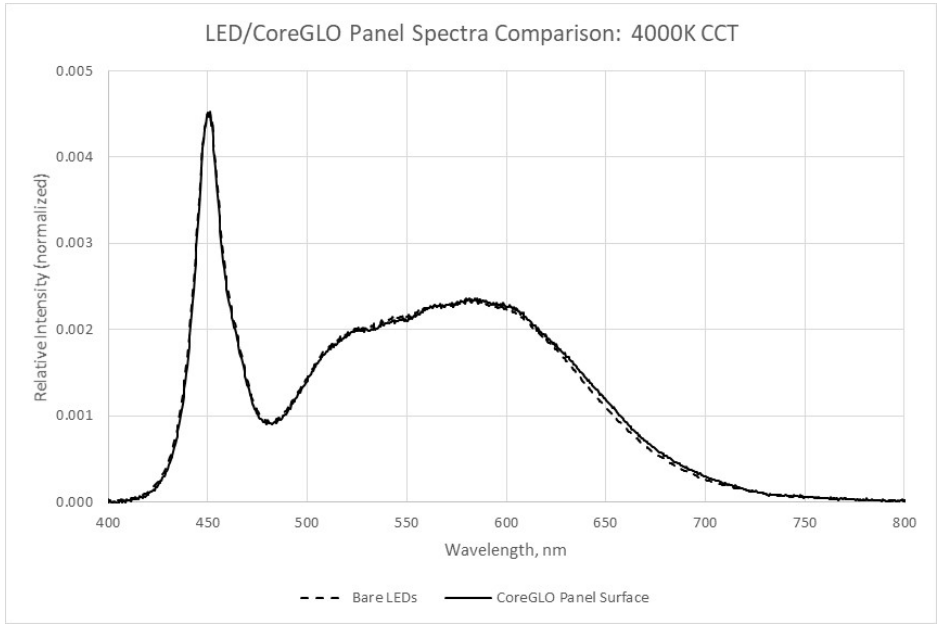
Trapping vs. extracting light

- Index-matched UV-cure material suppresses TIR
- High-RI nanoparticles (lossless light scattering)
- Near complete light extraction (light trapping loss is <2%)
- Up to 88% overall optical efficiency of the LED/waveguide lighting panel

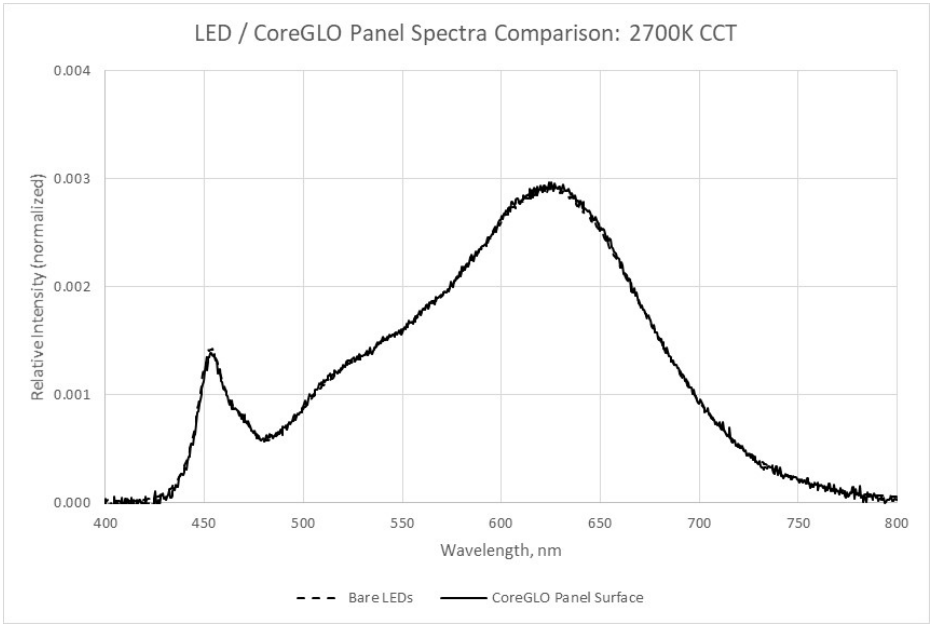


LED spectrum preservation

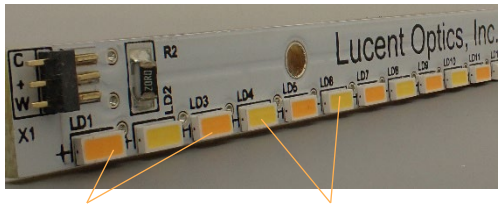
4,000K CCT, 85 CRI LEDs



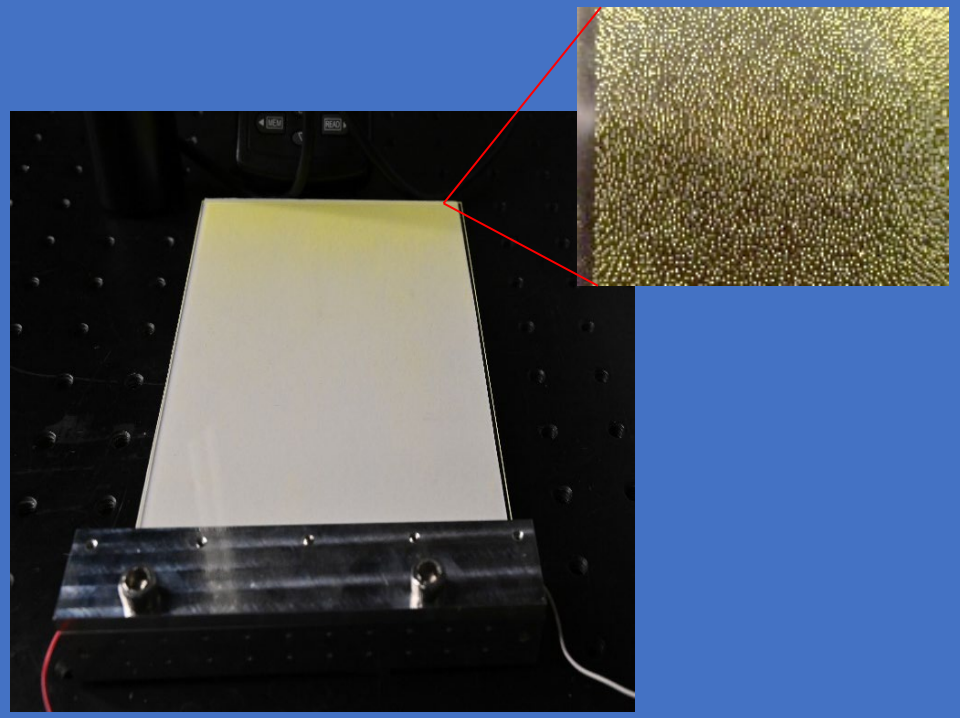
2,700K CCT, 90 CRI LEDs

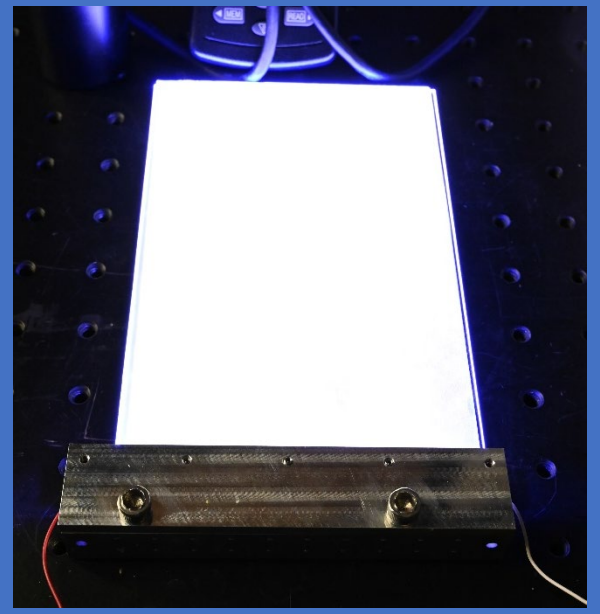


Color tunable waveguide panel (coming soon)



In-waveguide color conversion





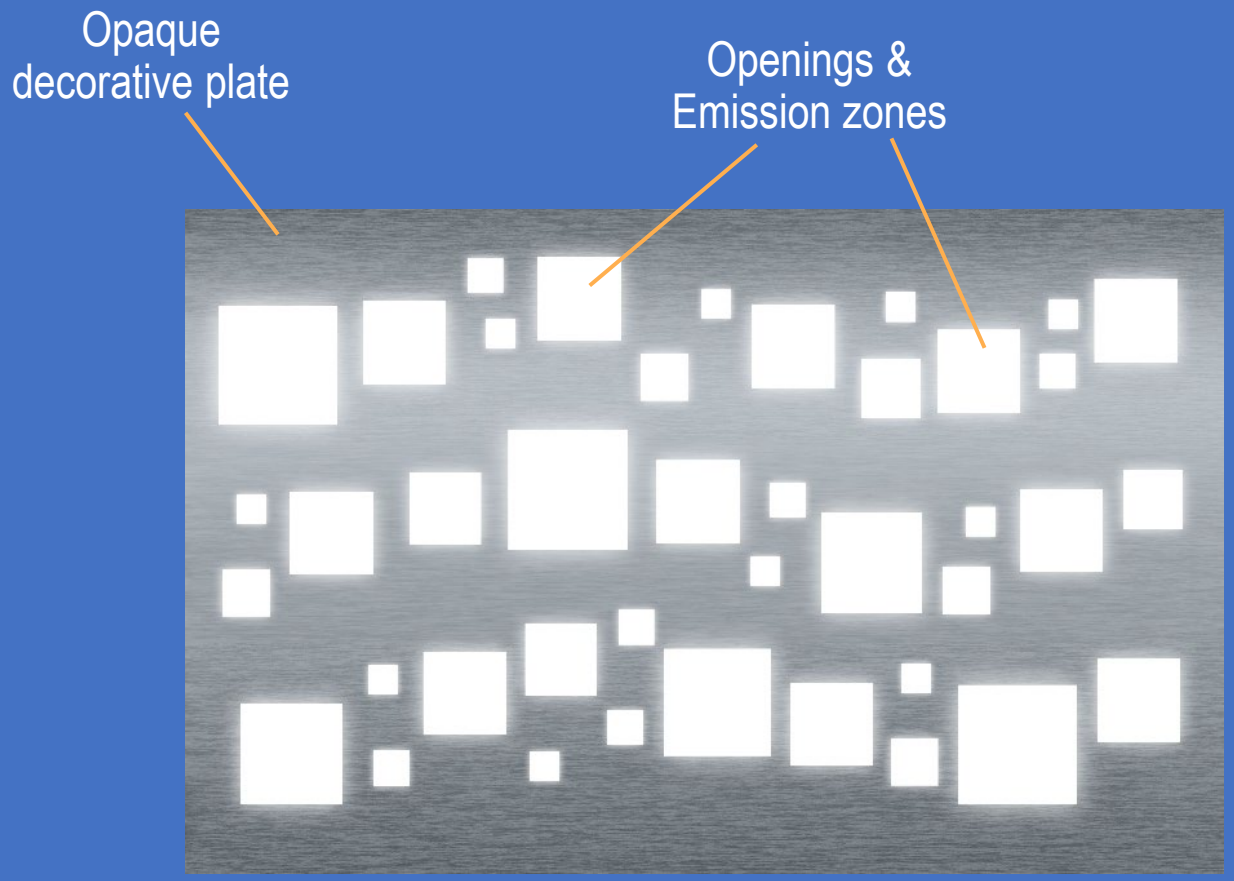
- Tapping into benefits of high-performance light converting (luminescent) materials without significantly increasing cost
- Phosphor particles embedded into microprinted structures
- Quantum dots?

LED waveguide luminaires: transparency

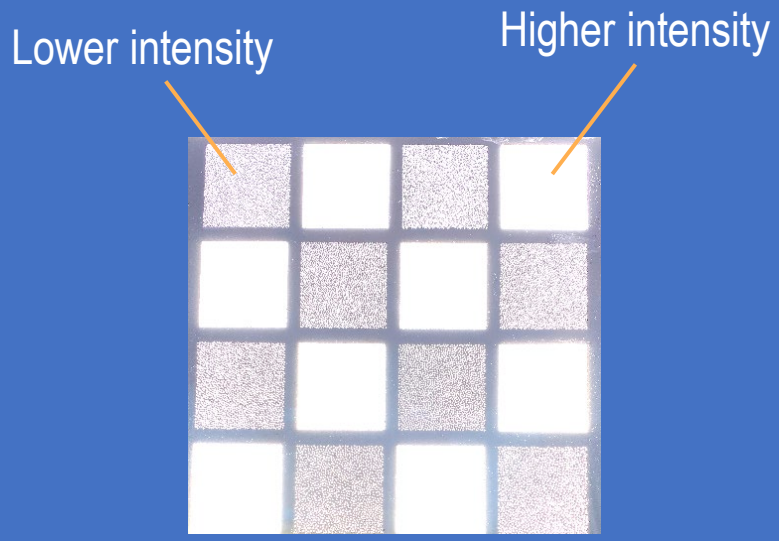
LEDs off

LEDs on

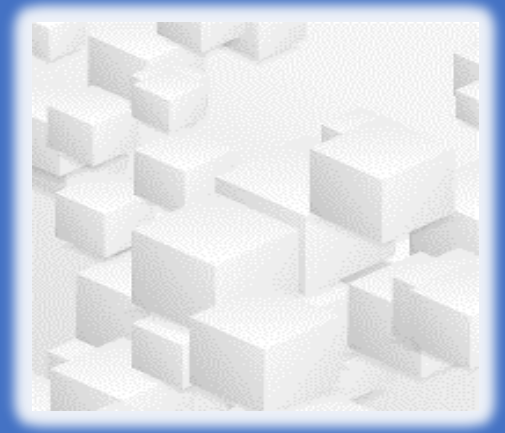
LED waveguide luminaires: segmented emission



LED waveguide luminaires: variable brightness

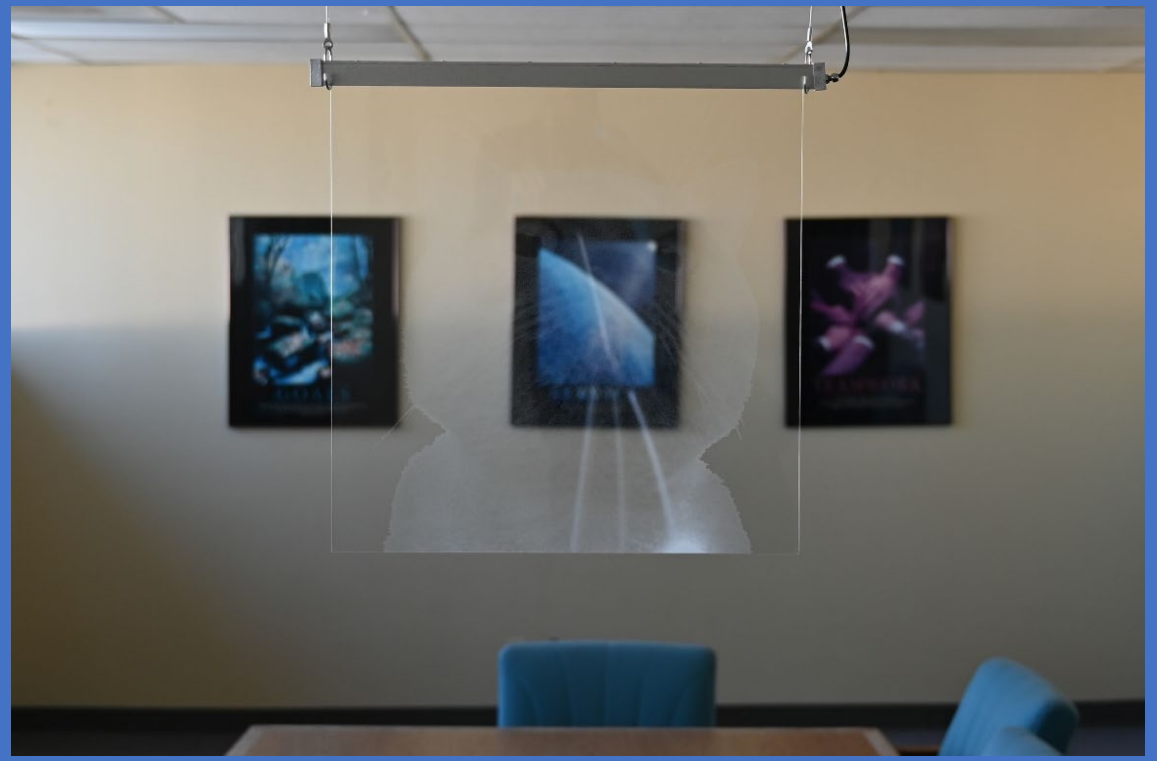


Emission pattern with
2 intensity levels



Multiple intensity levels forming
a “gray-scale” pattern

LED waveguide luminaires: image patterns



LED waveguide luminaires: image patterns

Summary

- Manufacturing technology for making diffuse light sources for thin, lightweight luminaires with innovative designs is readily available
- LEDs + optical waveguides combine high optical performance, low material intensity, sustainable manufacturing and lowest cost potential
- New & unique opportunities for lighting design and more rapid adoption of SSL
- Further directions for R&D and technology improvement:
  - Further thickness reduction
  - Developing LED sources specifically designed for thin waveguides (e.g., small size, side-emitting, etc.)
  - Further improving efficacy and color rendering, exploring luminescent waveguides
  - Improving control of angular emission distribution
  - Addressing scale up & mass production issues
  - Developing specific applications (luminaire design and building integration)
  - Exploring cross-technology lighting concepts, e.g., using waveguide-style light extraction in OLEDs, combining OLEDs with LED waveguides, etc.