



Lightguide Luminaire with Controlled Numerical Aperture for General Illumination

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Lightguide Luminaire Features

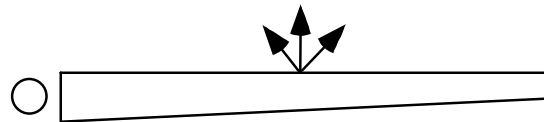
- Providing a new alternative to general illumination
- A light-guide providing high efficient light extraction and distribution.
- Single-pass design
- No specialized coatings or film layers
- Applications:
 - ▶ General illumination
 - ▶ Backlight for display
 - ▶ Signage

Light-Guide Designs

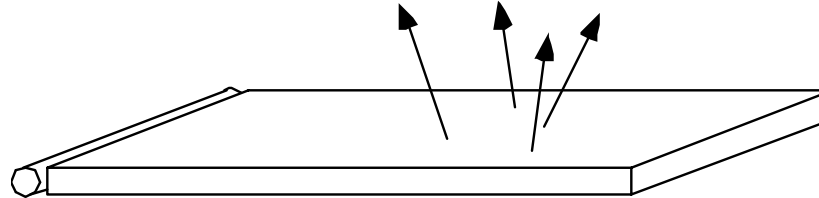
- Two fundamental designs are presented
- Front-surface pattern
 - ▶ Provides mostly forward-directed lighting



- Back-Surface Patterning
 - ▶ Provides surface normal-directed illumination



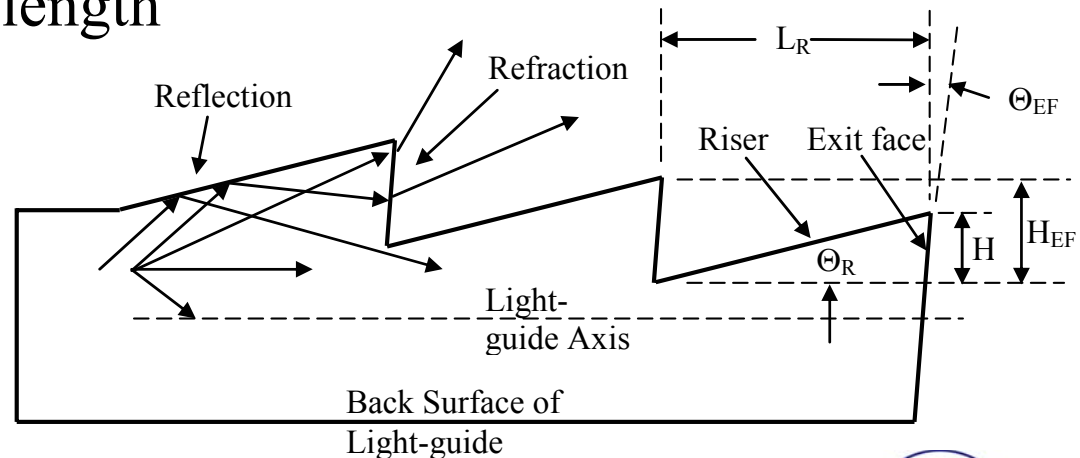
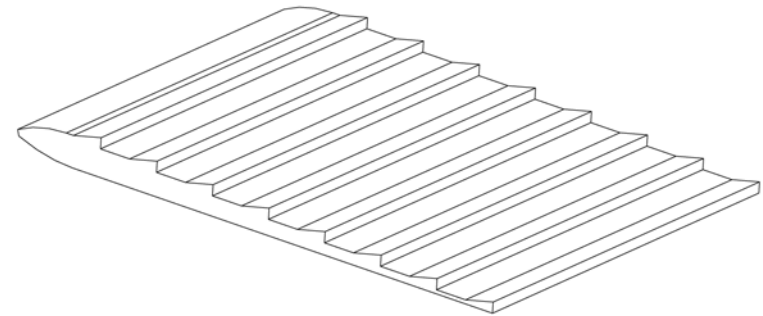
Principles of operation



- Each design utilizes surface relief features for light extraction
- Each design leverages both refraction and total-internal reflection
- Light is injected at one end of the light-guide
- Substantially all the light is extracted from the light-guide in a single pass
- Output light distribution and uniformity can be controlled with each design

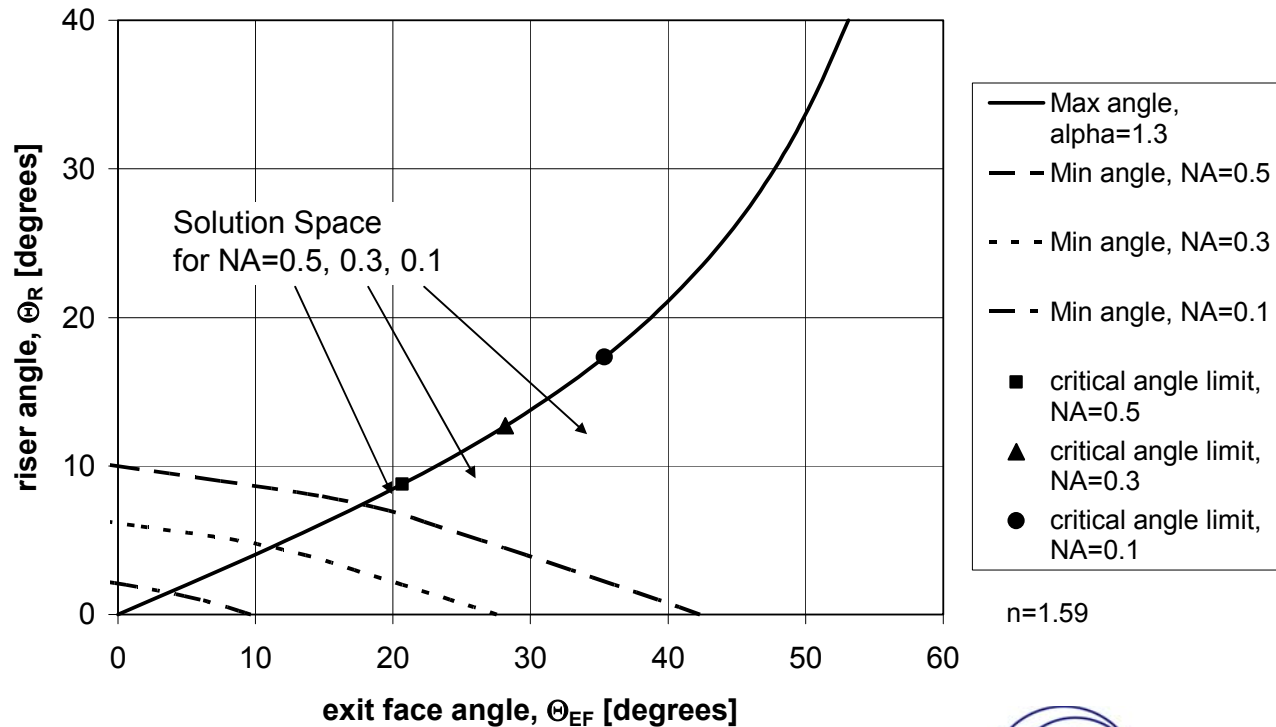
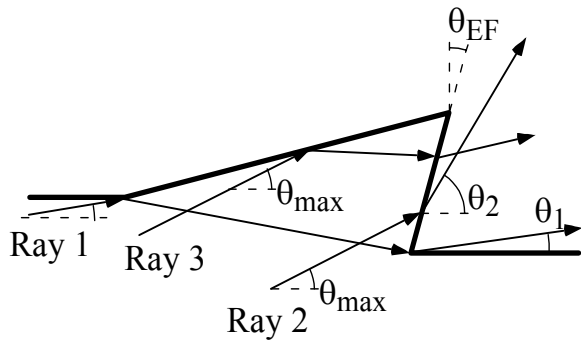
Front-Surface Patterned Light-guide

- Light coupled into one end
- Light exits through exit face of surface features
- Light undergoes TIR off all other surfaces
- Numerical aperture of the light is maintained down the length of the lightguide



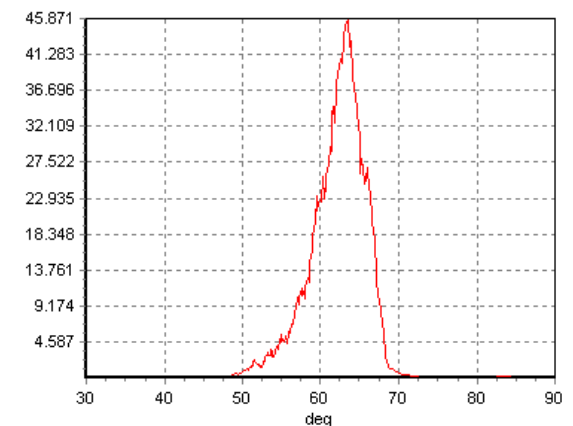
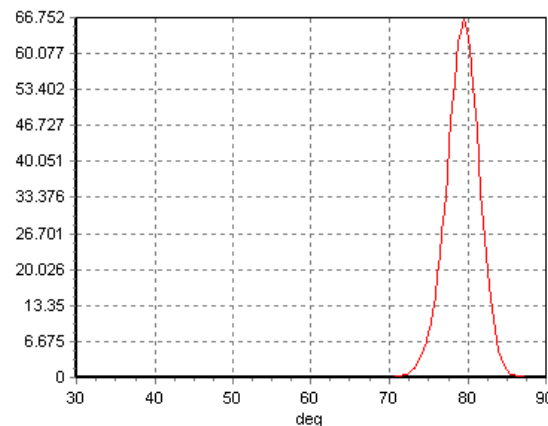
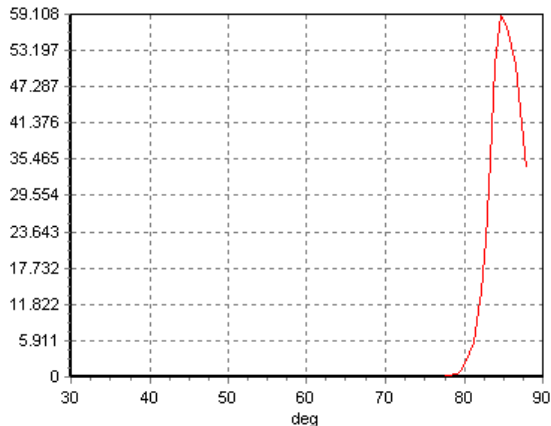
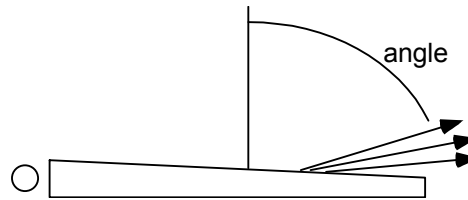
Design Rules

- Three limiting equations providing for 100% output coupling through exit face while maintaining NA preservation or reduction



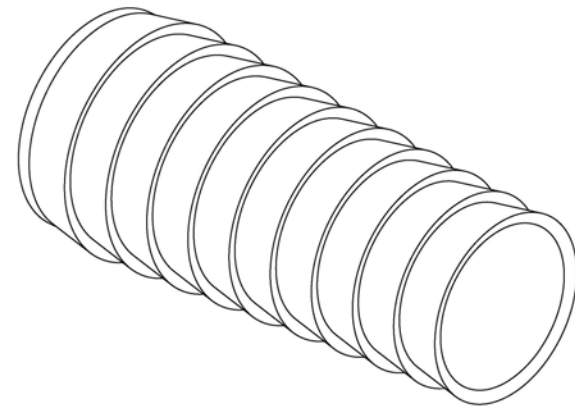
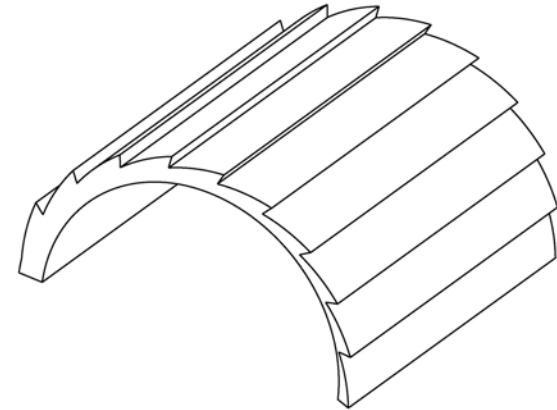
Front-Side Illumination Examples

- By adjusting the design parameters for a given refractive index and low input numerical aperture, the output light distribution can be adjusted between 60 and 90 degrees from the light-guide normal
- Shown are three examples for input NA of 0.1 and three different exit face angles in a 1.4 index material.



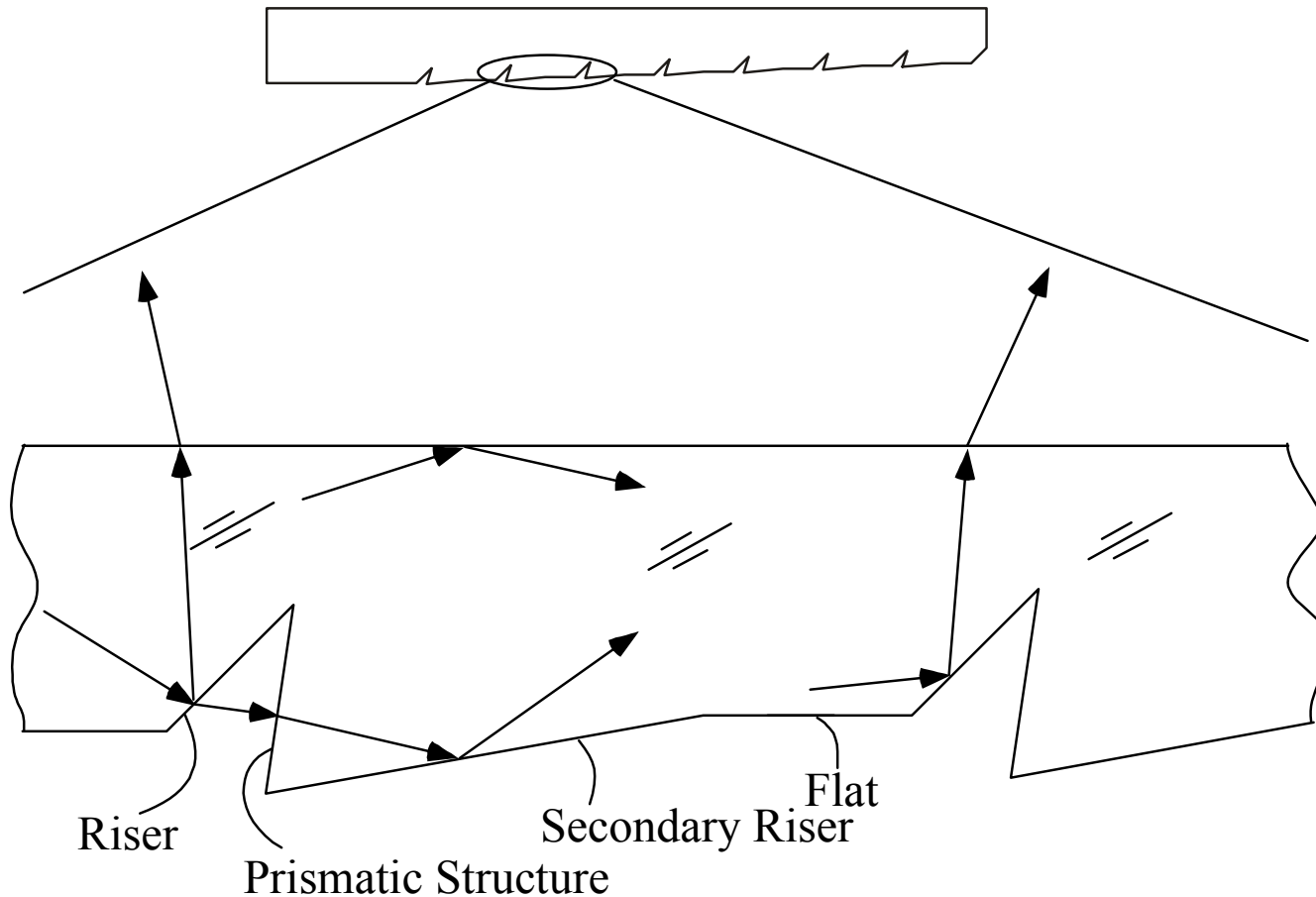
Illumination Variations Via Light-Guide Geometry Variations

- These variations are compatible with front-side patterning and injection molding processes.
- The limited illumination range of the front-side designs can be extended by adjusting the geometry of the light-guide



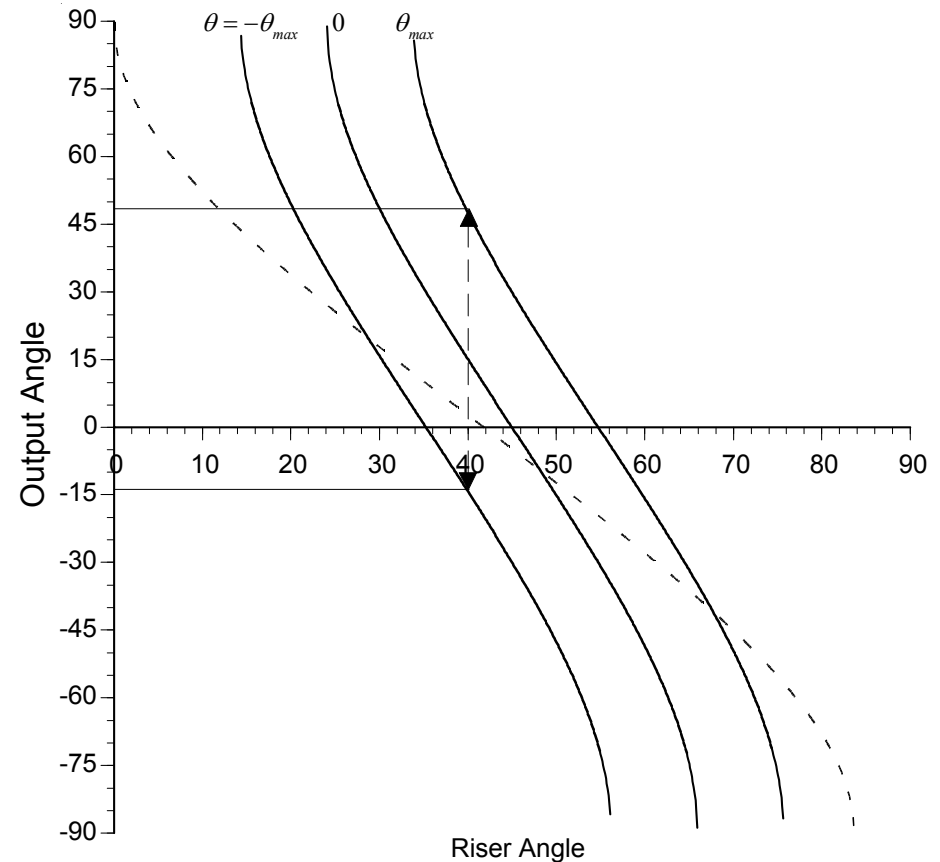
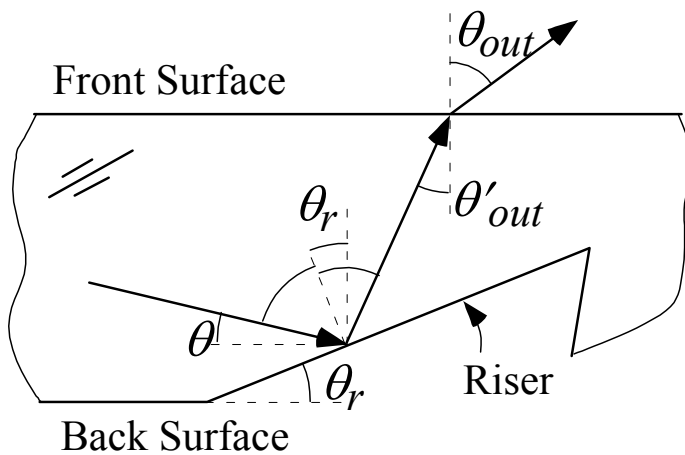
Back-Side Light Guide Principles

- Back-side is patterned with acute-angled features



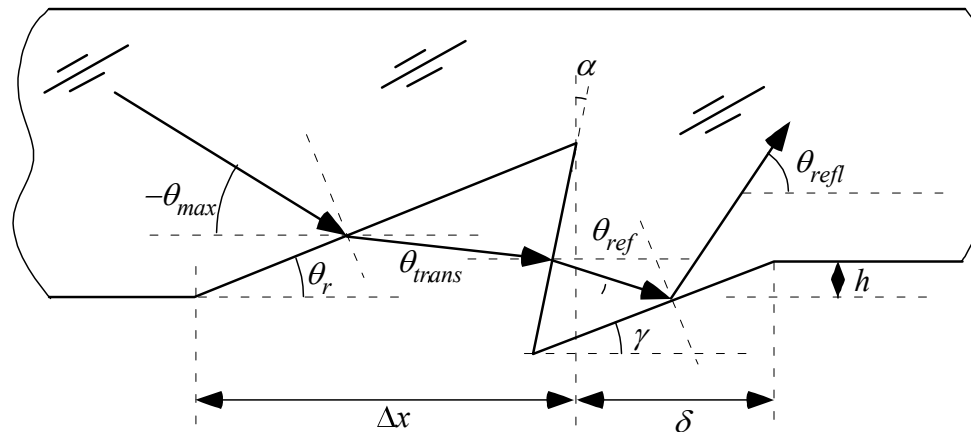
Back-Side Light Guide Principles

■ Output Angle vs. Riser Angle

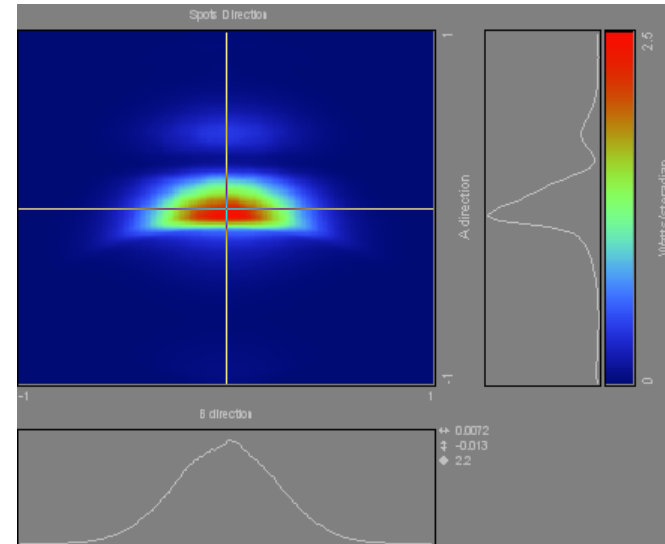
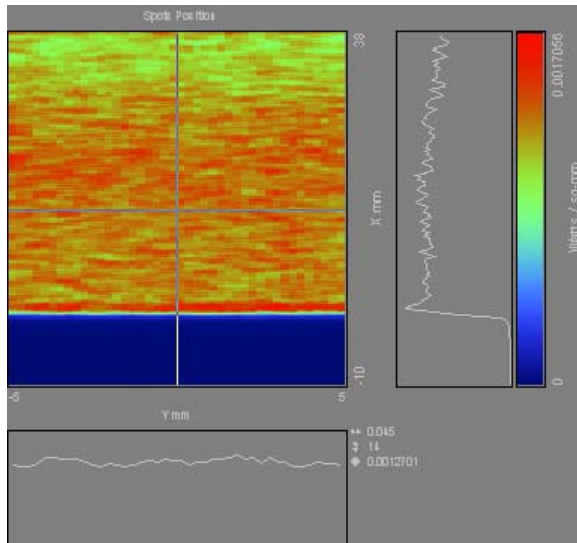


Back-Side Light Guide Principles

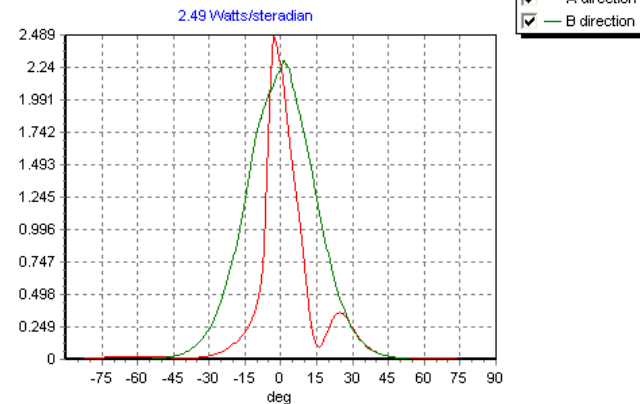
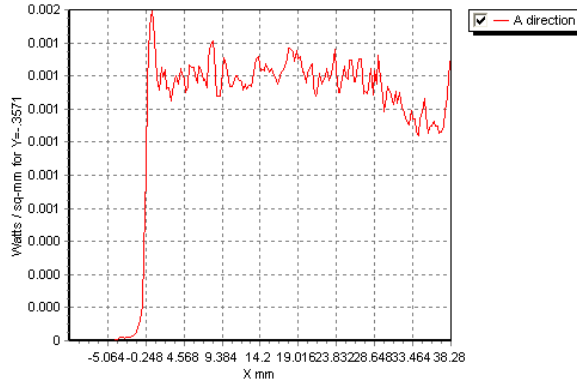
- Include a Secondary Riser for extreme NA conditions and efficient tapering of the lightguide.



Back-Surface Light-Guide Illumination Example

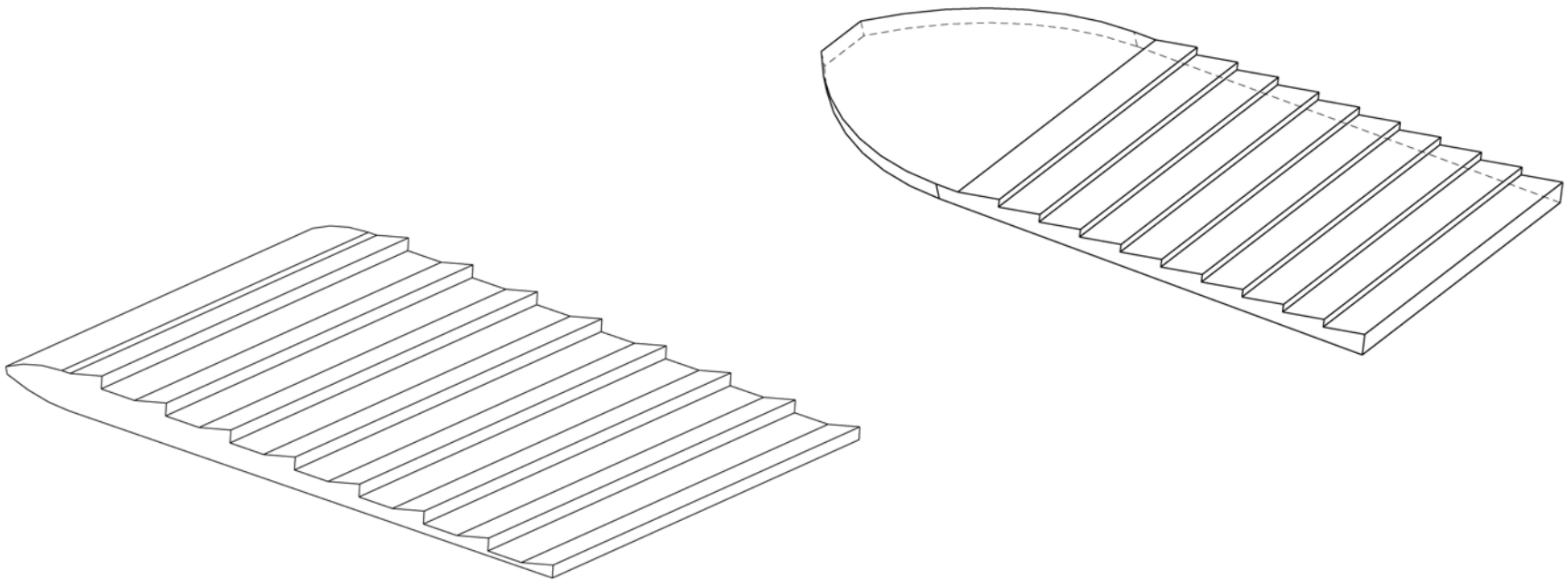


Example Output Distribution



Possible Design Variations for linear and point sources

- Linear sources can be collimated to reduce their NA
- Point sources can be collimated and extended to smaller NA line sources



Manufacturing Alternatives

- Injection molding
- Extrusion
- Roll-to-roll not possible due to back-angled features

Summary

- Two new light-guide designs provide:
 - ▶ Efficient illumination
 - ▶ Controlled single-pass light extraction
- Front side design provides illumination at angles greater than 60 degrees to surface normal
- Back-side design provide illumination substantially parallel to surface normal