Course Notes

SPIE Education Services

SC011
Design of Efficient Illumination Systems

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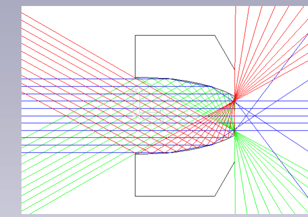
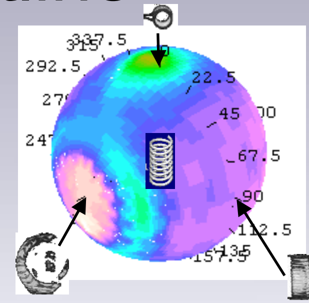
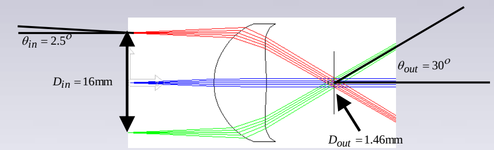
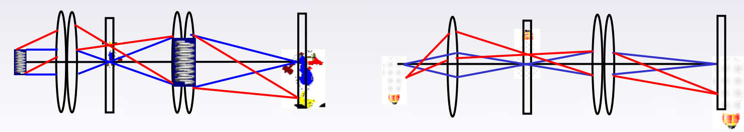
Outline



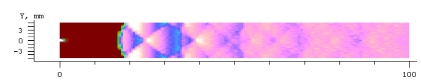


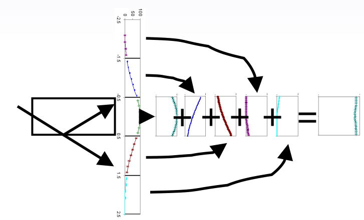


- **Photometry Fundamentals**
- **Limits to Flux Transfer**

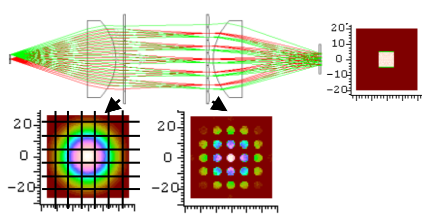


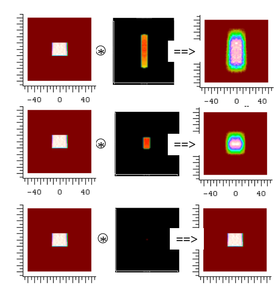
- **Classical Projection Uniformity**



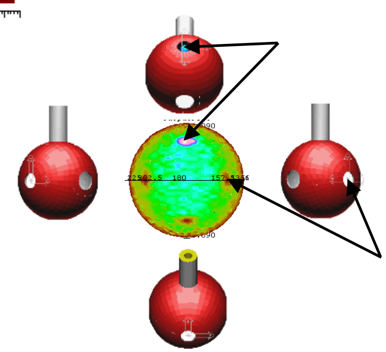


- **Mixing Rods**



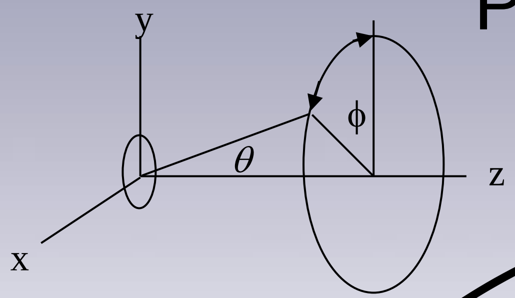


- **Lens Arrays**
- **Faceted Reflectors**



- **Integrating Cavities**

Photometry Relationships



L = Luminance, index = 1

If Intensity is constant
*Flux = Intensity * Solid Angle*

Intensity

$$\text{Flux} = \int_{\Omega} \text{Intensity} \ \sin(\theta) d\theta d\phi$$

If L is constant
*Intensity = L * Projected Area*

$$\text{Intensity} = \int_{A} L\cos(\theta) da$$

If L is constant
*Flux = L * Etendue*

Flux

$$\text{Flux} = \int_{A}\int_{\Omega} L\cos(\theta)\sin(\theta) da d\theta d\phi$$

Luminance

If Distance, R, is large
*I = Illuminance * R^2*

If PSA is constant over the area
*Etendue = Area * PSA*

$$\text{Illuminance} = 2\pi \int_{\Omega} L\cos(\theta)\sin(\theta) d\theta \ \ d\phi$$

If Luminance is constant
*Illuminance = L * Projected Solid Angle*

$$\text{Flux} = \int_{A} \text{Illuminance}\, da$$

Illuminance

If Illuminance is constant
*Flux = Illuminance * Area*

Angle-Area Tradeoff

- The etendue for a planar aperture in a symmetric system is

$$Etendue_{2D} = n\ D\ 2\sin\theta_{max}$$

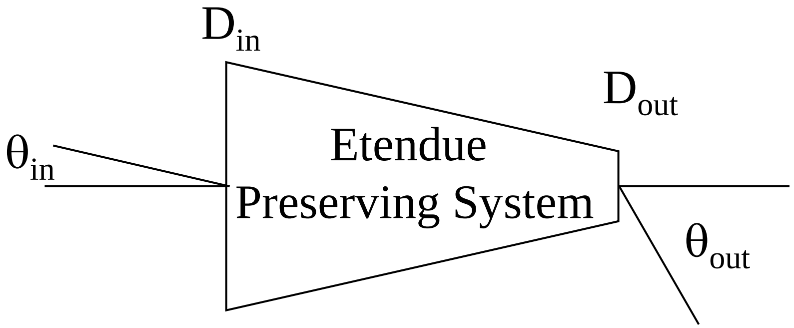
$$Etendue_{3D} = n^2\ \pi(D/2)^2\ \pi\sin^2\theta_{max}$$

- For an etendue preserving system,

$$n_{in}\ \sin\theta_{int}\ D_{in} = n_{out}\ \sin\theta_{out}\ D_{out} \quad \text{for 2D}$$

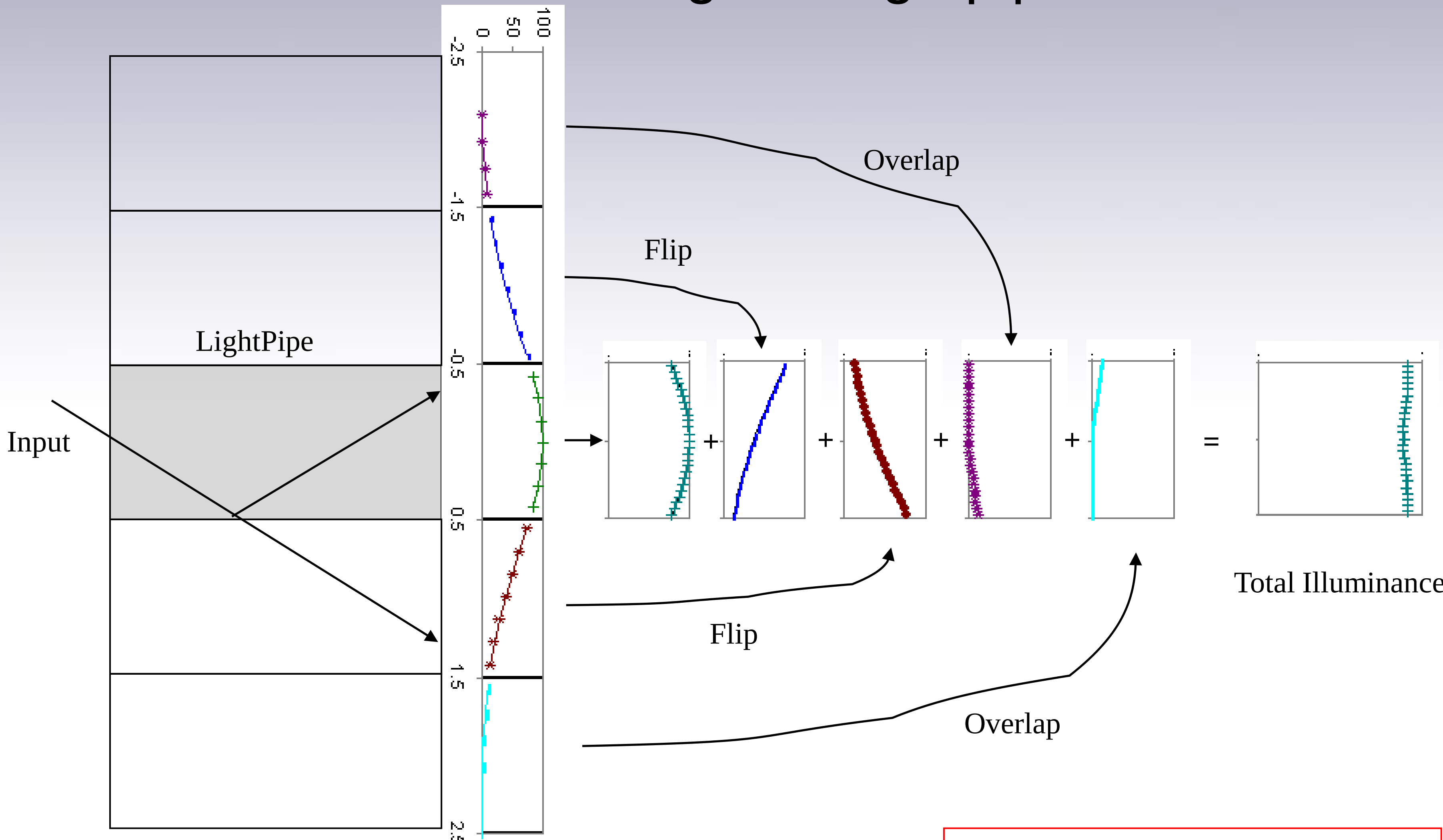
$$n^2_{in}\ \sin^2\theta_{in}\ D^2_{in} = n^2_{out}\ \sin^2\theta_{out}\ D^2_{out} \quad \text{for 3D}$$

- In a lossless system,
  - Decreasing the angular distribution requires spatial increase
  - Increasing the angular distribution requires spatial decrease



$$\sin\theta_{int}\ D_{in} = \sin\theta_{out}\ D_{out}$$

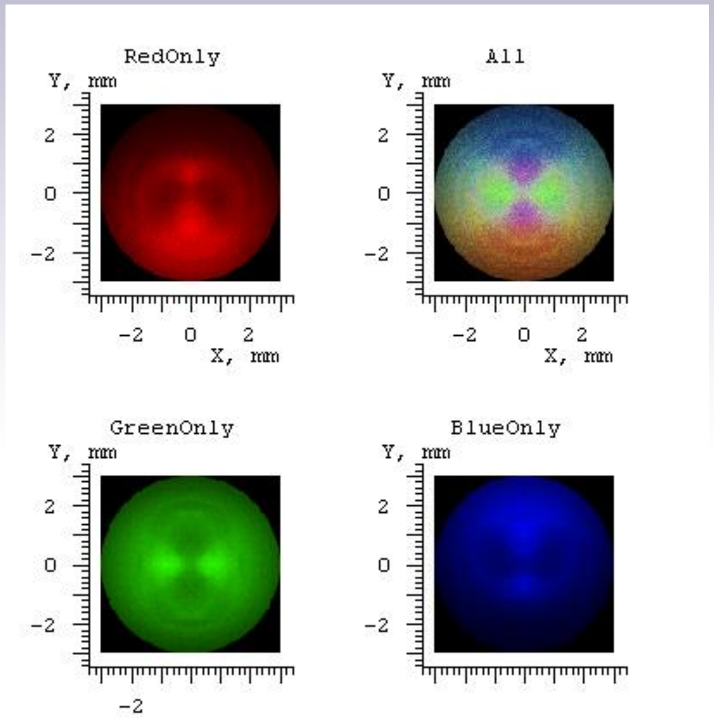
Kohler Superposition: Flip-n-Fold for Rectangular Lightpipe

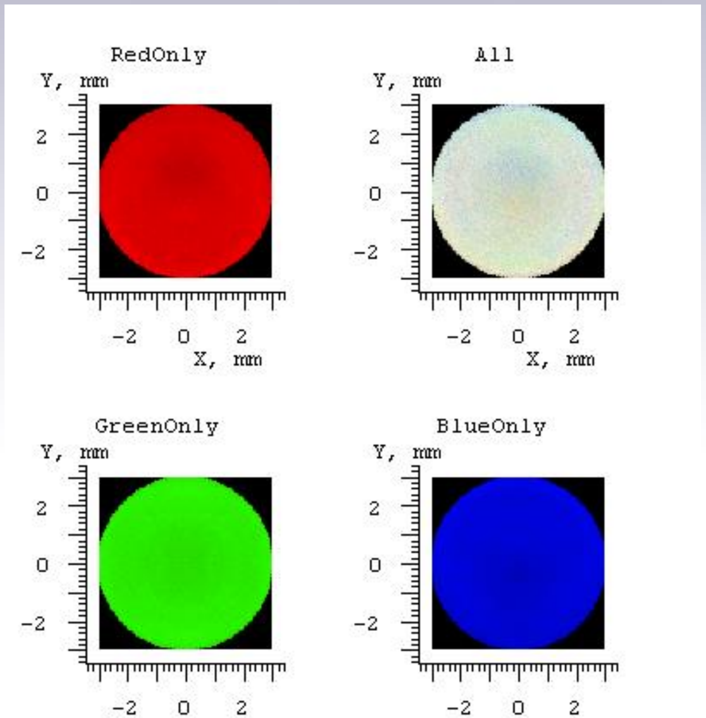


Illuminance At LightPipe Output with NO Sidewall Reflections

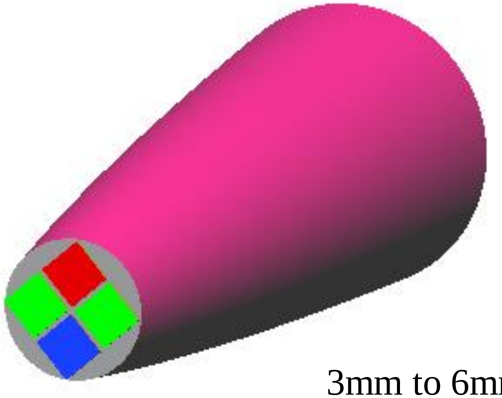
Illuminance at Lightpipe Output is the Superposition of subdistributions

Tapered Mixer Simulation:
RGB Smooth vs Rippled

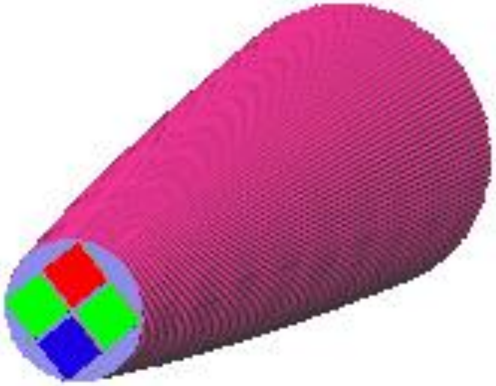




Smooth



Rippled



3mm to 6mm diameter, 18mm long