Progressive Photon Mapping Basics

Toshiya Hachisuka
Aarhus University

State of the Art in Photon Density Estimation
SIGGRAPH 2012 Course

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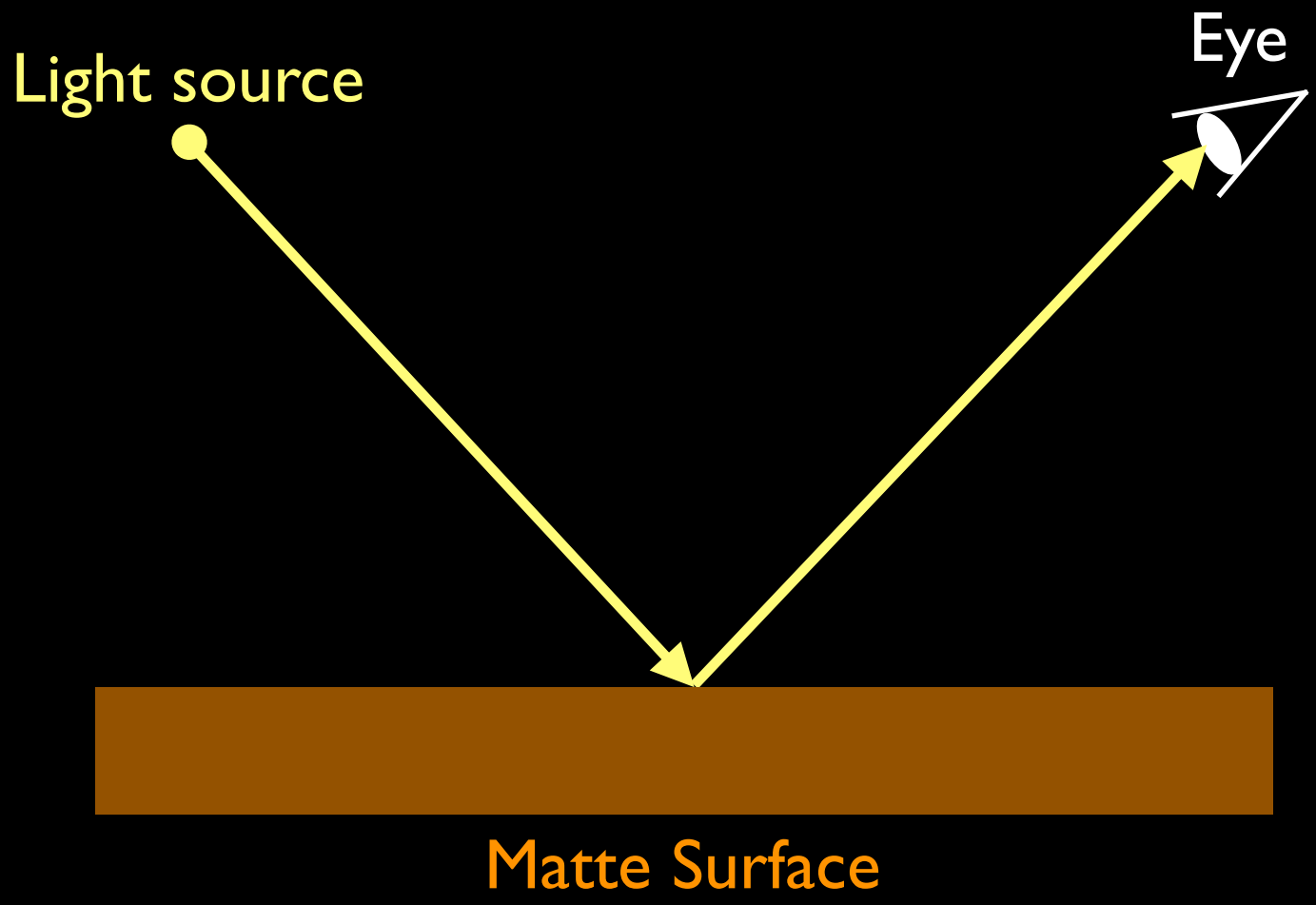
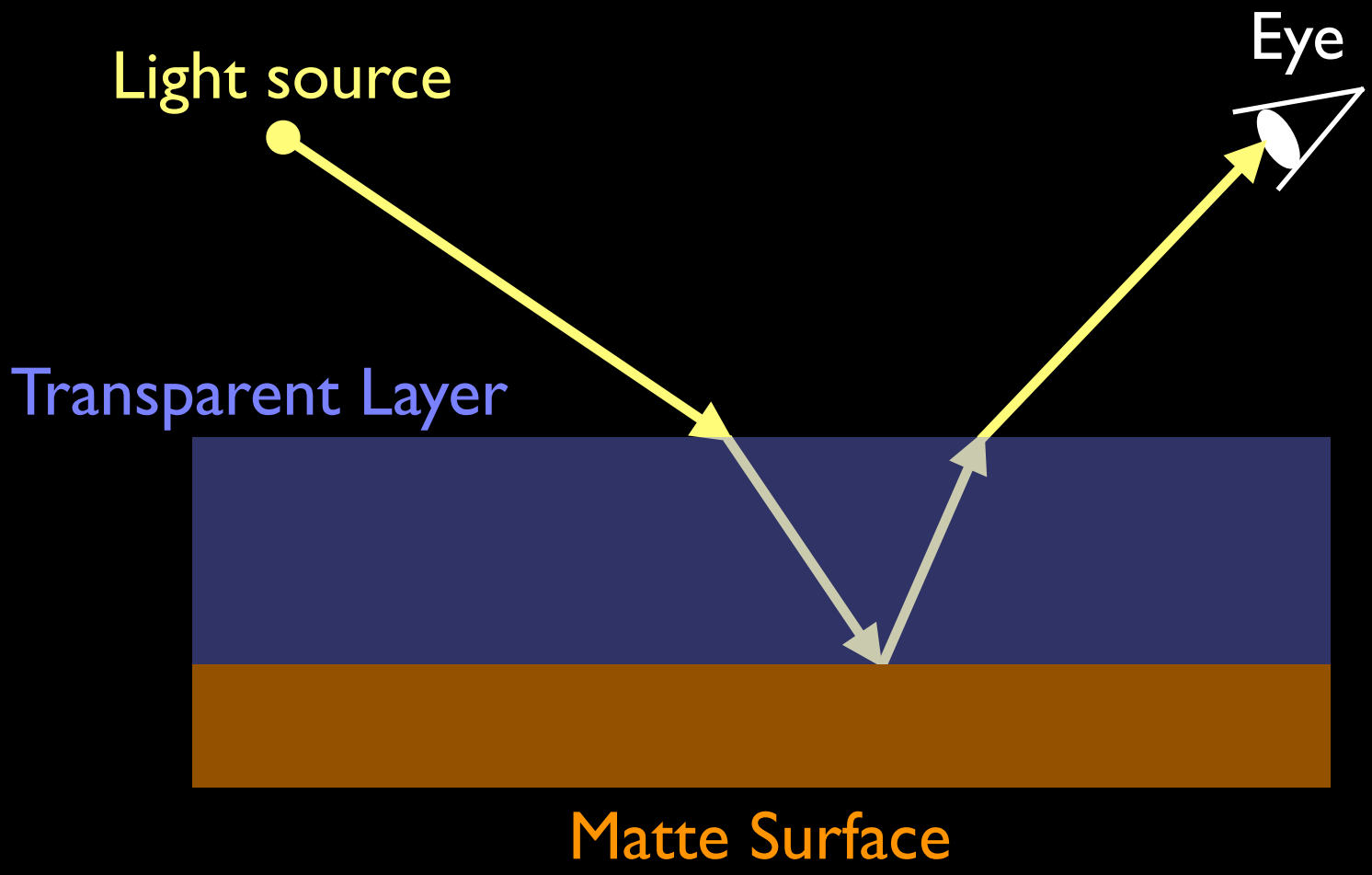
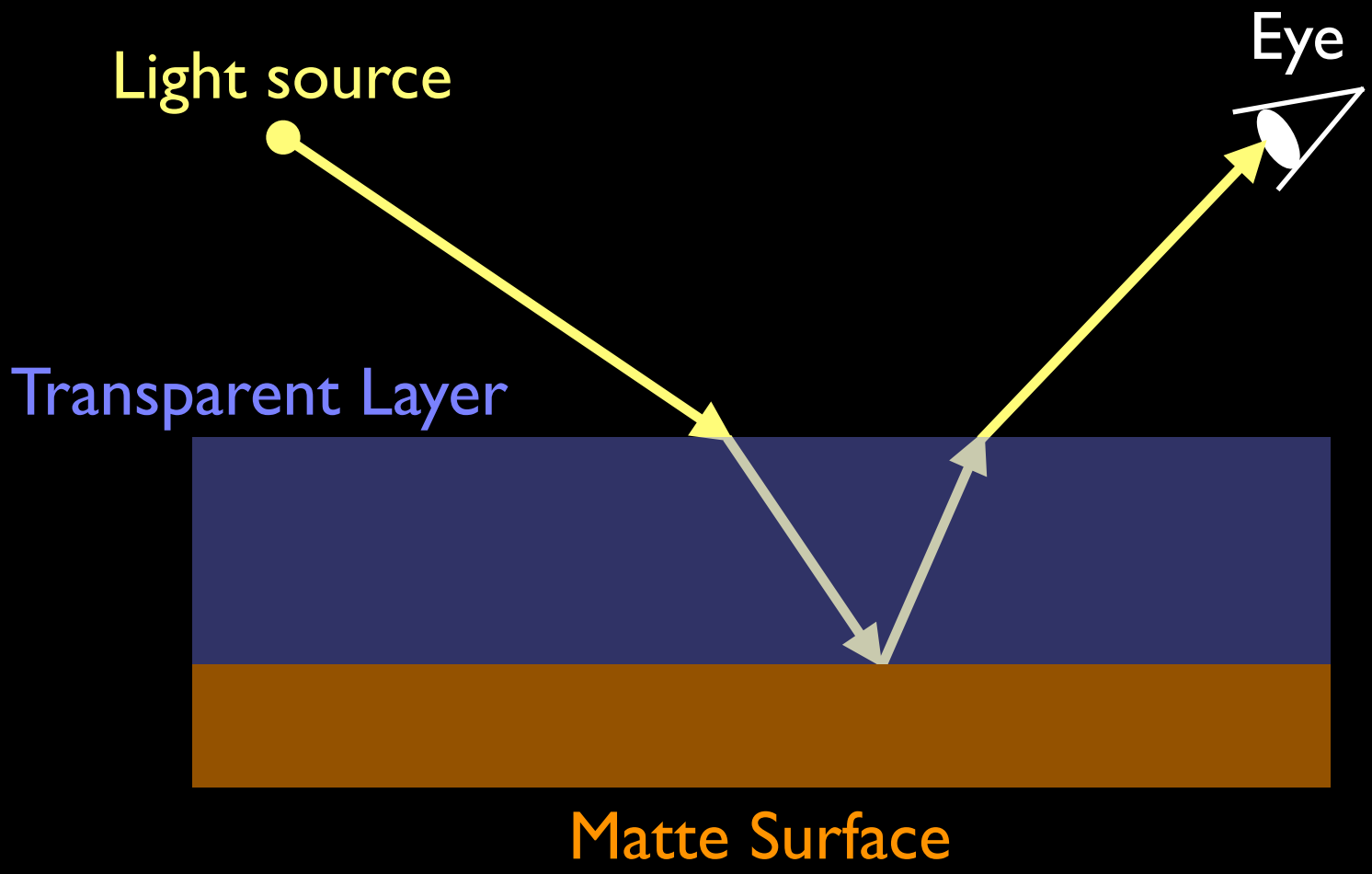
Global Illumination Algorithms

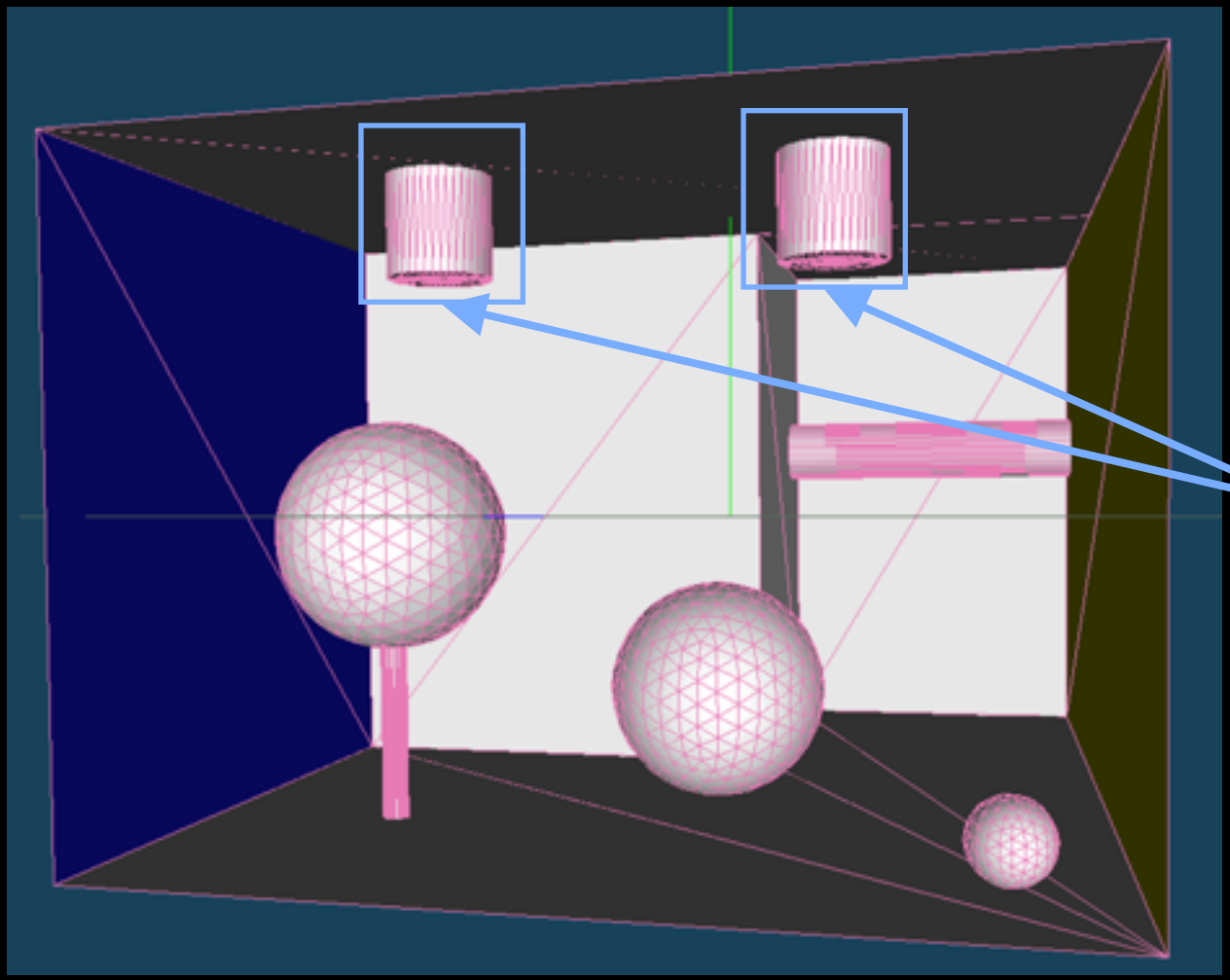
- Path Tracing [Kajiya 86]
- Light Tracing [Arvo 86][Dutré 93]
- Bidirectional Path Tracing [Lafortune 93][Veach 95]
- Photon Mapping [Jensen 95]
- Density Estimation [Shirley 95]
- Instant Radiosity [Keller 97]
- Metropolis Light Transport [Veach 97]
- Lightcuts [Walter 05]
- Energy Redistribution Path Tracing [Cline 05]
- ...


Light source
Eye
Matte Surface


Light source
Eye
Transparent Layer
Matte Surface

Specular-Diffuse-Specular Paths



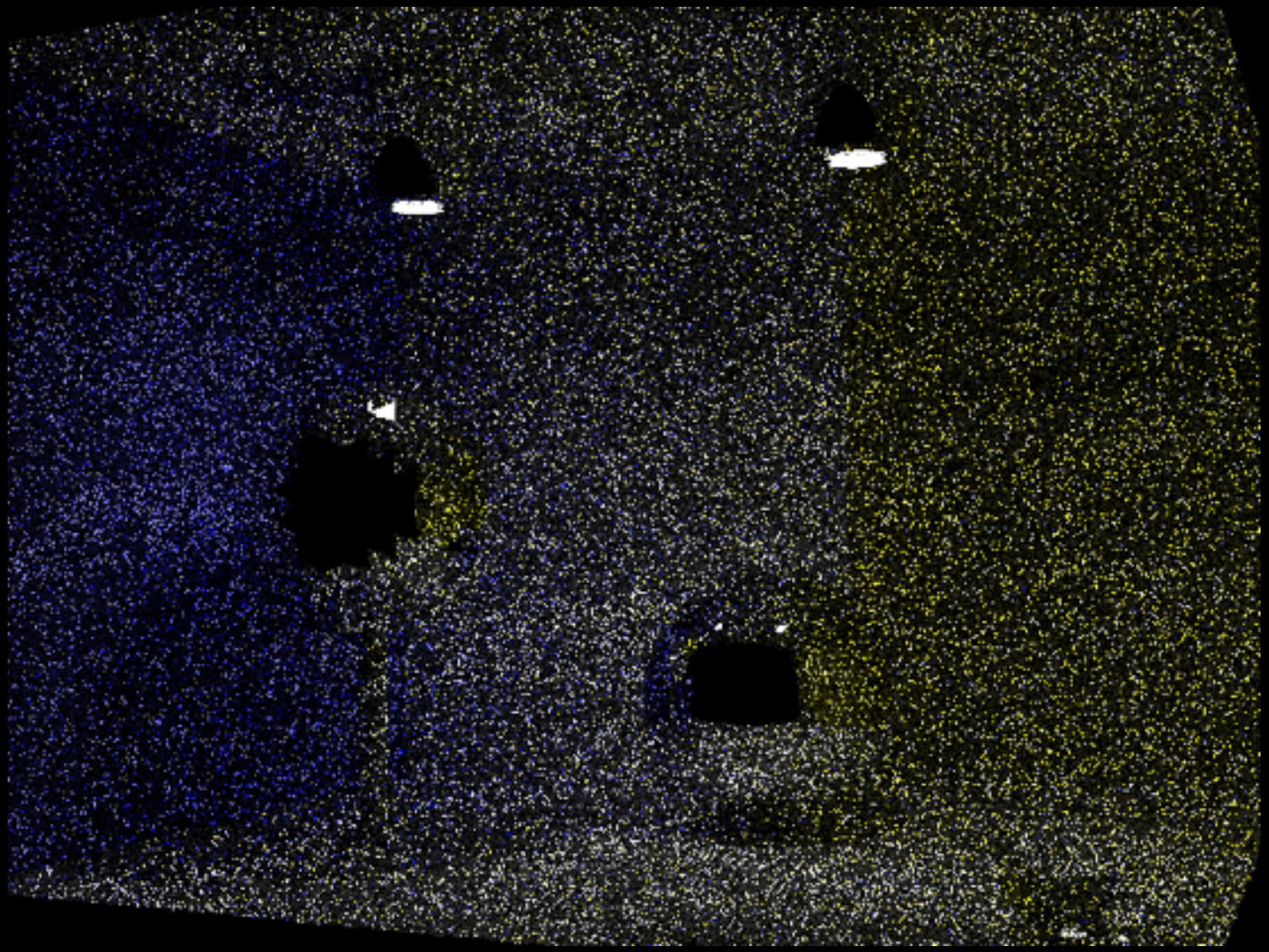


Metal tube

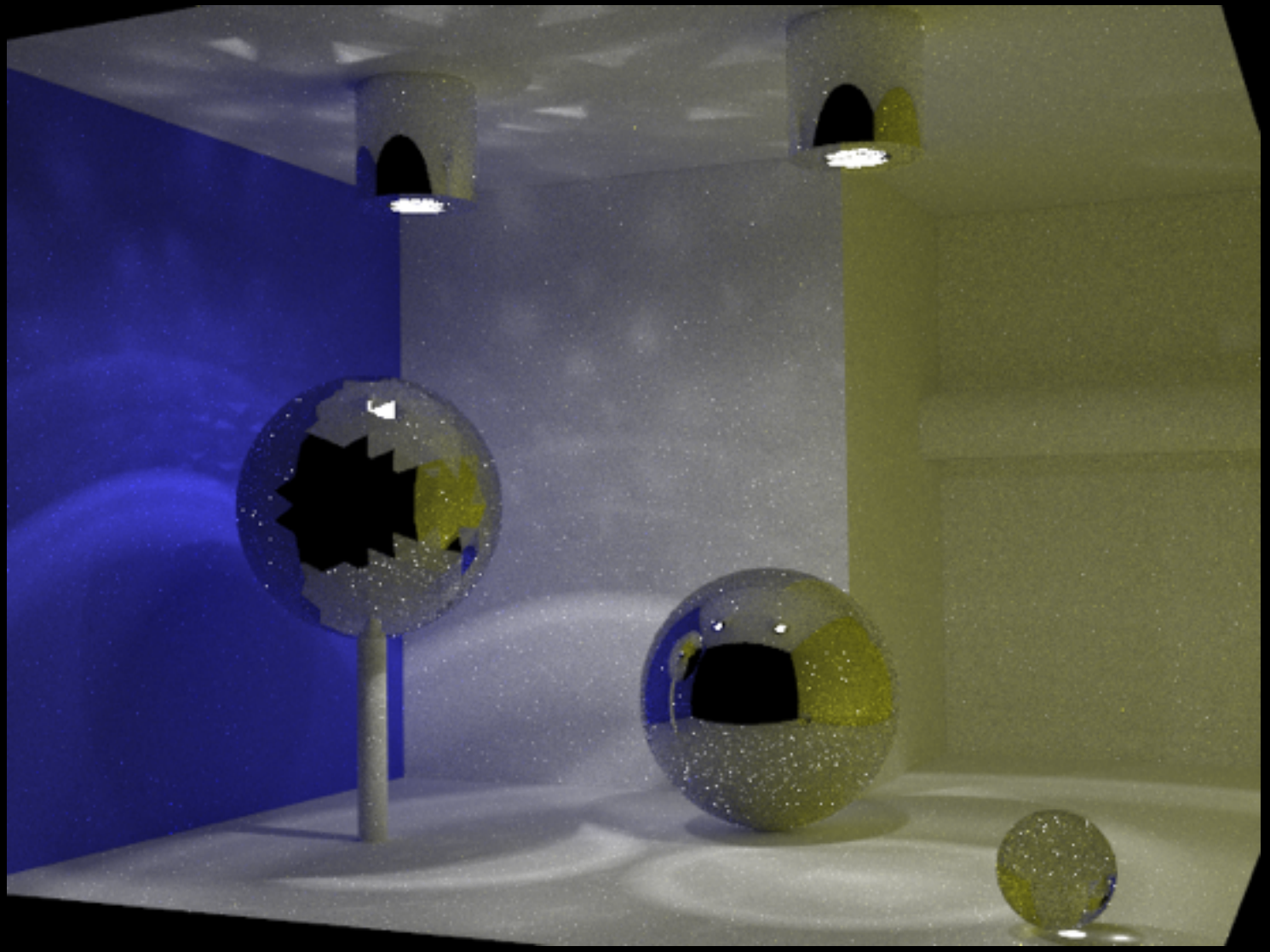
Light

Lens

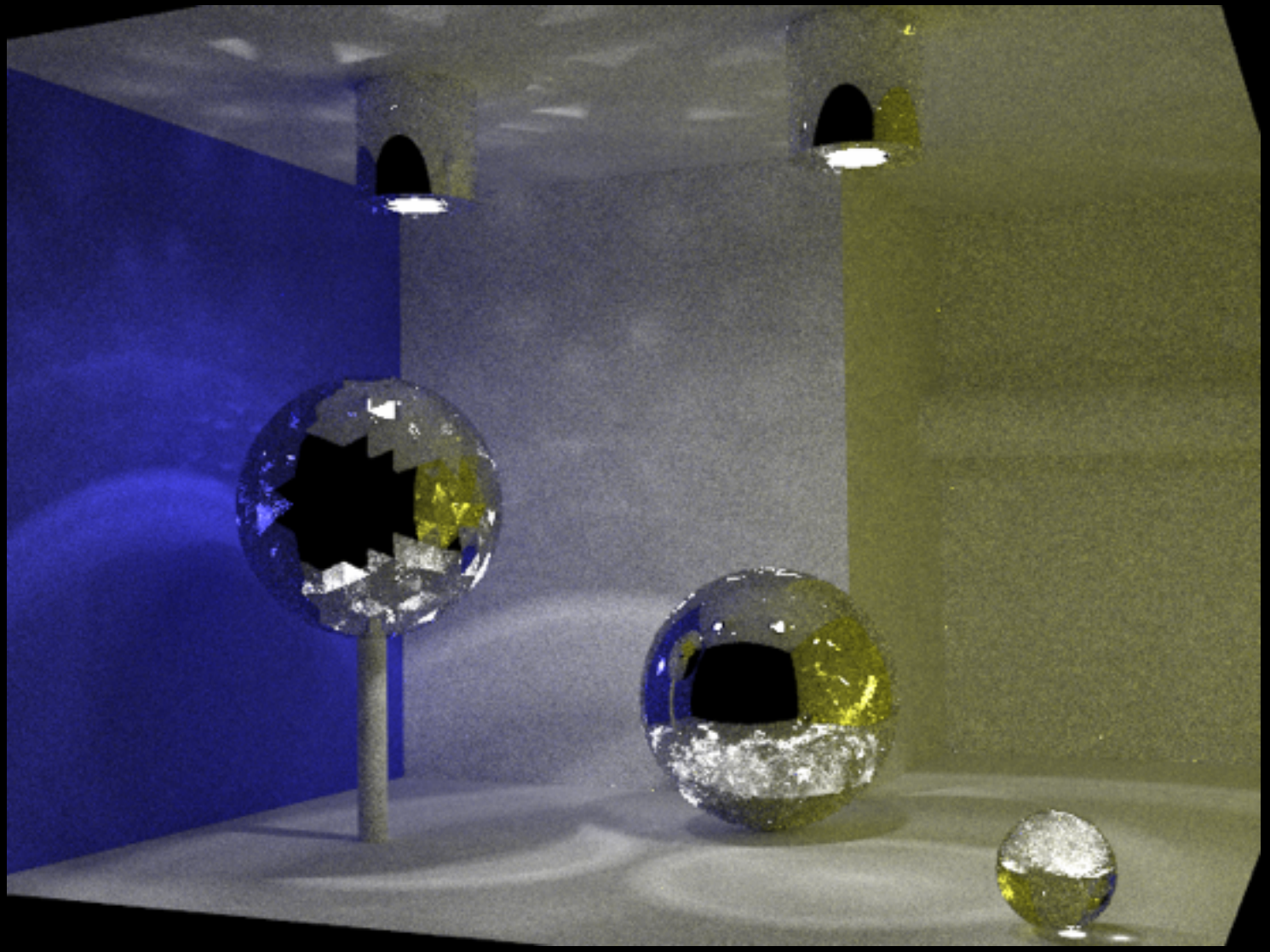
Path Tracing

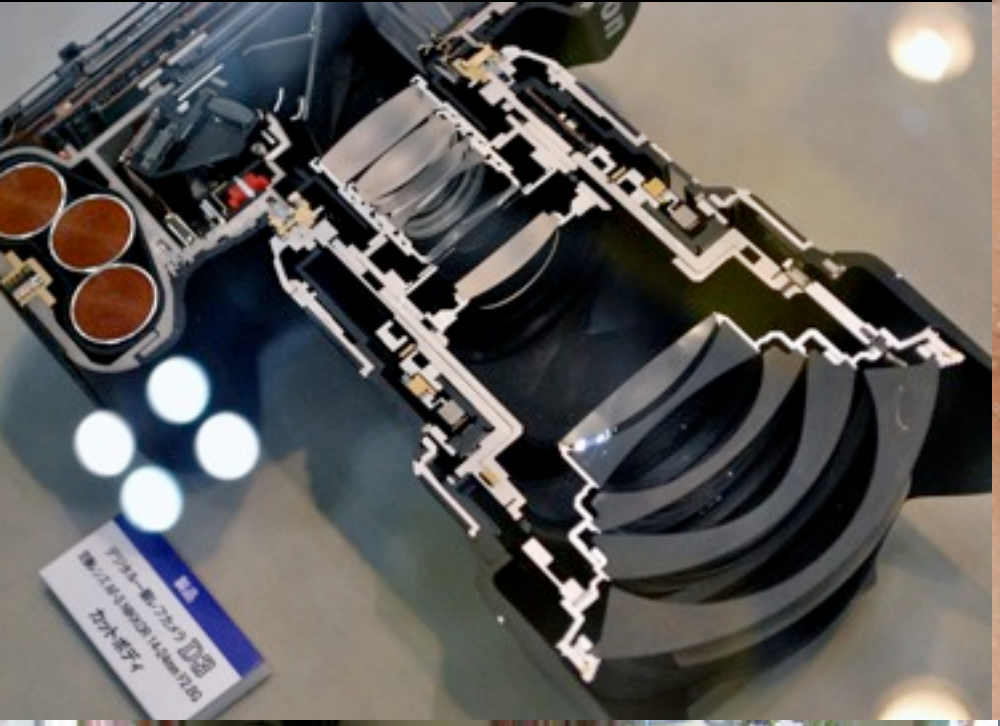


Bidirectional Path Tracing



Metropolis Light Transport





Specular-Diffuse-Specular Paths

- Existing methods are not robust for SDS paths
  - Path tracing
  - Bidirectional path tracing
  - Metropolis light transport
  - ...name your favorite

Specular-Diffuse-Specular Paths

- Existing methods are not robust for SDS paths
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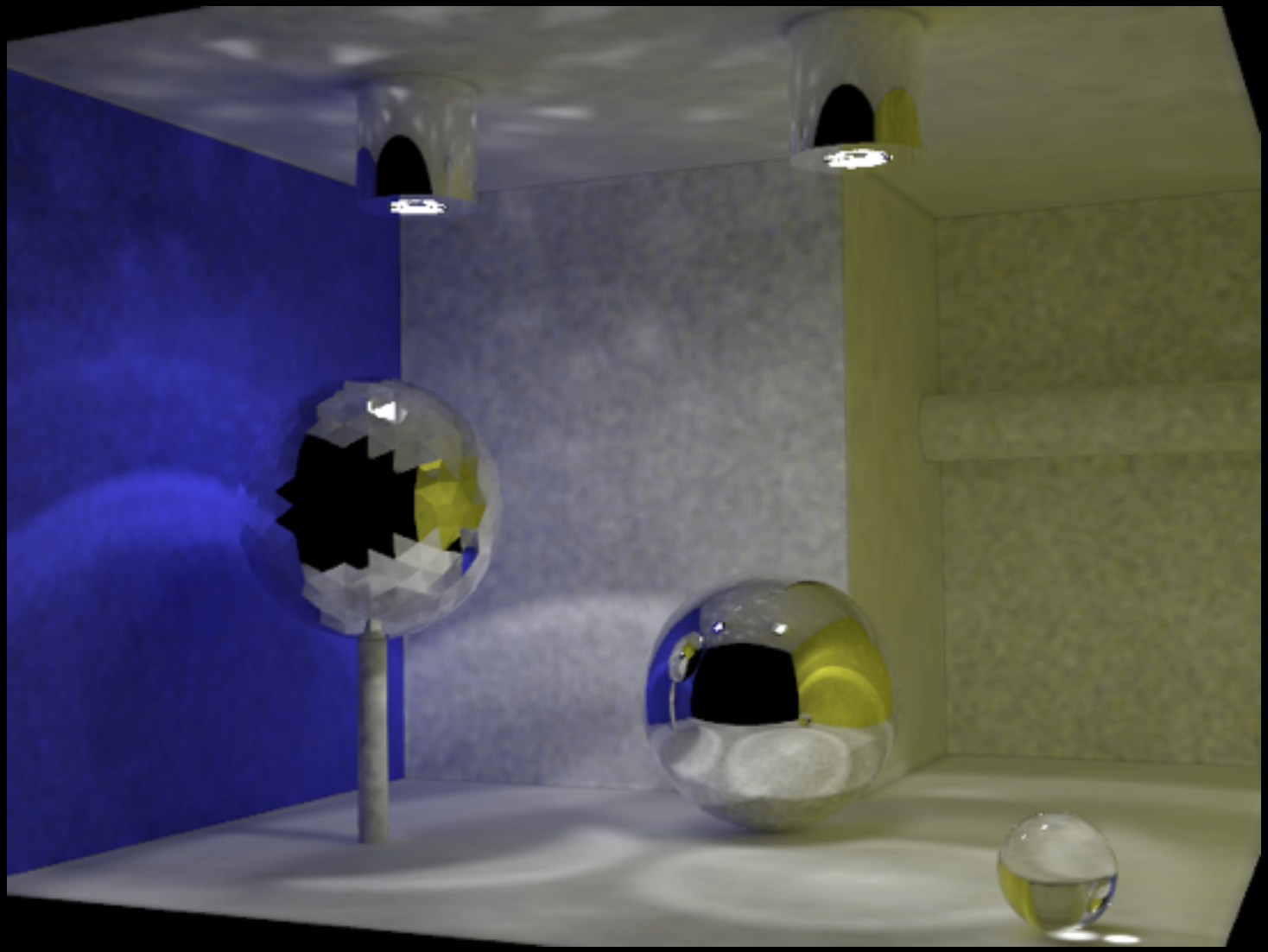
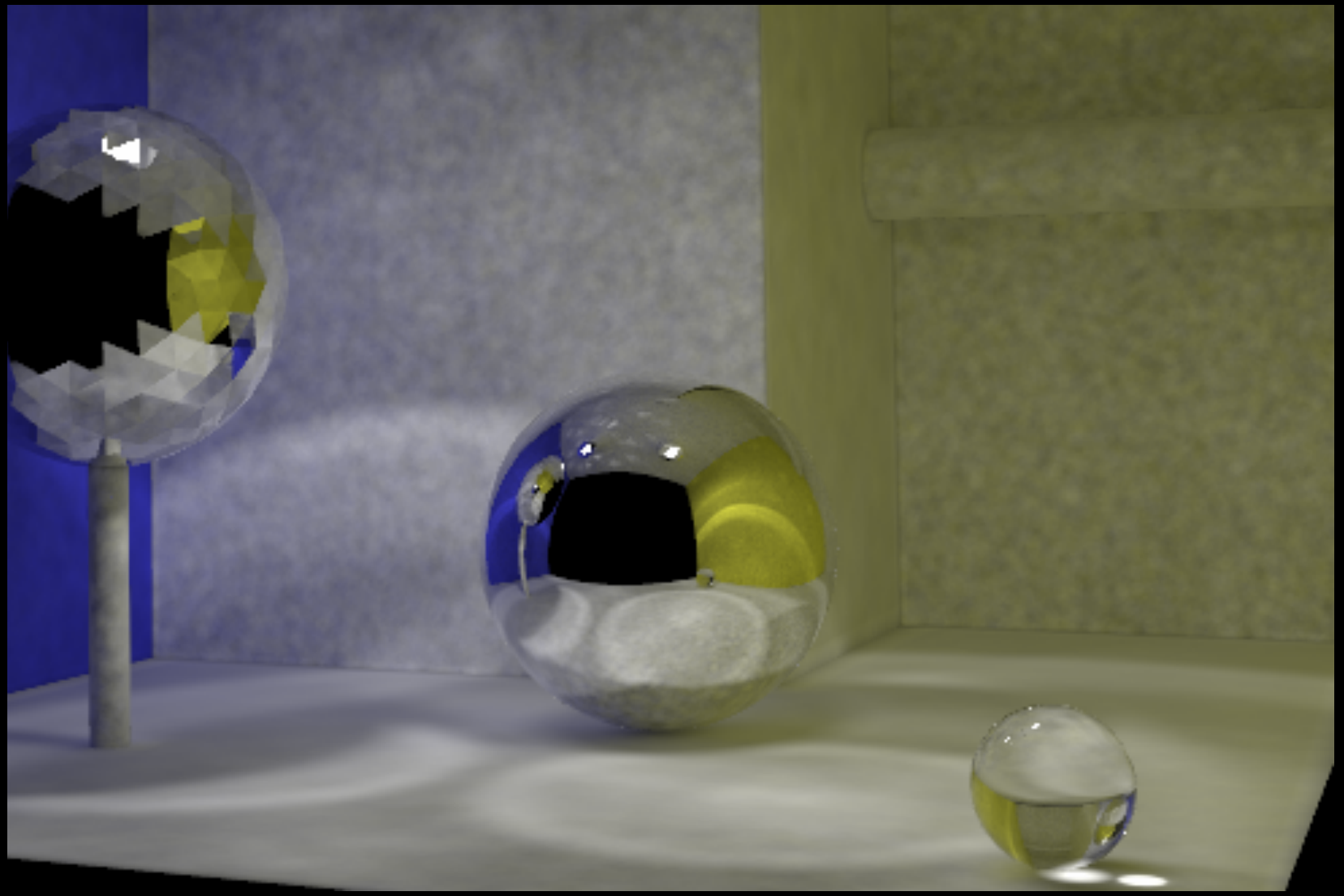
  - ...name your favorite
  - Photon mapping?

Photon Mapping



Photon Mapping



Convergence of Photon Mapping

More photons →

Convergence of Photon Mapping

$$L(x,\vec{\omega}) = \lim_{N\to\infty} \sum_{p=1}^{N^{\beta}} \frac{f_r(x,\vec{\omega},\vec{\omega}_p)\phi_p(x_p,\vec{\omega}_p)}{\pi r^2}$$

- Infinite number of nearby photons ($N^{\beta}\to\infty$)
- Infinitely small radius ($r\to 0$)

Convergence of Photon Mapping

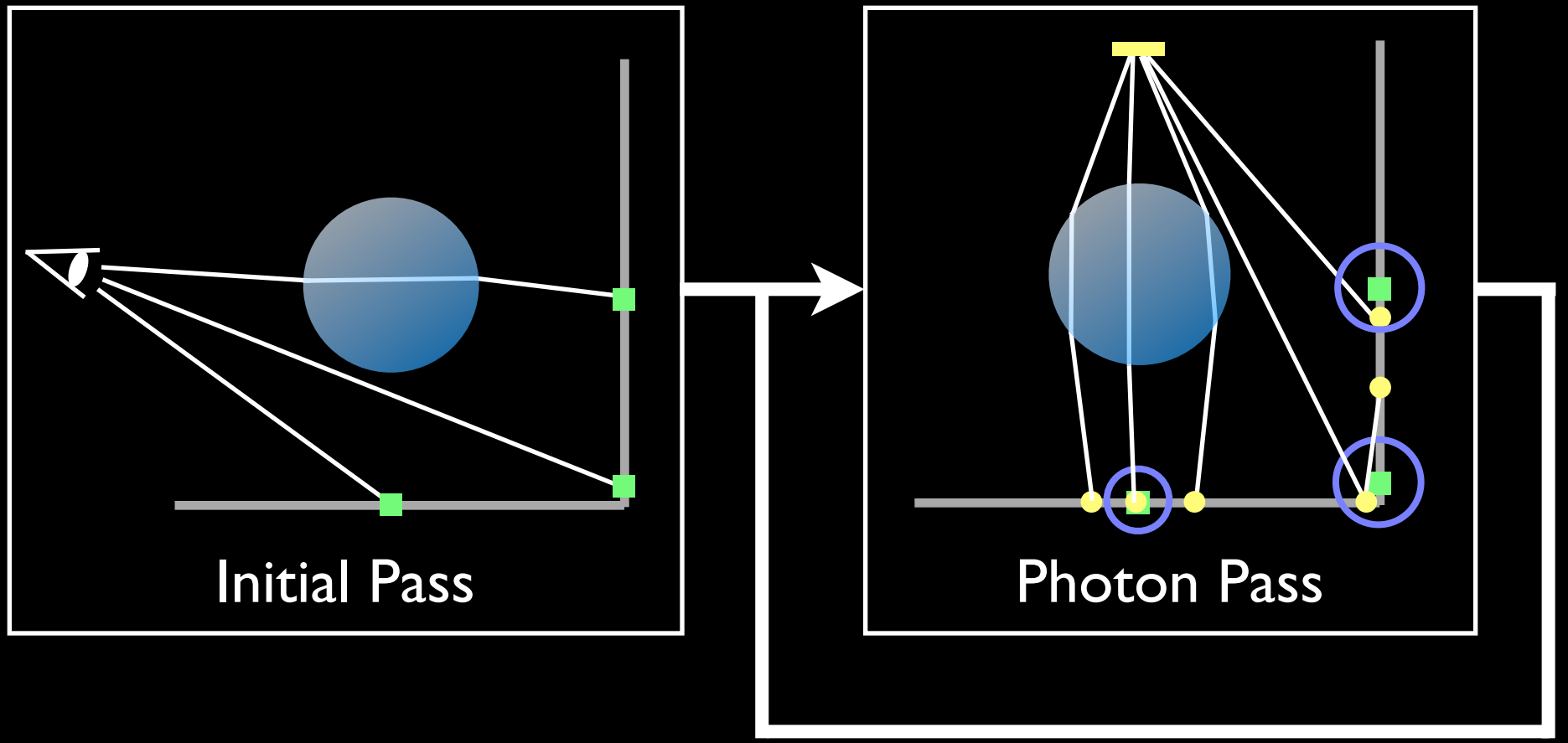
$$L(x,\vec{\omega}) = \lim_{N\to\infty} \sum_{p=1}^{N^{\beta}} \frac{f_r(x,\vec{\omega},\vec{\omega}_p)\phi_p(x_p,\vec{\omega}_p)}{\pi r^2}$$

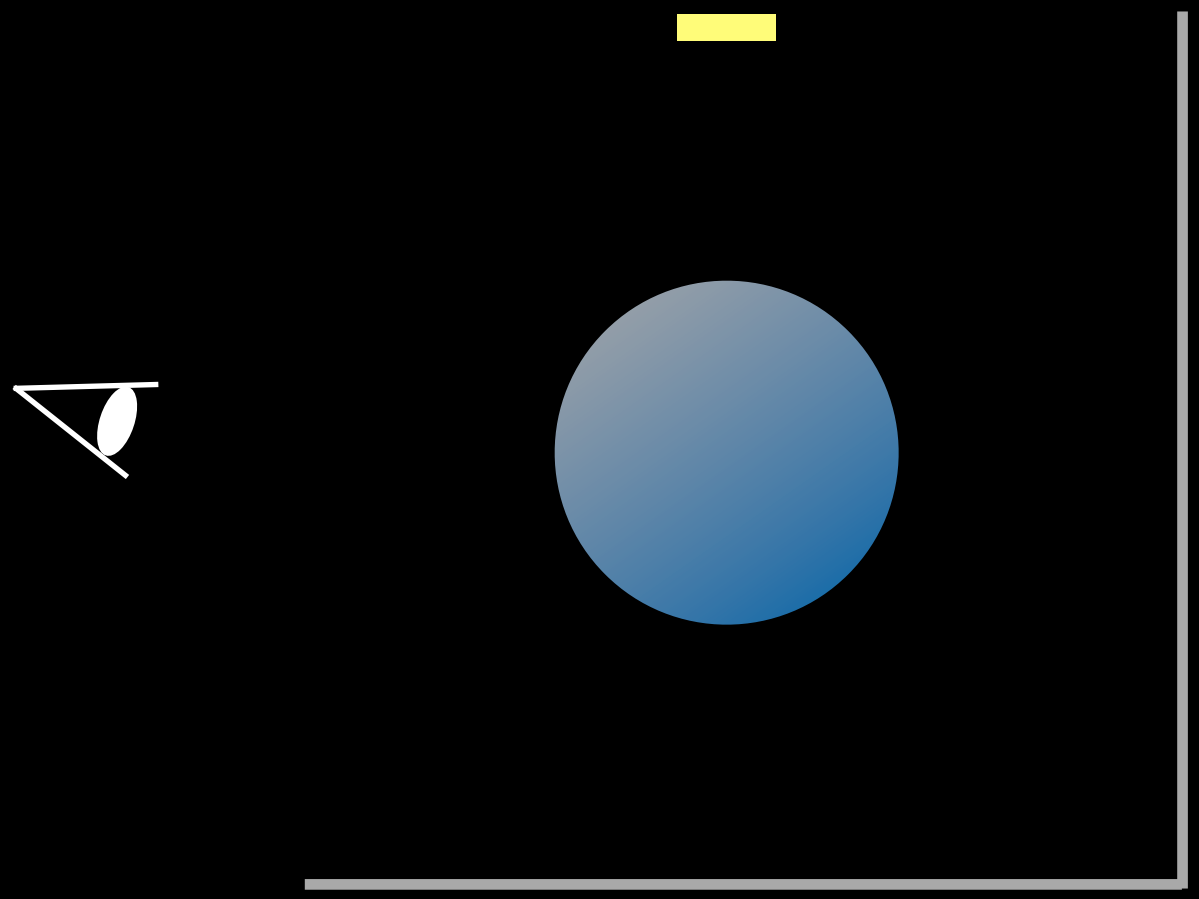
Infinite storage & photon tracing

- Infinite number of nearby photons ($N^{\beta}\to\infty$)
- Infinitely small radius ($r\to 0$)

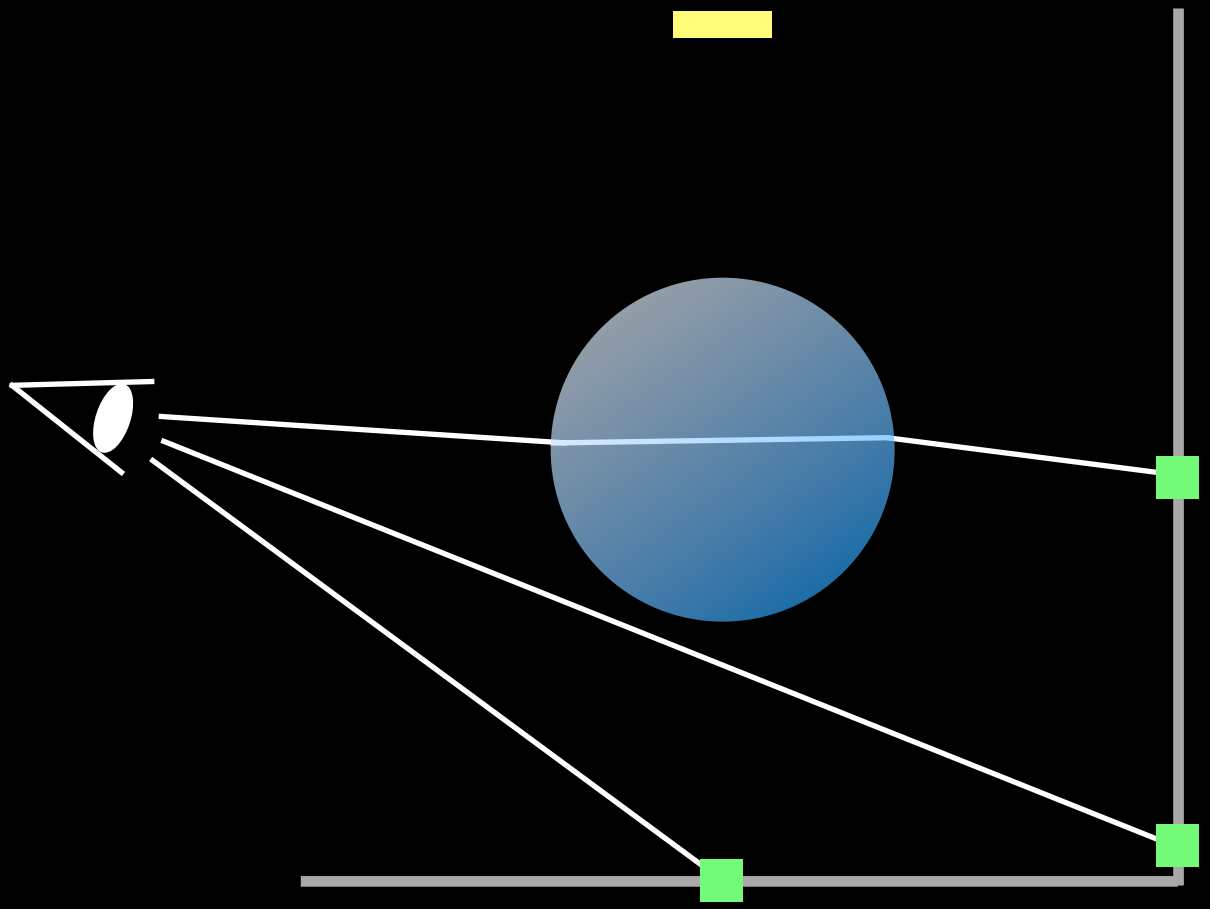
Solution:
Progressive Photon Mapping

Overview

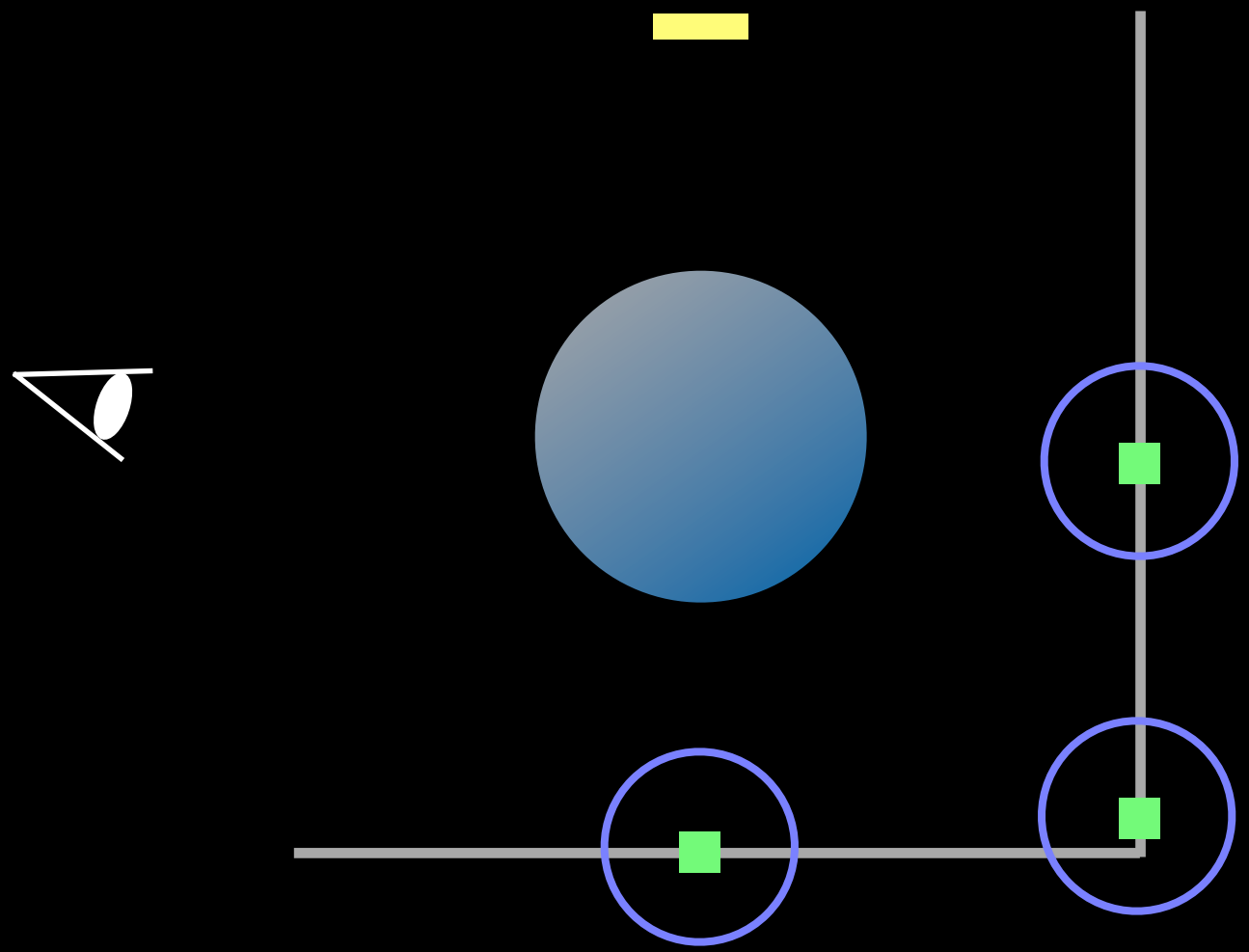




Initial Pass



Initial Pass

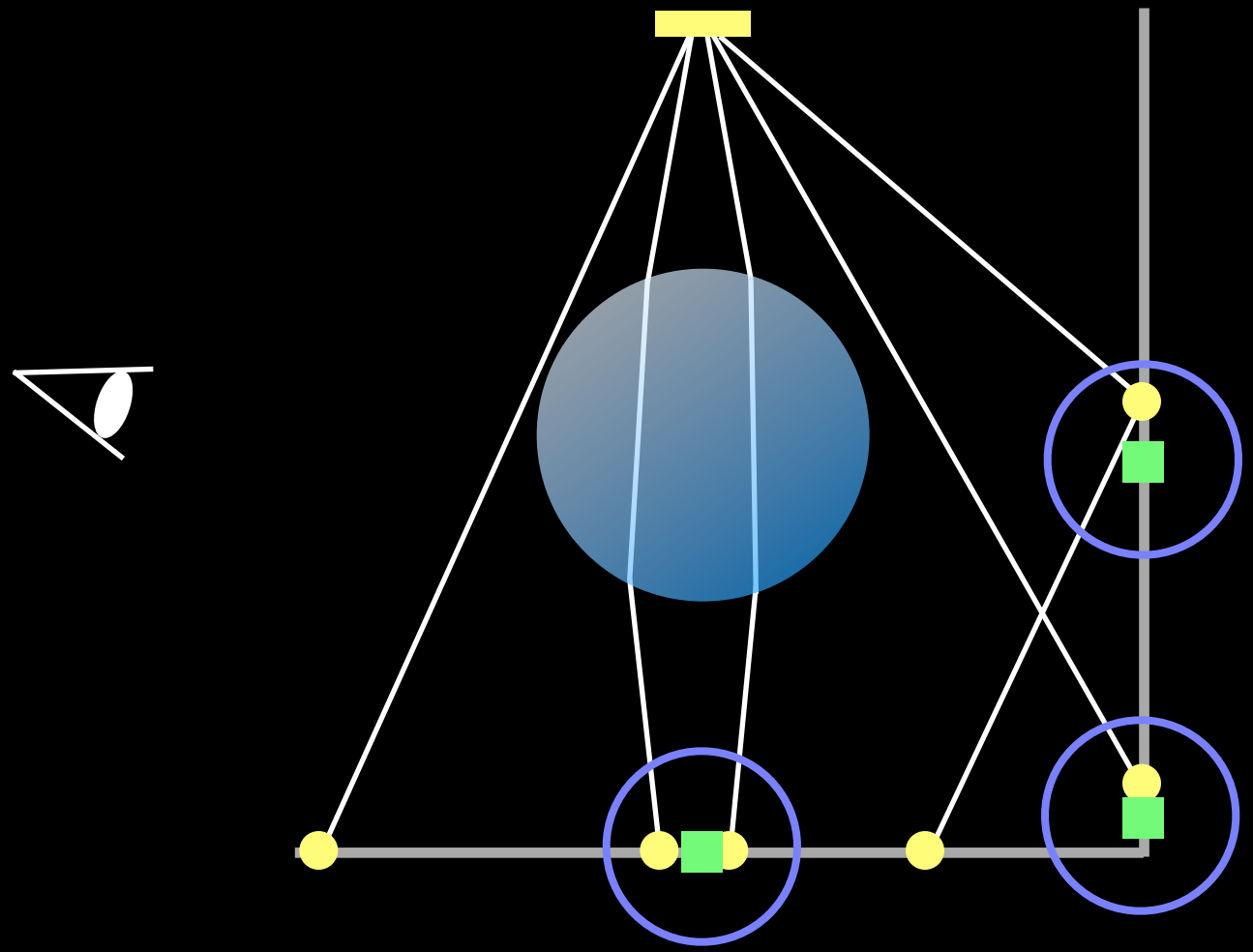


Photon Statistics

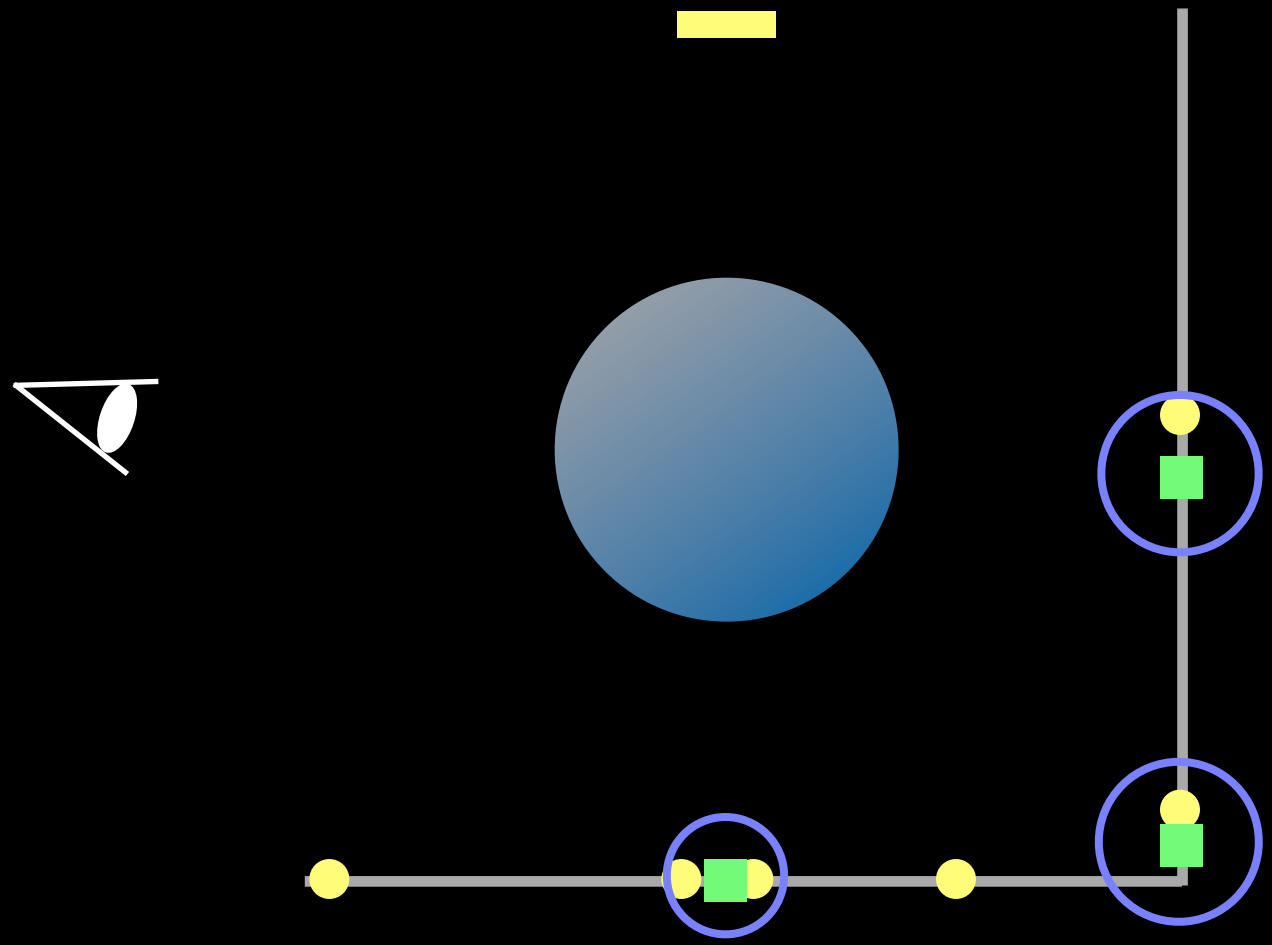
- Each measurement point:
  - Accumulated flux times BRDF $\tau_i\left(x, \vec{\omega}\right)$
  - Search radius $R_i\left(x\right)$
  - Local photon count $N_i(x)$

- Global:
  - Emitted photon count $N_e(i)$

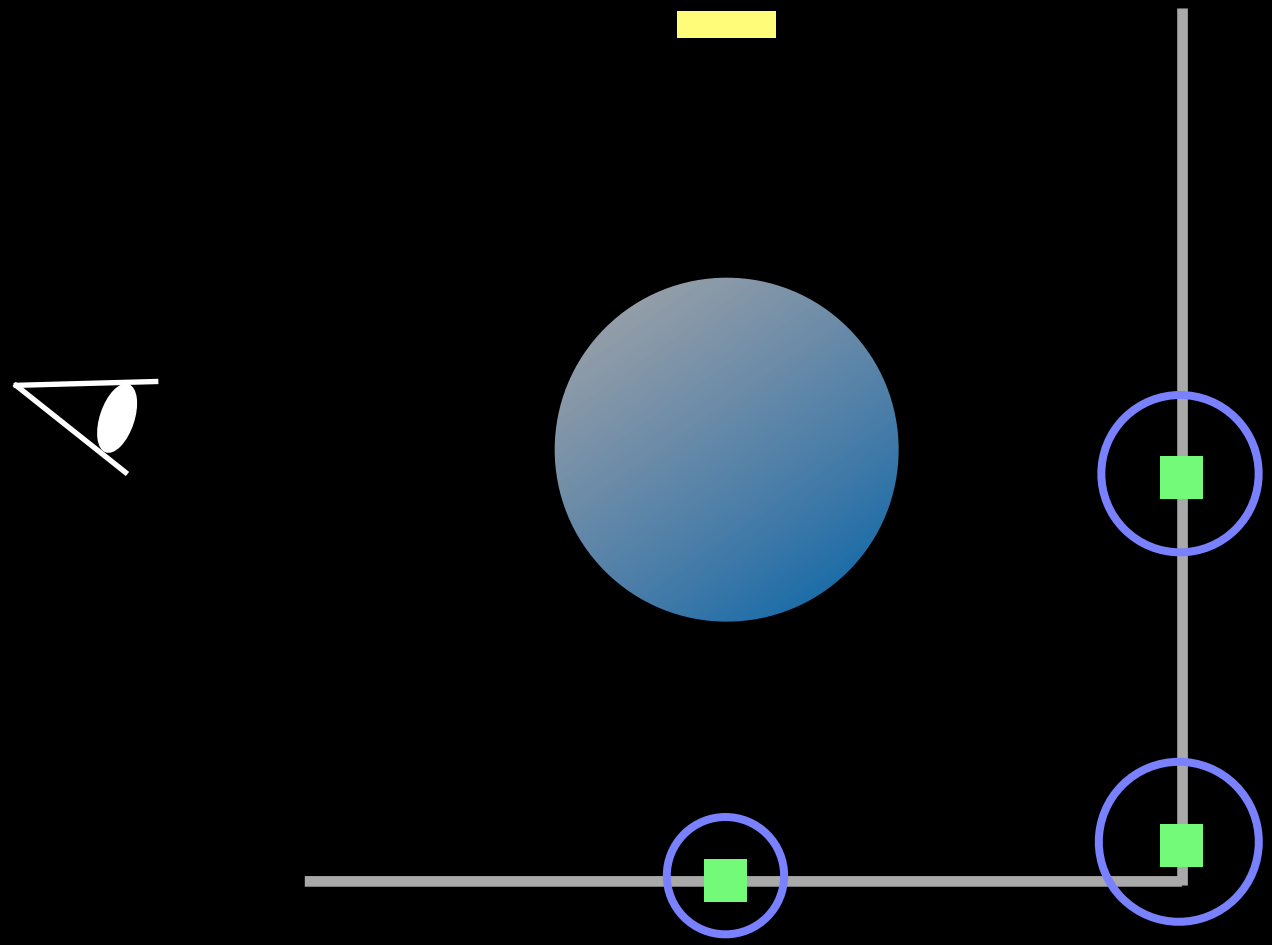
Photon Pass



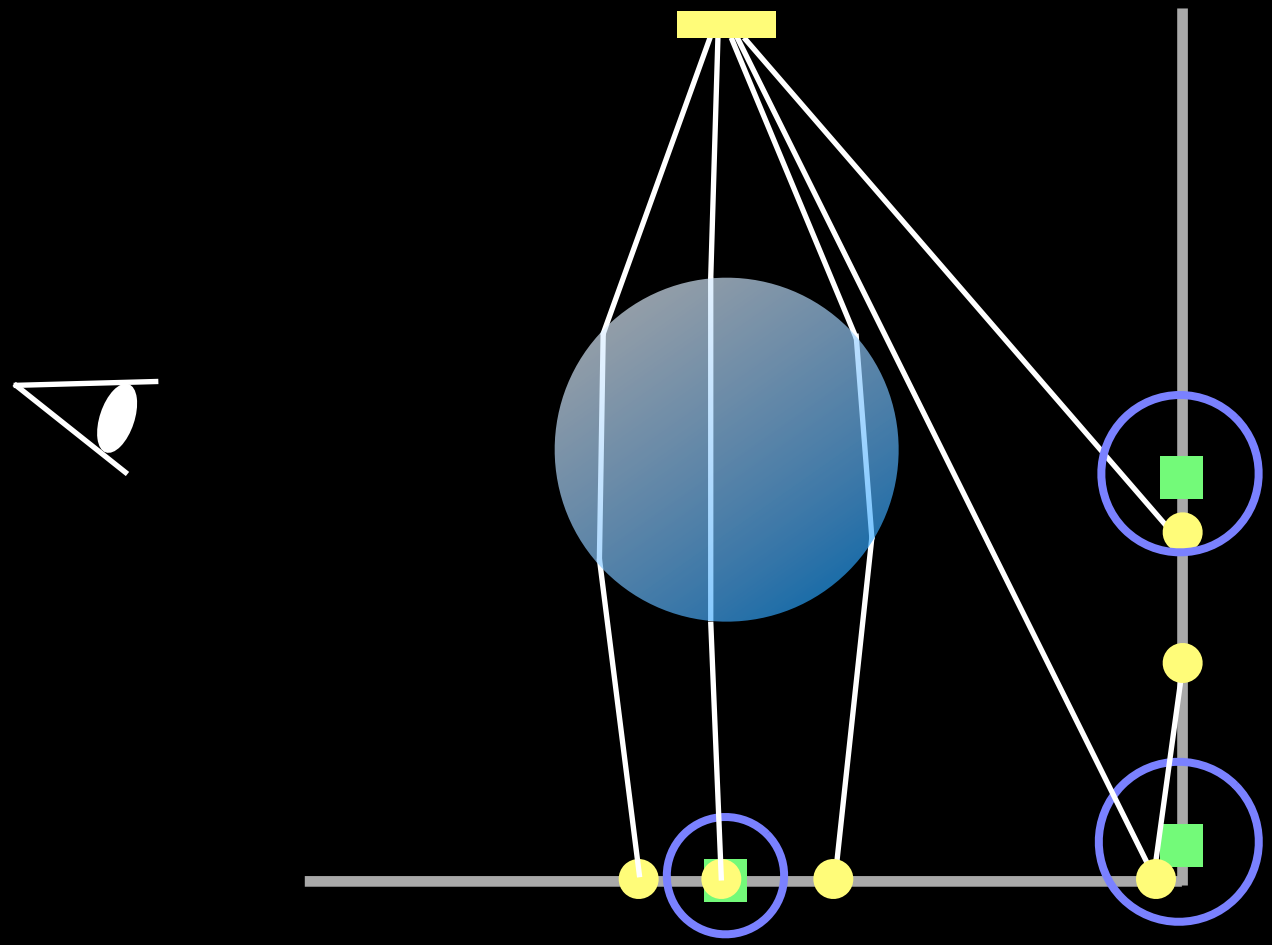
Photon Pass



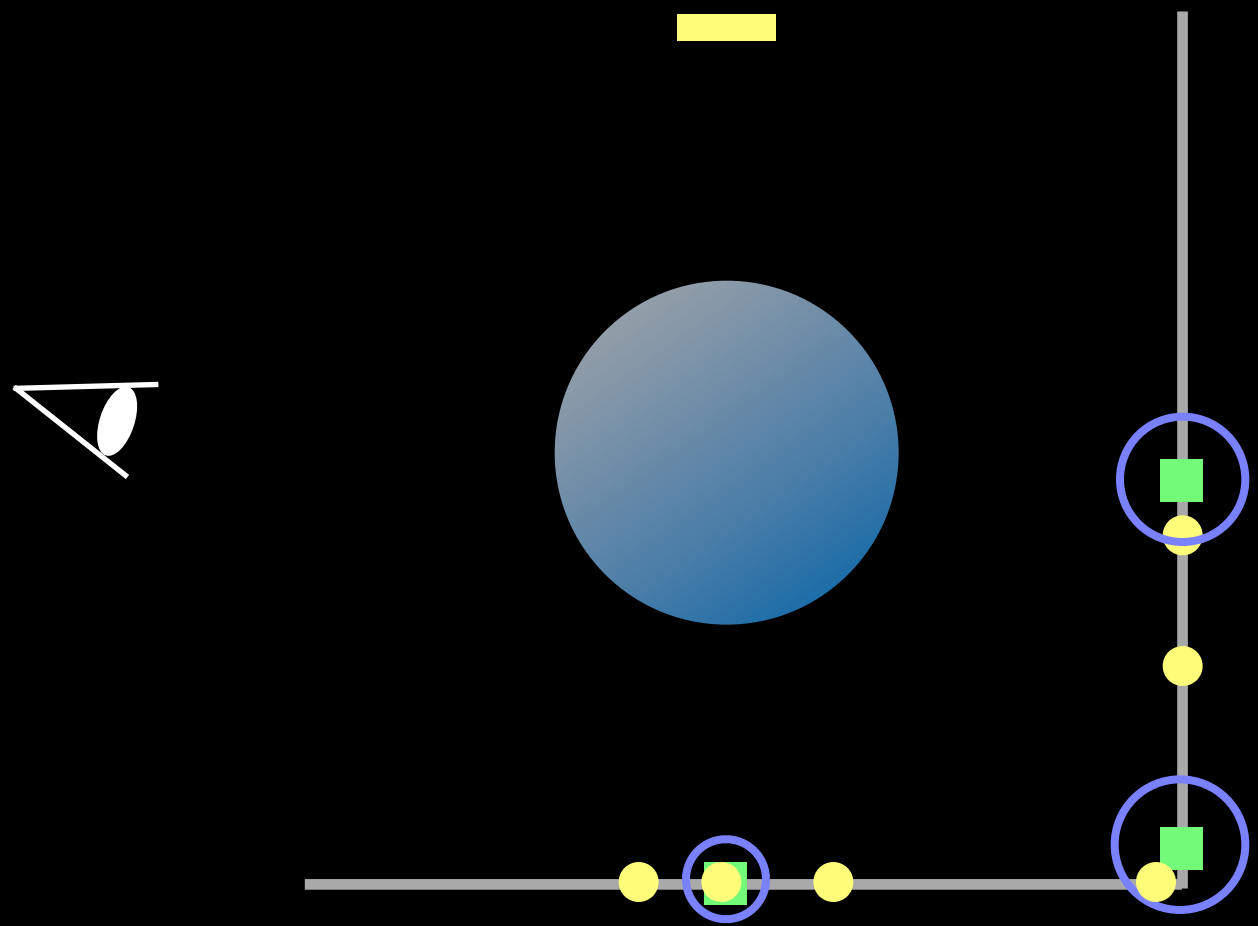
Photon Pass



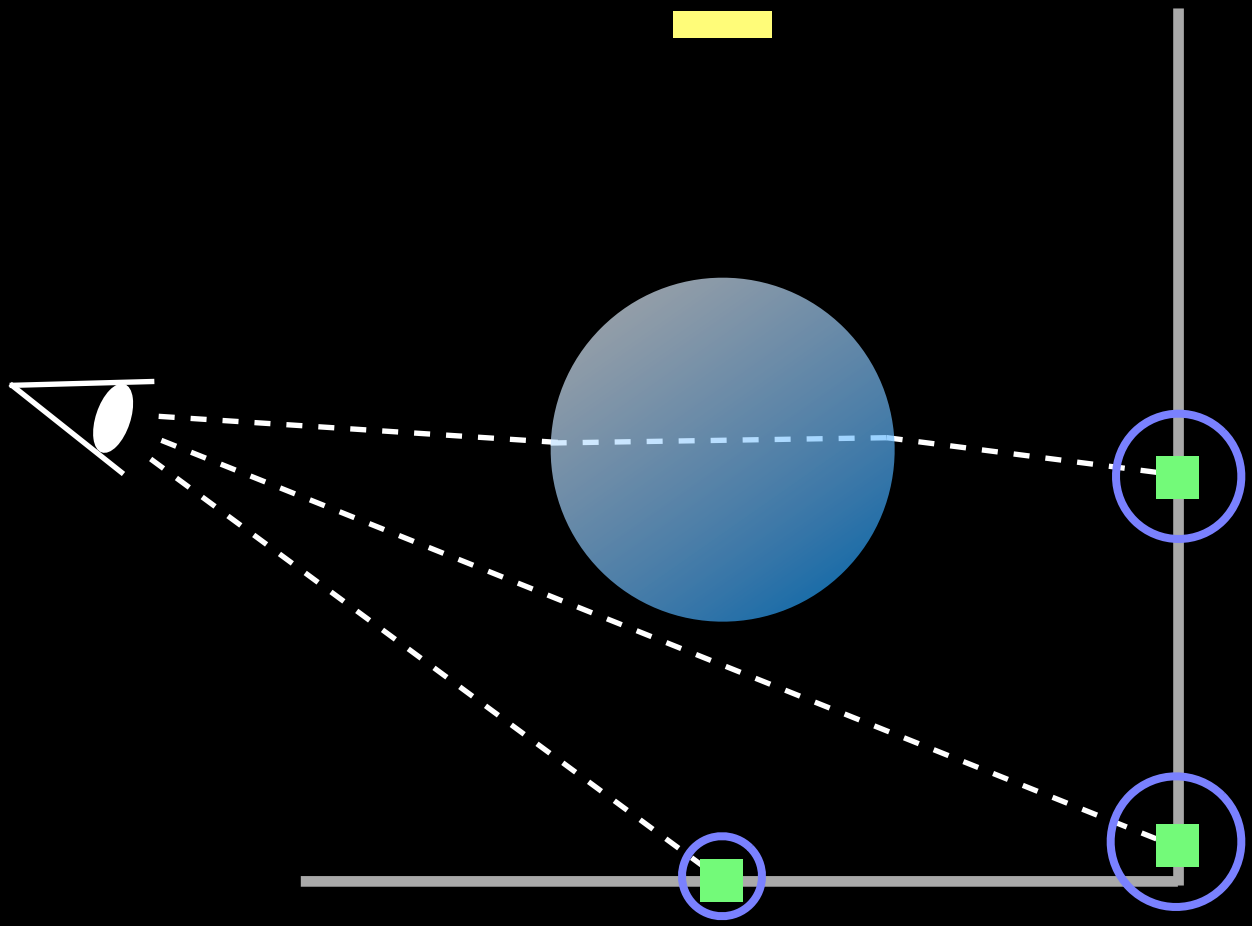
Next Photon Pass



Next Photon Pass



Rendering

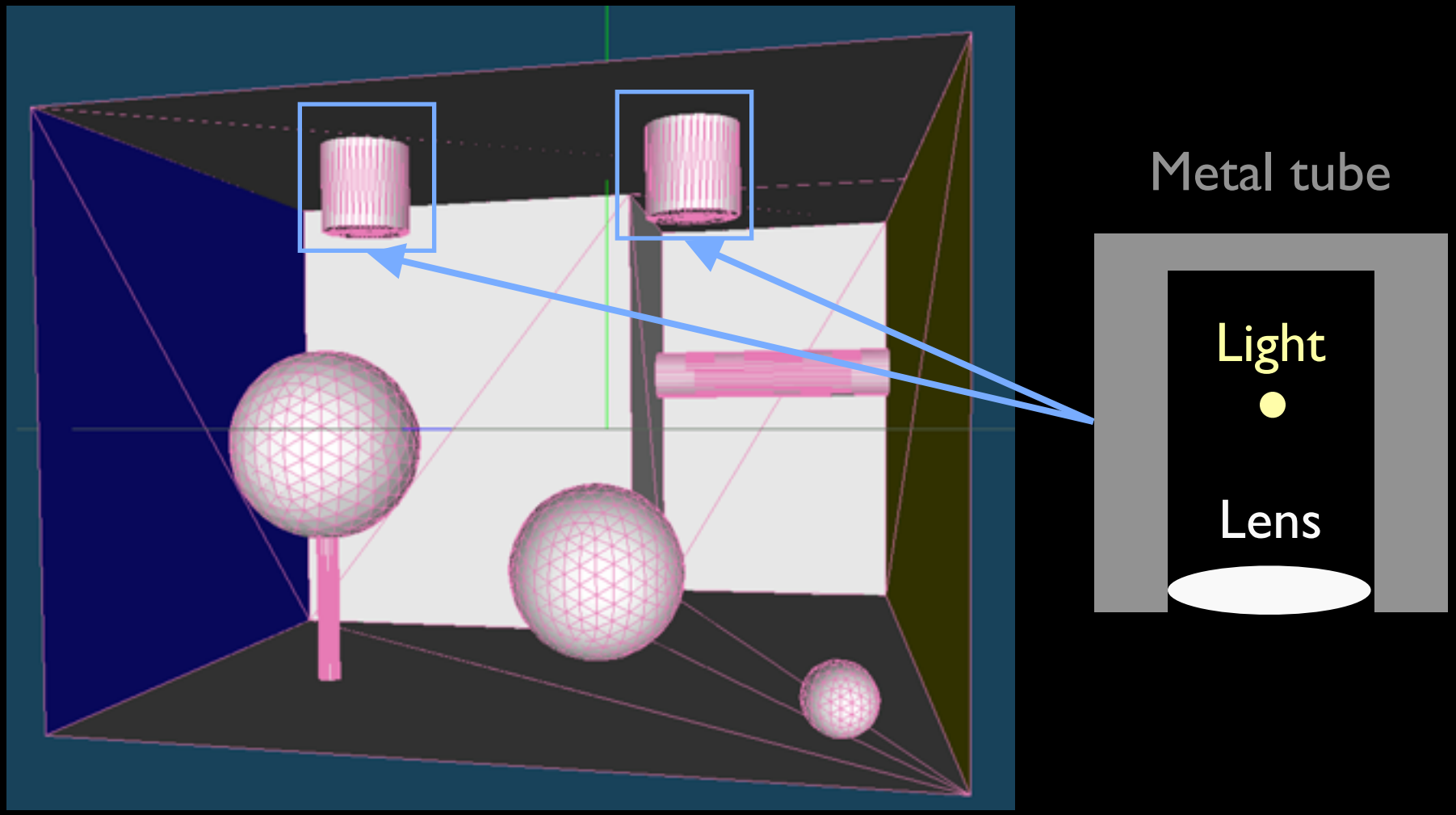


Progressive Density Estimation

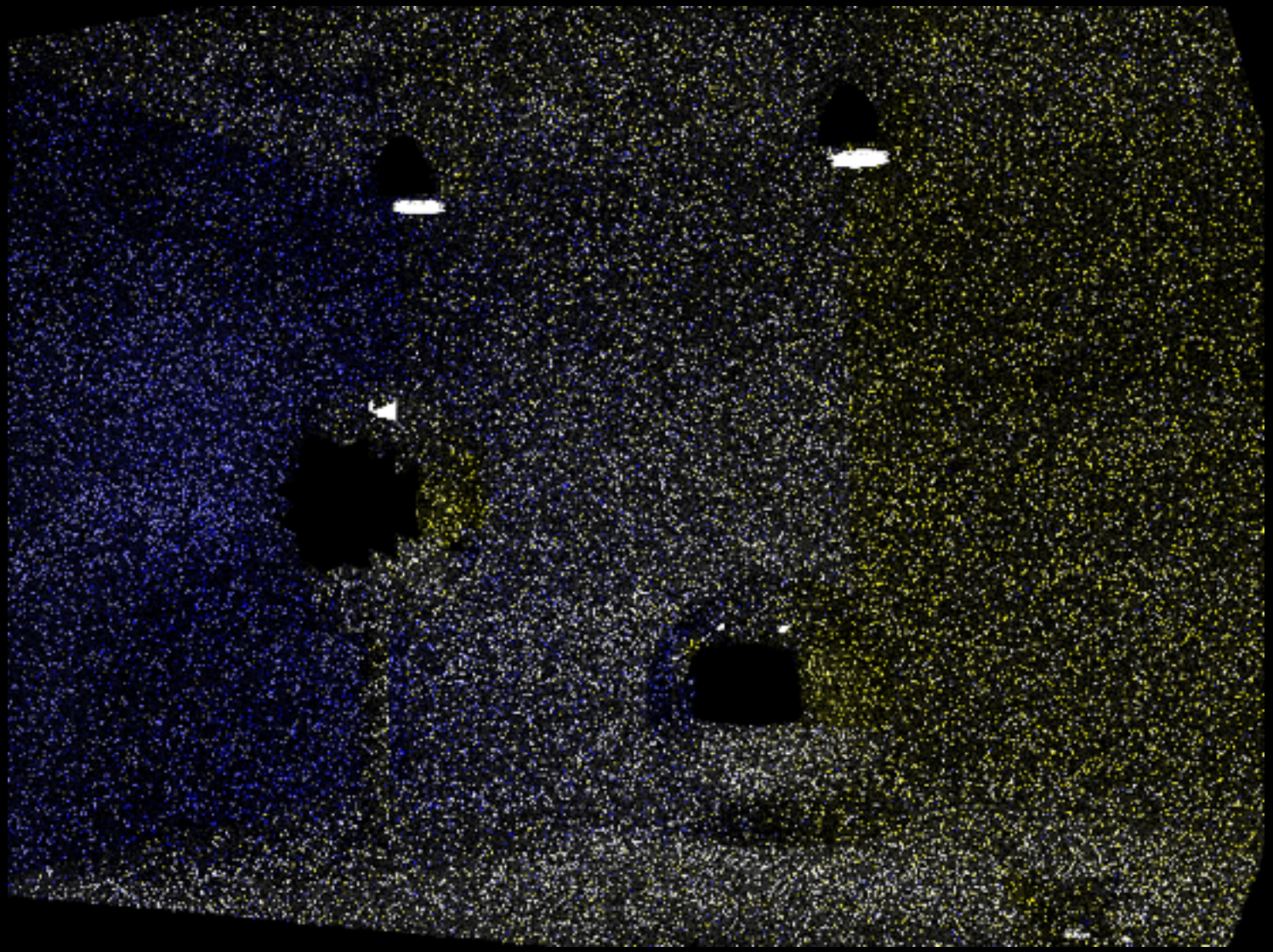
$$L_i\left(\vec{\omega}\right) = \sum_{p=1}^{N_i} \frac{f_r\left(\vec{\omega}, \vec{\omega}_p\right) \phi_p\left(\vec{\omega}_p\right)}{\pi R_i^2}$$

- Converges to the correct solution
  - Infinite number of photons
  - Infinitely small radius

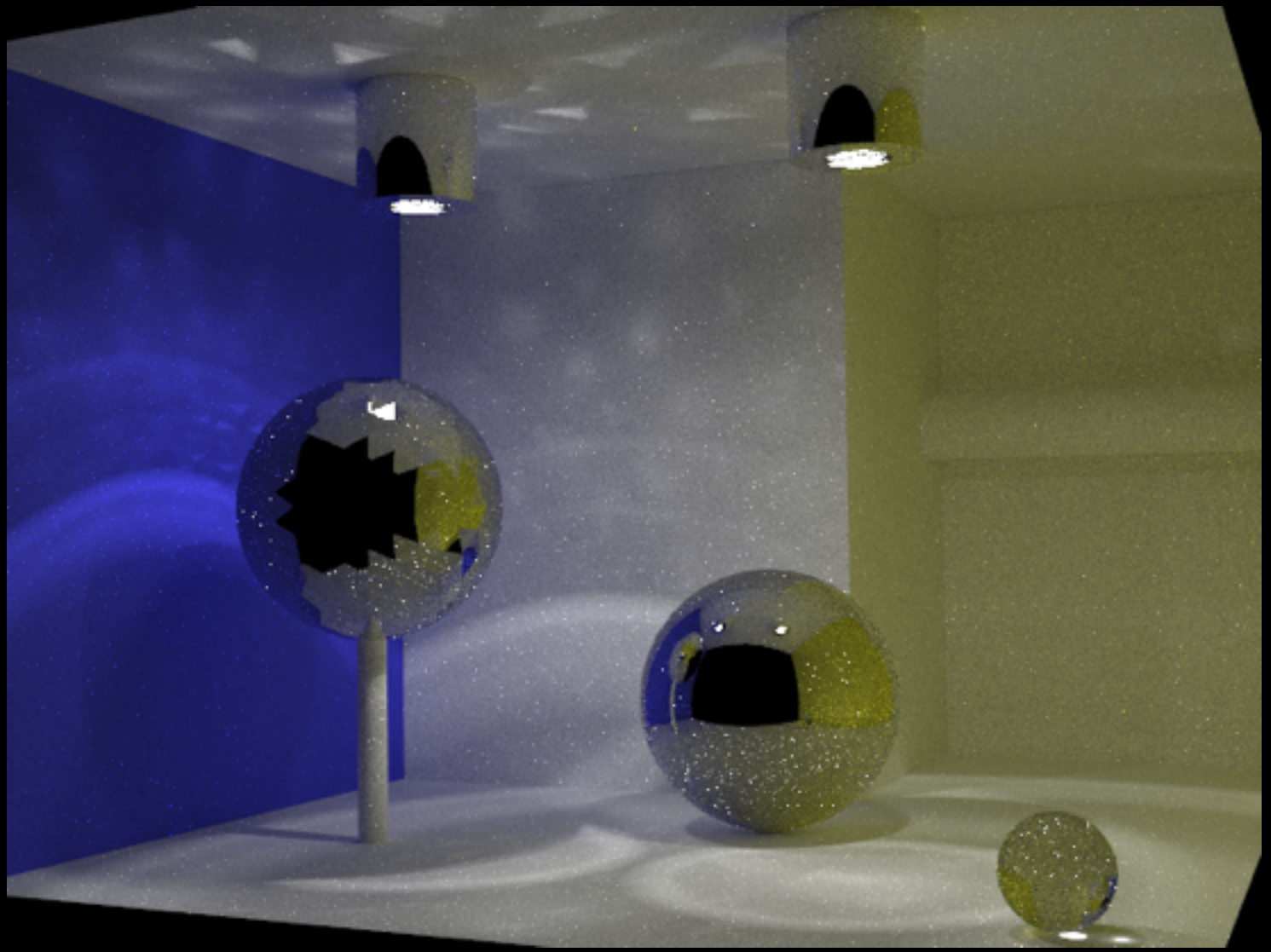
Equal-time Comparisons



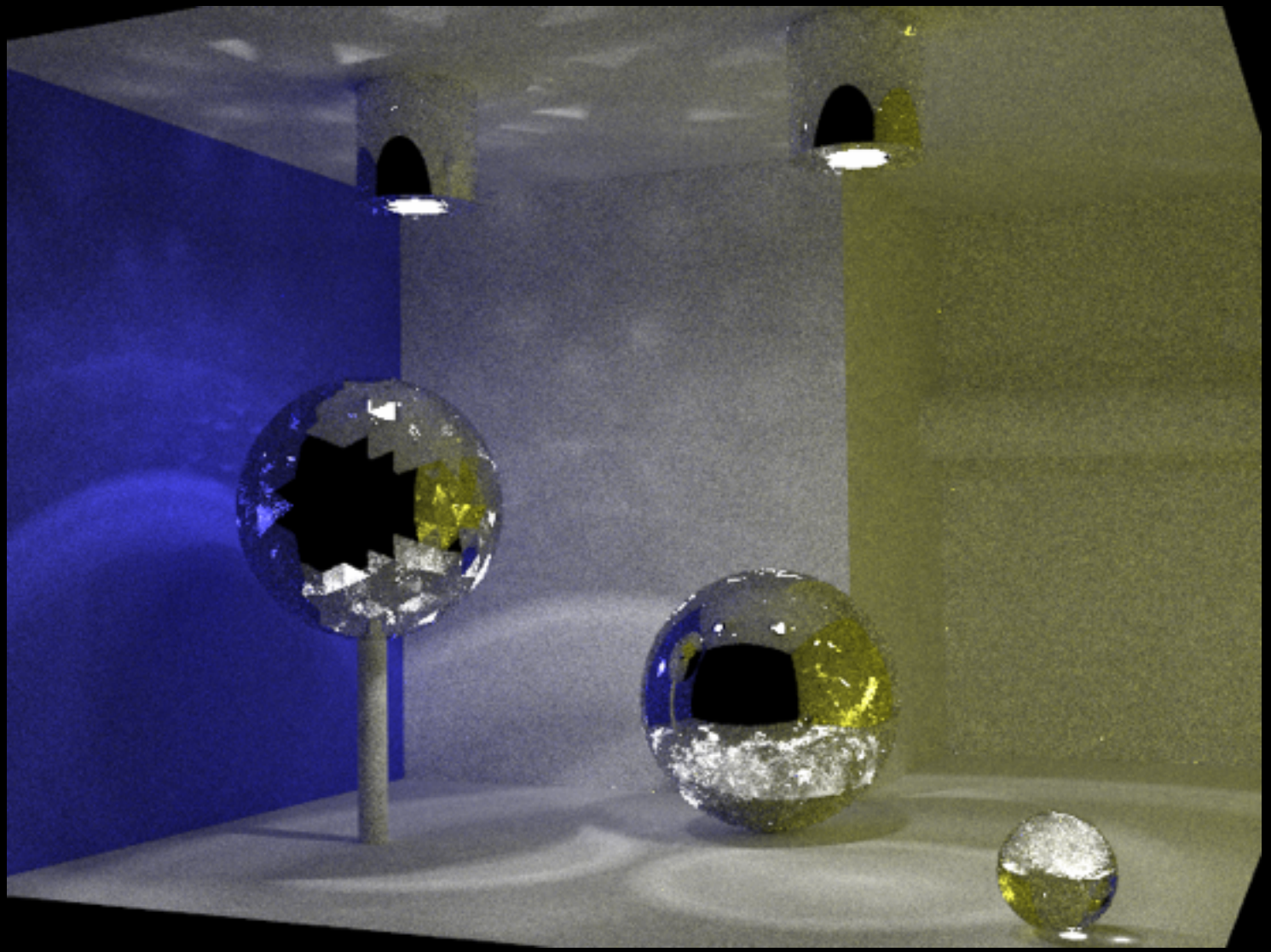
Path Tracing



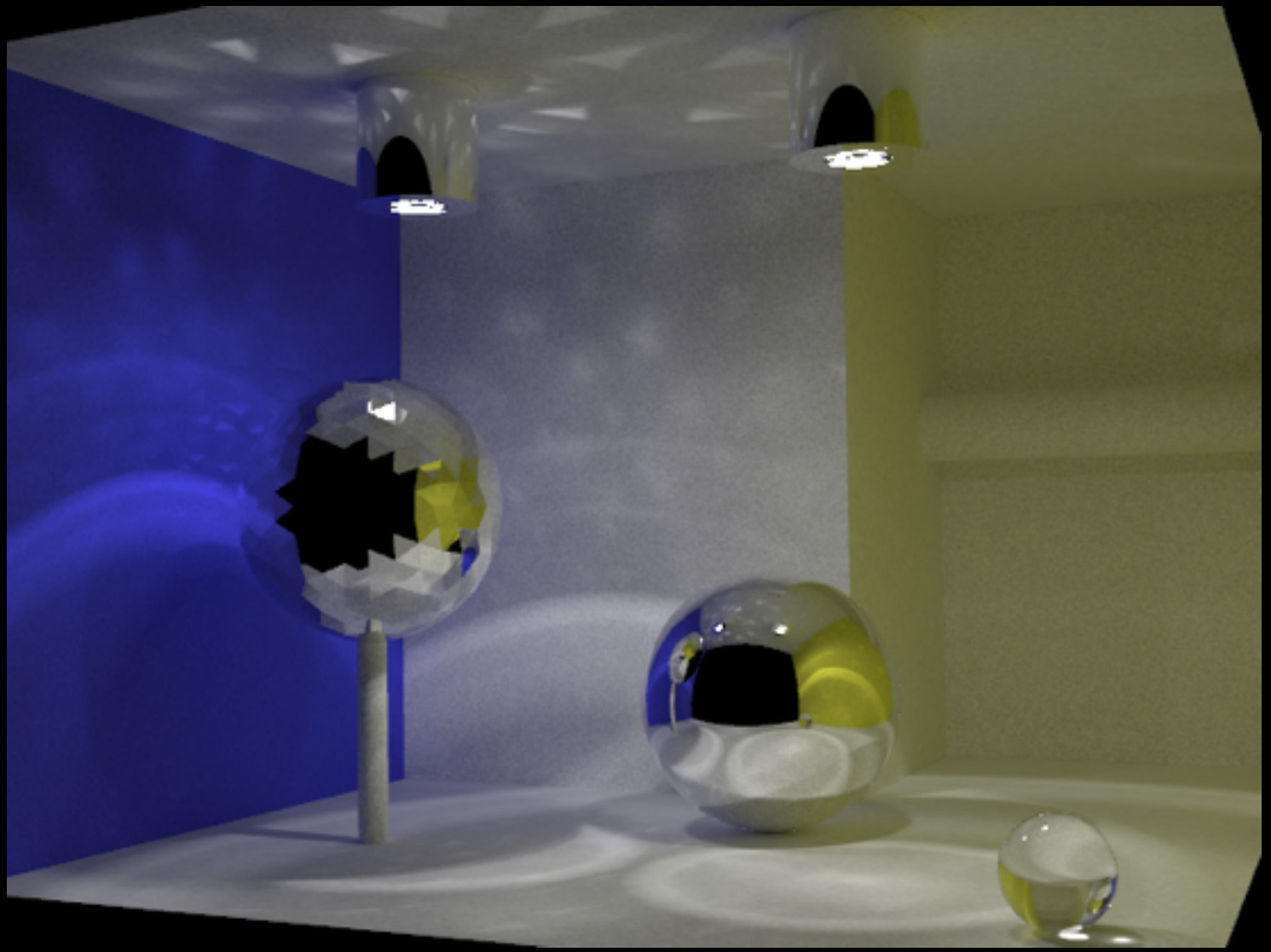
Bidirectional Path Tracing



Metropolis Light Transport



Progressive Photon Mapping



Bidirectional Path Tracing

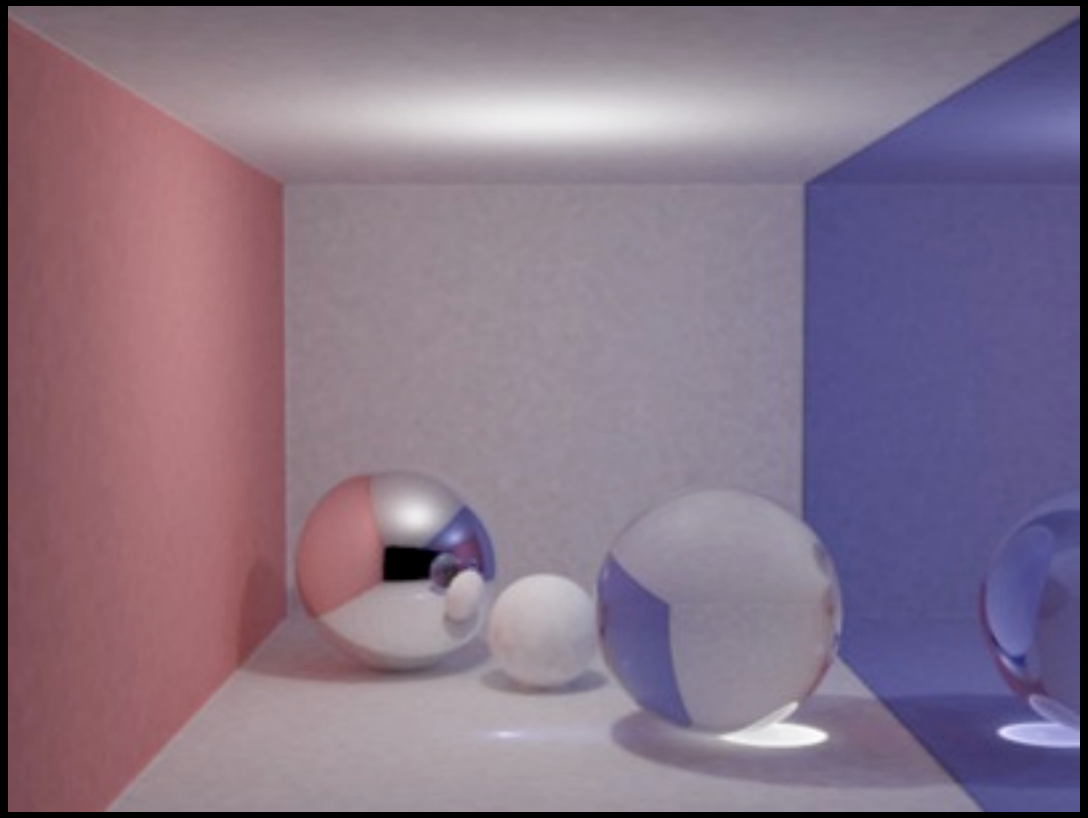
Progressive Photon Mapping

Metropolis Light Transport

Progressive Photon Mapping

Sample Code

- smallppm - 128 lines of working PPM code



cs.au.dk/~toshiya/smallppm.cpp

Summary

- Infinite number of photons without storing them - “Path tracing”nization of photon mapping

- Robust to specular-diffuse-specular paths
- Converges to the correct solution
- Easy to implement

PPM in the Wild

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GPL PHYSICALLY BASED RENDERER