Irradiance Importance Sampling

Bachelorarbeit
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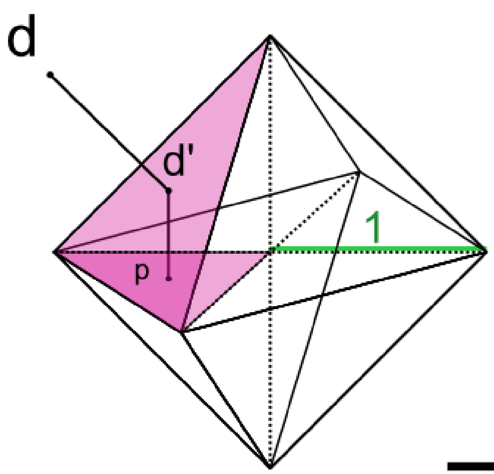
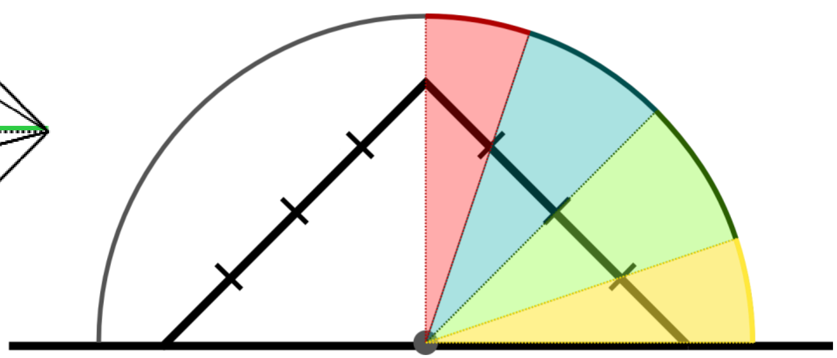
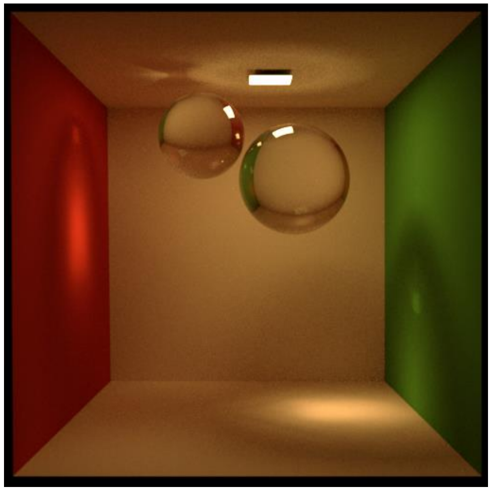
Institut für Visualisierung und Datenanalyse, Lehrstuhl für Computergrafik







Goal

- Photorealistic Images
- Improve Path Tracing

Rendering Equation:

$$L_o(x,\omega_o) = L_e(x,\omega_o) + \int_{\mathcal{S}^2} L_i(x,\omega_i)\cdot f_s(\omega_i,x,\omega_o)\cdot cos(\omega_i)d\sigma(\omega_i)$$

→ Monte-Carlo Integration:

$$\int_{\mathcal{S}^2} L_i(x,\omega_i)\cdot f_s(\omega_i,x,\omega_o)\cdot cos(\omega_i)d\sigma(\omega_i) \approx \frac{1}{N}\sum_{k=1}^{N}\frac{L_i(x,\omega_k)\cdot f_s(\omega_k,x,\omega_o)\cdot cos(\omega_k)}{p(\omega_k)}$$

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Importance Sampling: Options

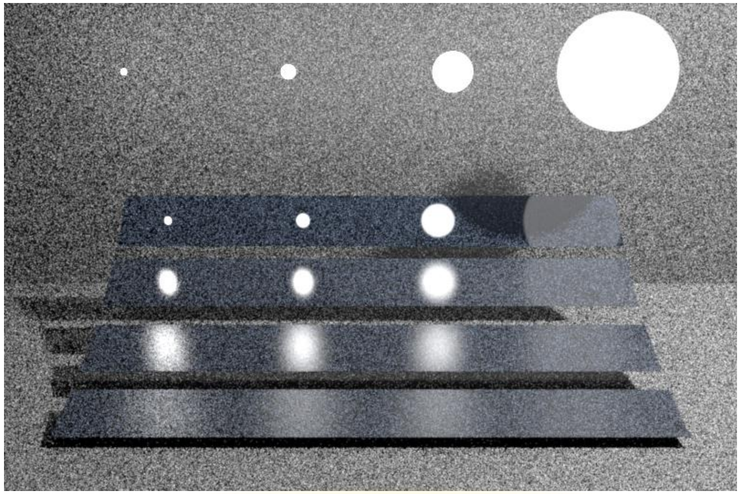
$$\int_{S^2} L_i(x, \omega_i) \cdot f_s(\omega_i, x, \omega_o) \cdot cos(\omega_i) d\sigma(\omega_i)$$

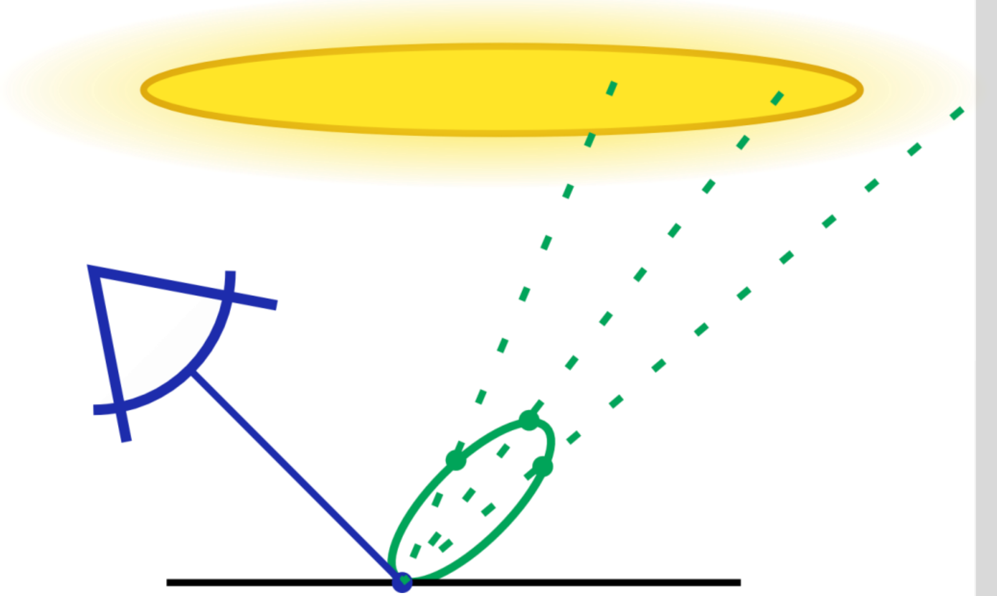
- The cosine: $p \propto cos$

Importance Sampling: Options

$$\int_{S^2} L_i(x,\omega_i)\cdot f_s(\omega_i,x,\omega_o)\cdot cos(\omega_i)d\sigma(\omega_i)$$

- The cosine: $p \propto cos$
- The BSDF: $p \propto f_s$





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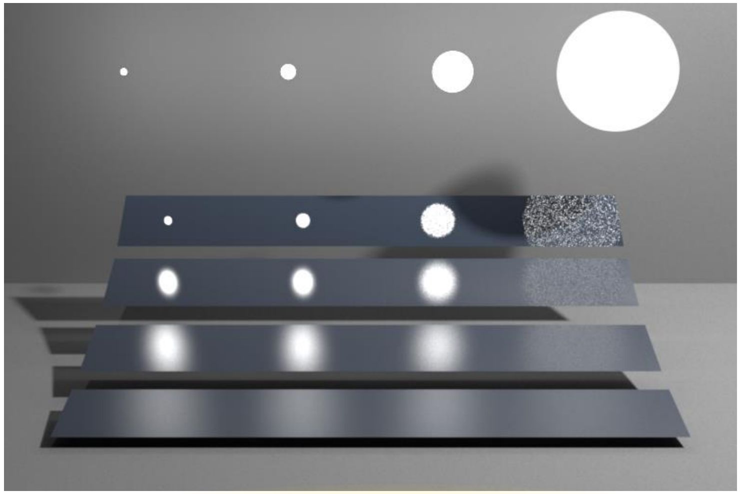
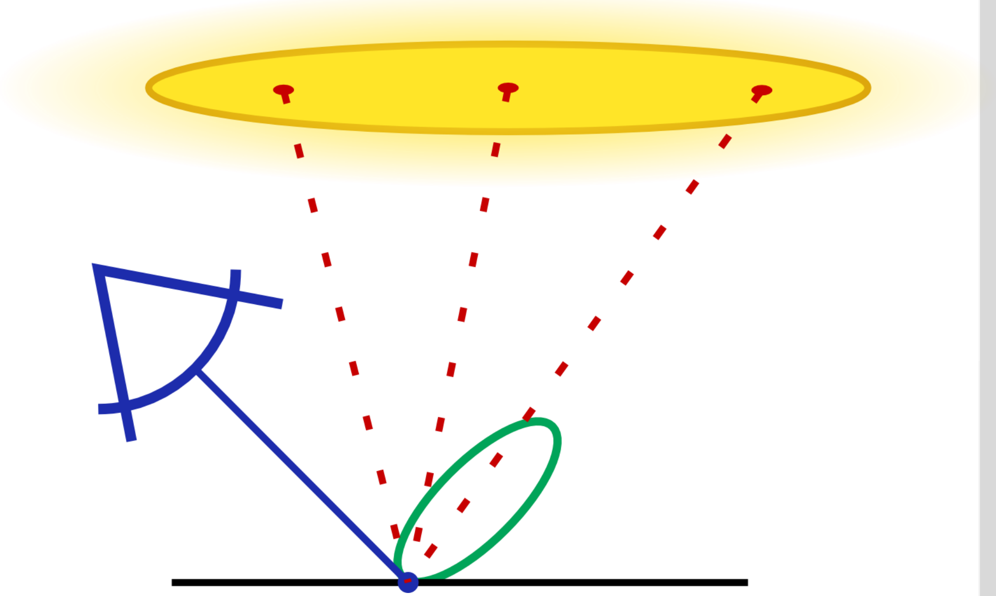
Importance Sampling: Options

$$\int_{S^2} L_i(x,\omega_i) \cdot f_s(\omega_i, x, \omega_o) \cdot cos(\omega_i) d\sigma(\omega_i)$$

- The cosine: $p \propto cos$
- The BSDF: $p \propto f_s$
- Incident Radiance (L_i):
  - Next event estimation (connection to light source)





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Importance Sampling: Options

$$\int_{S^2} L_i(x,\omega_i) \cdot f_s(\omega_i, x, \omega_o) \cdot cos(\omega_i) d\sigma(\omega_i)$$

- The cosine: $p \propto cos$
- The BSDF: $p \propto f_s$
- Incident Radiance (L_i):
  - Next event estimation (connection to light source)
  - **Caches for incident radiance**

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Steps

- Preprocessing ➔ Create Caches
- Rendering
  ➔ Create paths using…
  - Caches
  - BSDF
  - NEE

  ➔ Combine with Multiple Importance Sampling

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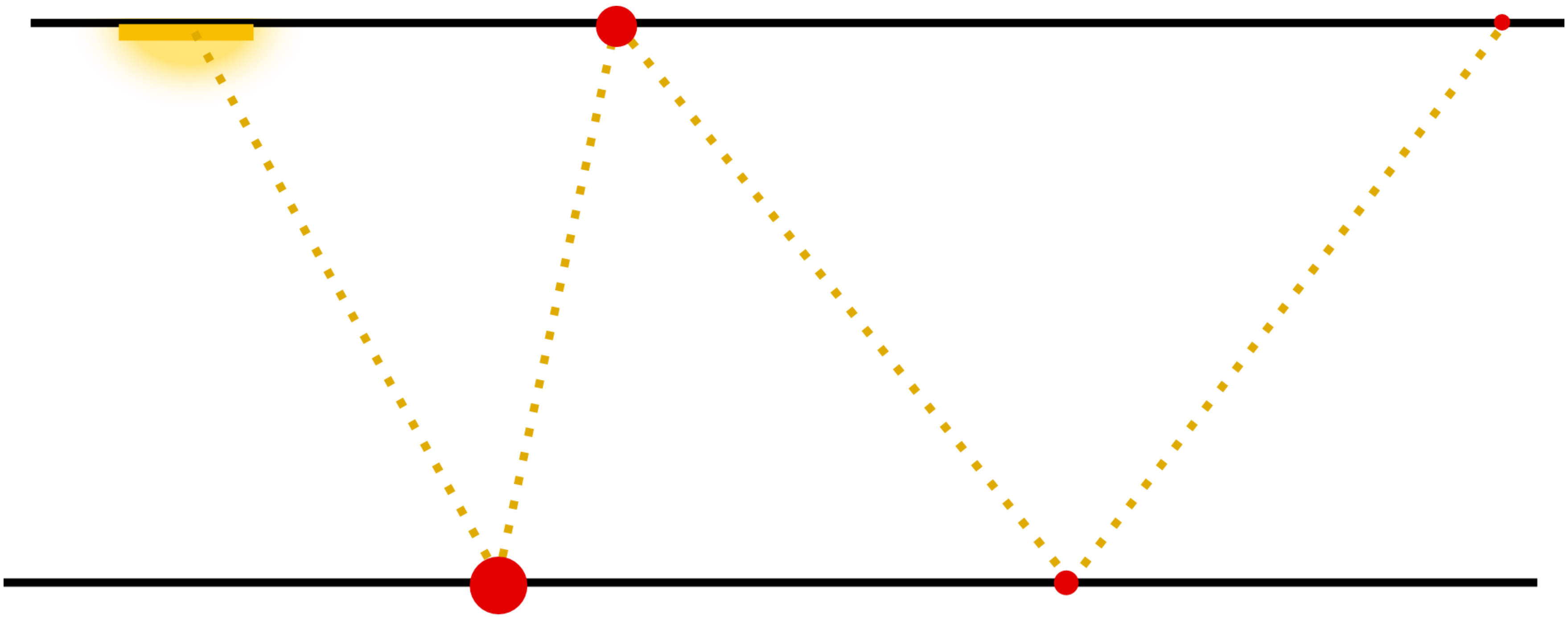
Preprocessing: Photon Mapping

- Photon:
  - Position
  - Incident direction
  - Energy



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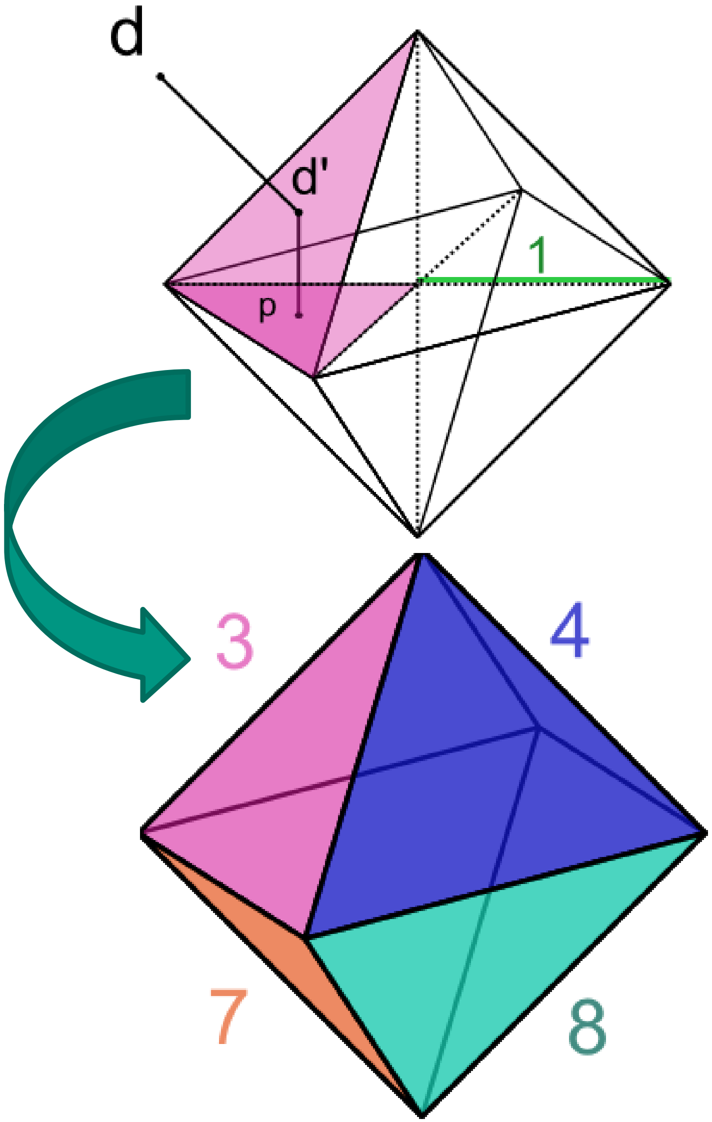
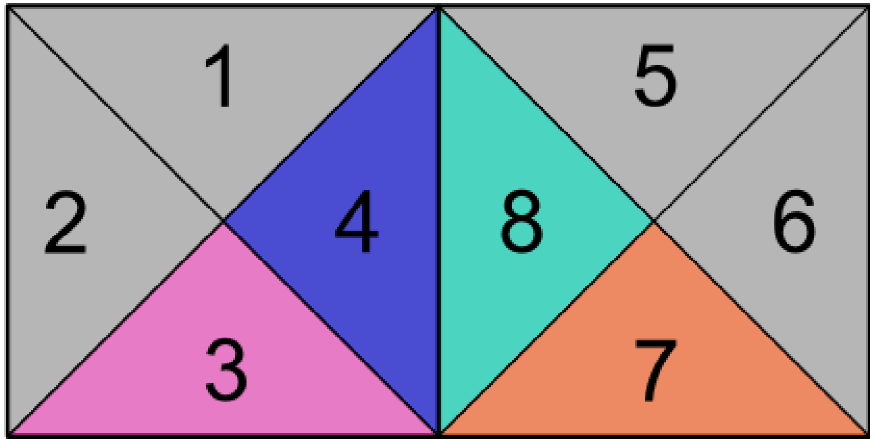
Preprocessing: Photon Mapping

- Photon:
  - Position
  - Incident direction
  - Energy
- Cancel Paths
  - Russian Roulette
  - Energy contribution too small
- k-d tree for fast nearest-neighbour search

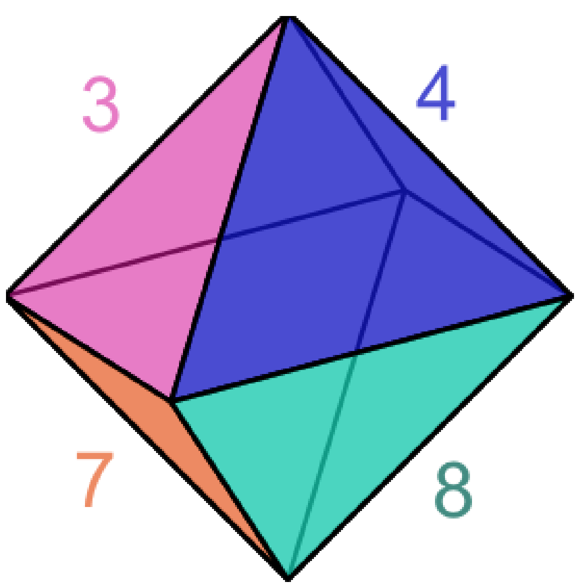
Cache Parameterization: Octahedron

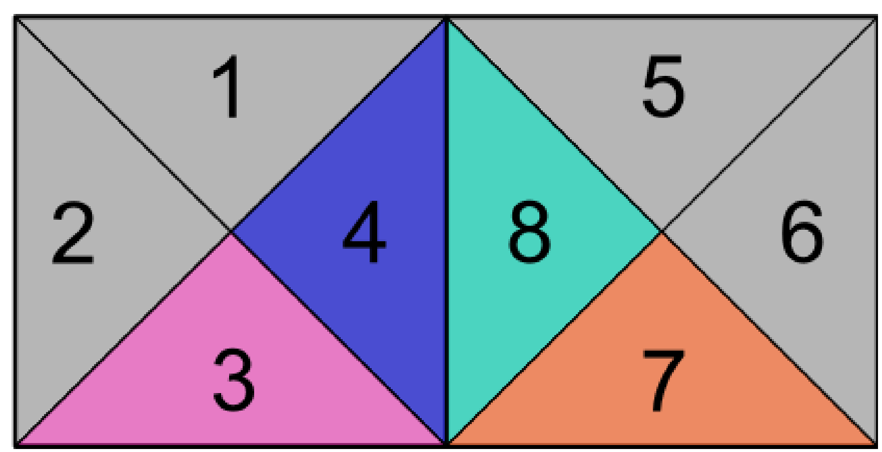




Cache Parameterization: Octahedron

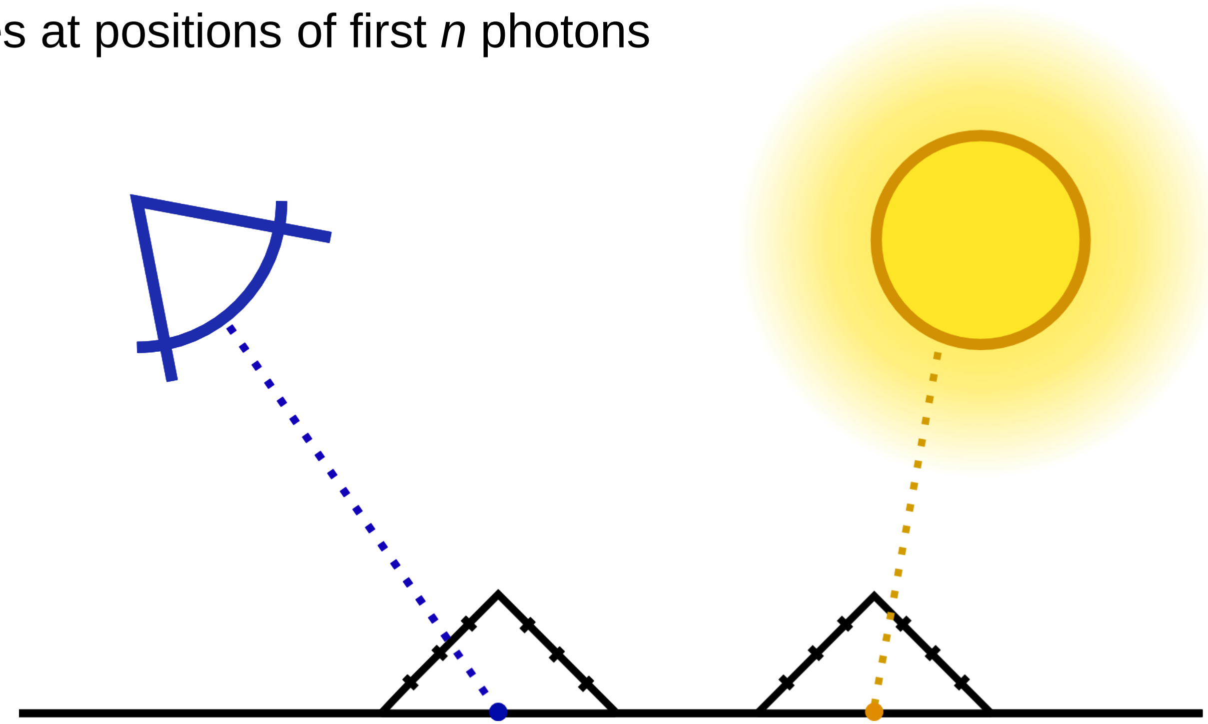
- Simple extension to both hemispheres
- Simple conversion direction ⇔ texel
- Texels cover similar solid angles





Preprocessing: Placing Caches

- From Camera rays:
  - One Cache per every 8x8 pixel block
- From Photons:
  - Place Caches at positions of first *n* photons



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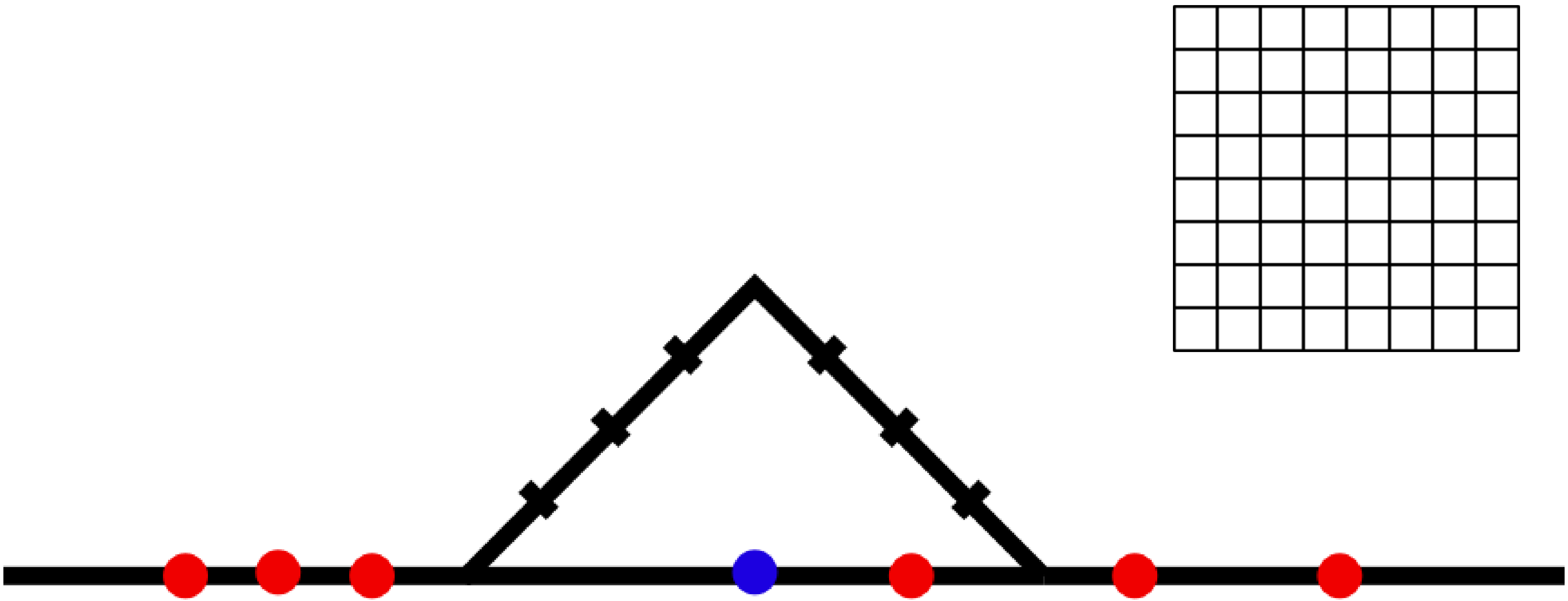
Preprocessing: Filling Caches

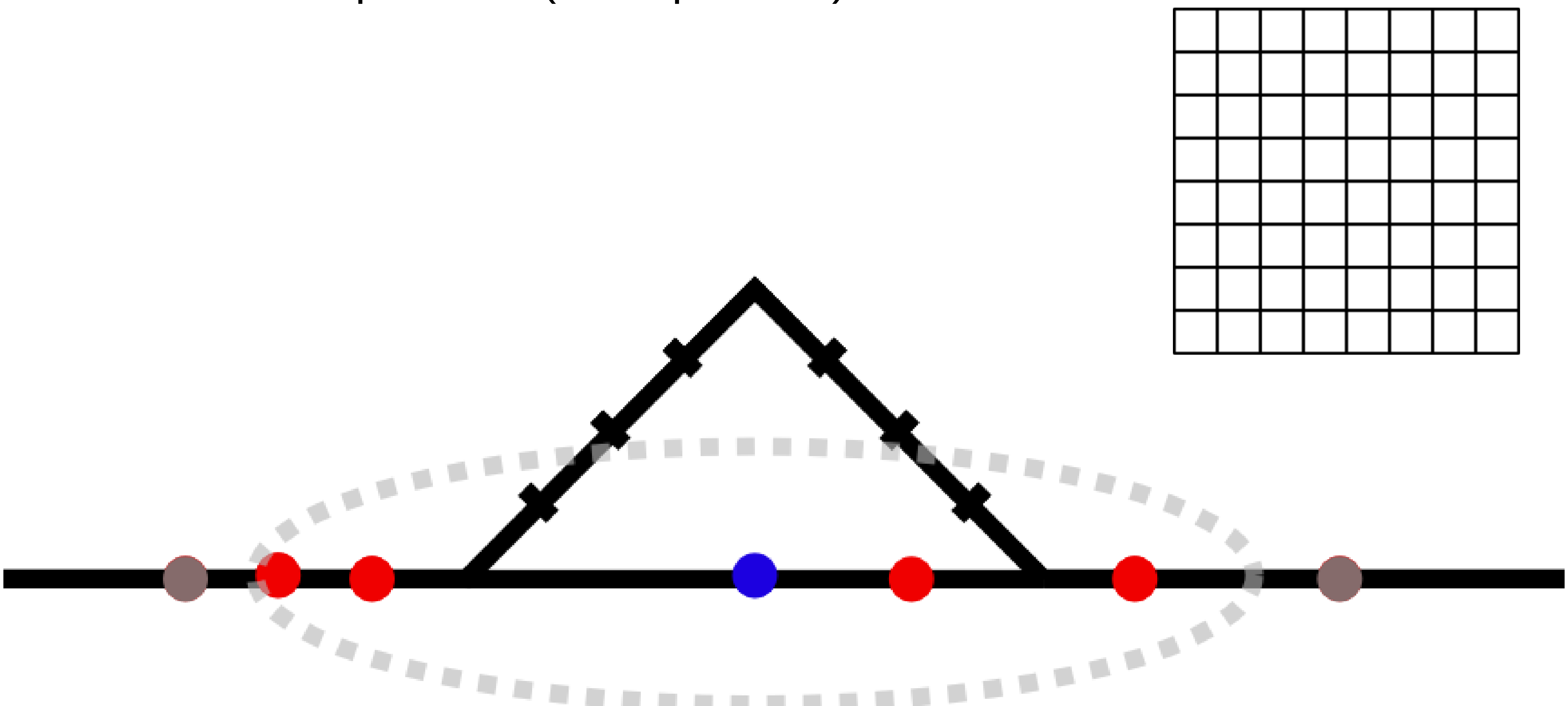
For every cache: Start with empty environment map (right)



Preprocessing: Filling Caches

For every cache:

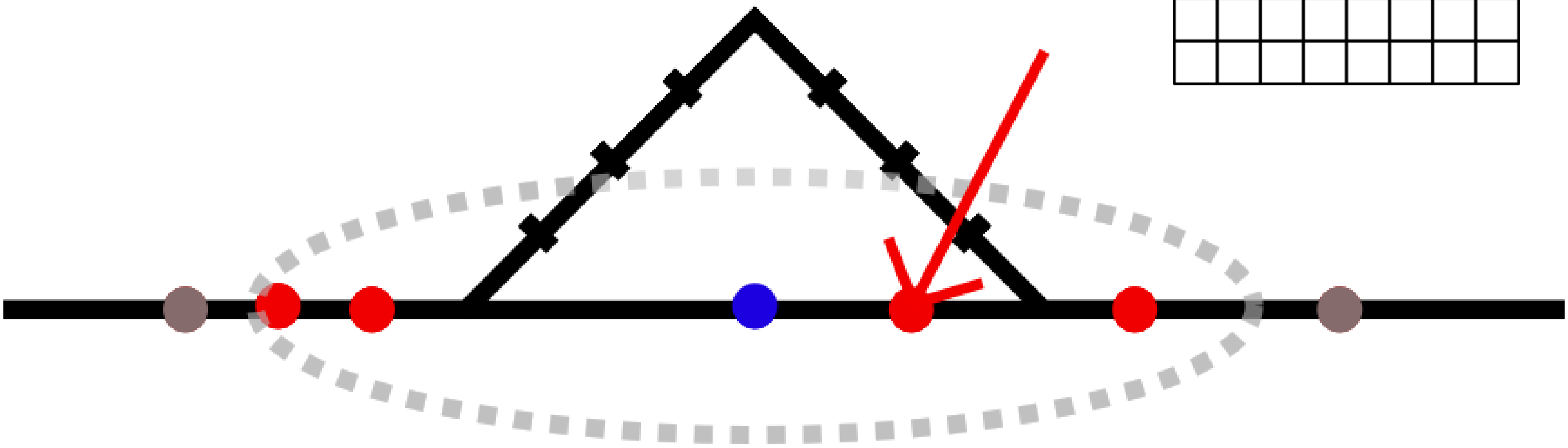
- For closest *k* photons: (Example: k=4)

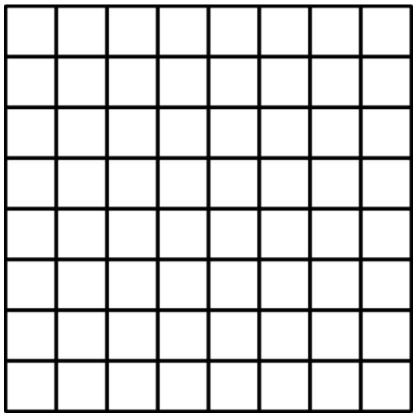


Preprocessing: Filling Caches

For every cache:

- For closest *k* photons:
  - Direction of photon

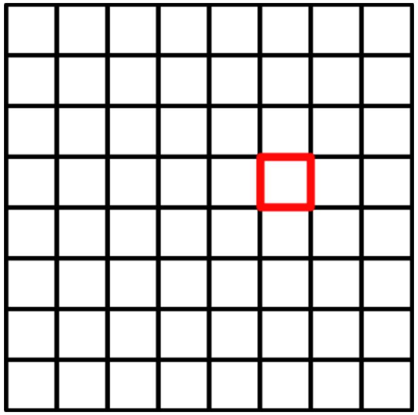


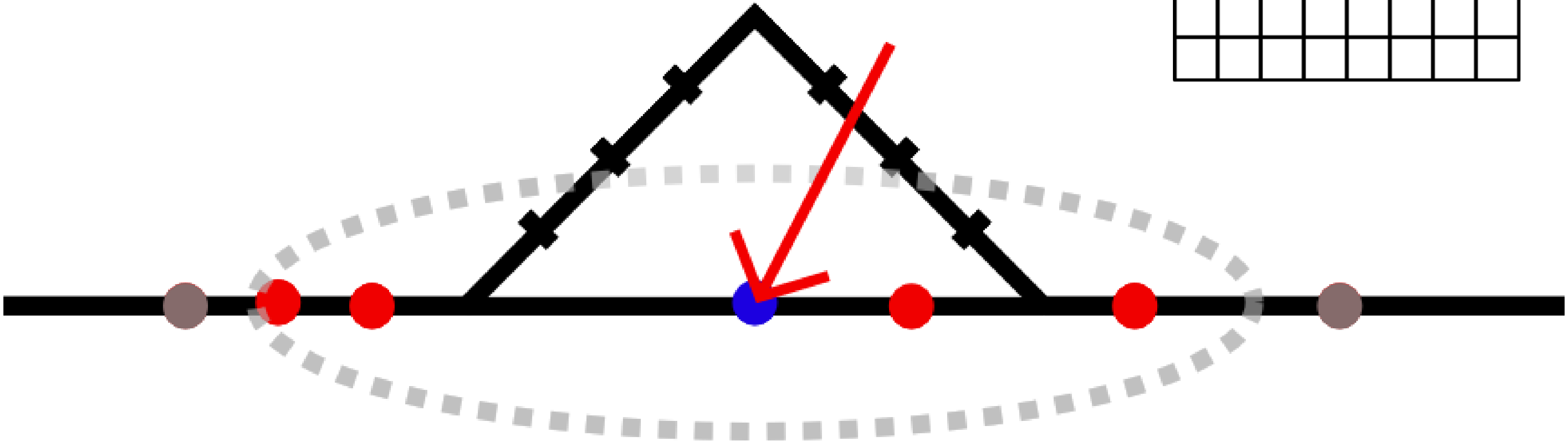


Preprocessing: Filling Caches

For every cache:

- For closest *k* photons:
  - Direction of photon → texel coordinate

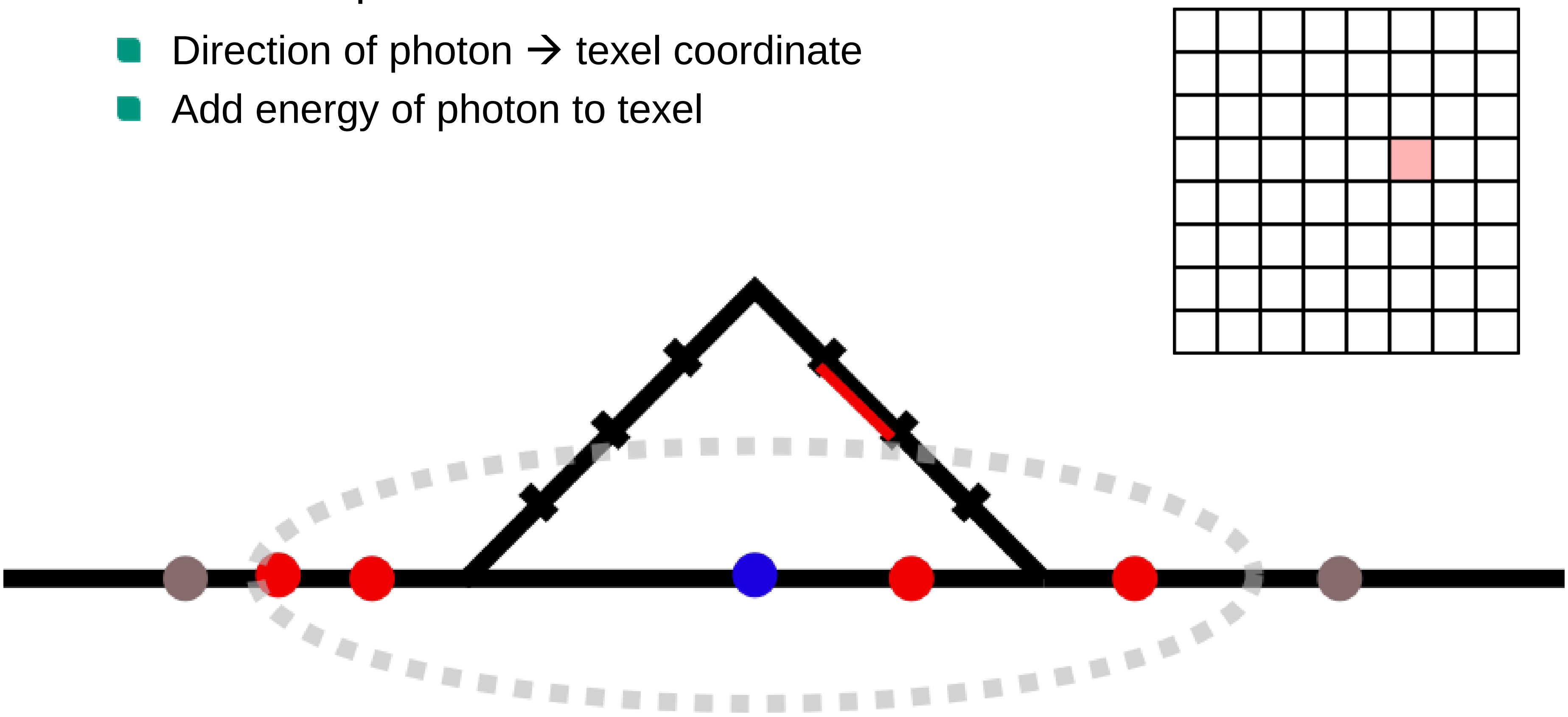




Preprocessing: Filling Caches

For every cache:

- For closest *k* photons:
  - Direction of photon → texel coordinate
  - Add energy of photon to texel



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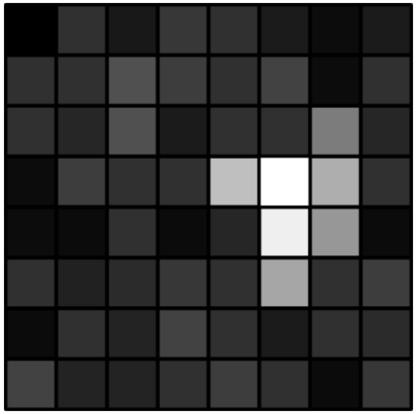
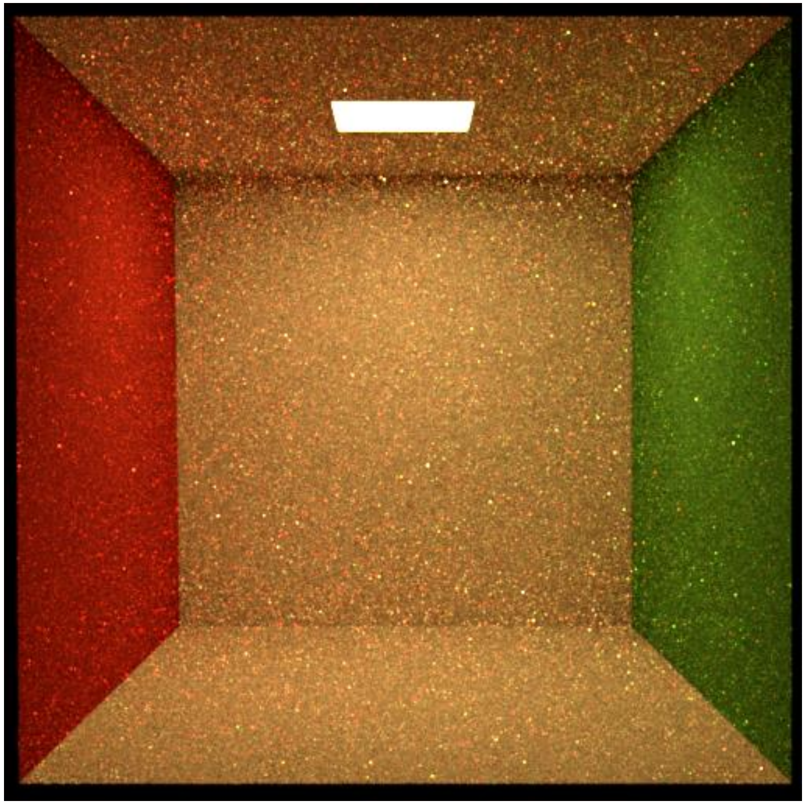
Preprocessing: Filling Caches

For every cache:

- For closest *k* photons:
  - Direction of photon → texel coordinate
  - Add energy of photon to texel

Resulting Environment Map:





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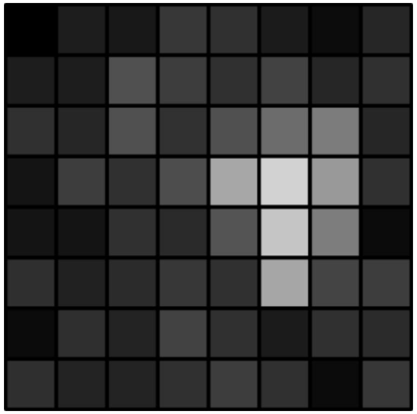
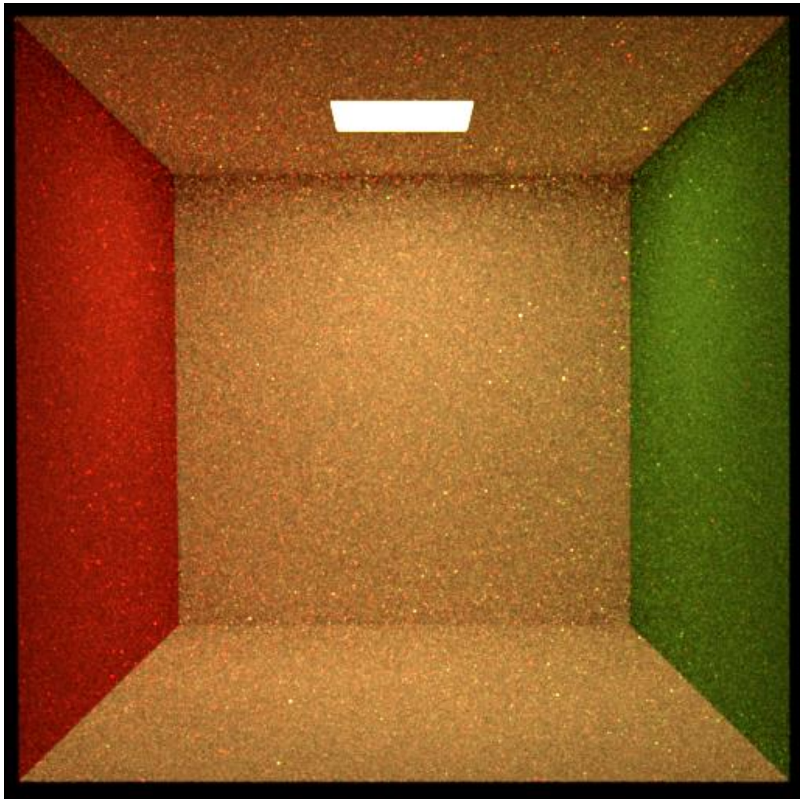
Preprocessing: Filling Caches

For every cache:

- For closest *k* photons:
  - Direction of photon → texel coordinate
  - Add energy of photon to texel
- Bilinear + Gaussian Filter





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Preprocessing: Filling Caches

For every cache:

- For closest *k* photons:
  - Direction of photon → texel coordinate
  - Add energy of photon to texel
- Bilinear + Gaussian Filter

Result:

Map filled with **relative energy** per incident direction

Preprocessing: Relative Energy → PDF

- Normalize sum of all texels to 1
- Monte Carlo Integration → Set all 0 texels to small value
- Normalize again

Result:

Map filled with PDF for incident radiance, **measured over texel space**

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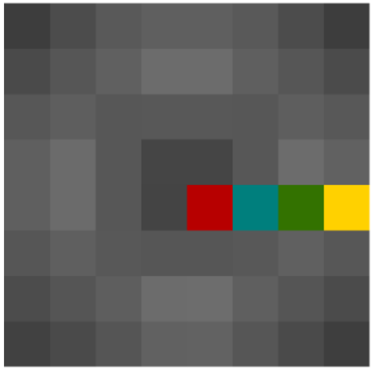
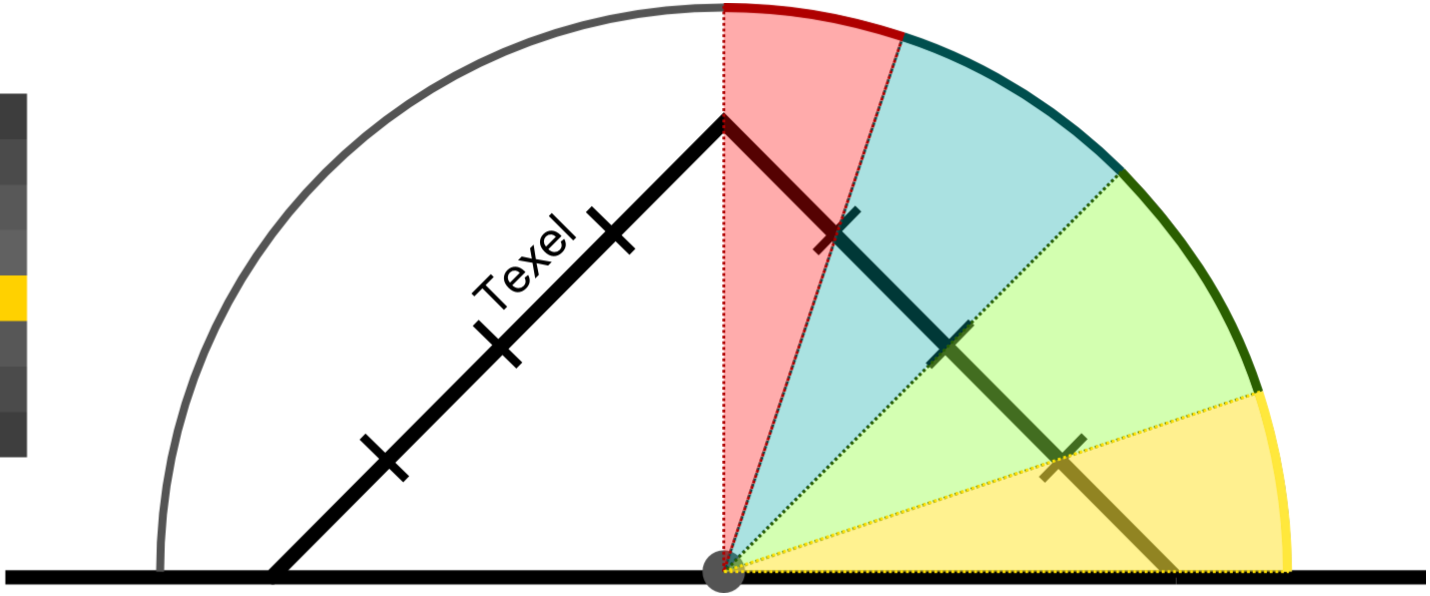
Preprocessing: PDF → PDF over solid angle

- Problem: Texels cover different amount of solid angle
  - More solid angle near the center
  - Less solid angle near the edges

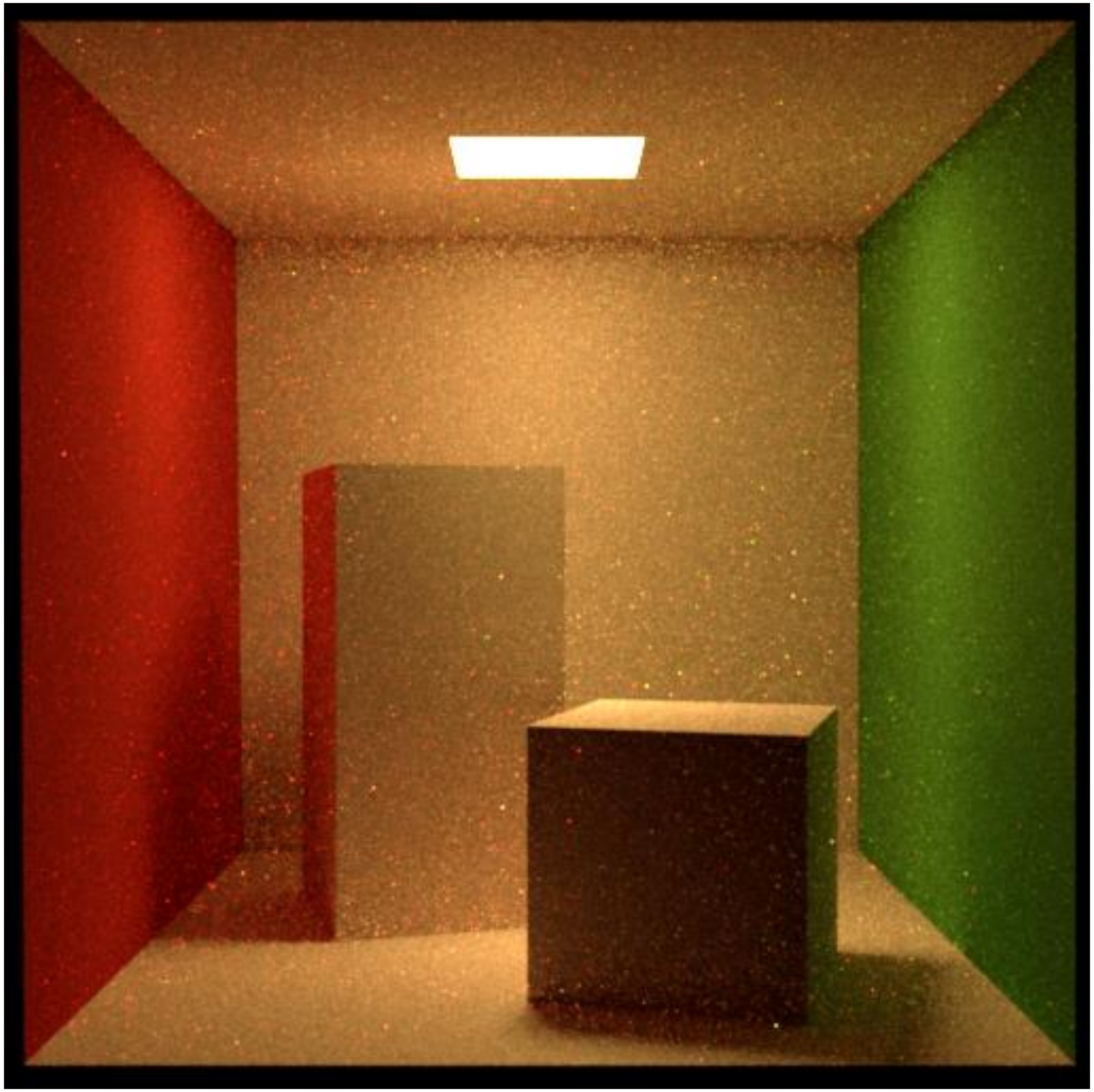




Preprocessing: PDF → PDF over solid angle

Wrong: convert with

Factor $\frac{number\ of\ texels}{2\pi}$



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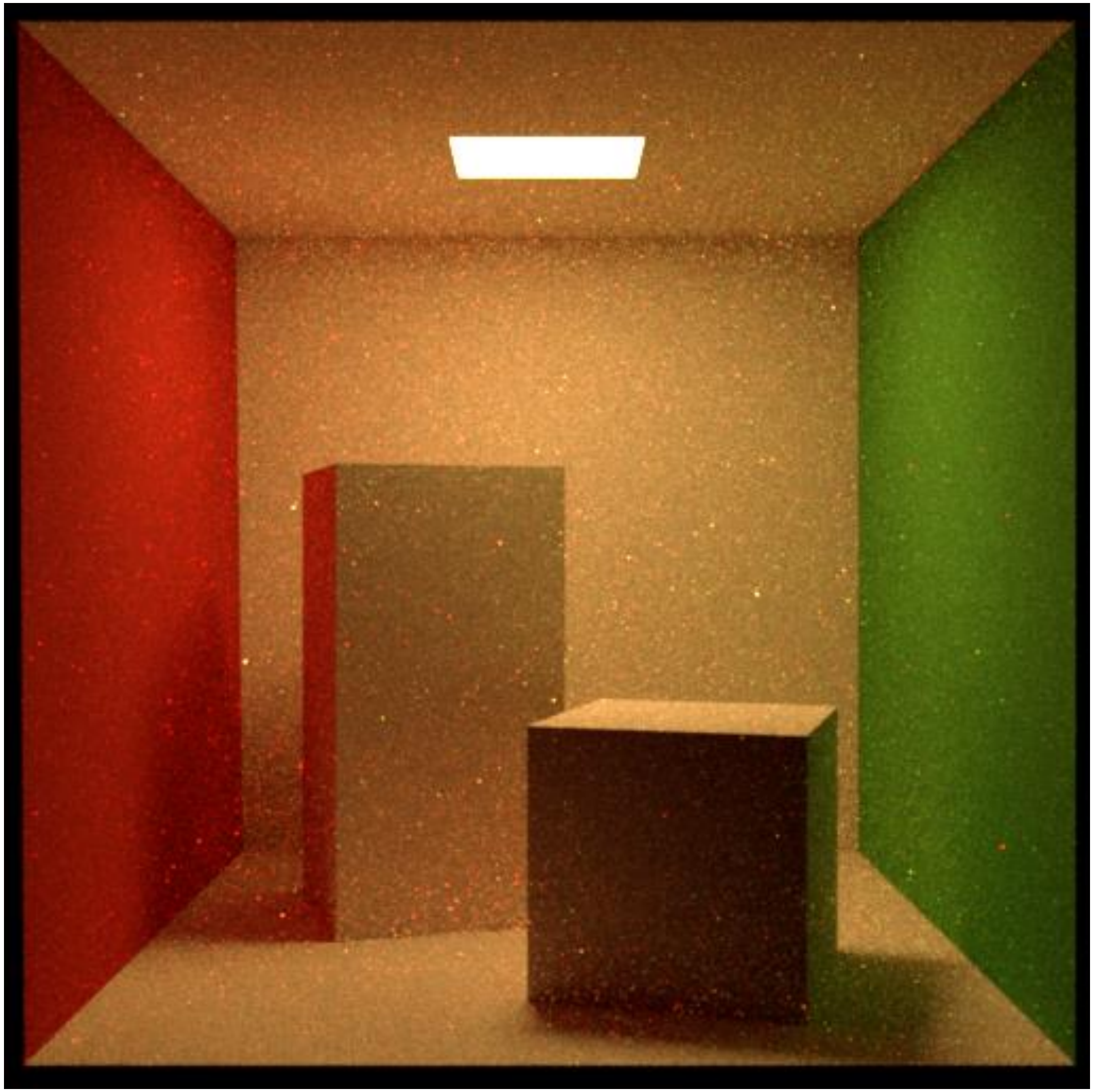
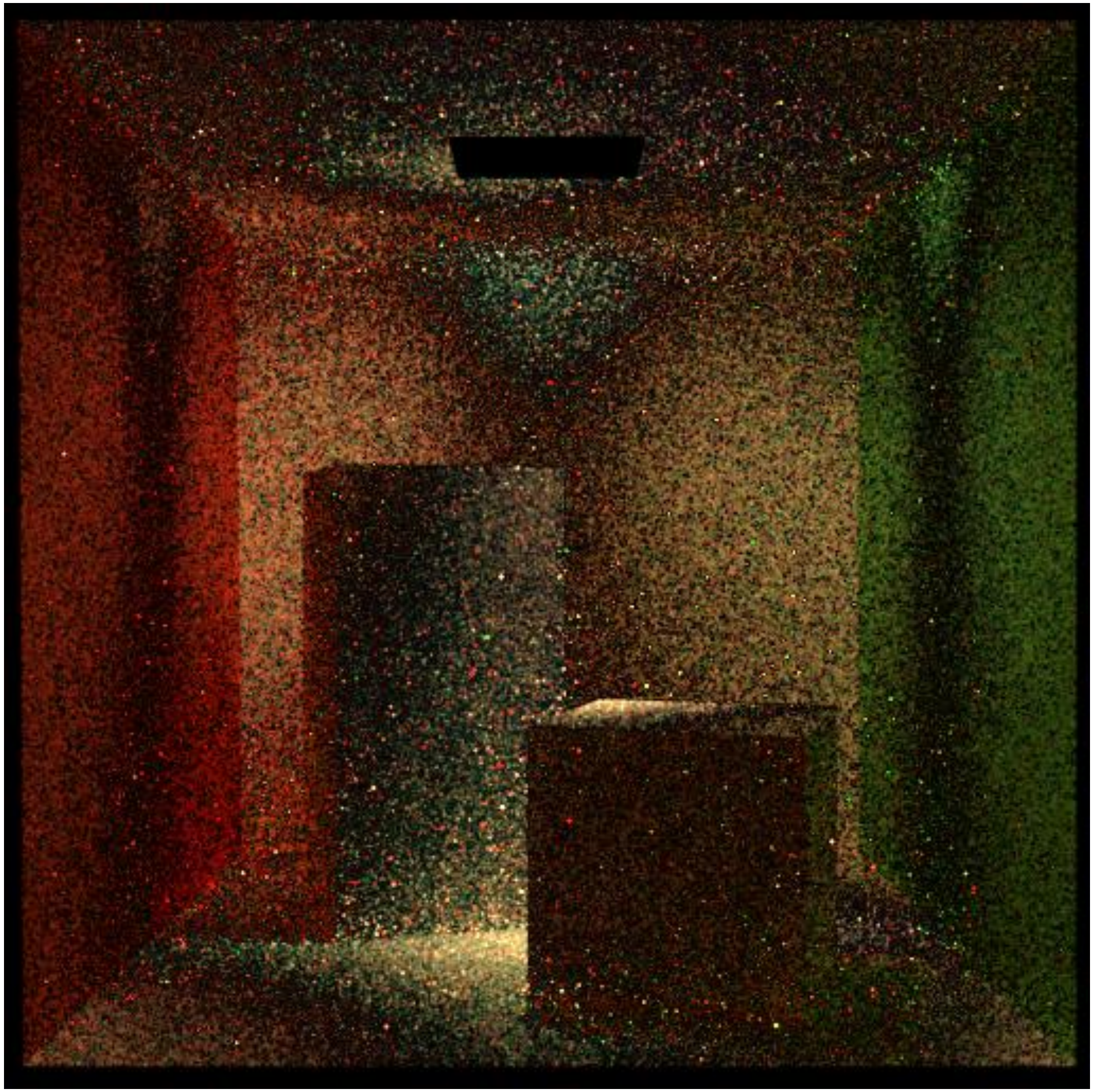
Preprocessing: PDF → PDF over solid angle

Correct conversion
to solid angle



Preprocessing: PDF → PDF over solid angle

Difference



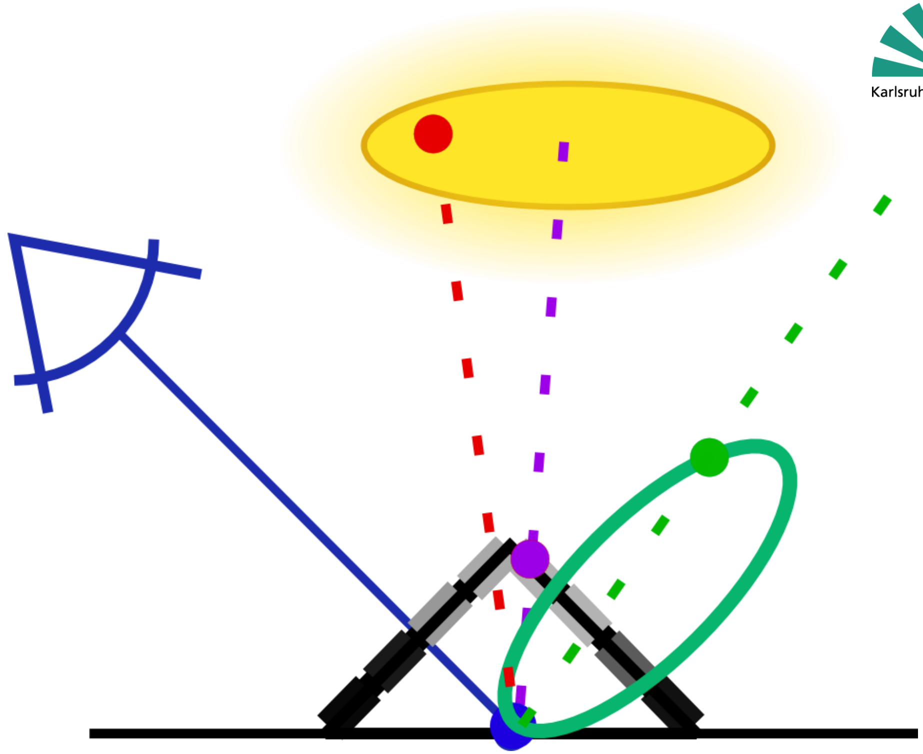
Final Cache

- Octahedron map with PDF over solid angle
- Octahedron map with CDF for sampling
- k-d tree for faster lookup

Rendering

Sample paths using…

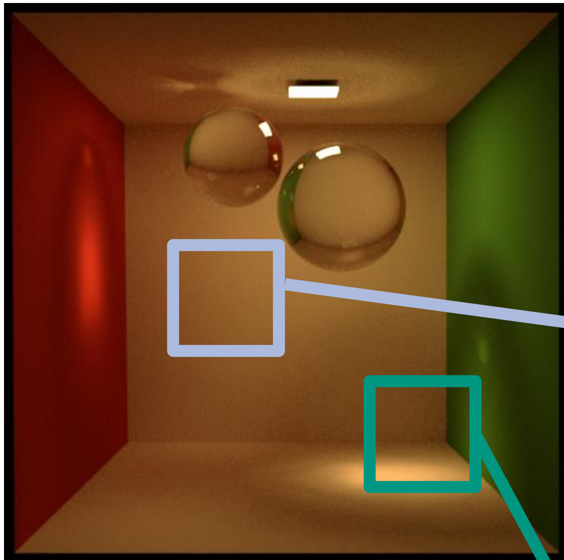
- Caches
- BSDF
- NEE

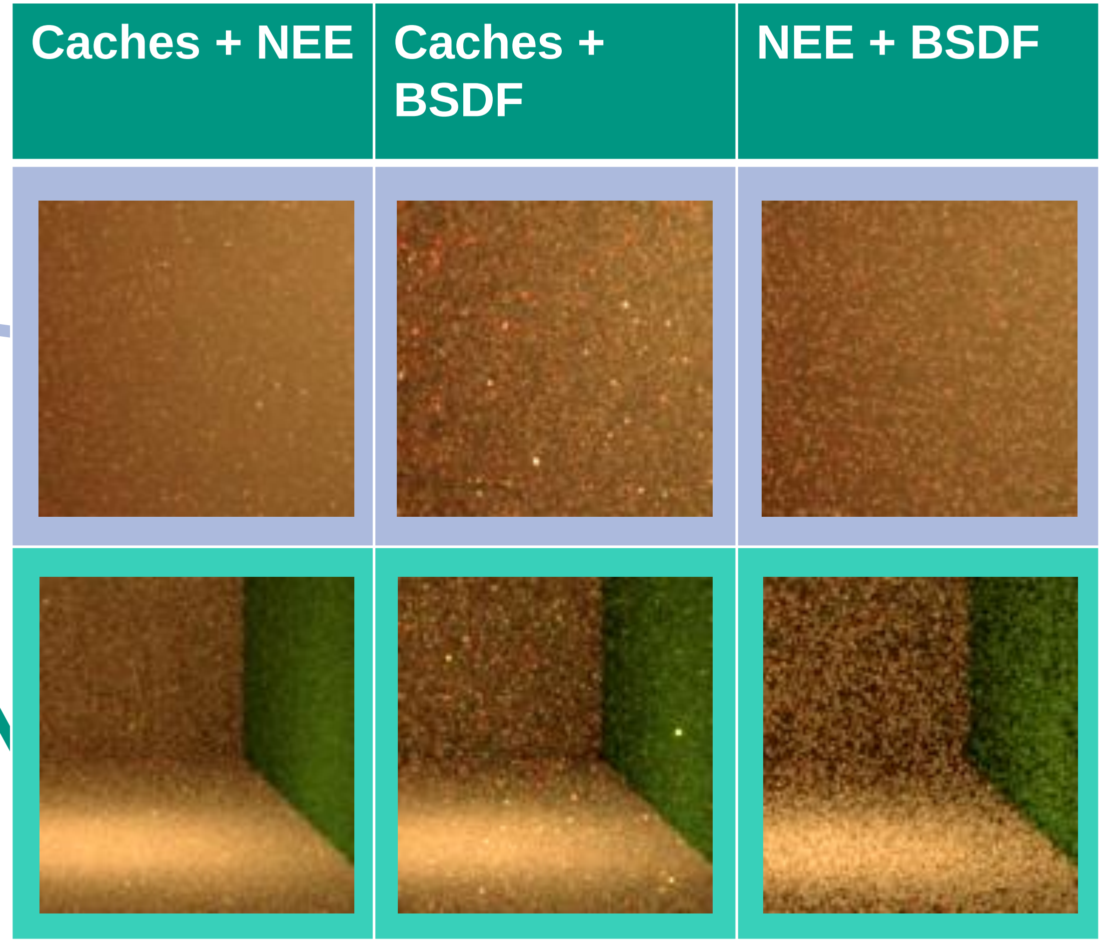


➔ Combine with Multiple Importance Sampling

➔ No Cache available? → switch to BSDF sampling

Results





256 samples per pixel
1 Mio. photons
20,000 caches
2000 photons per cache
16x16 texels per cache
42MB memory consumption

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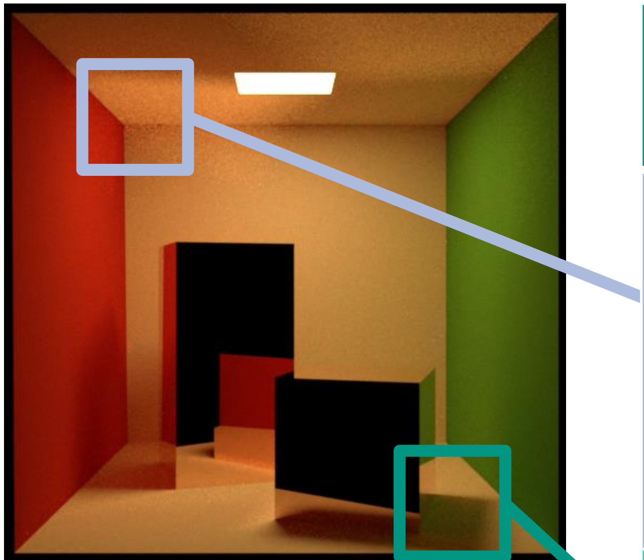
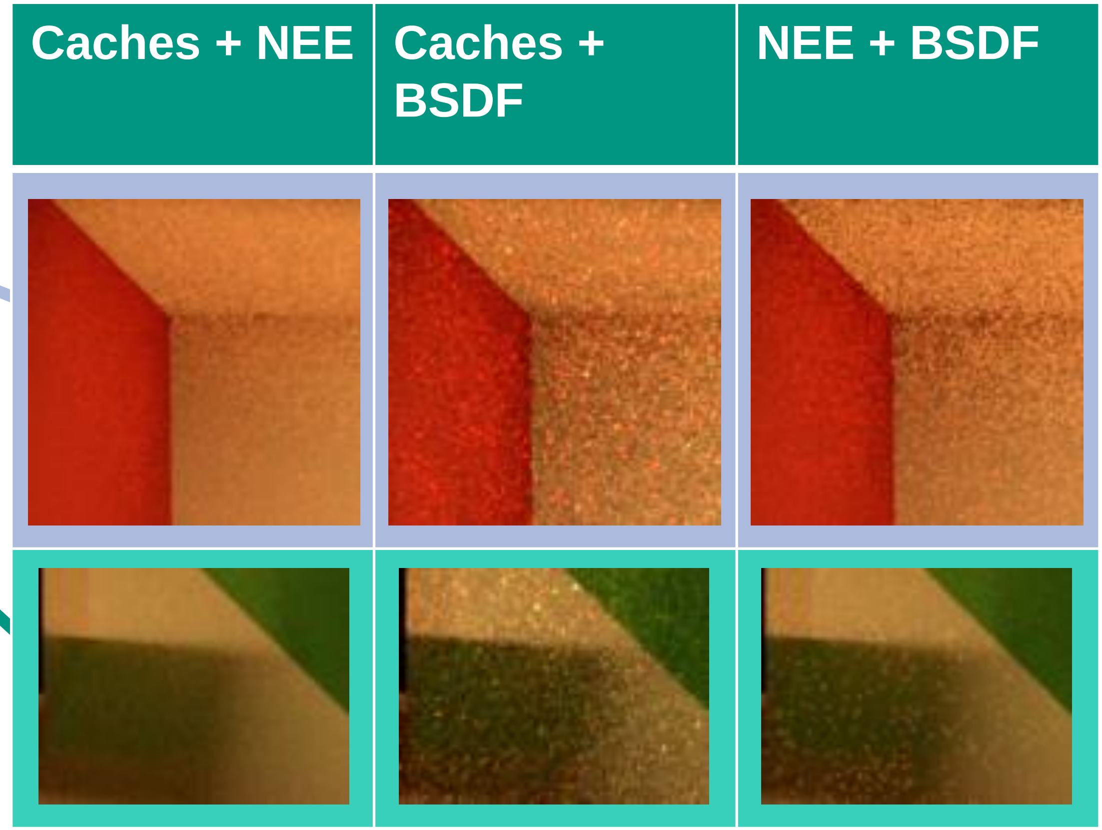
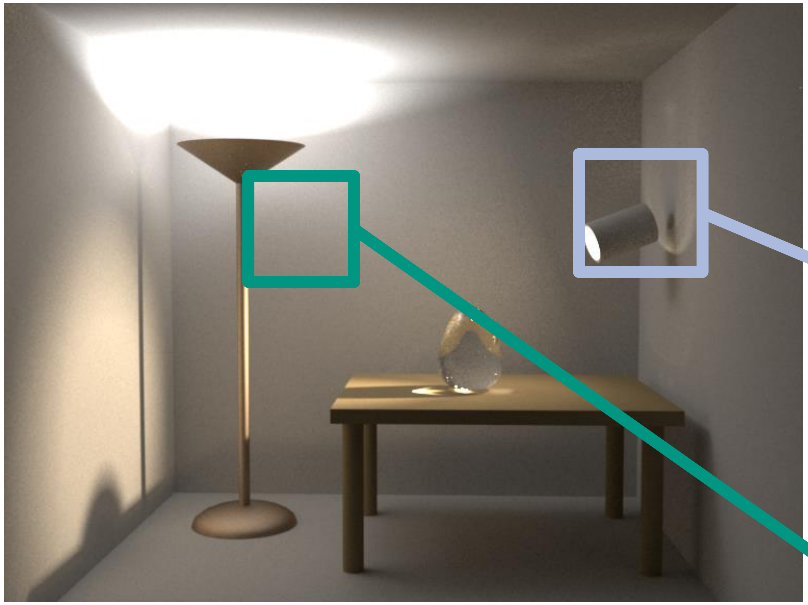
Results

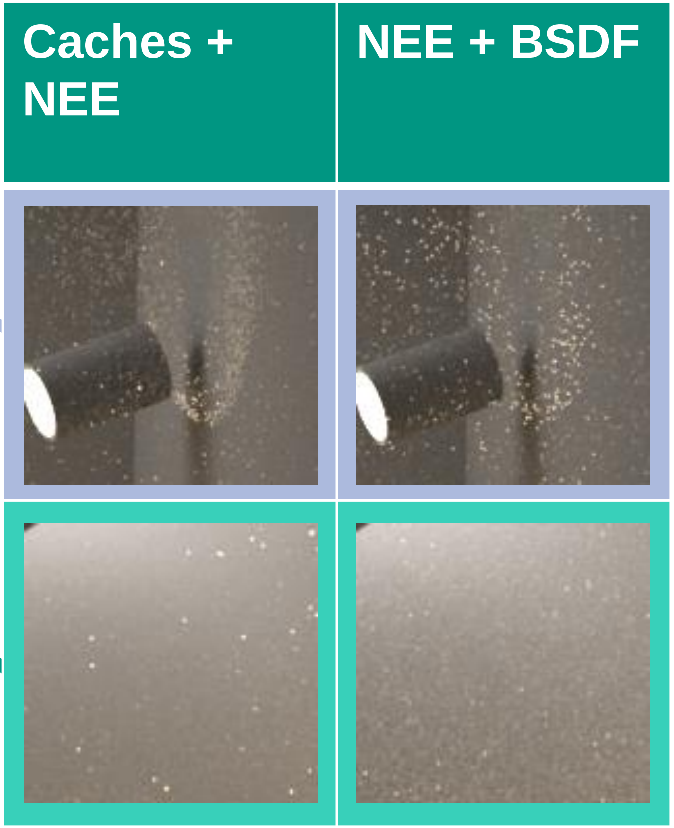




128 samples per pixel
800k photons
20k caches
1k photons per cache
16x16 texels per cache
42MB memory consumption

Results

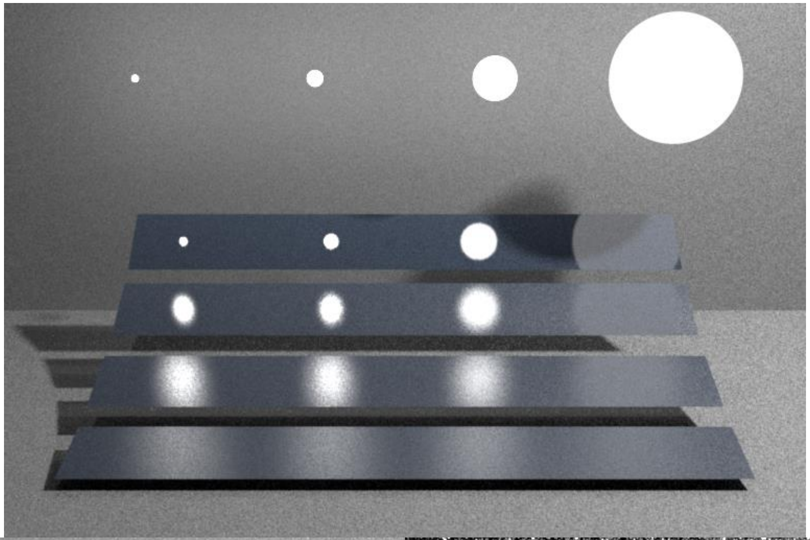




4096 samples per pixel
1.5 Mio. photons
30k caches
2k photons per cache
16x16 texels per cache
Xxx memory consumption
3300 triangles

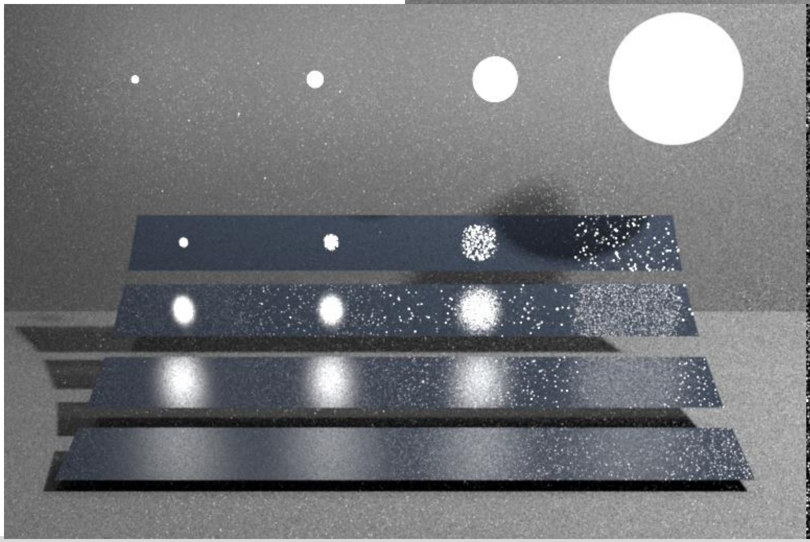
Results

NEE + BSDF

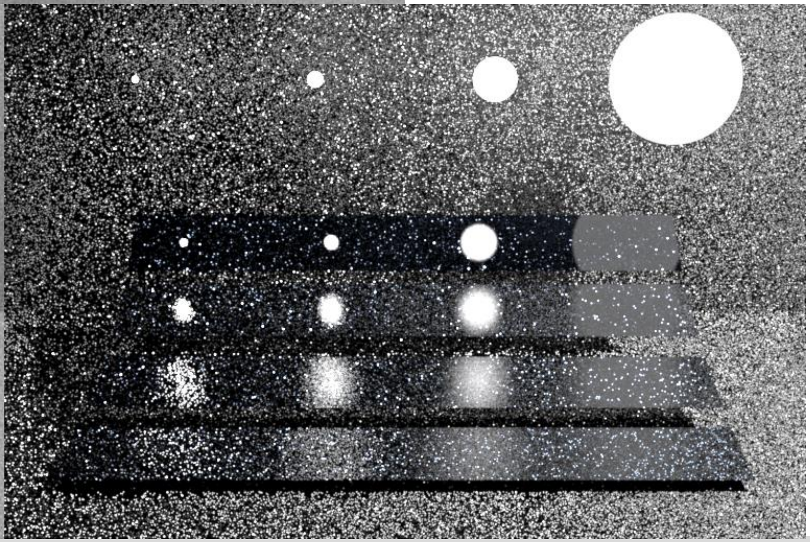


64 samples per pixel
1 Mio. photons
20k caches
2k photons per cache
16x16 cache resolution

Caches + NEE



Caches + BSDF



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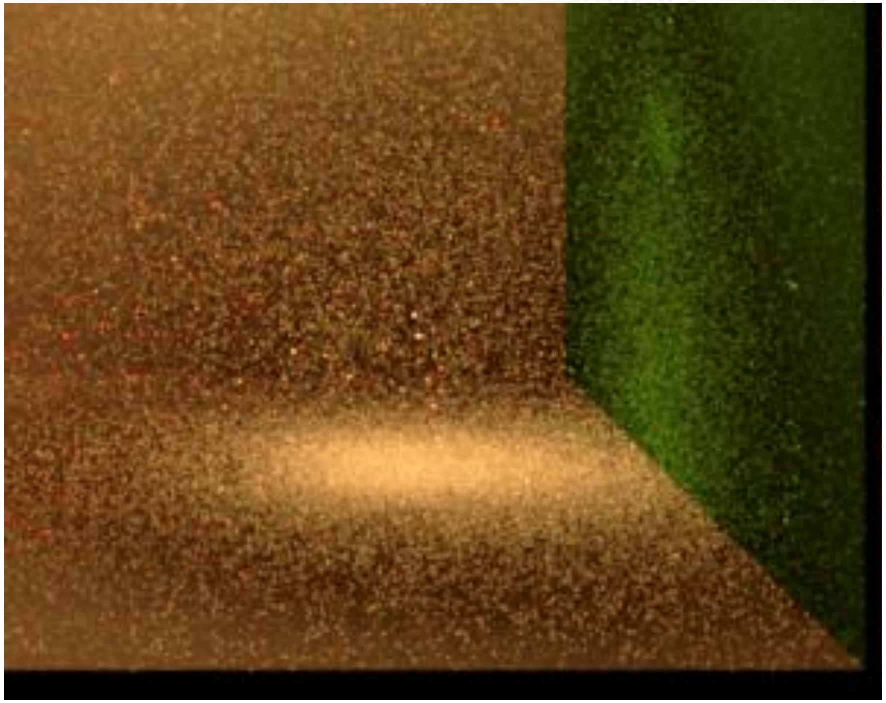
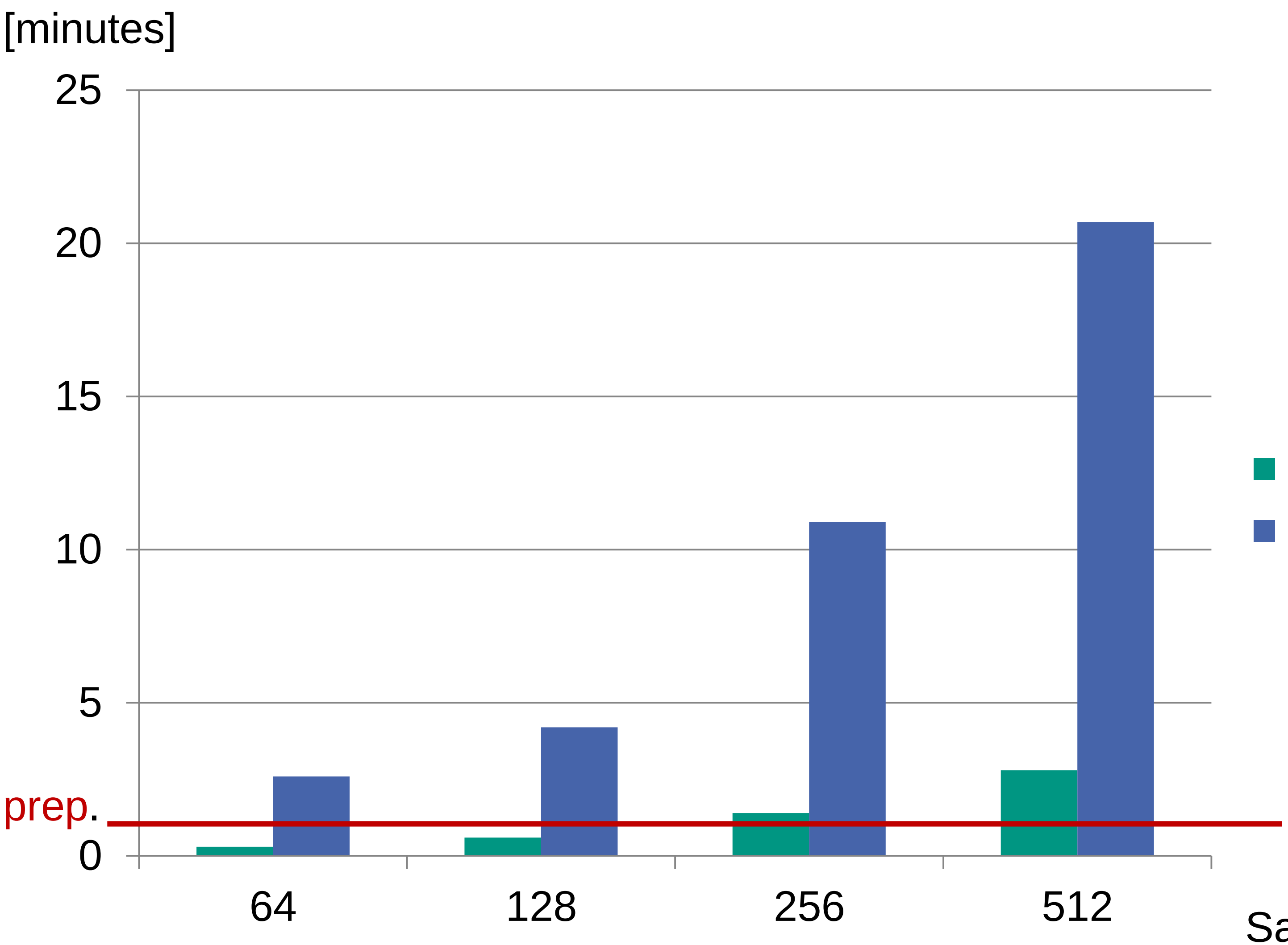
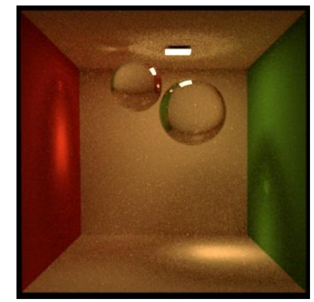
Different Cache Configurations: #photons



few photons in scene
(~ 10 000)

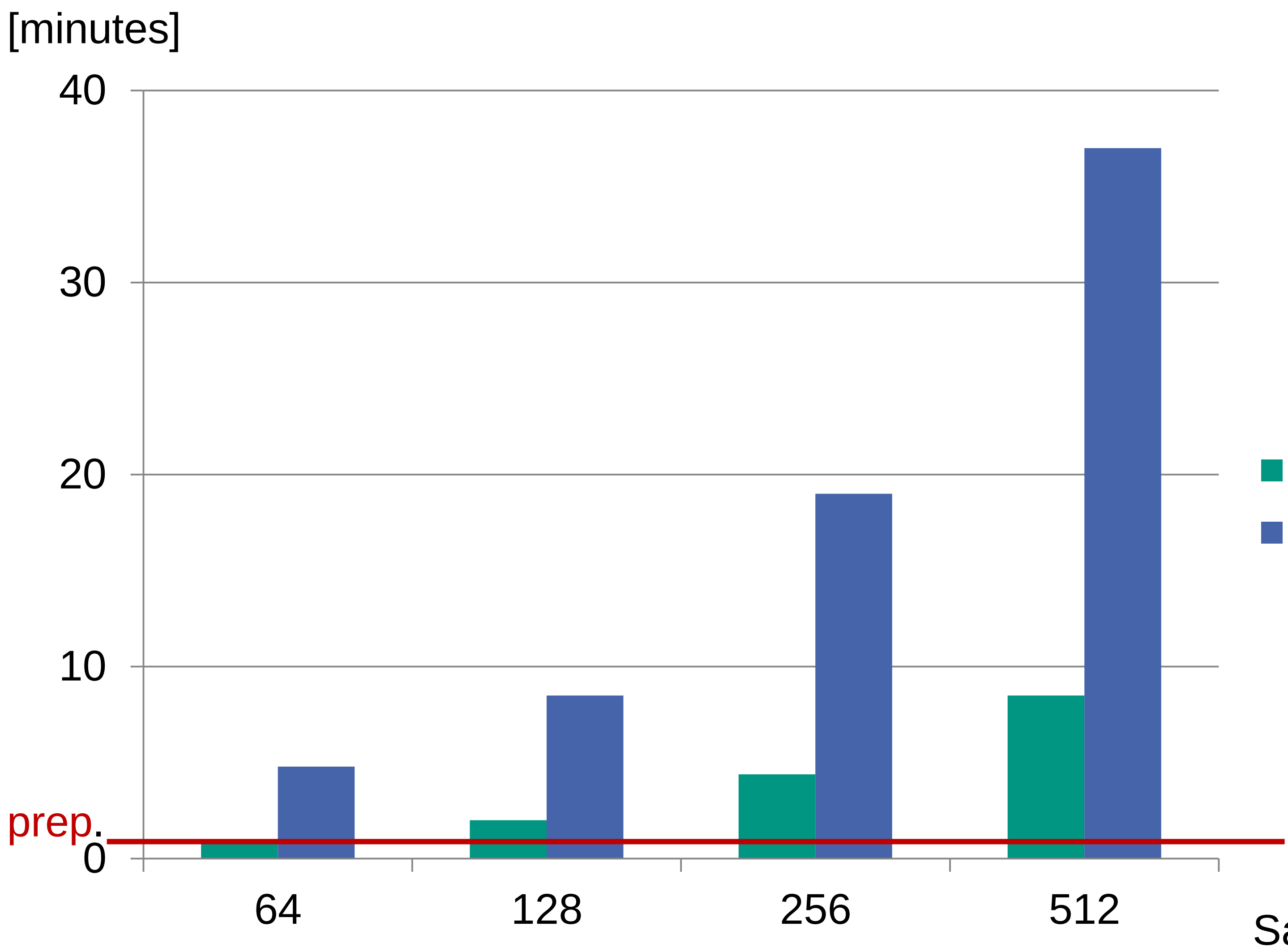
Render Times: Glass Sphere





1 Mio. photons
20k caches
2k photons per cache
14 primitives

Render Times: Glass Egg



1.6 Mio. photons
20k caches
2.5k photons per cache
3300 primitives

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Equal Time Comparison

NEE + Caches

NEE + Caches
128spp
8.4 min

NEE + BSDF
512spp
8.2 min

Equal Time Comparison

NEE + BSDF

NEE + Caches
128spp
8.4 min

NEE + BSDF
512spp
8.2 min

Conclusion

- Equally good image in similar time
- Better image with same sample-per-pixel - count

Conclusion

On-line Learning of Parametric Mixture Models for Light Transport Simulation

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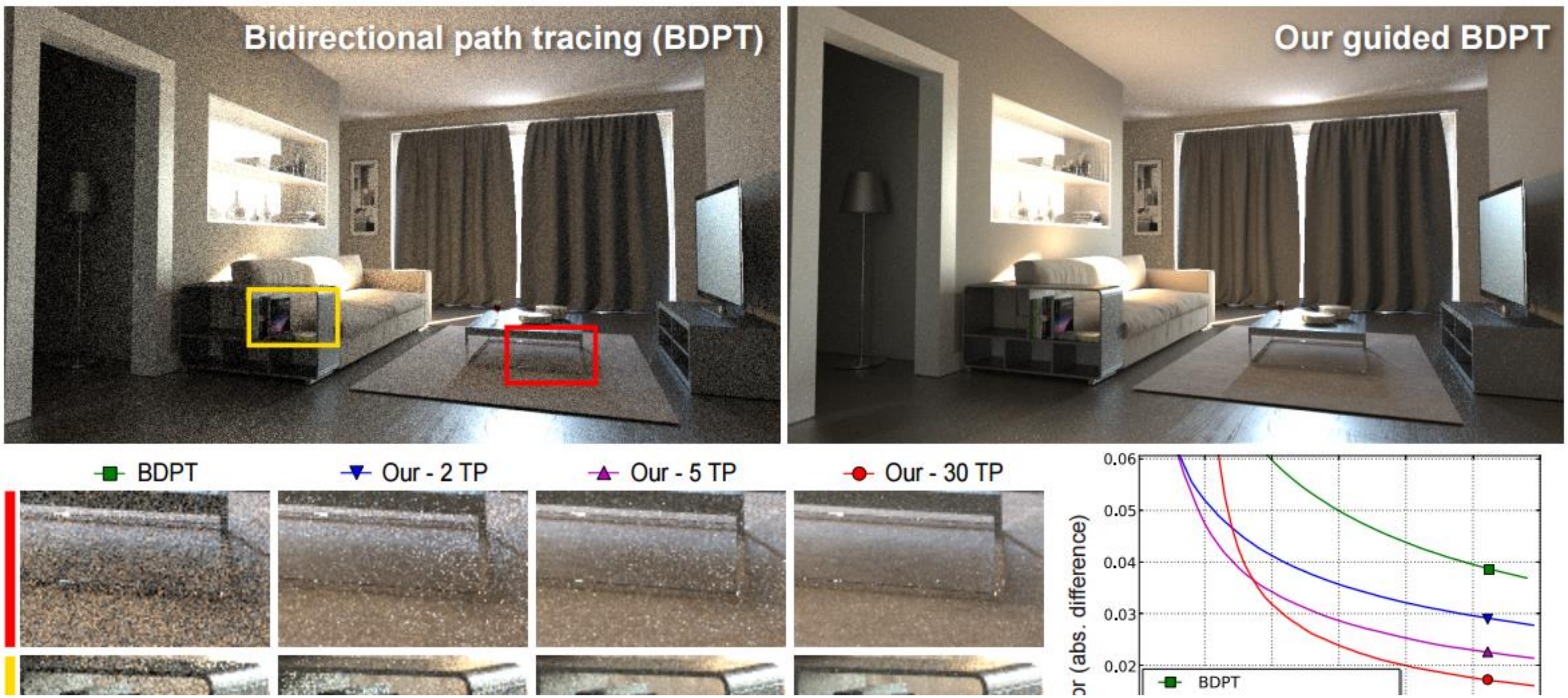
[1]Charles University in Prague [2]MPI Informatik, Saarbrücken



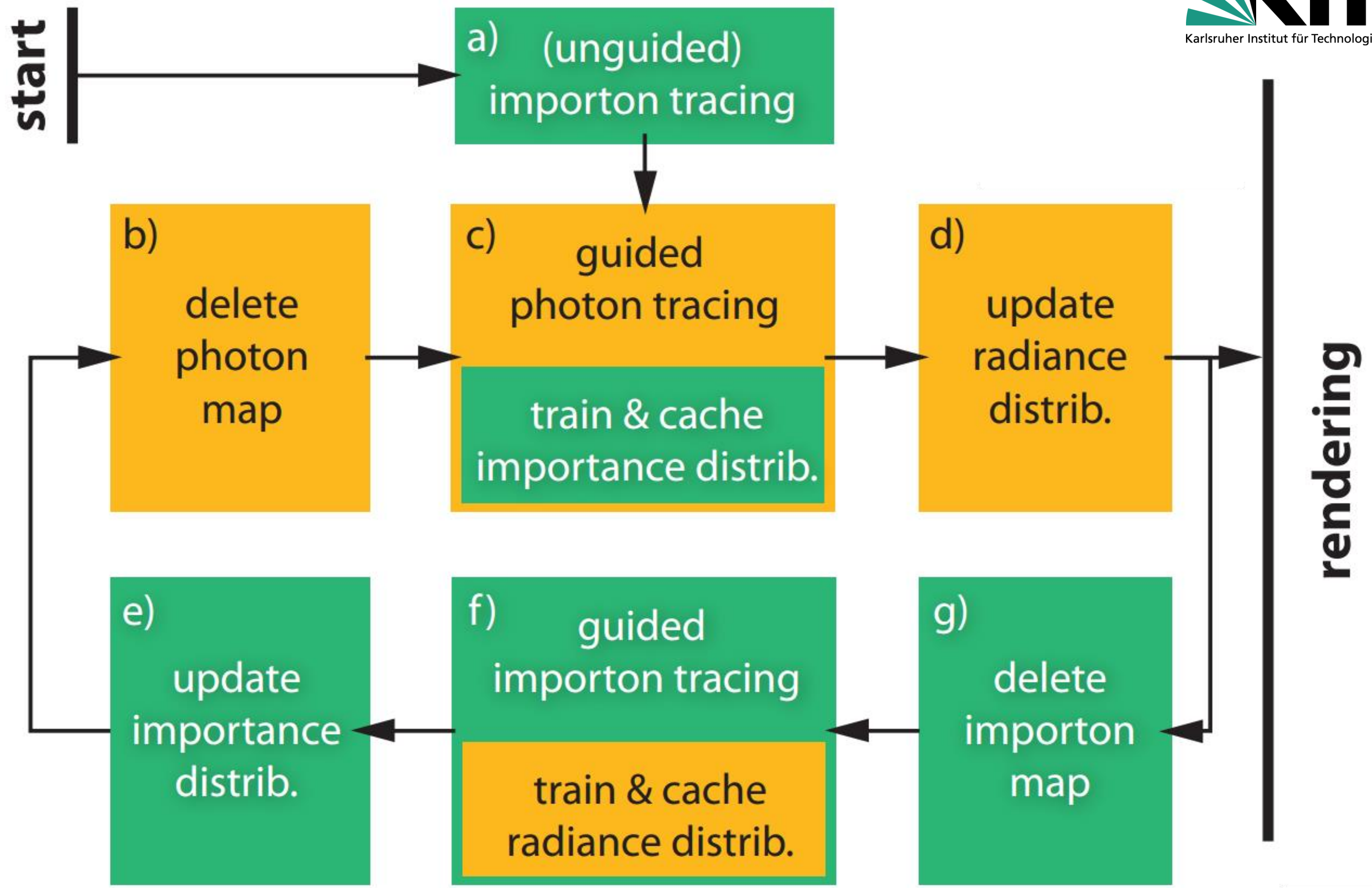
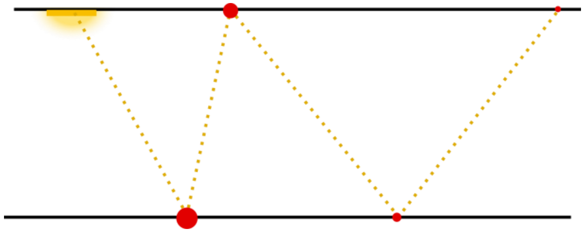


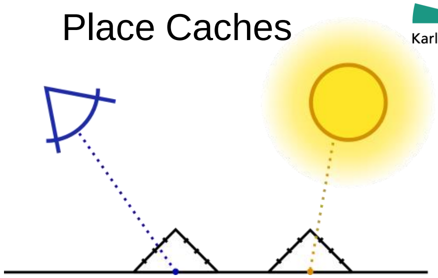
Figure 2: *The training phase preceding the rendering phase.*

Source: „On-line Learning of Parametric Mixture Models for Light Transport Simulation" (previous slide)
http://cgg.mff.cuni.cz/~jaroslav/papers/2014-onlineis/

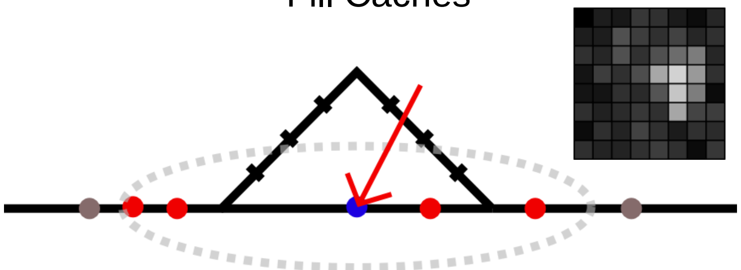
Photon Mapping



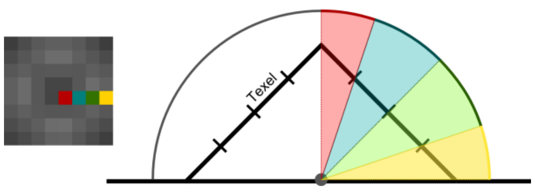
Place Caches



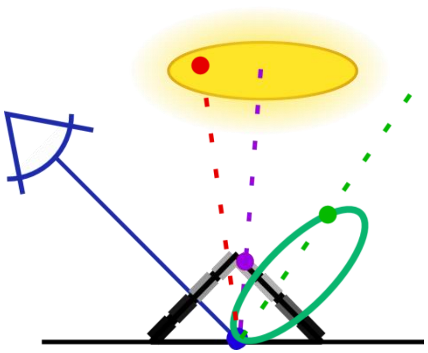
Fill Caches



PDF over solid angle



Path Tracing



https://github.com/Baconkeks/Irradiance-Importance-Sampling