Virtual Blue Noise Lighting

Tianyu Li*, Wenyou Wang*, Daqi Lin, and Cem Yuksel,

University of Utah

*joint first authors

All images are using 12K virtual lights

Virtual Blue Noise Lighting

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- Virtual Light **Placement**
- Virtual Light **Distribution**
- Virtual Light **Sampling**
- **Emission Profile** Computation

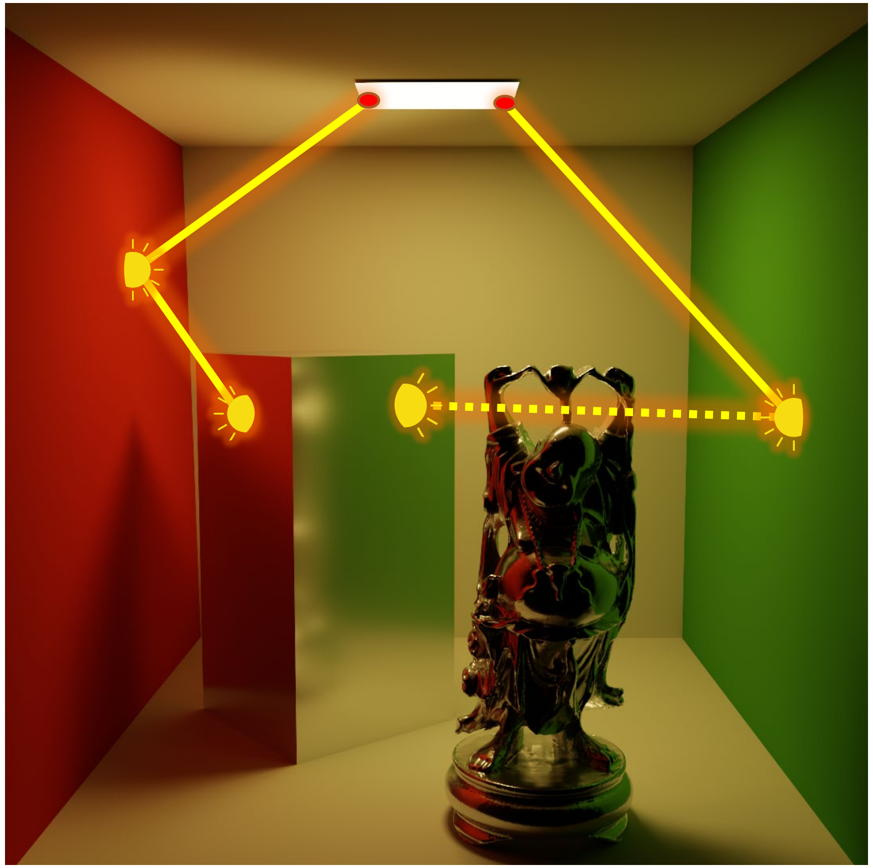
**joint first authors*

Virtual Light Methods

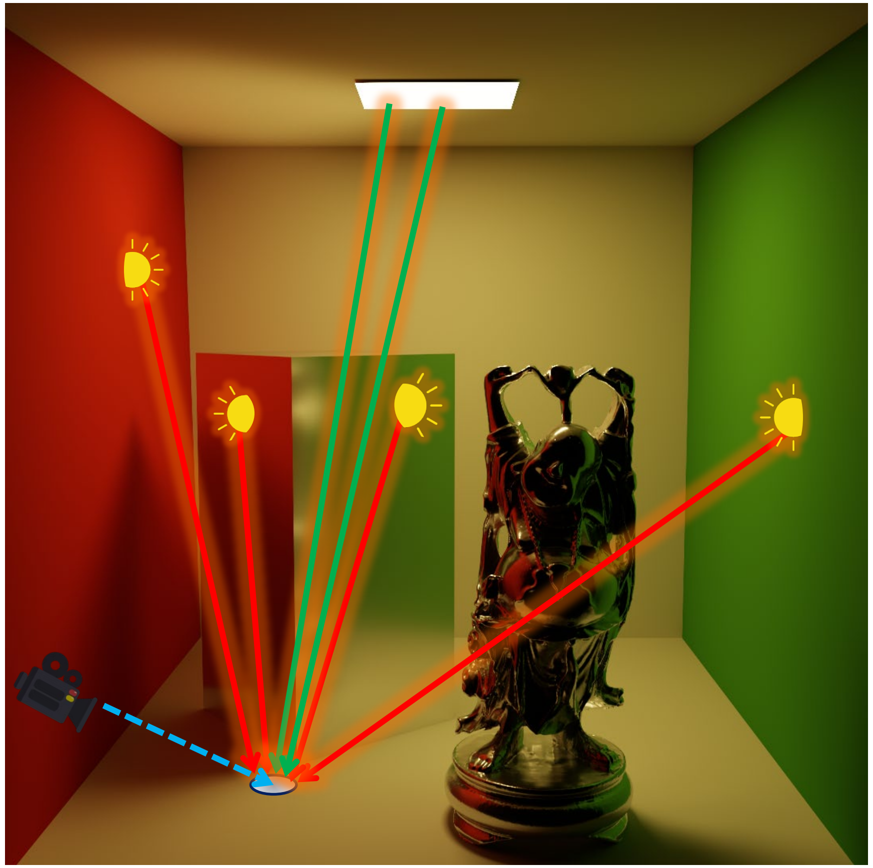
i.e. Instant Radiosity

Virtual Point Lights (VPLs)

[Keller 1997]



VPL Generation

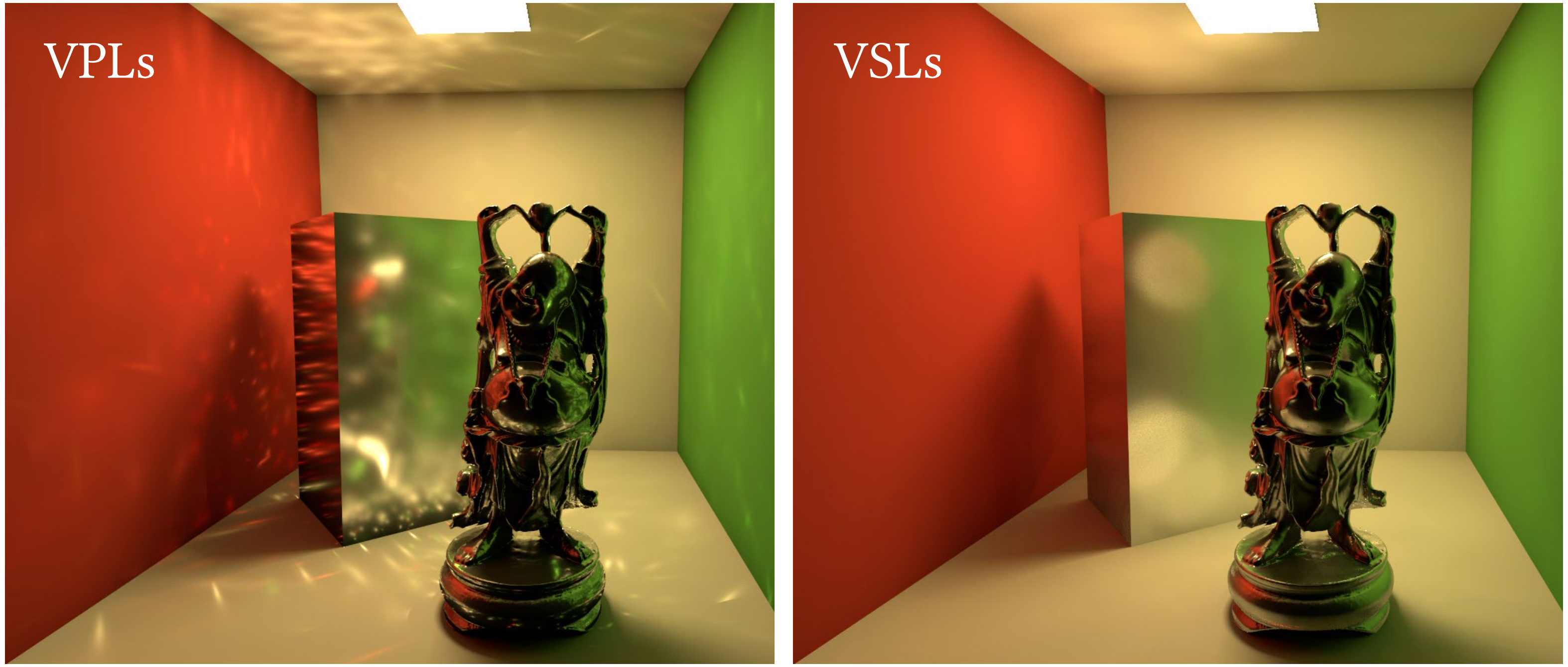


Final Gathering

Alexander Keller. 1997. Instant radiosity. In Proceedings of the 24th annual conference on Computer graphics and interactive techniques. 49–56.

Virtual Spherical Lights (VSLs)

[Hašan et al. 2009]

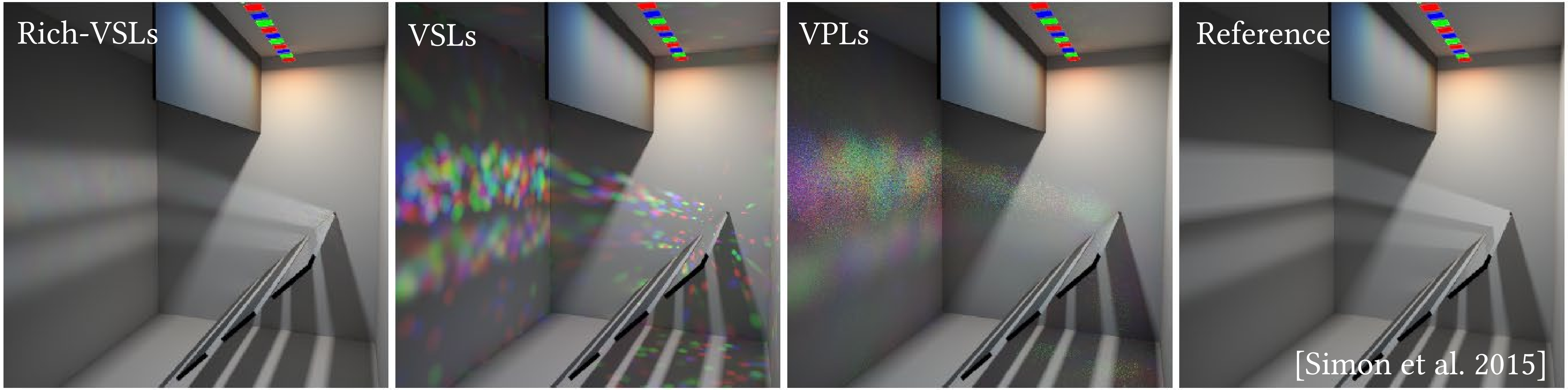


- No geometry term singularity, but an integral
- No splotches, but blurry

Miloš Hašan, Jaroslav Křivánek, Bruce Walter, and Kavita Bala. 2009. Virtual spherical lights for many-light rendering of glossy scenes. ACM Trans. Graph. 28, 5 (December 2009), 1–6. https://doi.org/10.1145/1618452.1618489

Rich-VPLs & Rich-VSLs

[Simon et al. 2015]

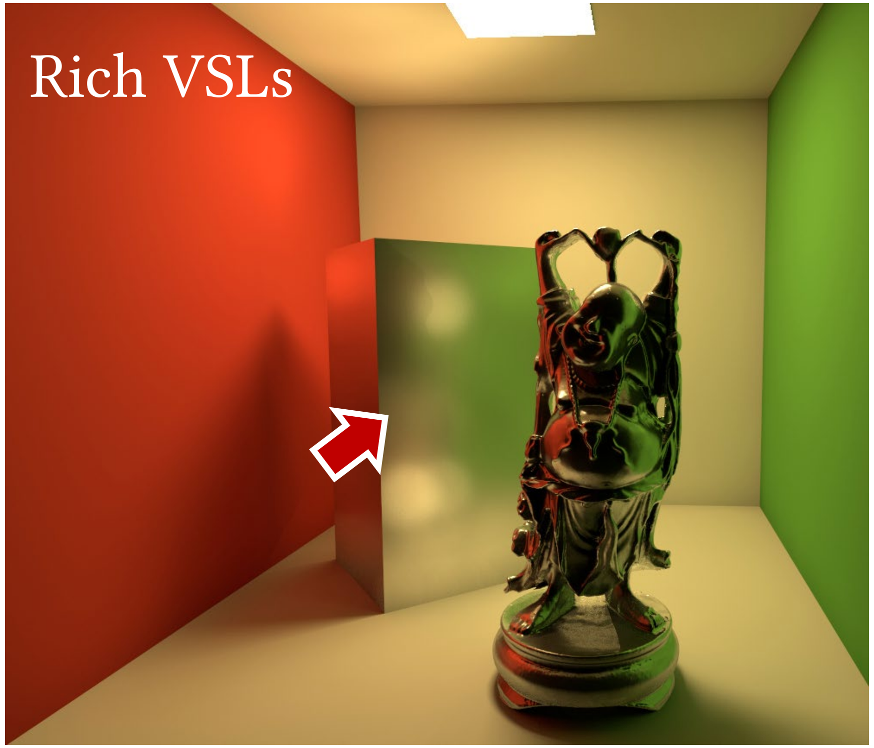


- Virtual lights with **emission profiles**
- Increased **storage cost** per virtual light

Simon, Florian & Hanika, Johannes & Dachsbacher, Carsten. (2015). Rich-VPLs for Improving the Versatility of Many-Light Methods. Computer Graphics Forum. 34. 10.1111/cgf.12585.

Rich-VSLs vs. Ours

[Hašan et al. 2009]



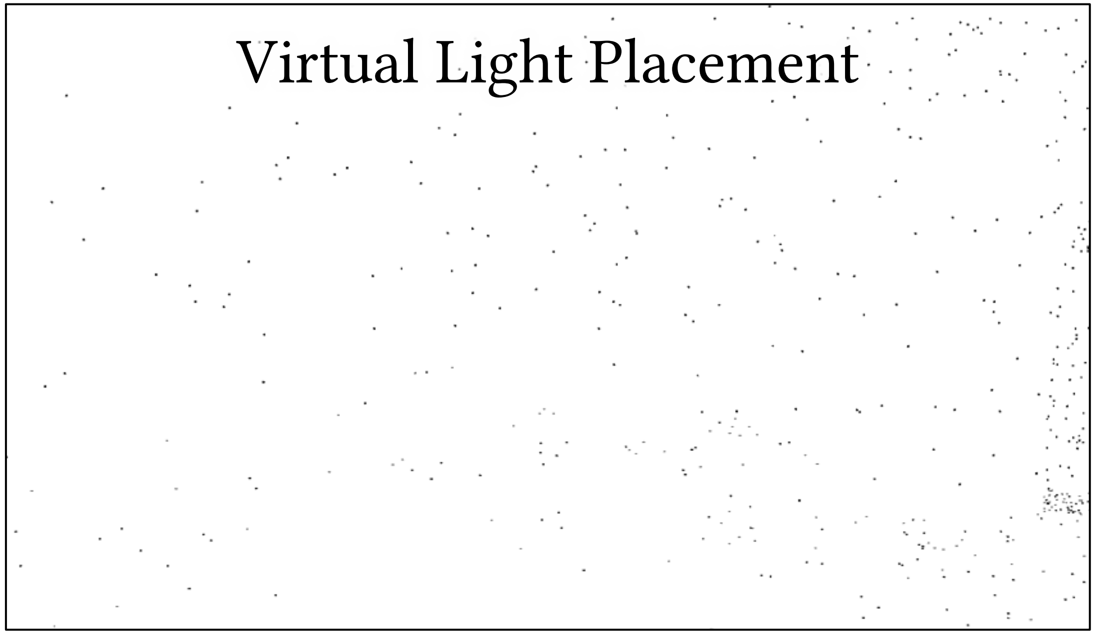
3 Problems

of Prior Virtual Light Methods

Problem 1

Virtual lights with no contribution to the final image

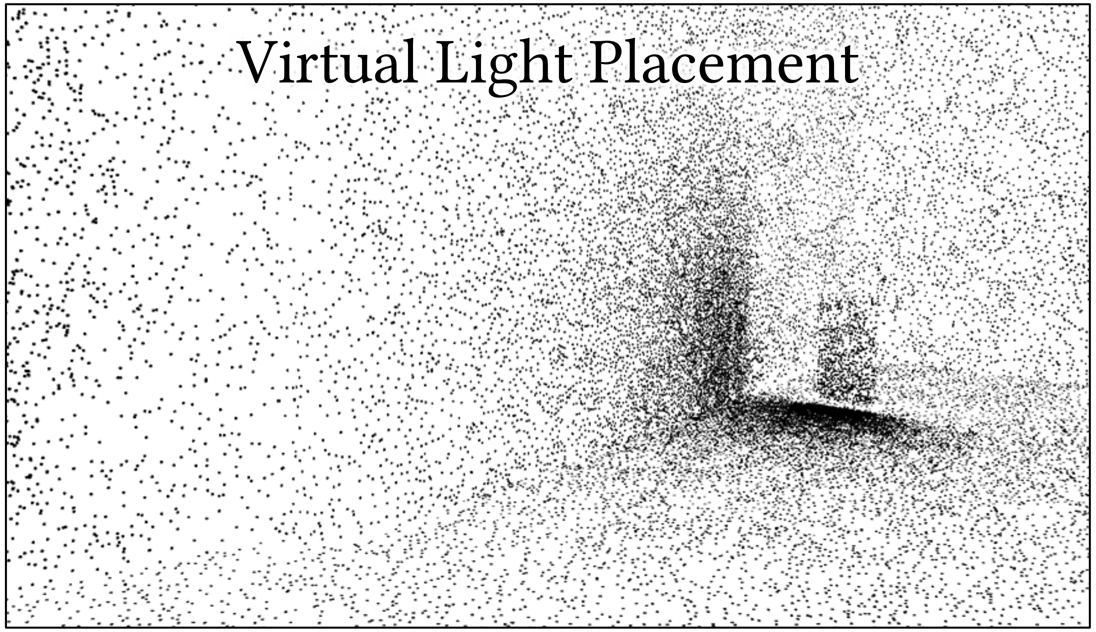
Veach Door scene



Problem 1

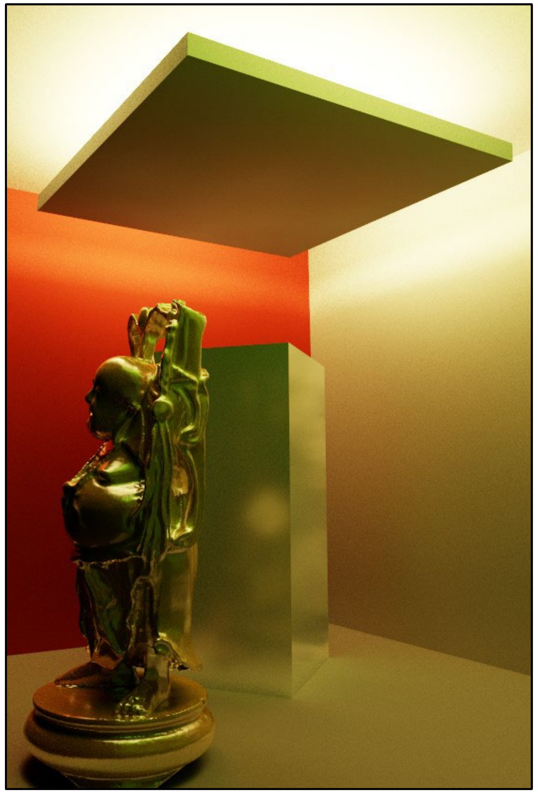
Virtual lights with no contribution to the final image

outside of the room

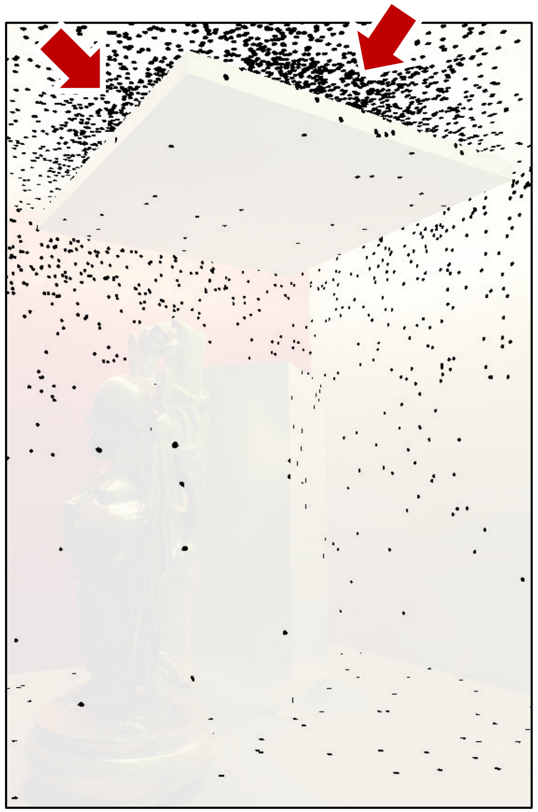


Problem 2

“Hot zones” are often over-sampled with many virtual lights.

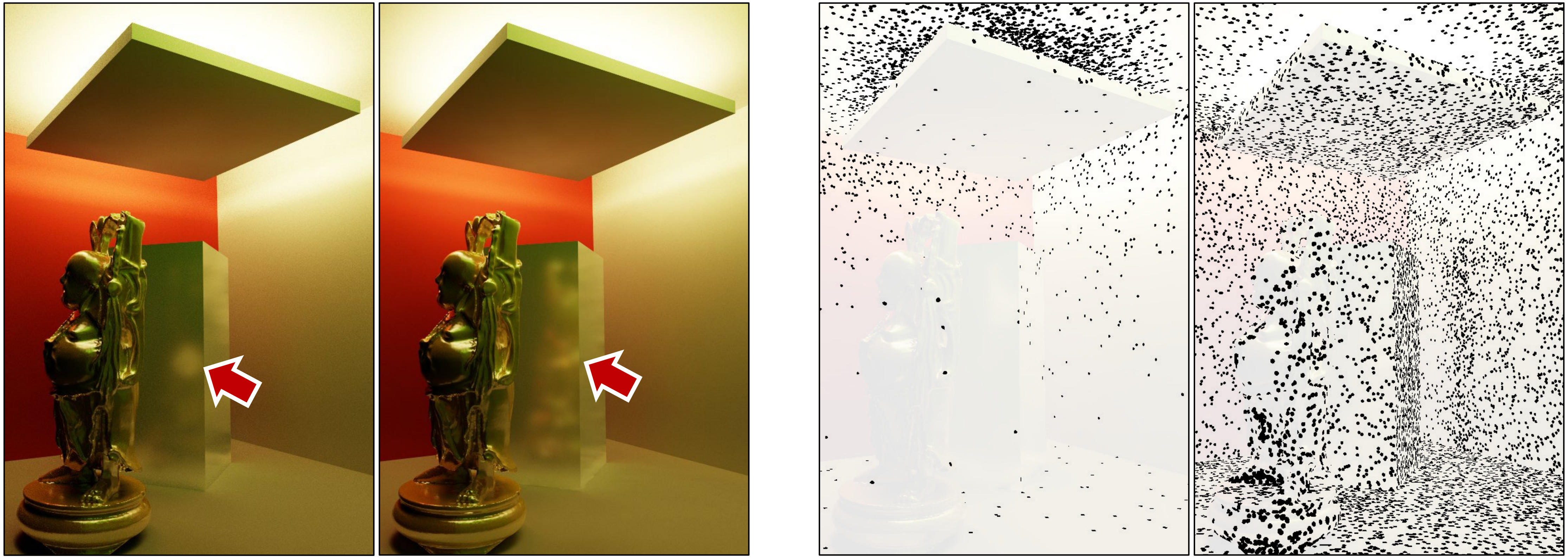


from light



Problem 2

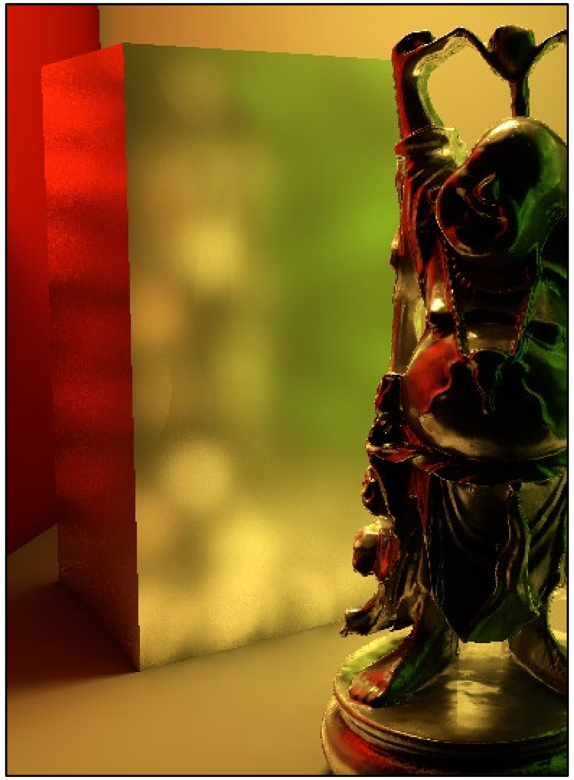
"Hot zones" are often over-sampled with many virtual lights.



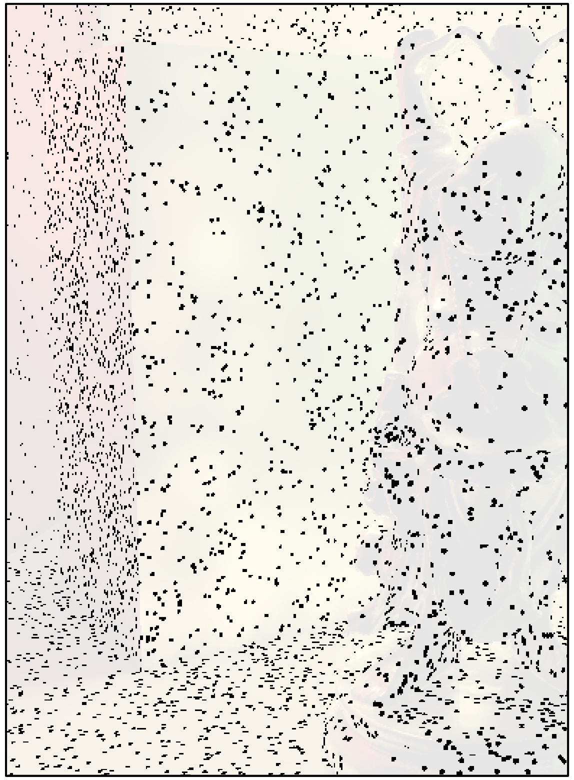
from light   from camera

Problem 3

Poor distribution of virtual lights

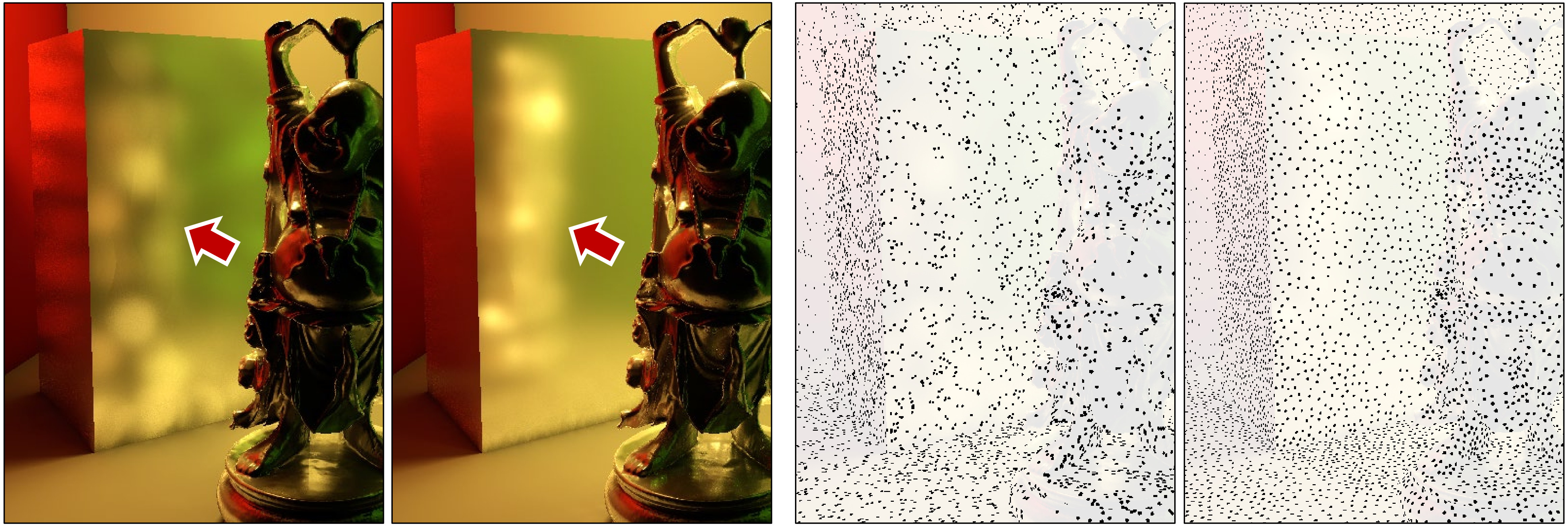


Random



Problem 3

Poor distribution of virtual lights



Random

Ours

Our Solutions

Problem 1: *unused virtual lights*

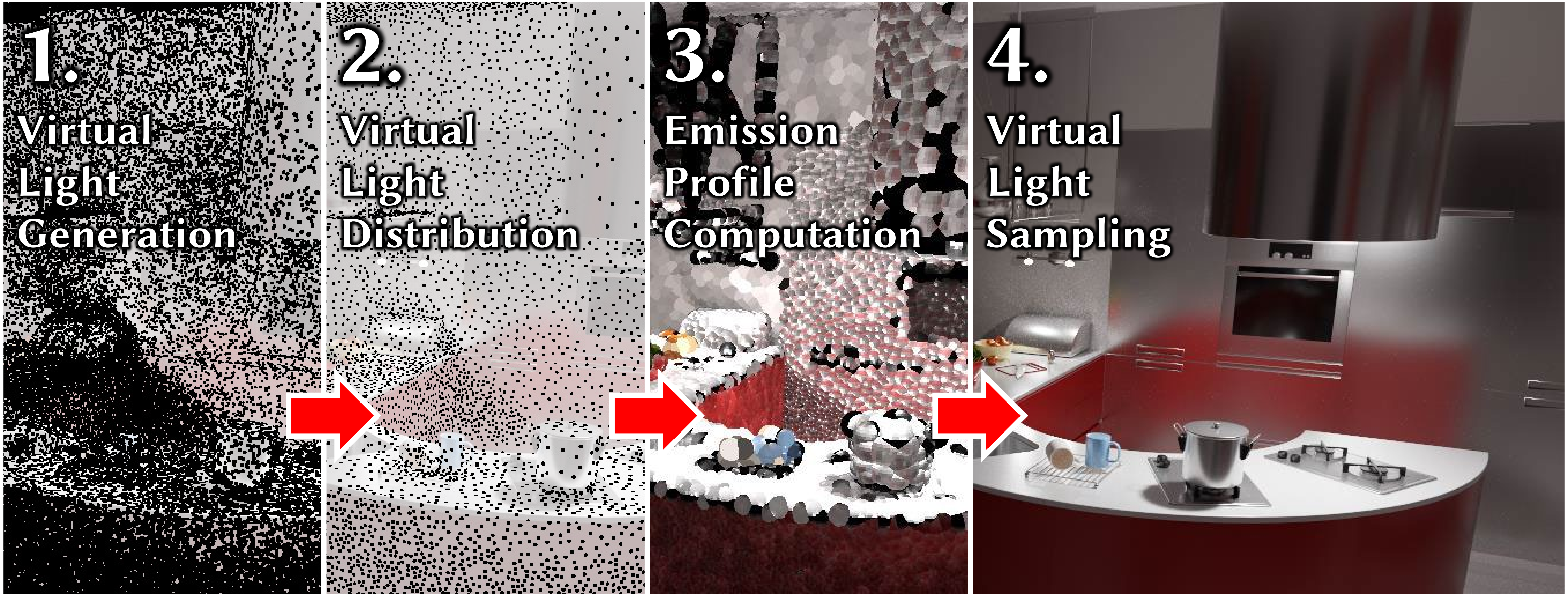
Problem 2: *hot zones*

- ✓ Virtual light generation from the camera

Problem 3: *random distribution*

- ✓ Sample Elimination

Virtual Blue Noise Lighting (VBNL)

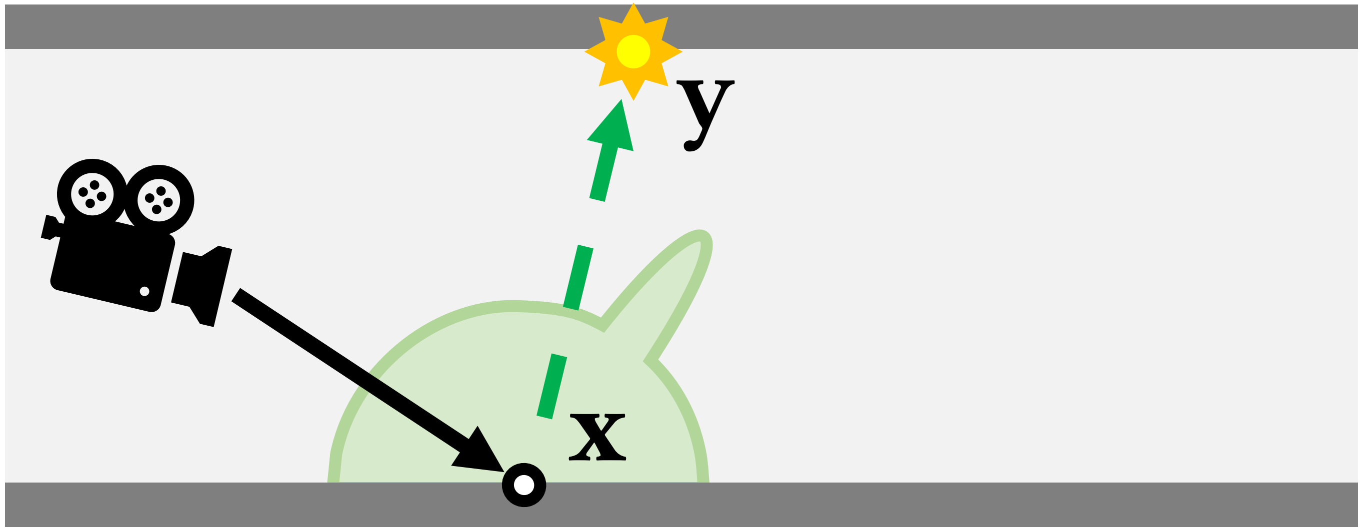


1.

Virtual Light Generation

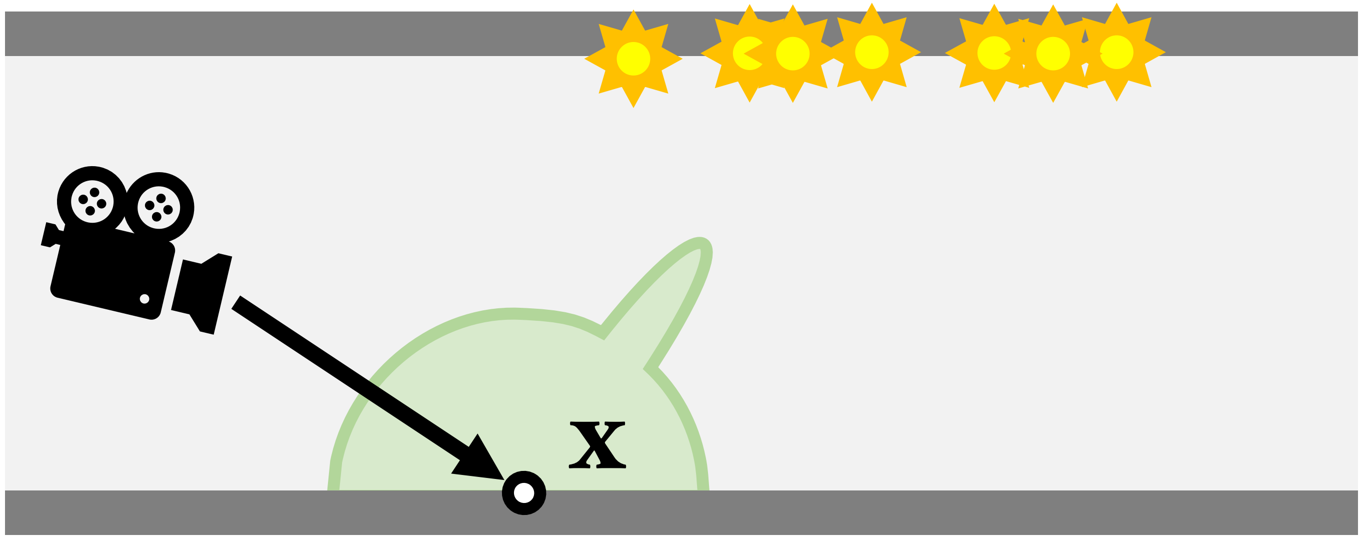
from Camera

Virtual Light Generation



- No wasted virtual lights
- Density ∝ camera importance.

Virtual Light Generation



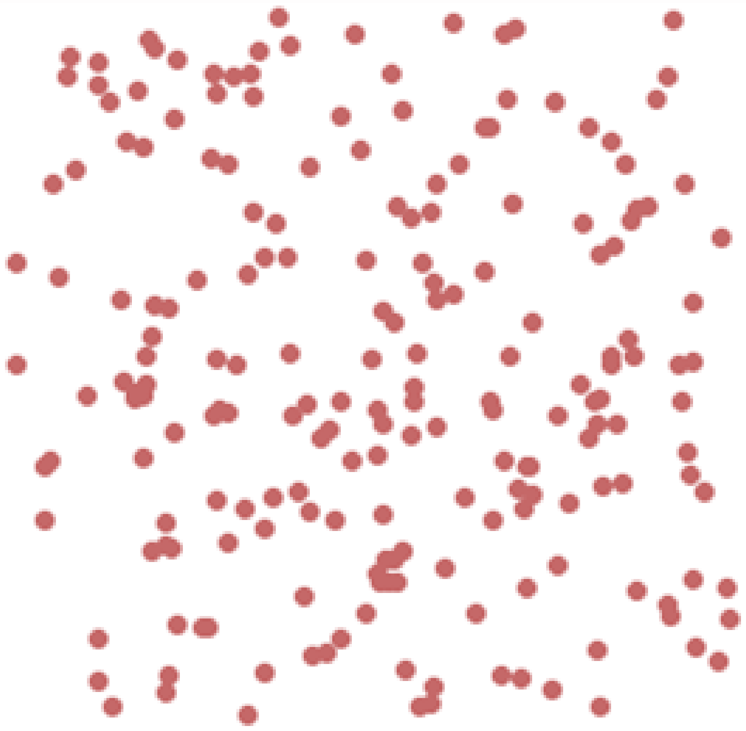
- No wasted virtual lights
- Density ∝ camera importance.

2.

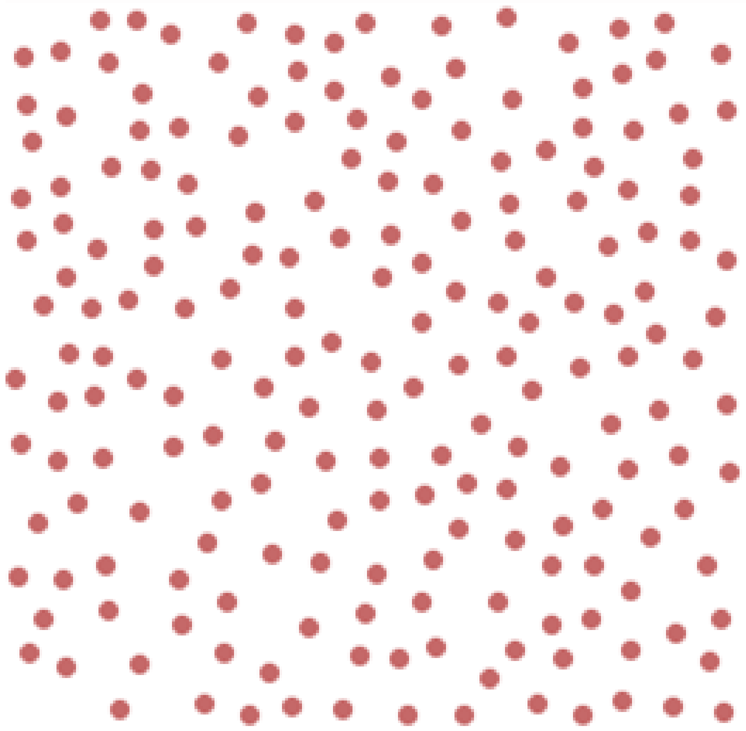
Virtual Light Distribution

Blue Noise via Sample Elimination

Virtual Light **Distribution**

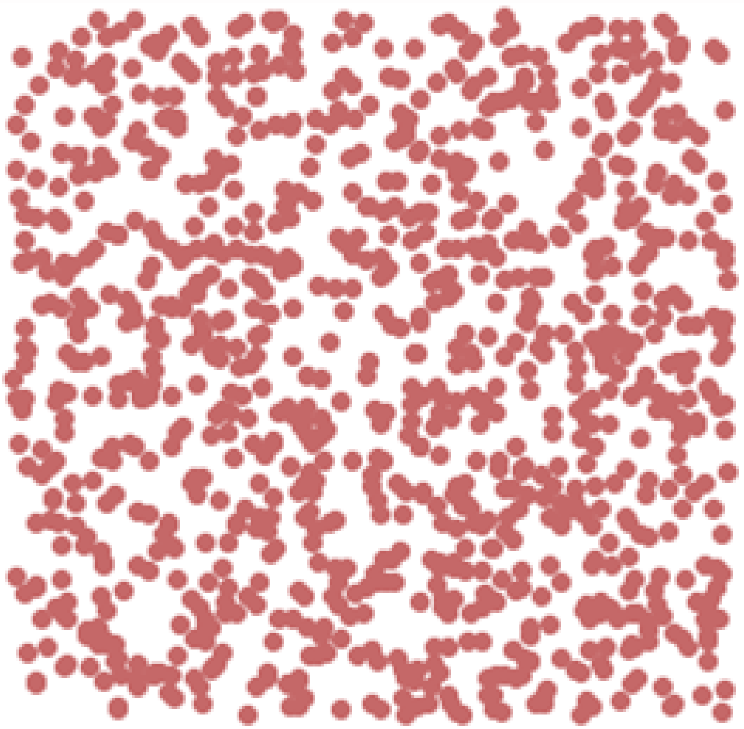


Random



Blue Noise

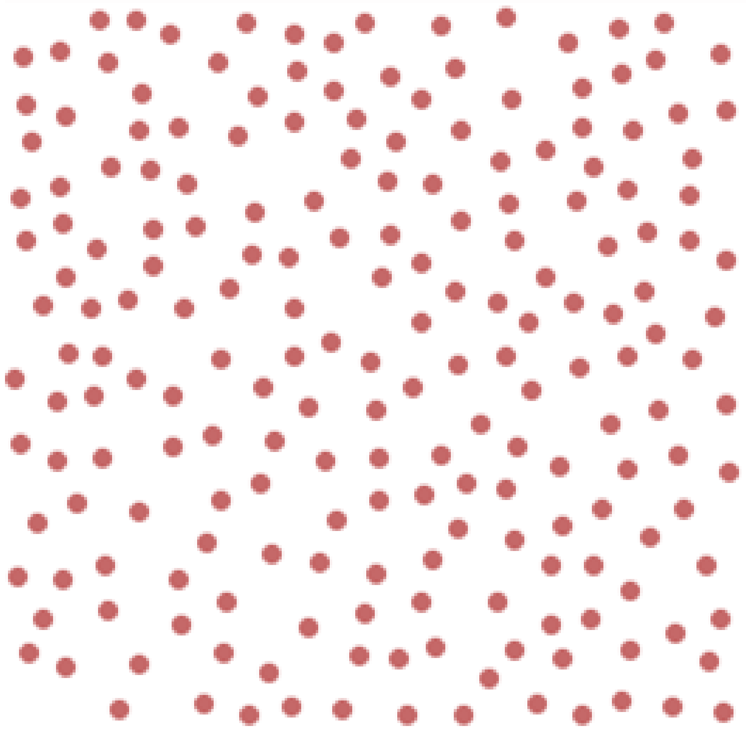
Virtual Light Distribution



Random

- Generate more virtual lights
- Remove some via **sample elimination**

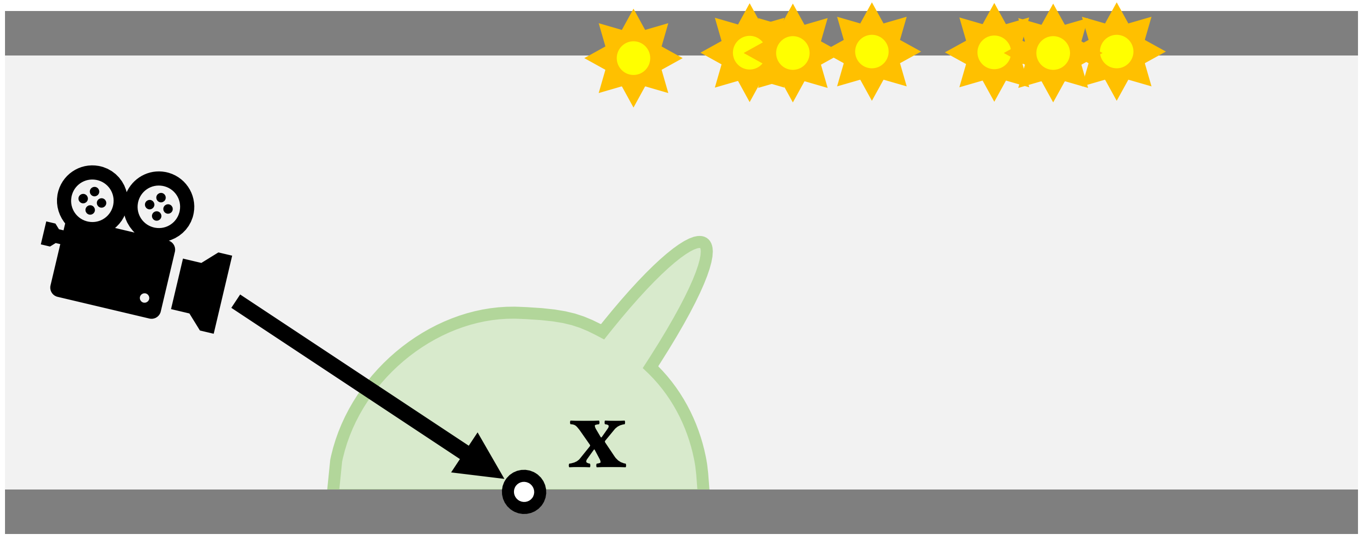
Virtual Light **Distribution**



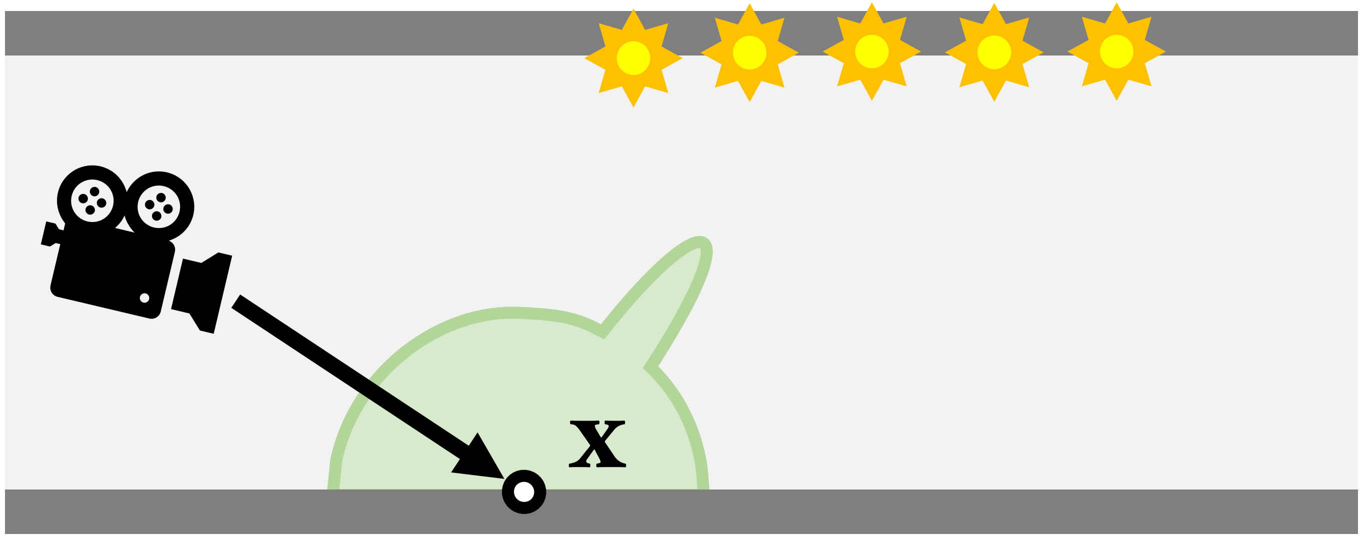
Blue Noise

- Generate more virtual lights
- Remove some via **sample elimination**

Virtual Light Distribution

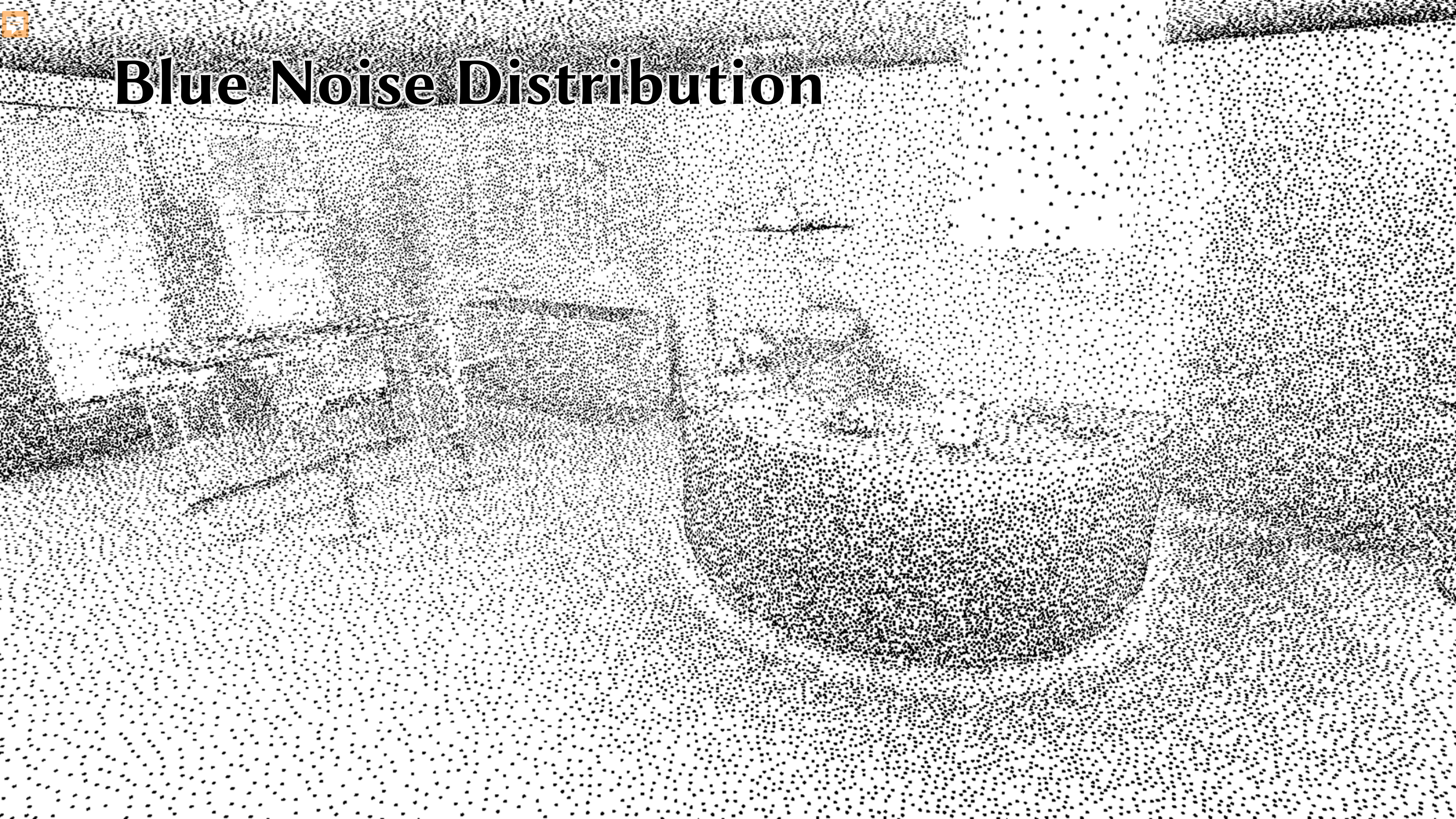


Virtual Light Distribution



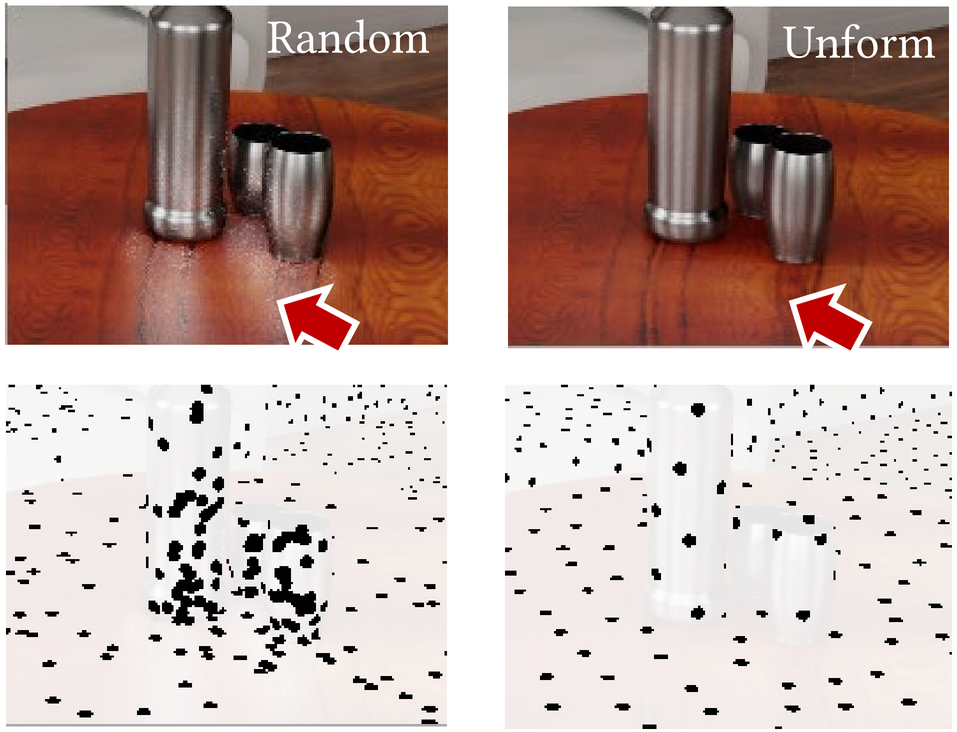

Initial Candidates

Blue Noise Distribution



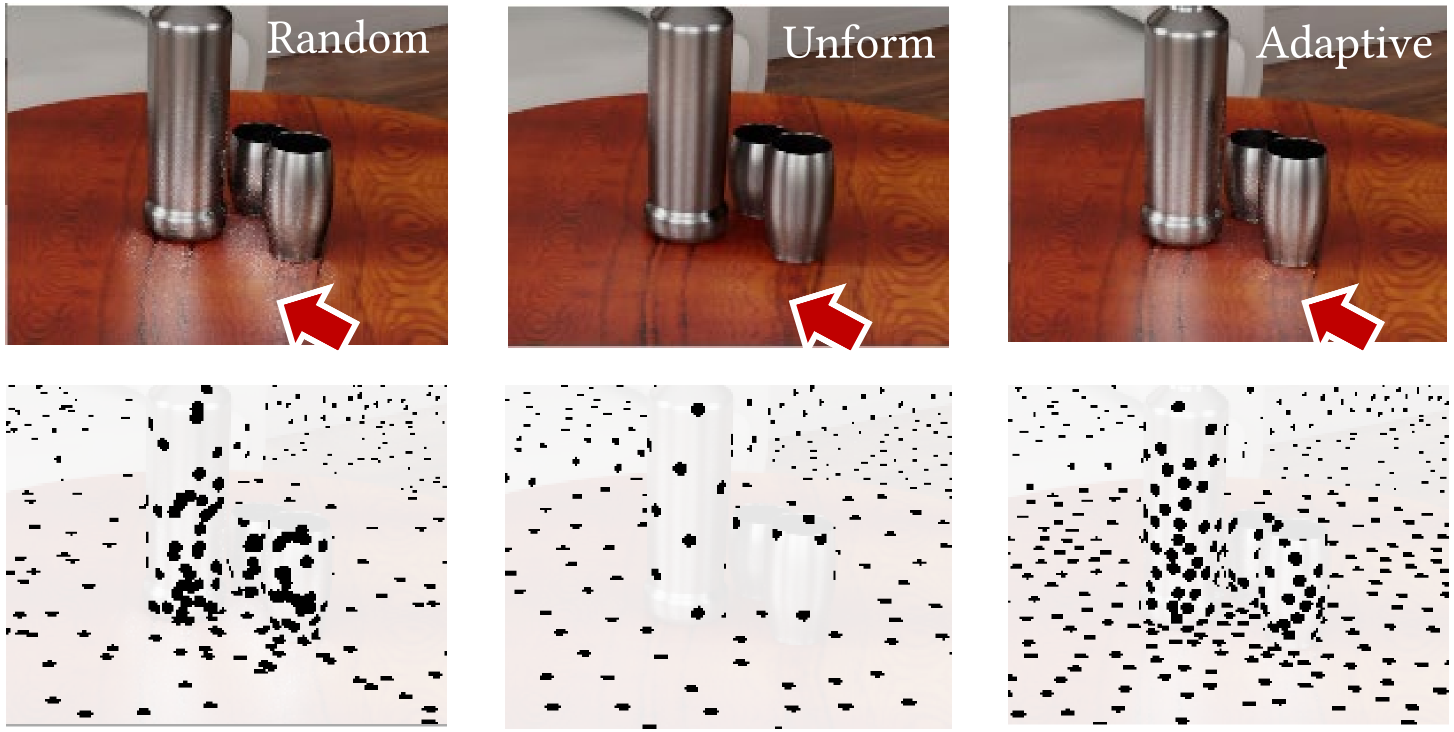
Uniform Sample Elimination

- Using the same Poisson disk radius is not always good.



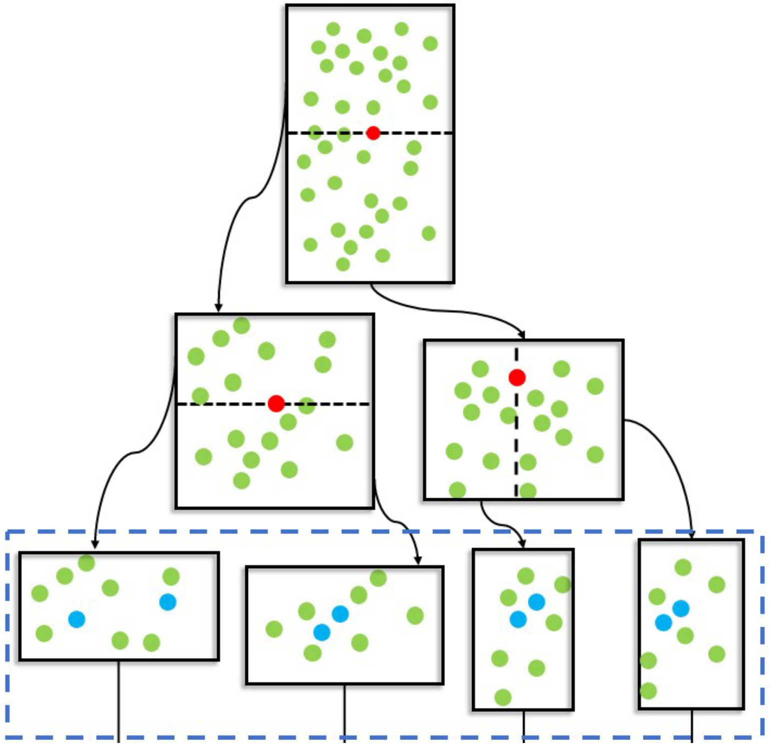
Adaptive Sample Elimination

- Do sampling elimination in the local domain.
- Each individual sample will have its own radius.

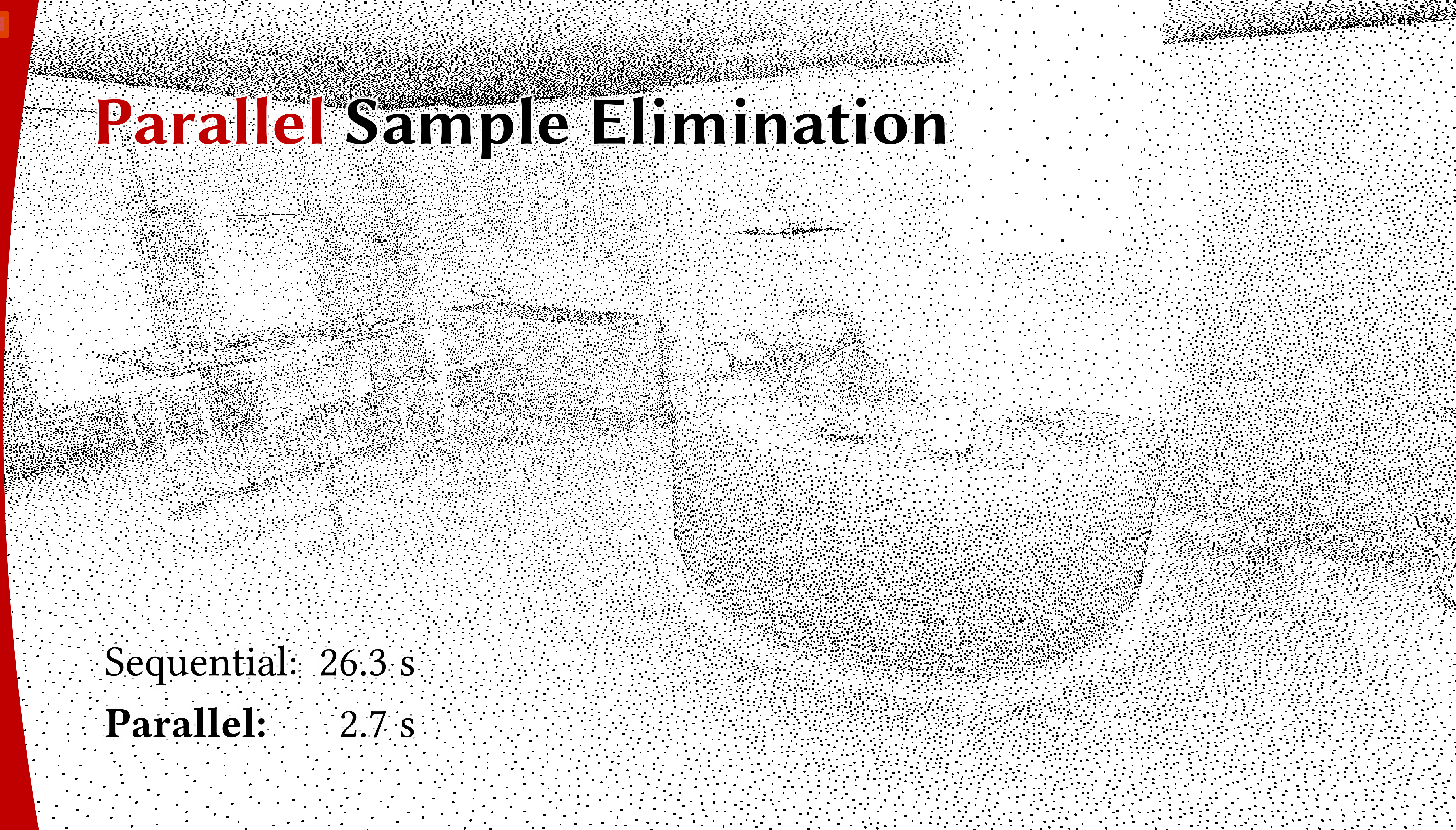


Parallel Sample Elimination

- Split the domain using a balanced k-d tree
- Perform sample elimination bottom up



Parallel Sample Elimination



Sequential: 26.3 s

Parallel: 2.7 s

3.

Emission Profile Computation

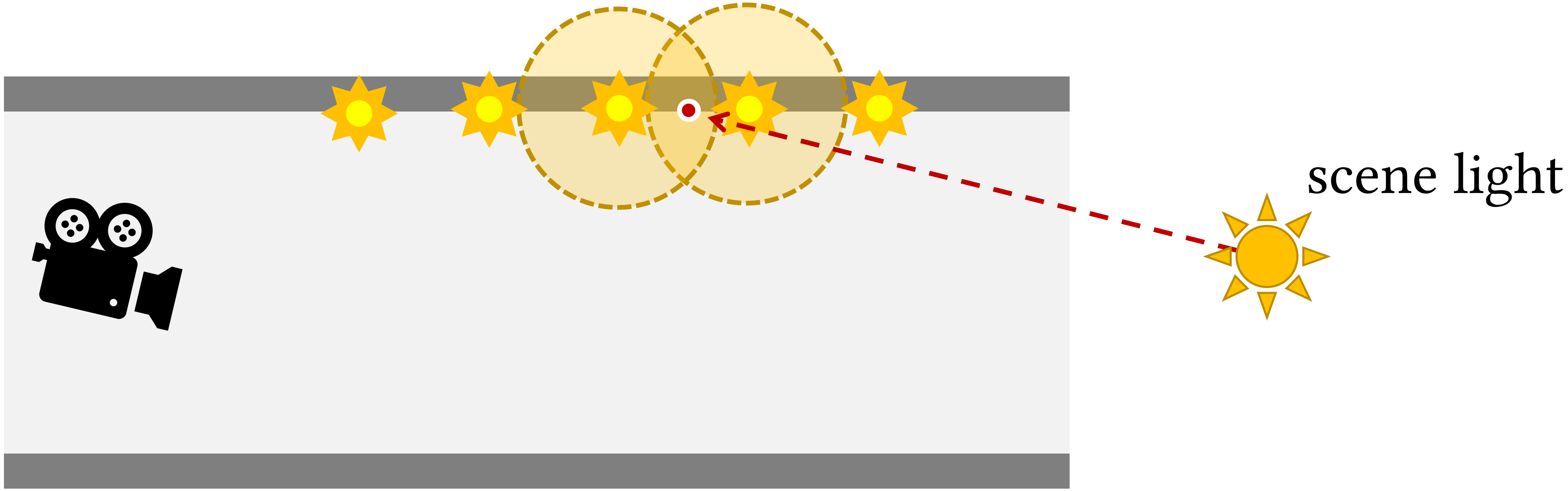
Photon Splitting

Emission Profile Computation

- Photon Tracing and Incident Radiance Estimation

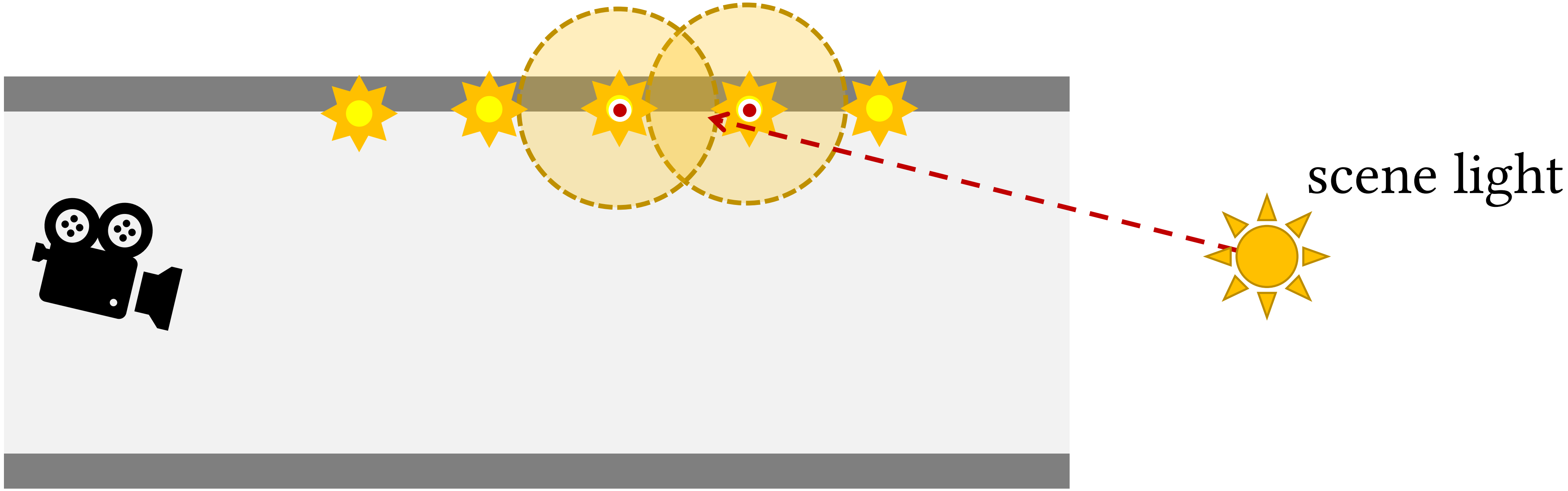
Emission Profile Computation

- Photon Tracing and Incident Radiance Estimation



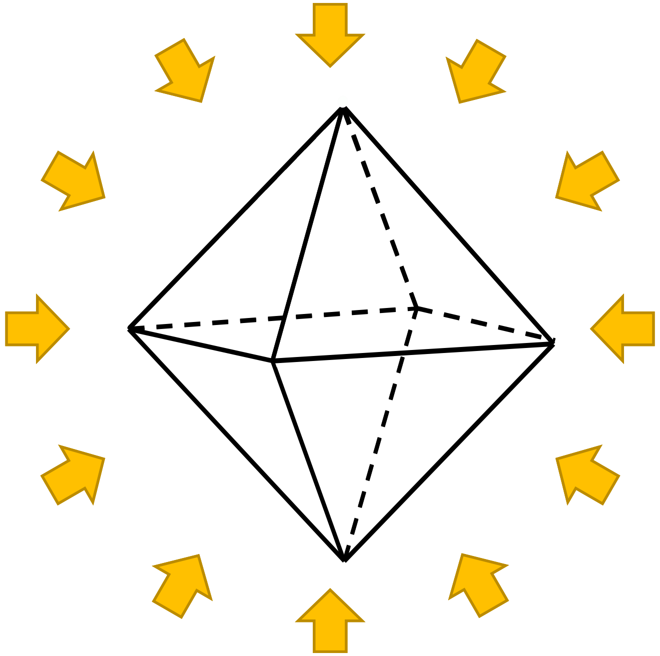
Emission Profile Computation

- Photon Tracing and Incident Radiance Estimation



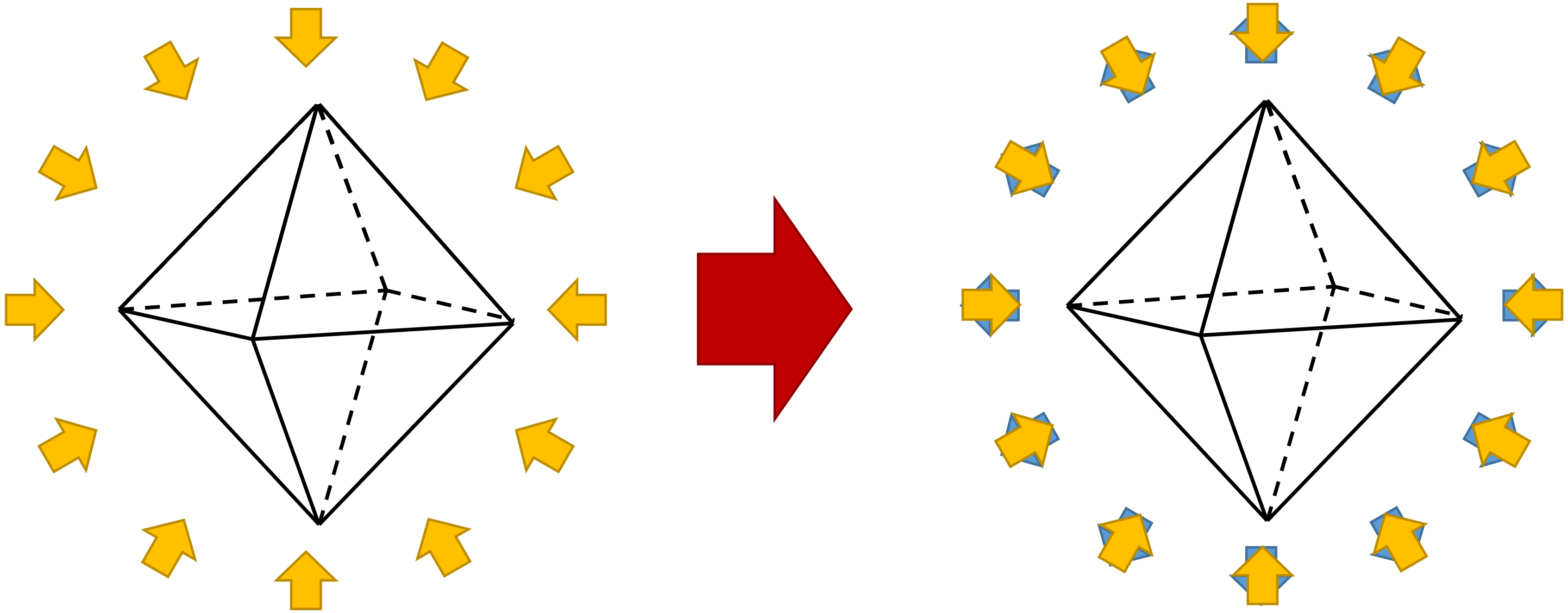
Emission Profile Computation

- Photon Tracing and Incident Radiance Estimation
- Radiance Conversion



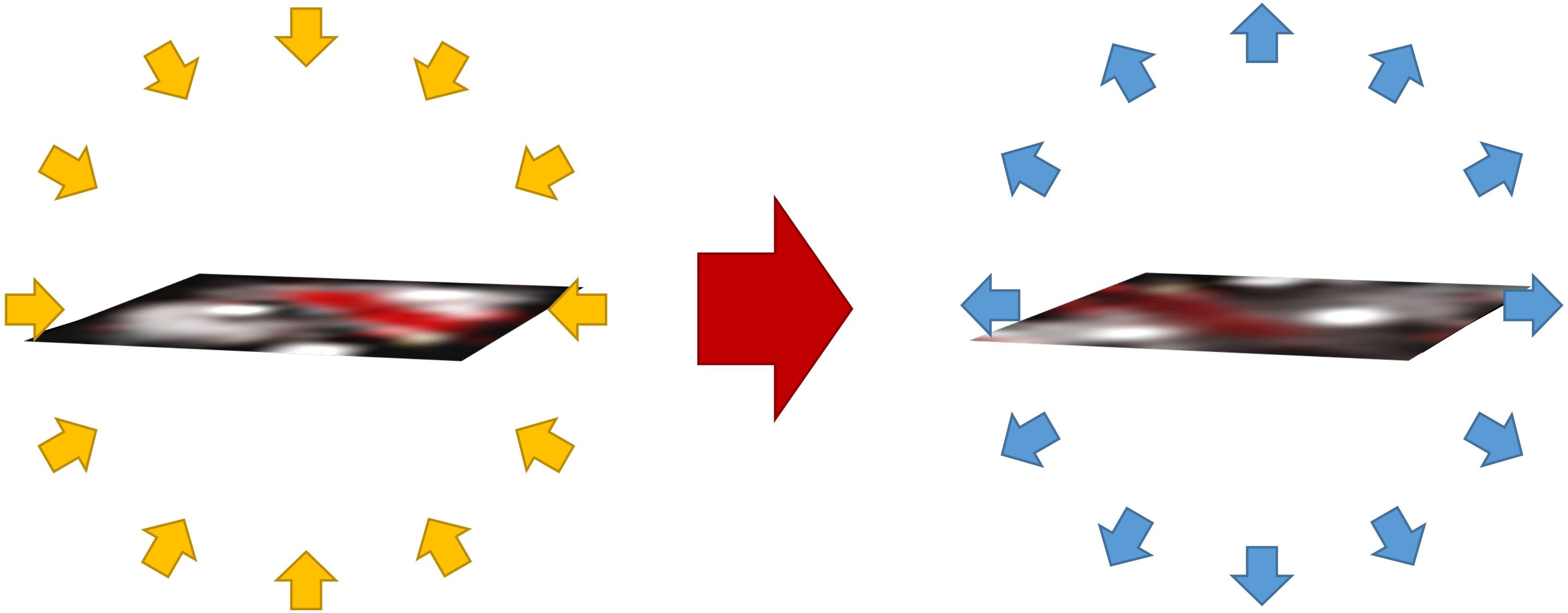
Emission Profile Computation

- Photon Tracing and Incident Radiance Estimation
- Radiance Conversion



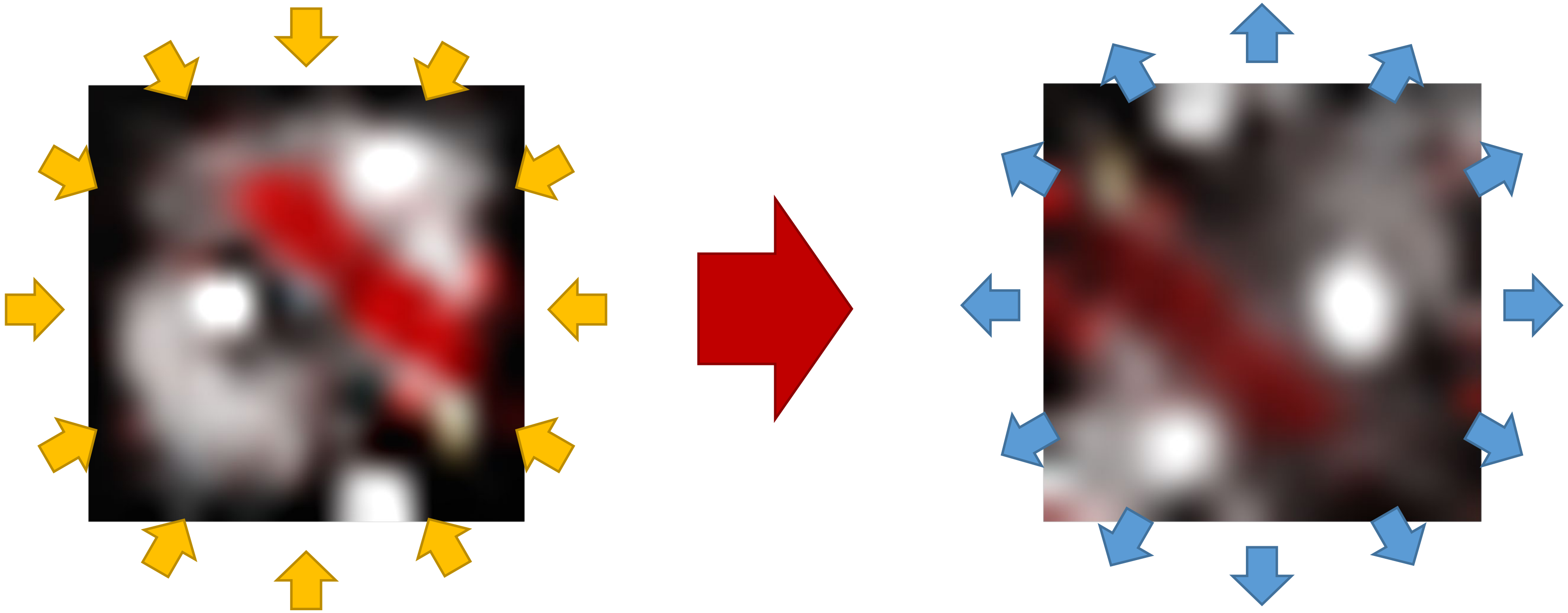
Emission Profile Computation

- Photon Tracing and Incident Radiance Estimation
- Radiance Conversion



Emission Profile Computation

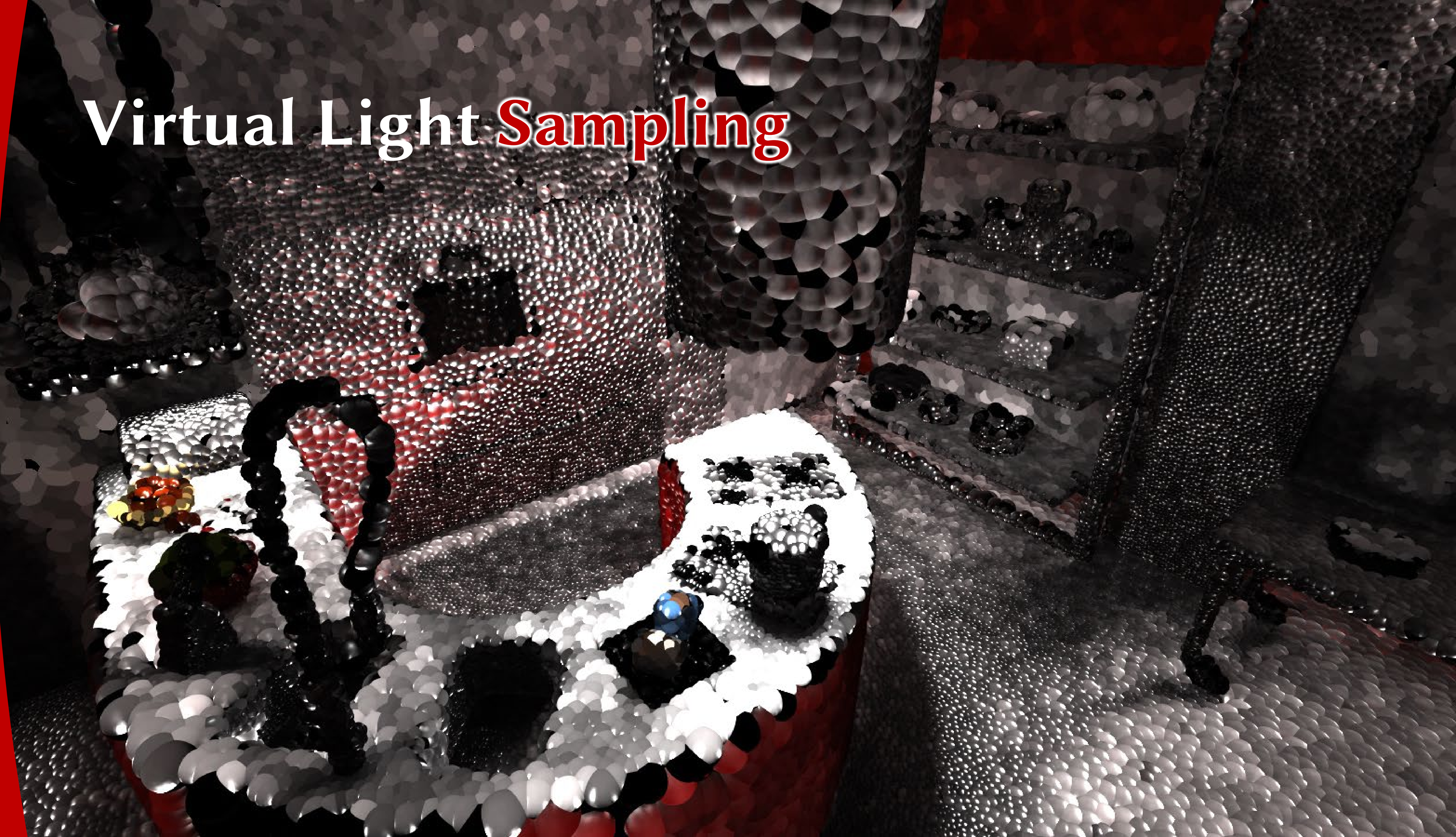
- Photon Tracing and Incident Radiance Estimation
- Radiance Conversion

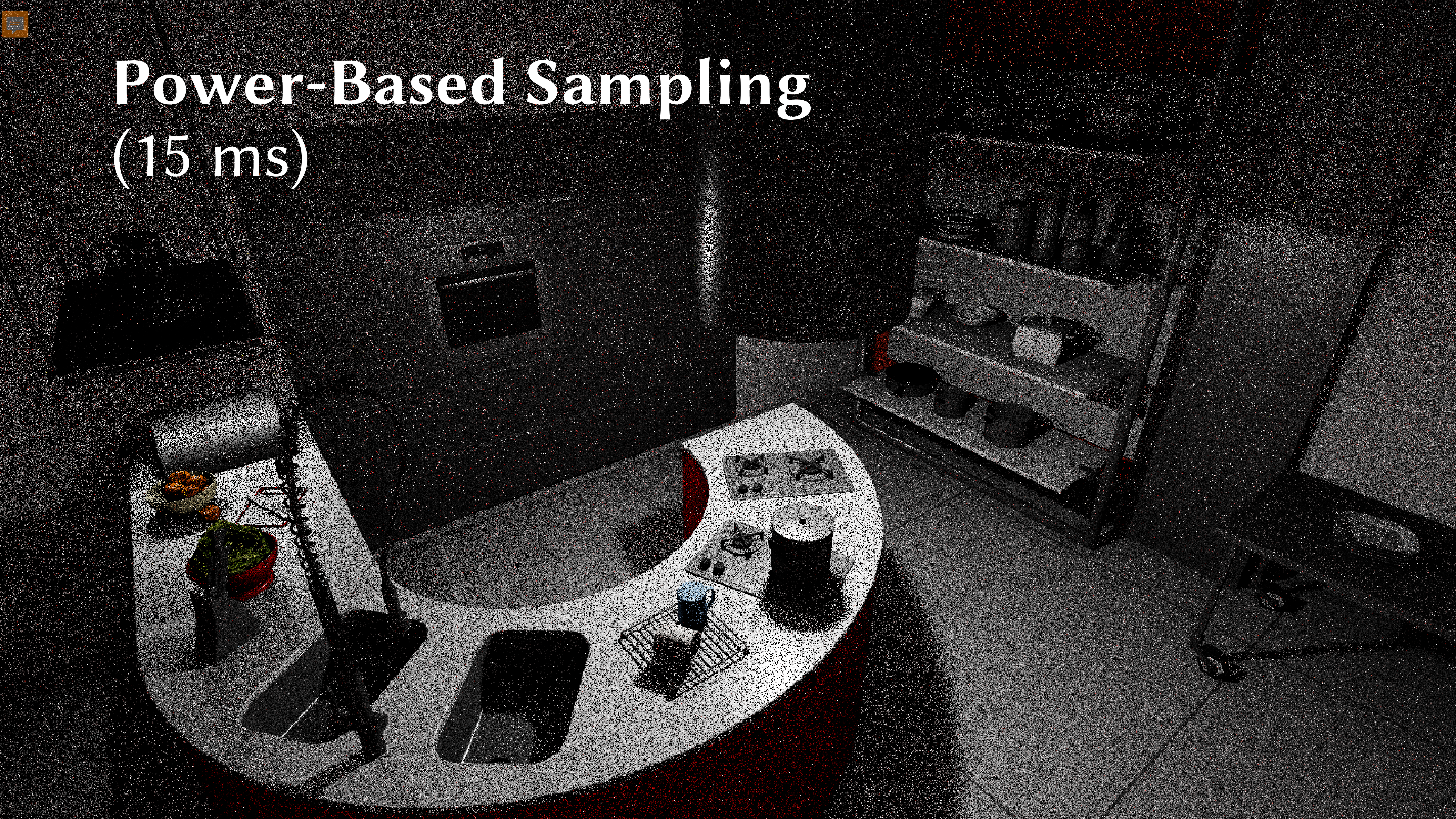


4.

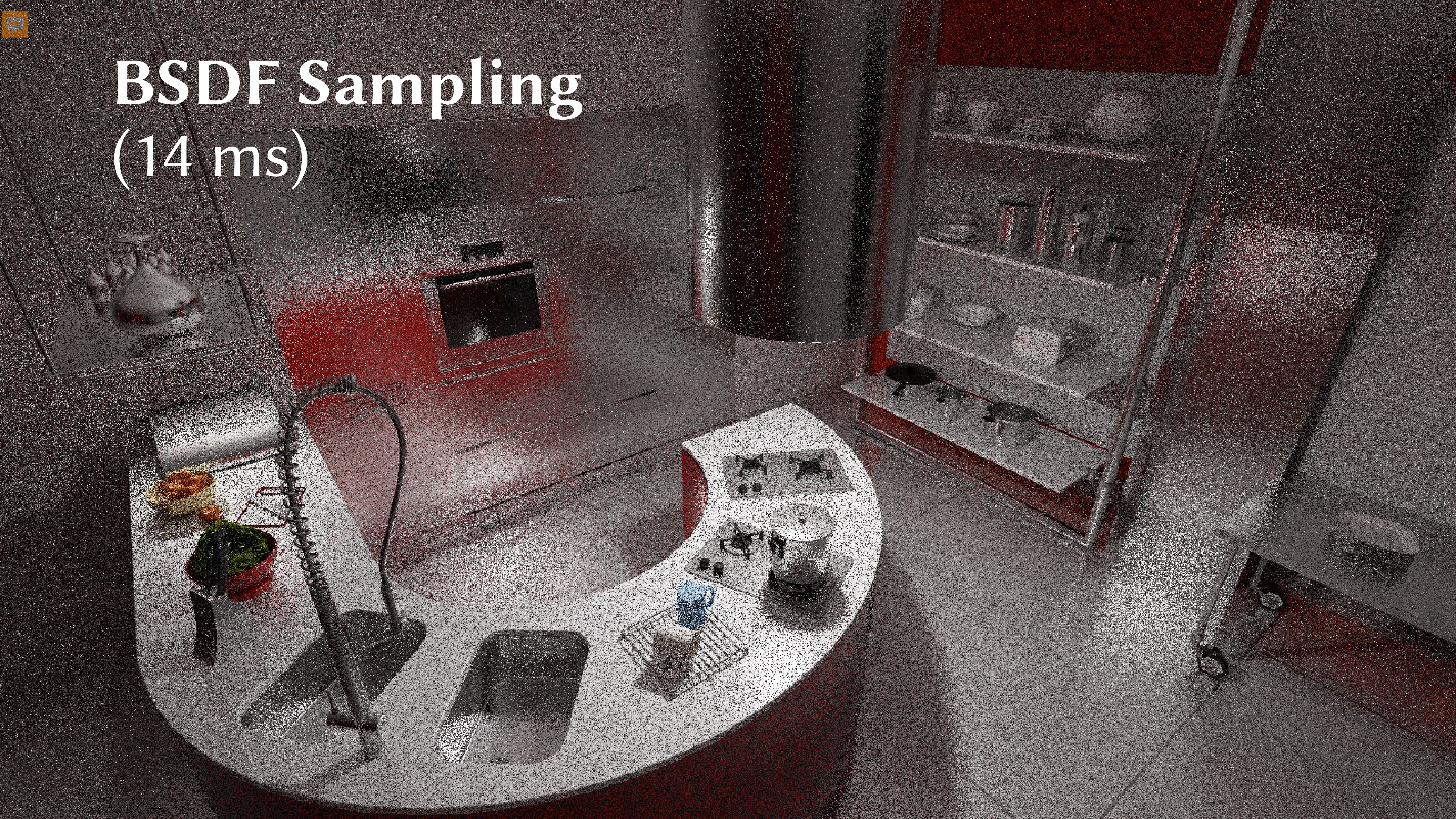
Virtual Light Sampling

Virtual Light Sampling

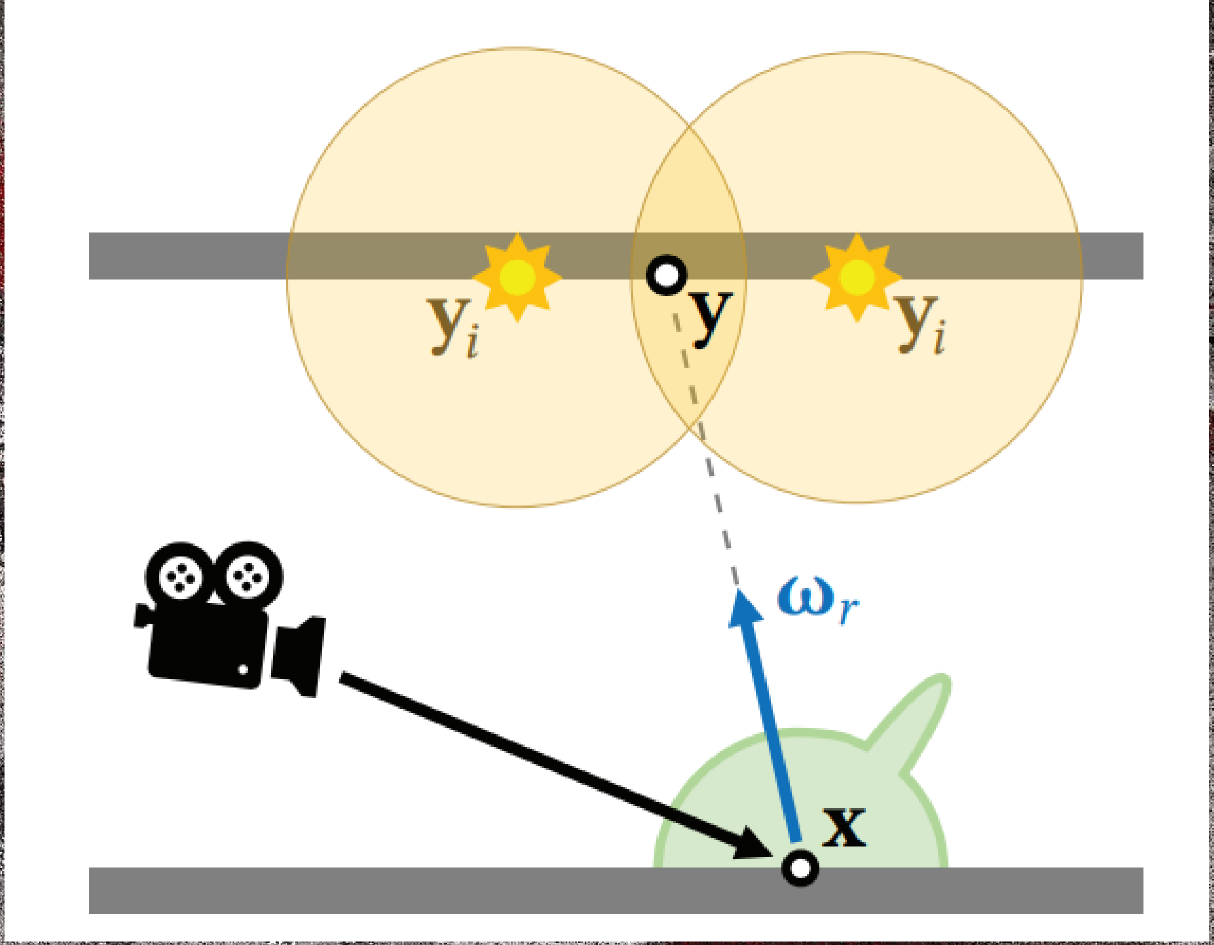


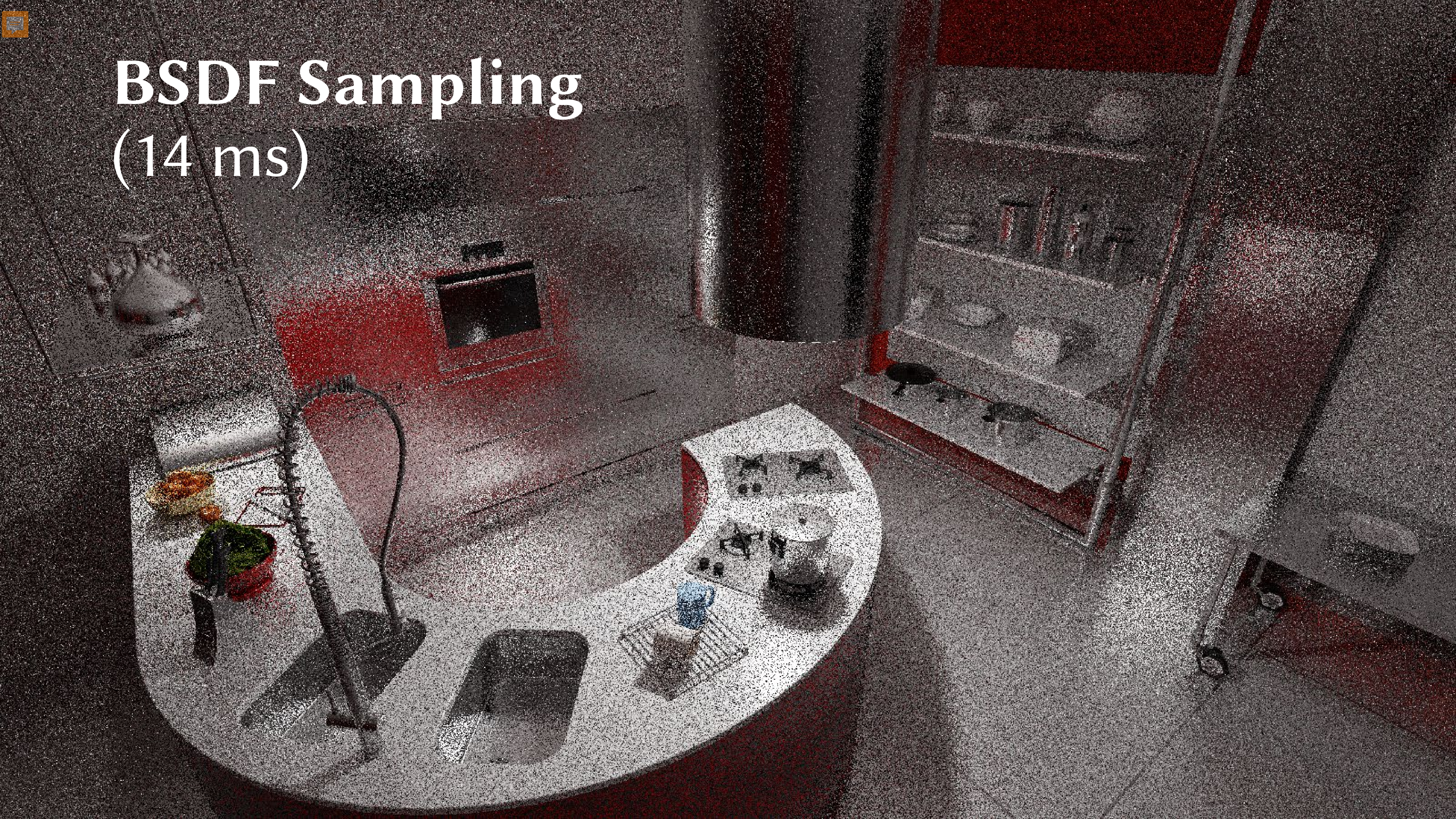

Power-Based Sampling
(15 ms)

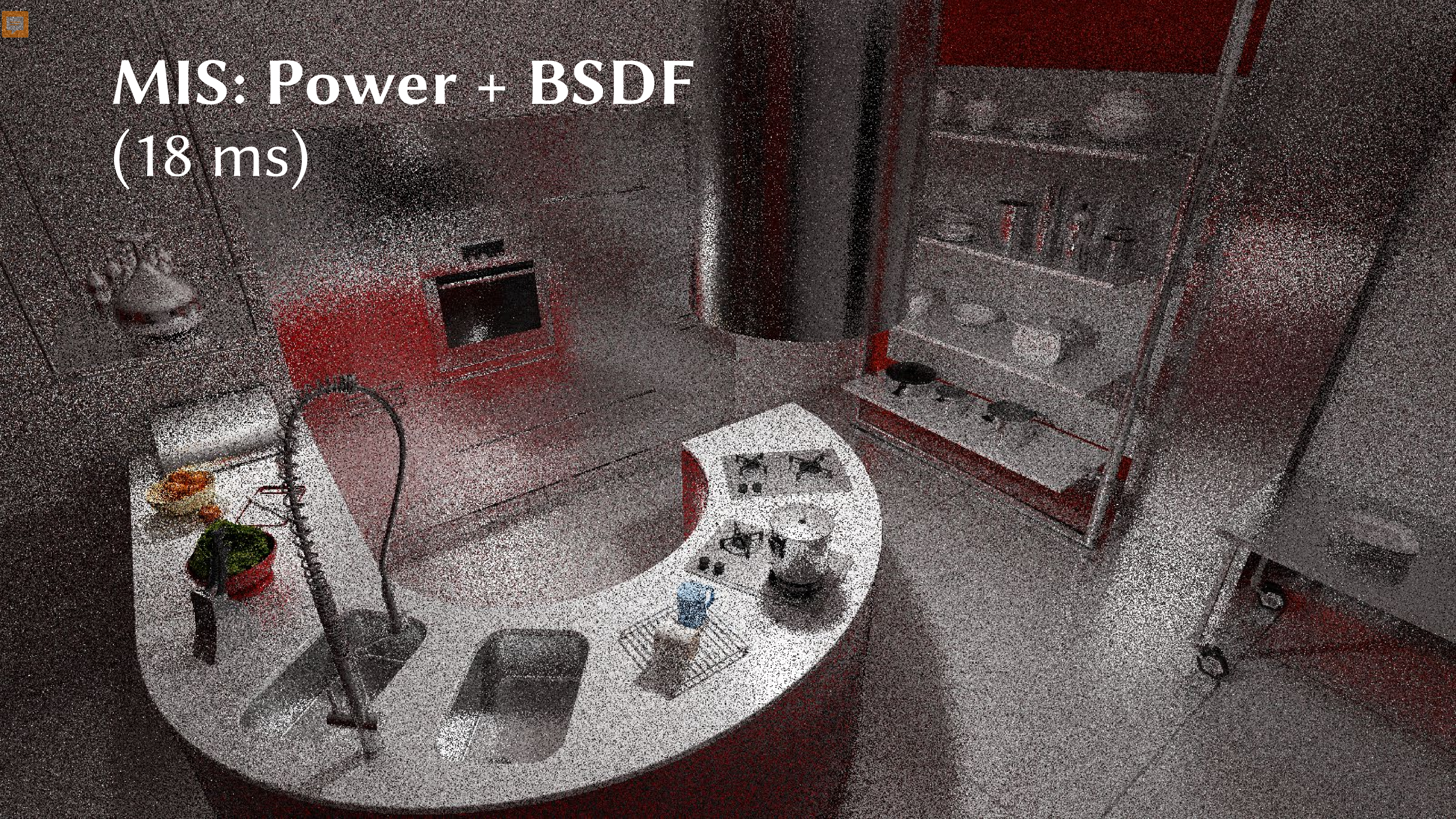

Light BVH
(22 ms)


BSDF Sampling
(14 ms)

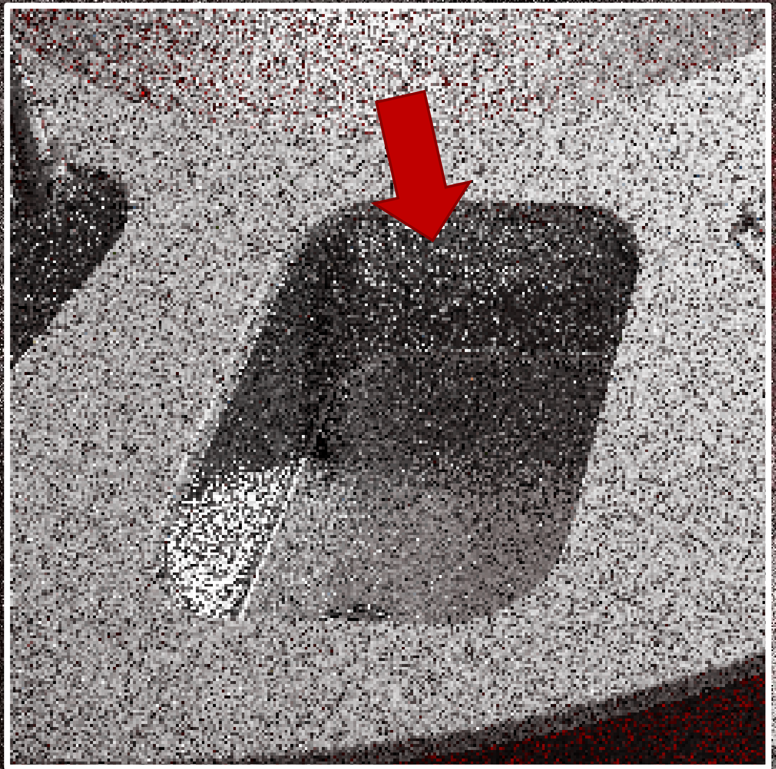
BSDF Sampling
(14 ms)



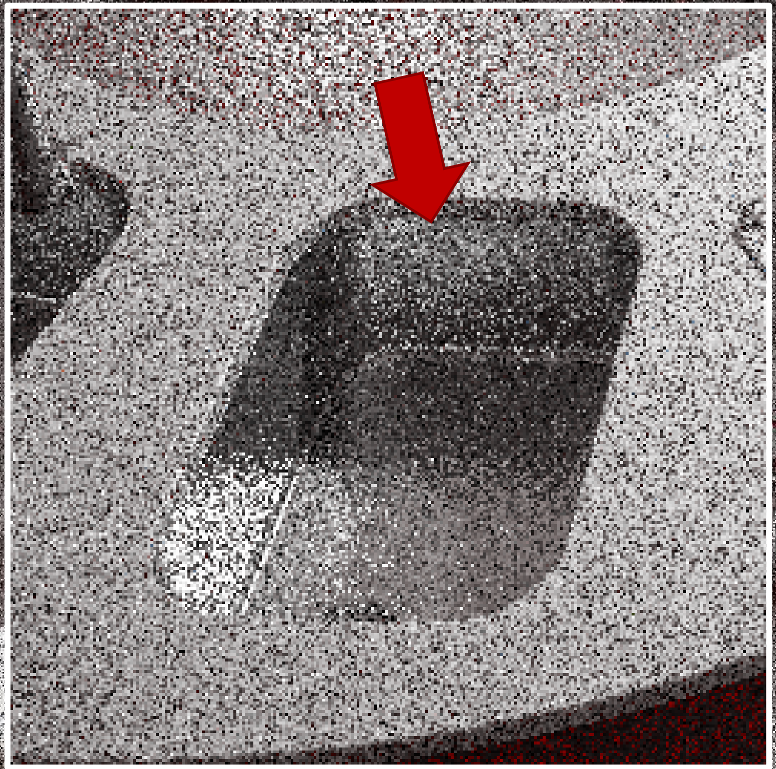

BSDF Sampling
(14 ms)


MIS: Power + BSDF
(18 ms)

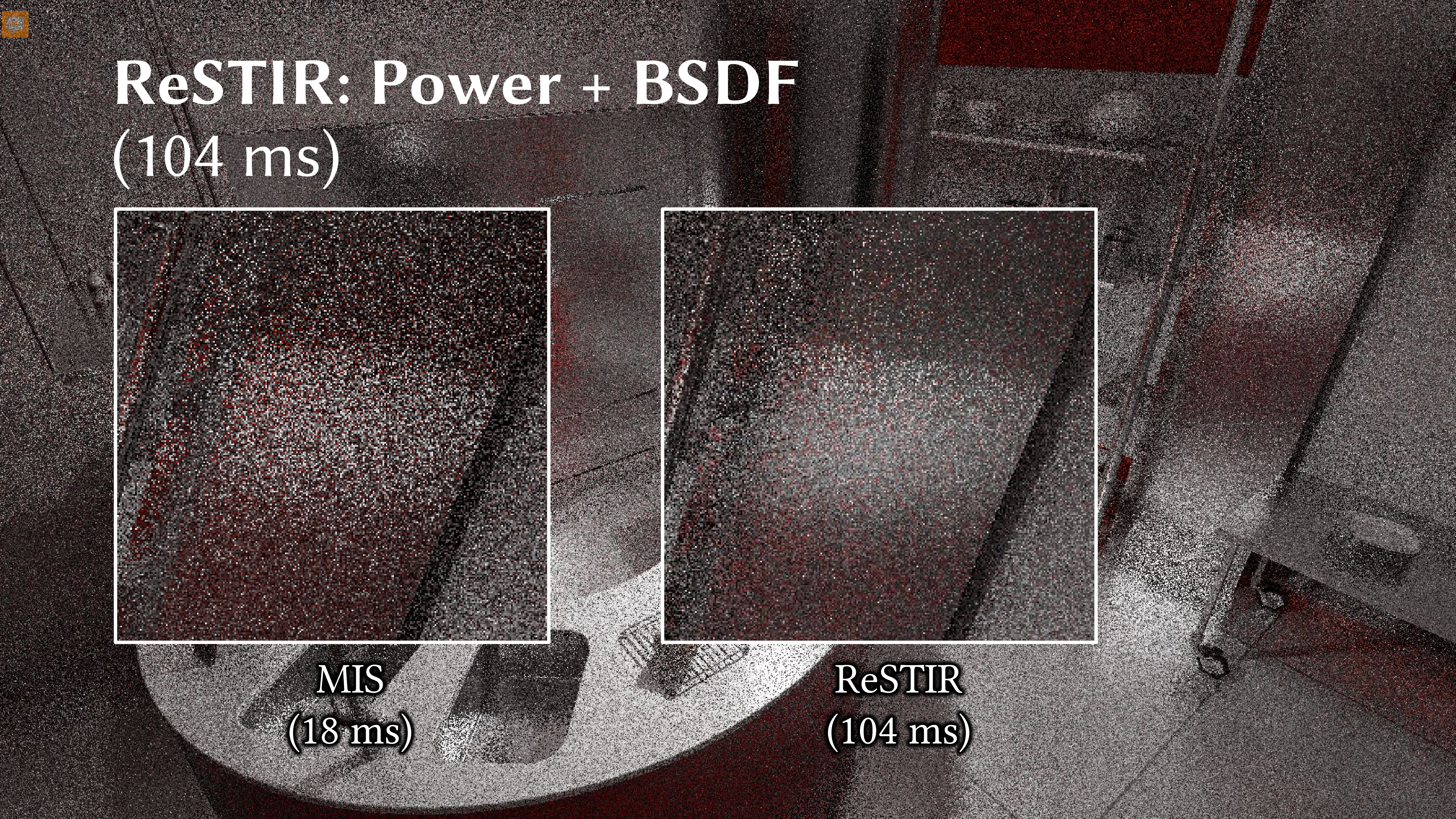
MIS: Power + BSDF
(18ms)



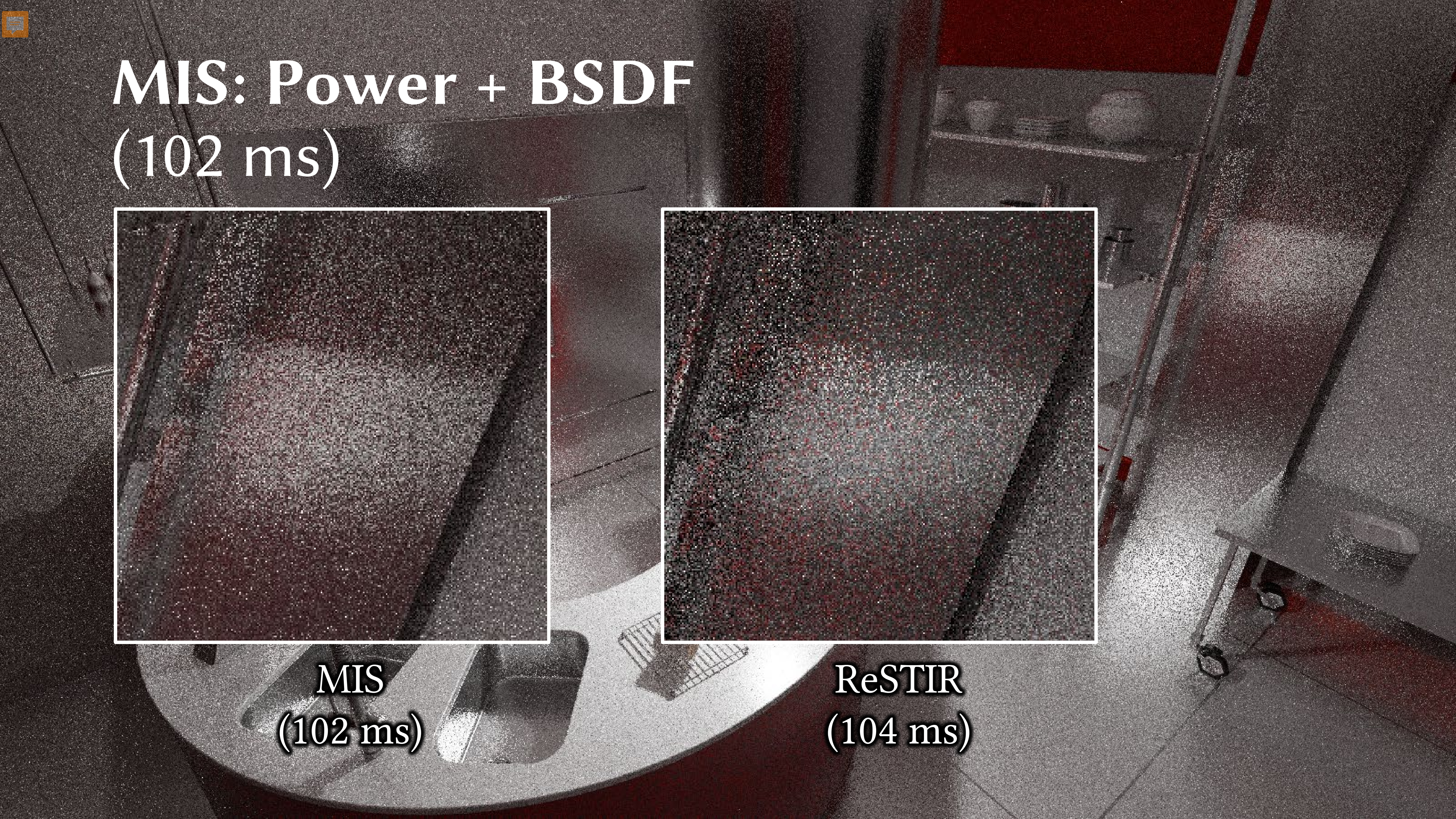
BSDF Sampling
(14 ms)



MIS
(18 ms)


ReSTIR: Power + BSDF
(104 ms)
MIS
(18 ms)
ReSTIR
(104 ms)

MIS: Power + BSDF
(102 ms)

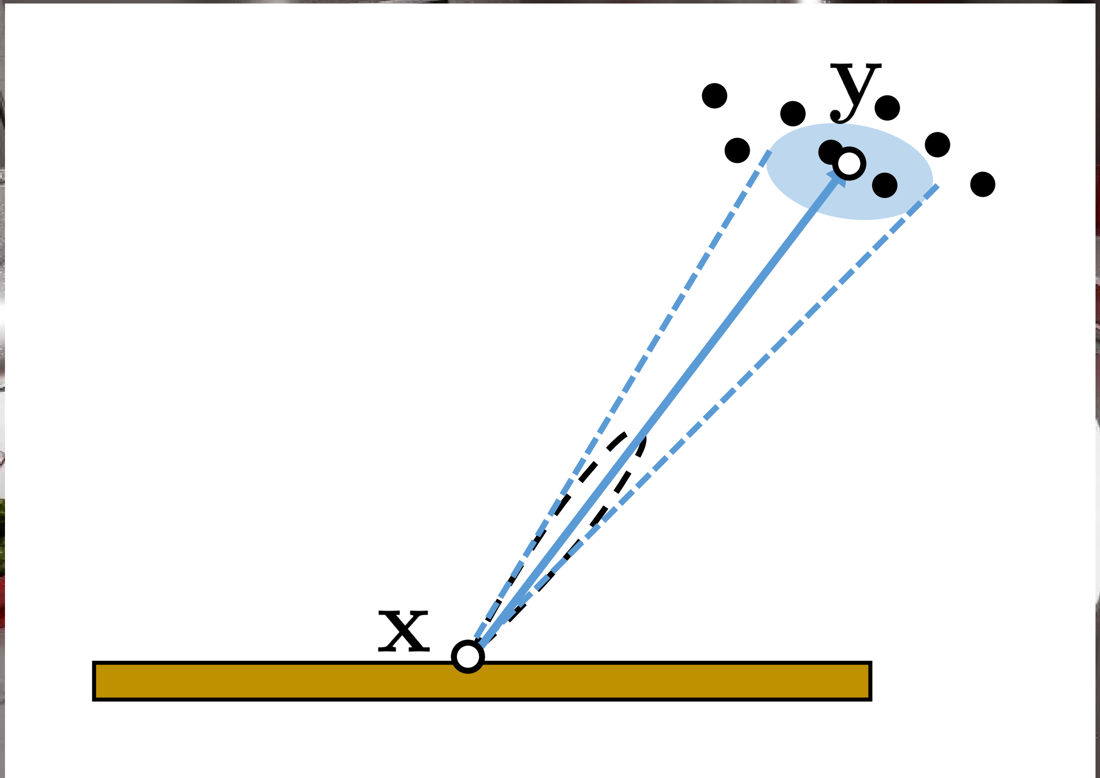


MIS
(102 ms)

ReSTIR
(104 ms)

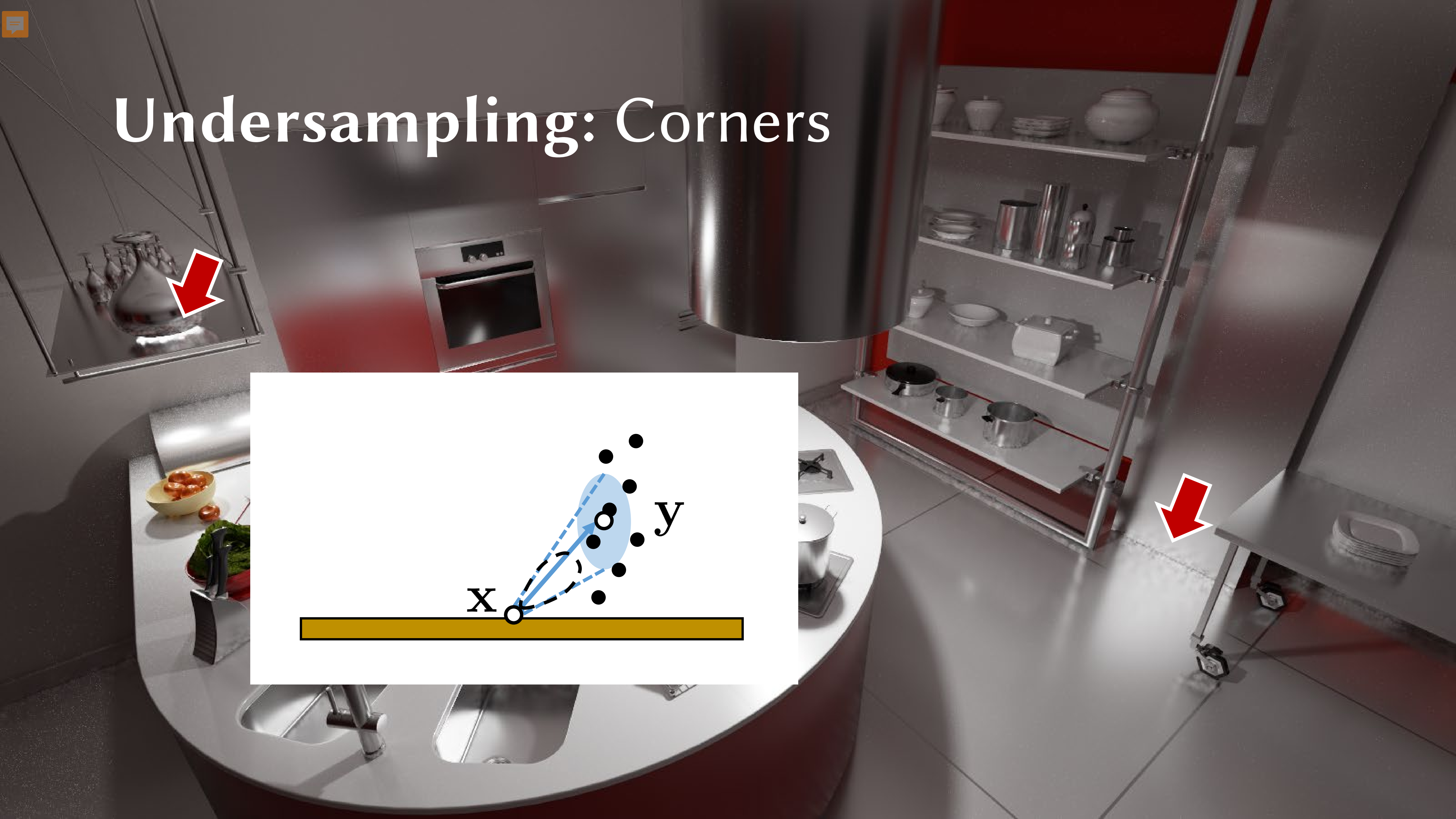
Undersampling: Highly Specular Surfaces

Undersampling: Highly Specular Surfaces



Undersampling: Corners

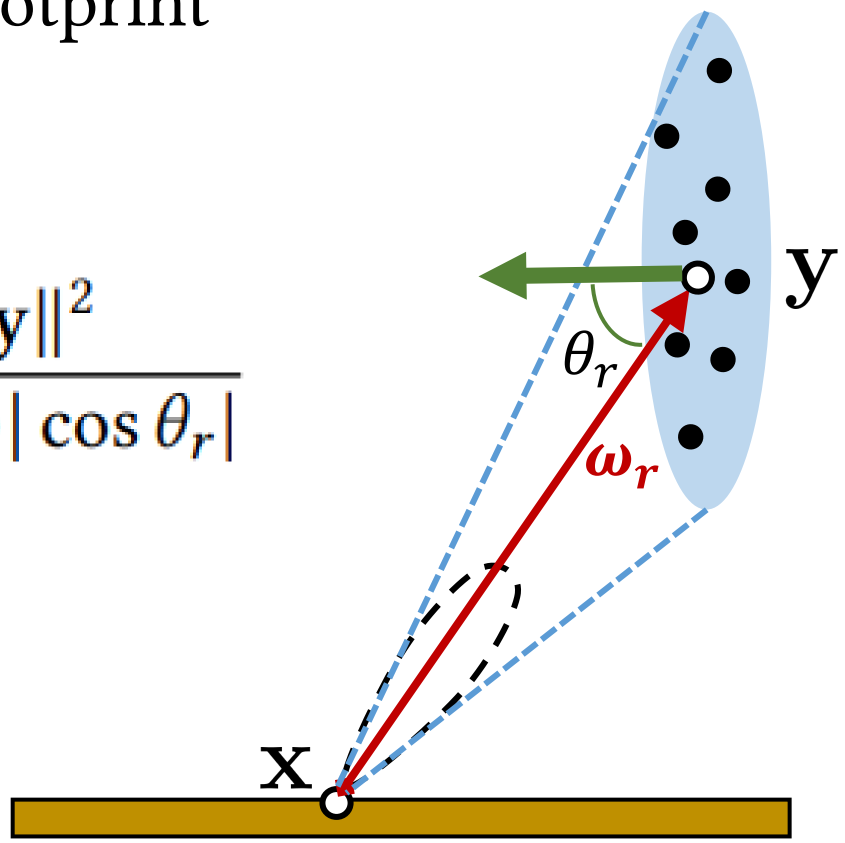
Undersampling: Corners



Adaptive Camera Path Extension

- Estimated Sample Footprint

$$a(\mathbf{x}, \omega_r) = \frac{\|\mathbf{x} - \mathbf{y}\|^2}{p_{\mathrm{BSDF}}(\omega_r)|\cos\theta_r|}$$

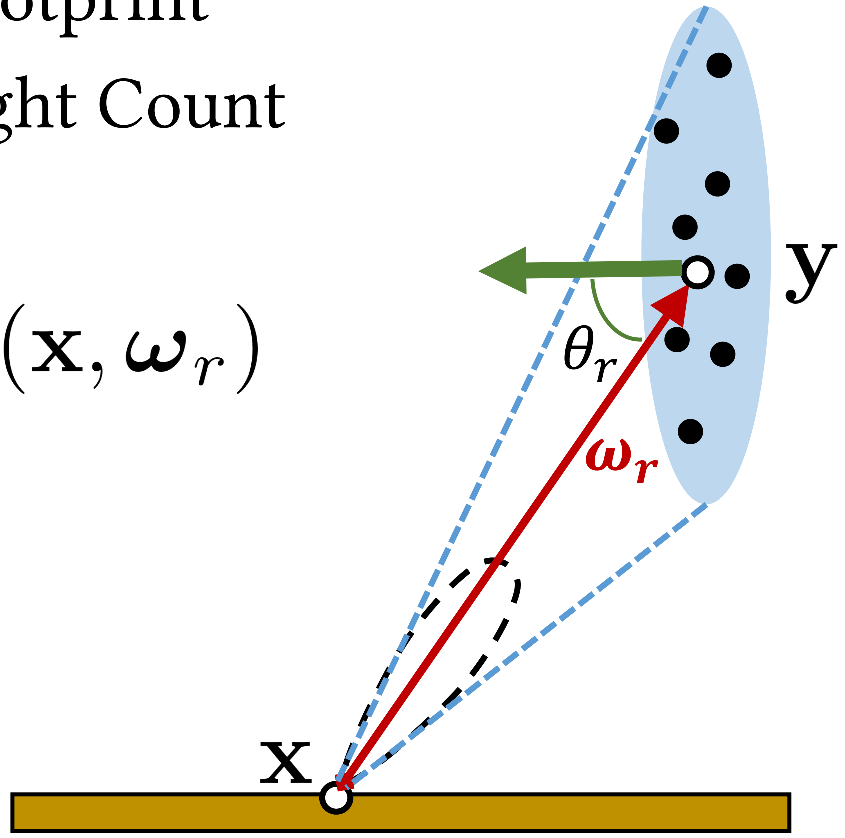


Adaptive Camera Path Extension

- Estimated Sample Footprint
- Estimated Virtual Light Count

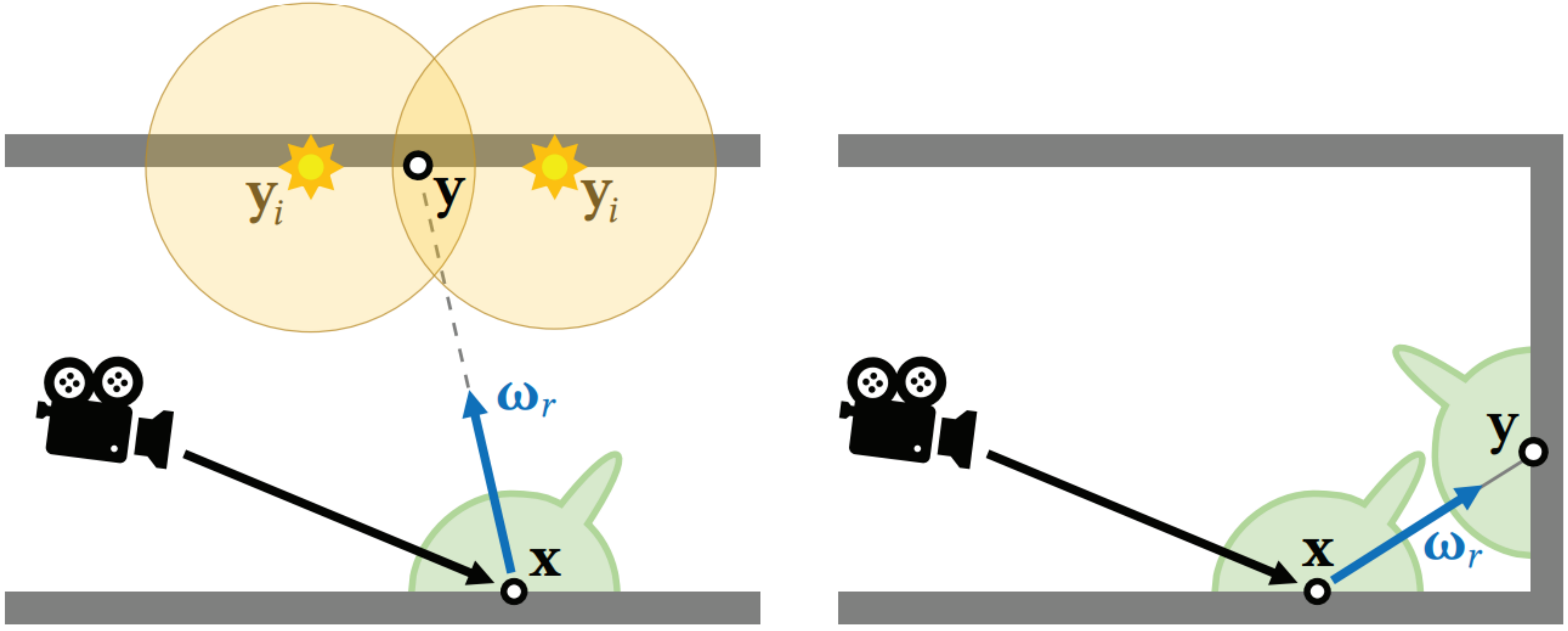
$$n = \bar{\rho}(\mathbf{y})a(\mathbf{x}, \boldsymbol{\omega}_r)$$

Virtual Light
Density



Adaptive Camera Path Extension

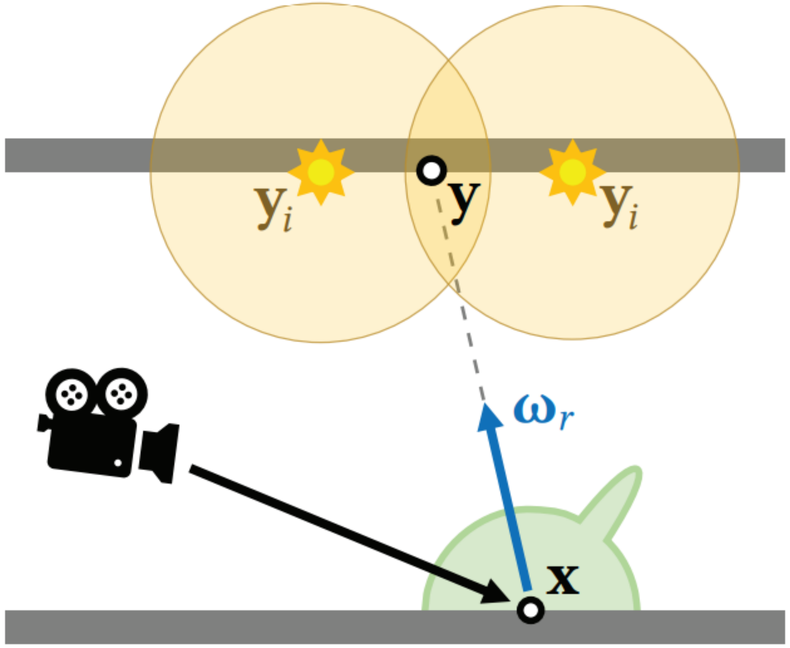
- Terminate or extend the path based on estimated virtual light count.



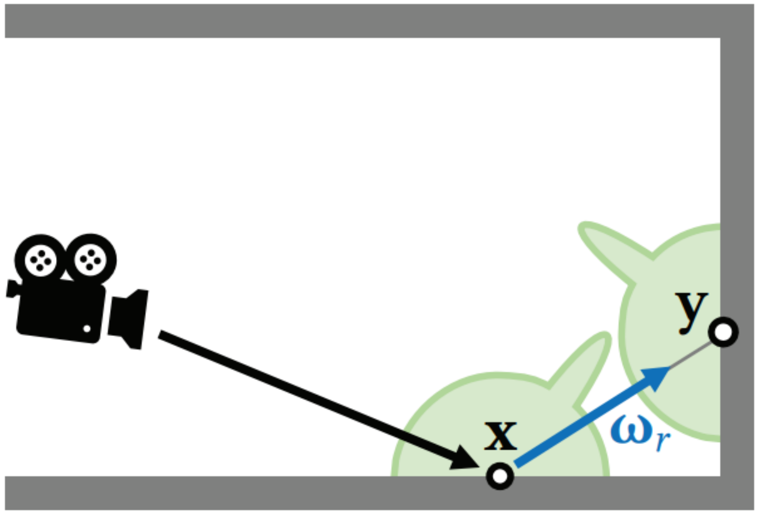
n is large enough　　　　n is too small

Adaptive Camera Path Extension

- Prevent sharp changes using two used-defined parameters: n_{min} and n_{max}



n is large enough



n is too small

Without Camera Path Extension

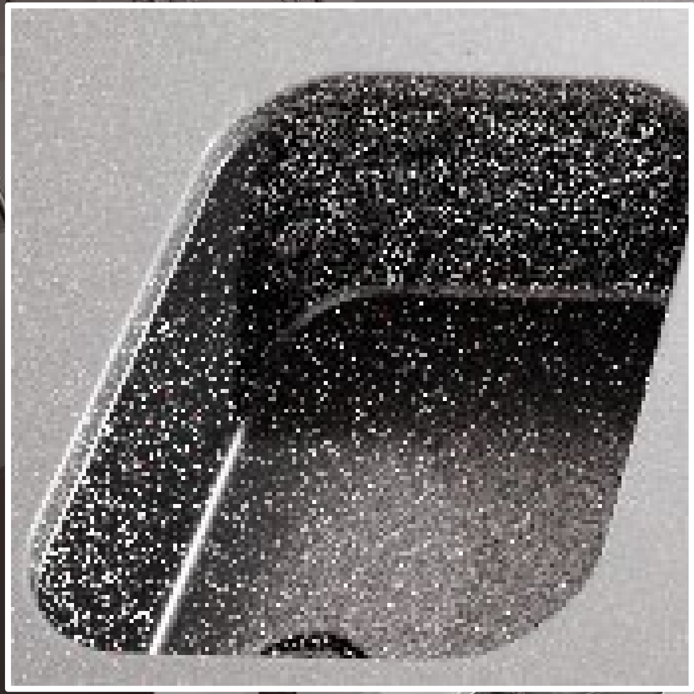
With Camera Path Extension

Adaptive Camera Path Extension

Results

Kitchen

Kitchen (Prep. + Shade) time



Rich-VSL
(69 + 7) s

Ours
(5.6 + 1.4) s

Kitchen (Prep. + Shade) time

Path Tracing
1.4 s

Ours
(5.6 + 1.4) s


Kitchen (Prep. + Shade) time
Path Tracing
7 s
Ours
(5.6 + 1.4) s

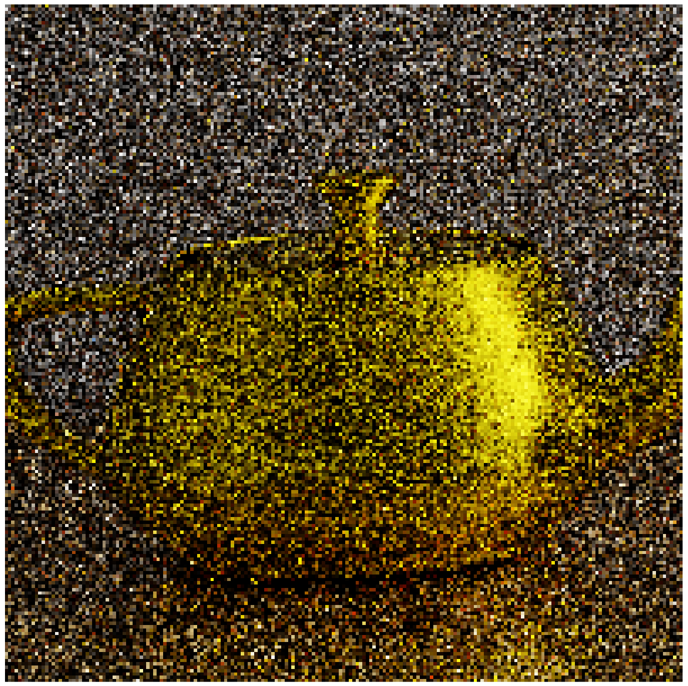
Veach Door

Veach Door (Prep. + Shade) time

Rich-VSL
(304 + 8) s

Ours
(6.6 + 1.4) s

Veach Door (Prep. + Shade) time



Path Tracing
1.4 s

Ours
(6.6 + 1.4) s

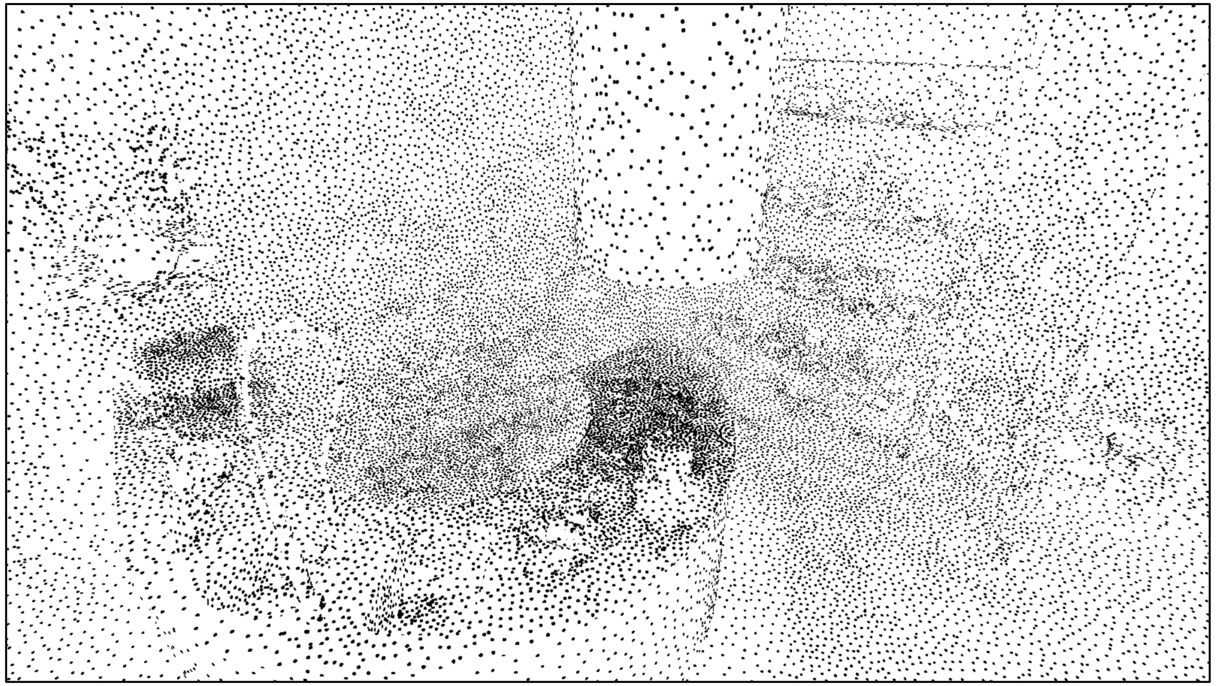
Veach Door (Prep. + Shade) time

Path Tracing
8 s

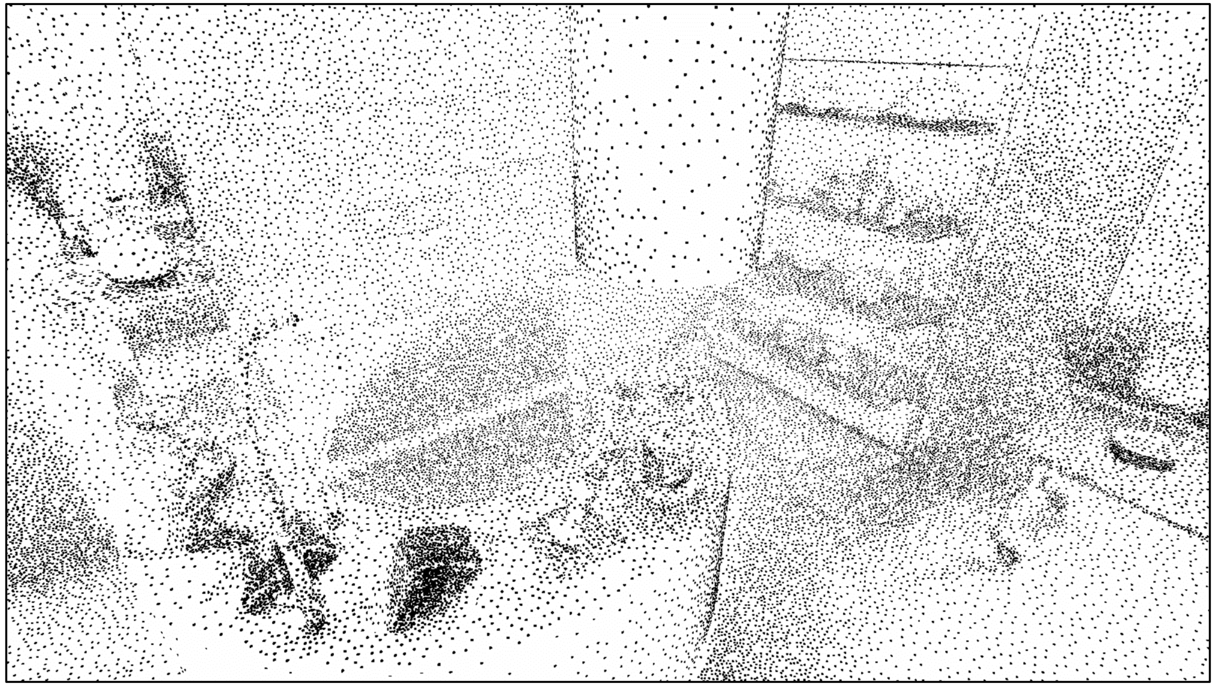
Ours
(6.6 + 1.4) s

Virtual Light Distribution

Rich VSLs

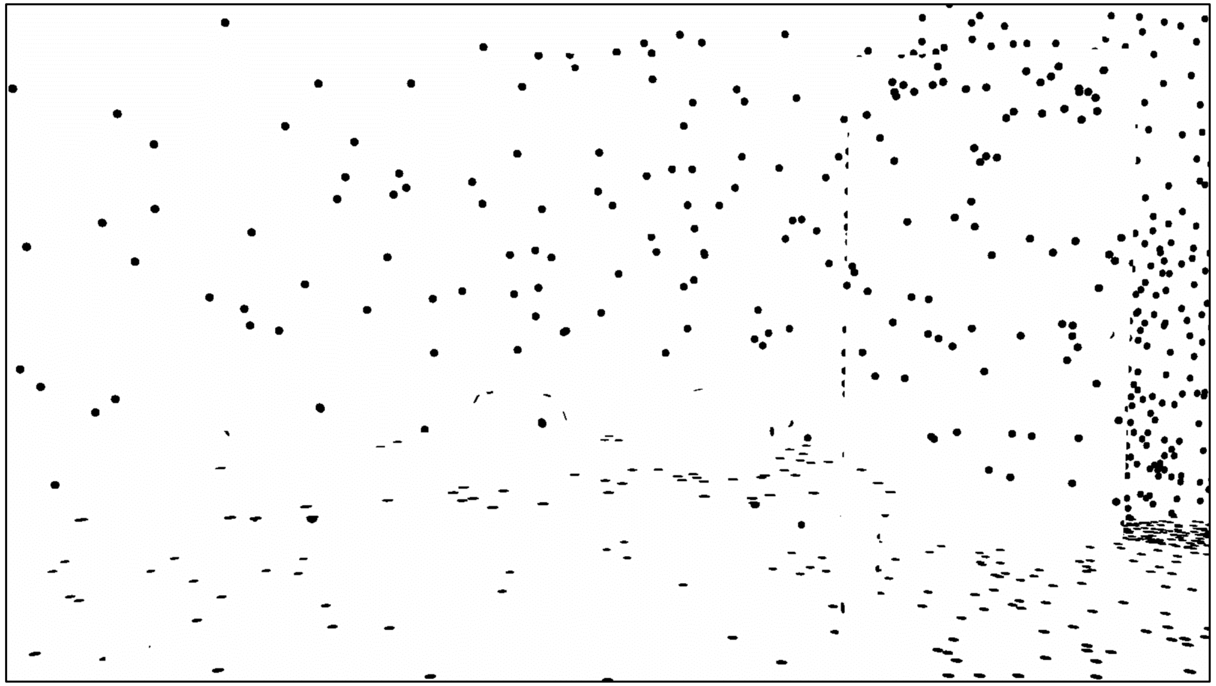


Ours



Virtual Light Distribution

Rich VSLs



Ours

Conclusion

Virtual Blue Noise Lighting

Virtual Blue Noise Lighting

- Virtual Light Placement

  Camera paths

- Blue Noise Distribution

  Adaptive sample elimination

- Emission Profiles

  Photon splitting

- Sampling

  MIS: BSDF + power-based

  Adaptive camera path extension

Virtual Blue Noise Lighting

Tianyu Li*, Wenyou Wang*, Daqi Lin, and Cem Yuksel,

University of Utah

Source Code & More:
https://graphics.cs.utah.edu/research/projects/virtual-blue-noise-lighting/

**joint first authors*