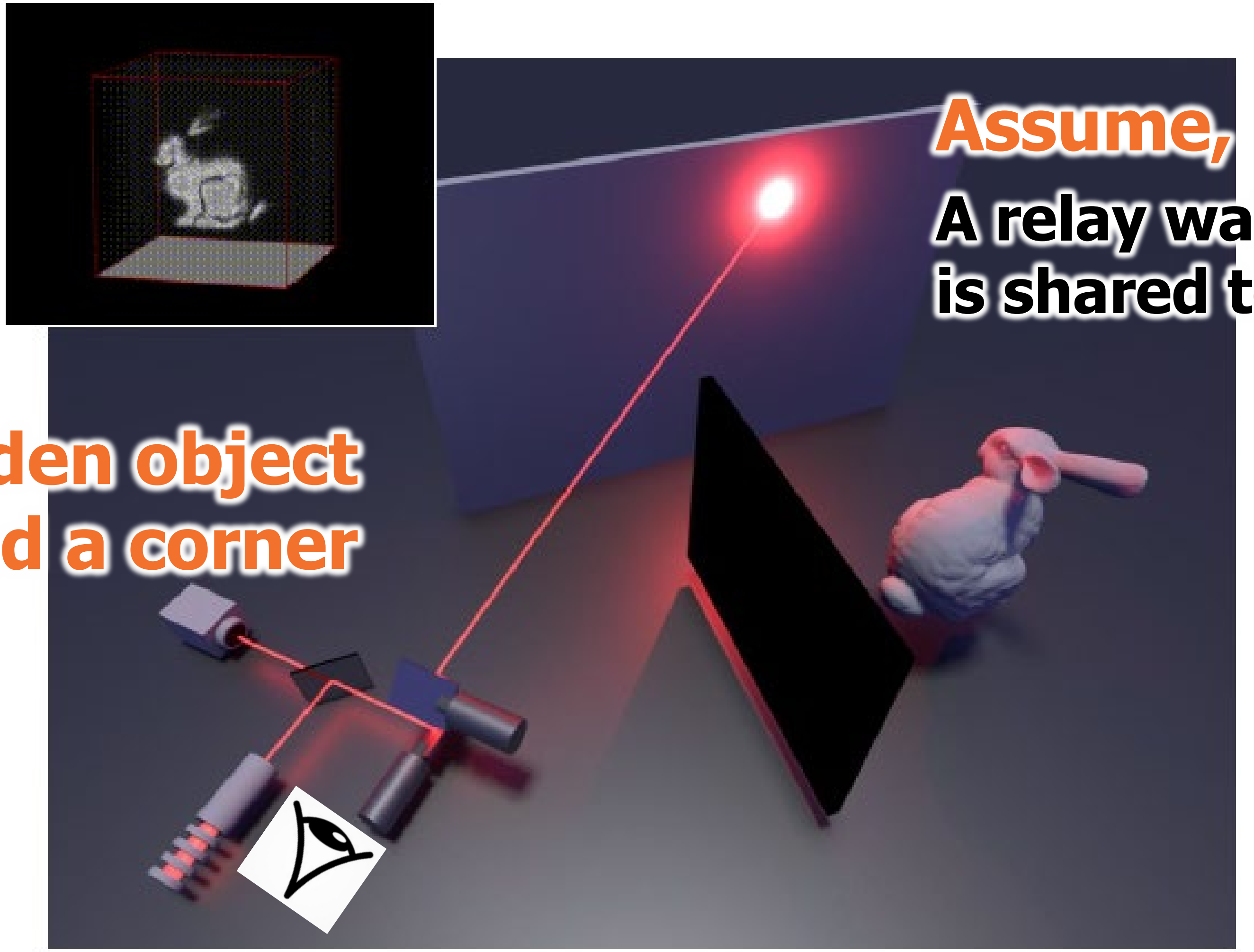
NeRF-like
Non-line-of-sight Imaging

Team 2

Kiseok Choi Donggun Kim

Non-line-of-sight (NLOS) Imaging



Seeing a hidden object around a corner

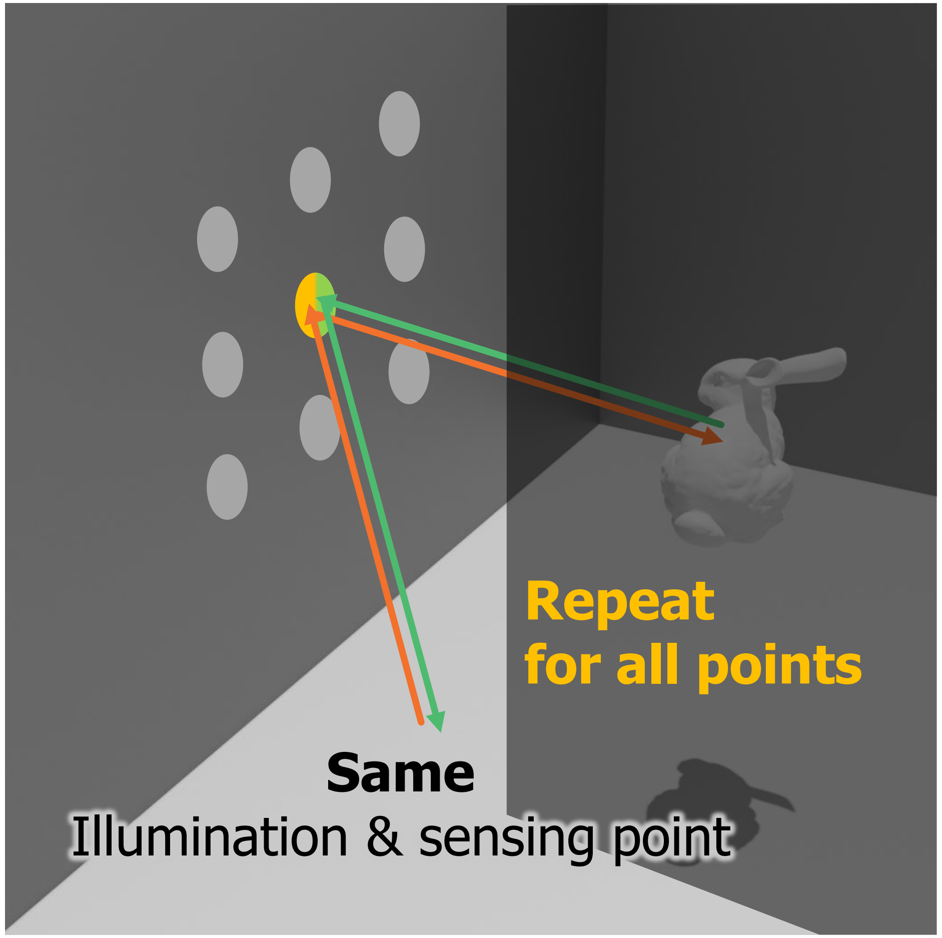
Assume,

A relay wall (not a mirror) is shared to both sides

David B. Lindell, Computational Imaging Lecture 12(p.35), Stanford University 2021.

Confocal vs. Non-confocal

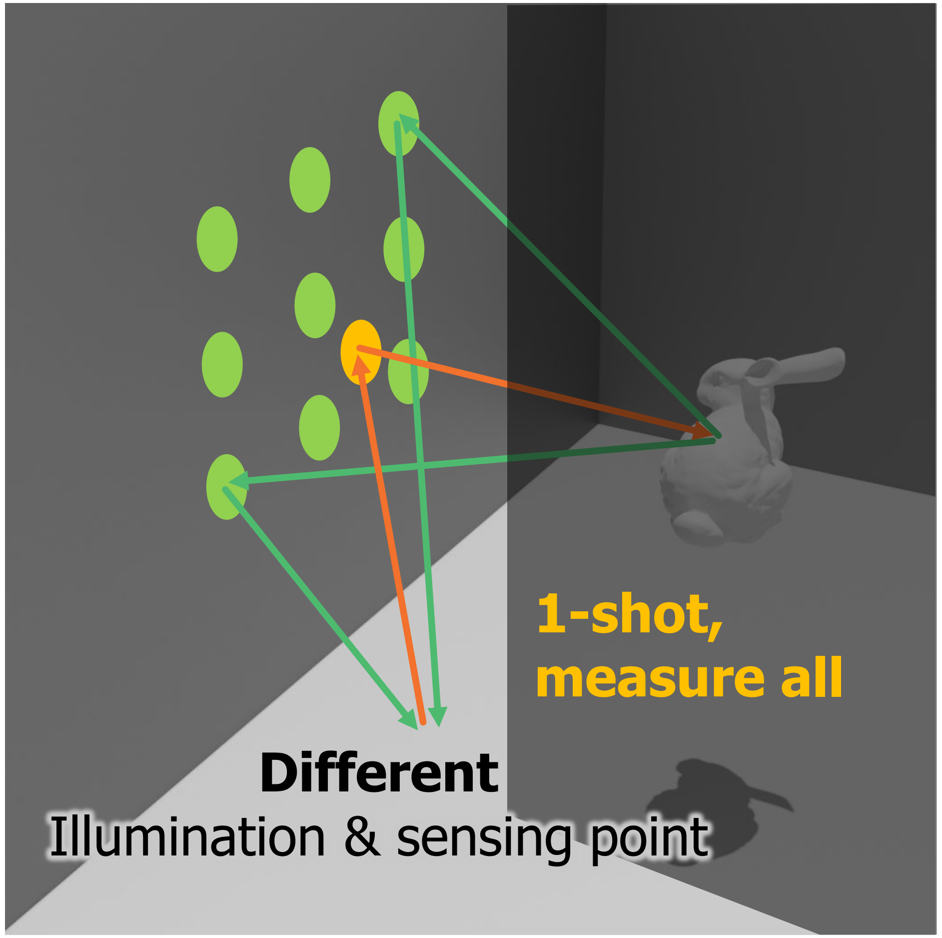
Confocal



Repeat for all points

Same
Illumination & sensing point

Non-Confocal



1-shot, measure all

Different
Illumination & sensing point

Related Papers

- Confocal non-line-of-sight imaging based on the light-cone transform (Nature Comm. 2018)

  → Light Cone Transform (confocal)

- Non-line-of-sight imaging using phasor-field virtual wave optics (Nature 2019)

  → Phasor-field (confocal, non-confocal)

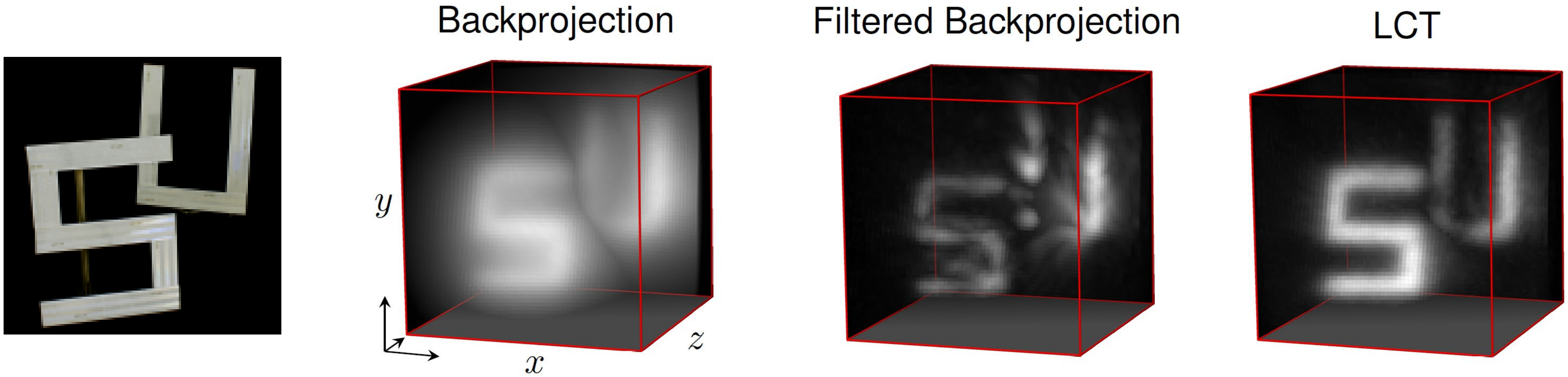
- Non-line-of-Sight Imaging via Neural Transient Fields (TPAMI 2021)

  → NeTF (confocal, non-confocal)

Light Cone Transform (LCT)

Matthew O’Toole et al., Nature 2018

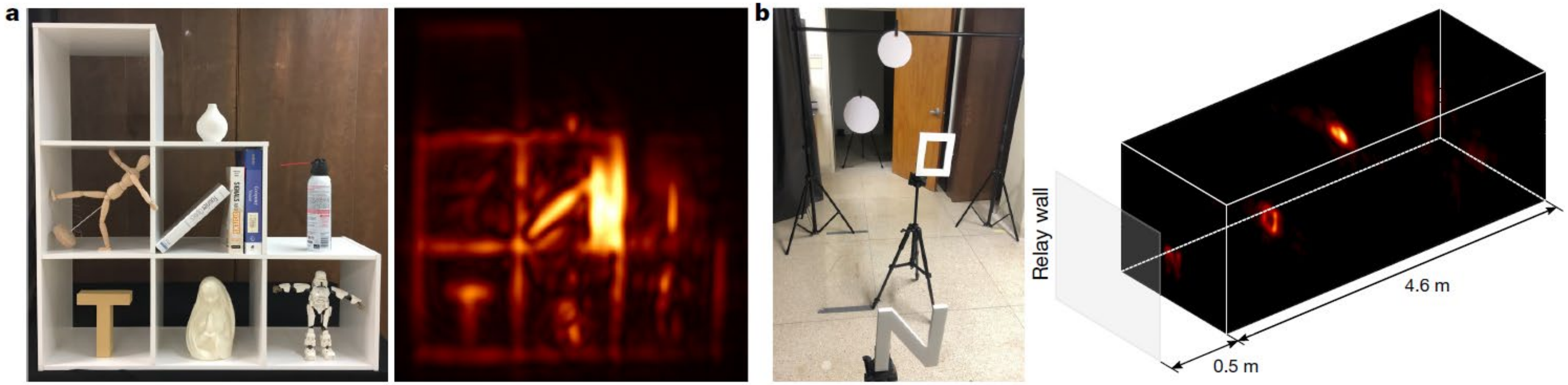
Confocal non-line-of-sight imaging based on the light-cone transform

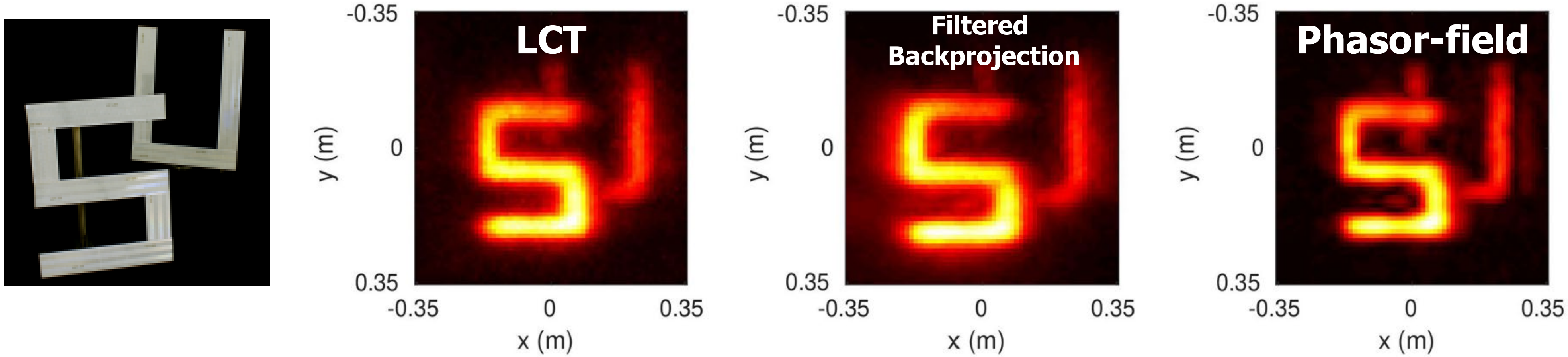


Phasor-field

Xiaochun Liu et al., Nature 2019

Non-line-of-sight imaging using phasor-field virtual wave optics

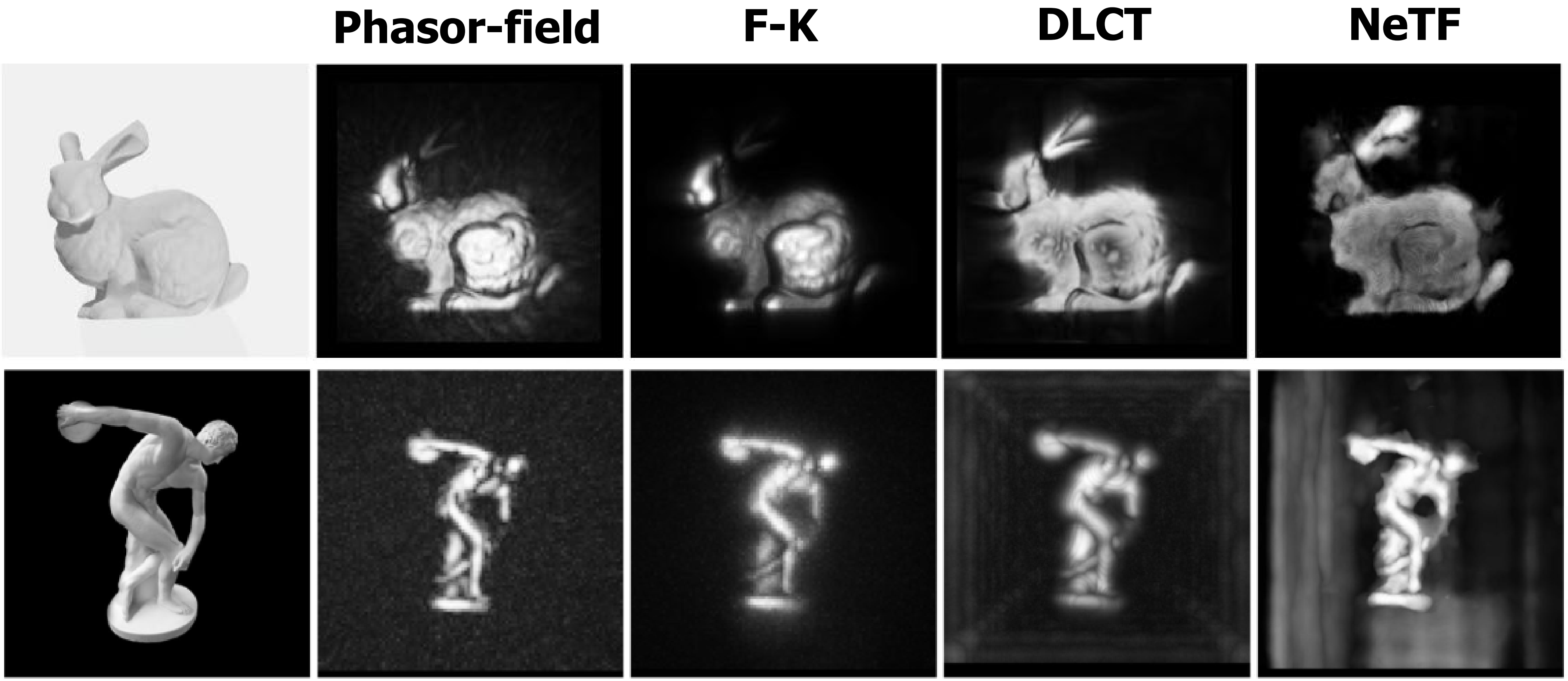




NeTF

Siyuan Shen et al., TPAMI 2021

Non-line-of-Sight Imaging via Neural Transient Fields



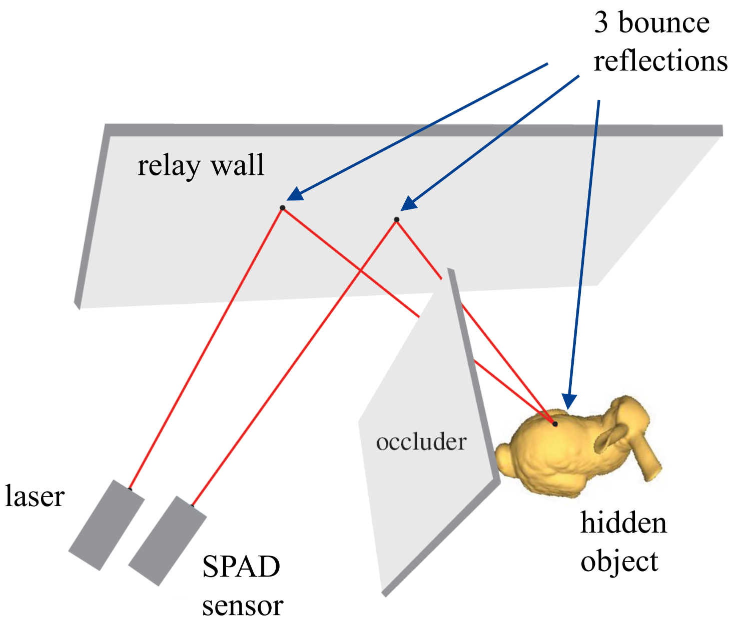
* SPAD: Single Photon Avalanche Diode

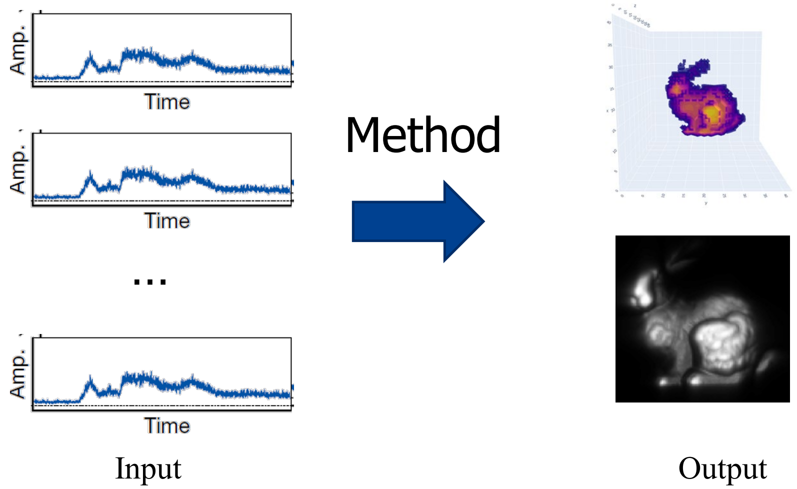
Problem

- Hardware Set-up
  - Laser + SPAD sensor
  - Diffuse reflection in a relay wall
  - 3 bounce reflections during a light transport

- Requirement
  - Input: transient intensity
  - Output: 3D point cloud or front-side 2D image (with albedo or radiance)

- Method?

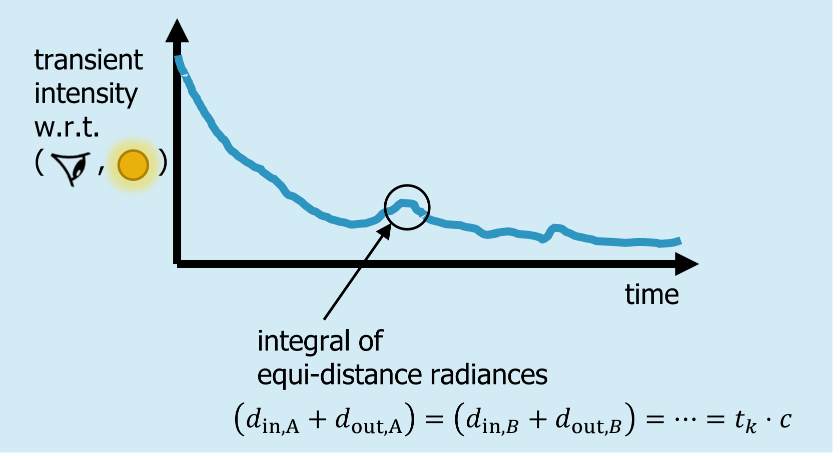


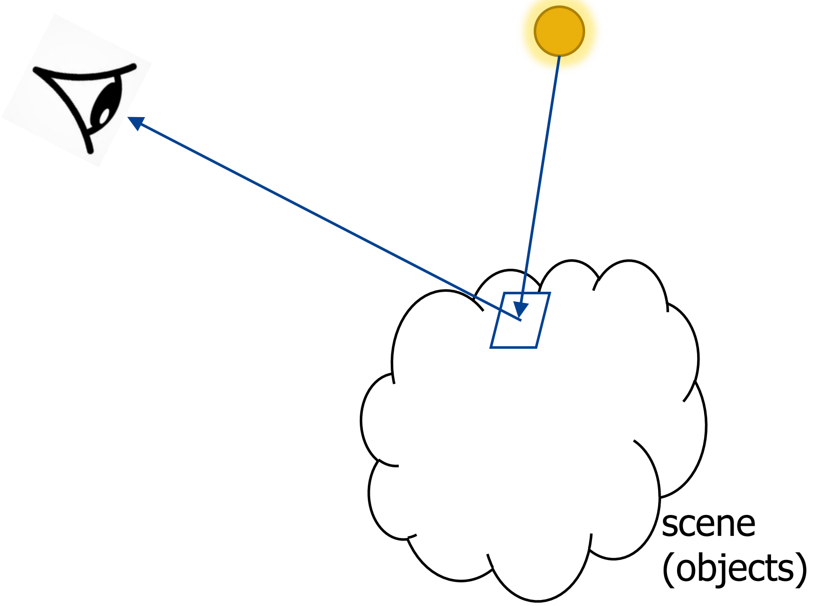


Chia-Yin Tsai et al., Beyond Volumetric Albedo — A Surface Optimization Framework for Non-Line-of-Sight Imaging, CVPR 2019.

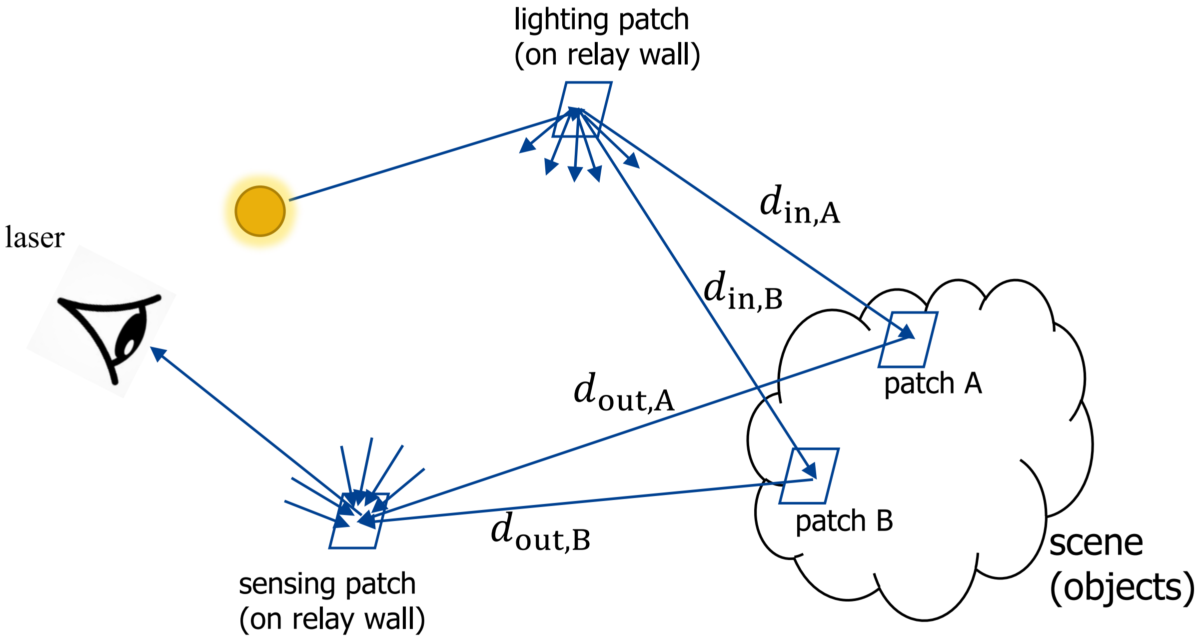
Problem

- Transient intensity
  (assumption: inter-reflection within scene is negligible.)





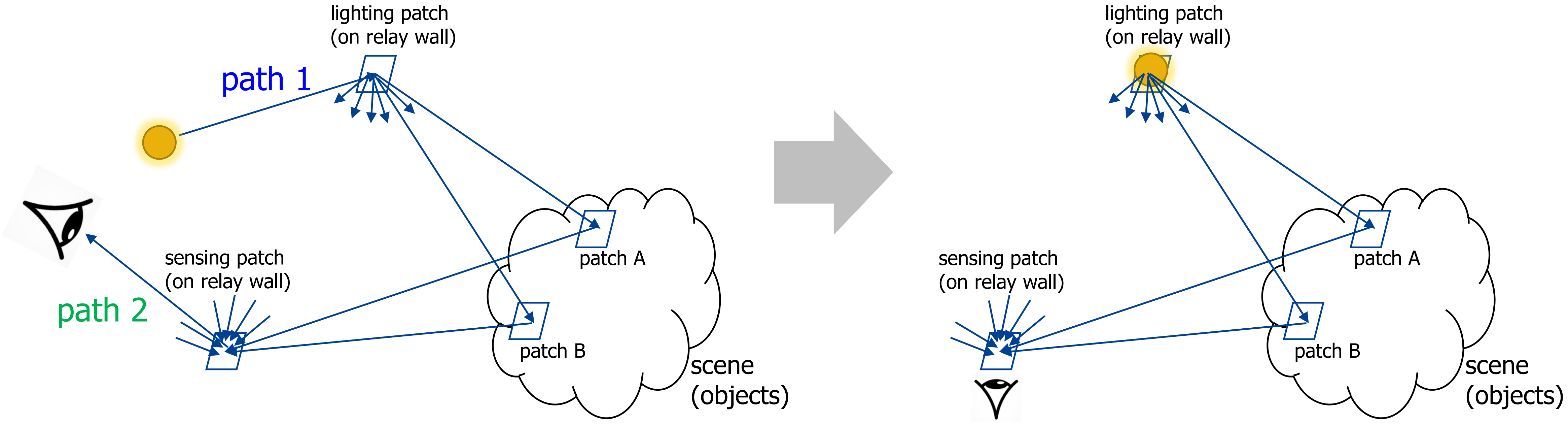
radiance of
line-of-sight ray



radiance of
non-line-of-sight ray
(transient intensity)

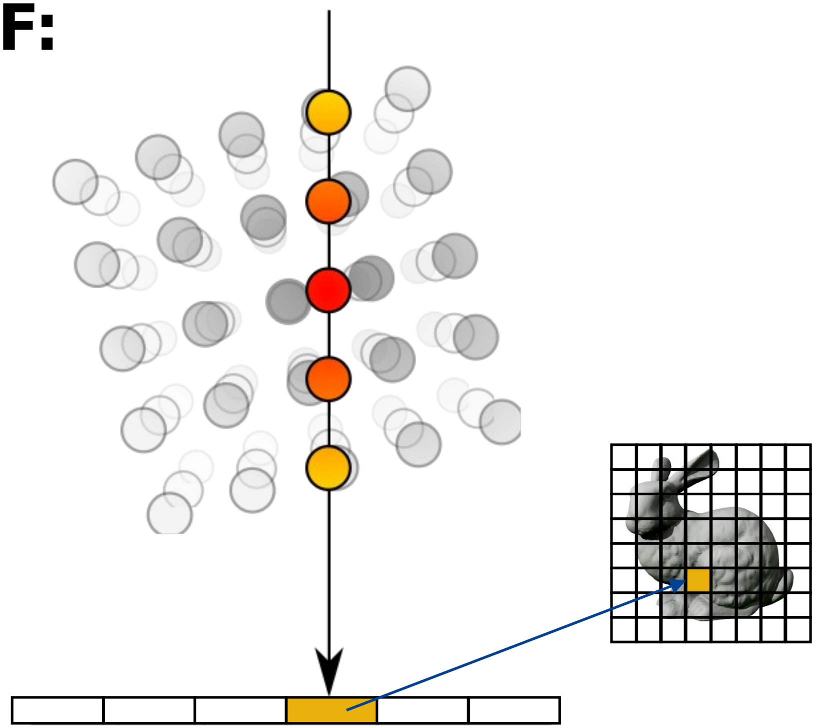
Problem Simplification

- 3-bounce model → 1-bounce model
  - Direct energy attenuation from the light source is constant for all lighting positions (path 1).
  - Direct energy attenuation to the sensor is constant for all sensing positions (path 2).

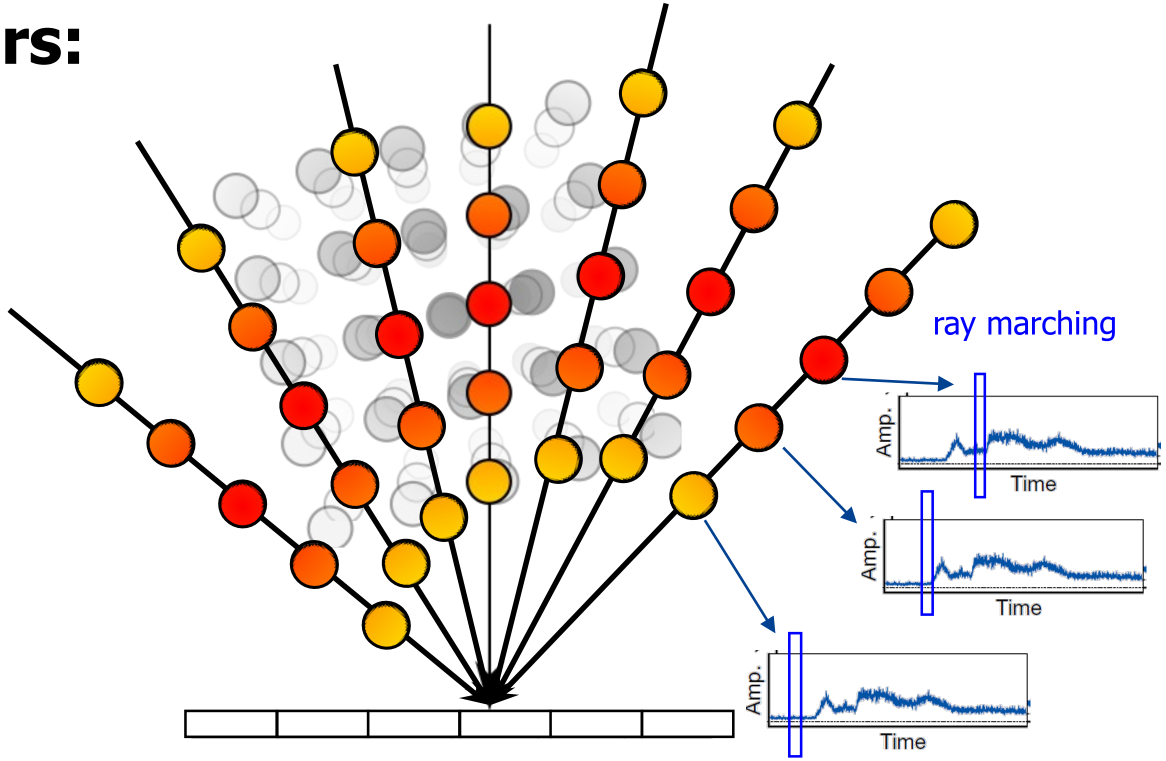


NeRF-like NLOS Imaging

NeRF:

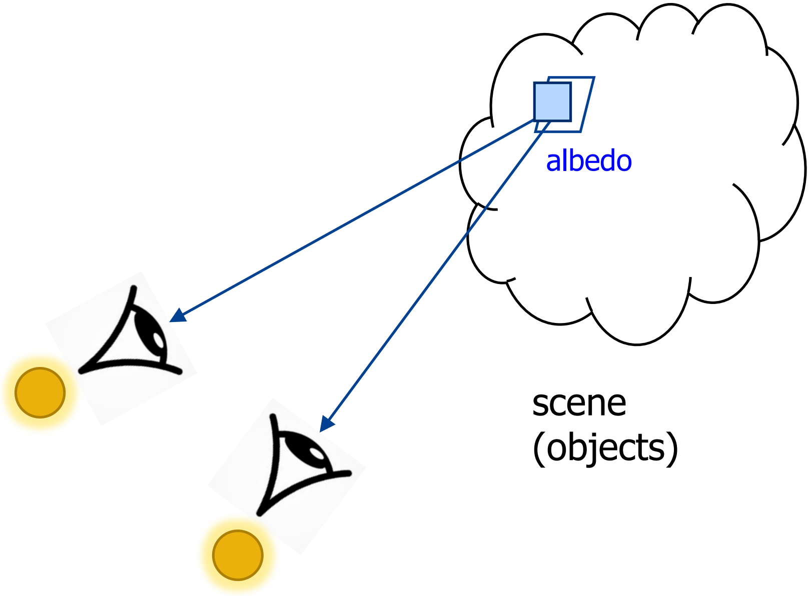


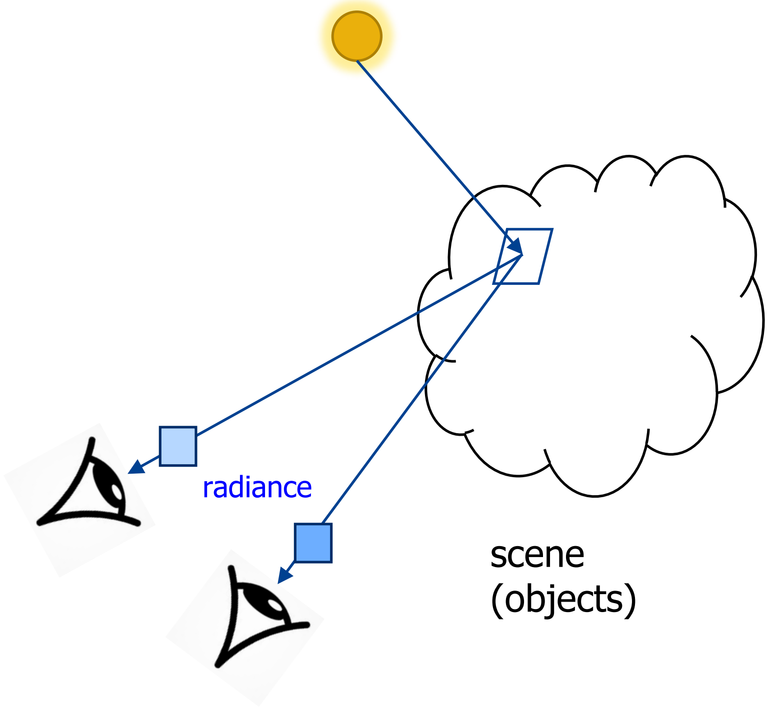
Ours:



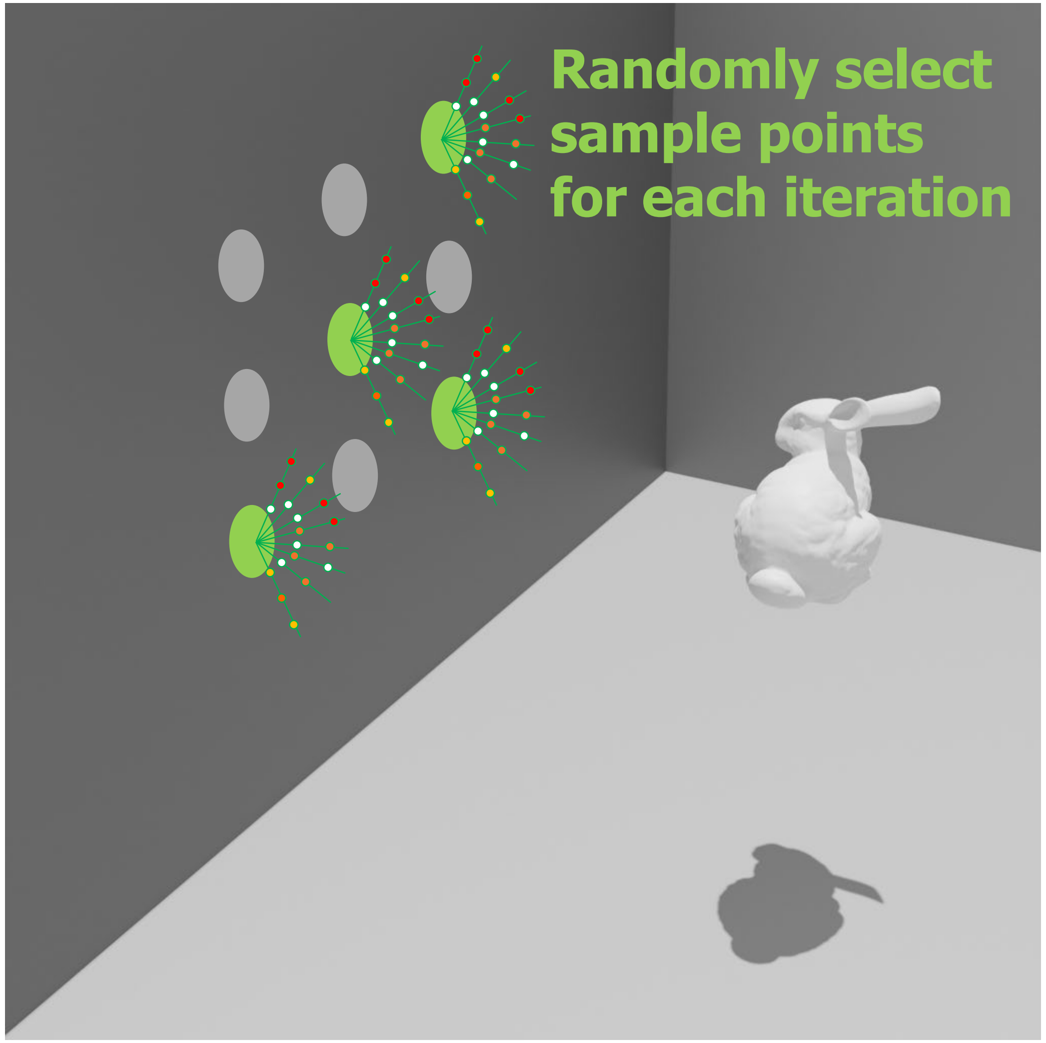
NeTF vs. Our Method

- NeTF: Final output is view-independent albedos.
  Confocal setup is assumed.
- Ours: Final output is view-dependent radiances
  Non-confocal setup is assumed.

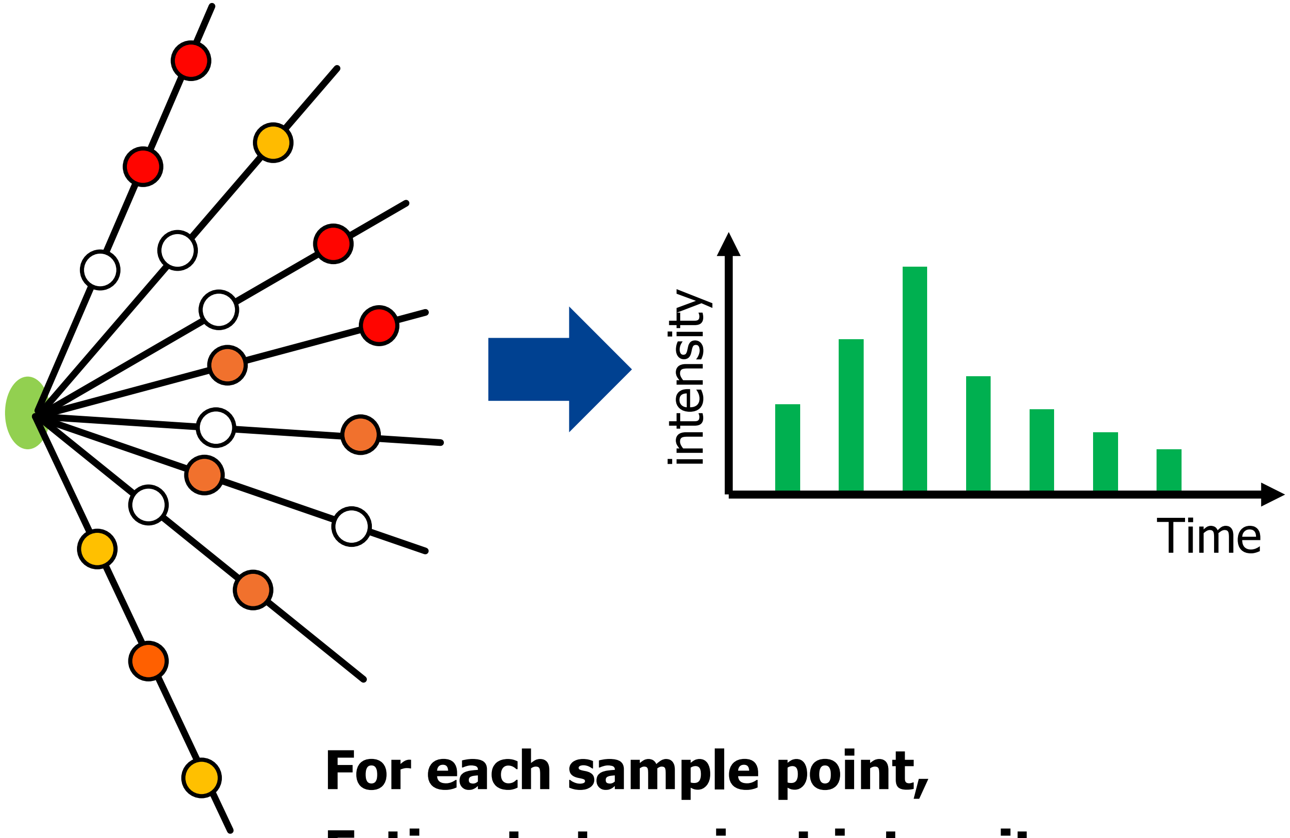




Batch Selection



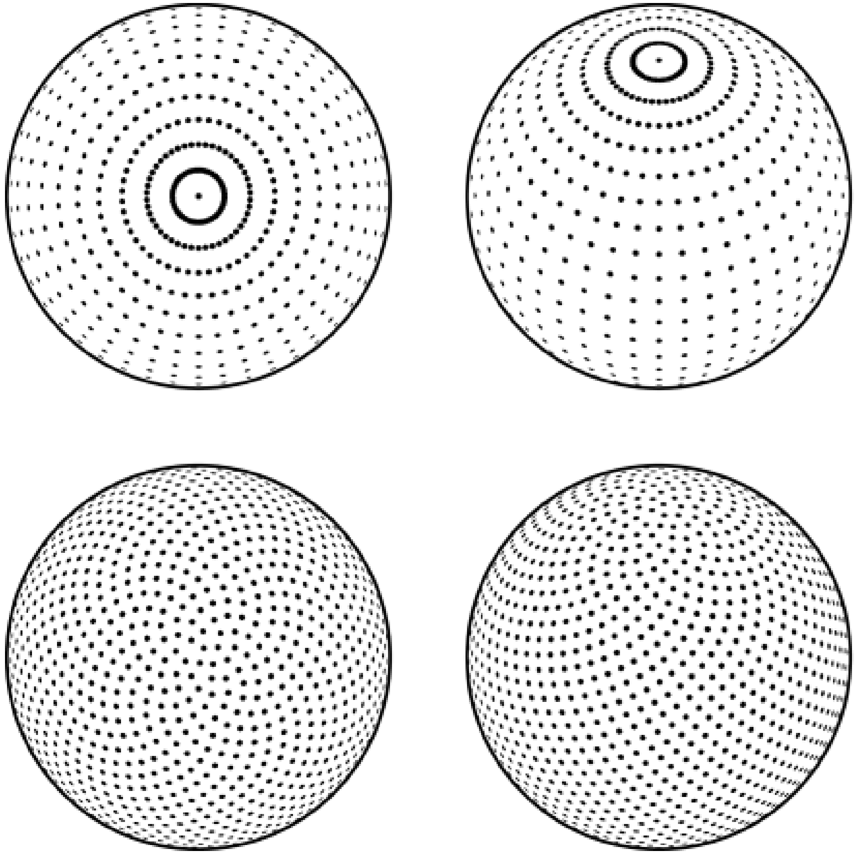
Randomly select sample points for each iteration



**For each sample point,
Estimate transient intensity
via transient volume render**

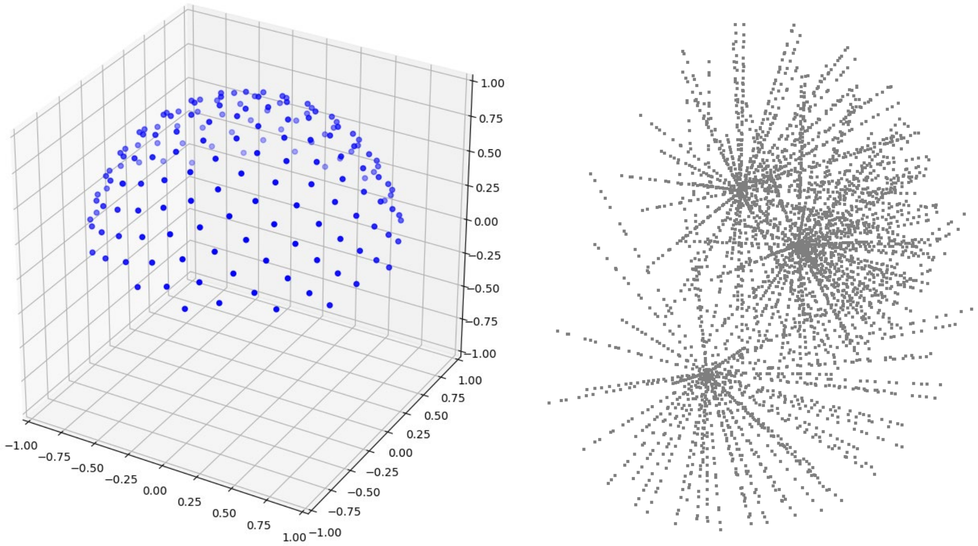
Uniform Random Sampler

Fibonacci sampling: Uniform sampling on sphere + Random rotation



Theta, phi
uniform sampling

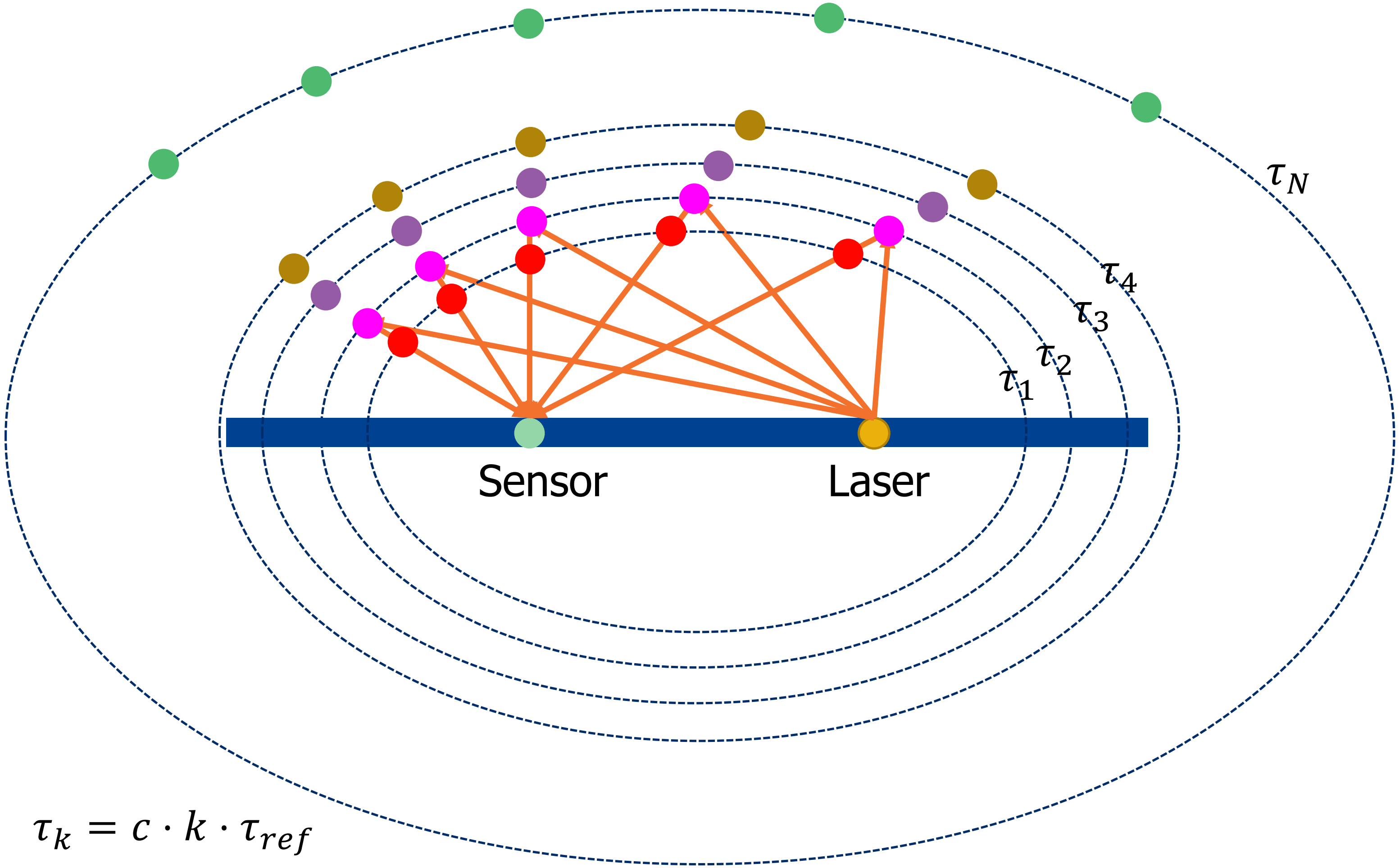
Fibonacci
sampling



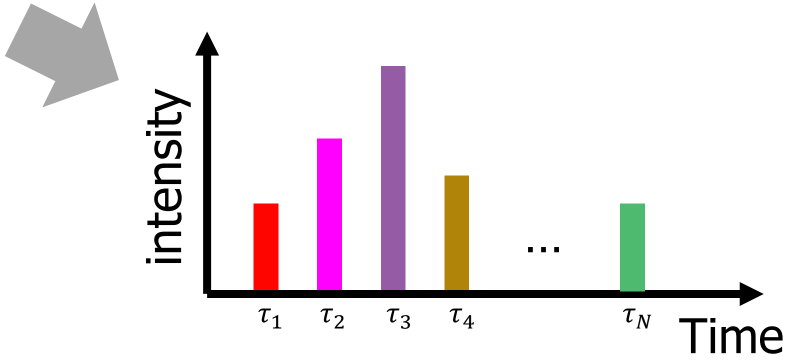
Our generated ray directions & samples
on hemisphere

https://www.arxiv-vanity.com/papers/0912.4540/

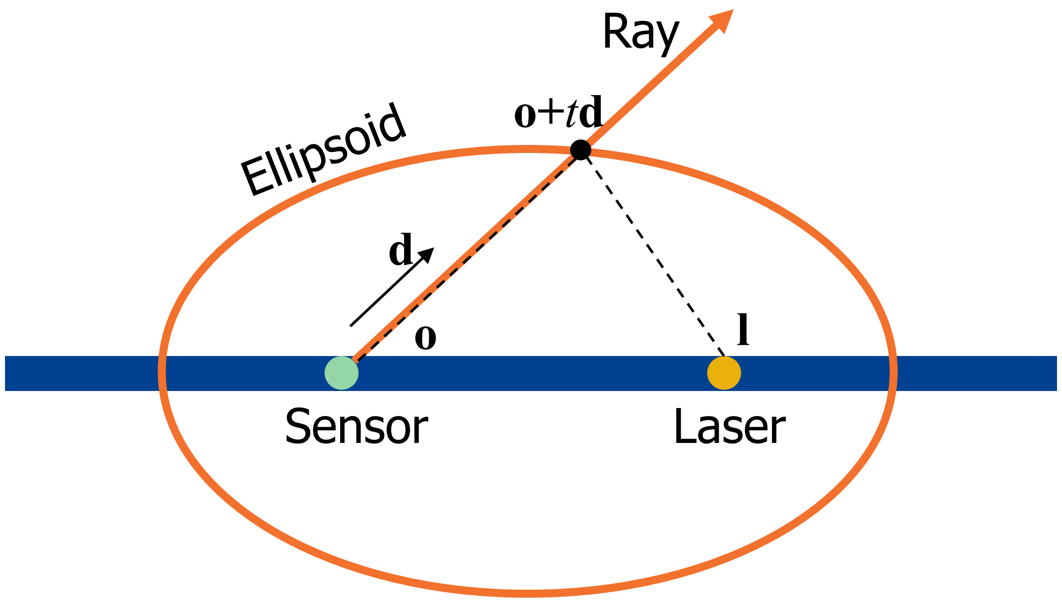
Transient Ray Marcher



$$\tau_k = c \cdot k \cdot \tau_{ref}$$



Ray-Ellipsoid Intersection



Problem. Suppose that $\|\mathbf{d}\| = 1$, $\mathbf{o} \neq \mathbf{l}$, $\mathbf{d} \nparallel \mathbf{l} - \mathbf{o}$, and $\tau \geq \|\mathbf{l} - \mathbf{o}\|$.

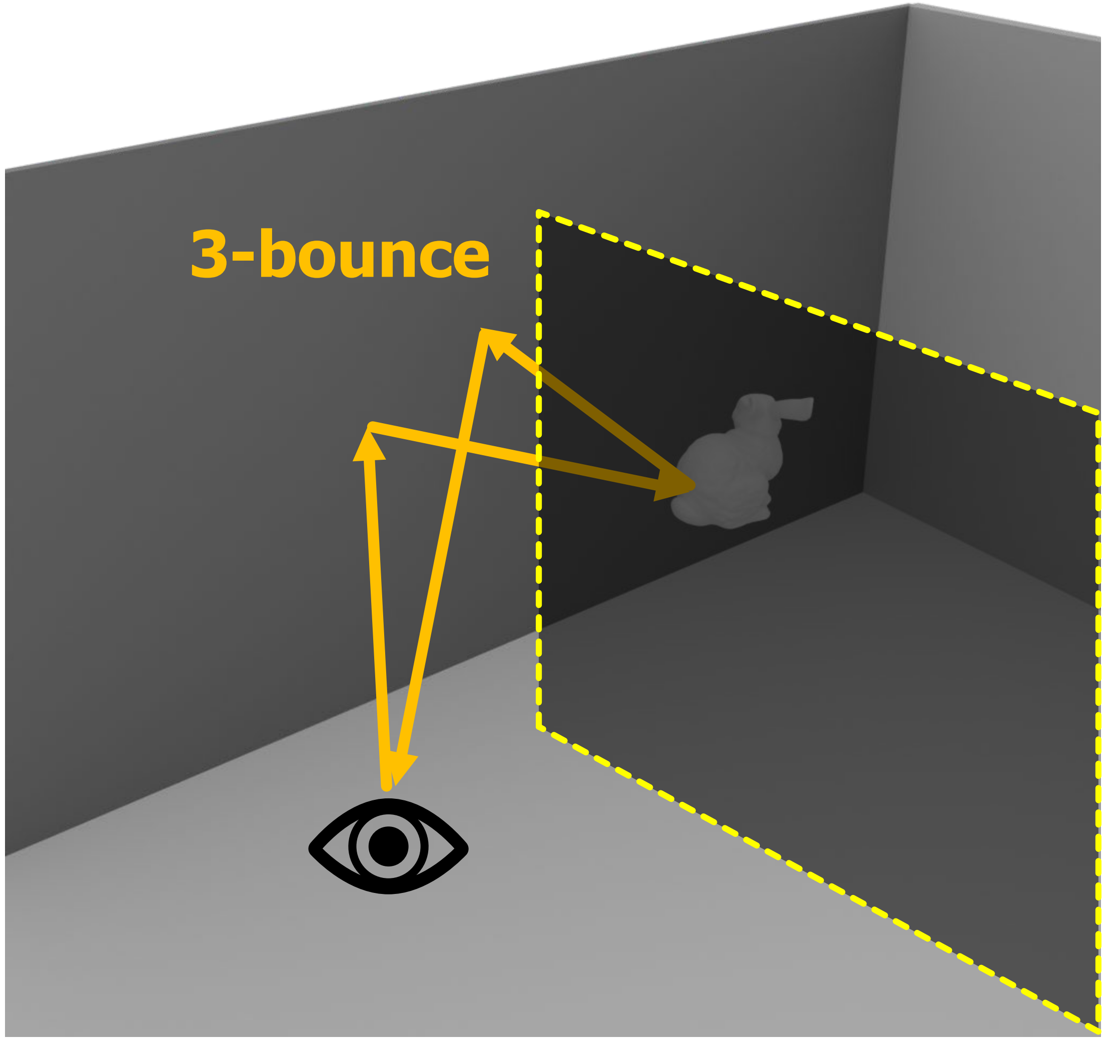
$$\mathbf{o} + t\mathbf{d} \in \mathcal{E}(\mathbf{o}, \mathbf{l}; \tau) := \left\{\mathbf{x} \in \mathbb{R}^3 \mid \|\mathbf{x} - \mathbf{o}\| + \|\mathbf{x} - \mathbf{l}\| = \tau\right\}$$

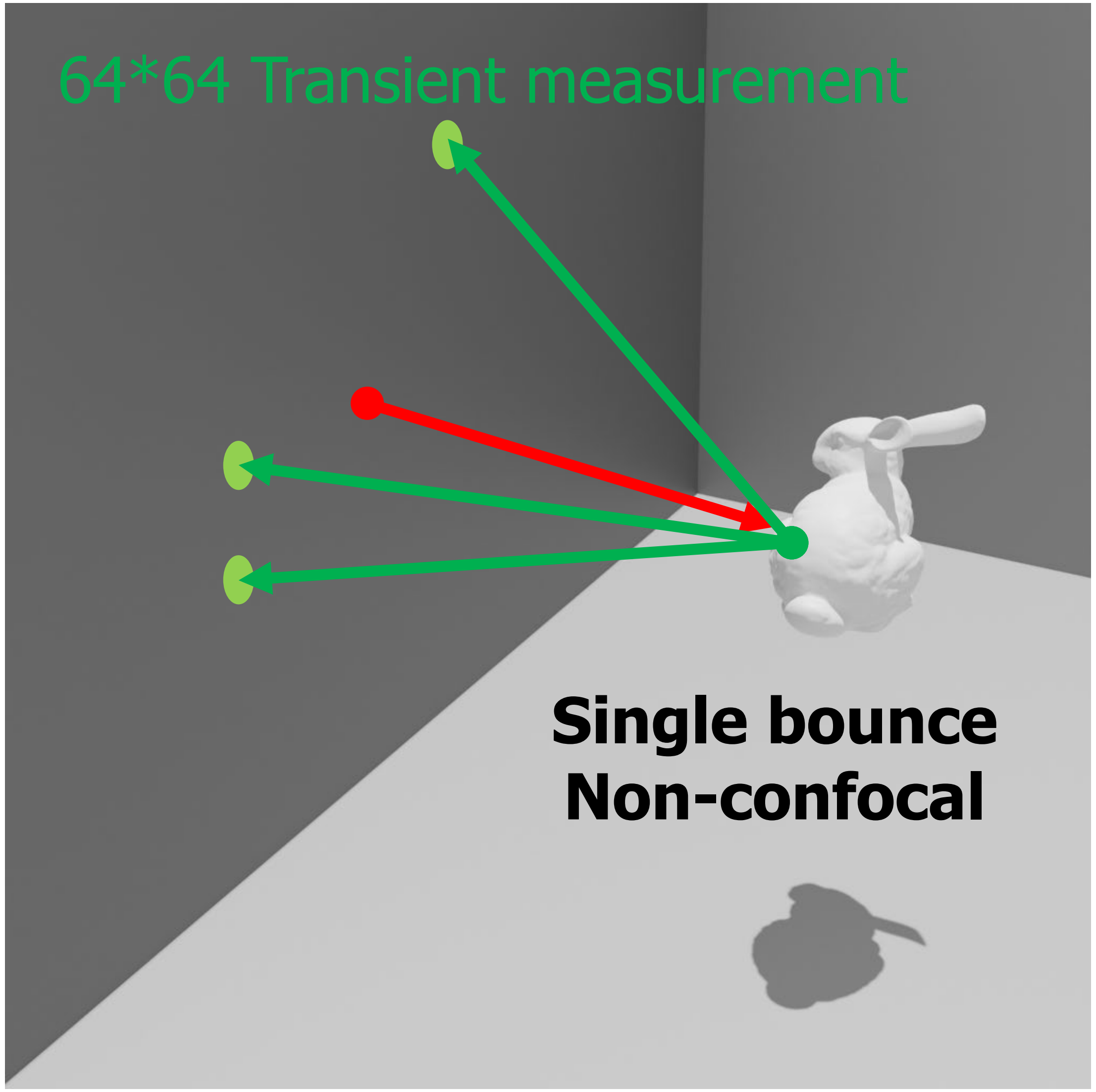
has the intersection at:

$$\therefore\ t = \frac{(d_x l + \tau)\left(\tau^2 - l^2\right)}{2\left[d_x^2\left(\tau^2 - l^2\right) + d_y^2 \tau^2\right]},$$

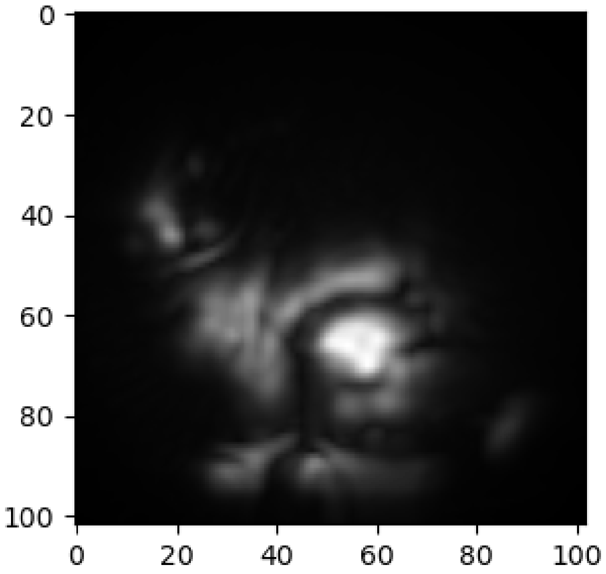
$$\text{where } d_x = \mathbf{d} \cdot \operatorname{normalize}(\mathbf{l} - \mathbf{o}),\ d_y = |\mathbf{d} \times \operatorname{normalize}(\mathbf{l} - \mathbf{o})| = \sqrt{1 - d_x^2}$$

Setup


3-bounce


64*64 Transient measurement
Single bounce
Non-confocal

Result

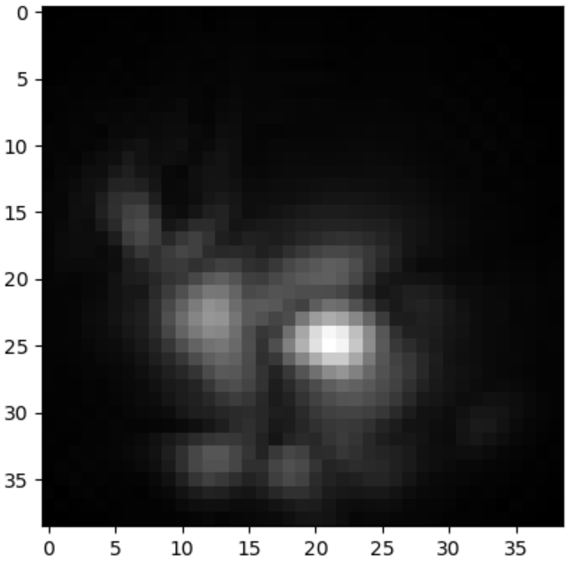


Phasor-field

High-res

Input: 256*256*512

Out: 100*100

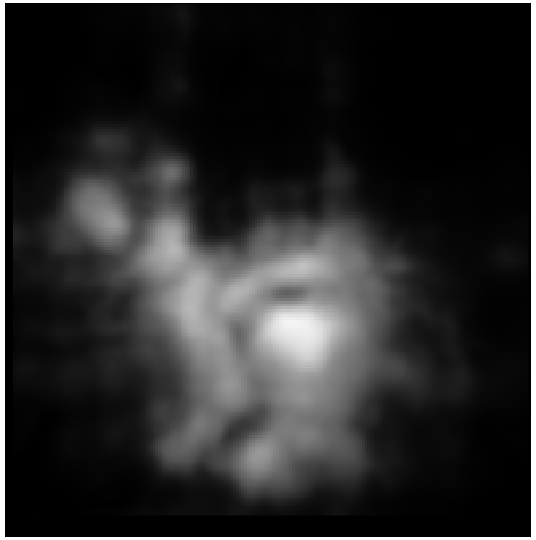


Phasor-field

Low-res

Input: 64*64*128

Out: 39*39



Ours

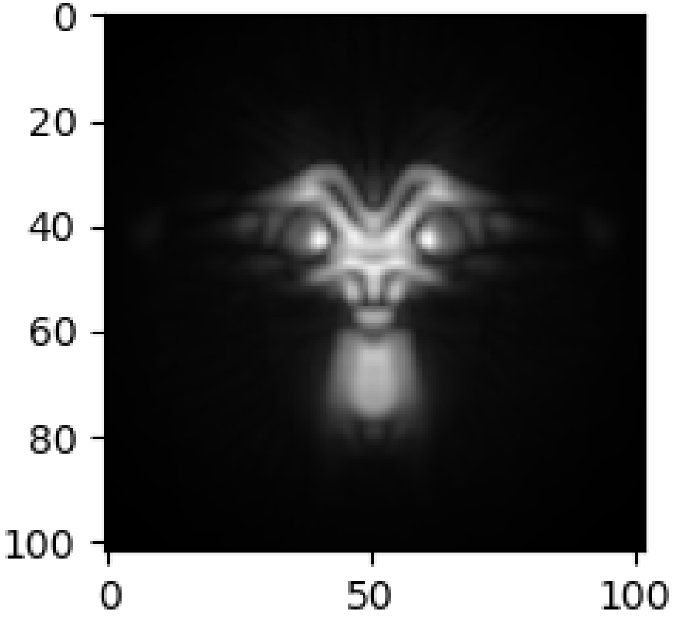
Low-res

Input: 64*64*128

Output: Any (128*128)

(Not exact)

Result

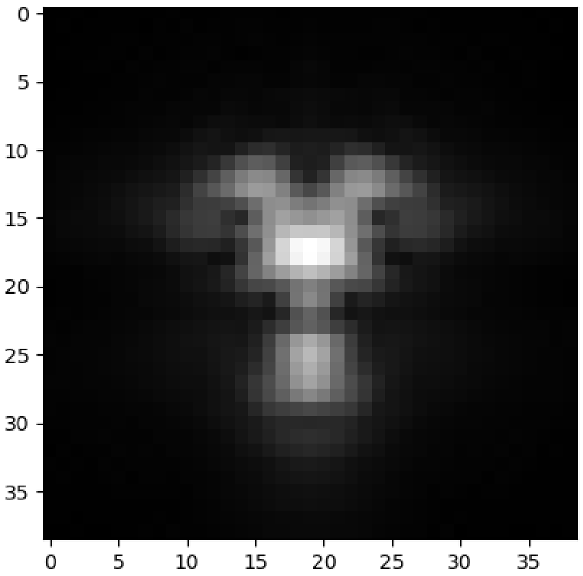


Phasor-field

High-res

Input: 256*256*512

Out: 100*100

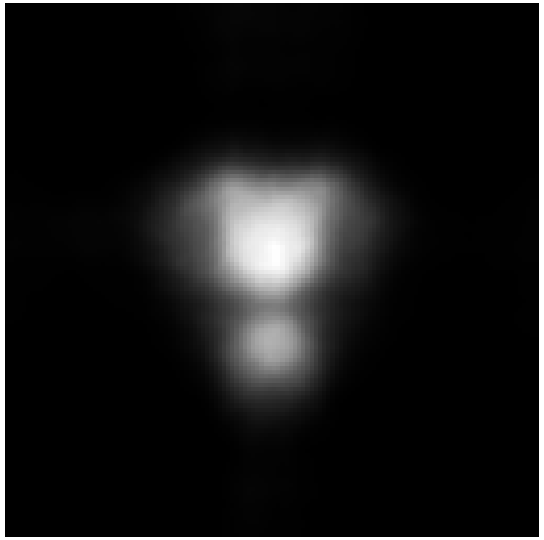


Phasor-field

Low-res

Input: 64*64*128

Out: 39*39



Ours

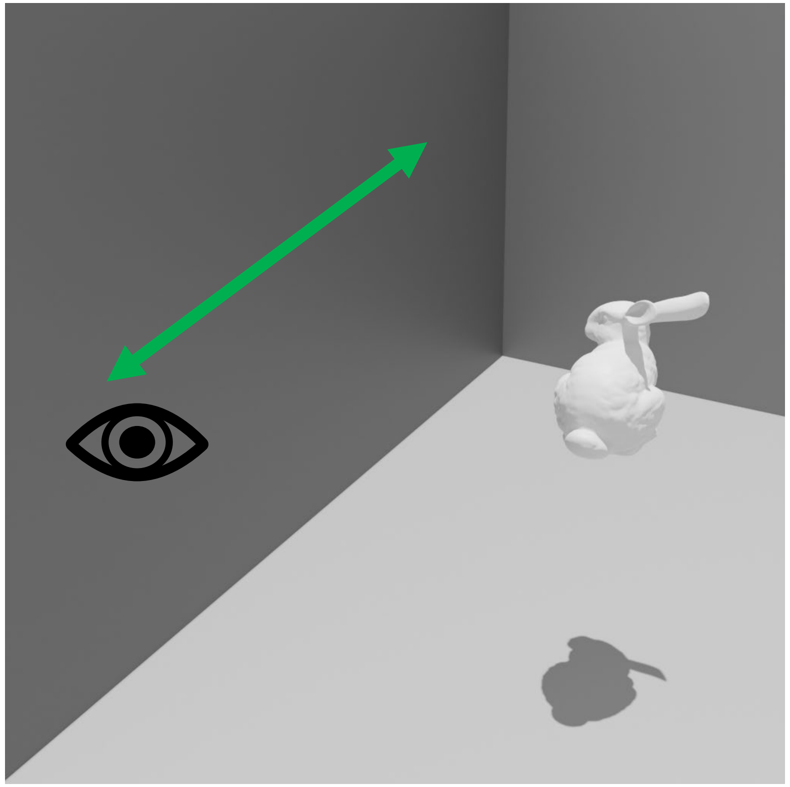
Low-res

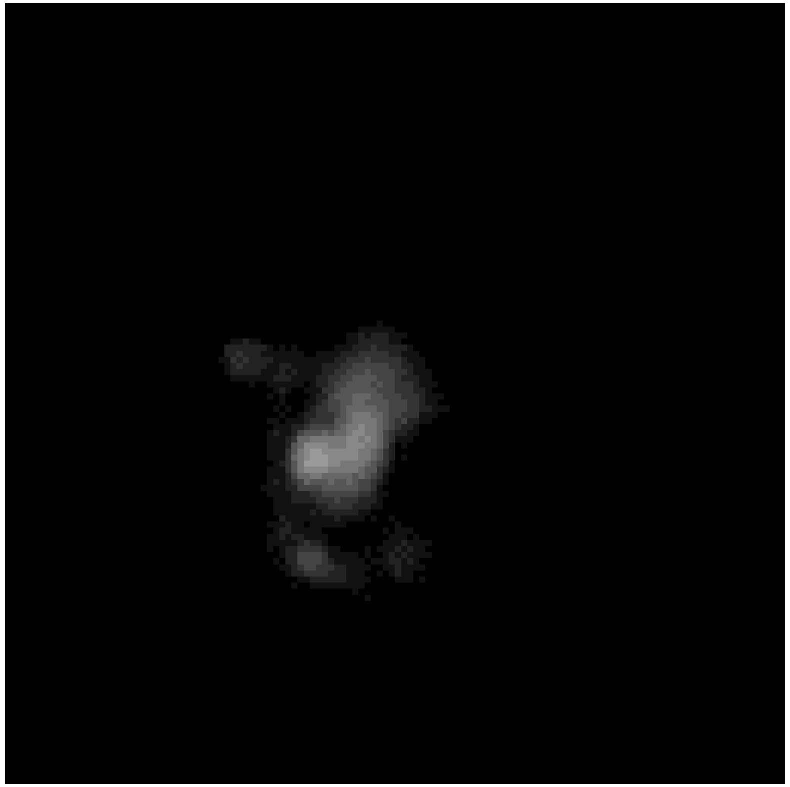
Input: 64*64*128

Output: Any (128*128)

(Not exact)

Result





Novel view synthesis

Input: 64*64*128

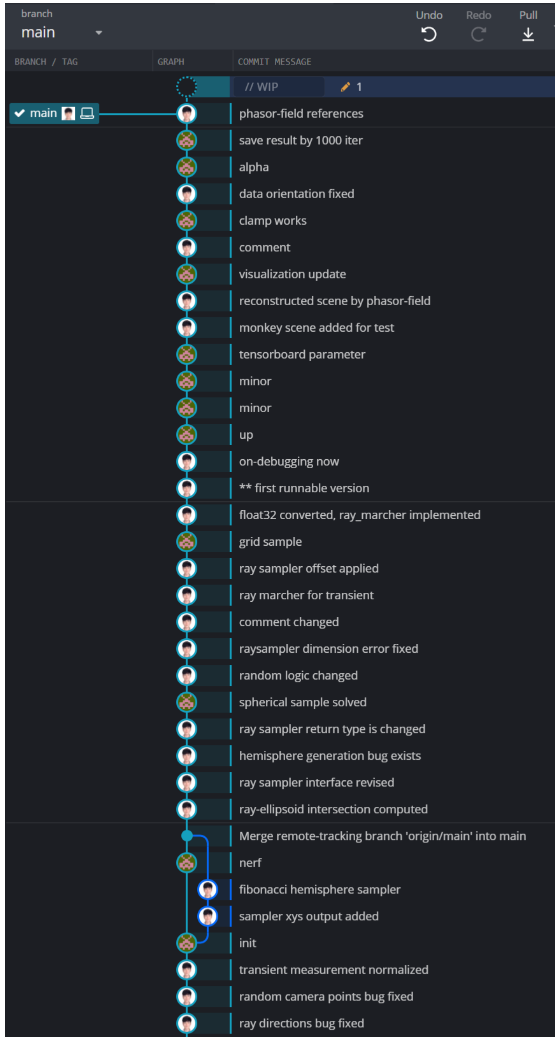
Output: Any (128*128)

Conclusion

- We proposed NeRF-like NLOS imaging method.
  - Next generation sampling scheme (non-confocal) is applicable.
  - Rendering of an arbitrary view within limited directions is possible.
  - Improved NeRF variants are applicable for better performance. (KiloNeRF, FastNeRF, Mip-NeRF, RefNeRF etc.)

- There are several limitations in our method.
  - Training time is necessary.

Role Distribution



```
phasor-field references
save result by 1000 iter
alpha
data orientation fixed
clamp works
comment
visualization update
reconstructed scene by phasor-field
monkey scene added for test
tensorboard parameter
minor
minor
up
on-debugging now
** first runnable version
float32 converted, ray_marcher implemented
grid sample
ray sampler offset applied
ray marcher for transient
comment changed
raysampler dimension error fixed
random logic changed
spherical sample solved
ray sampler return type is changed
hemisphere generation bug exists
ray sampler interface revised
ray-ellipsoid intersection computed
Merge remote-tracking branch 'origin/main' into main
nerf
fibonacci hemisphere sampler
sampler xys output added
init
transient measurement normalized
random camera points bug fixed
ray directions bug fixed
```

Kiseok Choi

- Survey of NLOS imaging papers
- Simulation data generation
- Ray marcher design & implementation
- Ray sampler/ray marcher/MLP integration
- Training a neural network
- Result analysis, Presentation preparation

Donggun Kim

- Survey of NeRF papers
- Random sampler design & implementation
- MLP implementation
- Software structure generation
- Training a neural network
- Result analysis, Presentation preparation

Reference

- Ben Mildenhall et al., NeRF: Representing Scenes as Neural Radiance Fields for View Synthesis, ECCV 2020, 1-25.
- Matthew O'Toole et al., Confocal non-line-of-sight imaging based on the light-cone transform, Nature 2018, Vol. 555, 338-341.
- Xiaochun Liu et al., Non-line-of-sight imaging using phasor-field virtual wave optics, Nature 2019, Vol. 572, 620-623.
- Siyuan Shen et al., Non-line-of-sight imaging via neural transient fields, TPAMI 2021, Vol. 43, No. 7, 2257-2268.