Secrets of Parthenon Renderer

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Disclaimer

Not all of my observations are fully validated by scientific experiments, though they are based on my experience.

Take them with a grain of salt!

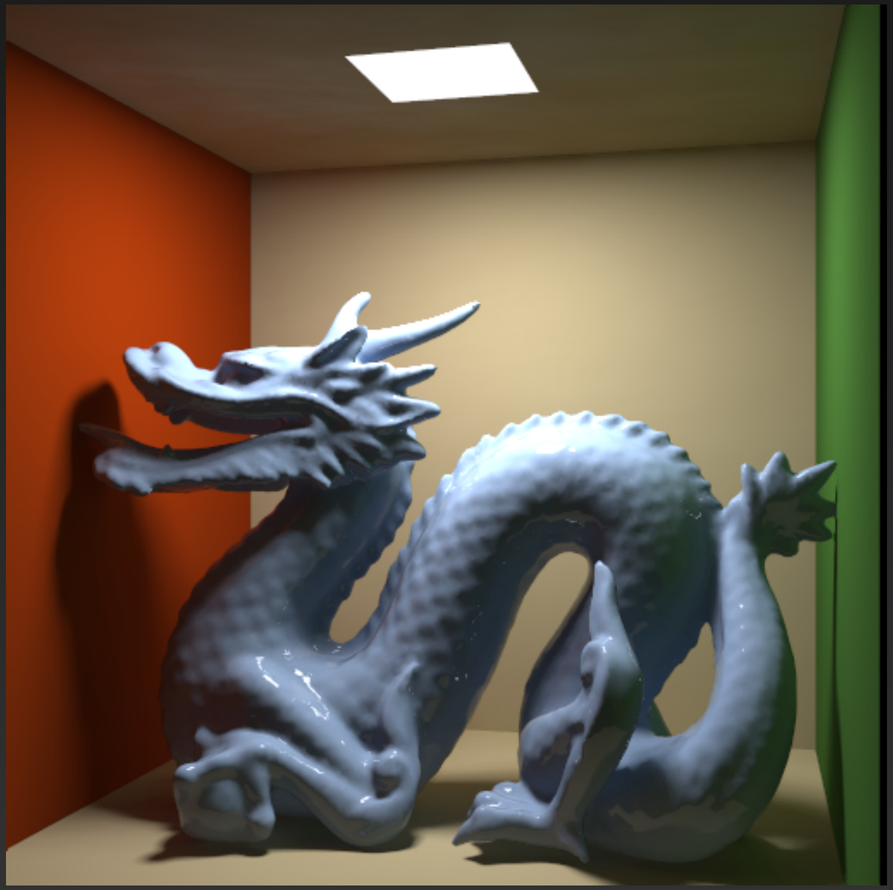
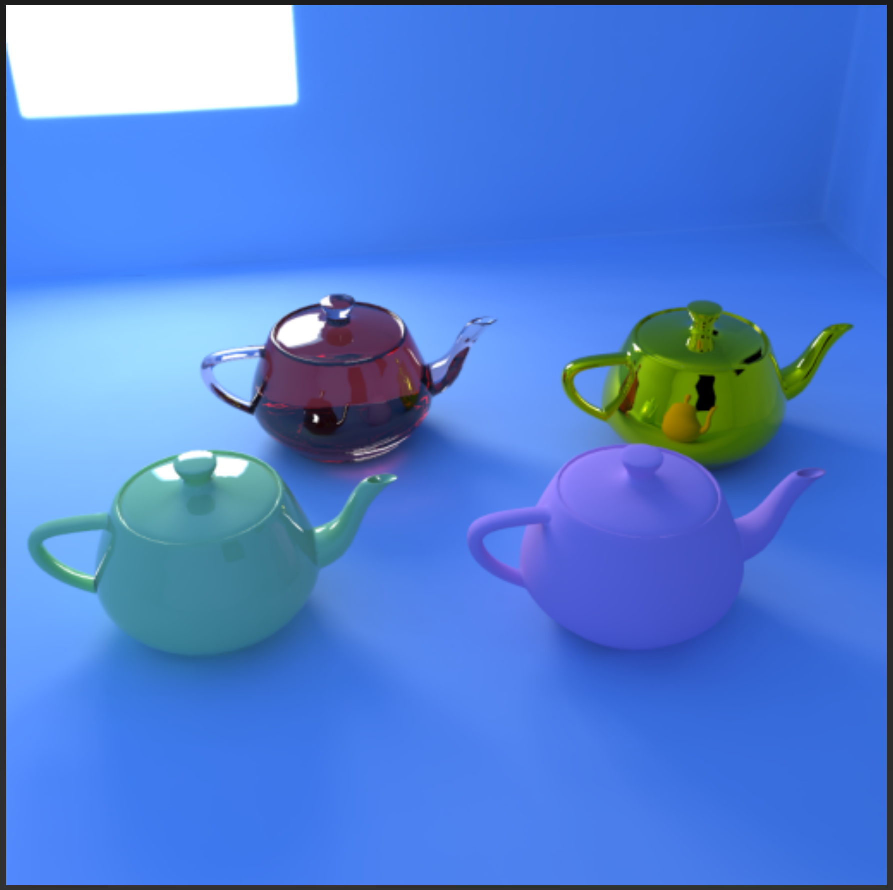
15 years ago...

GPUs in 2002 ⇒ 2017

- More complex operations (64 inst. ⇒ 64K inst.)
- Faster computation (30G FLOPS ⇒ 3T FLOPS)

What is “Parthenon Renderer”?

- CPU/GPU combined offline rendering system
- Released in 2002 (= the rise of the GPGPU era)
- Publicly and commercially available back then

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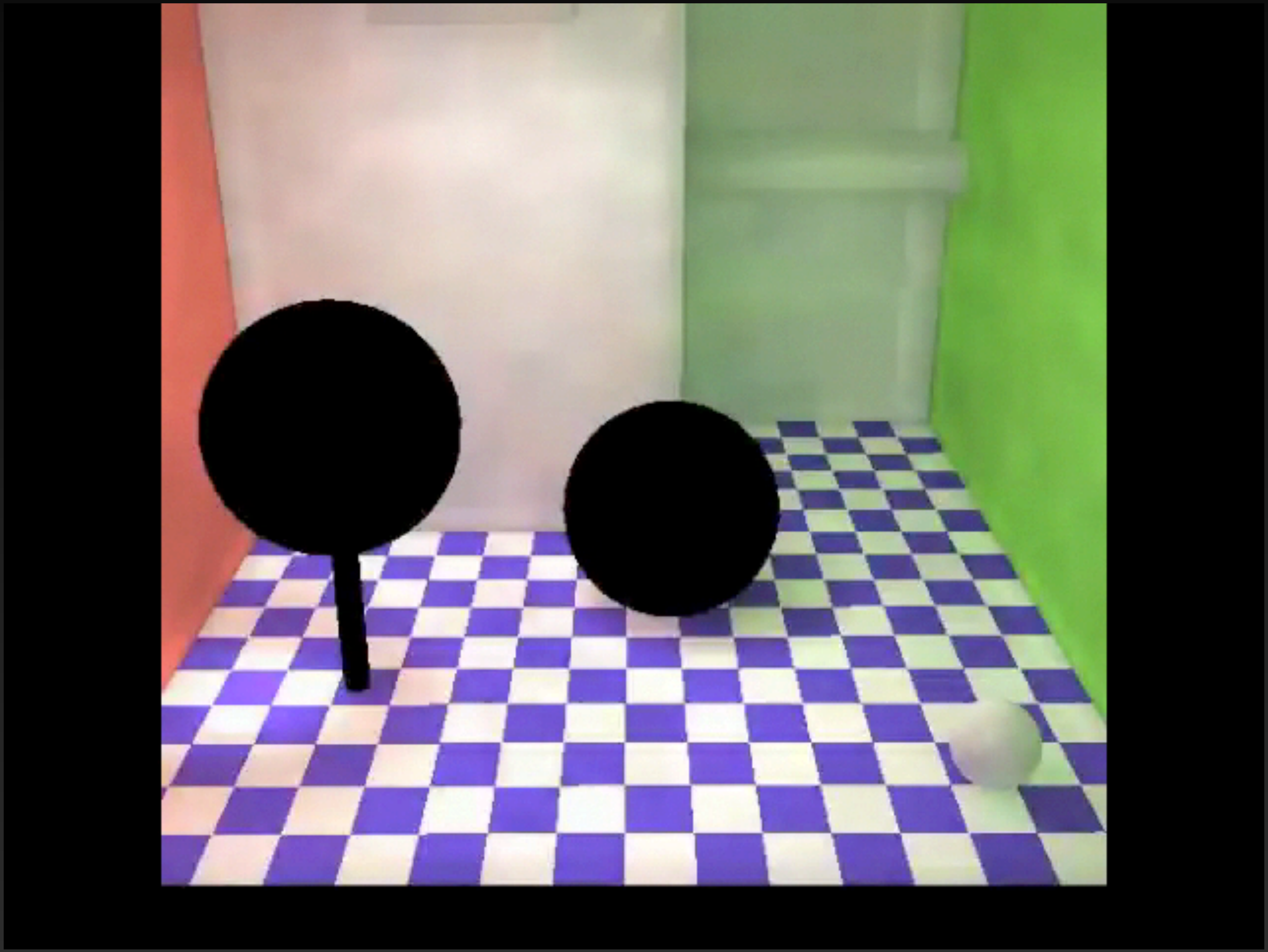
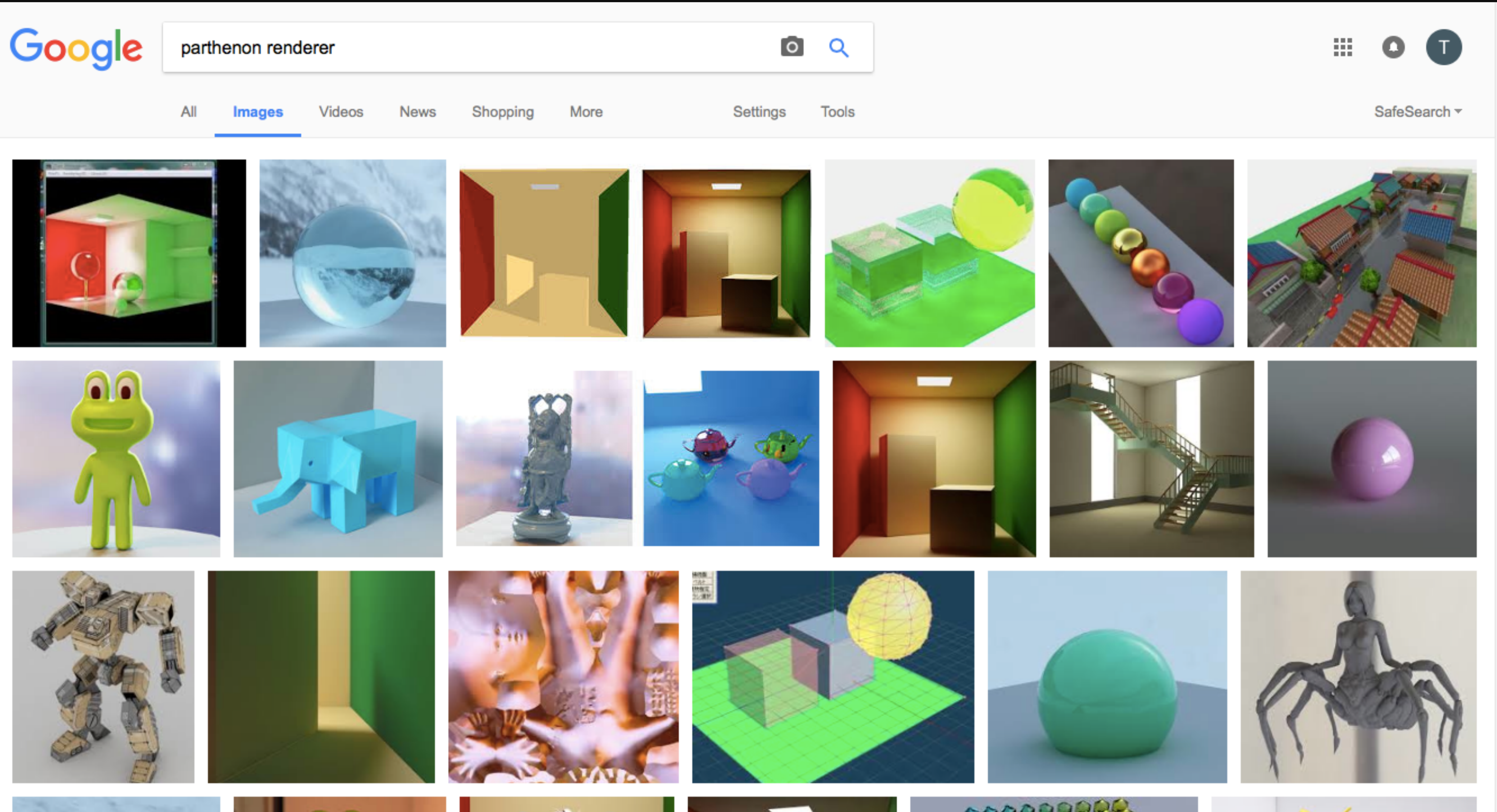


Pentium4 2.7 GHz & Radeon 9700 Pro

What is “Parthenon Renderer”?



Why now?

- Examples of how techniques become (non) obsolete
- High-ends in 2002 are low-ends in 2017
- Hopefully useful to predict the future

System Overview

How Parthenon Works

- Photon mapping + Final Gathering
- Mapping computation to rasterization units
- Asynchronous computation with CPU and GPU

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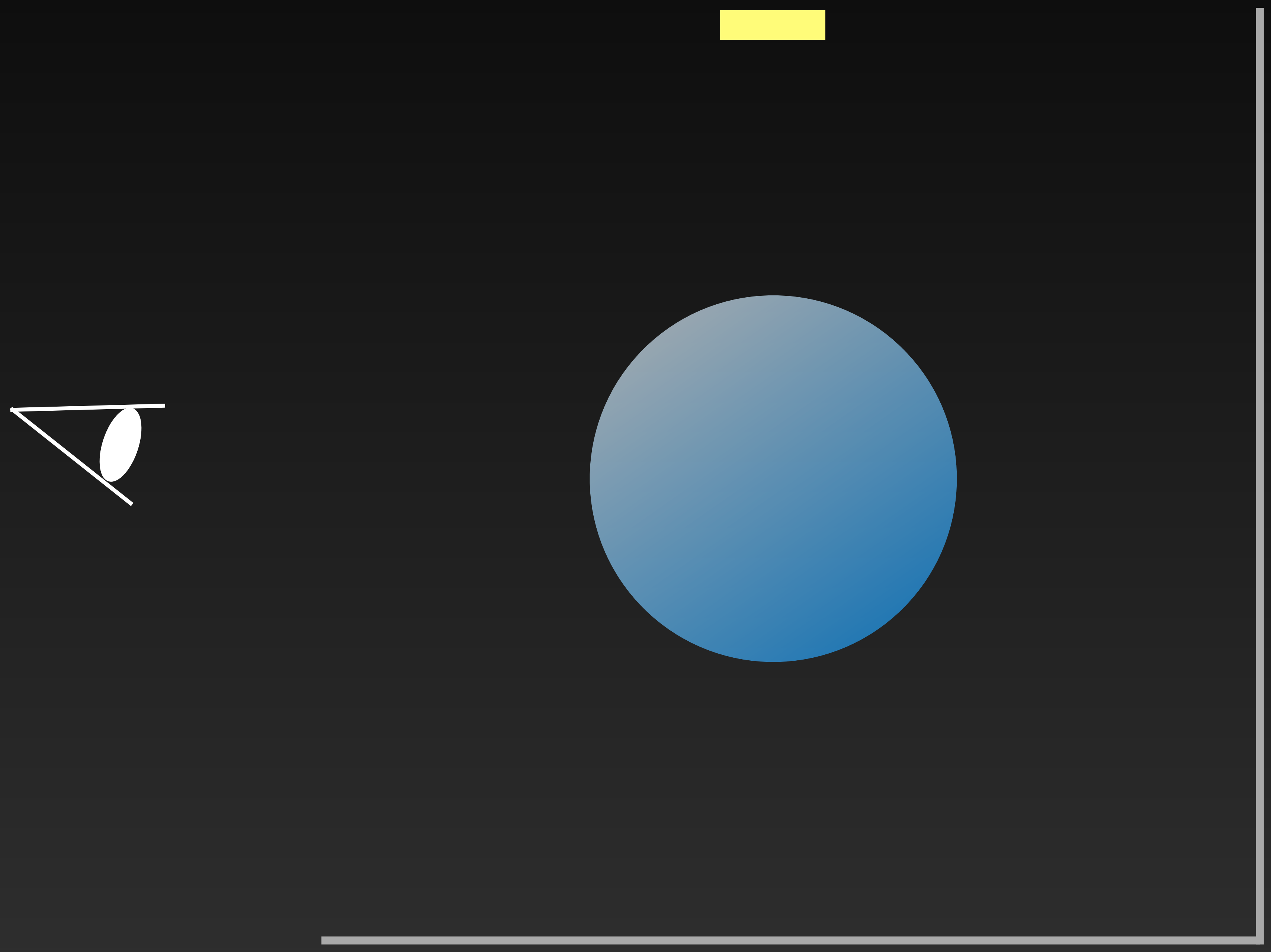
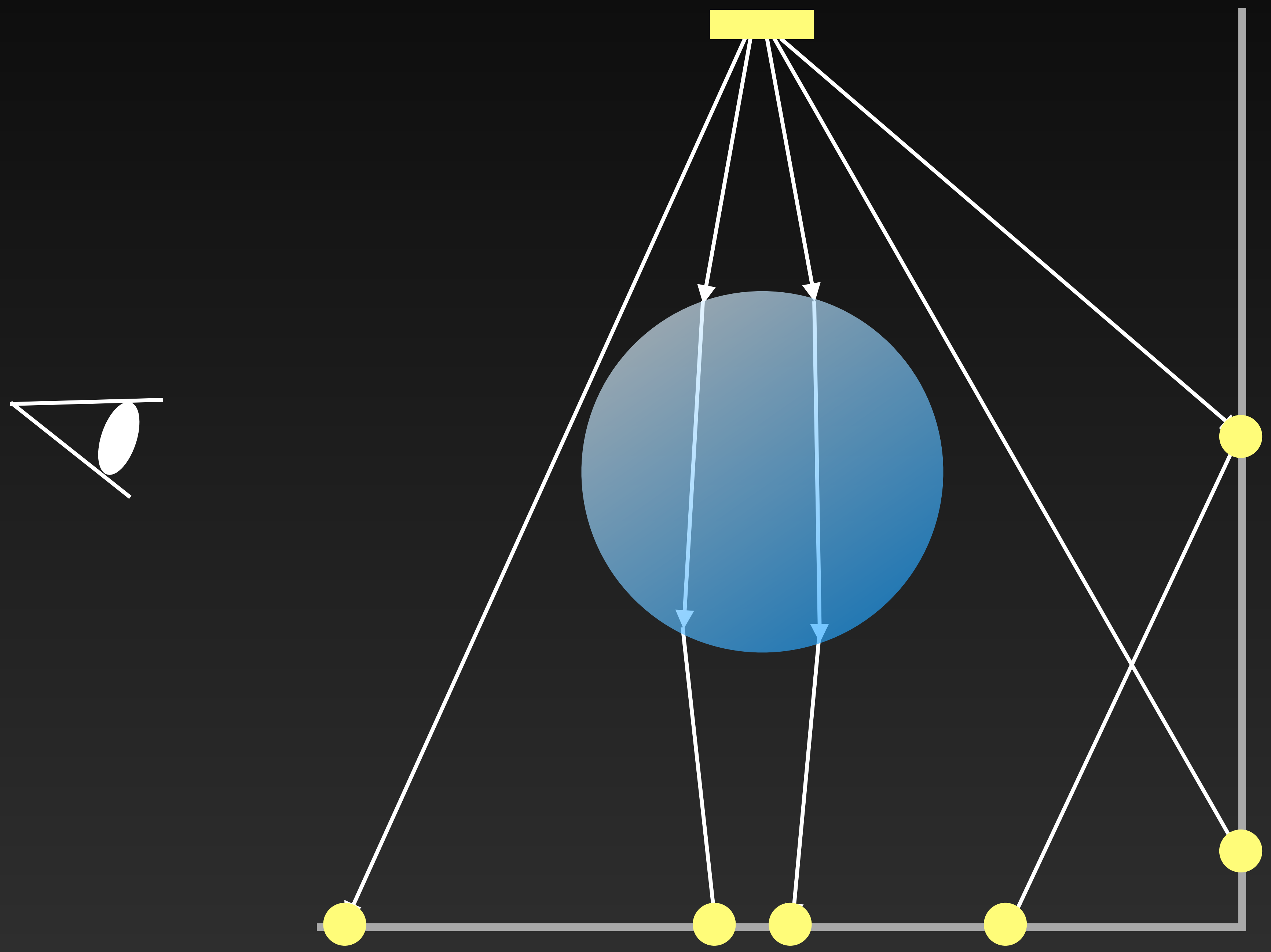


Photon Mapping



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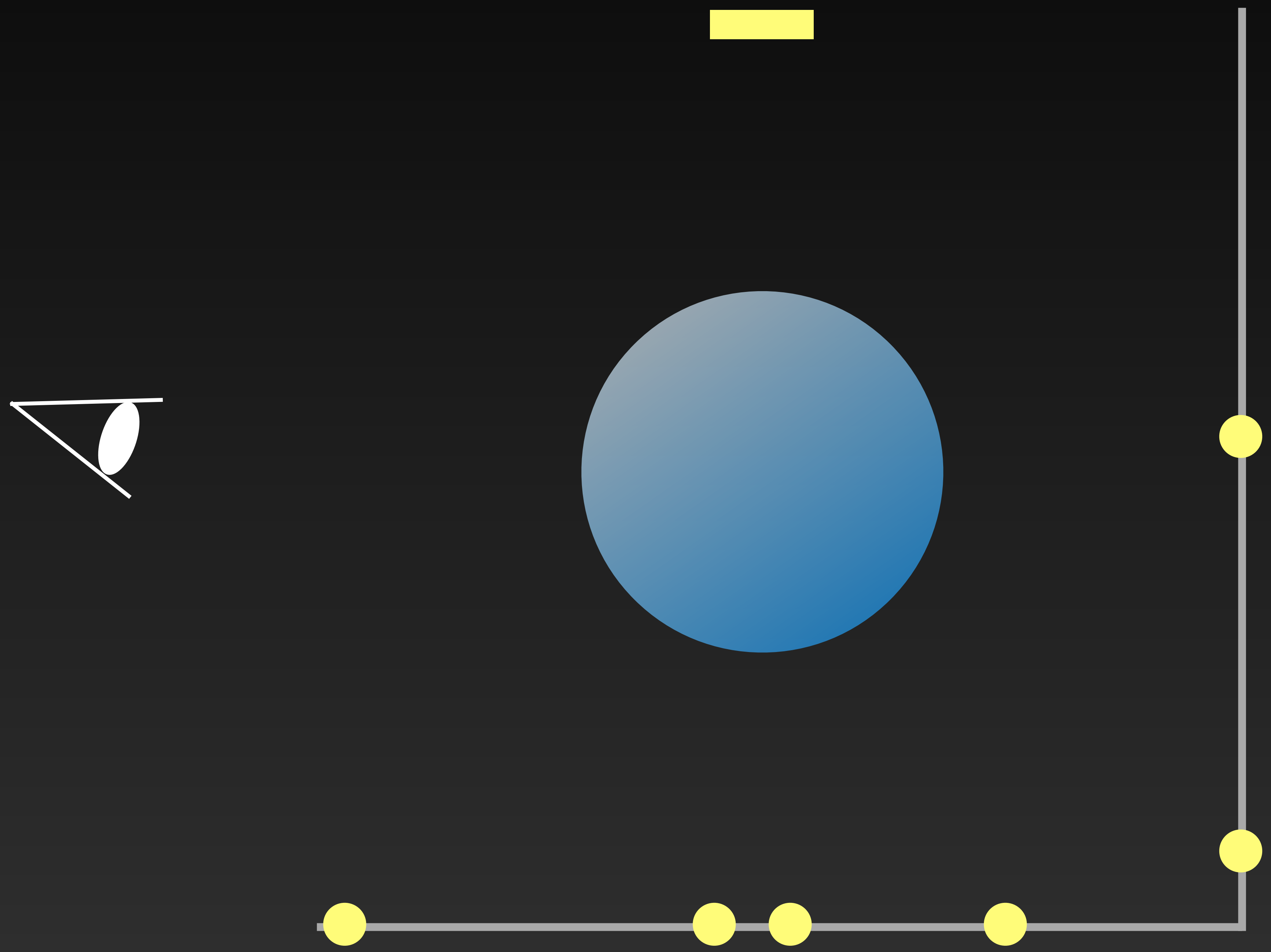

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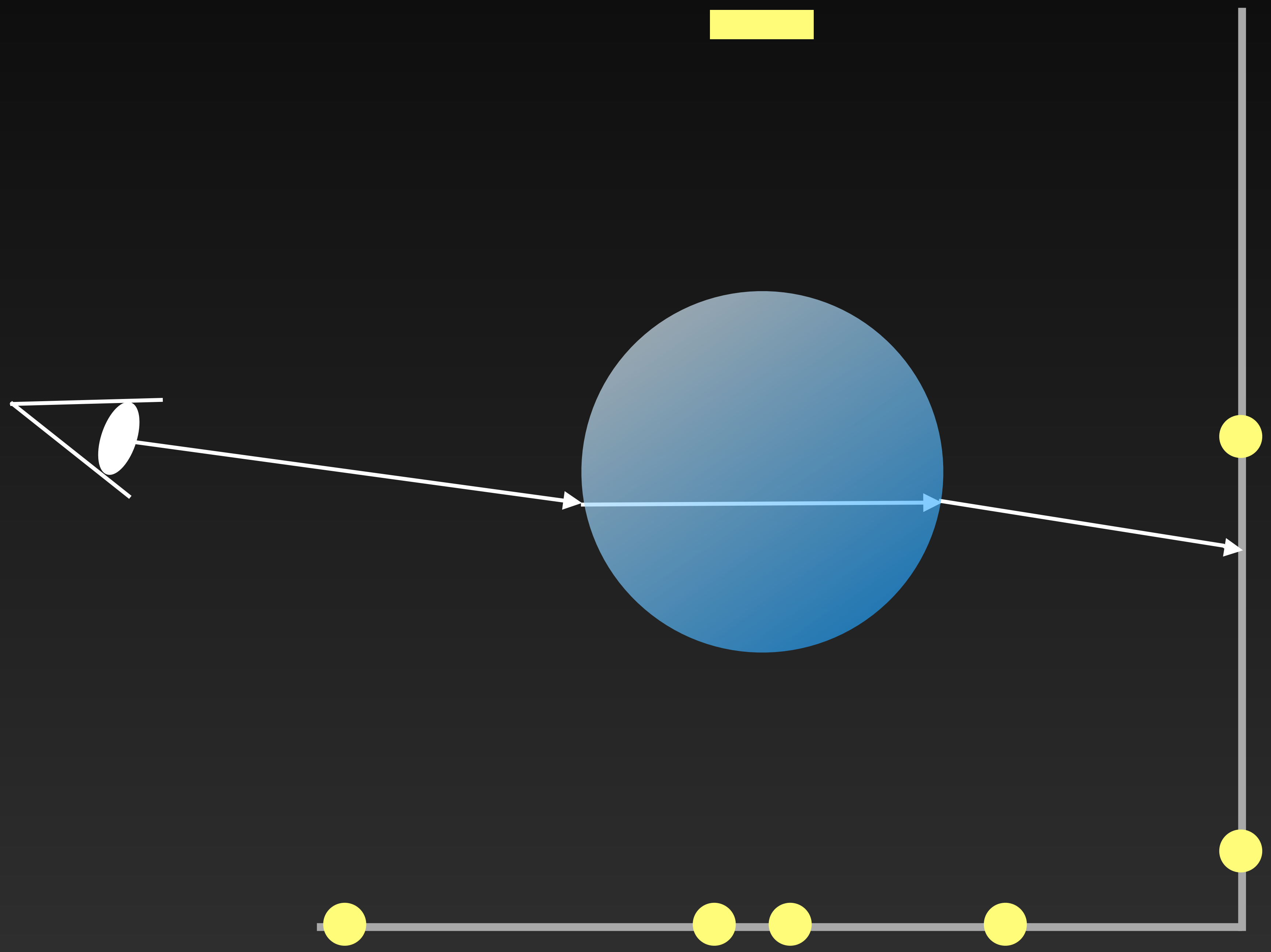

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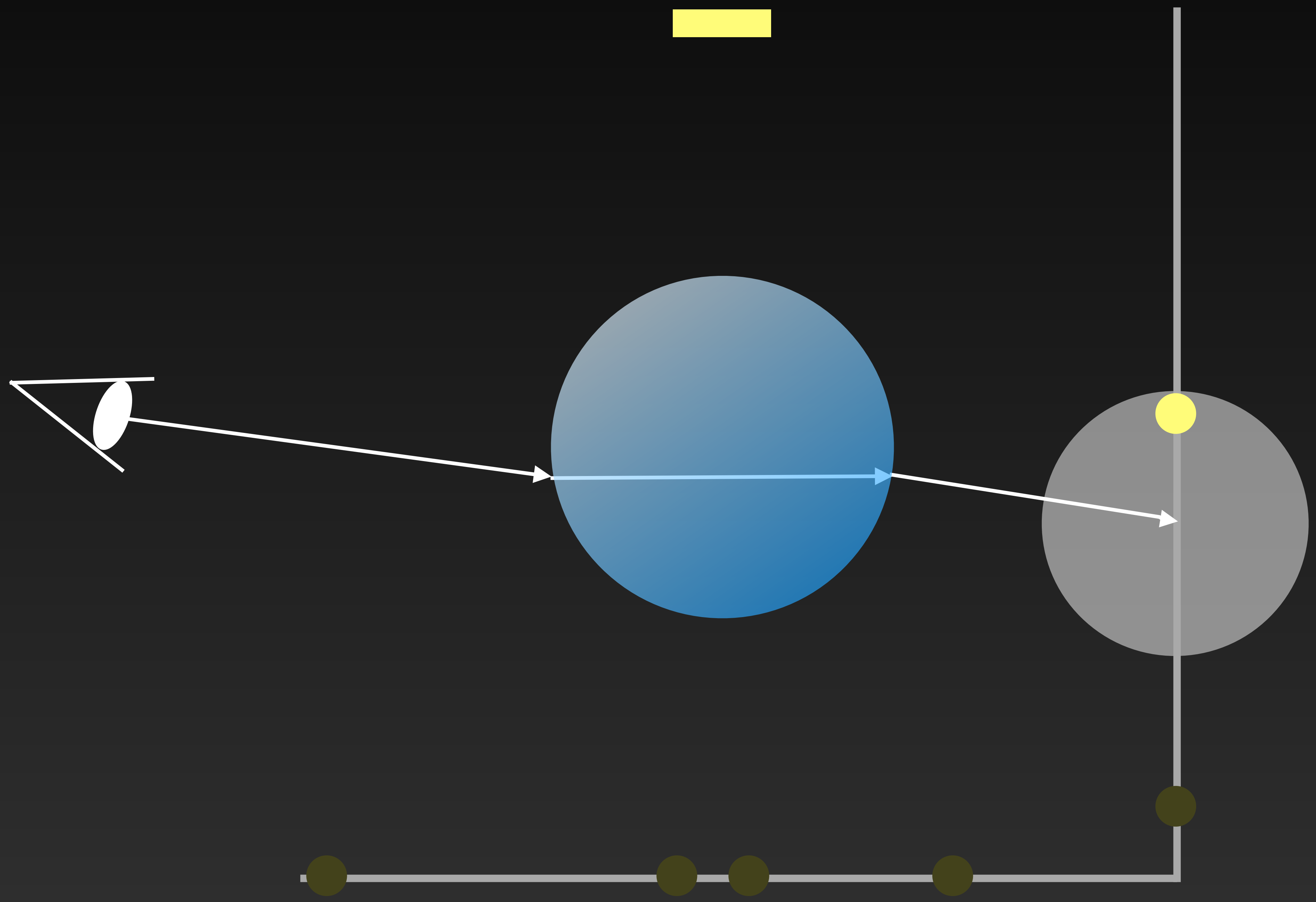

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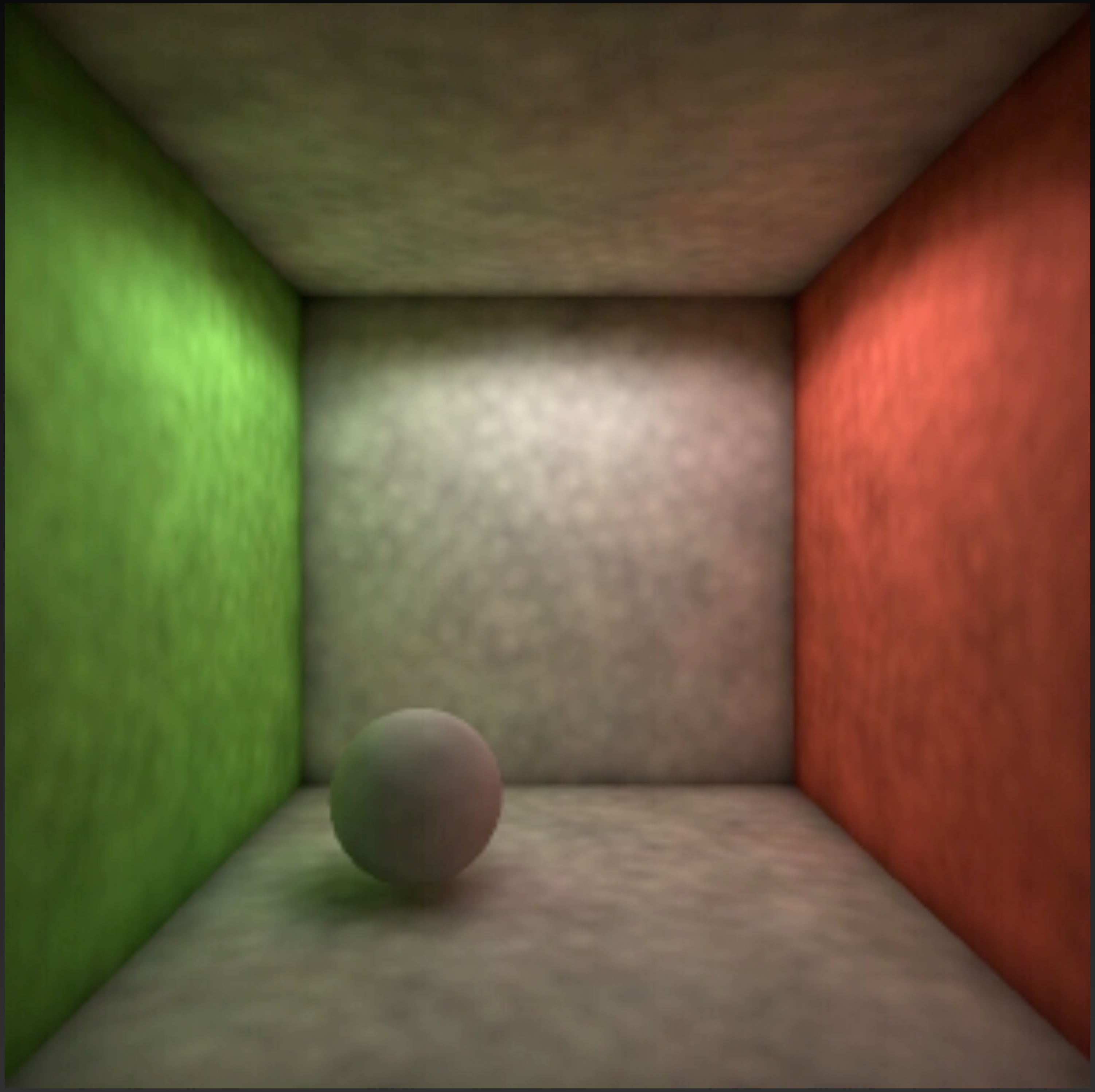
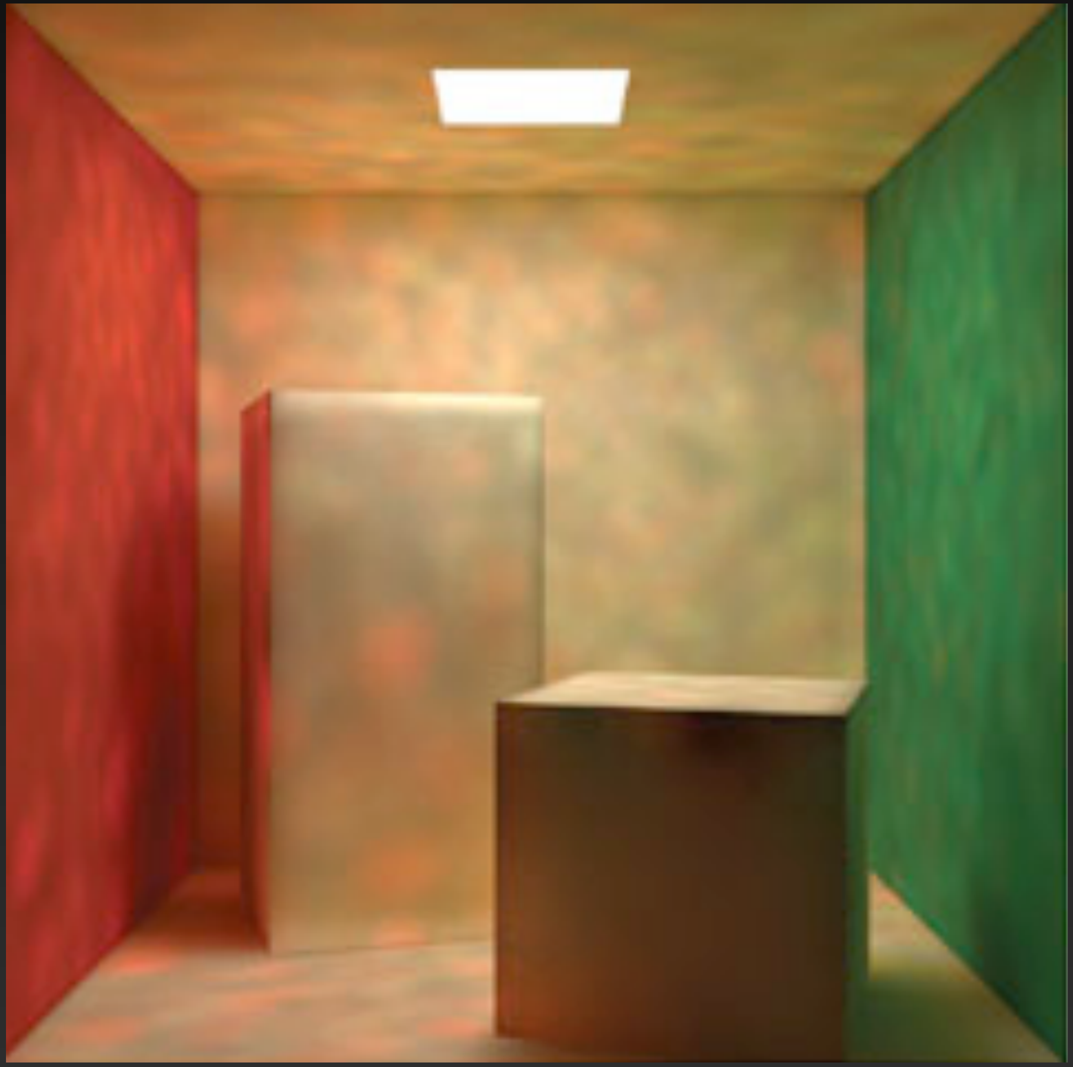
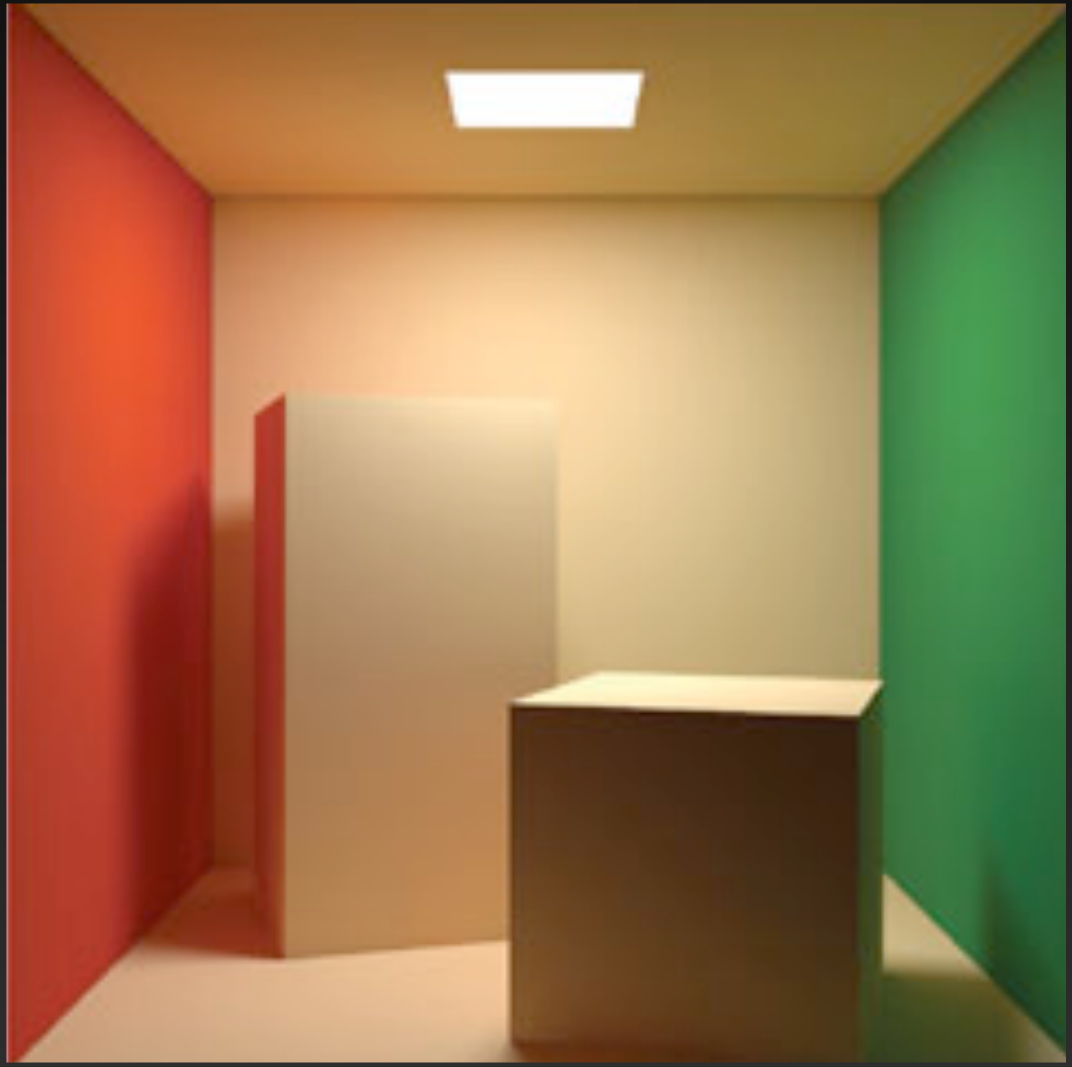


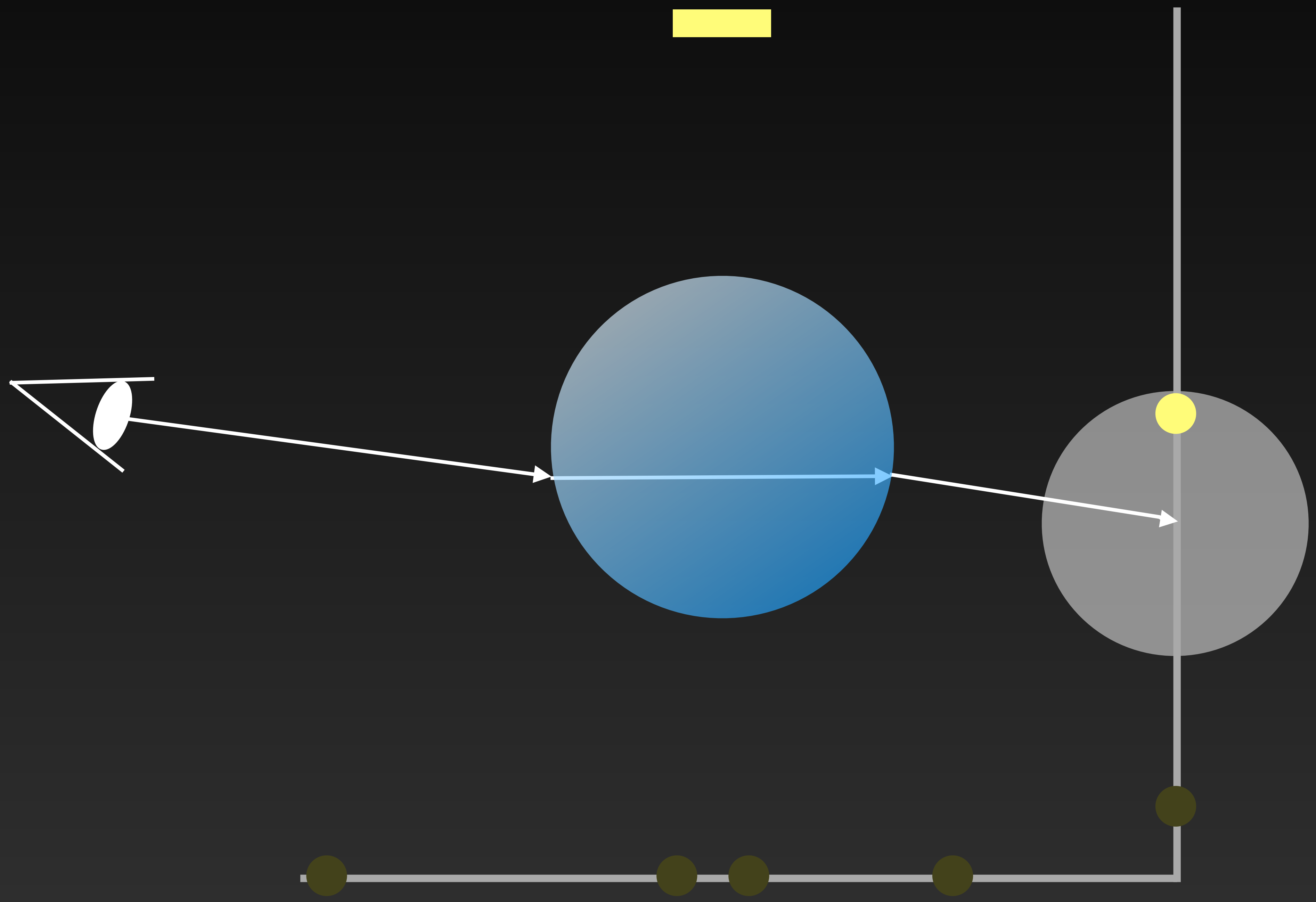
Photon Mapping + Final Gathering

- “Clean” the rough solution


Photon Mapping


Photon Mapping + FG

Photon Mapping + Final Gathering



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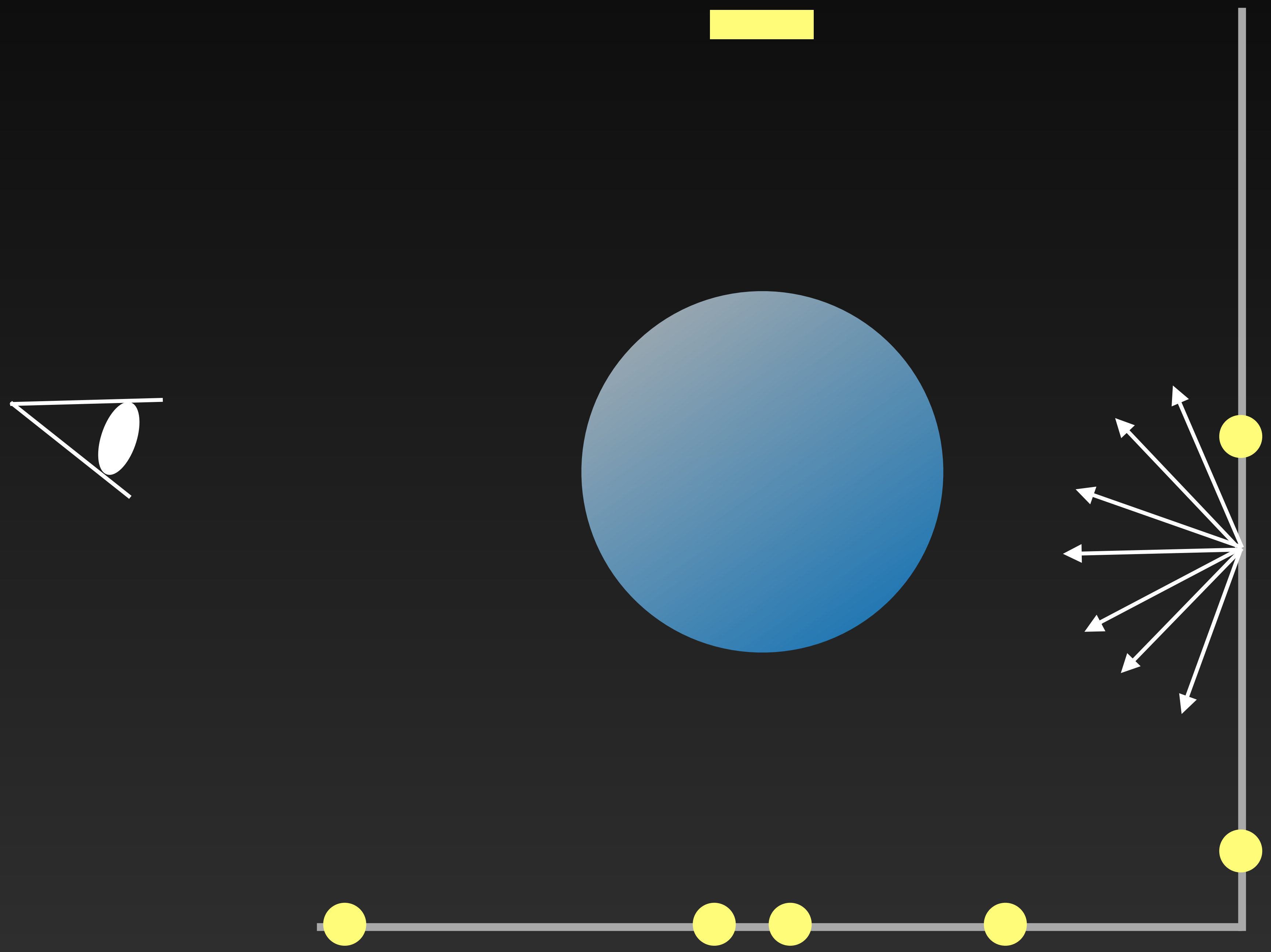

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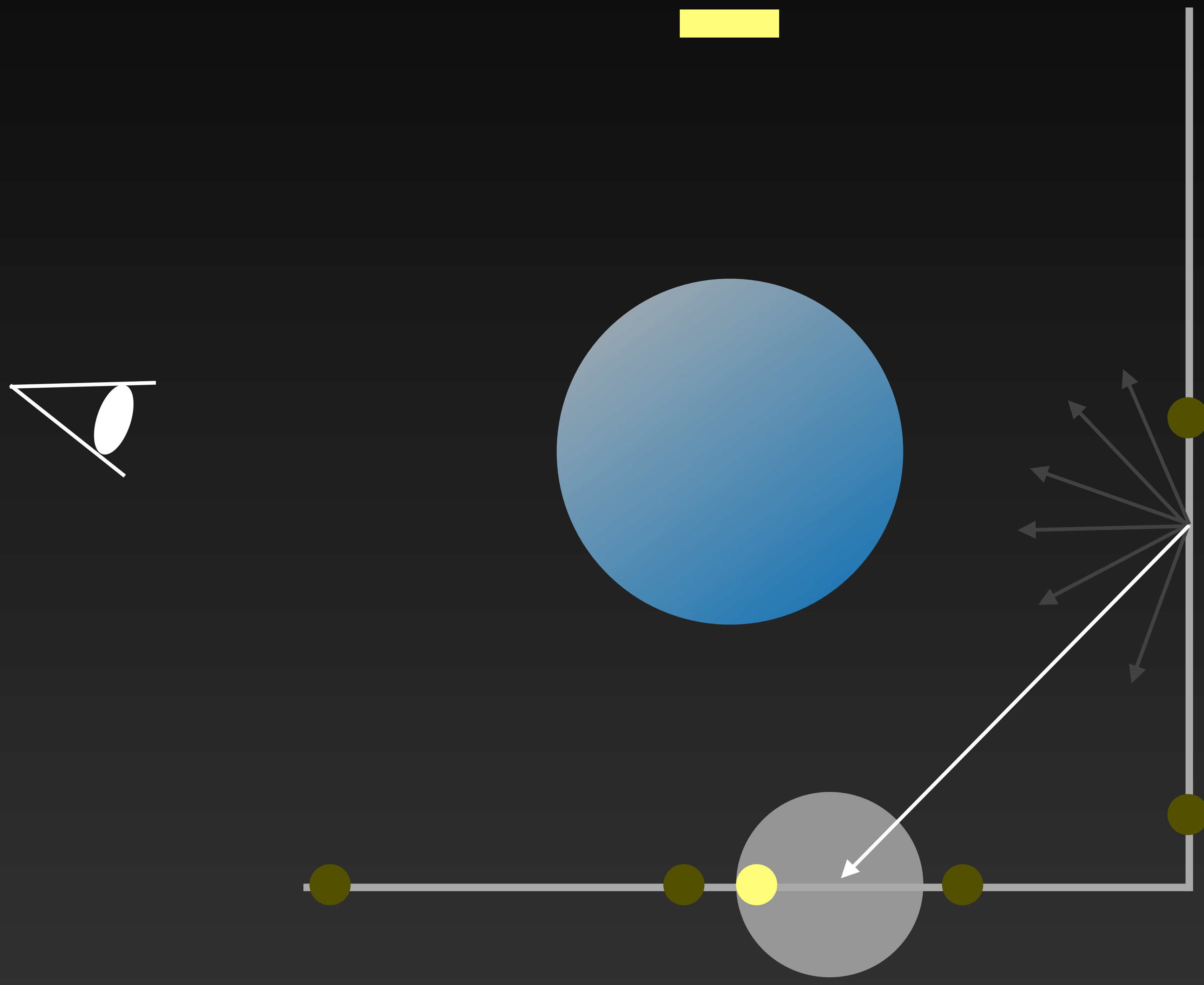


Observations

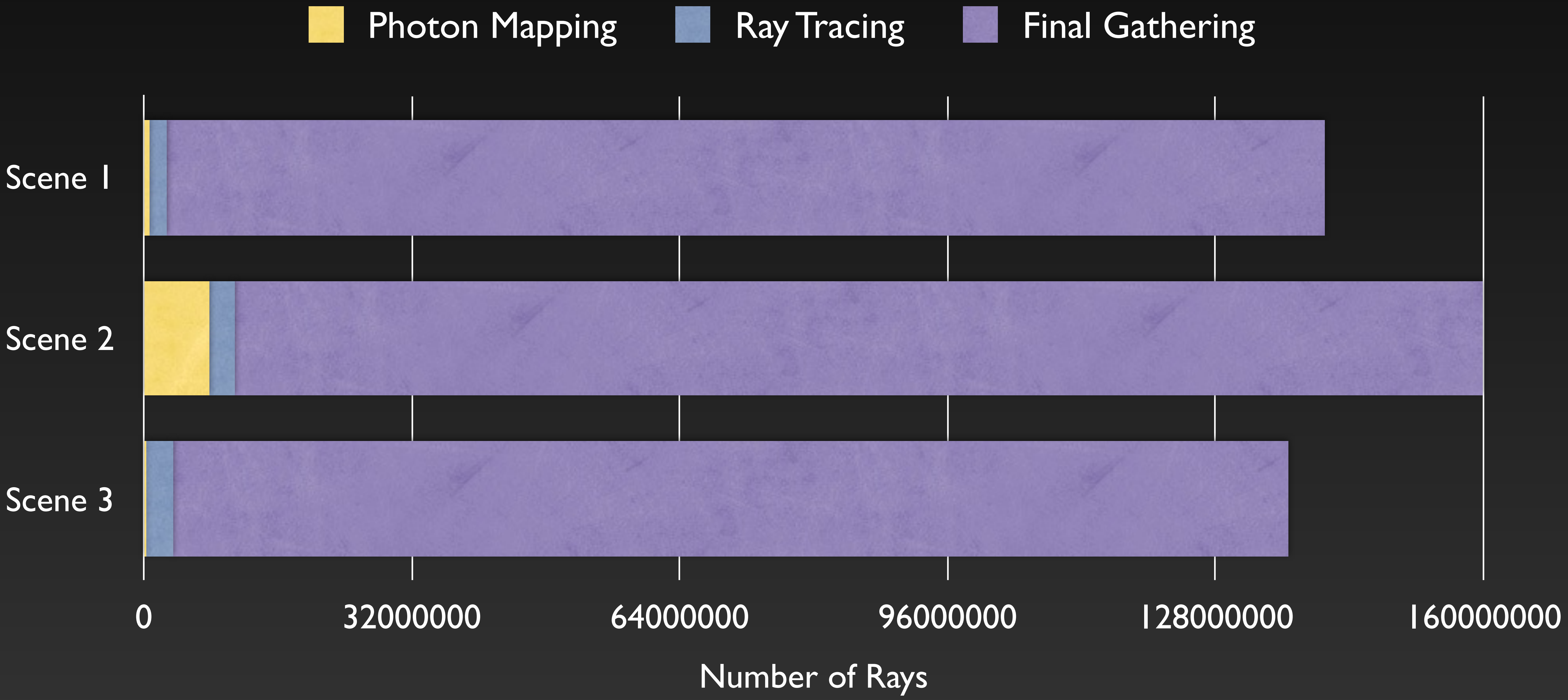
- Algorithmic complexity
- Computation cost

Observations - Complexity

- Final gathering is a simple process
  - Sample rays over the hemisphere
- Photon mapping is a complex process
  - Sampling light sources and BRDFs, kNN search

Observations - Cost

- Photon mapping is cheap, but final gathering is not



Main Idea

- CPU (in 2002)
  - Good at complex tasks but slow
- GPU (in 2002)
  - Good at simple tasks but fast

Main Idea

- CPU (in 2002)
  - Photon mapping and ray tracing
- GPU (in 2002)
  - Final gathering

Does this make sense today?

- GPU ray tracing is practical today
  - Should be able to do everything on GPU today
  - Only if you have a good GPU

Solution for Low-end GPUs

- Not everyone has high-end GPUs
  - GeForce GTX 580 ≈ 1.5T FLOPS
  - GeForce GT 520 ≈ 150G FLOPS

Solution for Low-end GPUs

- Not everyone has high-end GPUs
  - Radeon 9800 XT ≈ 50G FLOPS (in 2002)
  - GeForce GT 520 ≈ 150G FLOPS

Solution for Low-end GPUs

- Some rough estimates
  - 100M rays/sec on GPU
    10M rays/sec on a single CPU core
  - 1.5T FLOPS (10x faster than a single CPU core)
    150G FLOPS (as fast as a single CPU core)

Solution for Low-end GPUs

Low-end GPUs in 2017

≈

High-end GPUs in 2002

≈

Single core of CPUs in 2017

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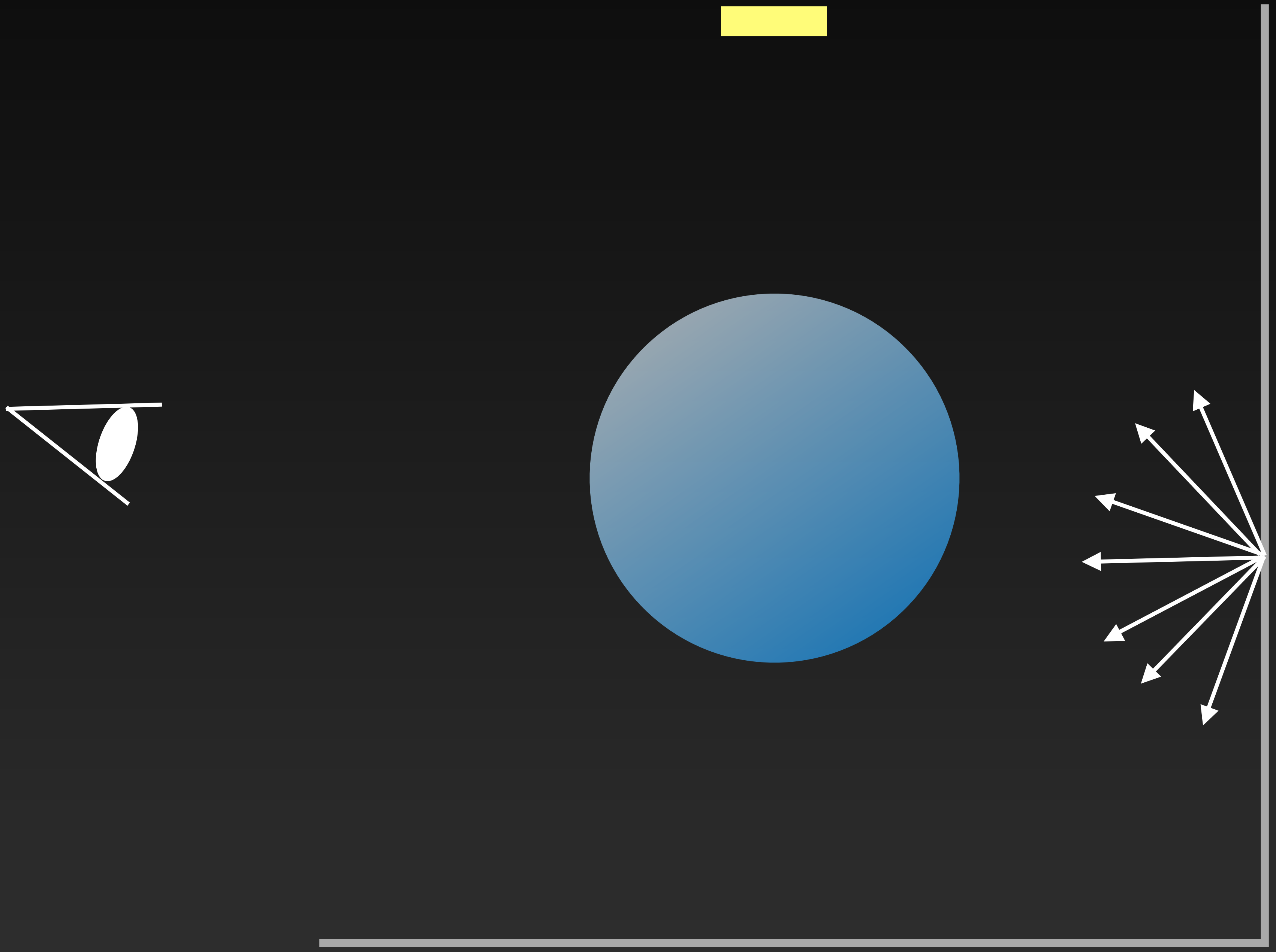
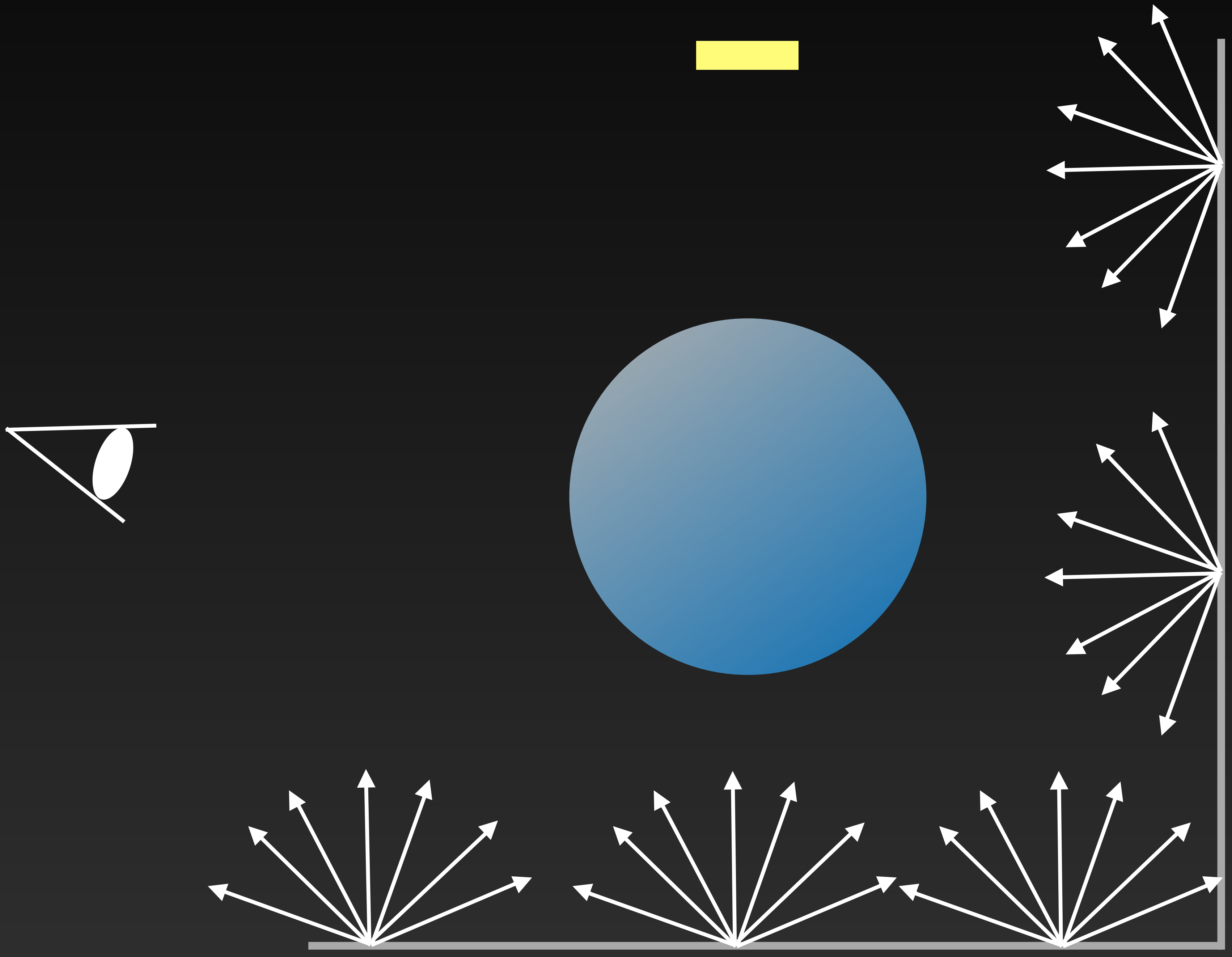
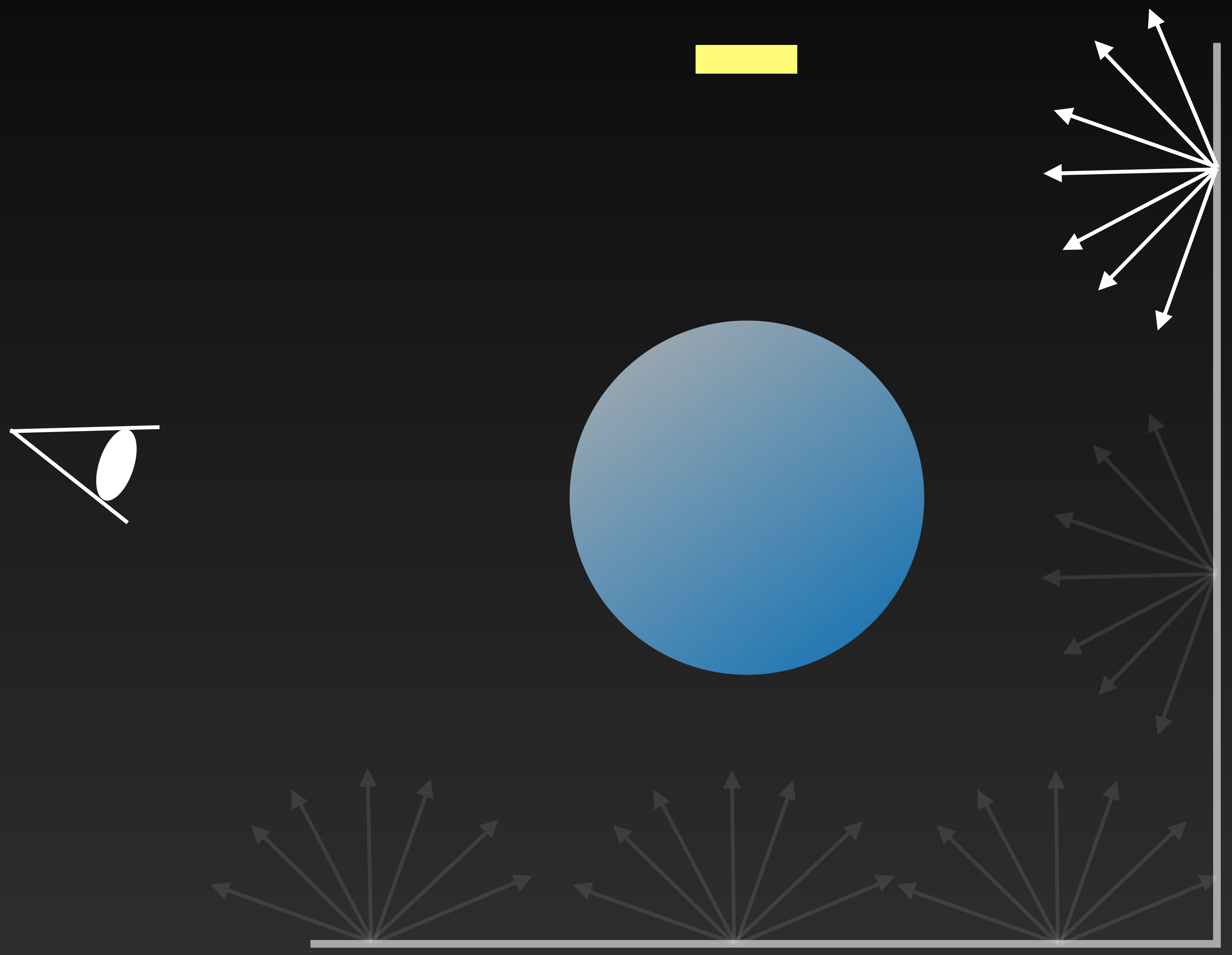
Precomputation

- Store the result of photon mapping into a mesh
  - Similar to light maps computation
  - Directional info encoded by SH coefficients





Grouping by Position



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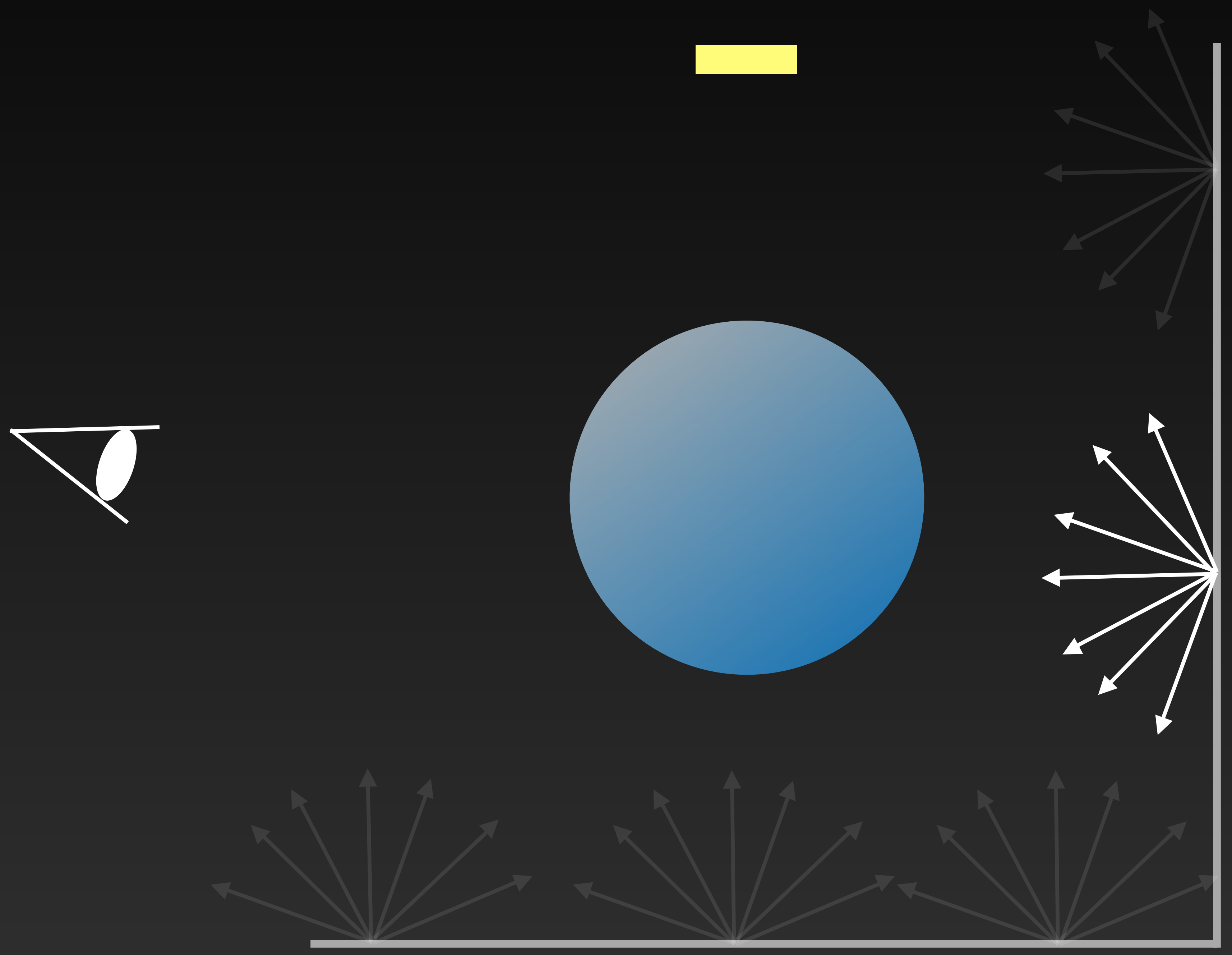

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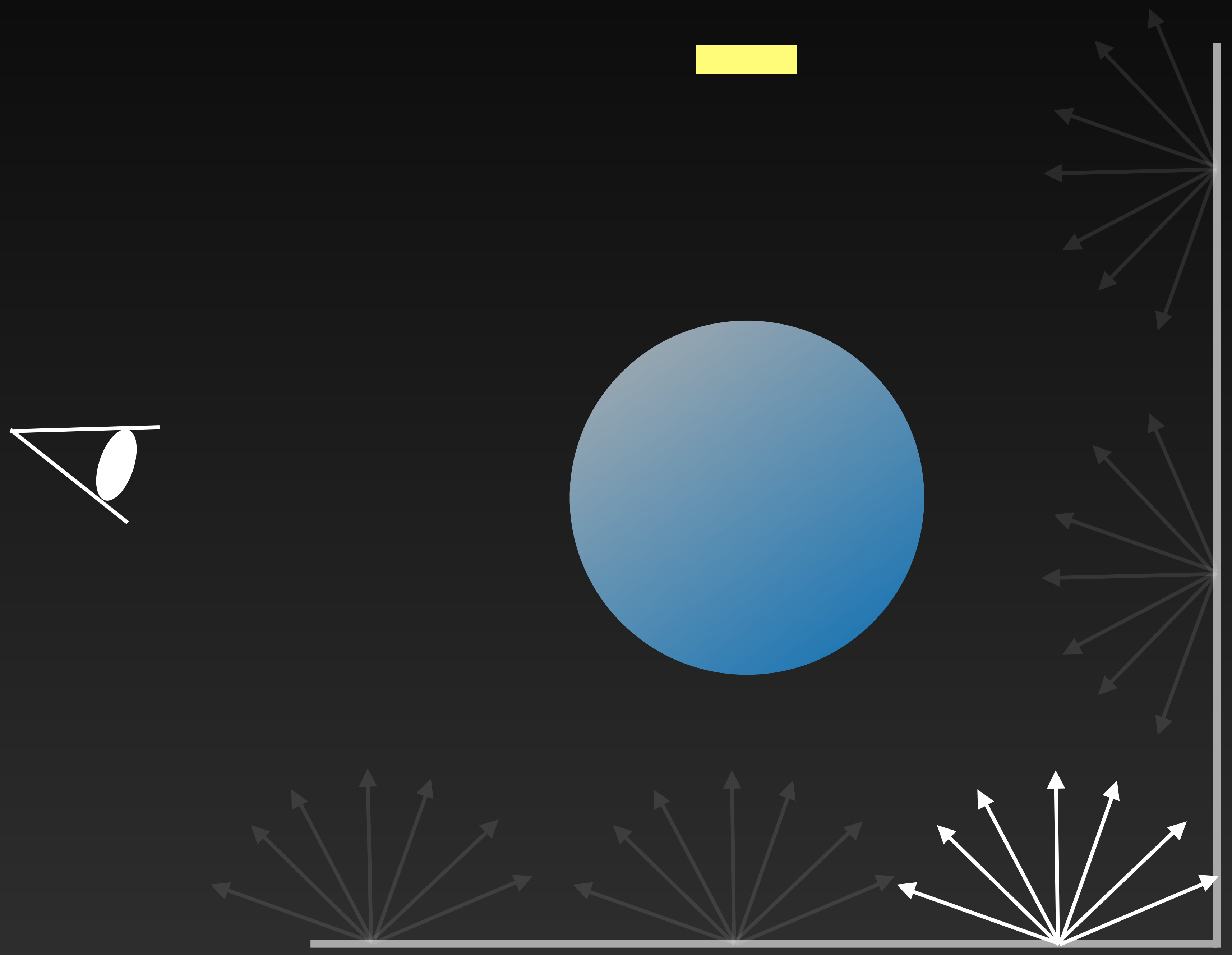

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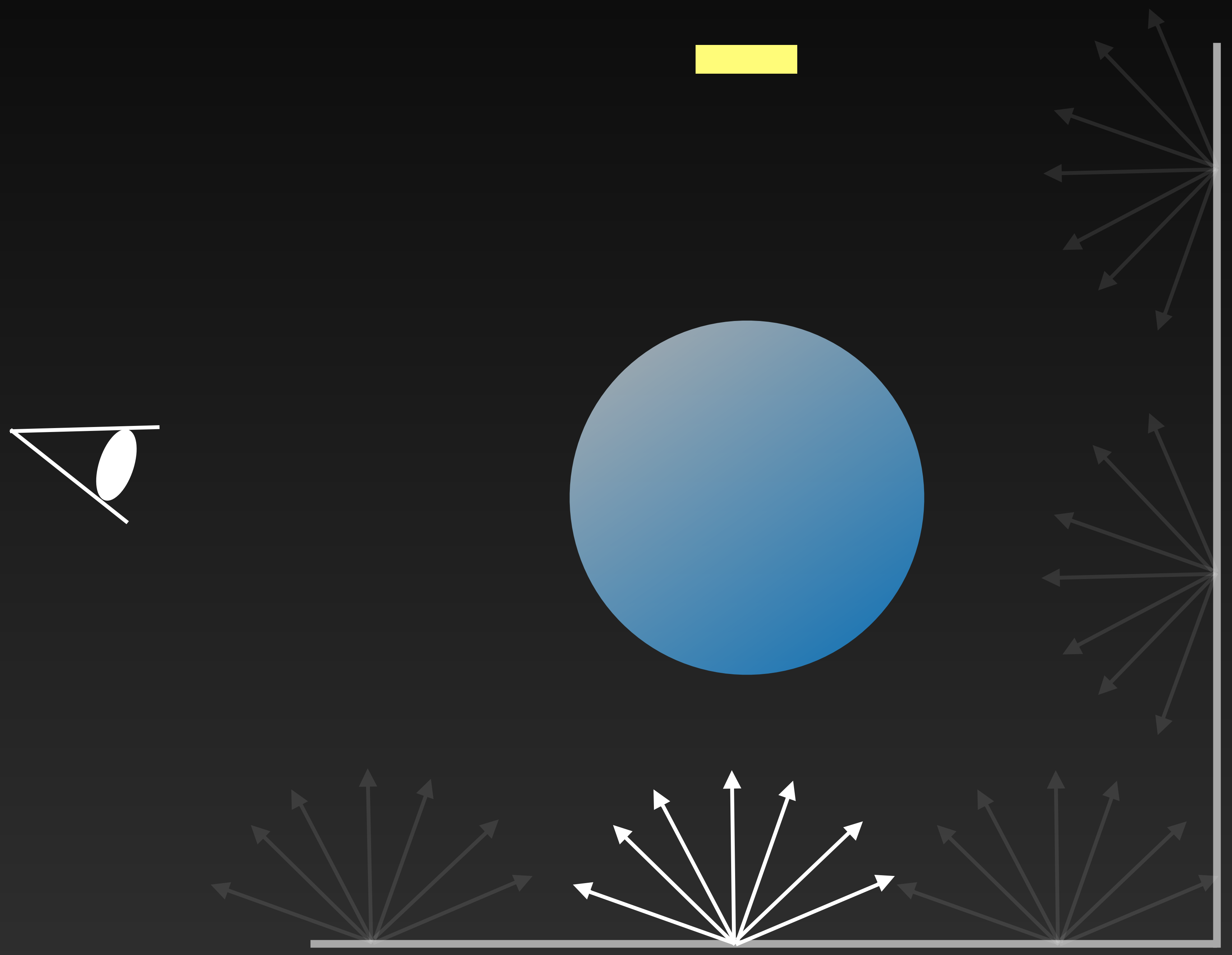

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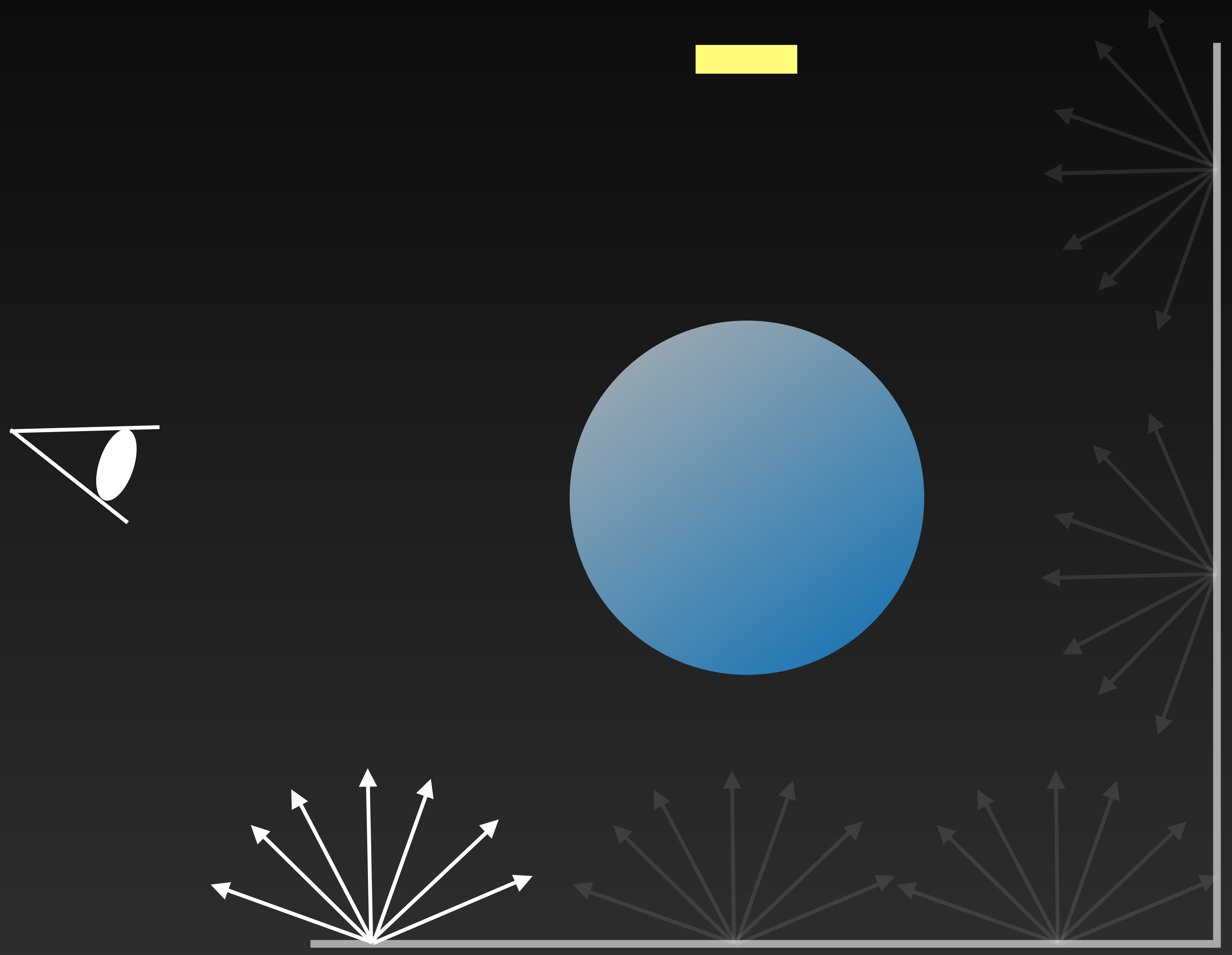
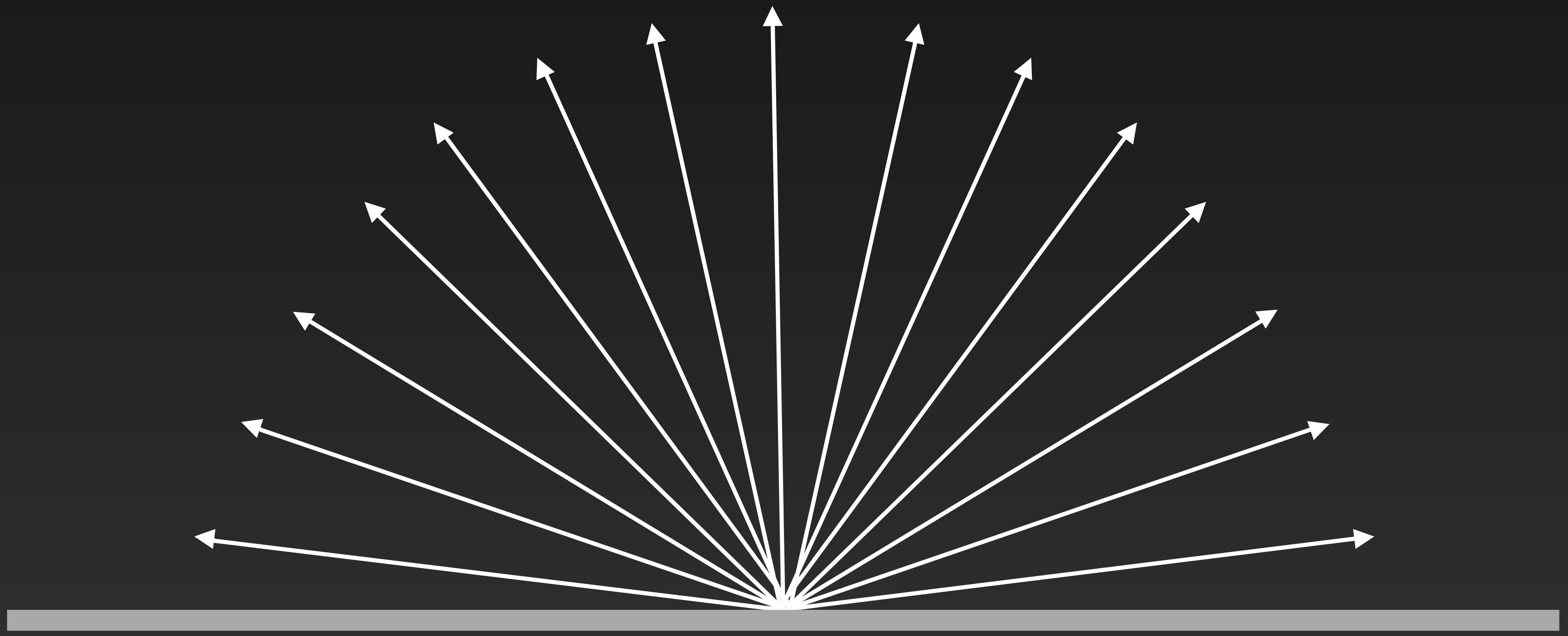


Grouping by Position

- Map the FG process on rendering cube maps



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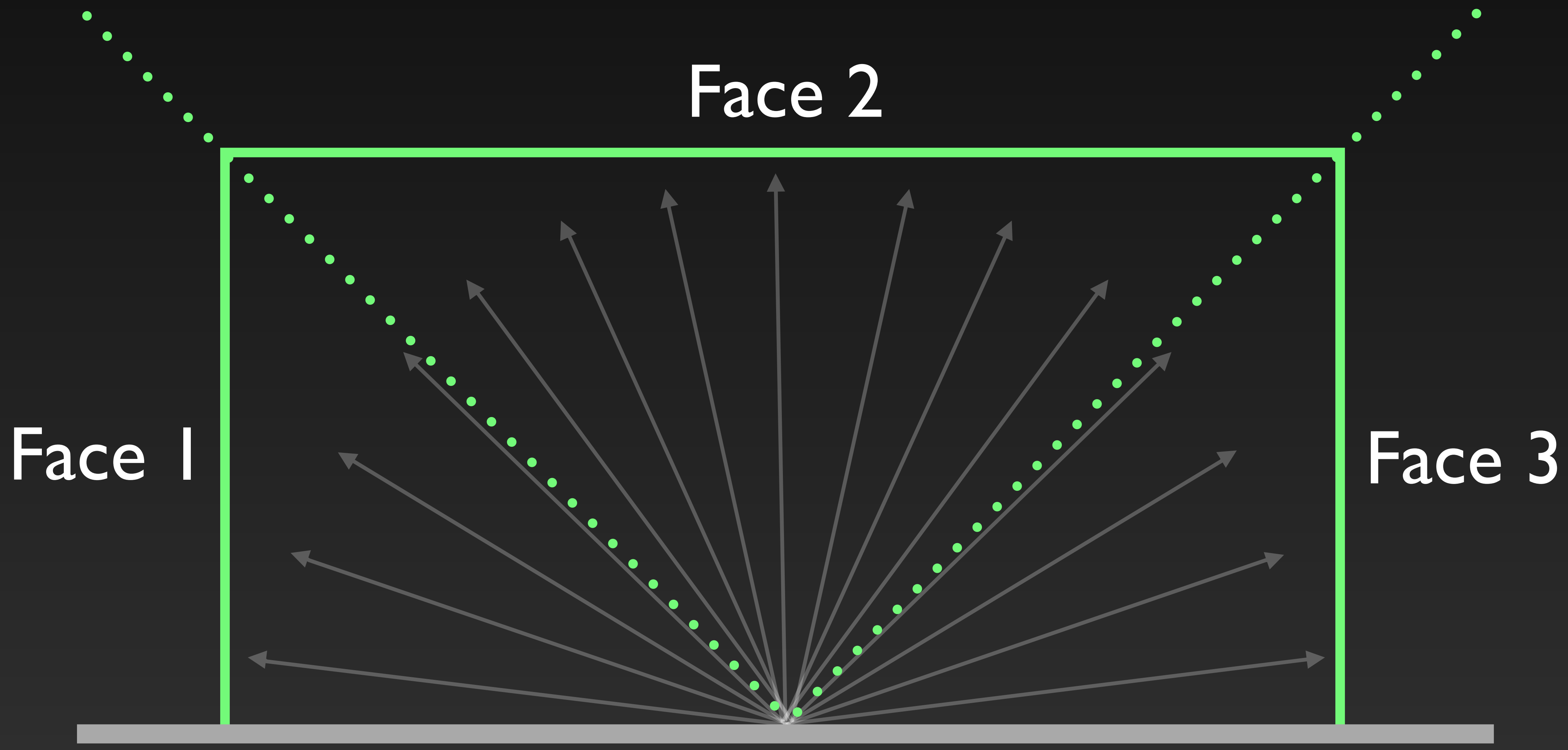
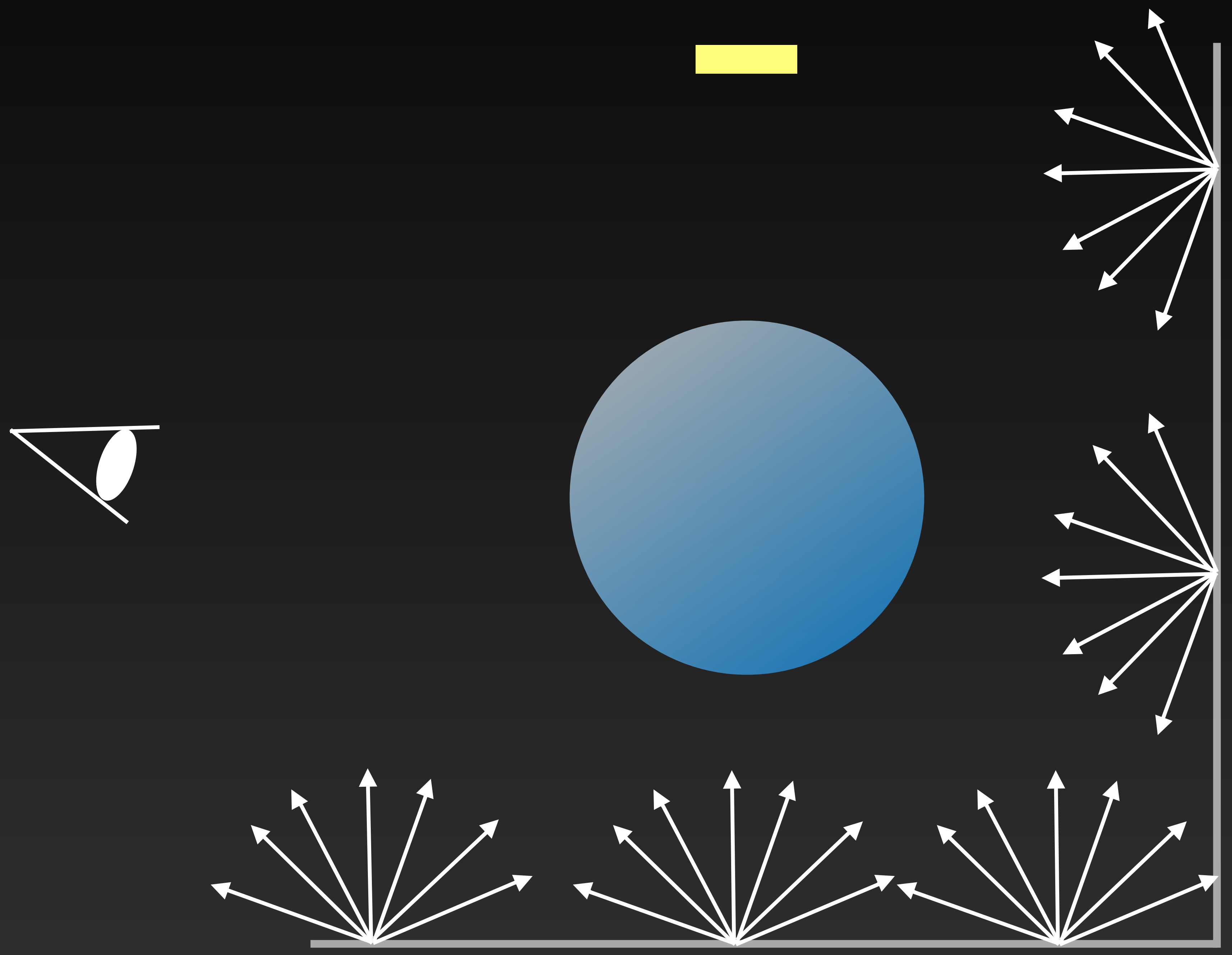
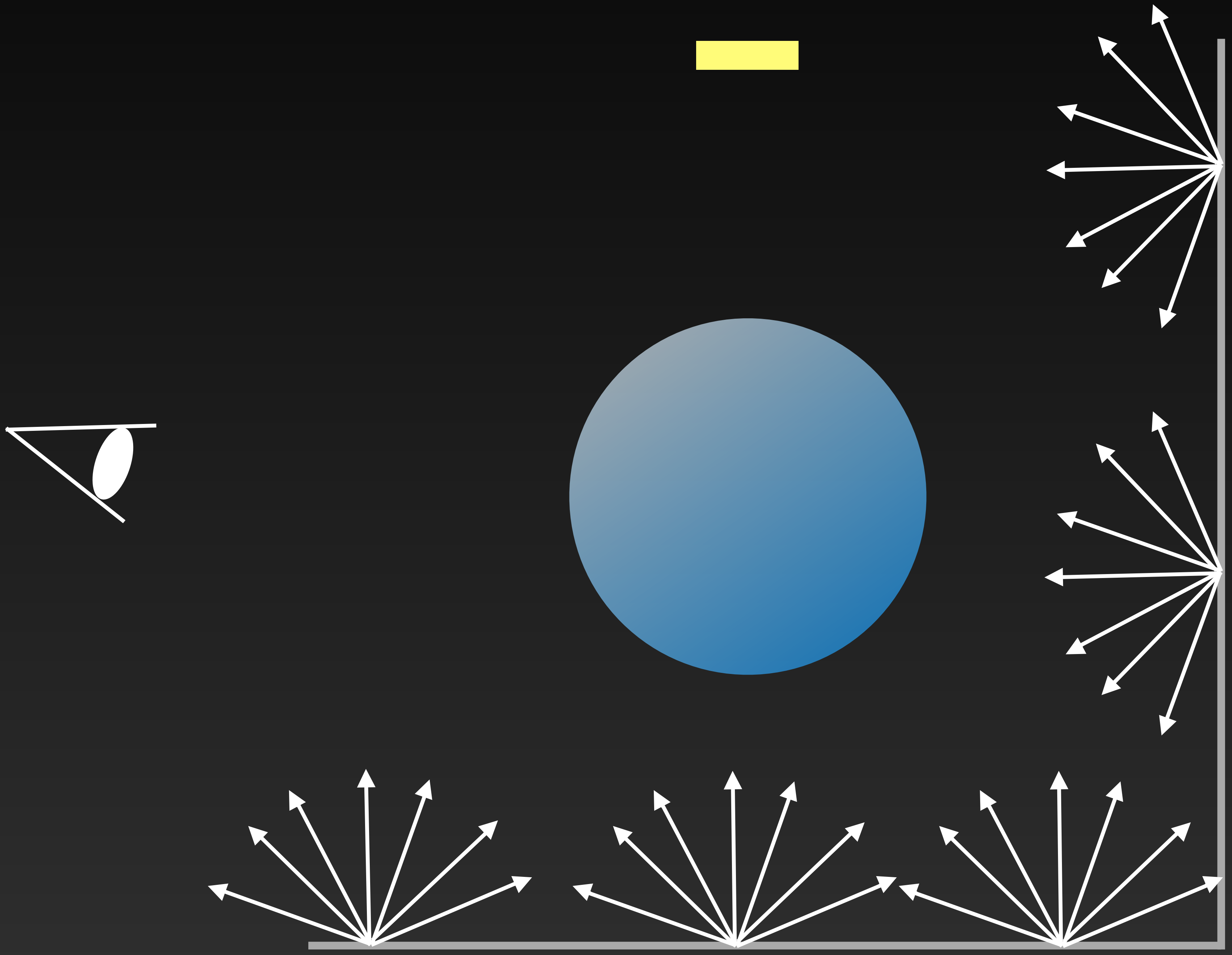


Grouping by Position

- Too many rasterizations of the scene
    - Number of final gathering points
      = Number of pixels
      = Number of rasterization passes
      = O(1M)
- Recent research use this with many approximations



Grouping by Direction



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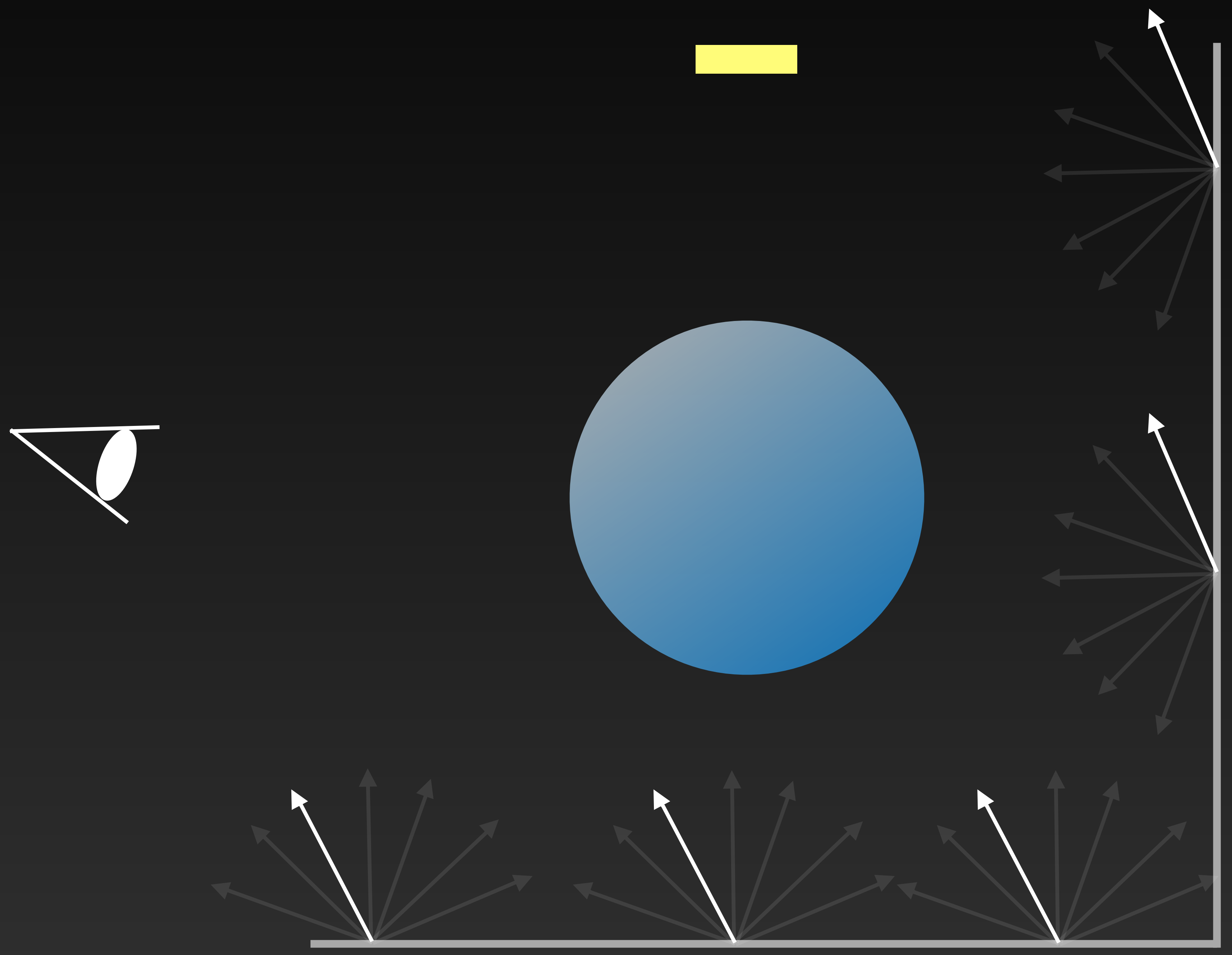
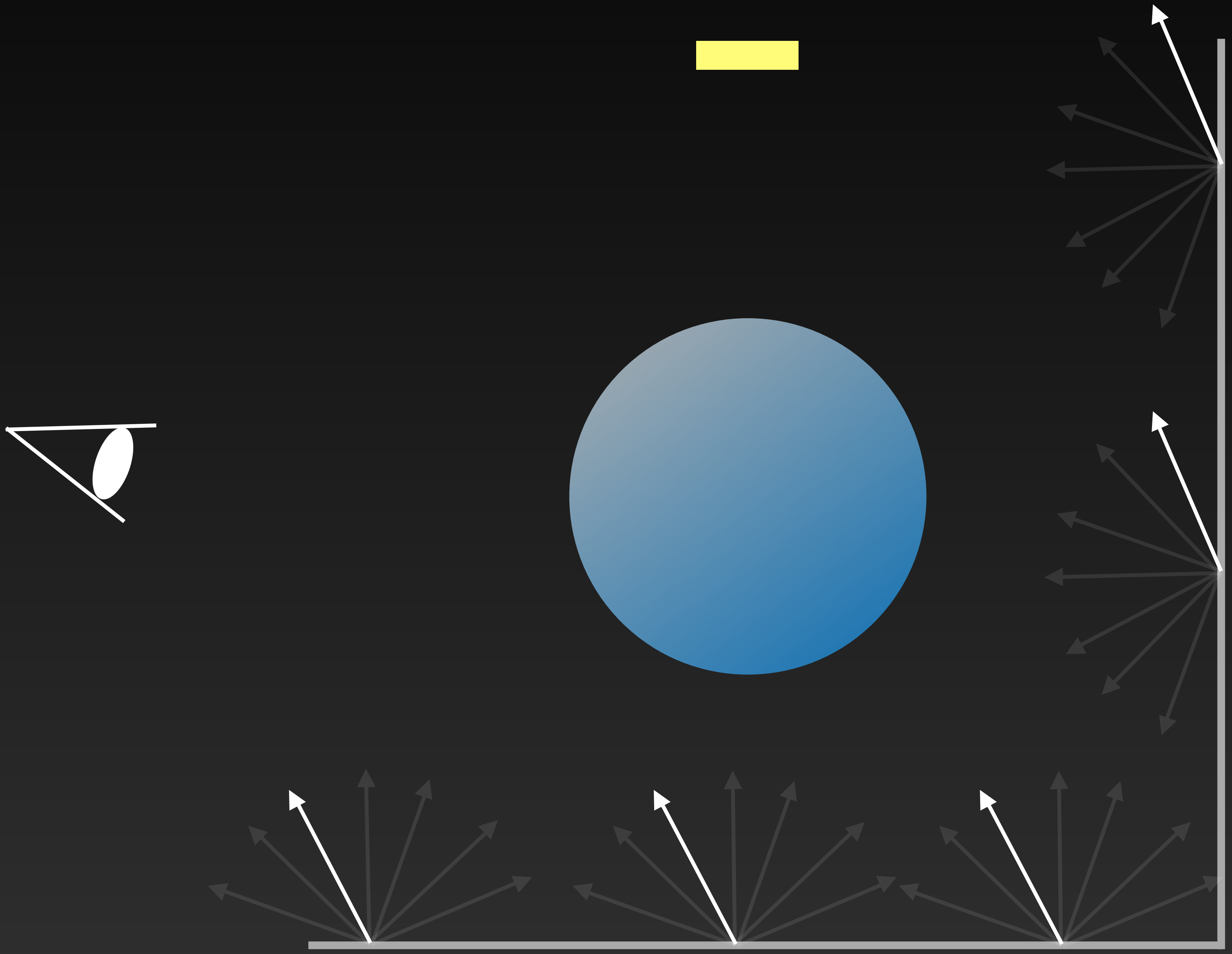
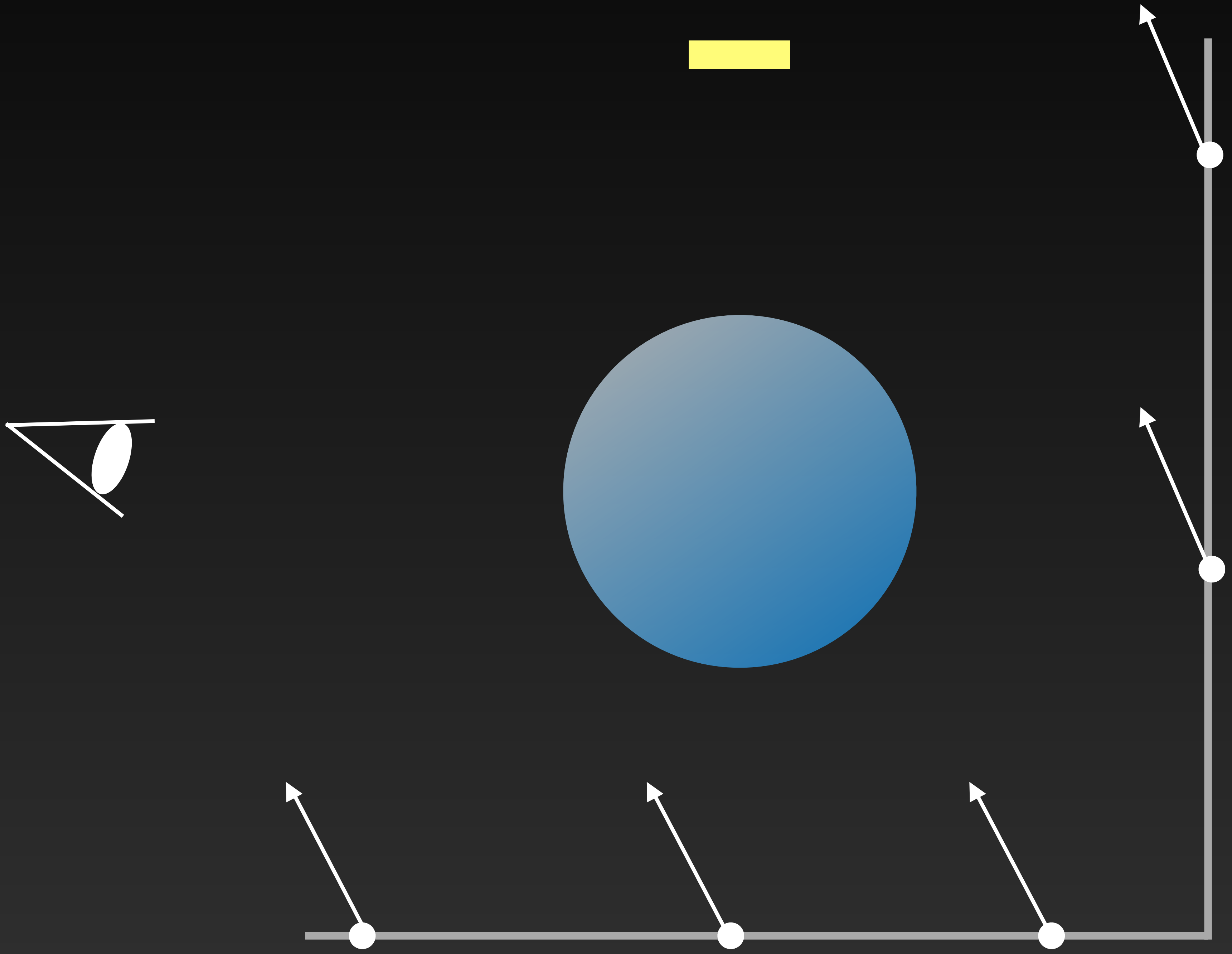
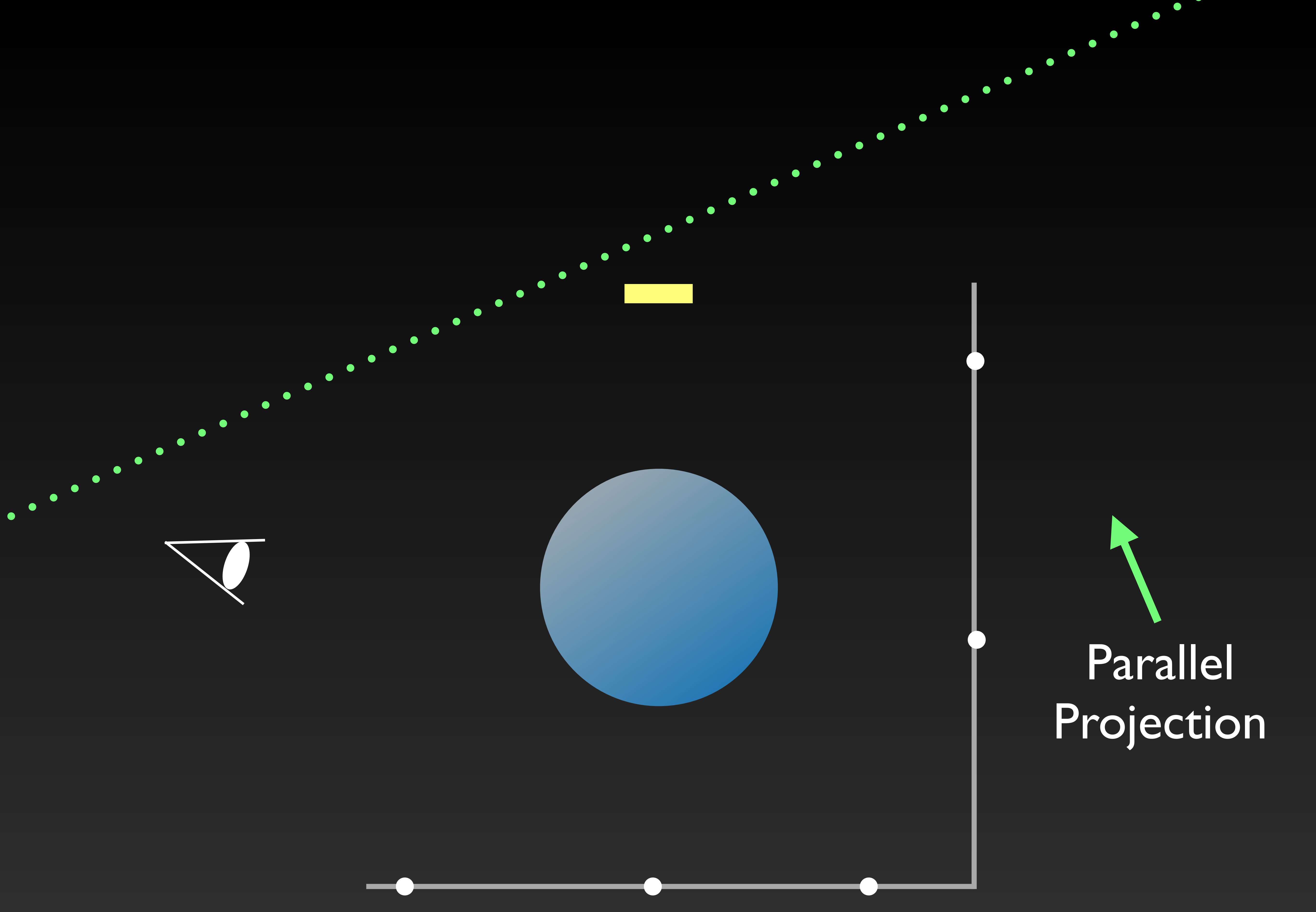


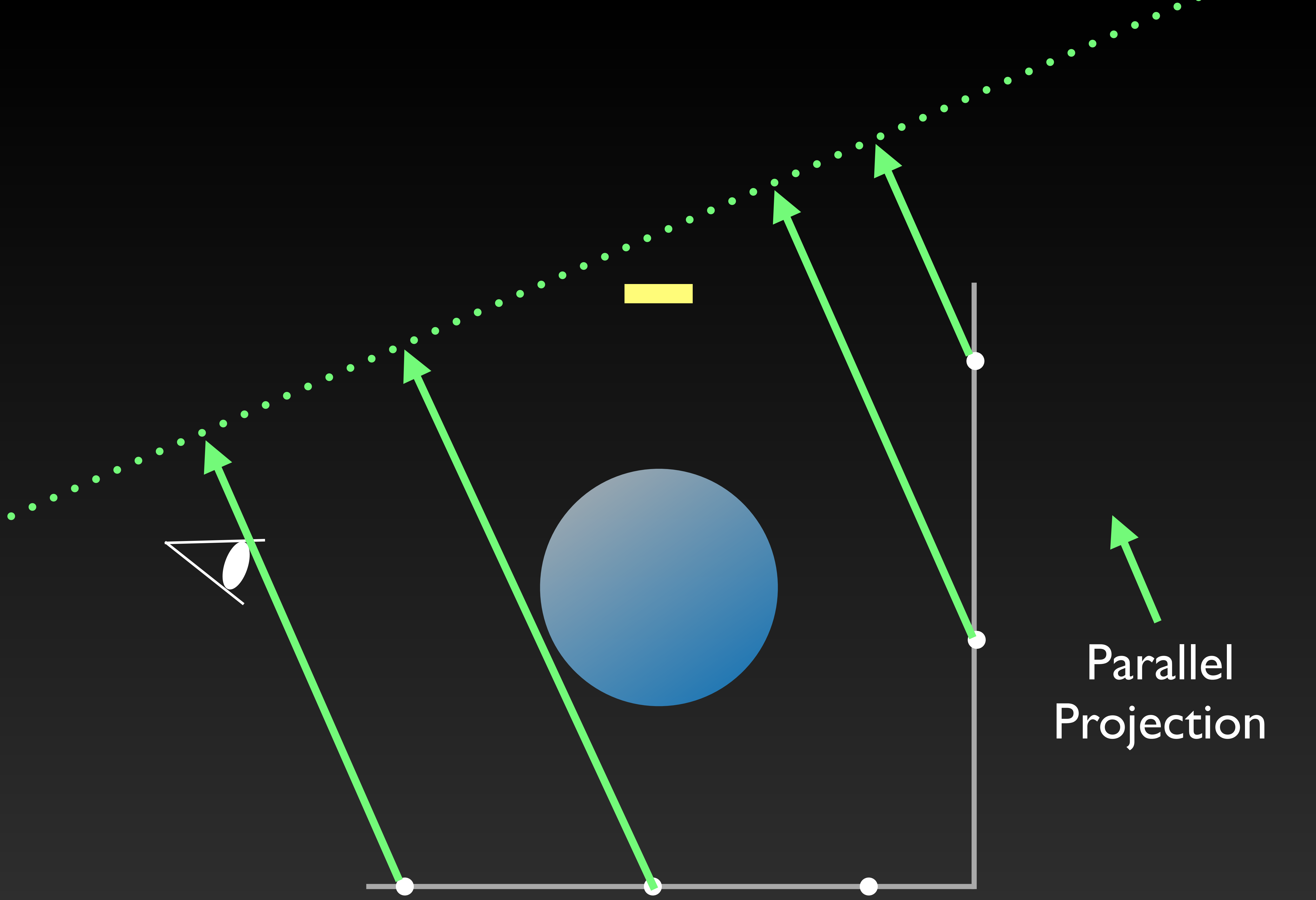
Grouping by Direction

- Ray bundle [Szirmay-Kalos and Purgathofer 1998]
- Can be mapped into a parallel projection

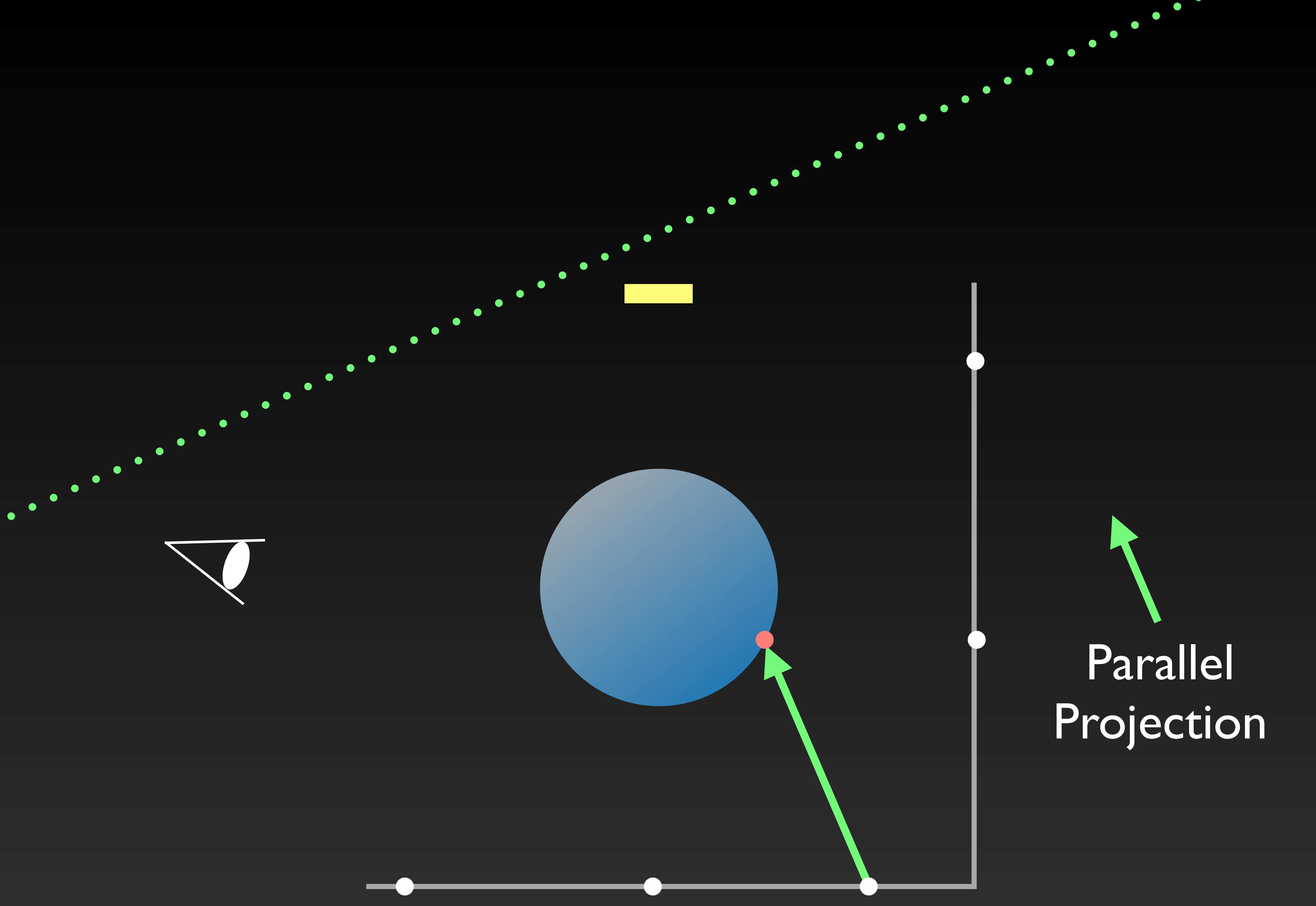





Parallel
Projection



Parallel Projection

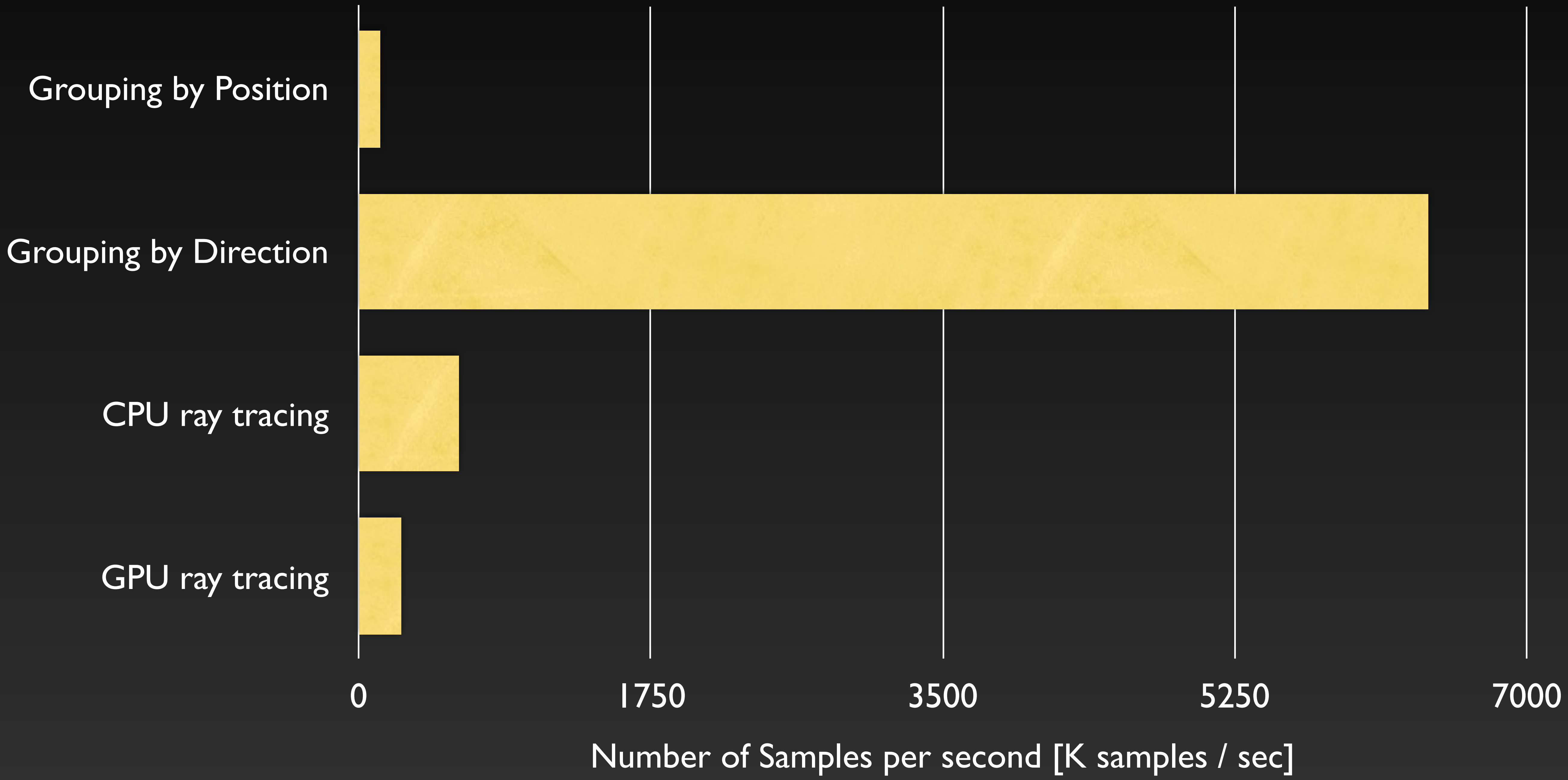

Parallel
Projection

Grouping by Direction

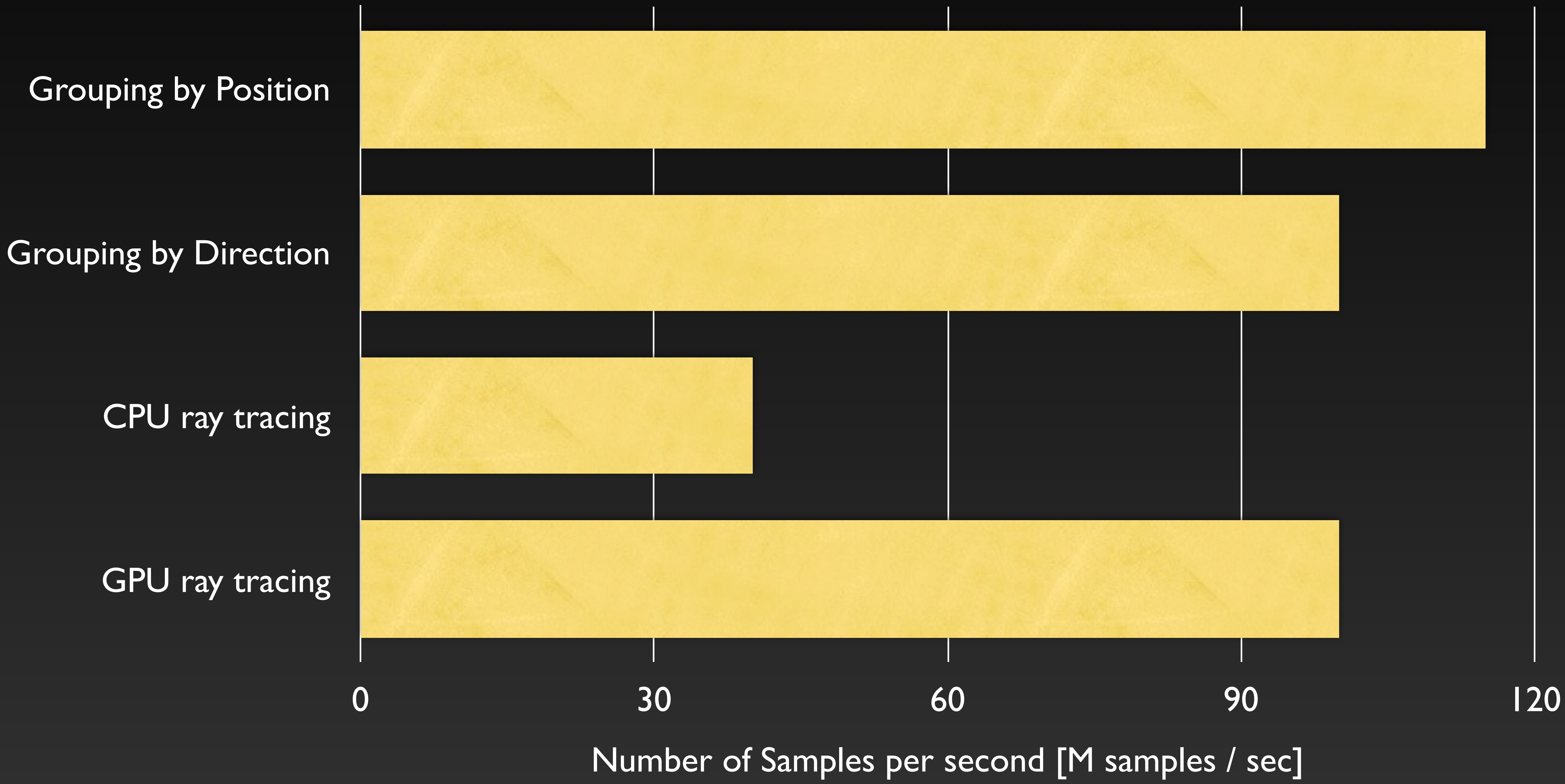
- Significantly fewer rasterizations of the scene
    - Number of final gathering directions
      = Number of final gathering samples
      = Number of rasterization passes
      = $O(100) \ll O(1M)$

- More details in GPU Gems 2

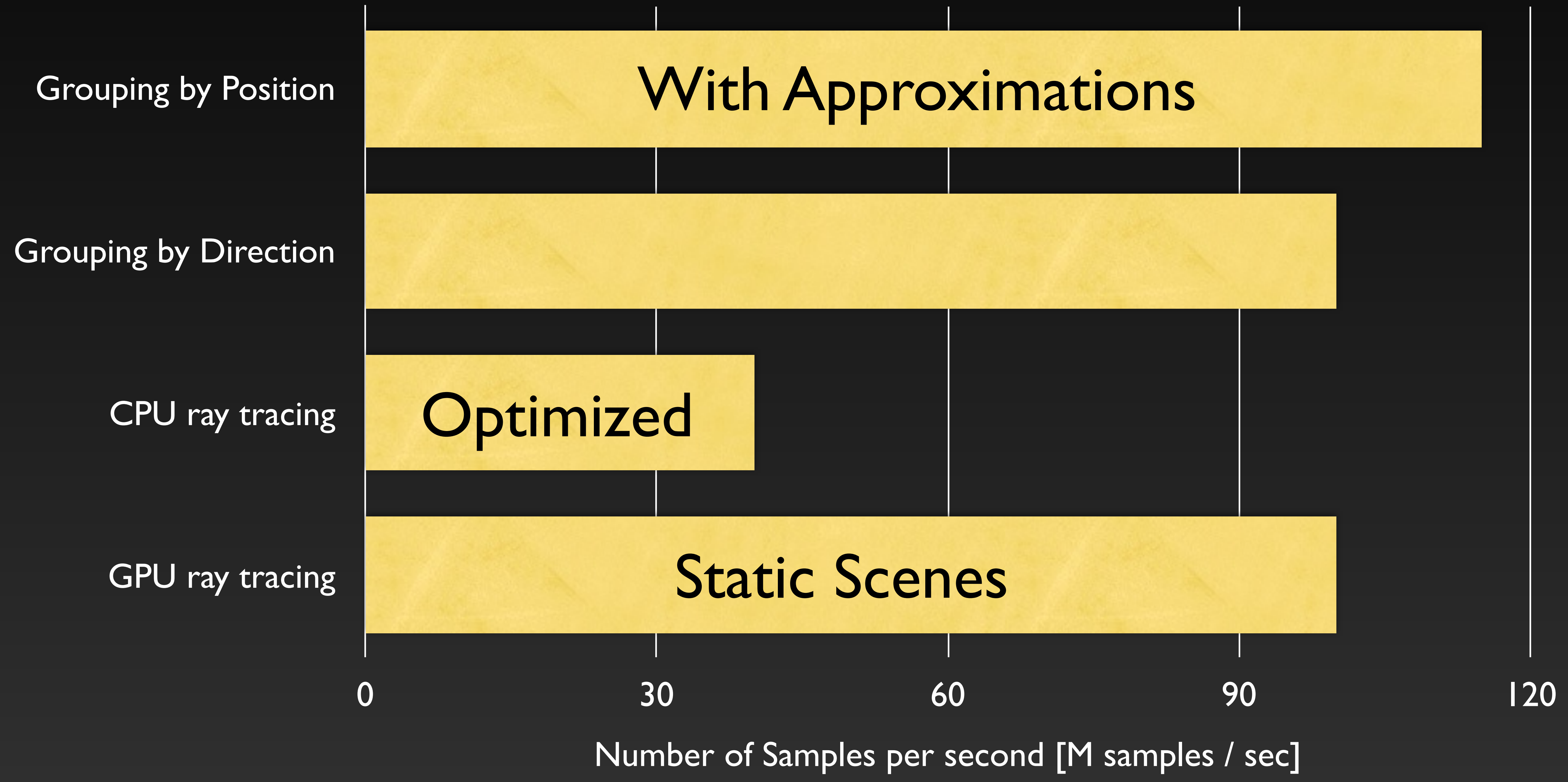
Performance in 2002



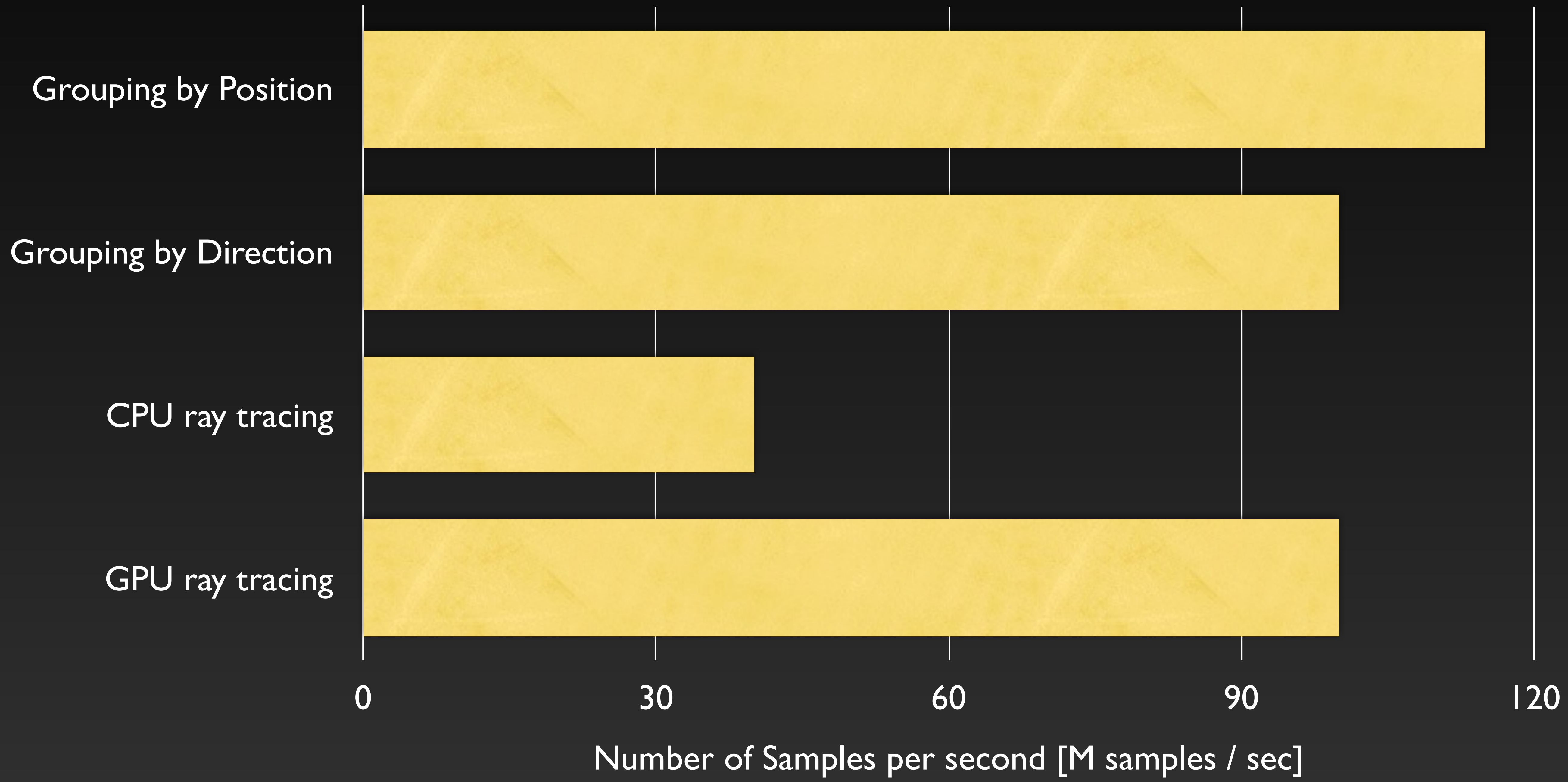
Performance in 2017



Performance in 2017



Does this make sense today?



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- CPU
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- GPU
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Do both at the same time

- GPU
  - Final gathering

Asynchronous Computation

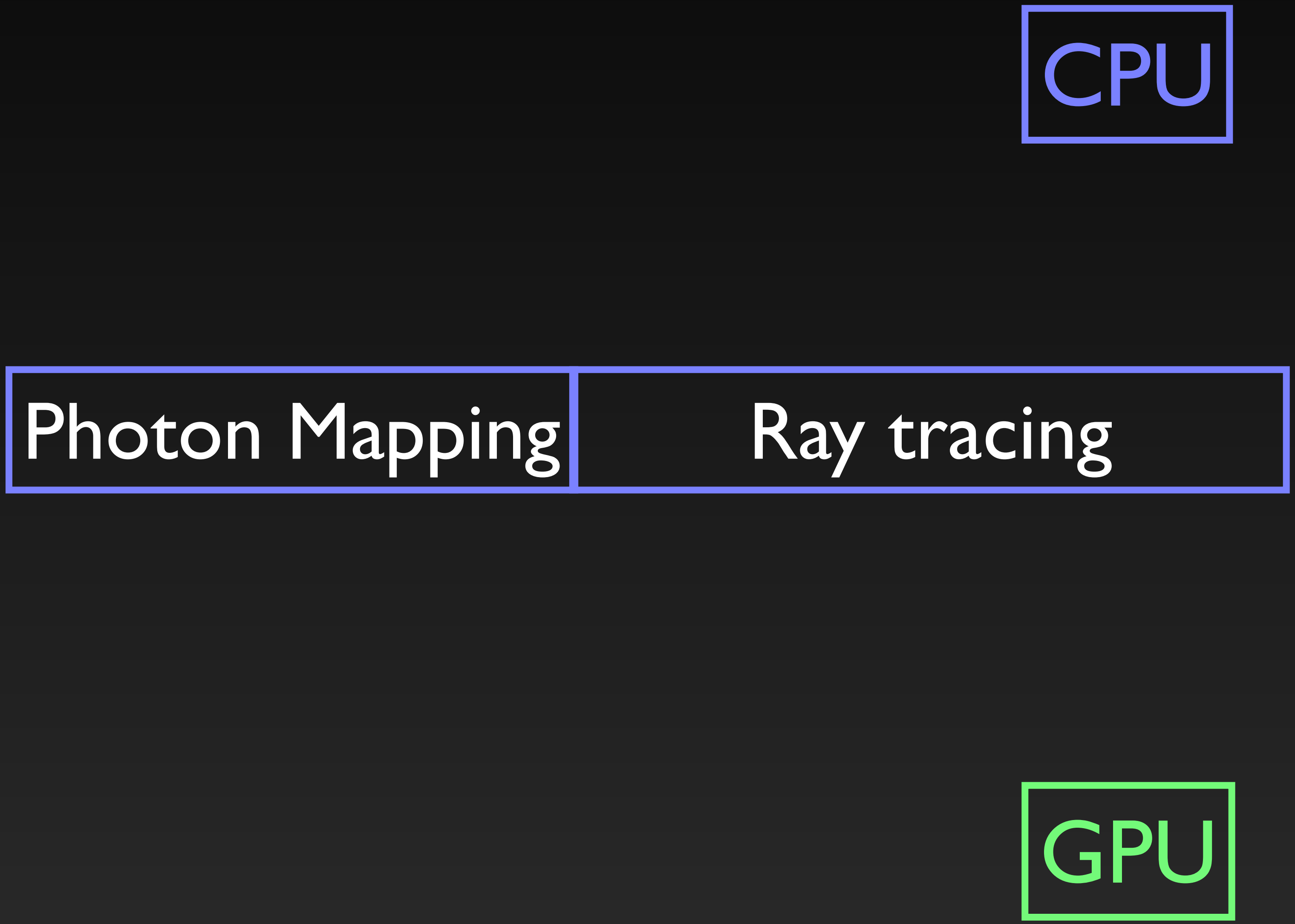
Asynchronous Computation

CPU

Photon Mapping

GPU

Asynchronous Computation



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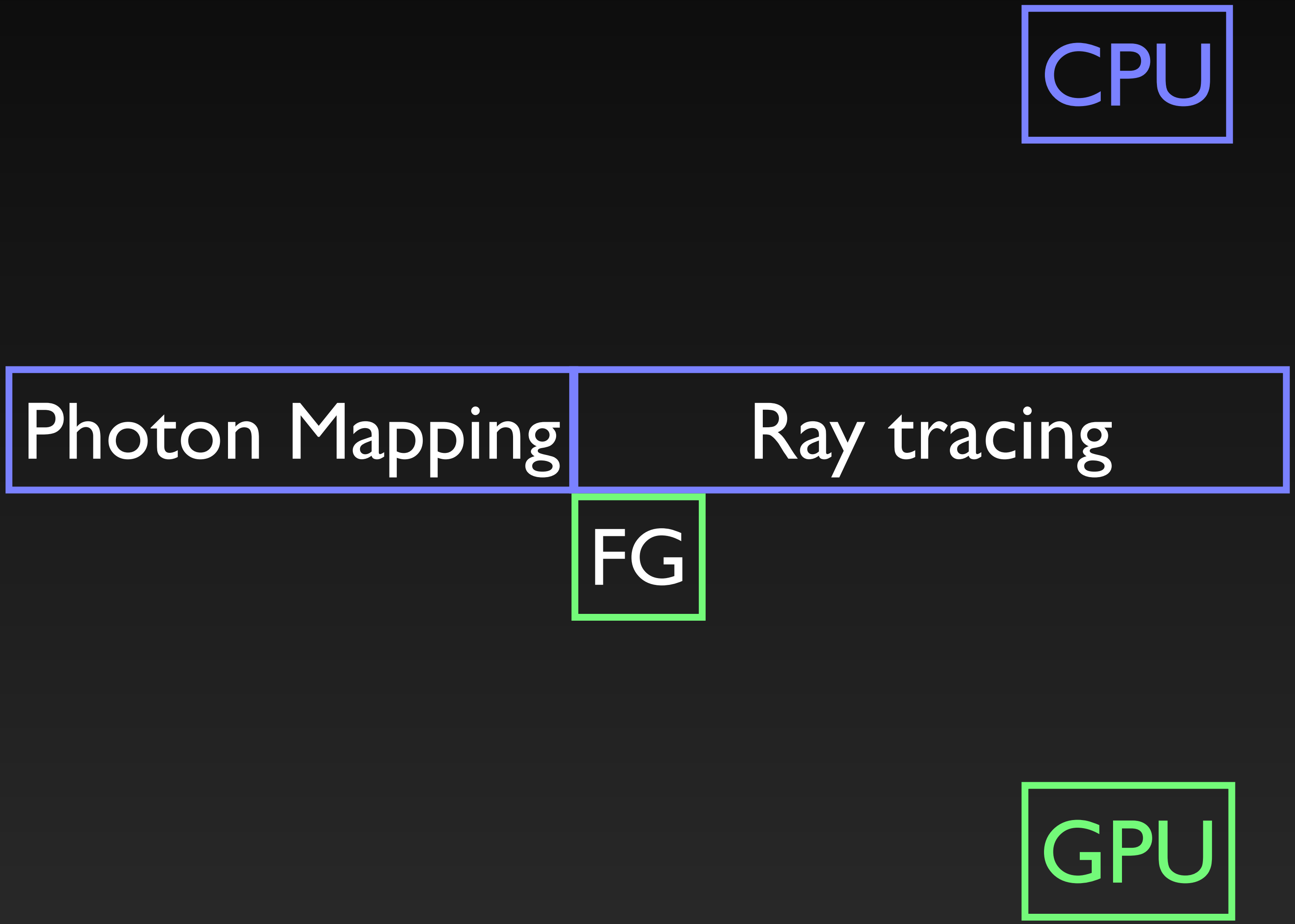

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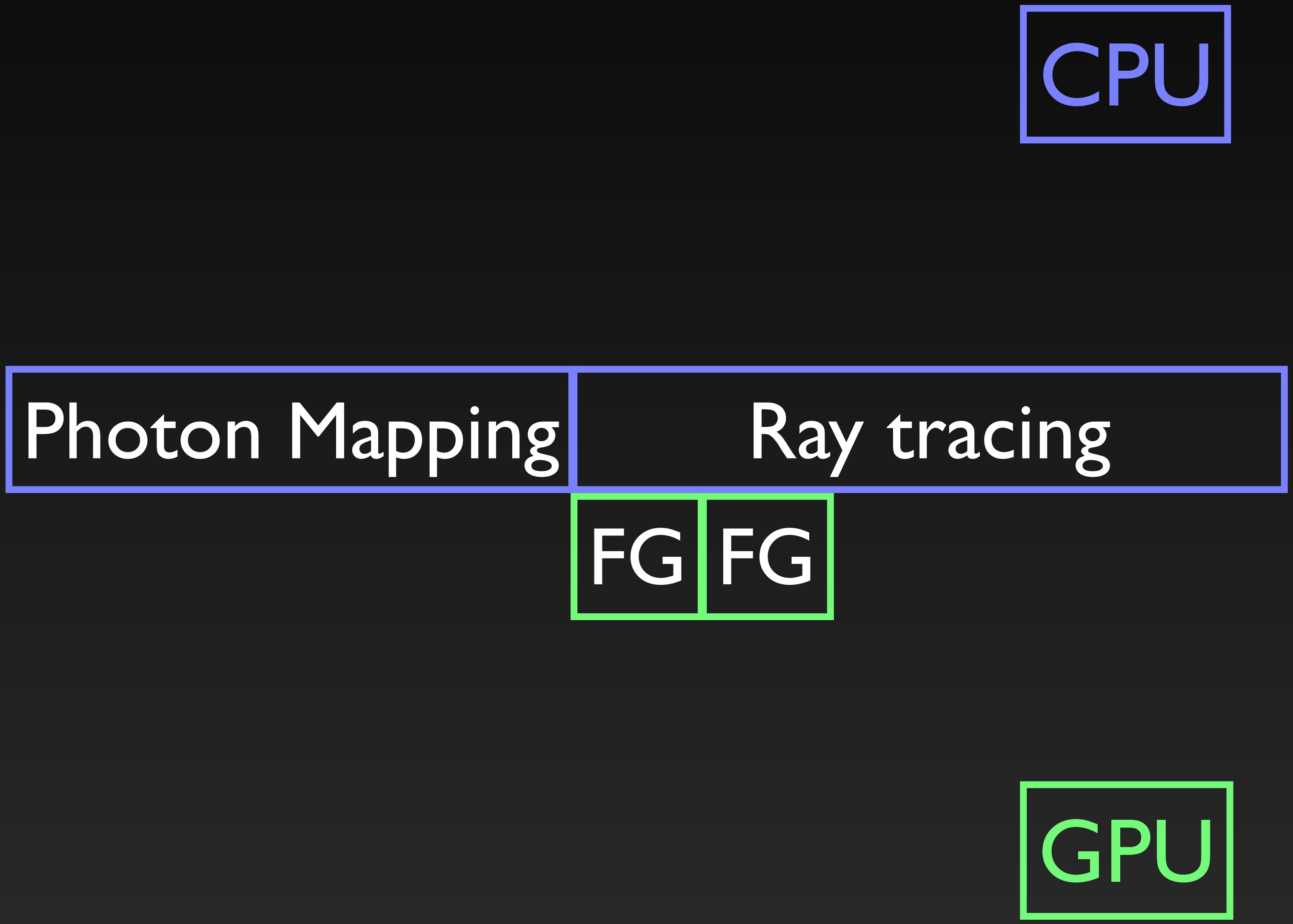

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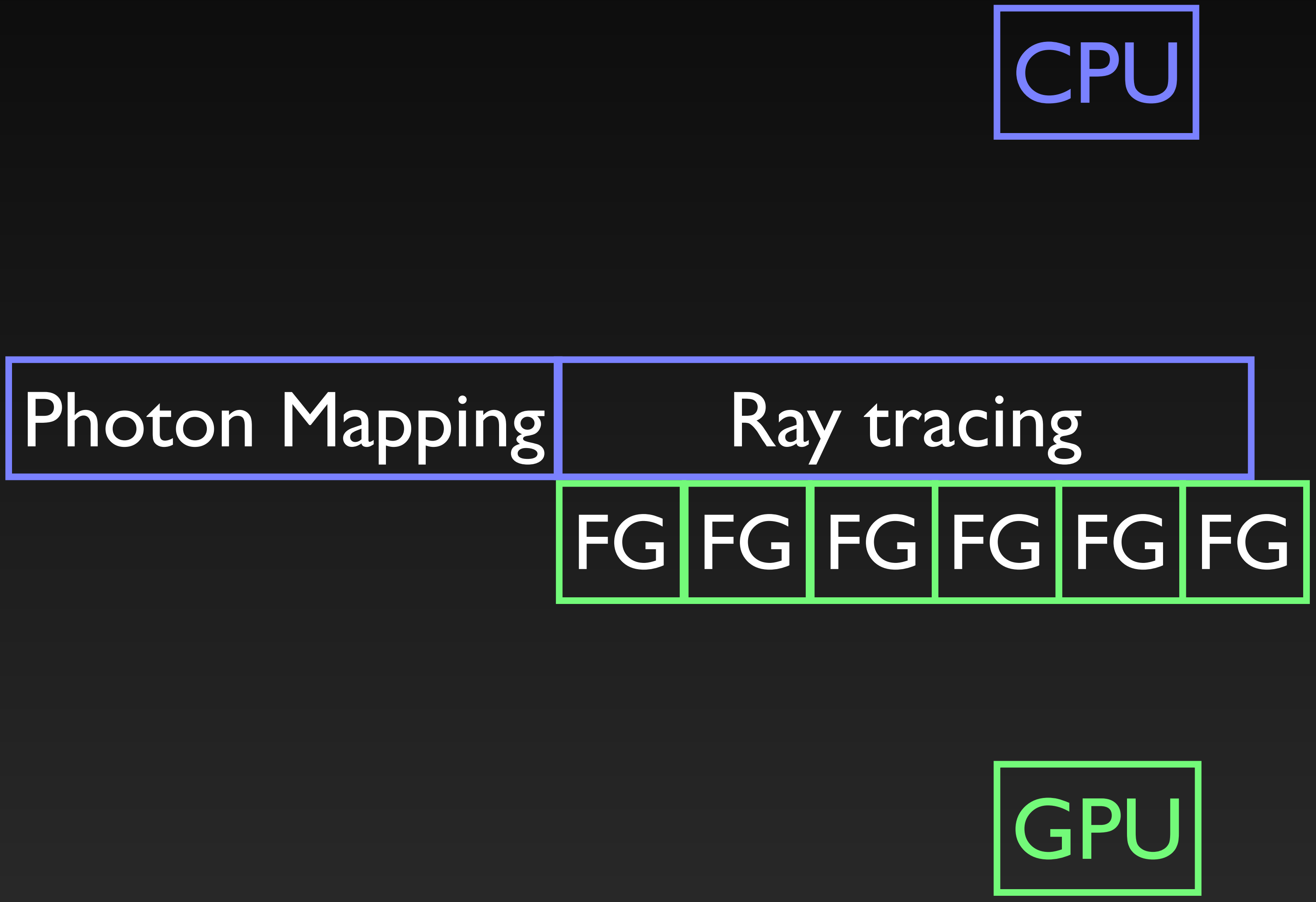

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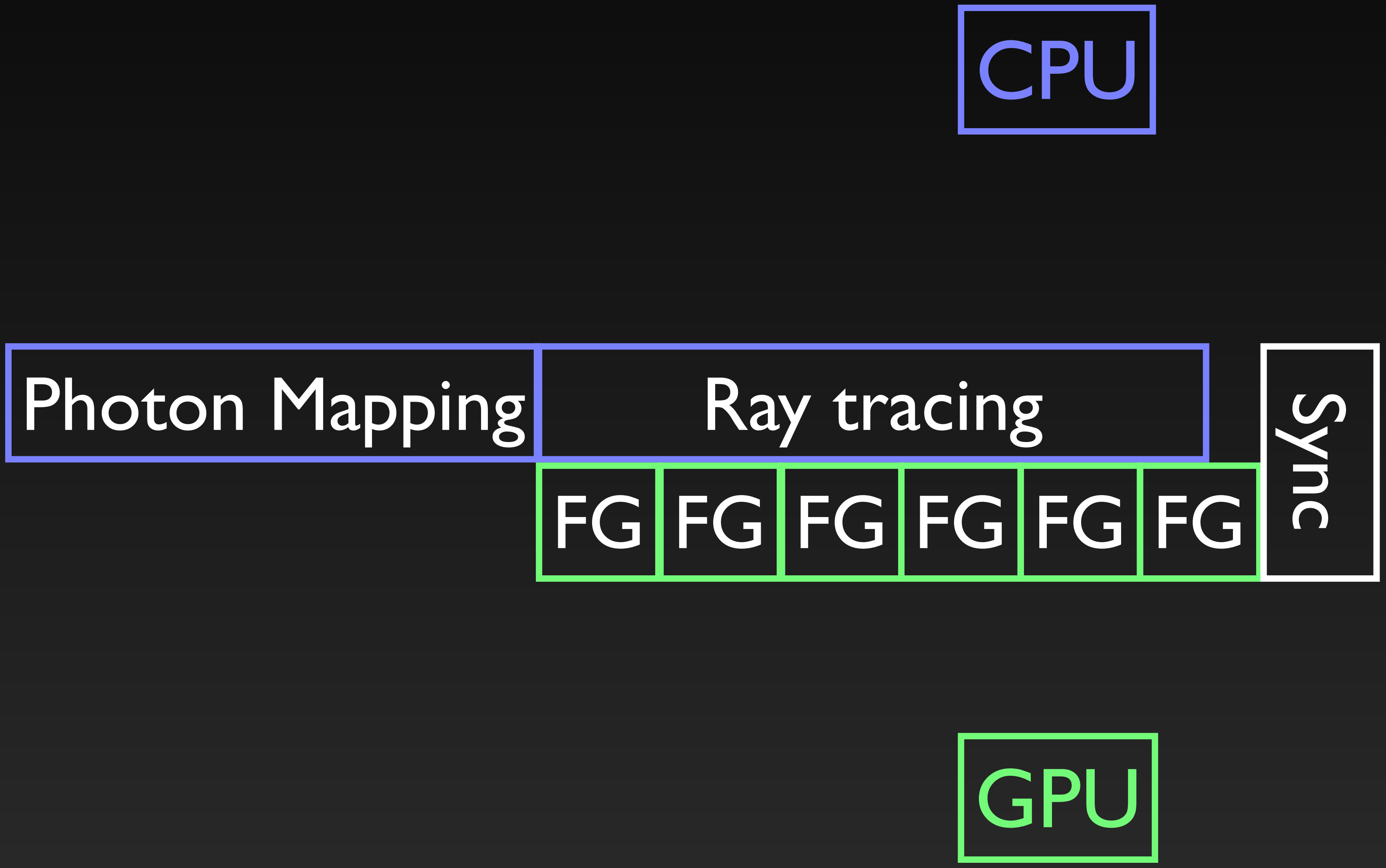

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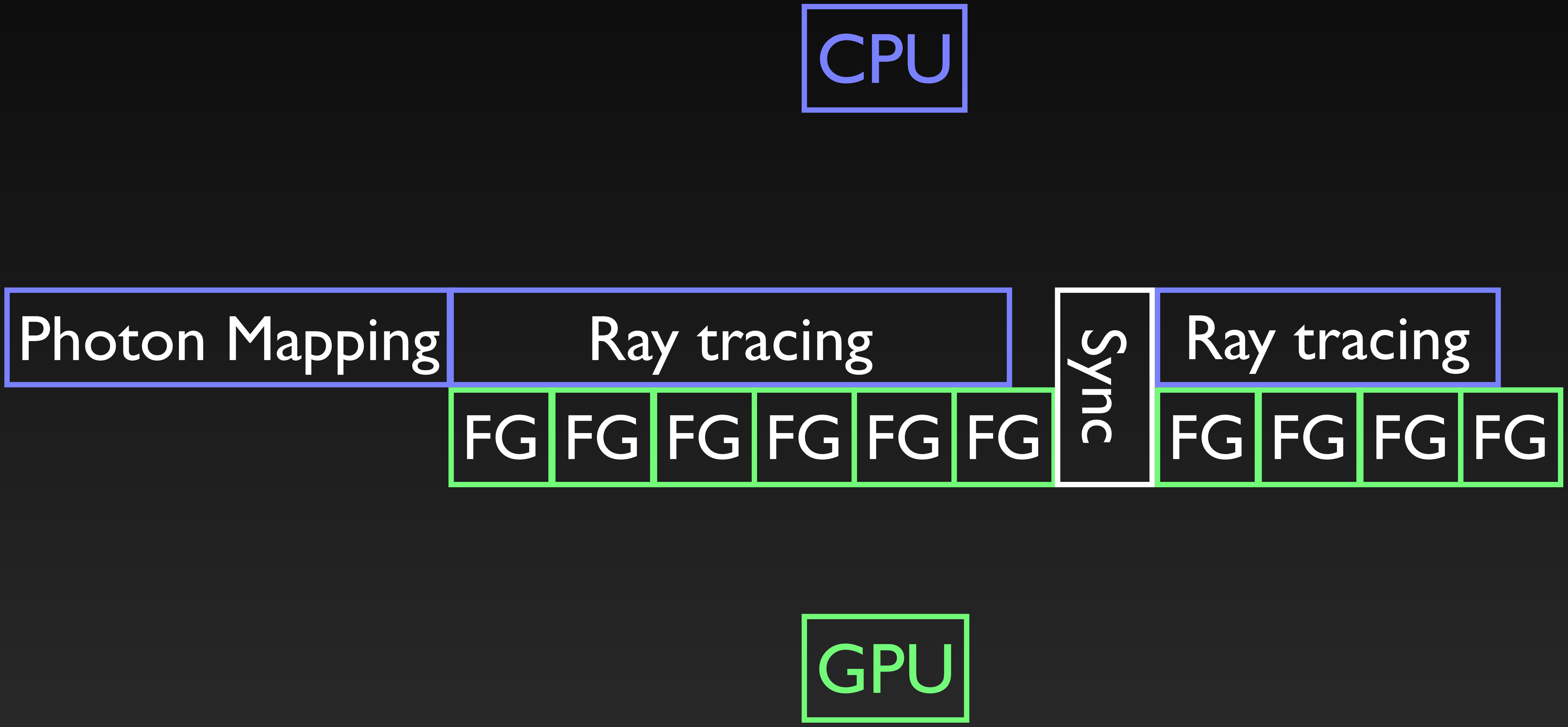

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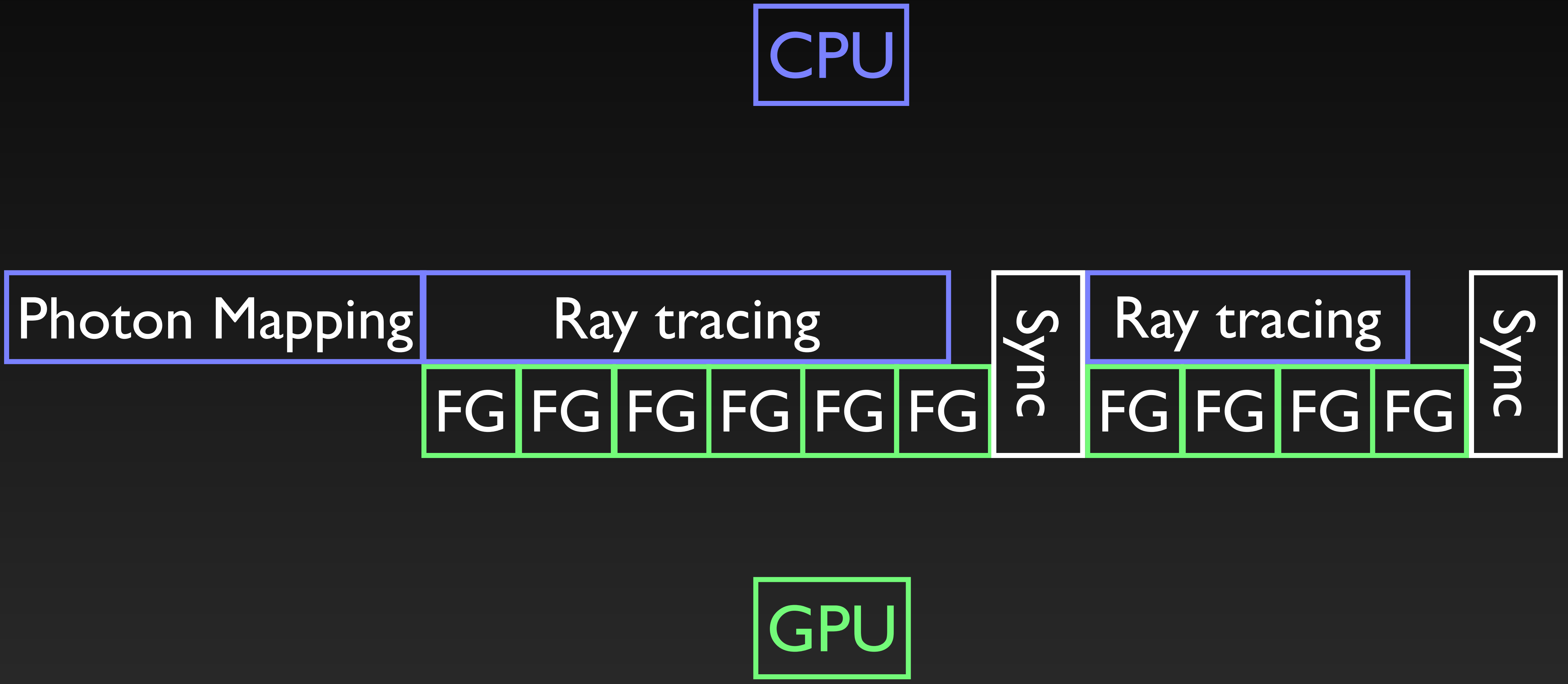

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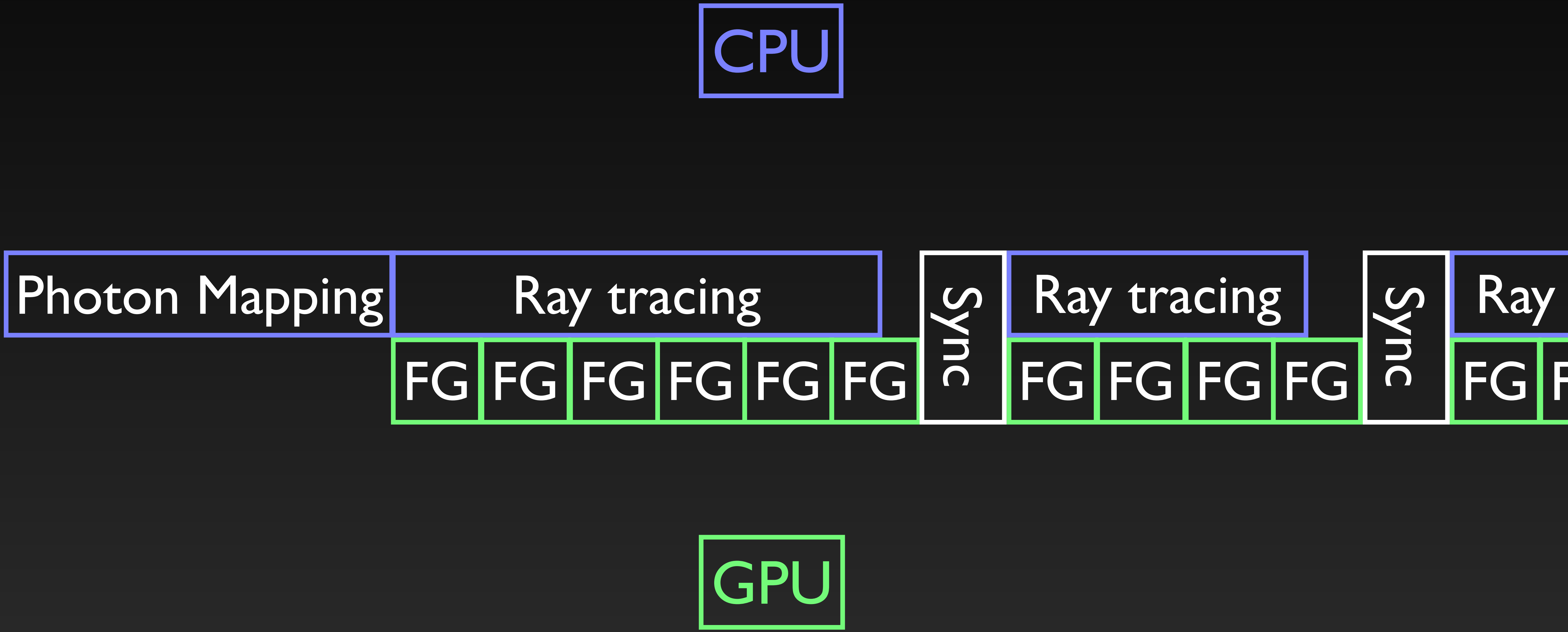

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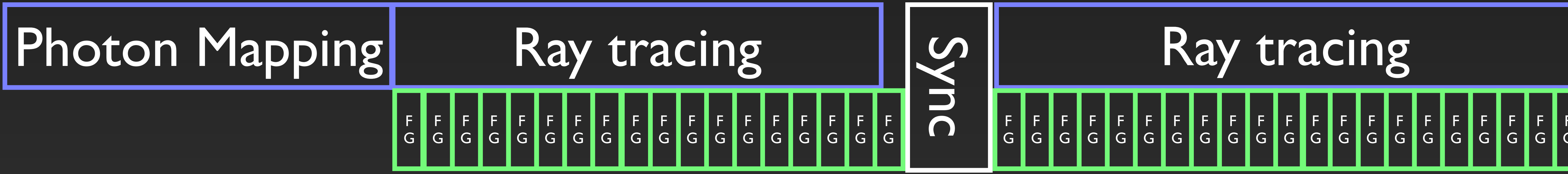
- 40 FG samples ≈ 1 RT sample (in 2002)
- 400 FG samples ≈ 1 RT sample (in 2017)



Some Other Details

- Utilizes shadow mapping units
    - Direct illumination and 1st photon trace
    - Fake caustics
- Über shader (i.e., single shader handles all materials)
    - No choice in 2002
    - Still compromised choice today for some systems

Closing Remarks

In retrospect ...

- Testing for many GPUs was painful
  - Parthenon runs on both Radeon and GeForce
  - Only solution for testing is to actually run
  - Checking specs do not help in the end, you know
- Still true today
  - Worse in my opinion since GPUs are everywhere

In retrospect ...

- Heterogeneous computation was painful
  - Power balance of CPU and GPU has changed a lot
  - Managing duplicated codes for CPU and GPU
- Maybe still true today
  - OpenCL can be a solution if it works as designed

In retrospect ...

- Going to the right direction of GPU rendering
  - but too early - users were not ready
  - and too immature - technology was not there

- Still somewhat true today, but much better
  - People recognized well what GPUs can do
  - Virtually anything on CPUs can be done on GPUs

Summary

- Parthenon Renderer
  - One of the first GPU rendering systems
  - Many choices are out-of-date, but not all of them
- Some remarks
  - Heterogeneous computing might not be a good idea
  - Supporting different GPUs can still be painful
  - Old techniques for high-ends can be useful and practical for low-ends now