Lesson 6
HDR: Tone Mapping, Bloom effect
PV227 – GPU Rendering

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31. 10. 2018

HDR – Theory Basics

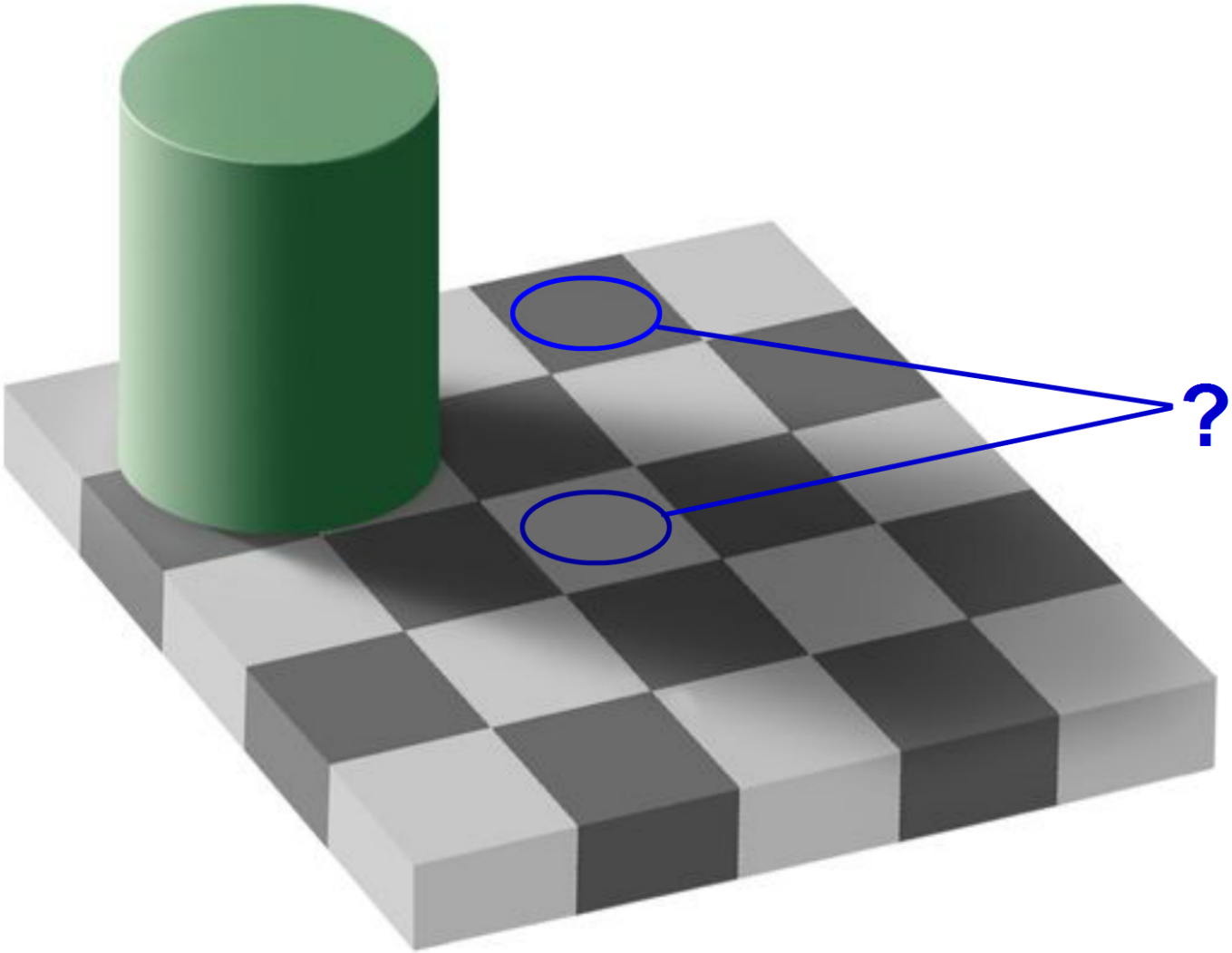
- High Dynamic Range
  - HDRI (“high dynamic range imaging”)
  - HDRR (“high dynamic range rendering”)
- Developed to make on-screeen rendering more natural (human-eye like)
- Range of intensities:
  - software: often only 8 bits $\Rightarrow$ only 256 steps
  - hardware: quite limited (black is not black, bright white is much less brighter than sun light)
  - human eye. . .

Human Eye – Range of perceptible intensities

illumination condition	illuminance (lux)
Full moon	1
Street lighting	10
Home lighting	30 to 300
Office desk lighting	100 to 1 000
Surgery lighting	10 000
Direct sunlight	100 000

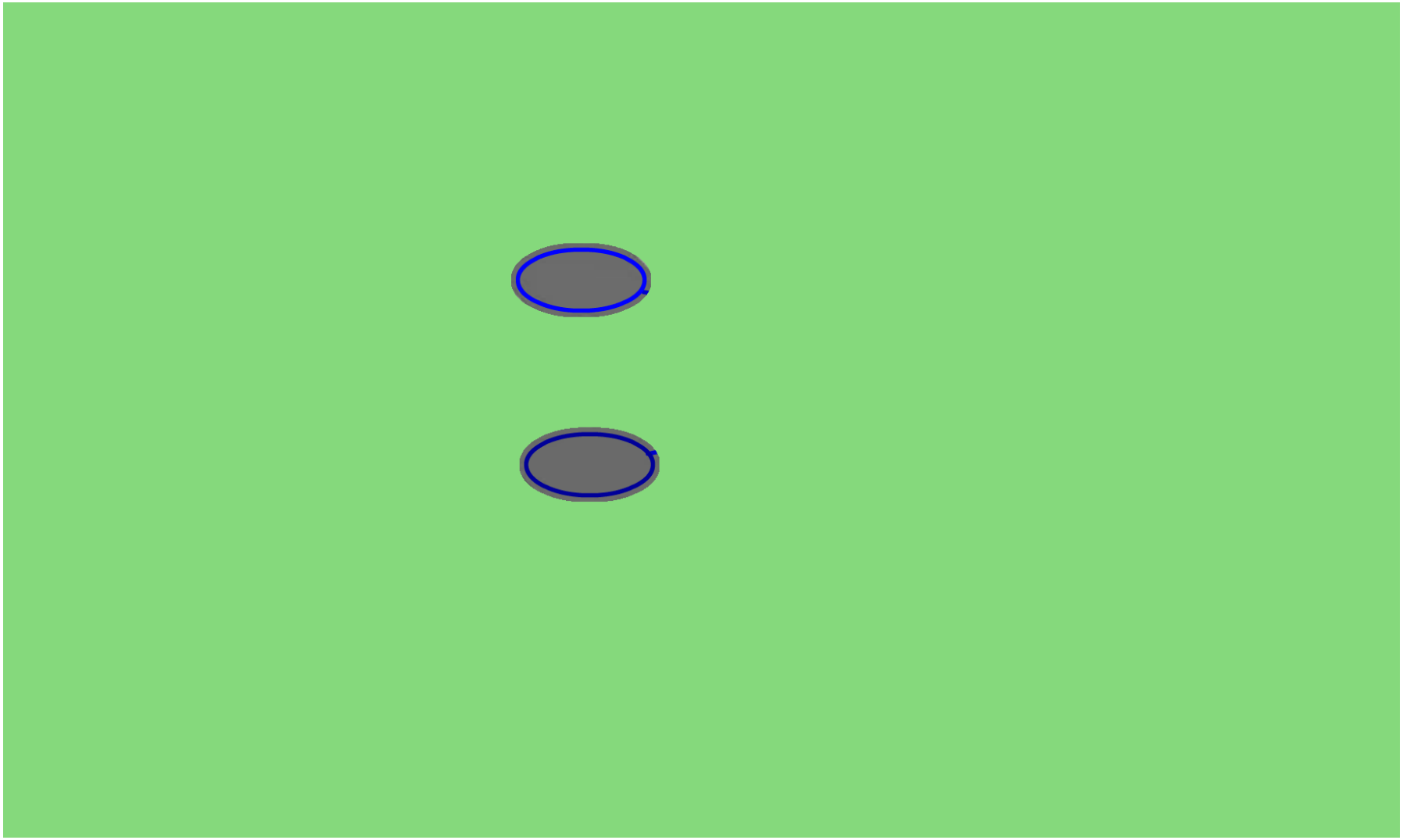
Vast range of perceptible intensities. But not **concurrently**!

Human Eye Perception Imperfection



What are the colors of marked fields?

Human Eye Perception Imperfection



What are the colors of marked fields? The SAME!

Capturing, Rendering

- We can capture (or model) and “realistically” render both the dark scenes and the bright scenes without HDR.

- The problem is with scenes with high dynamic range...

Capturing HDR Content

To capture HDR content with LDR camera:

1. capture more shots with different exposure settings
2. Compose final image with “tone mapping” technique

EV -4

EV -1

EV +1

EV +4

Source: https://en.wikipedia.org/wiki/High-dynamic-range_imaging

Rendering HDR Content

Various methods to convert HDR content into LDR image exists:

Contrast reduction

Local tone mapping

HDR Effects

- Bloom (blooming, glow) – “overflowing” of light to surrounding objects
- Other buffers, techniques:
  - light maps,
  - skybox,
  - . . .
- Advanced technique: “Temporally Coherent Local Tone Mapping”: https://youtu.be/6yItM8UB7k4

Implemantation of HDR Rendering

- Common color buffer format: R8G8B8
  - Don't forget: values are clamped to range $< 0.0, 1.0 >$
- We need high dynamic range buffer
  - We can simply switch to R16G16B16A16F
  - No clamping of values

```
glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA16F, win_width,
win_height, 0, GL_RGBA, GL_FLOAT, nullptr);
```

HDR Tone Mapping – Overview

- Set-up HDR buffer (TASK 1)
- First pass: compute lighting of scene into HDR buffer
  - The SAME computations, just no clamping of values
- Second pass: use one of algorithms to tone map HDR buffer to (LDR) frame-buffer (TASK 2)
- Following passes: reuse existing HDR buffer to other effects...

Tone Mapping – “Reinhard” technique

Among the simplest tone mapping techniques – simple remapping of HDR values to range $< 0.0, 1.0 >$ by division.

```
// read color from HDR texture
vec3 hdrColor = texture(hdrBuffer, TexCoords).rgb;

// simple reinhard mapping
vec3 result = hdrColor / (hdrColor + vec3(1.0));
```

Tone Mapping – “Adjustable Exposure” technique

Allow us to render scene with different exposures:

$$rgb = 1 - 2^{-hdr * exposure}$$

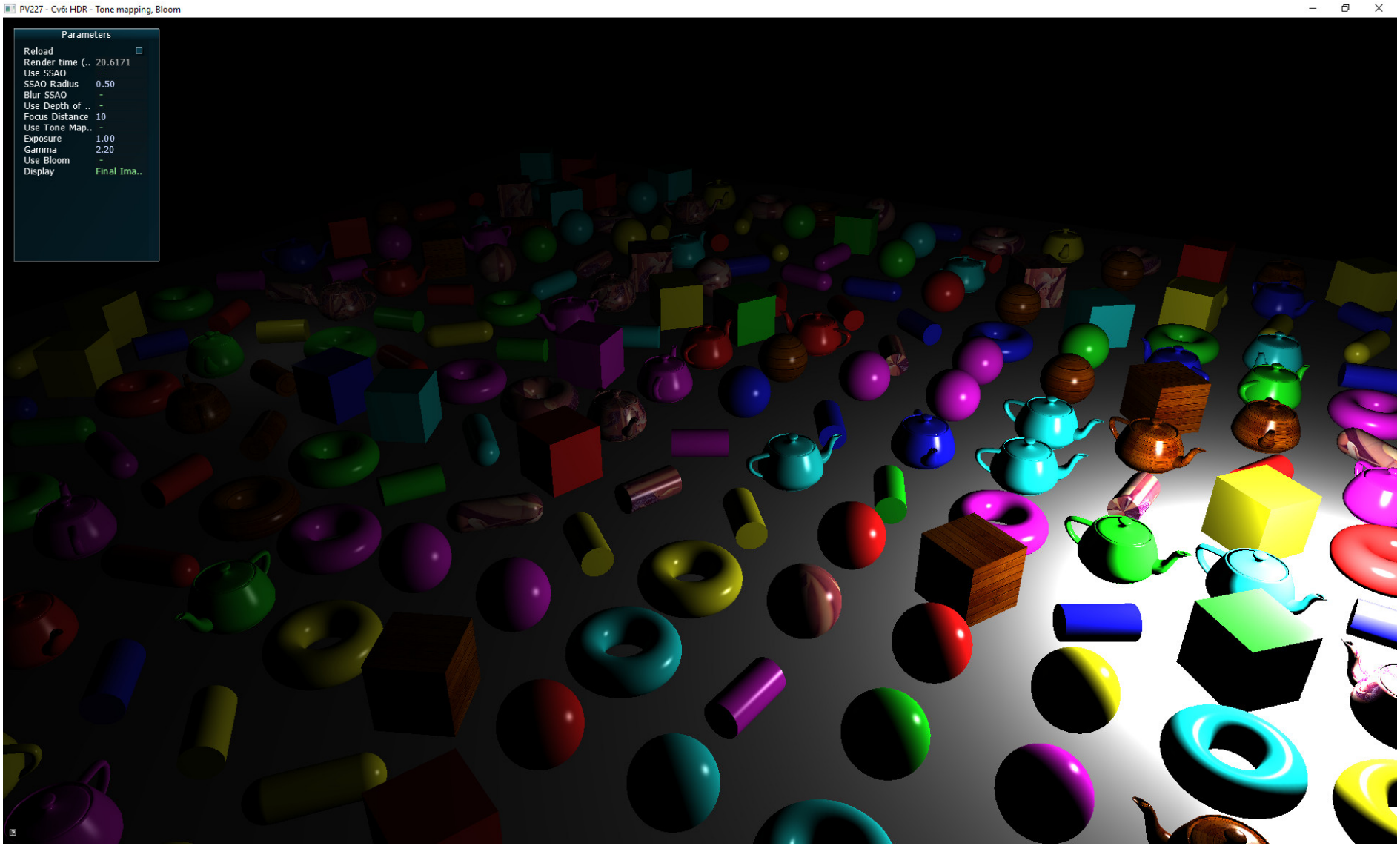
```
// read color from HDR texture
vec3 hdrColor = texture(hdrBuffer, TexCoords).rgb;

// Exposure tone mapping
vec3 mapped = vec3(1.0) - exp2(-hdrColor * exposure);
```

Tone Mapping – Gamma Correction

Could be combined with all tone mapping techniques.

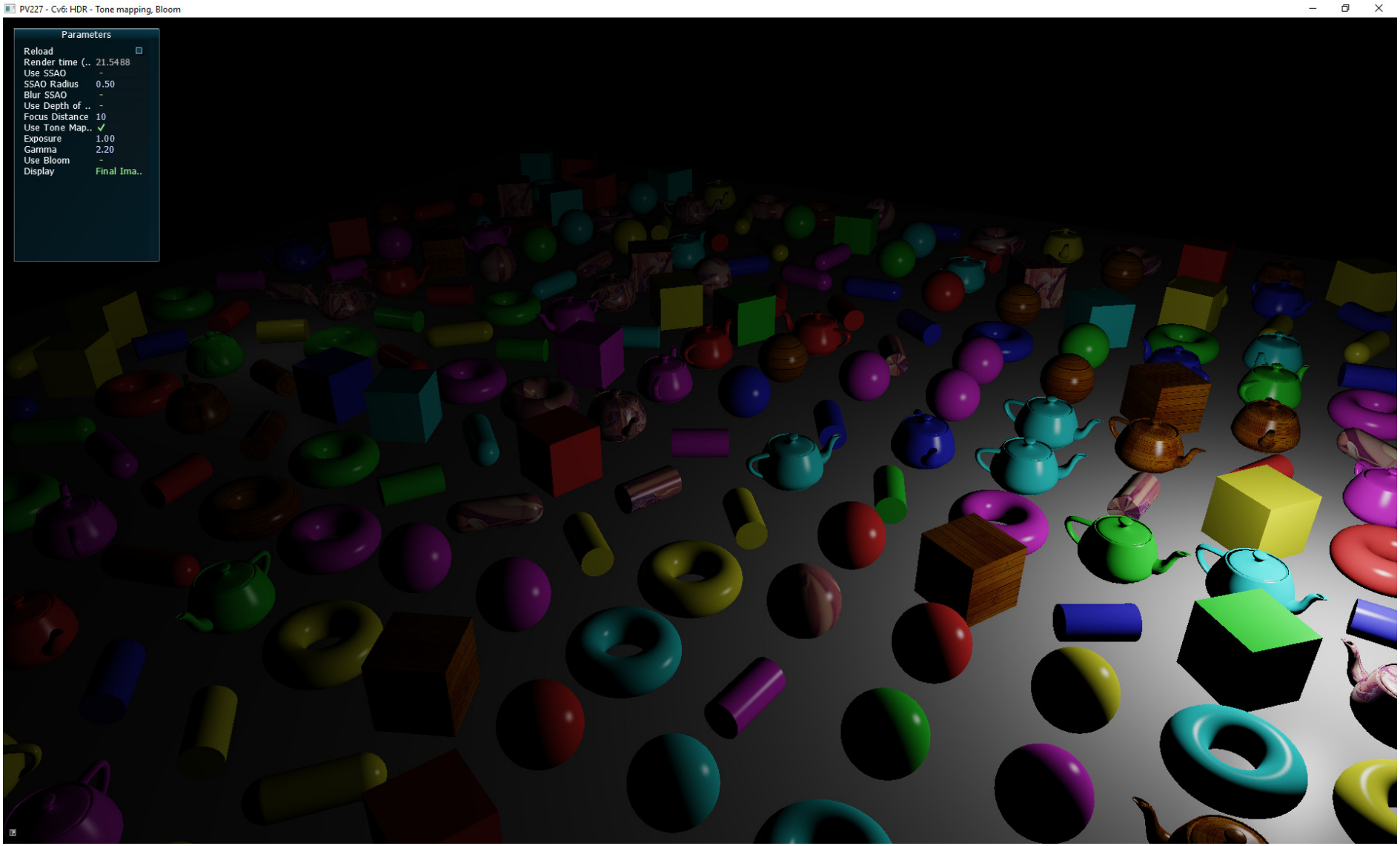
```
// read from texture
// Do a tone mapping
vec3 mapped = ...

// Gamma correction
mapped = pow(mapped, vec3(1.0 / gamma));
```

Tone Mapping – Results



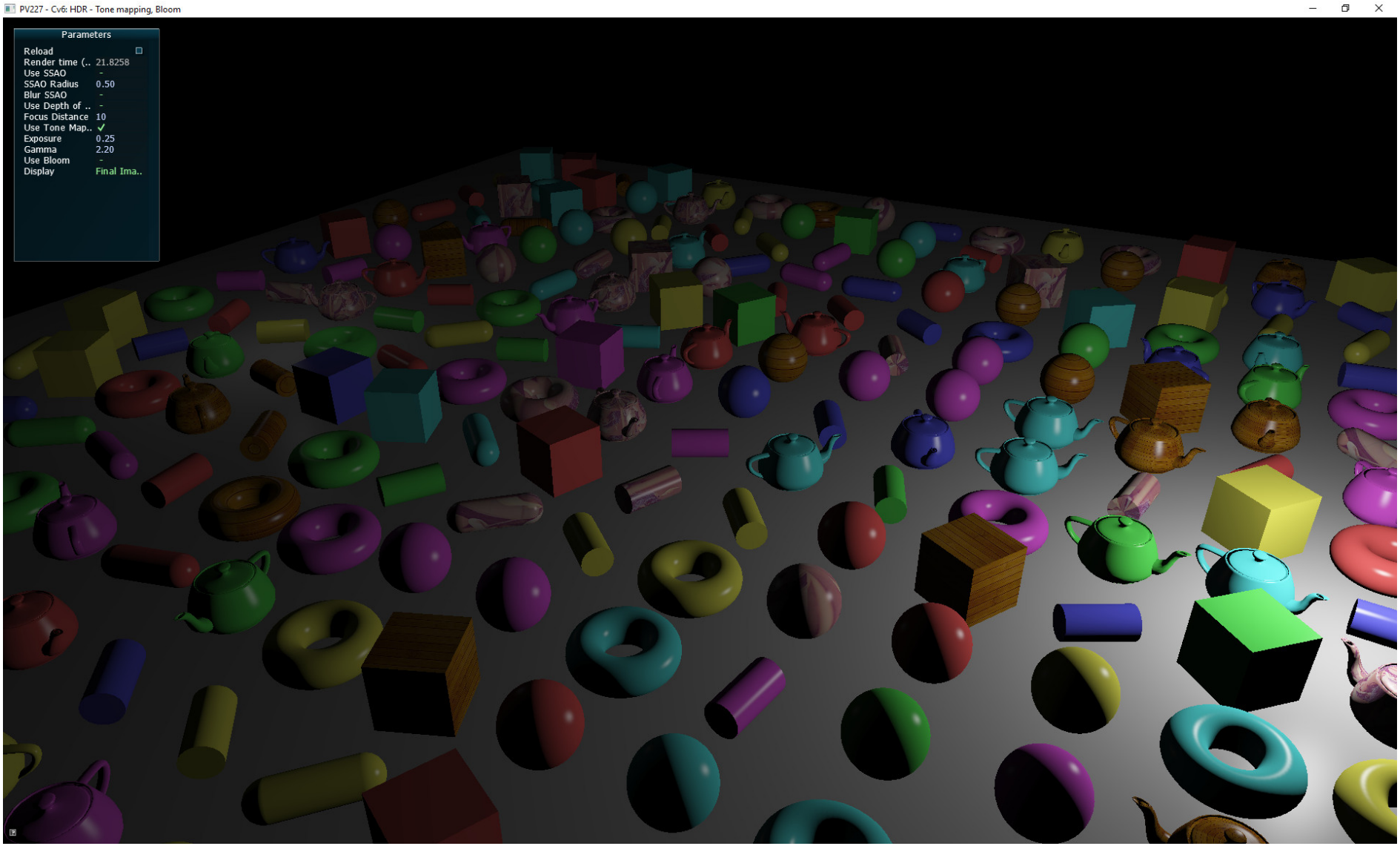
Tone mapping: none

Tone Mapping – Results



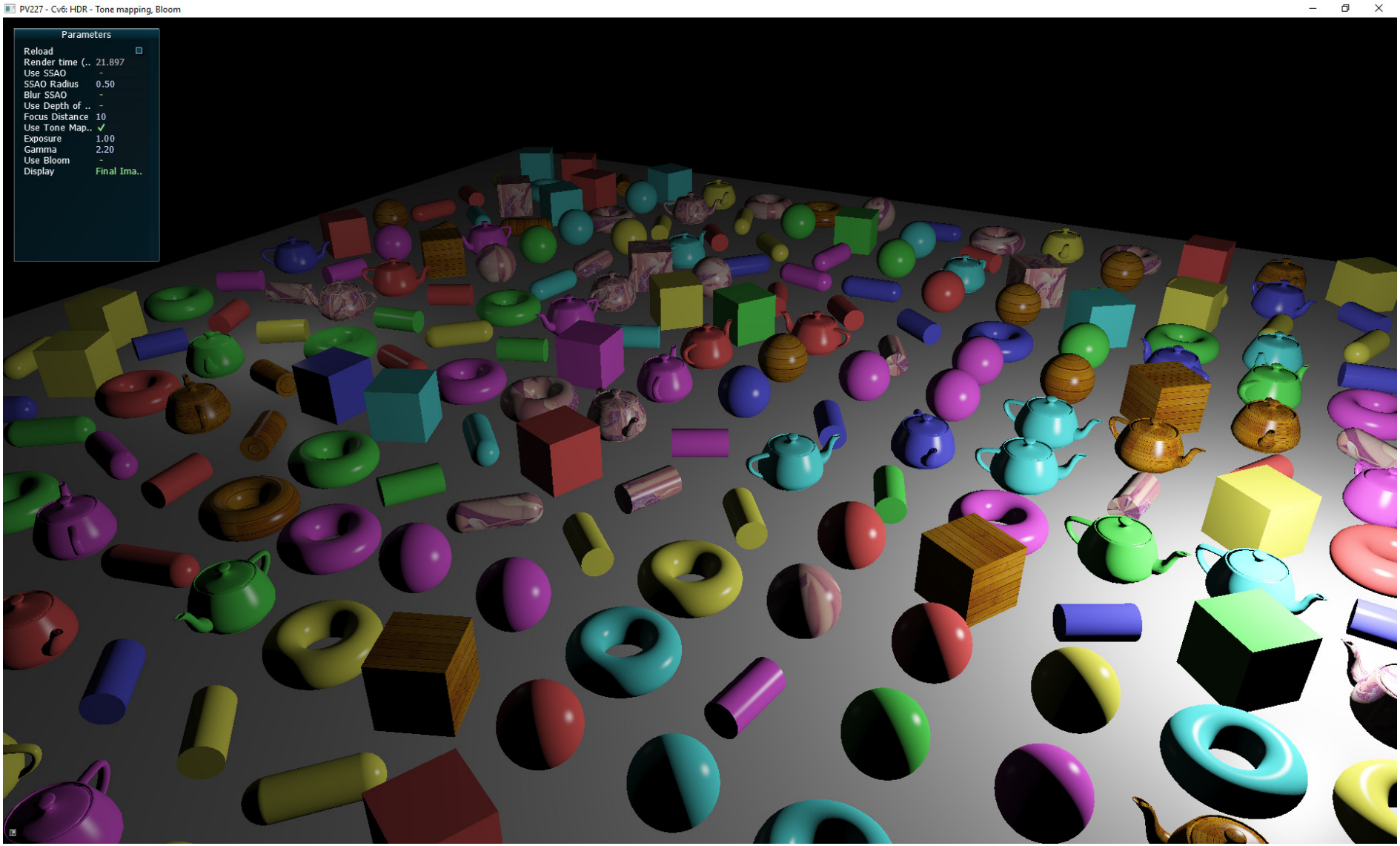
Tone mapping: “Reinhard” technique

Tone Mapping – Results



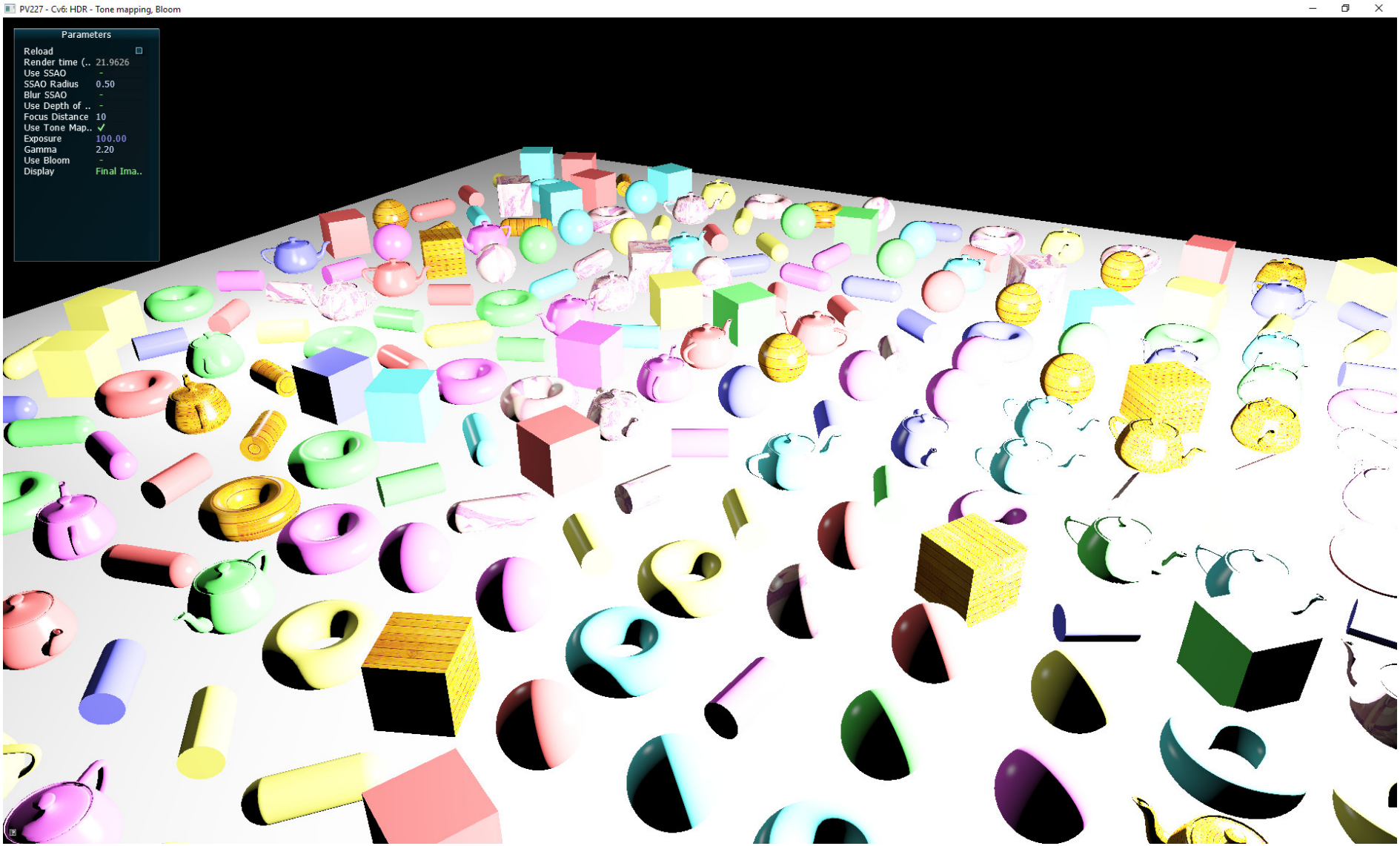
Tone mapping with exposure: 0.25

Tone Mapping – Results



Tone mapping with exposure: 1.0

Tone Mapping – Results



Tone mapping with exposure: 100

Bloom Effect (Blooming, Glow)

- Imperfection of human eye (or camera sensor) which is overwhelmed by bright light. Light is “overflowing” to surrounding cells (pixels).
- In CG – added artificially to increase realism.
- Bloom can be used also in LDR, but with HDR make more sense.

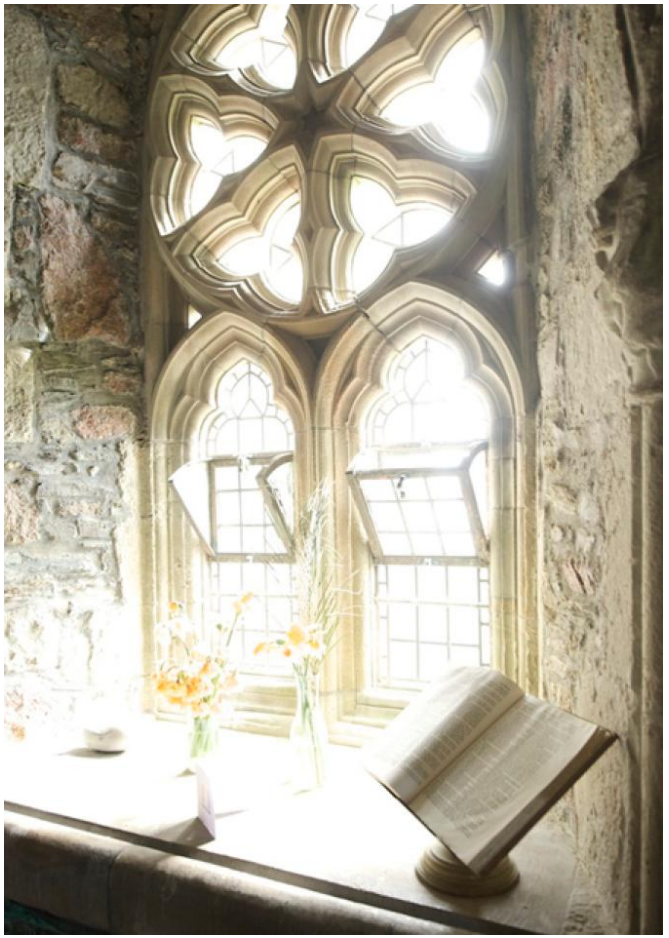


Figure Source: http://www.nationalgeographic.com/photography/photo-tips/overexposure-on-purpose-richardson/

Bloom Effect – CG example

Source: http://learnopengl.com/#!Advanced-Lighting/Bloom

Bloom Effect – Implementation Overview

1. Lit the scene (as always)
2. Fill buffer of pixels with high brightness (highlights) (TASK 3)
3. Blur the highlights buffer to simulate glow effect (TASK 4)
4. Compose original rendering with blurred highlights (TASK 5)

- How many passes we need?
- Do we need deferred shading? Can we exploit it? How?
- Where is HDR in this?

Bloom – Highlights Filtering (TASK3)

- In what shader?
- Compare fragment brightness to some threshold
  - We are working with HDR buffers, threshold could be simply 1.0f
  - Hint: brightness of pixel. . . `vec3(0.299f, 0.587f, 0.114f)`

Bloom – Blurring (TASK4)

Blurring shader

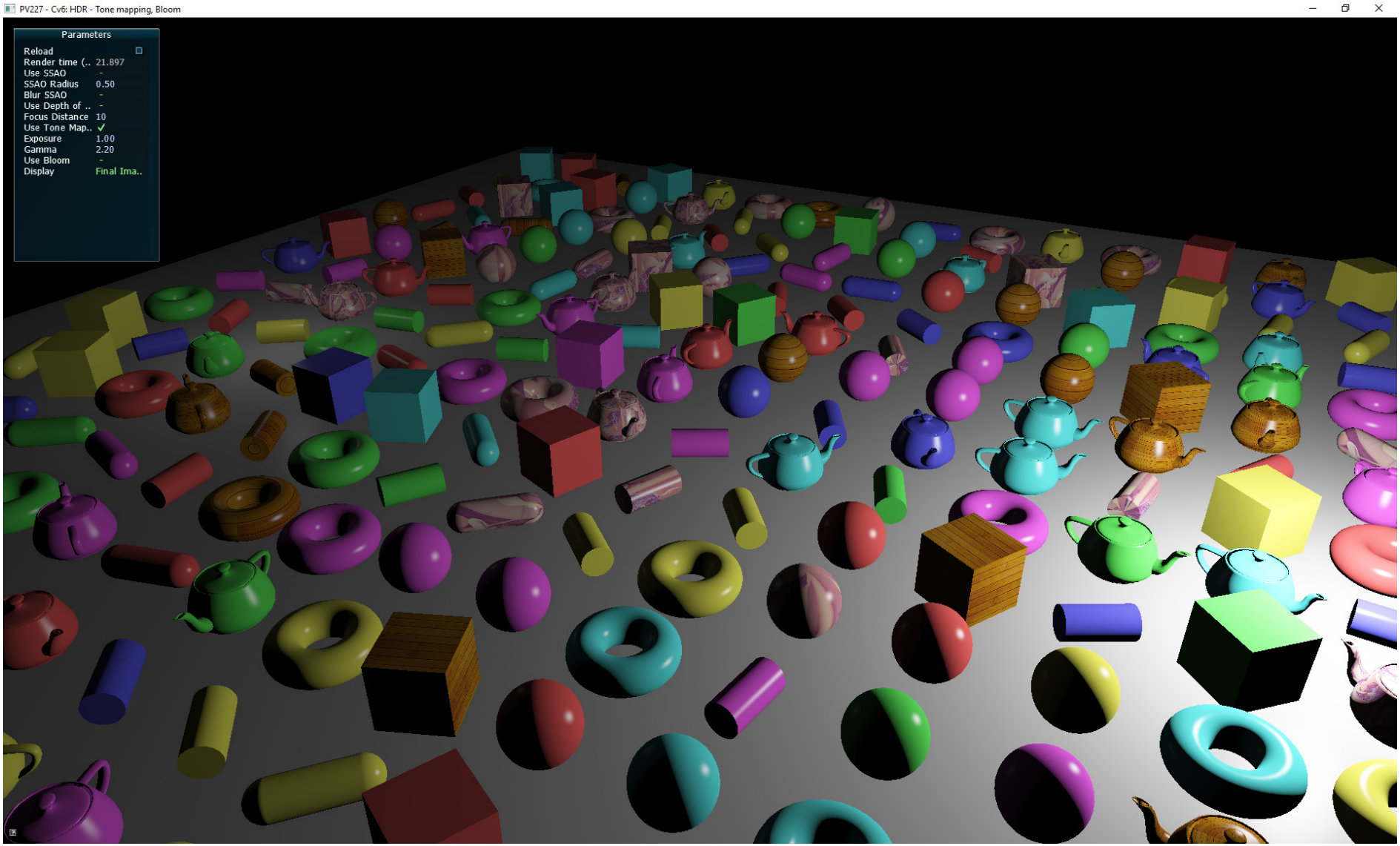
- What is difference from `blur_SSAO` shader?
- Blur possibilities:
  - Simple average
  - Gaussian
  - Repeated blurring – later
  - Separable kernels
  - ...
- Think about effectiveness

Bloom – Composition (TASK5)

Could be complicated in LDR, pretty easy with HDR buffers:

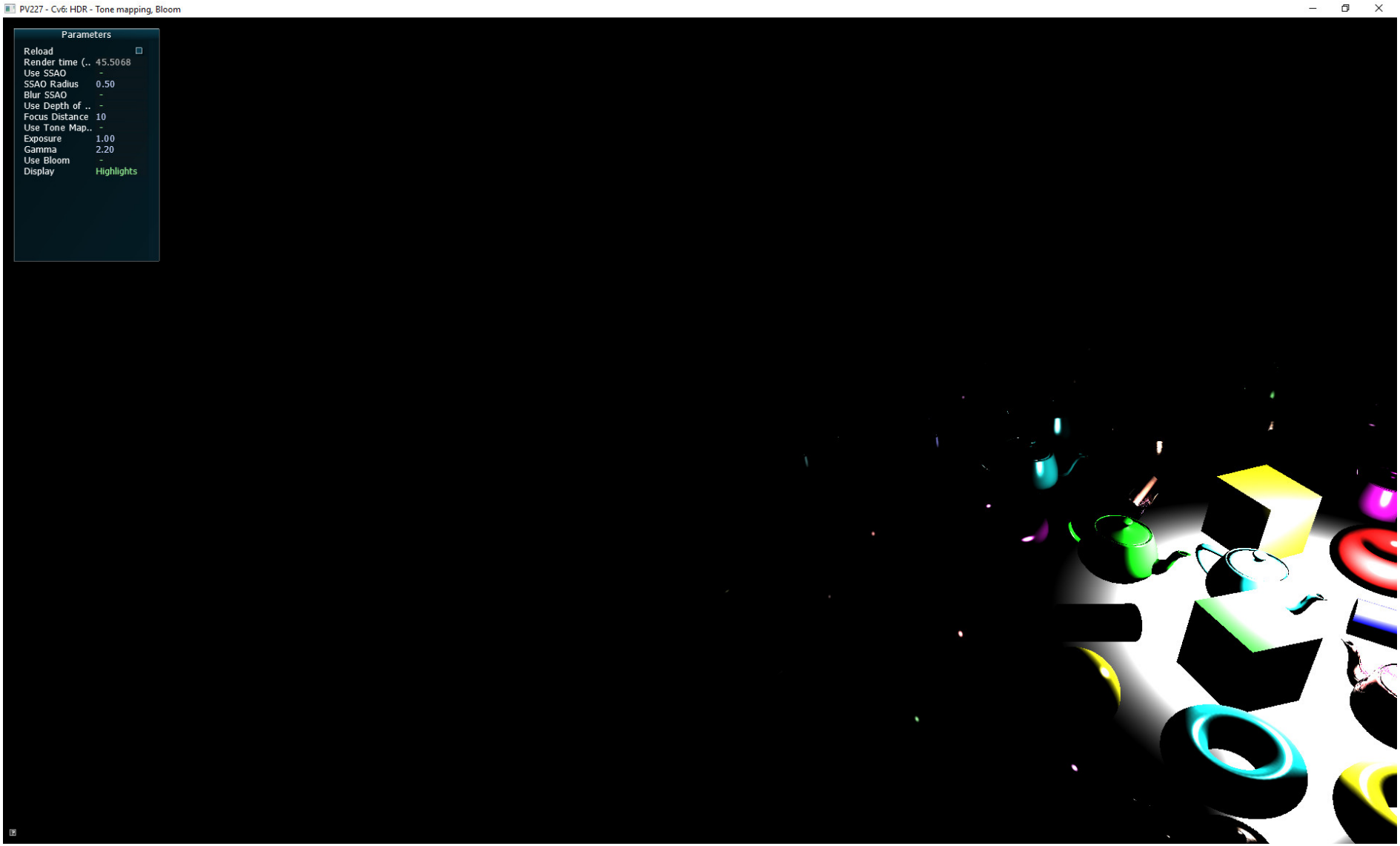
1. Simply add values of lit scene and blurred highlights
2. Use tone mapping as before

Bloom – Results



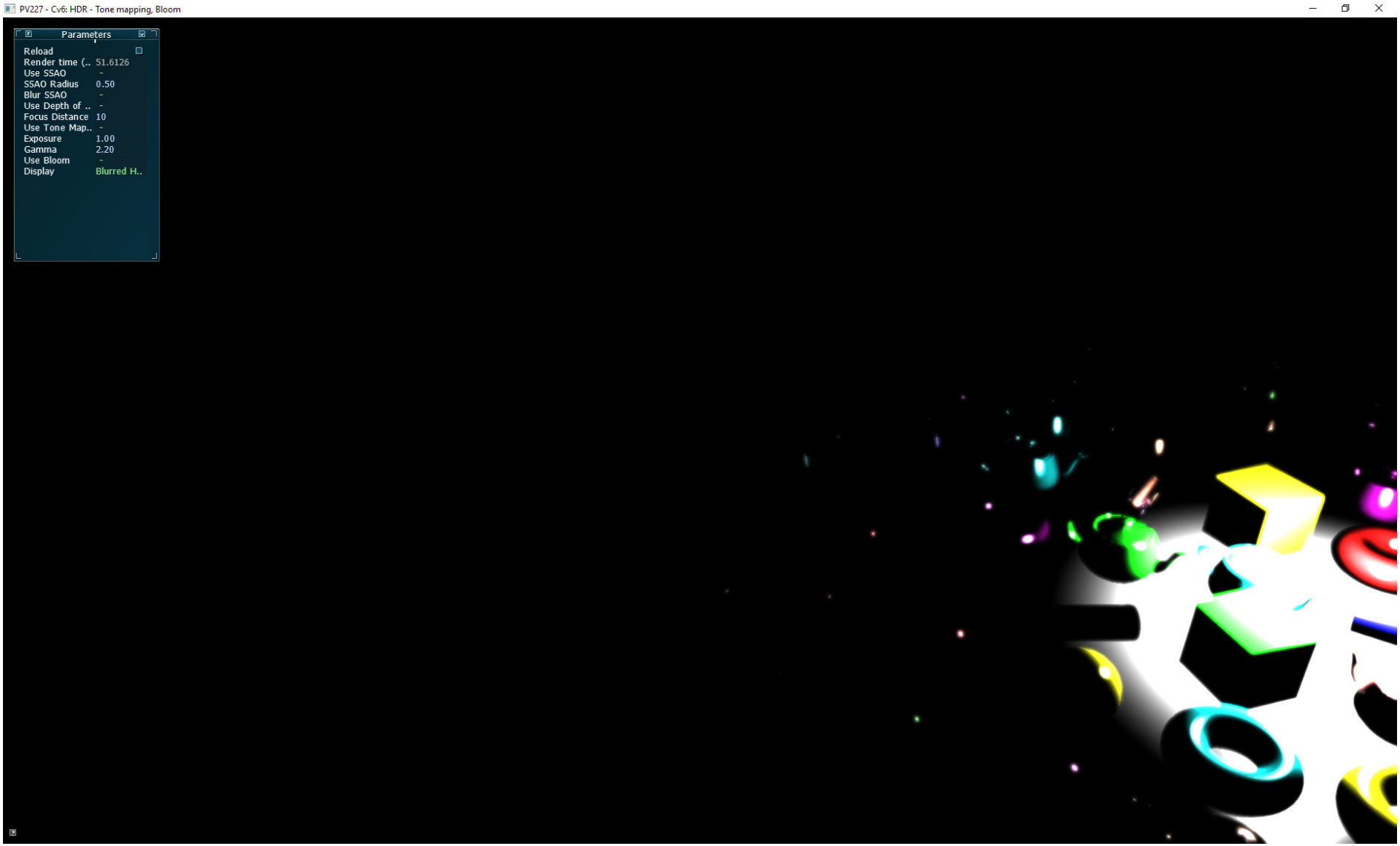
Rendering without bloom

Bloom – Results



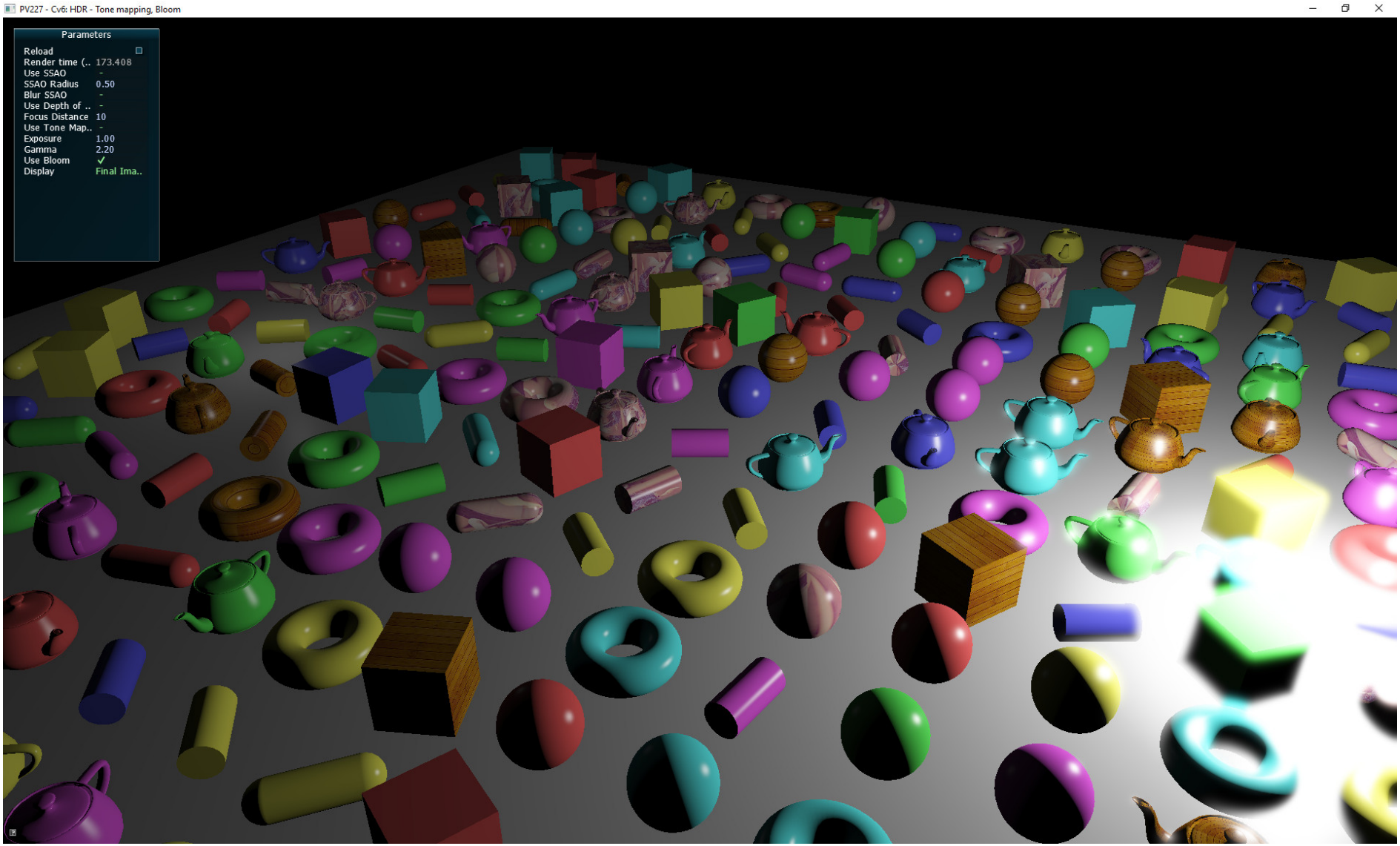
Debug: highlights buffer

Bloom – Results



Debug: blurred buffer

Bloom – Results



Final image with bloom effect

What Next?

- How to combine effects?
  - We can have: SSAO, HDR (Tone mapping + Bloom), DoF, Grain, Flares, etc.
  - Lots of buffers needed – lots of memory needed
  - Lots of “logic” needed to do it effectively
- Post-effect double buffering trick:
  - For combining various post-process effects
  - “Double buffer” for blurring – bonus task (TASK4b)
    - ⋆ Is it faster than separable kernels blurring?

Further Reading

- John Hable: *Uncharted 2: HDR lighting*
  - Extensive desciption of HDR in context of AAA game:
    - ⋆ gamma,
    - ⋆ linear space,
    - ⋆ filmic tone mapping,
    - ⋆ A lot more
  - http://www.slideshare.net/ozlael/hable-john-uncharted2-hdr-lighting
- About convolution computing
  https://cg.ivd.kit.edu/downloads/GPUComputing_assignment_3.pdf