Efficient rendering in The Division 2

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WE DARE YOU TO COME CLOSER
THAN YOU


中華門
THE FUN STARTS W.
DRINK


CHINESE SUPERMARKET

Focus of talk

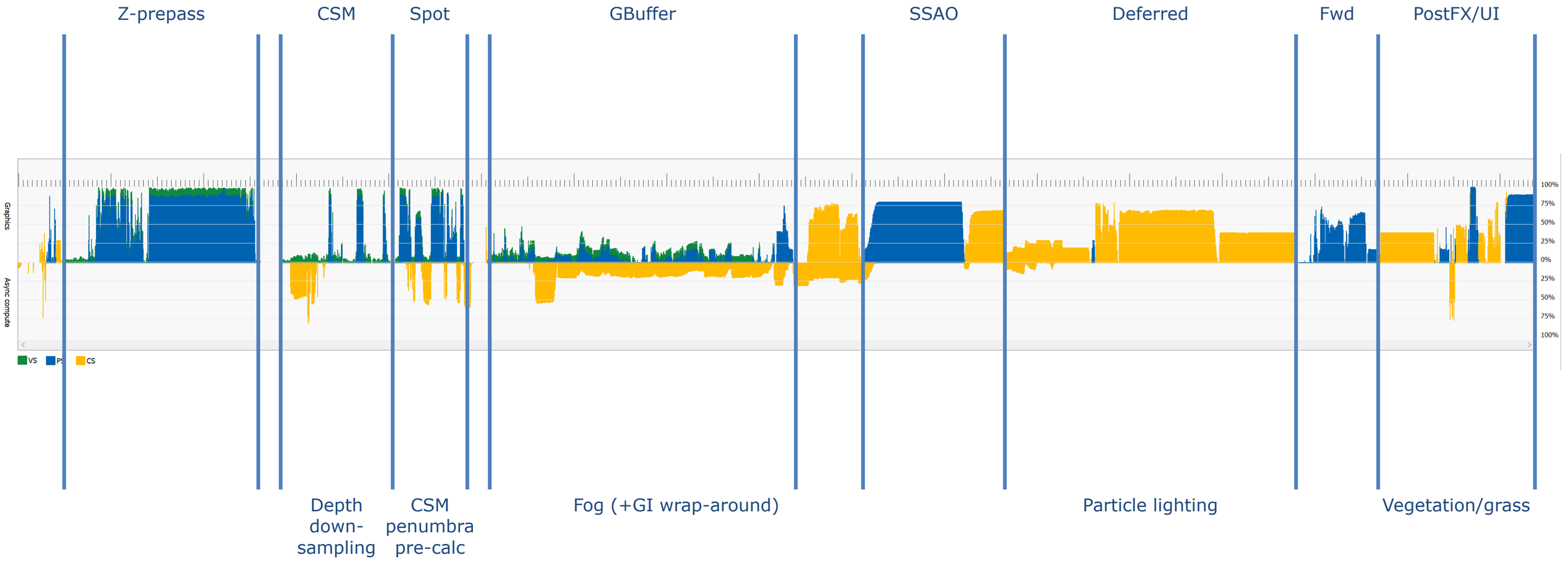
Efficient submission of GPU workloads

Deferred command lists

Asynchronous compute

(Raul) AMD DevTech and collaboration


snowdrop™


Z-prepass
CSM
Spot
GBuffer
SSAO
Deferred
Fwd
PostFX/UI
Graphics
Async compute
100%
75%
50%
25%
0%
25%
50%
75%
100%
VS
PS
CS
Depth down-sampling
CSM penumbra pre-calc
Fog (+GI wrap-around)
Particle lighting
Vegetation/grass

Overall pipeline

- CPU/render/GPU work interleaved
- Submit early, submit often
  - No render graph or *a priori* knowledge of frame layout
- Automatic resource transition tracking
  - But with opt out (untracked)

Interesting frame numbers

- 50-60 submits
- 200 transitions/100 barriers
- 3-6K draws
- 3-6M primitives
- (Some vendors) More time spent submitting than building immediate command lists

Render core

- Handles non-command list operations
  - Resource creation:
    - Buffers, pixel storages, textures, RTs, ...
  - Render state/PSO
- Manages *render contexts*
  - Graphics/compute/deferred/DMA

Render contexts

- DirectX® 11 like API for command list operations
- Resource binding based around enum’d slots
- Keeps internal cached state
- Each public context is paired with a worker thread + task queue
- Rendering is ”just” posting tasks to the appropriate task queue

Rendering objects

- Encapsulated into *render queues*
  - Templatified on sorting strategy
- Can do three things
  - Prepare – sort and group instances
  - Flush – render objects
  - Reset

Filling a render queue

- Culling outputs a 32-bit mask for where to draw each object
  - Z-prepass, gbuffer, CSMs, ...
- Bitmask + object flags decide render queues
- We have 30+ render queues

Flushing a queue

- Setup render state for the entire queue
- Upload per-instance (4 uints) data to GPU
  - Single copy per render queue
- For each instance group:
  - Set PSO/buffers/VBs/IBs/...
  - DrawIndexedInstanced

Updating buffers

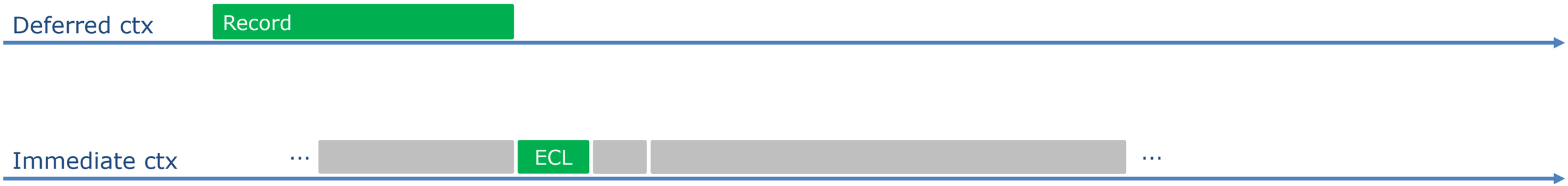
- All transient data
  - Copy into upload buffers
  - Then, copy into GPU-local buffer
- Shaders only read from GPU-local buffers!

Not faster, but more stable frame

Deferred command lists

- Handled by thread local *deferred render contexts*
- Recording done without transitions tracking
  - Liberal use of asserts on transitions/barriers to trap misuse
- Buffer uploads goes straight to DMA without waiting for the execute

Deferred command list example



Deferred command list example

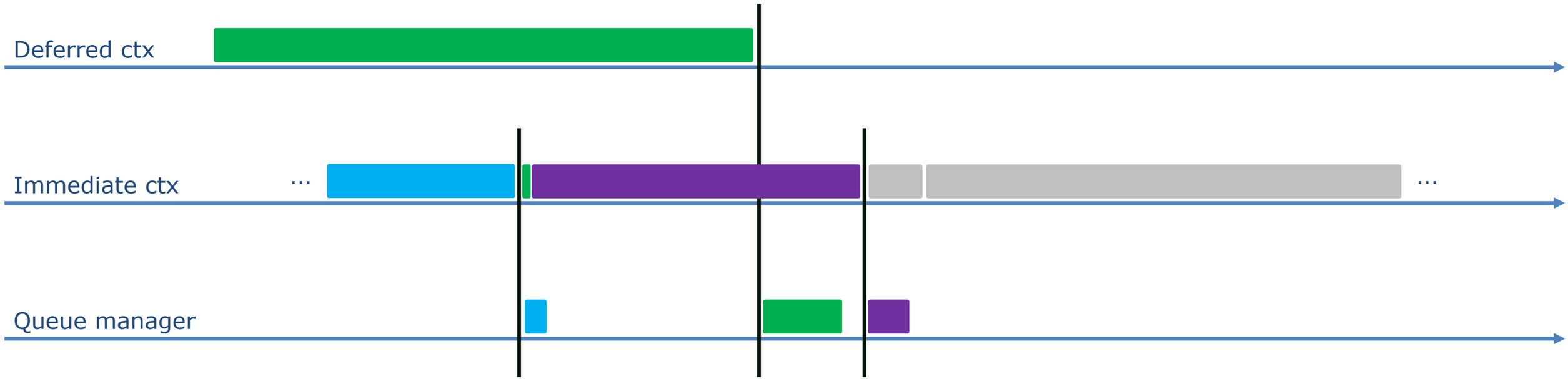
Command list chaining

- Available on some consoles
- Allows executing a command list while it is being recorded
- Minimize risk of CPU stalling CPU and GPU
- Not available in DirectX® 12… ☹

Solution: Emulate!!!

- Enter *Queue Manager*
- Handles command list operations
  - ExecuteCommandLists, Close, Reset
  - Hides CPU cost of those operations
- Has its own worker thread and task queues
- In effect: a custom driver thread ☺

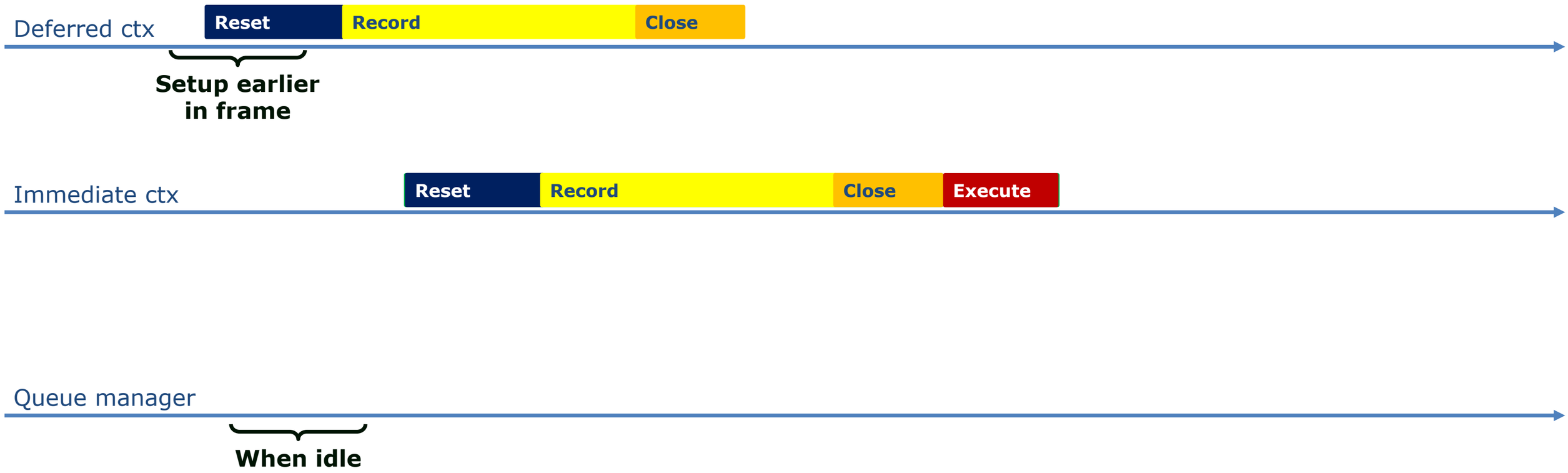
Queue manager example



Queue manager

- Queue manager submits what it can
- Atomics to track command list state
  - Recording, open
- One queue per context
- Round-robins executes in priority order
  - Compute, Graphics, DMA

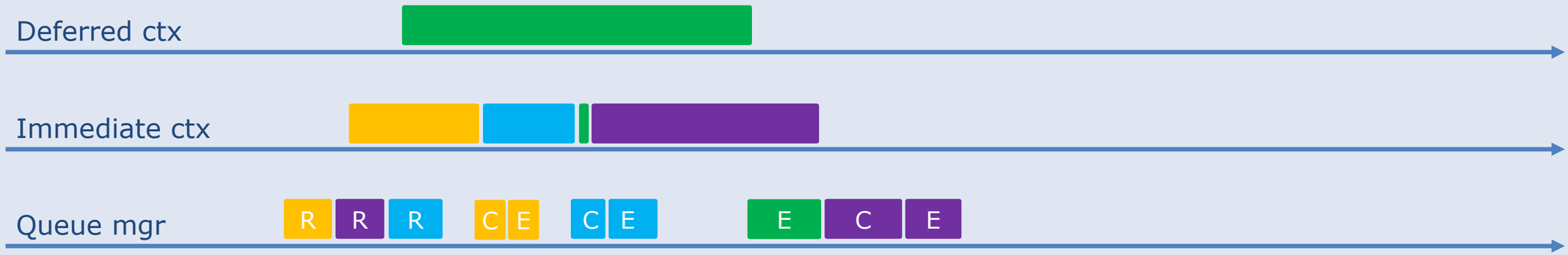
Queue manager details



Queue manager comparison

Naive

Queue mgr



Queue manager

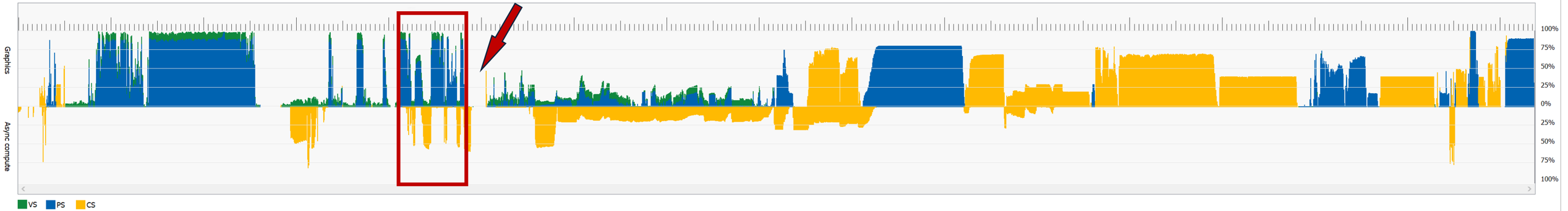
- Eliminates most CPU stalls
- Speculatively prepares command lists
  - Avoids command list create/reset stalls
- Elide superfluous signal/waits

Async compute

- Submits also handled by the queue manager
- 2 types of compute workloads
  - Dependent on gfx state
  - Independent
- Used for workloads that do not need to finish soon

Async compute examples

- Depth downsampling and light culling
- Fog and volumetrics
- Rain/snow GPU particles
- Sky coverage sampling
- Grass/vegetation updates
- Shadows (variable penumbra pre-calc)
- GI relighting



- Async compute is stalling the gfx pipe!
  - Can result in GPU under-utilization
- On consoles: limit async compute occupancy
- Not current possible on PC ☹
  - D3D12_COMMAND_QUEUE_PRIORITY

Key takeaways

- Check time spent inside DirectX® 12
  - Maybe you need a driver thread too?
- Experiment with buffer upload patterns
- Look at your async compute behaviour!
  - Would low-prio workloads help you?
  - If so, help us push Microsoft + IHVs ☺

AMD DevTech

- Helping devs get the most out of:
  - Tools
  - Driver
  - Hardware
  - Shader Compiler

Existing optimizations in Snowdrop

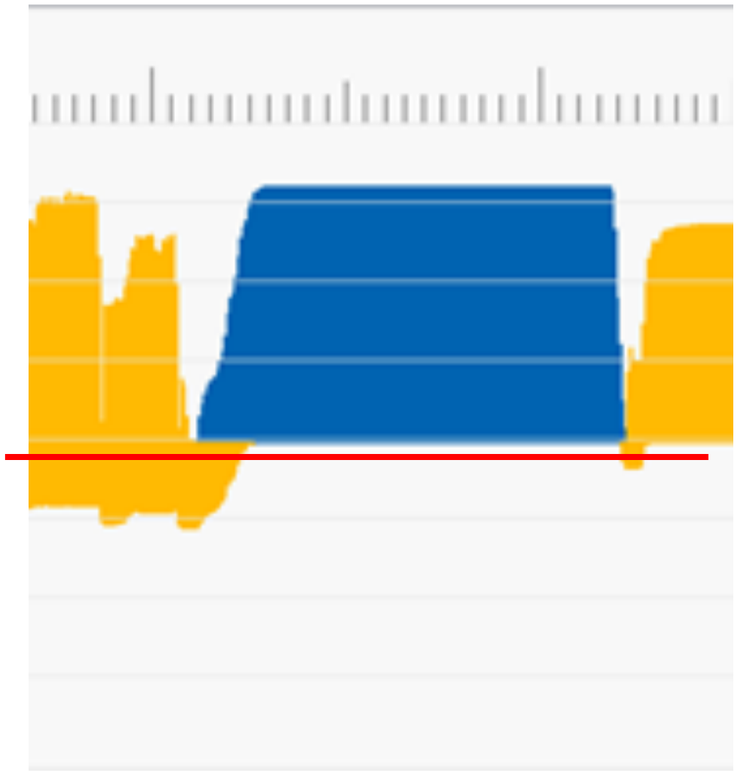
- Use SGPRs
- Optimized LODs
- Sorting by state
- Batching barriers
- Root signature order
- Use of async compute

Better async

- Async is awesome
- Can we do better?
- Typical usage is:
  - Graphics queue, for what I need ASAP
  - Async queue, for not time critical
- Problem: Async and Graphics queue may compete

Better async

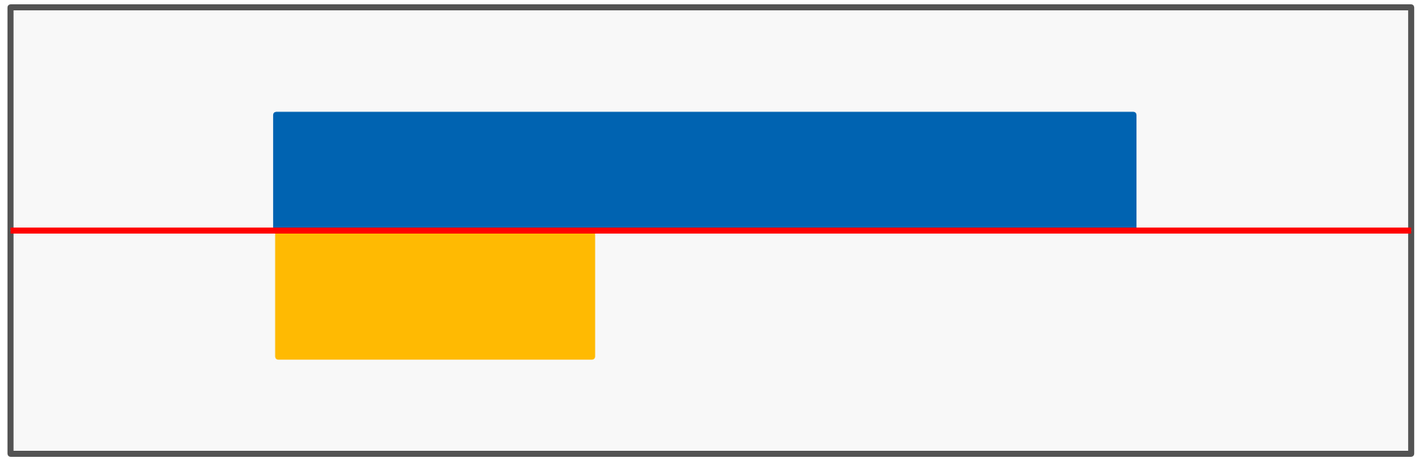
- Competing for execution resources



Screenshot of Radeon(TM) GPU Profiler taken on Radeon(TM) Vega64 and Threadripper(TM) based system.

Better async

- Competing for cache



Better async

- Solution: Parallelize unalike workloads

Memory dominated	Shader Throughput	Geometry dominated
Shadow Mapping ROP heavy workloads Many Gbuffer operations DMA operations: - Texture upload - Heap defrag	Deferred lighting (usually) Many Postprocessing effects Most compute tasks: -Texture compression -Physics -Simulation	Rendering highly detailed modules

Ongoing research

- Interest from several developers
- Expose a way to slow down the async pipe
- Still experimenting…
- Results are so far are exciting!
- PC is tricky

Ongoing research

- Competing for cache

Questions?

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