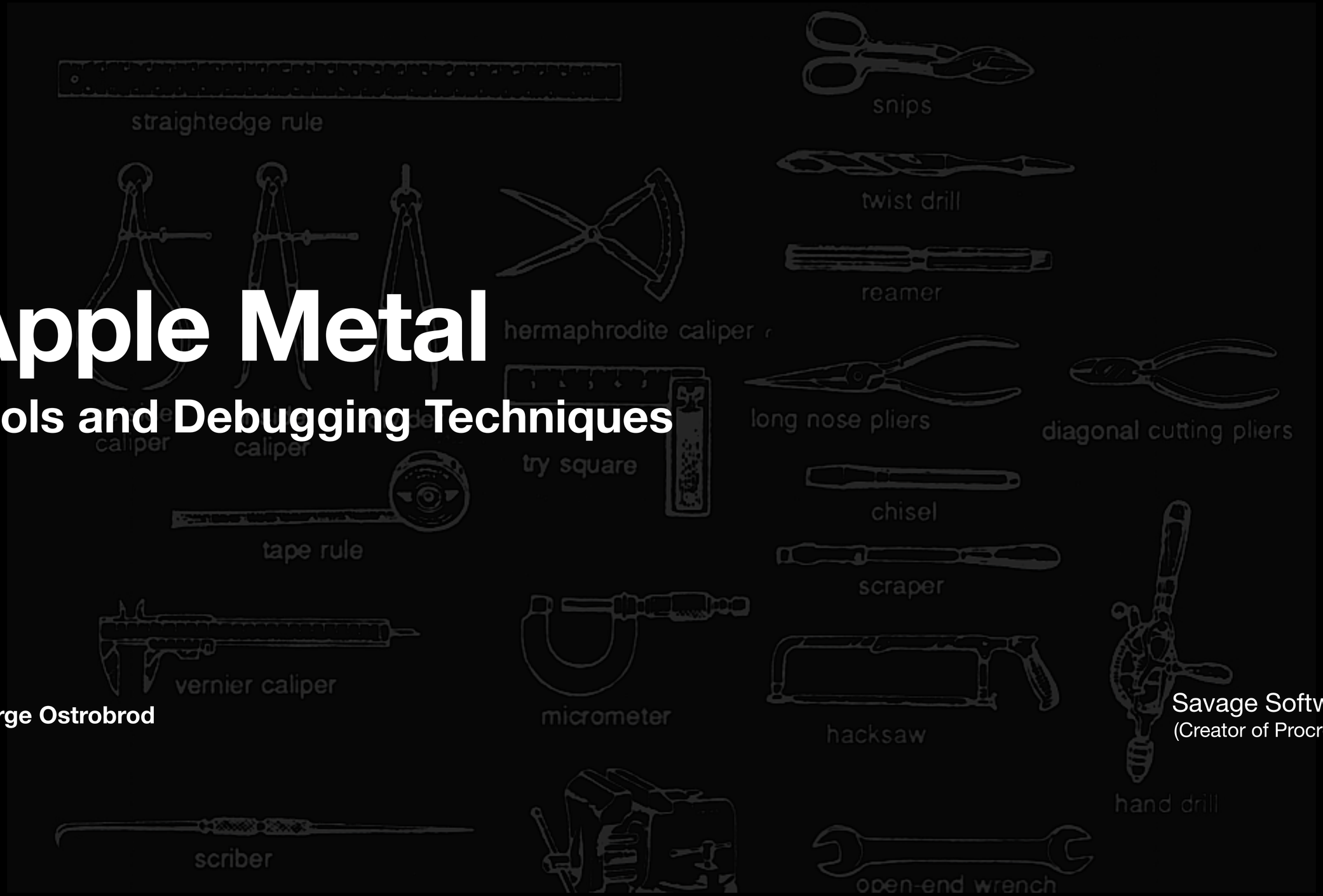


Apple Metal

Tools and Debugging Techniques

George Ostrobrod

Savage Software
(Creator of Procreate)

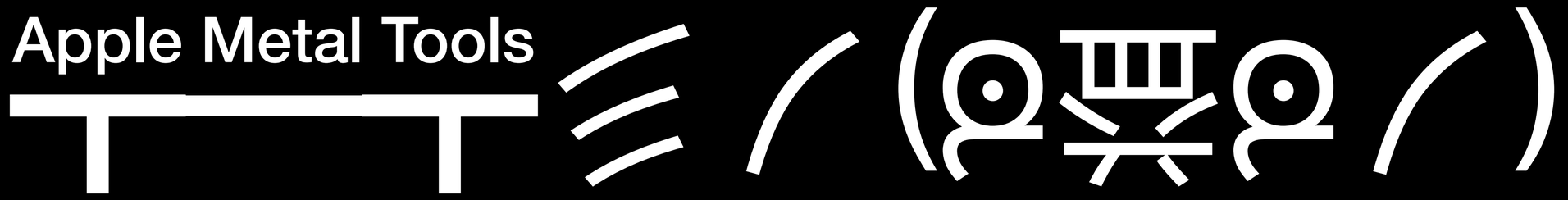
Apple Metal Tools

- Metal System Trace (Instruments)
- GPU Frame Capture (XCode)
- GPU Frame Capture (in code)

Apple Metal Tools

- Metal System Trace (Instruments)
- GPU Frame Capture (XCode)
- GPU Frame Capture (in code)

Apple Metal Tools



THANK YOU

Questions?

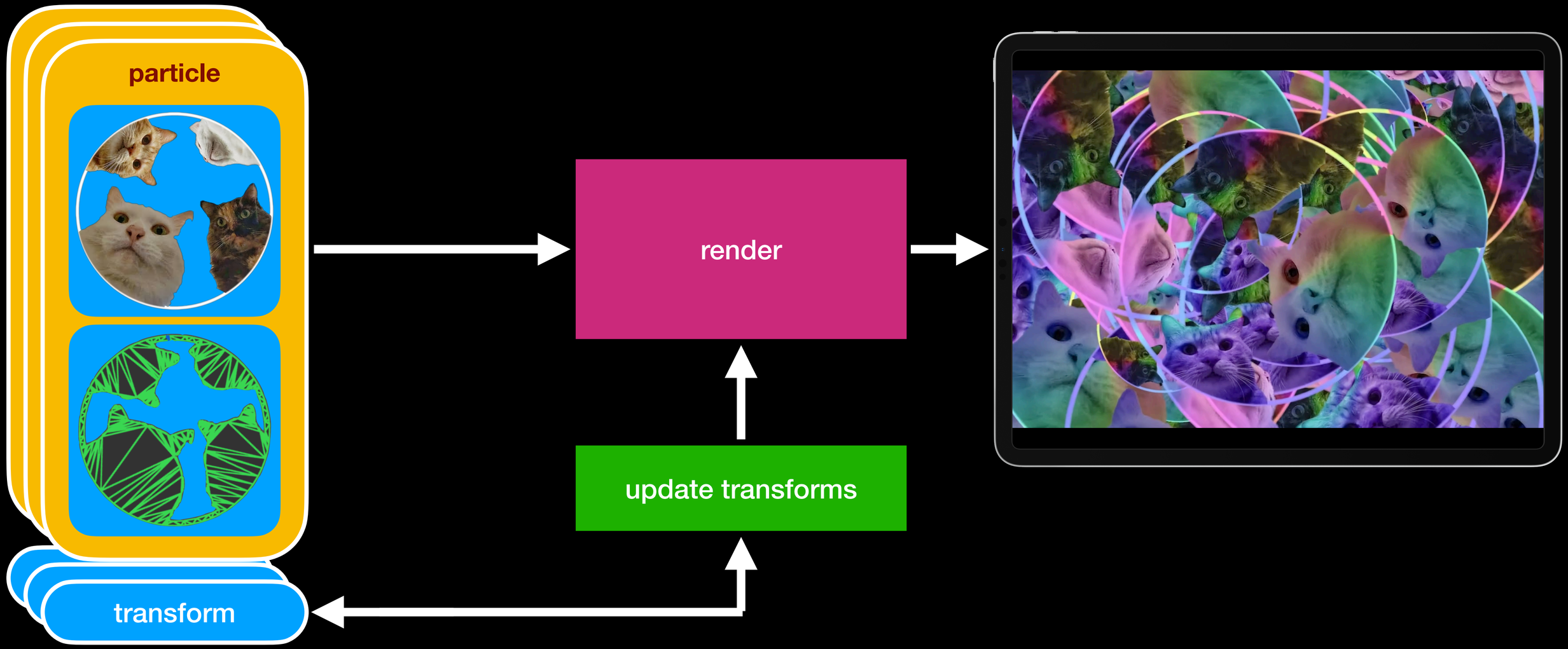
Presentation Plan

- Problem (and experimental task)
- Apple’s tools
  - Documentation
  - Metal System Trace (Instruments)
  - GPU Frame Capture (XCode + Metal API)
- Manual solving problems

EXPERIMENTAL TASK

Cats (compute + render)

EXPERIMENTAL TASK



PERFORMANCE

Profiling

CORRECTNESS

Debugging

INSTRUMENTS

Apple Documentation

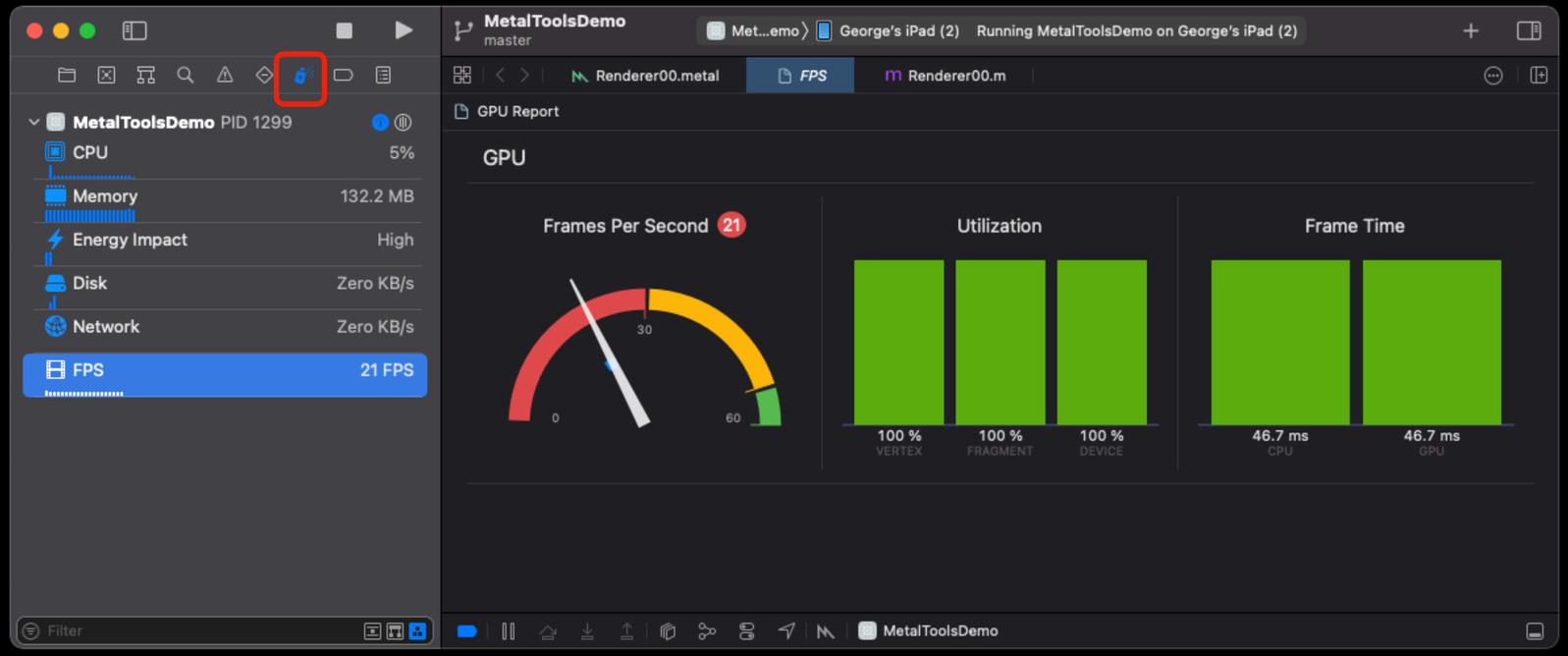
Documentation

- Metal Feature Set Tables
- Metal Shading Language Specification
- Metal Performance Shaders
- Metal API Documentation

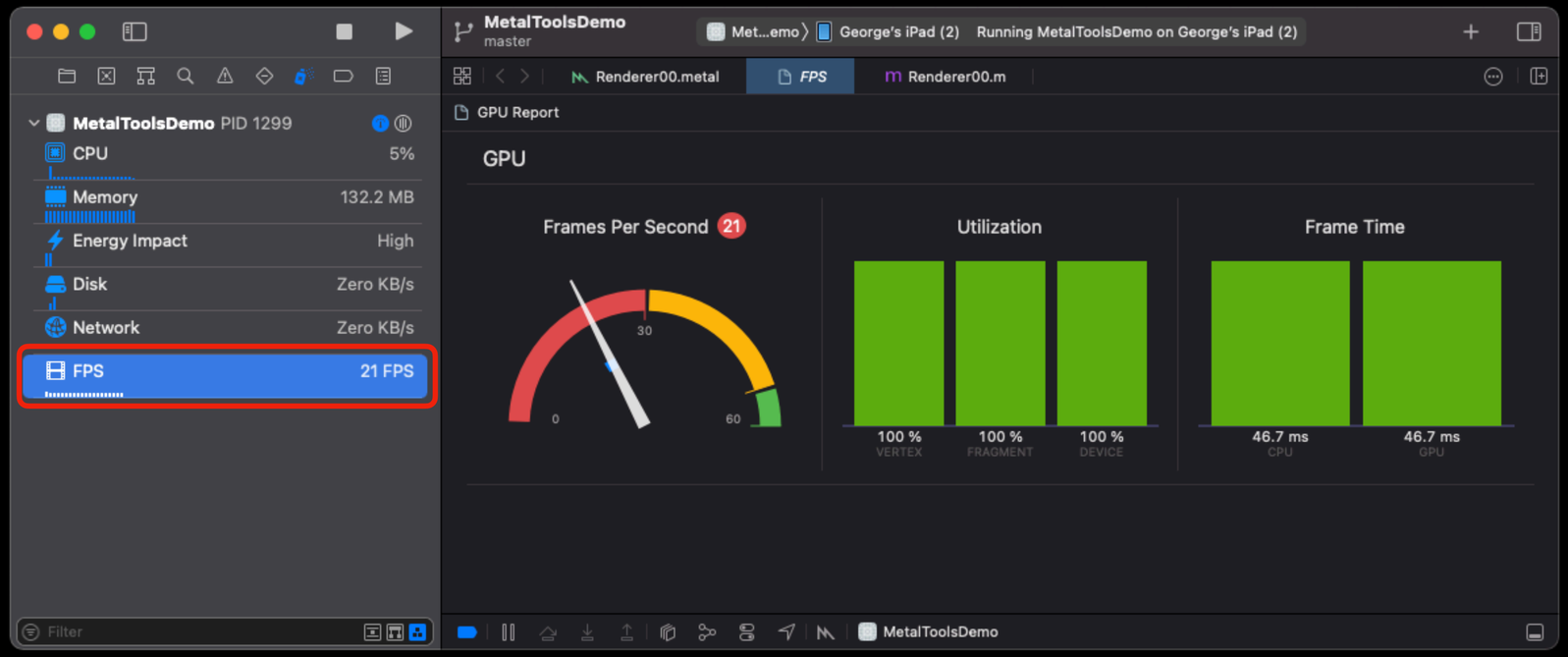
XCODE

Debug Navigator: GPU

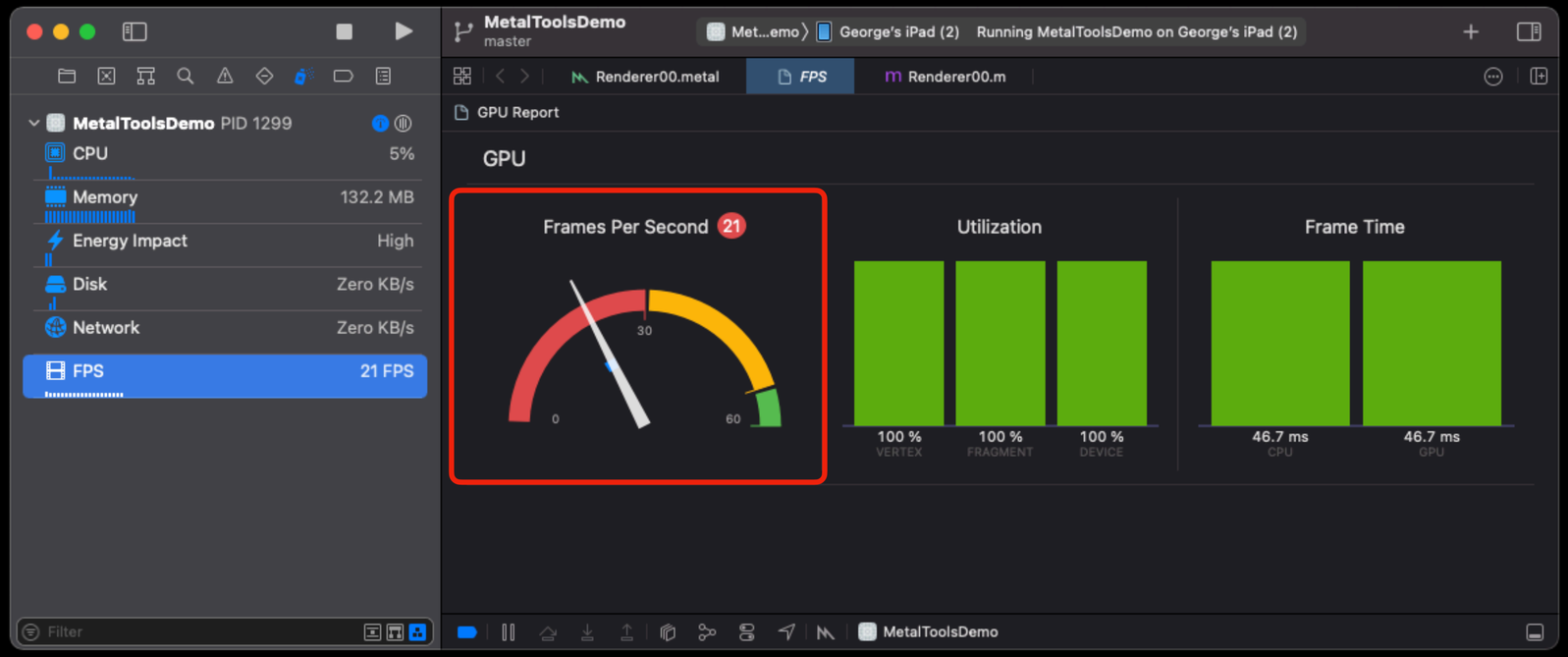
Debug Navigator: GPU



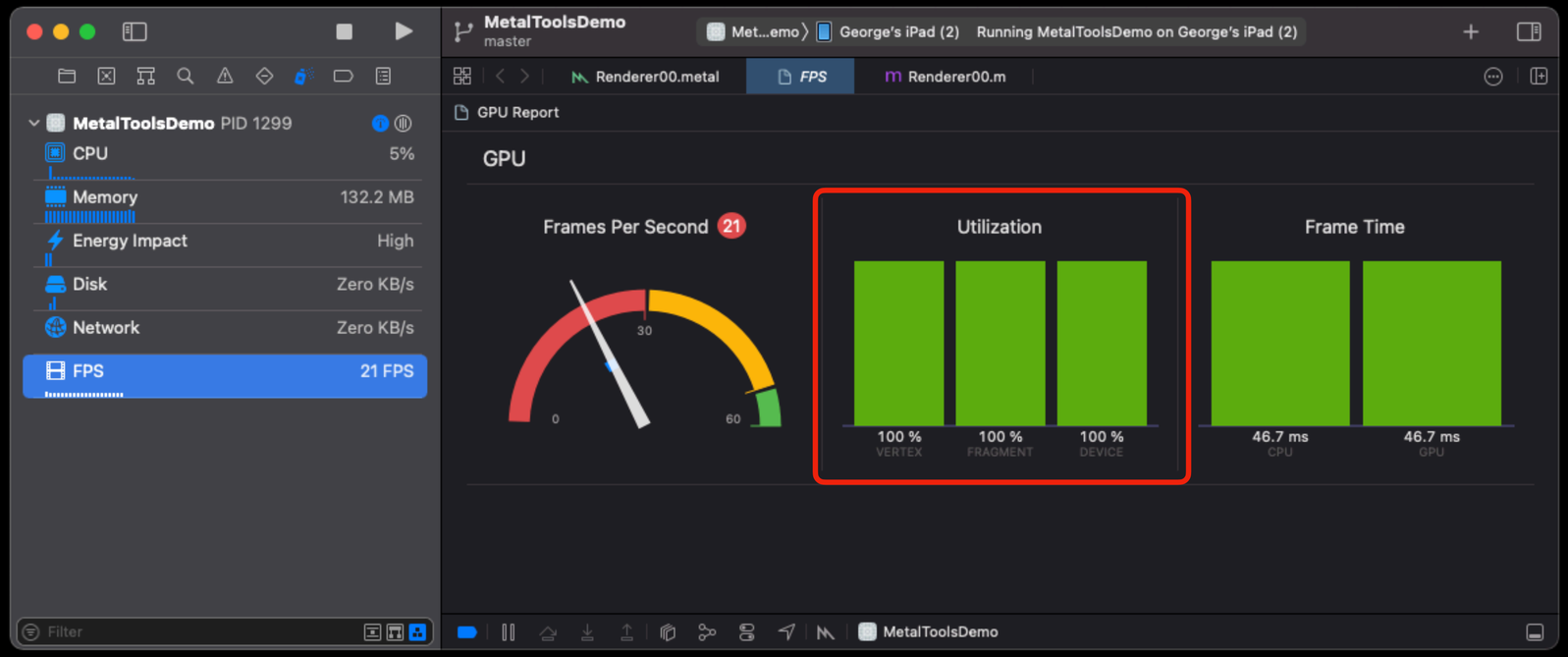
Debug Navigator: GPU



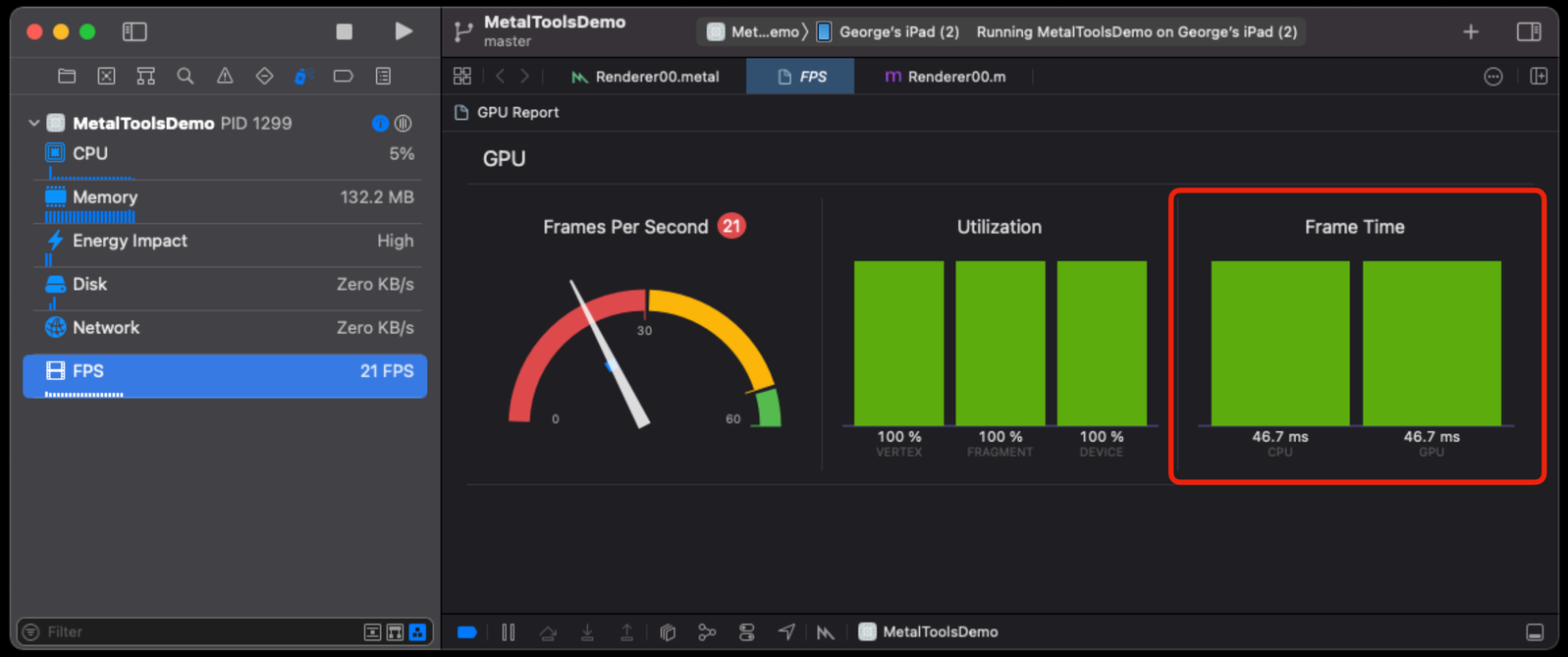
Debug Navigator: GPU



Debug Navigator: GPU



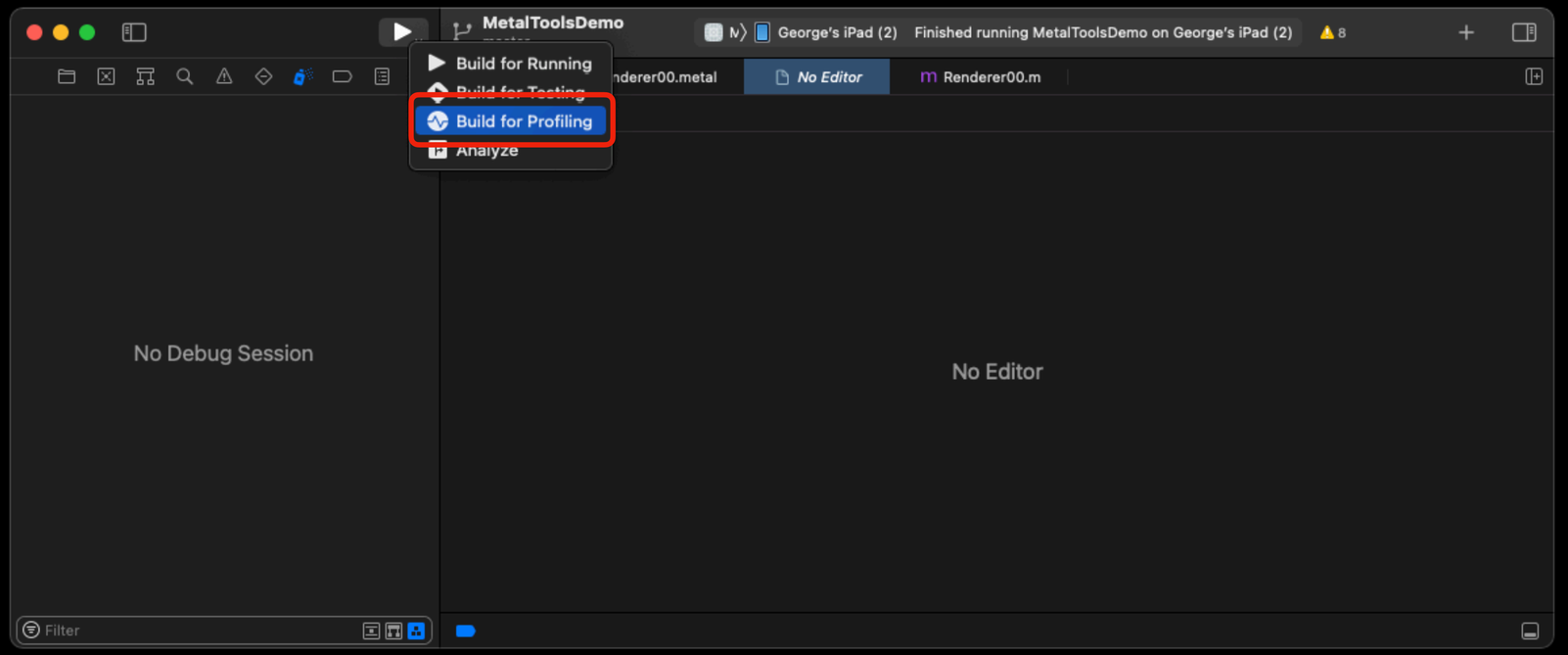
Debug Navigator: GPU



INSTRUMENTS

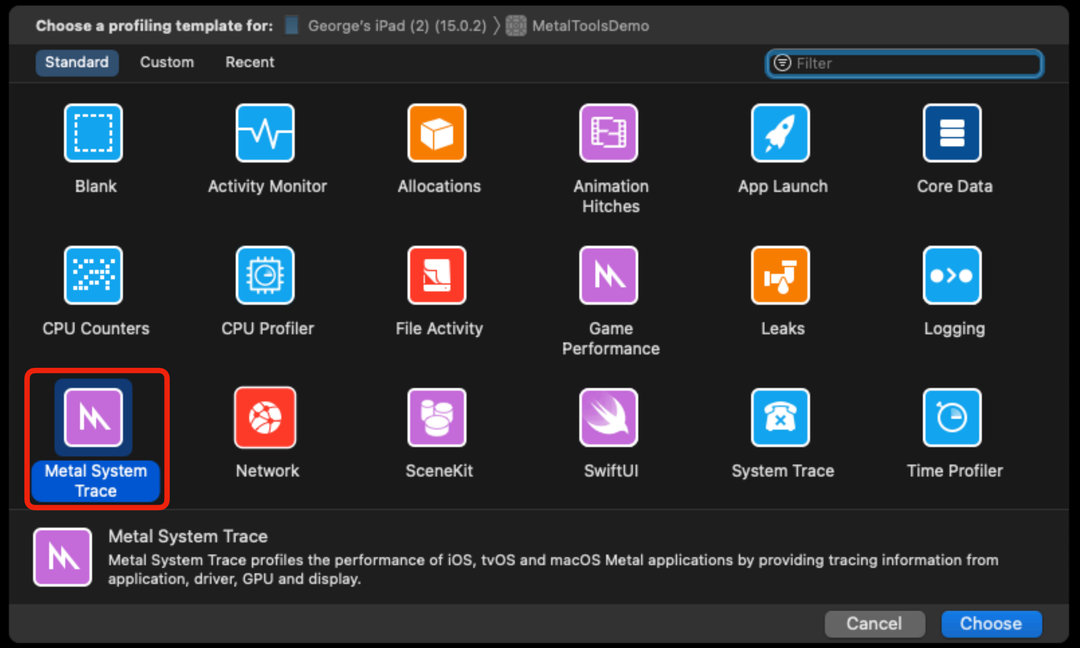
Metal System Trace

Profiling: Metal System Trace

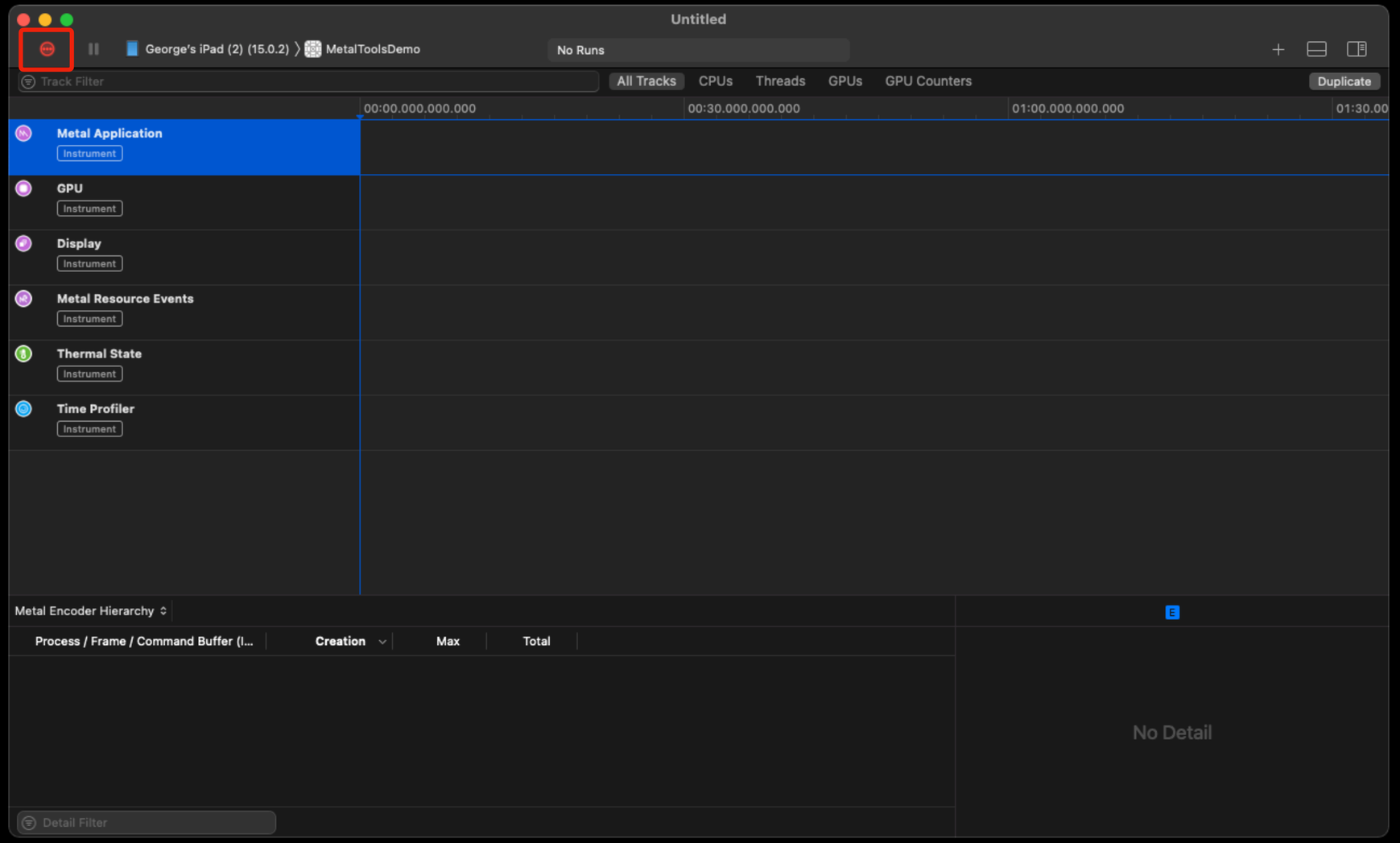


Product → Profile (⌘ + I)

Profiling: Metal System Trace



Recording Options



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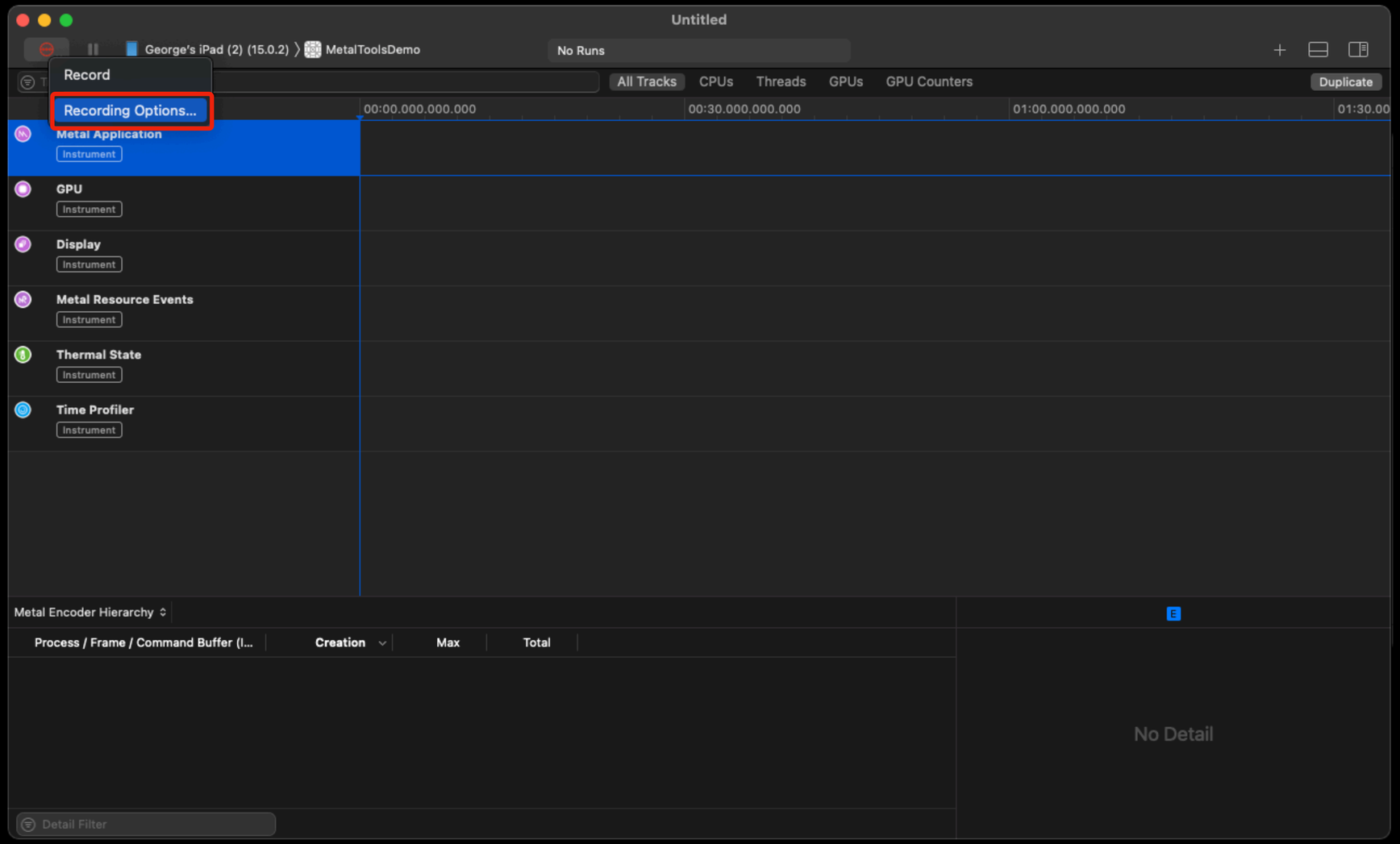

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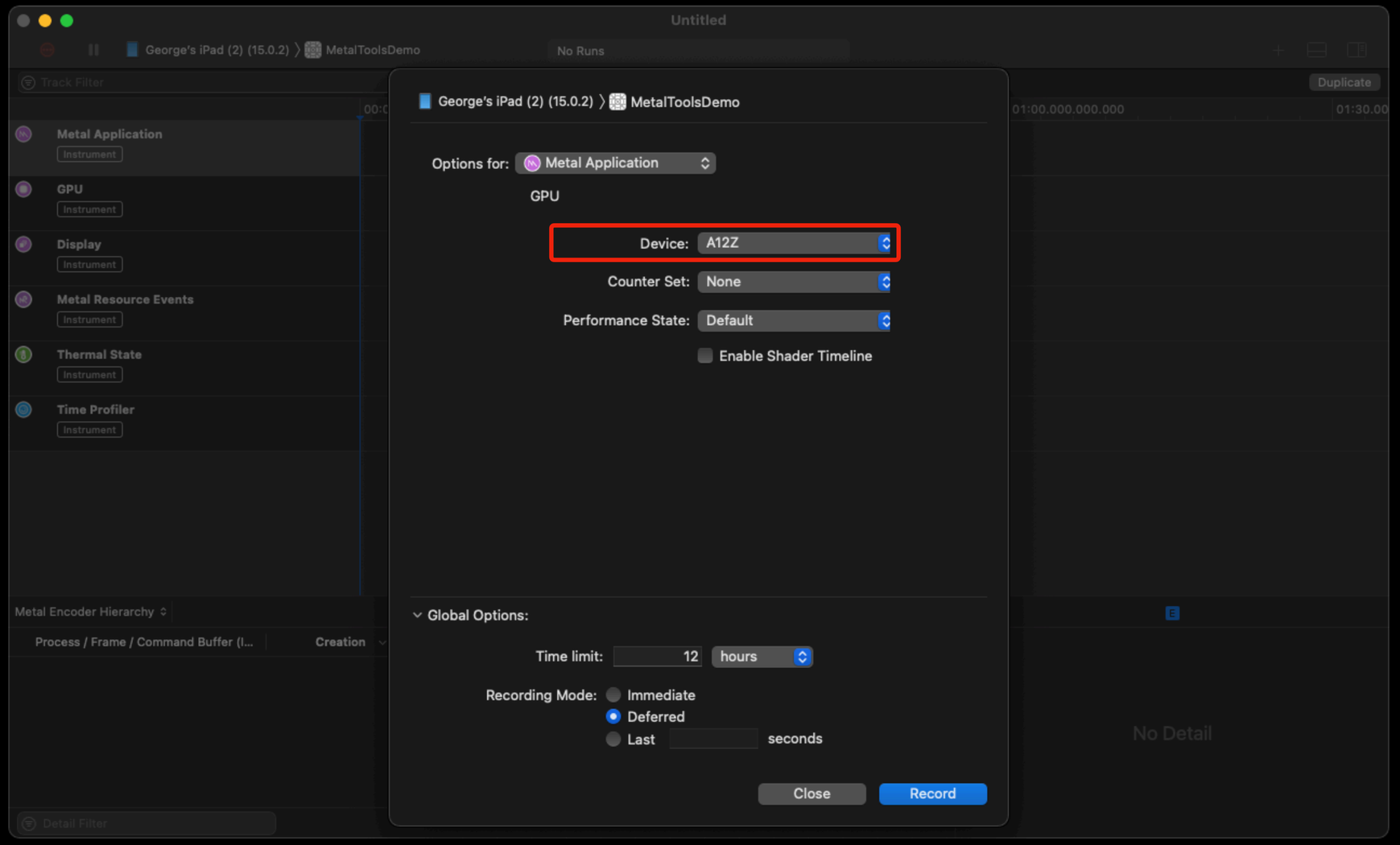

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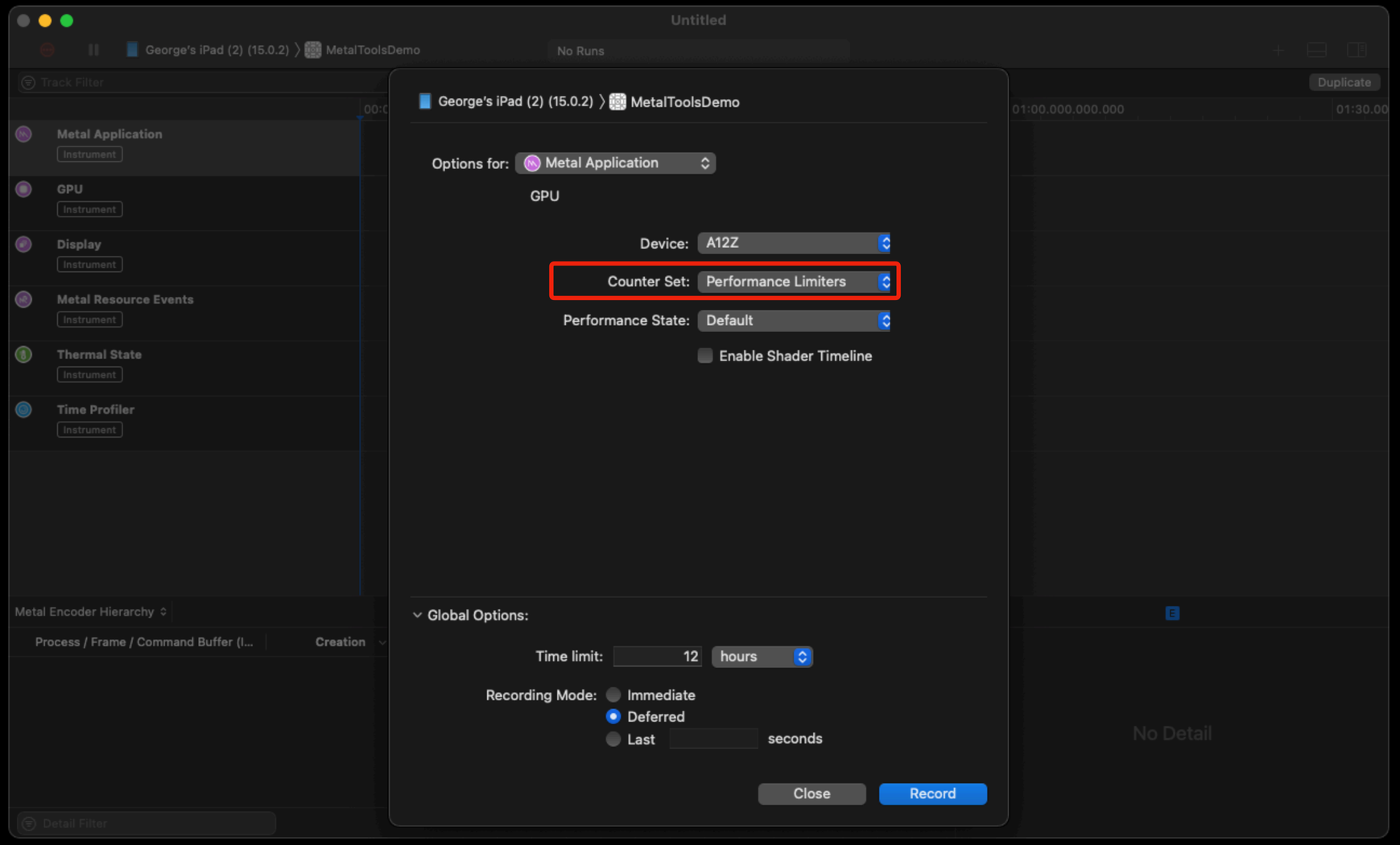
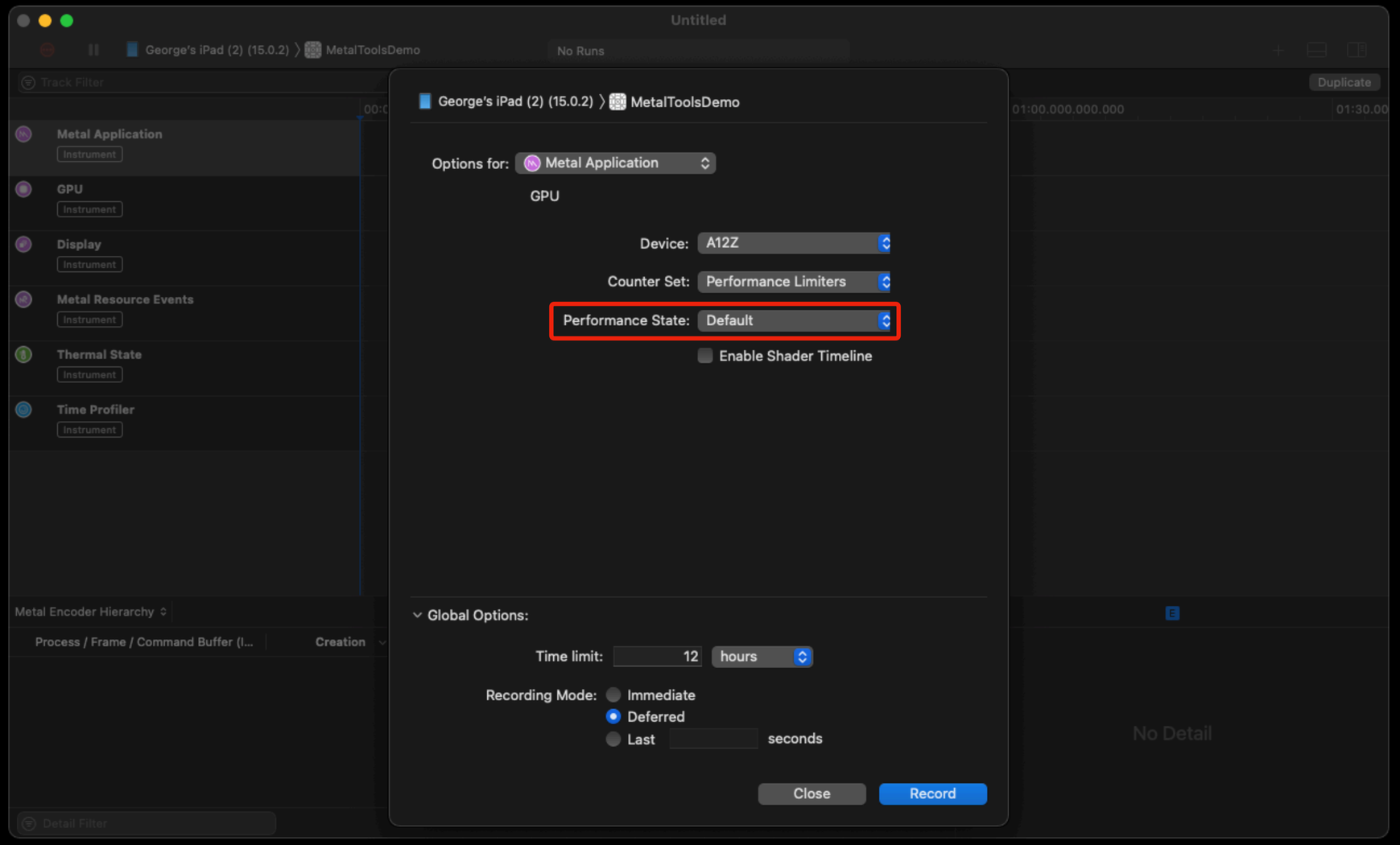


Recording Options



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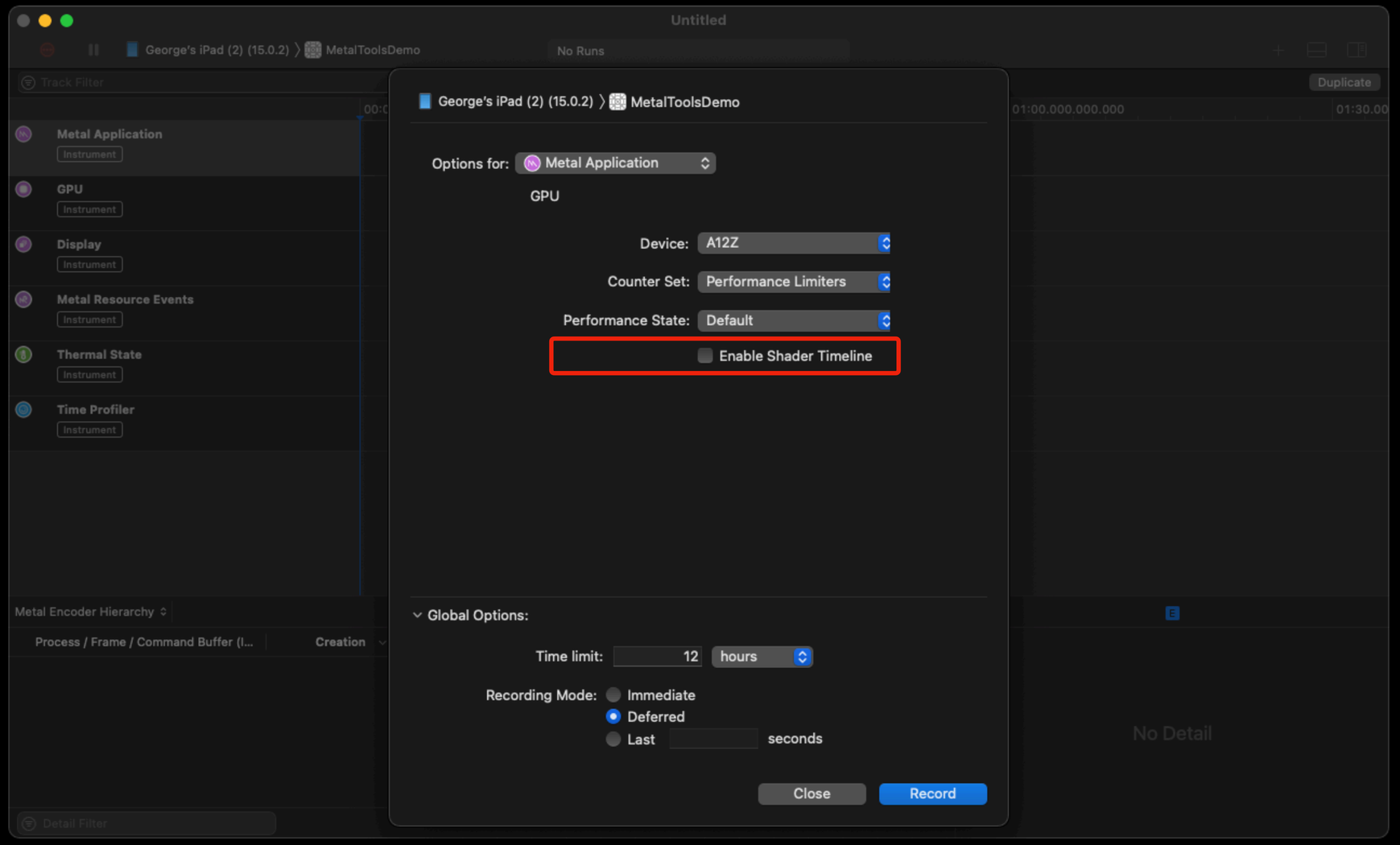

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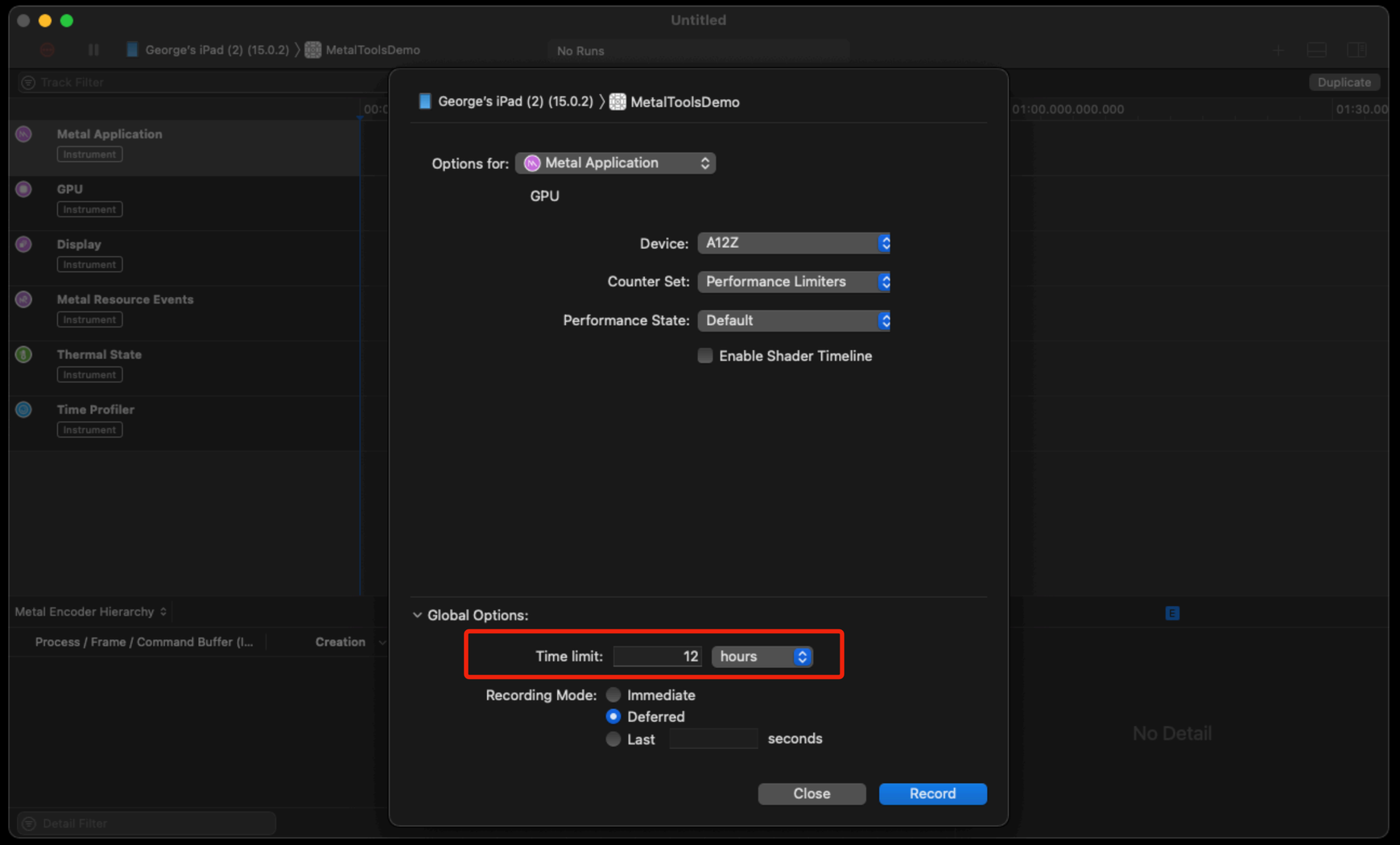

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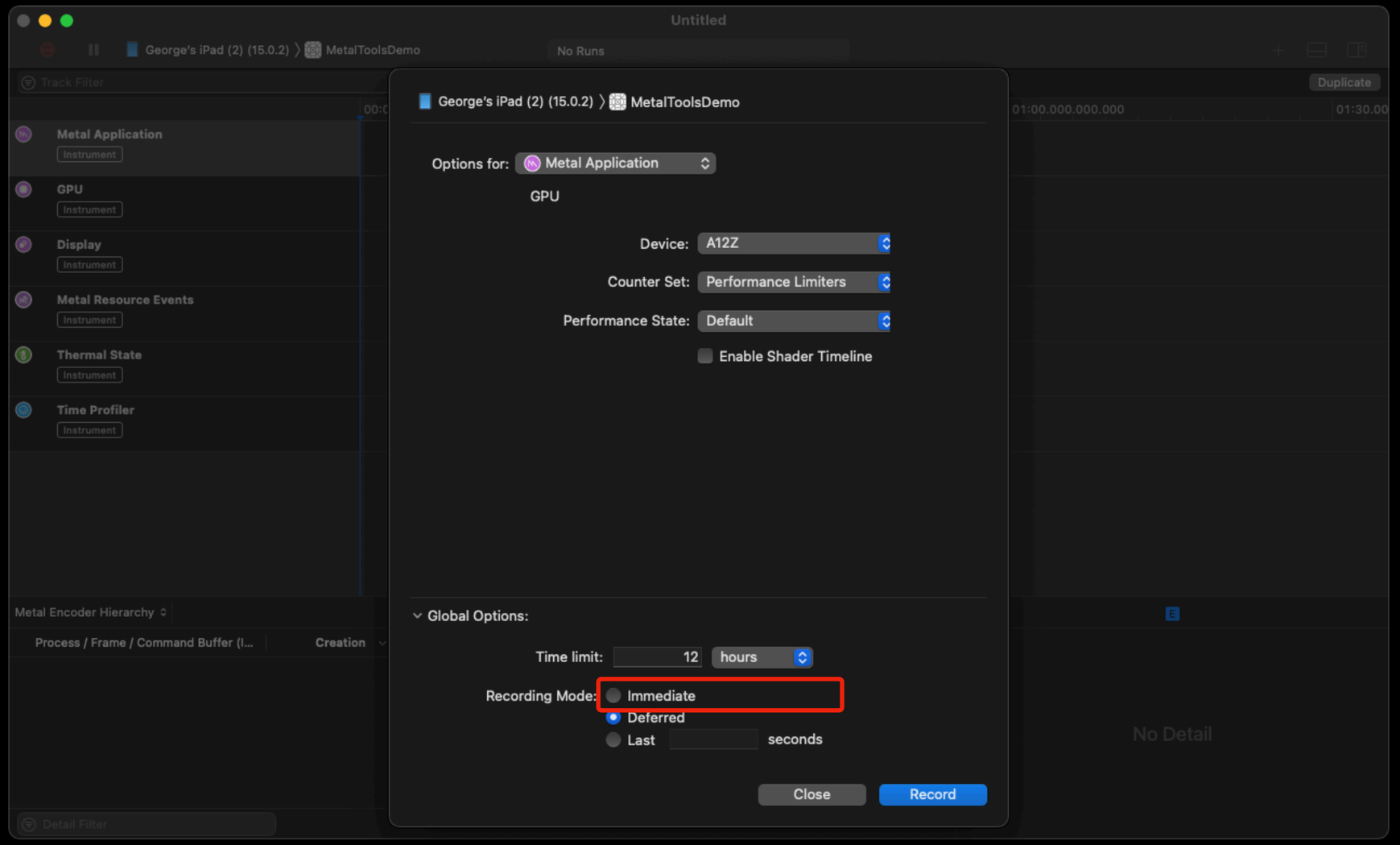

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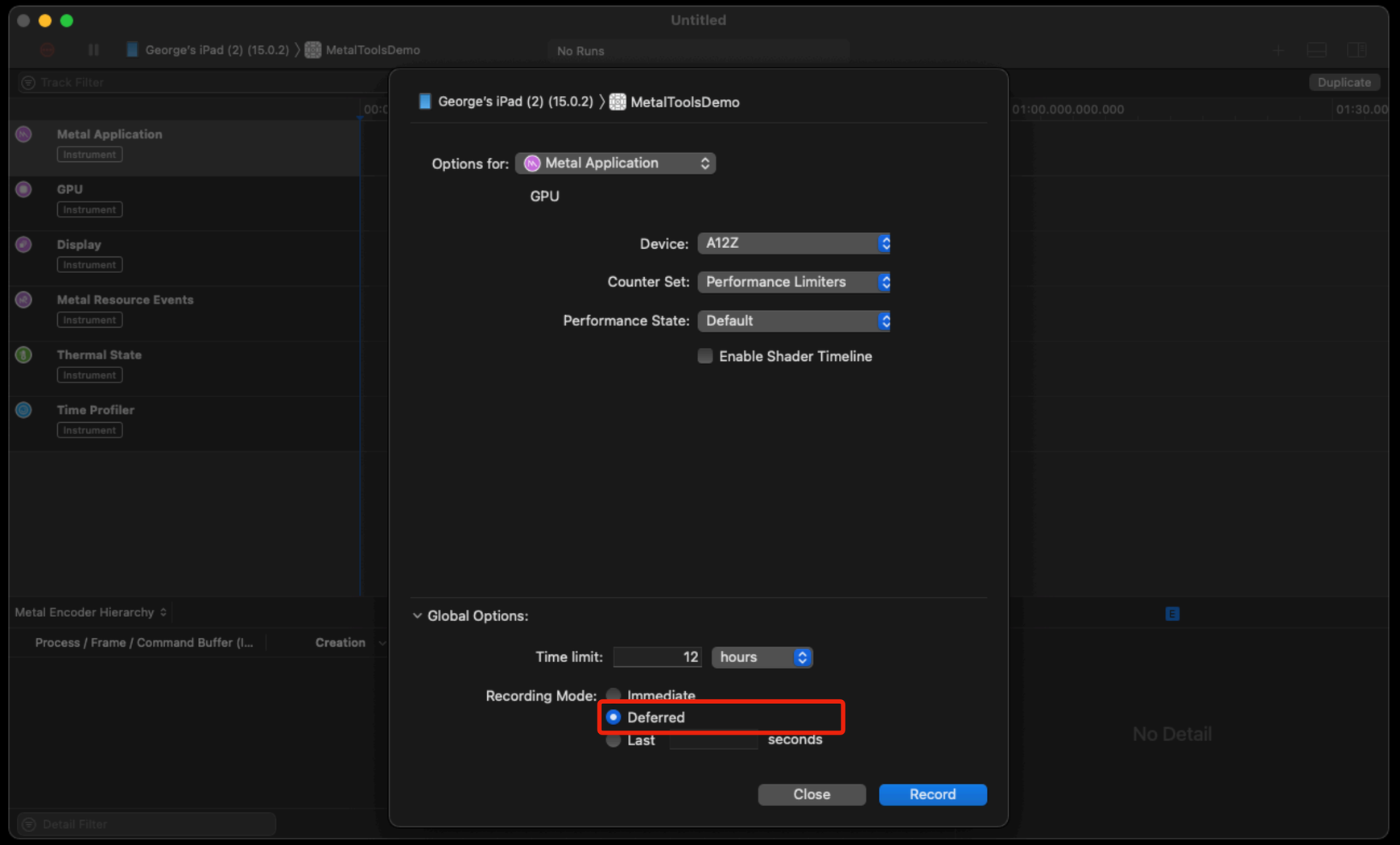
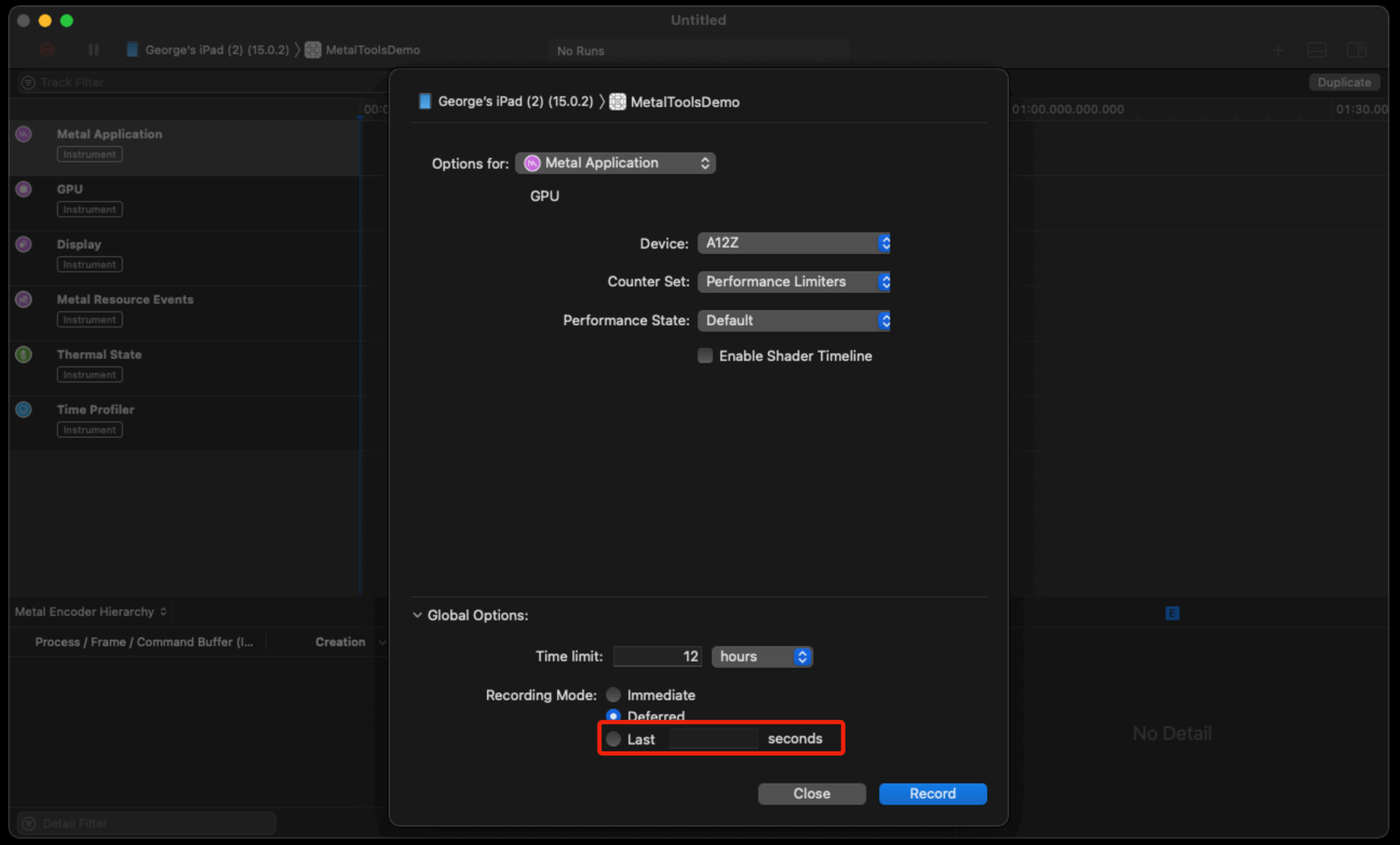
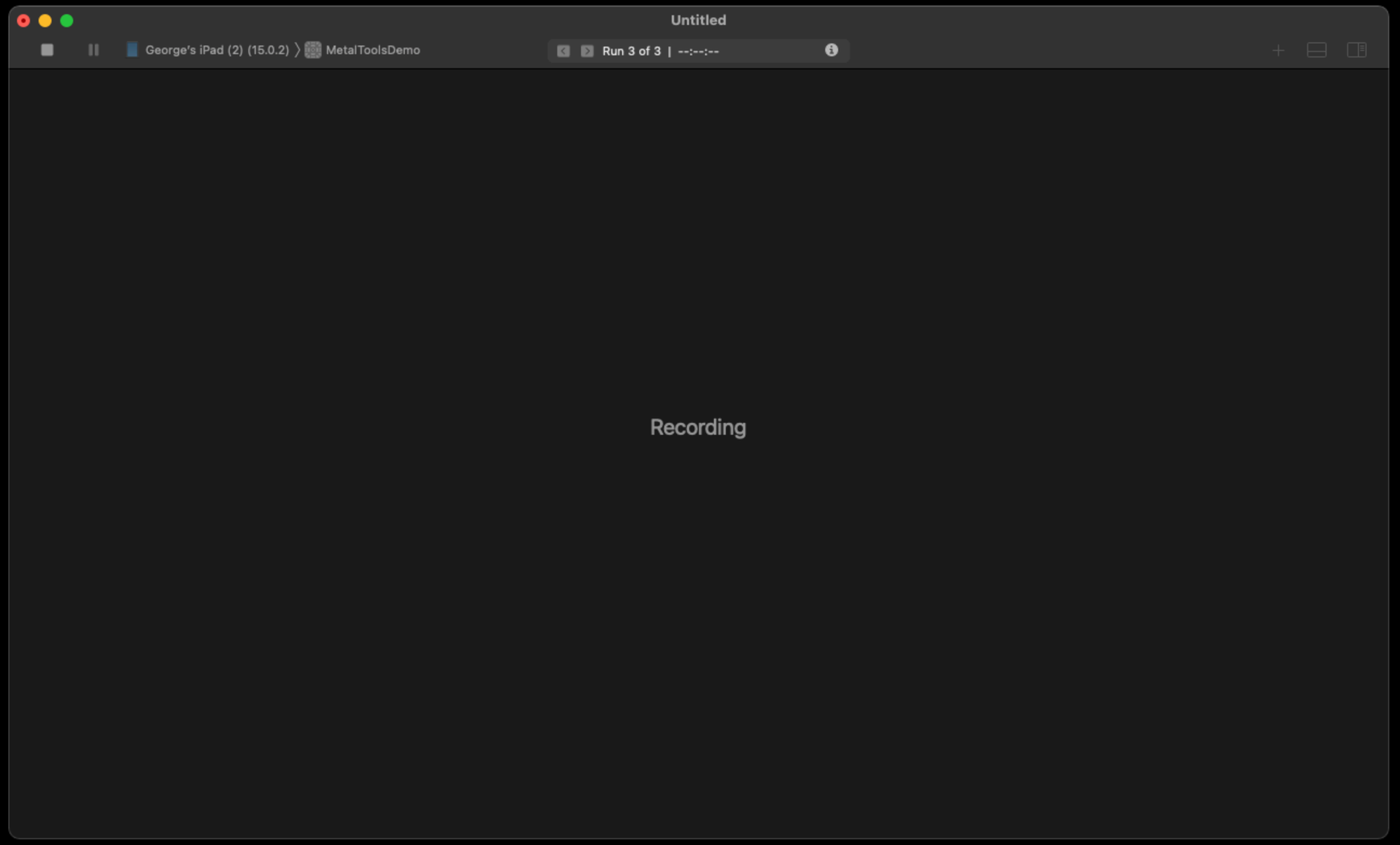


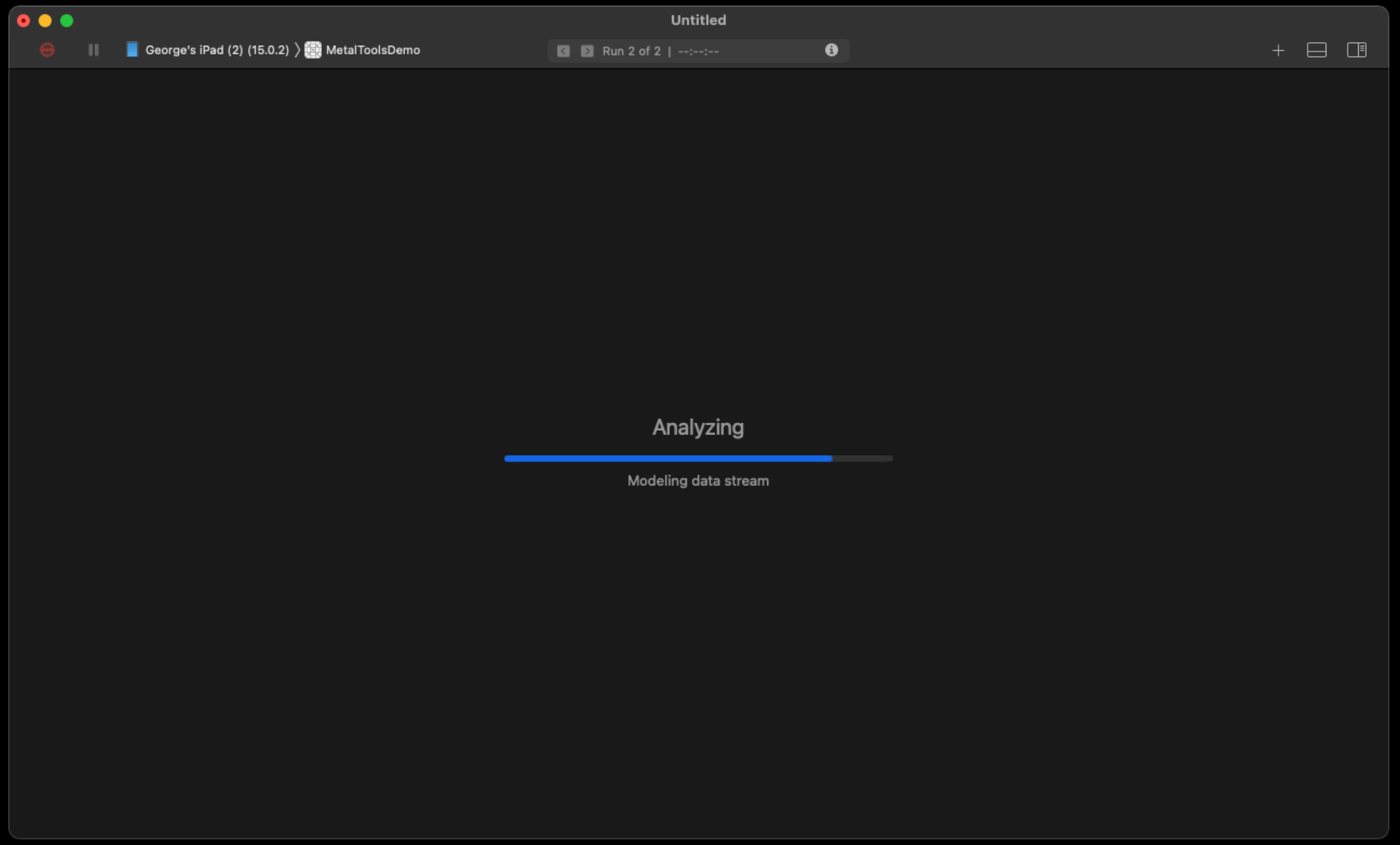
Recording Options



Recording


Untitled
George's iPad (2) (15.0.2)
MetalToolsDemo
Run 3 of 3 | --:--:--
Recording

Recording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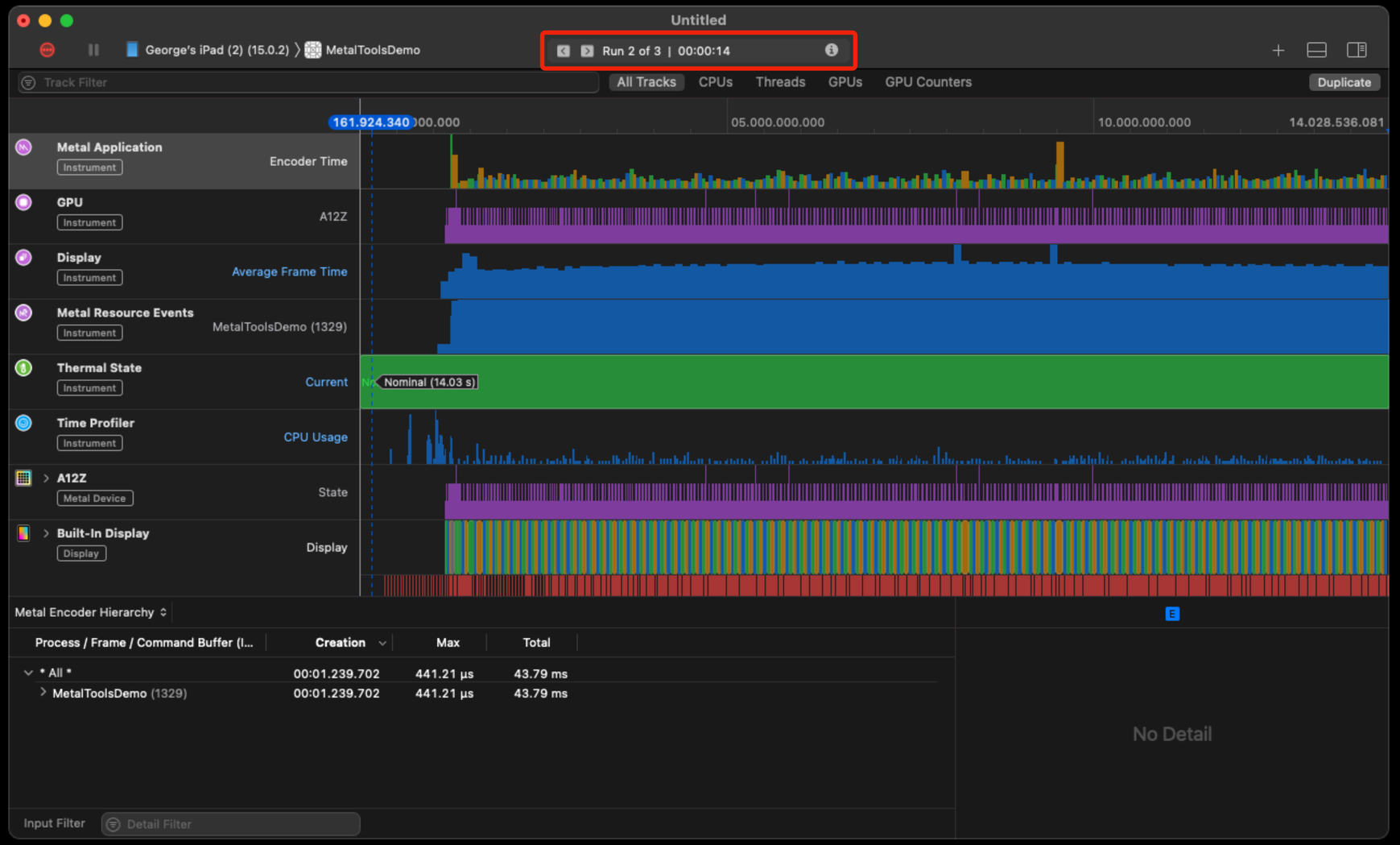
George's iPad (2) (15.0.2)
MetalToolsDemo
Run 2 of 2 | --:--:--
Analyzing
Modeling data stream

Records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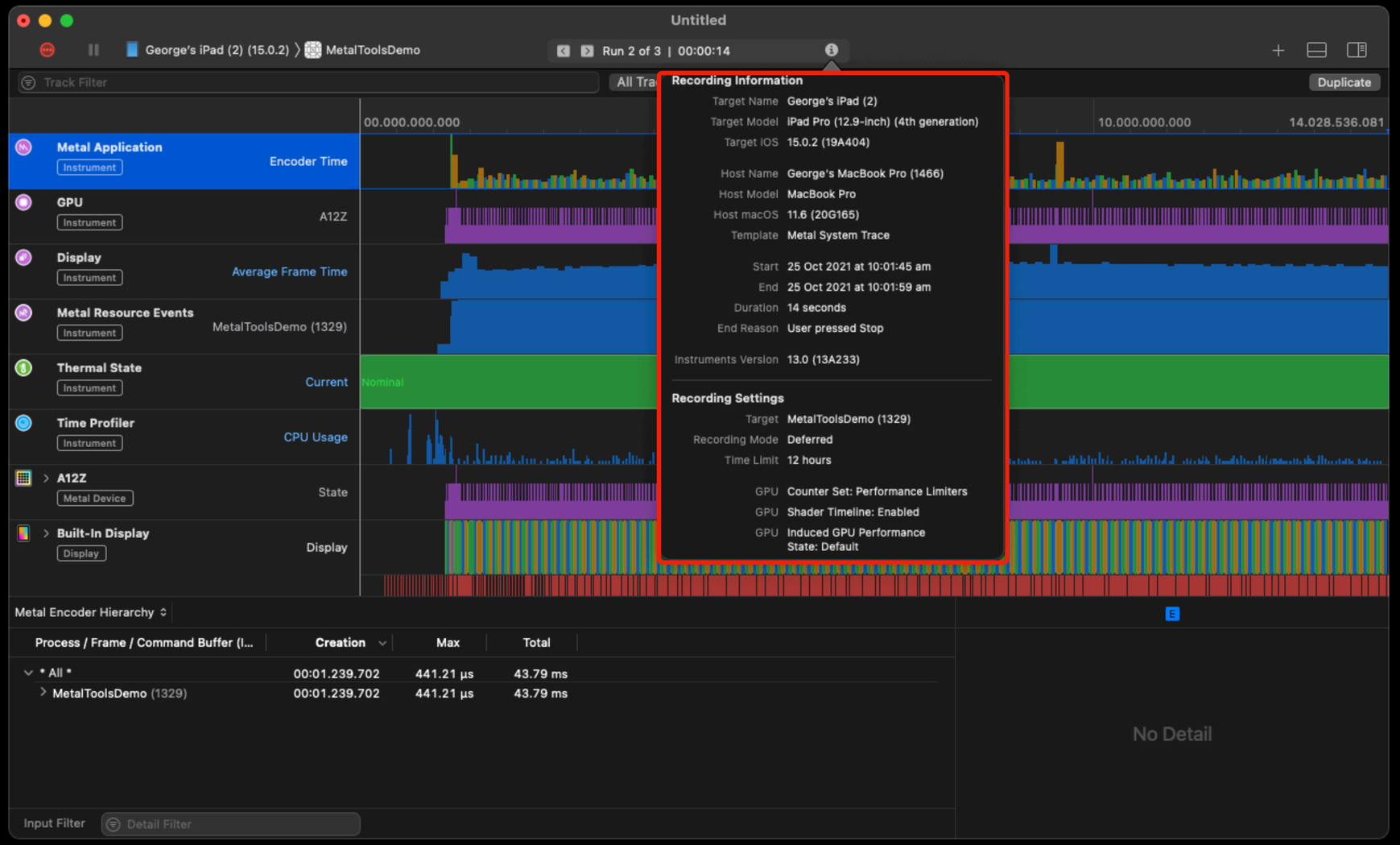
George's iPad (2) (15.0.2) 〉 MetalToolsDemo
Run 2 of 3 | 00:00:14
Track Filter
All Tracks
CPUs
Threads
GPUs
GPU Counters
Duplicate
161.924.340
05.000.000.000
10.000.000.000
14.028.536.081
Metal Application
Instrument
Encoder Time
GPU
Instrument
A12Z
Display
Instrument
Average Frame Time
Metal Resource Events
Instrument
MetalToolsDemo (1329)
Thermal State
Instrument
Current
Nominal (14.03 s)
Time Profiler
Instrument
CPU Usage
A12Z
Metal Device
State
Built-In Display
Display
Display
Metal Encoder Hierarchy
Process / Frame / Command Buffer (I...
Creation
Max
Total
* All *
00:01.239.702
441.21 µs
43.79 ms
MetalToolsDemo (1329)
00:01.239.702
441.21 µs
43.79 ms
No Detail
Input Filter
Detail Filter

Records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MetalToolsDemo
Run 2 of 3 | 00:00:14
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Thermal State
Instrument
Current
Nominal
Time Profiler
Instrument
CPU Usage
A12Z
Metal Device
State
Built-In Display
Display
Display
Recording Information
Target Name George's iPad (2)
Target Model iPad Pro (12.9-inch) (4th generation)
Target iOS 15.0.2 (19A404)
Host Name George's MacBook Pro (1466)
Host Model MacBook Pro
Host macOS 11.6 (20G165)
Template Metal System Trace
Start 25 Oct 2021 at 10:01:45 am
End 25 Oct 2021 at 10:01:59 am
Duration 14 seconds
End Reason User pressed Stop
Instruments Version 13.0 (13A233)
Recording Settings
Target MetalToolsDemo (1329)
Recording Mode Deferred
Time Limit 12 hours
GPU Counter Set: Performance Limiters
GPU Shader Timeline: Enabled
GPU Induced GPU Performance State: Default
Metal Encoder Hierarchy
Process / Frame / Command Buffer (I...
Creation
Max
Total
* All *
00:01.239.702
441.21 µs
43.79 ms
MetalToolsDemo (1329)
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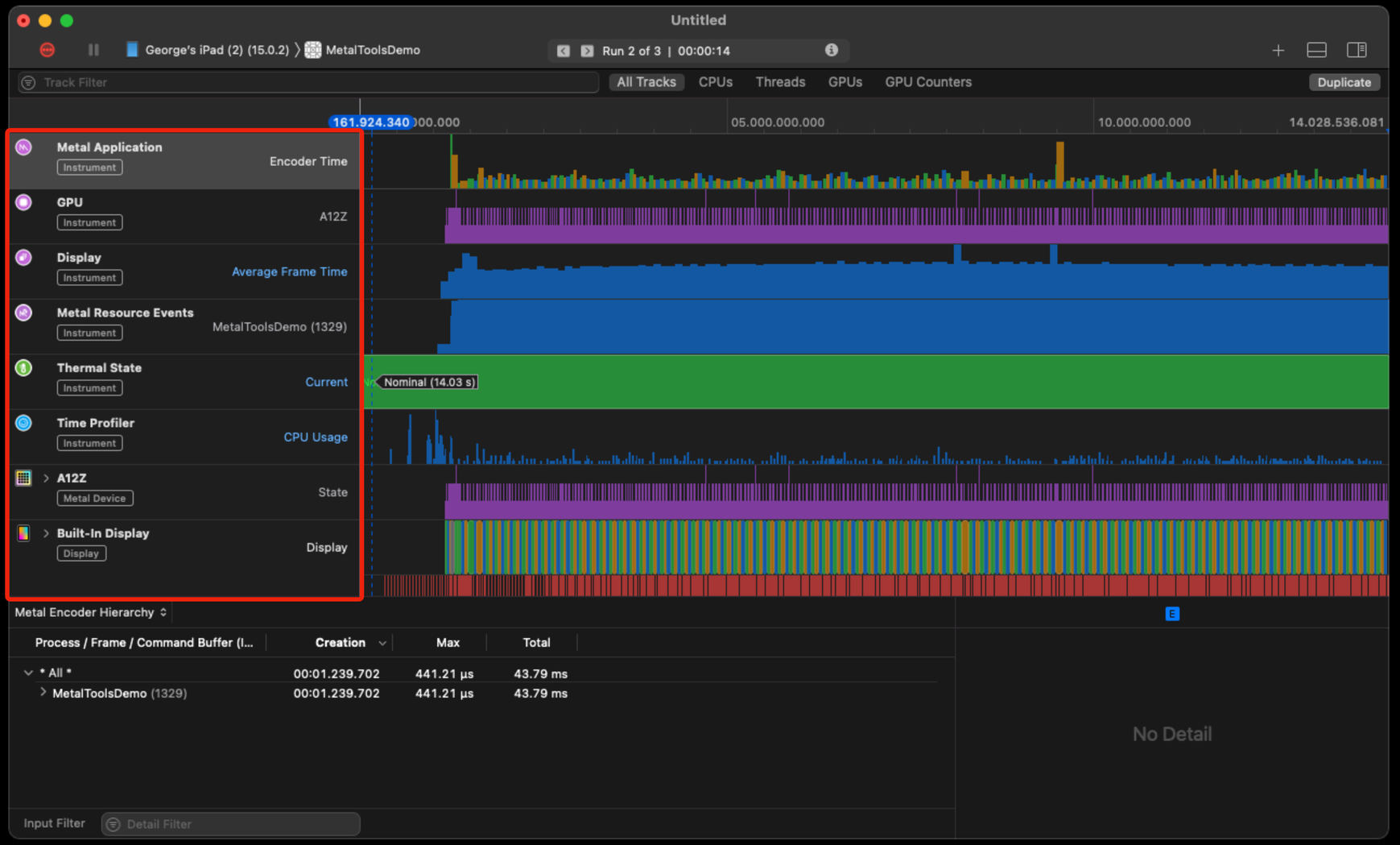
Tracks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George's iPad (2) (15.0.2) 〉 MetalToolsDemo
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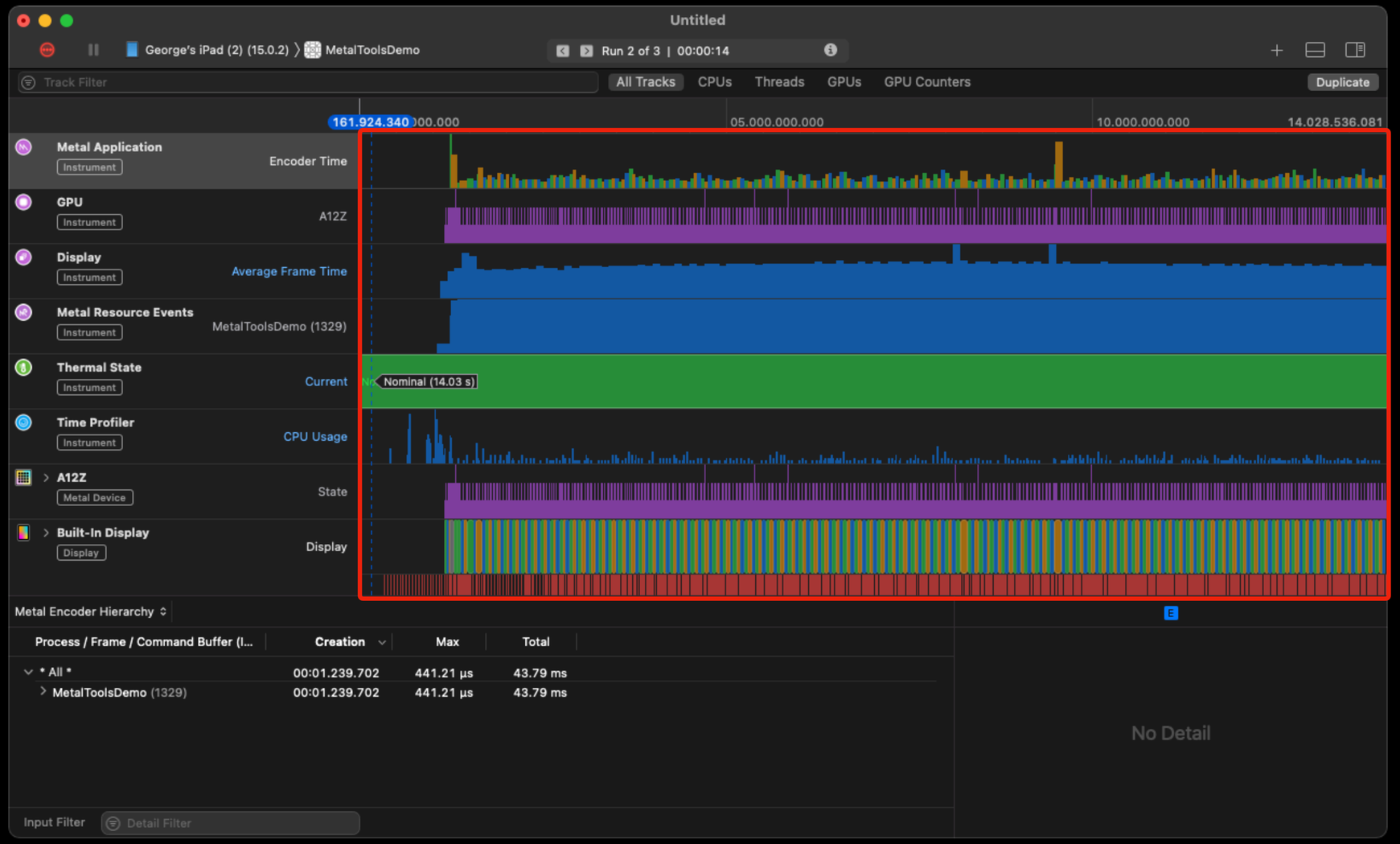
Tracks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George's iPad (2) (15.0.2)
MetalToolsDemo
Run 2 of 3 | 00:00:14
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All Tracks
CPUs
Threads
GPUs
GPU Counters
Duplicate
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Metal Encoder Hierarchy
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* All *
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43.79 ms
MetalToolsDemo (1329)
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441.21 µs
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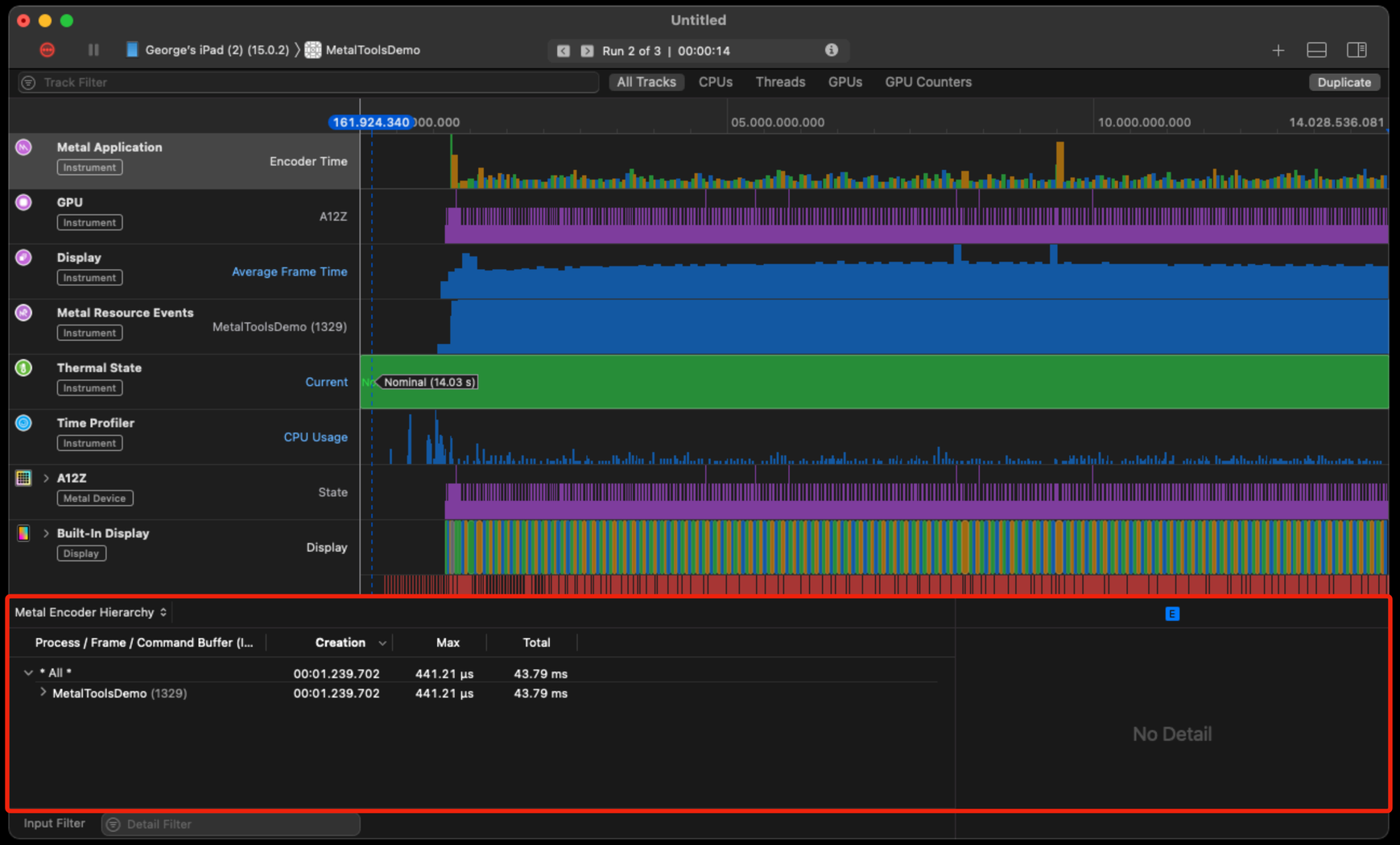
Detail Filter

Details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Time Profiler
Instrument
CPU Usage
A12Z
Metal Device
State
Built-In Display
Display
Display
Metal Encoder Hierarchy
Process / Frame / Command Buffer (I...
Creation
Max
Total
* All *
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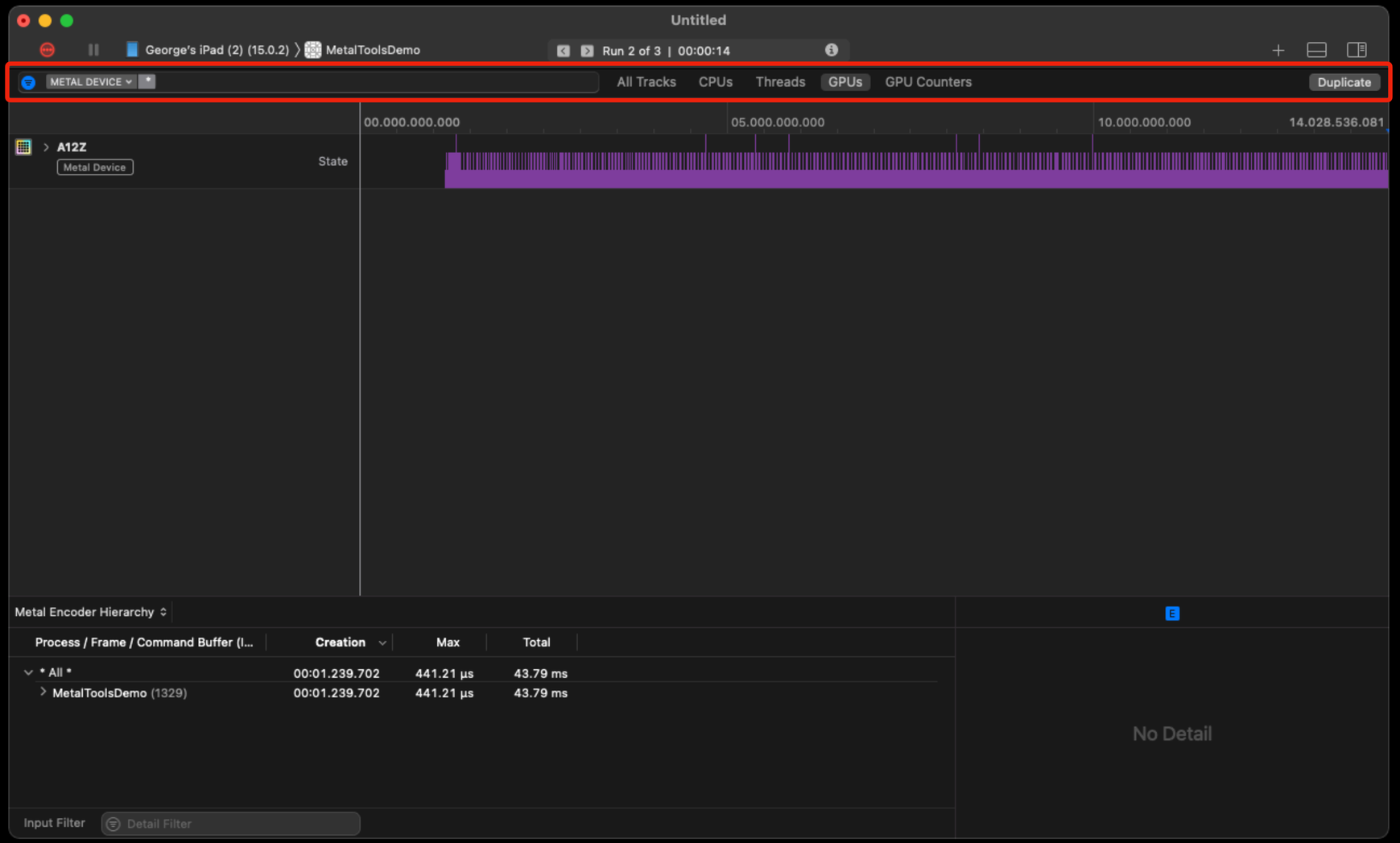
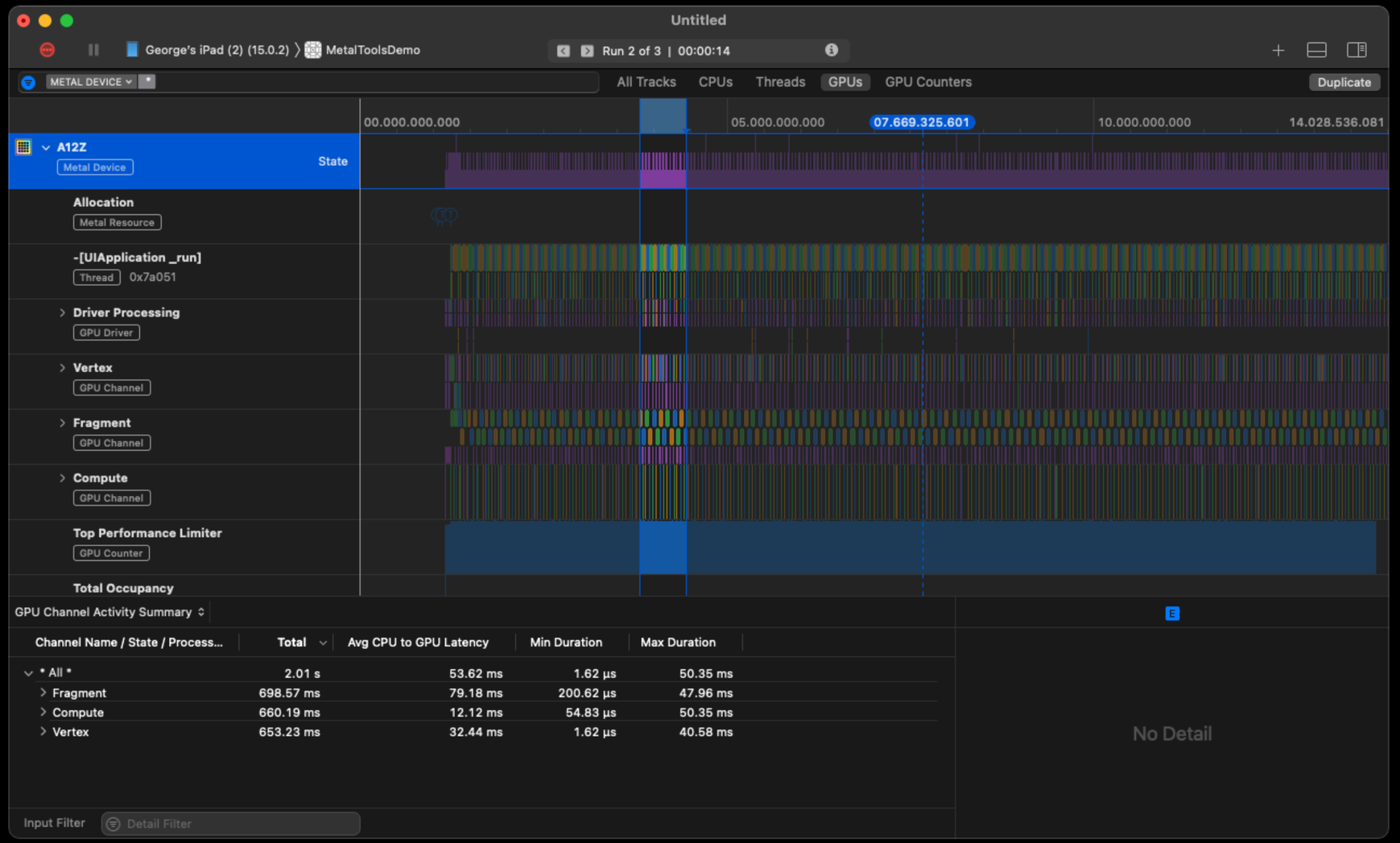
441.21 µs
43.79 ms
MetalToolsDemo (1329)
00:01.239.702
441.21 µs
43.79 ms
No Detail
Input Filter
Detail Filter

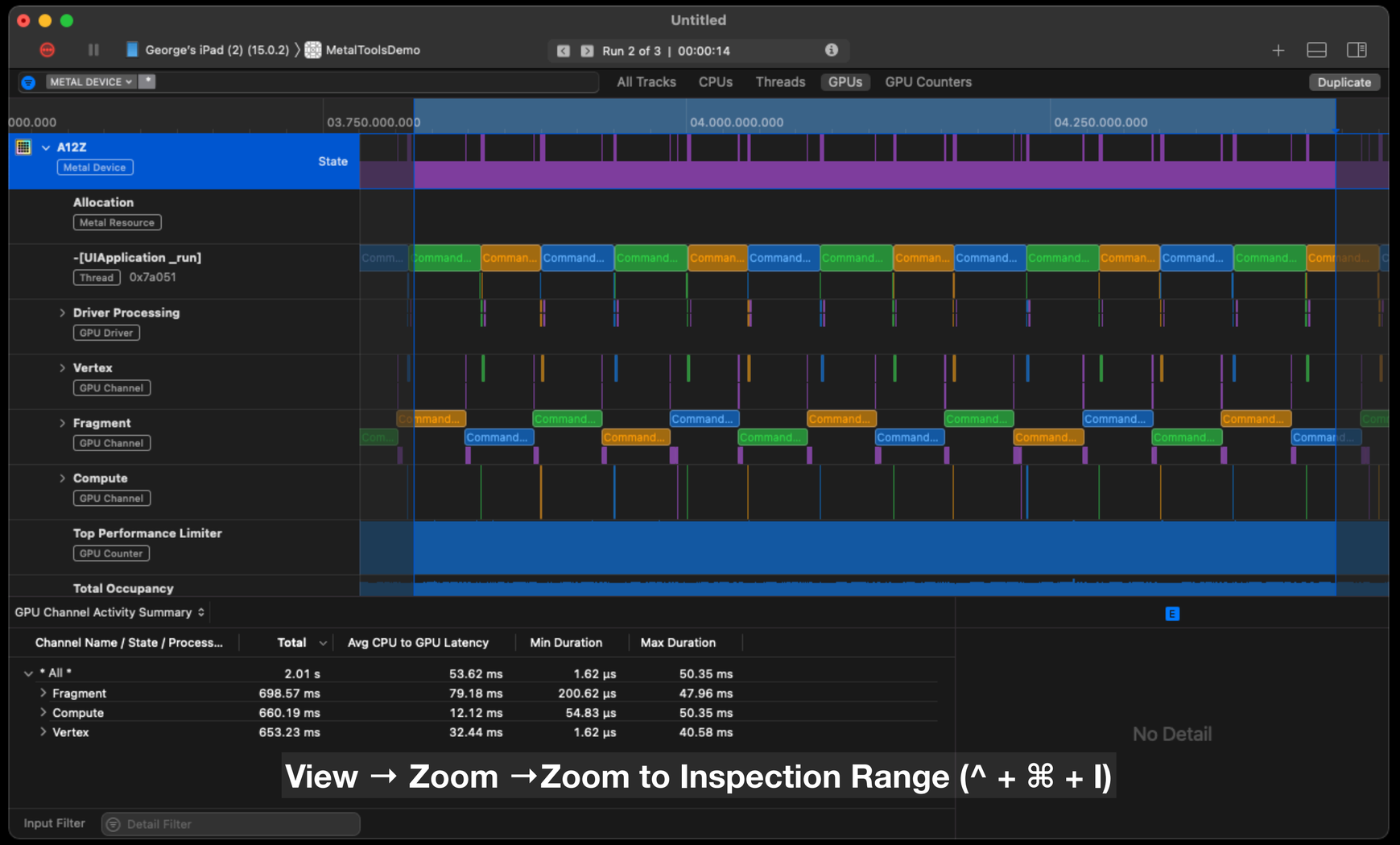
Tracks: Filters



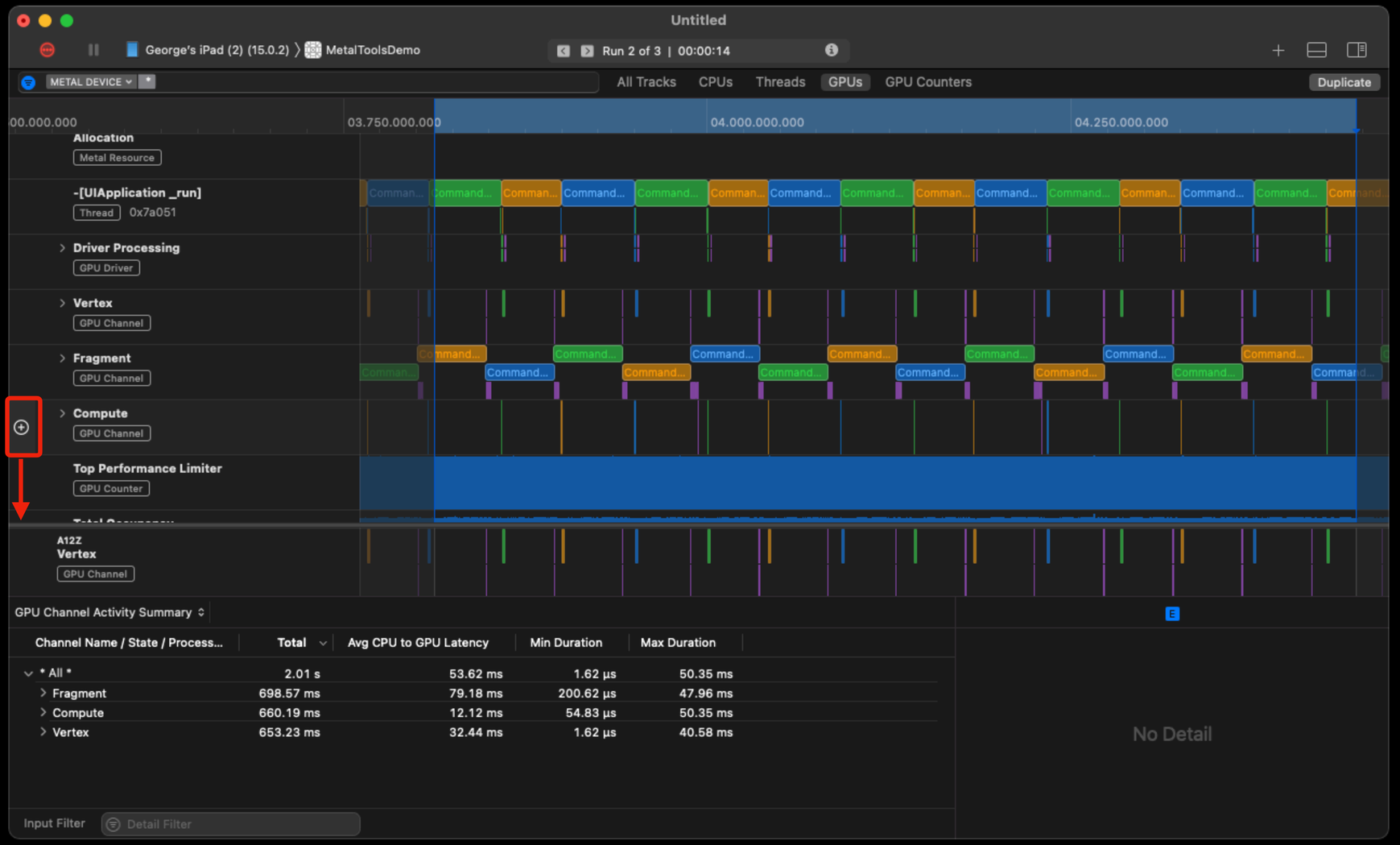
Tracks: Zoom


Untitled
George's iPad (2) (15.0.2)
MetalToolsDemo
Run 2 of 3 | 00:00:14
METAL DEVICE
All Tracks
CPUs
Threads
GPUs
GPU Counters
Duplicate
00.000.000.000
05.000.000.000
07.669.325.601
10.000.000.000
14.028.536.081
A12Z
Metal Device
State
Allocation
Metal Resource
-[UIApplication _run]
Thread
0x7a051
Driver Processing
GPU Driver
Vertex
GPU Channel
Fragment
GPU Channel
Compute
GPU Channel
Top Performance Limiter
GPU Counter
Total Occupancy
GPU Channel Activity Summary
Channel Name / State / Process...
Total
Avg CPU to GPU Latency
Min Duration
Max Duration
* All *
2.01 s
53.62 ms
1.62 µs
50.35 ms
Fragment
698.57 ms
79.18 ms
200.62 µs
47.96 ms
Compute
660.19 ms
12.12 ms
54.83 µs
50.35 ms
Vertex
653.23 ms
32.44 ms
1.62 µs
40.58 ms
No Detail
Input Filter
Detail Filter

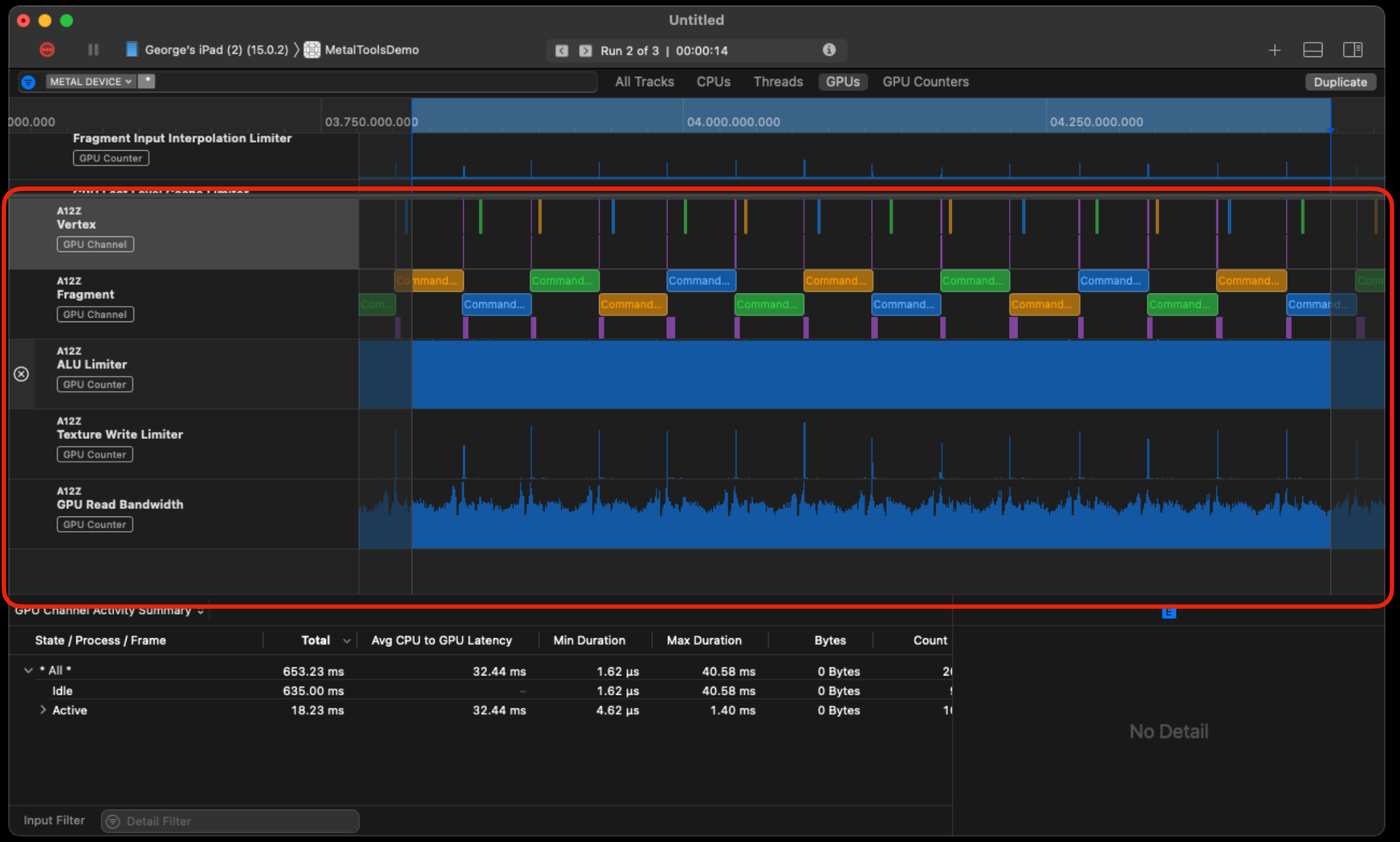
Tracks: Zoom


Untitled
George's iPad (2) (15.0.2) 〉 MetalToolsDemo
Run 2 of 3 | 00:00:14
METAL DEVICE
All Tracks
CPUs
Threads
GPUs
GPU Counters
Duplicate
000.000
03.750.000.000
04.000.000.000
04.250.000.000
A12Z
Metal Device
State
Allocation
Metal Resource
-[UIApplication _run]
Thread
0x7a051
Driver Processing
GPU Driver
Vertex
GPU Channel
Fragment
GPU Channel
Compute
GPU Channel
Top Performance Limiter
GPU Counter
Total Occupancy
GPU Channel Activity Summary
Channel Name / State / Process...
Total
Avg CPU to GPU Latency
Min Duration
Max Duration
* All *
2.01 s
53.62 ms
1.62 µs
50.35 ms
Fragment
698.57 ms
79.18 ms
200.62 µs
47.96 ms
Compute
660.19 ms
12.12 ms
54.83 µs
50.35 ms
Vertex
653.23 ms
32.44 ms
1.62 µs
40.58 ms
No Detail
View → Zoom →Zoom to Inspection Range (^ + ⌘ + I)
Input Filter
Detail Filter

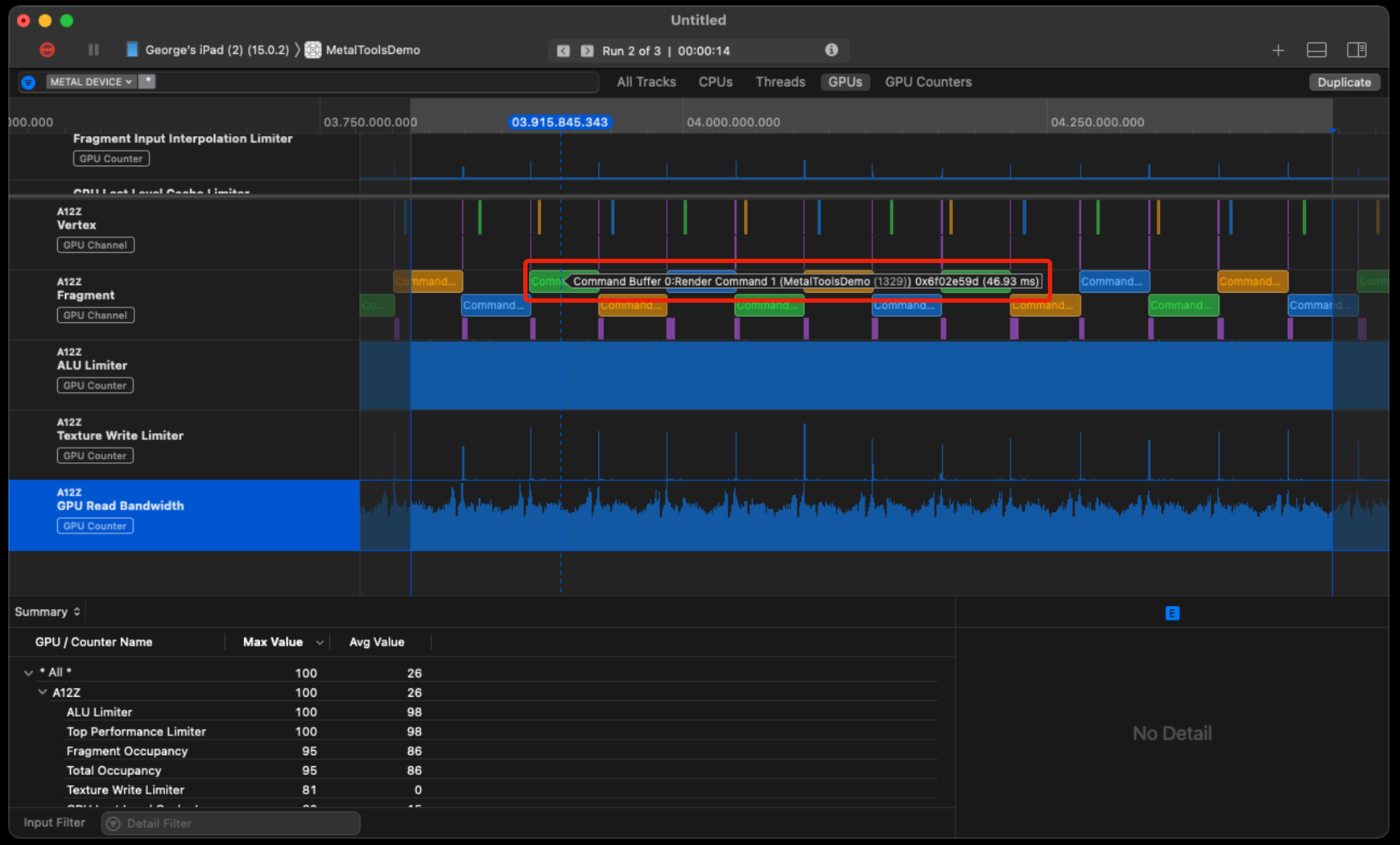
Tracks: Selecting



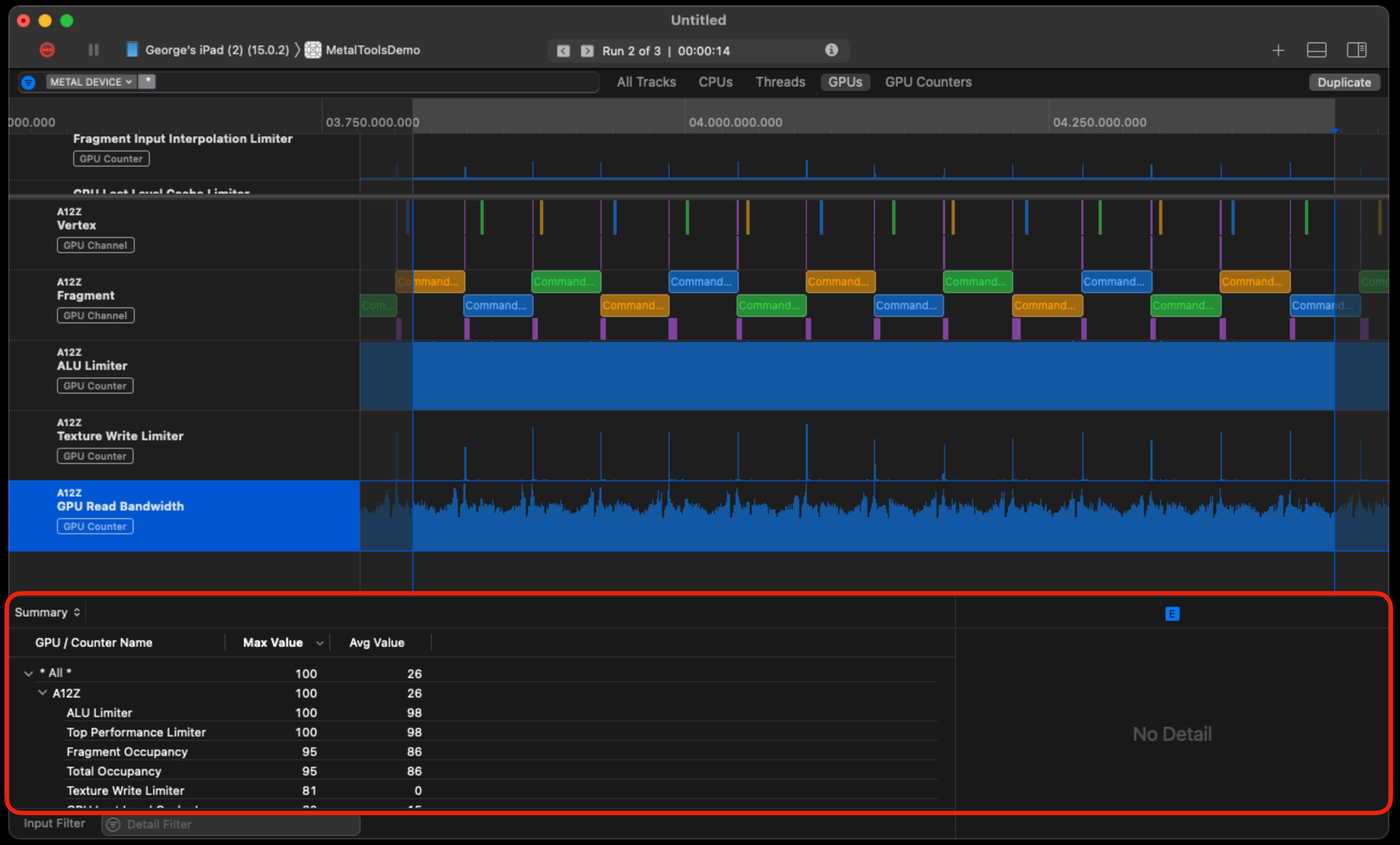
Tracks: Selecting



Tracks: Event Preview



Tracks: Event Details



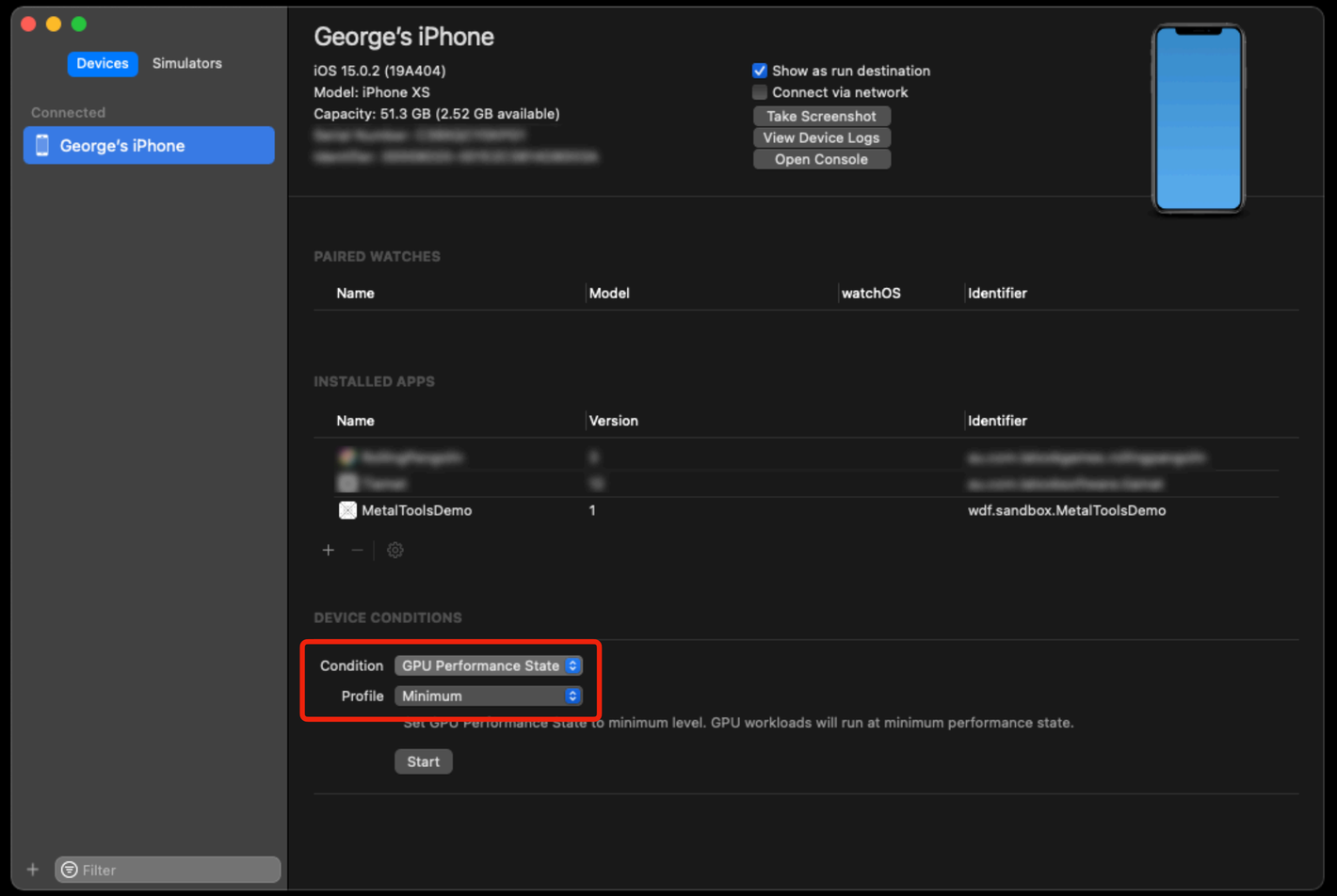
PREPARATION

Devices and Simulators

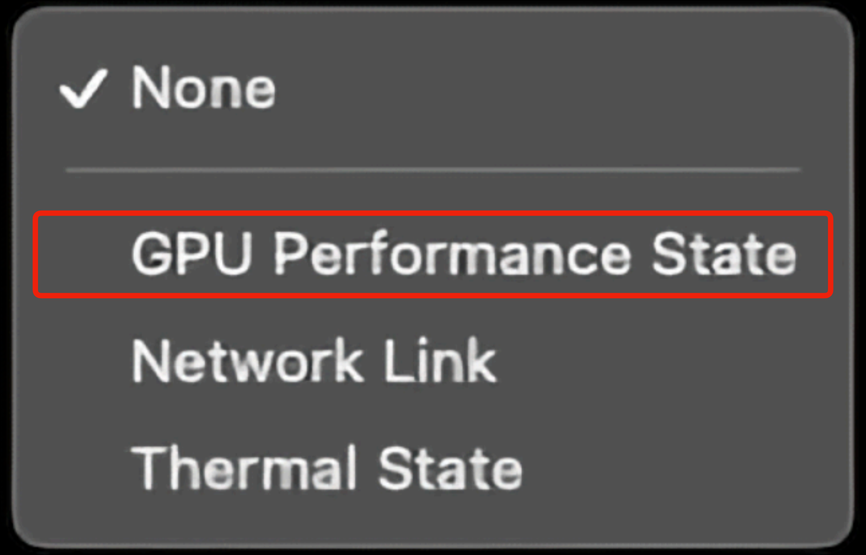
Device Setup

Window → Devices and Simulators

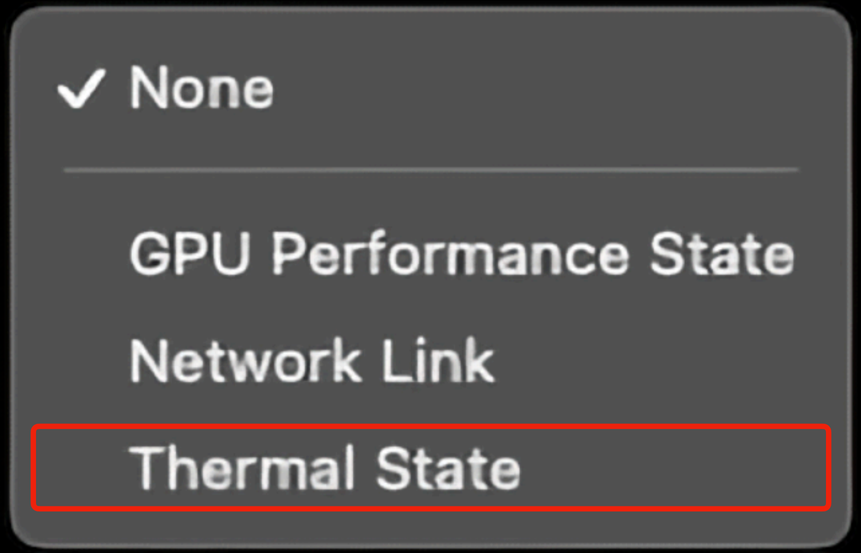
Device Setup



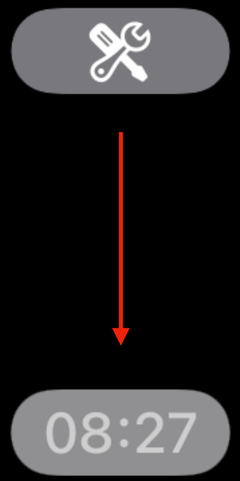
Device Setup



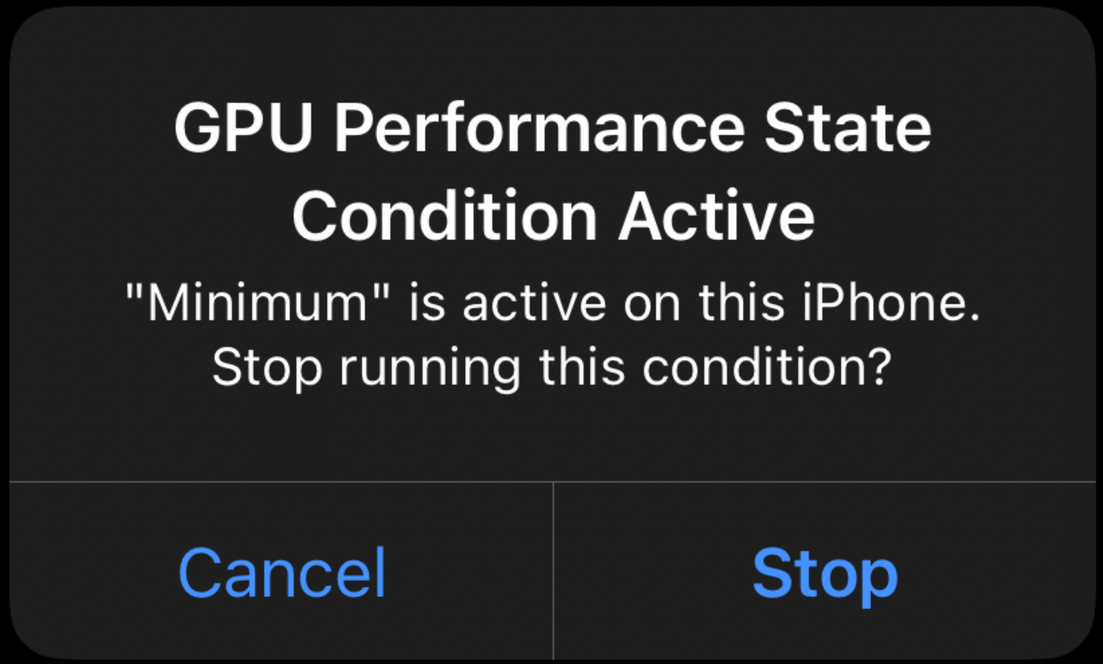
Device Setup



Device Setup



Device Setup



Simulators

- Nothing interesting in Instruments
- No conditions
- No record options
- Nothing interesting in GPU Capture

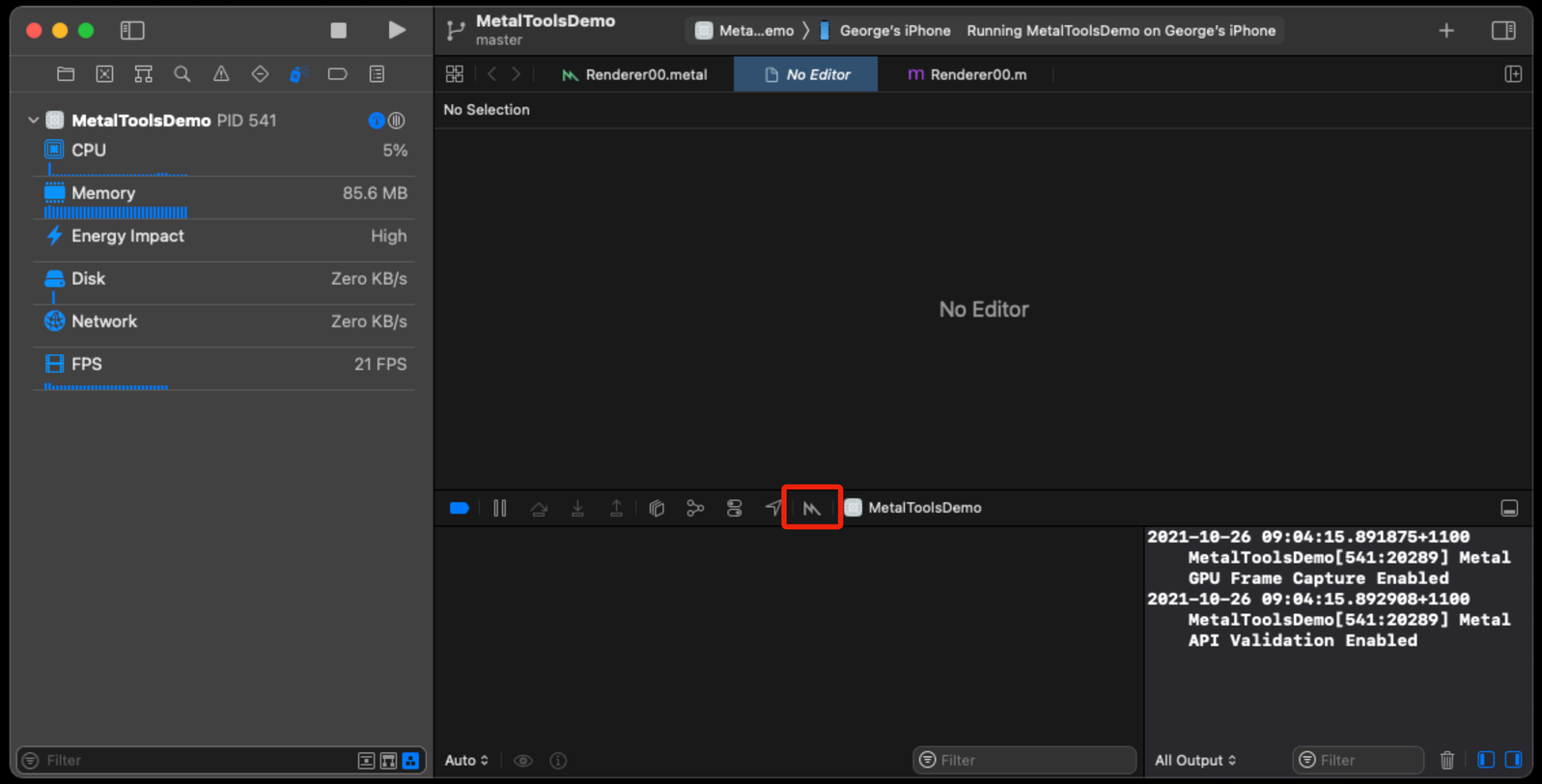
Simulators

- Nothing interesting in Instruments
- No conditions
- No record options
- Nothing interesting in GPU Capture

XCODE

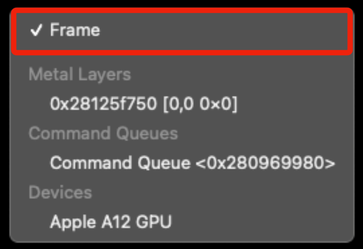
GPU Frame Capture

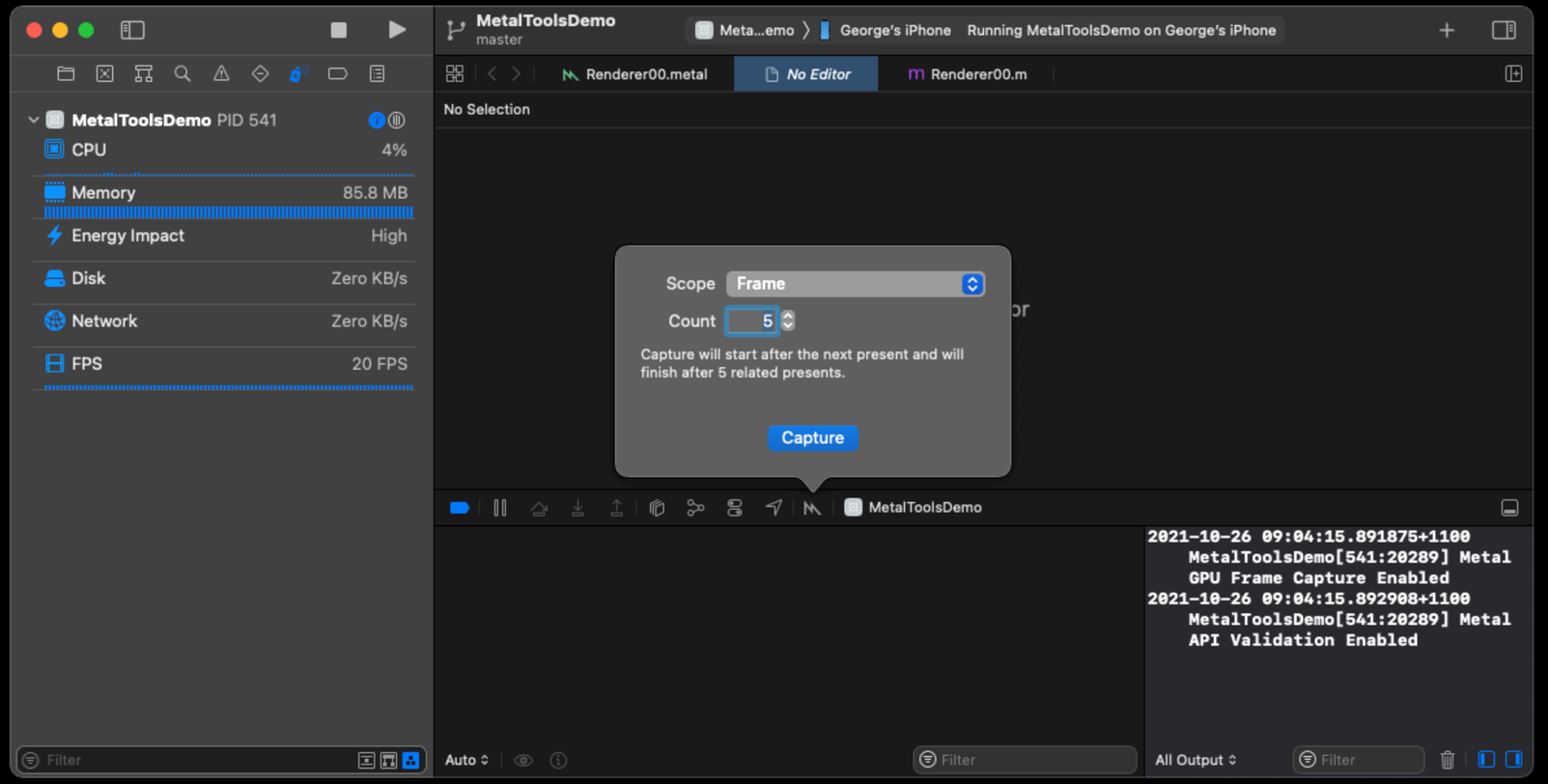
GPU Frame Capture



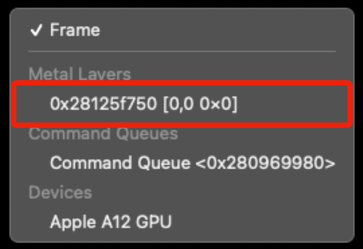
Debug → Capture GPU Workload

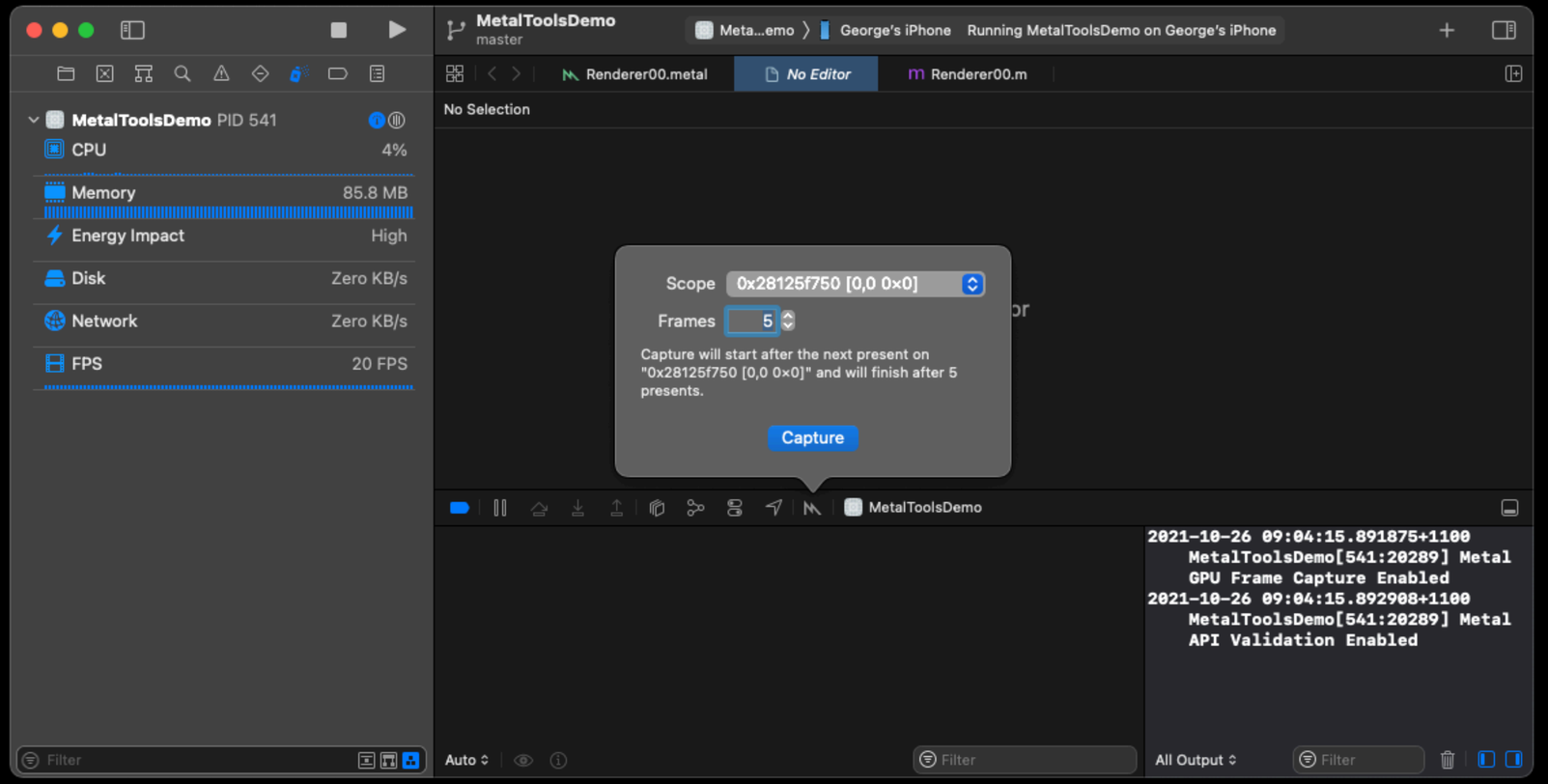
GPU Frame Capture



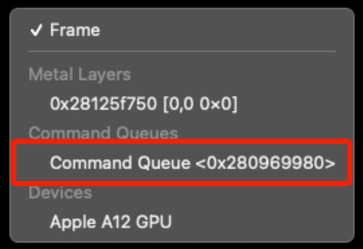


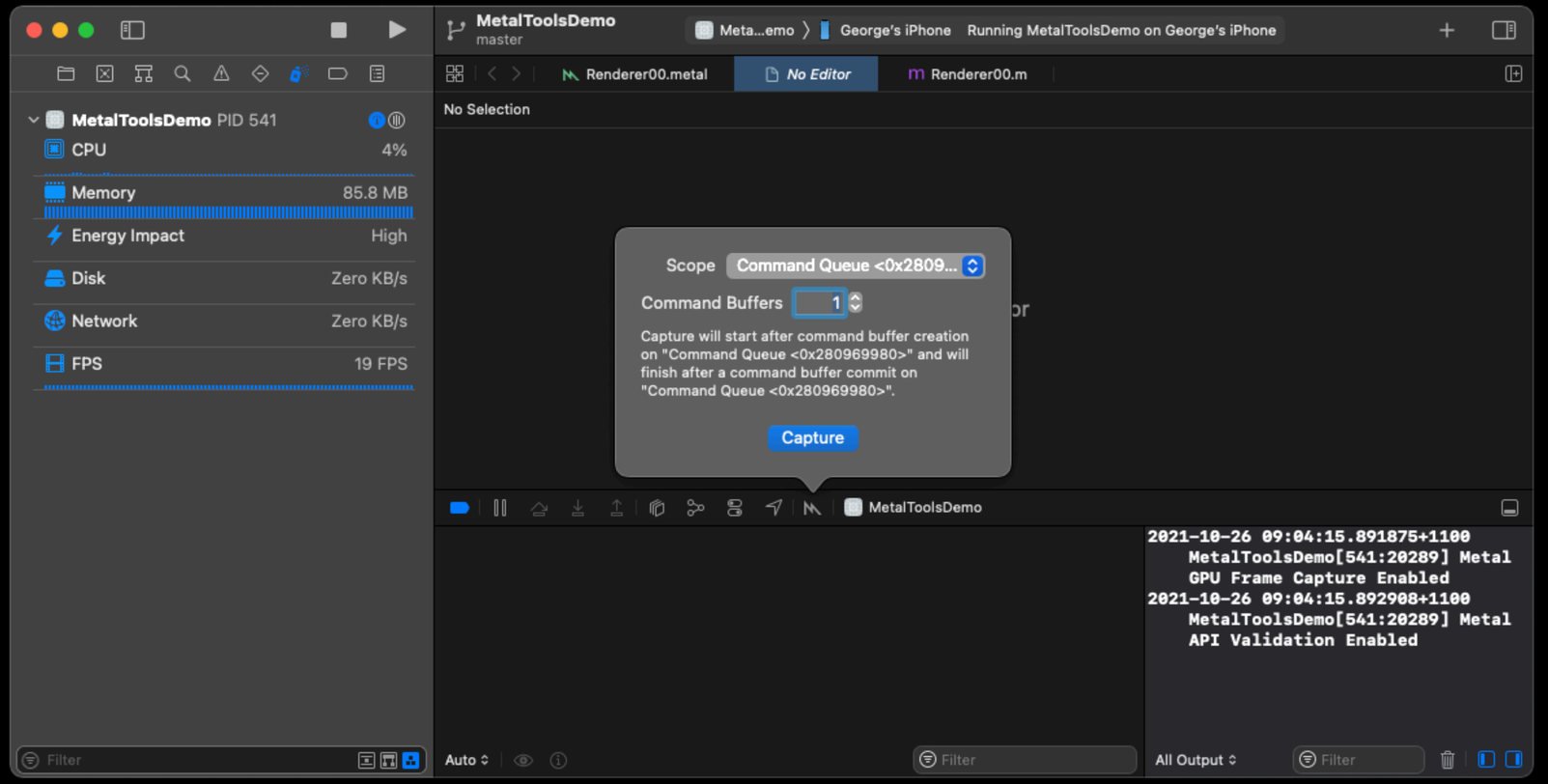
GPU Frame Capture



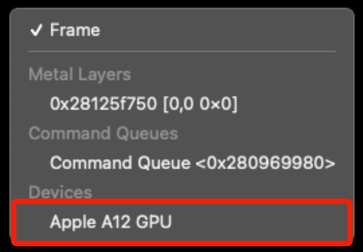


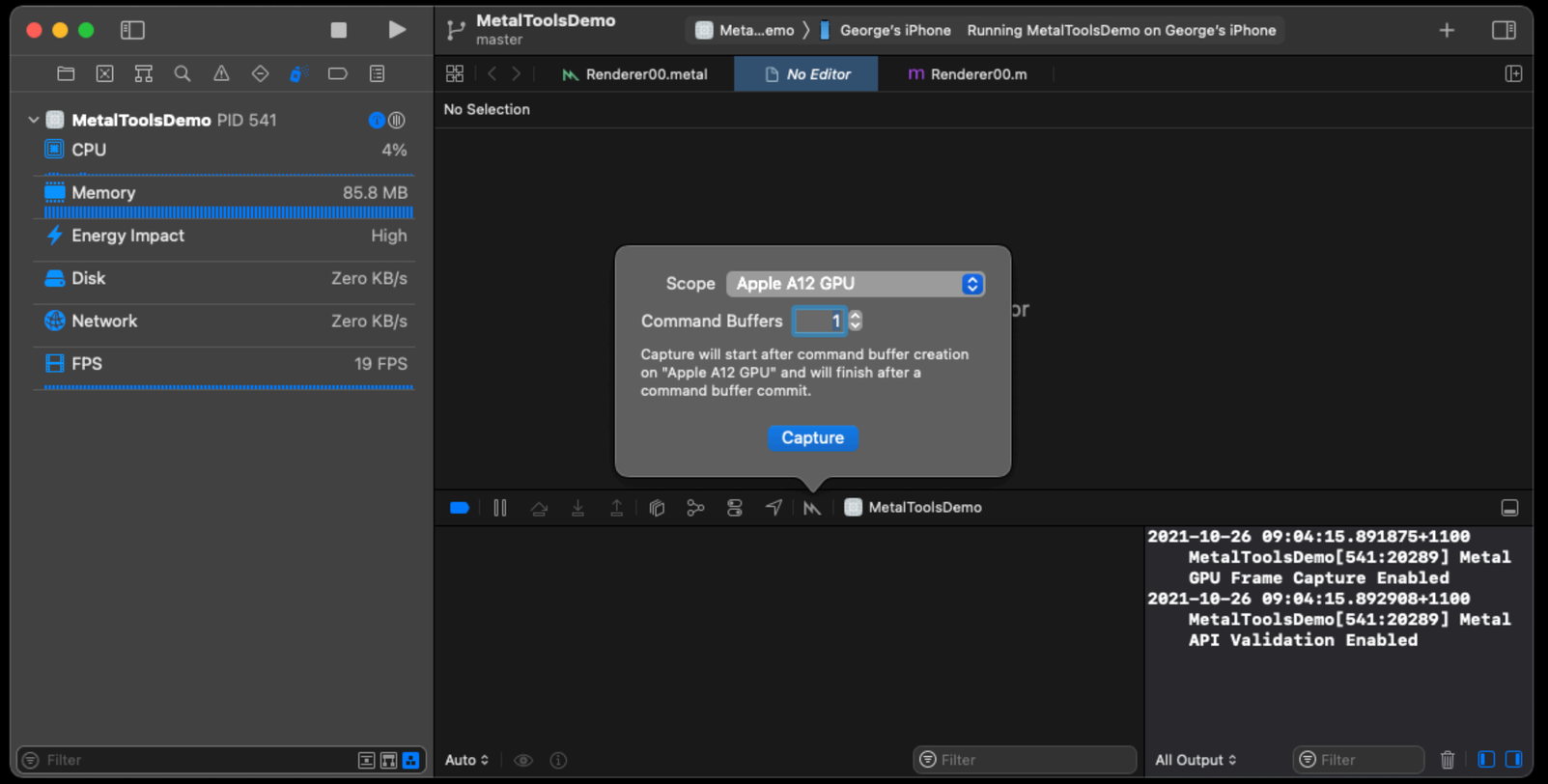
GPU Frame Capture



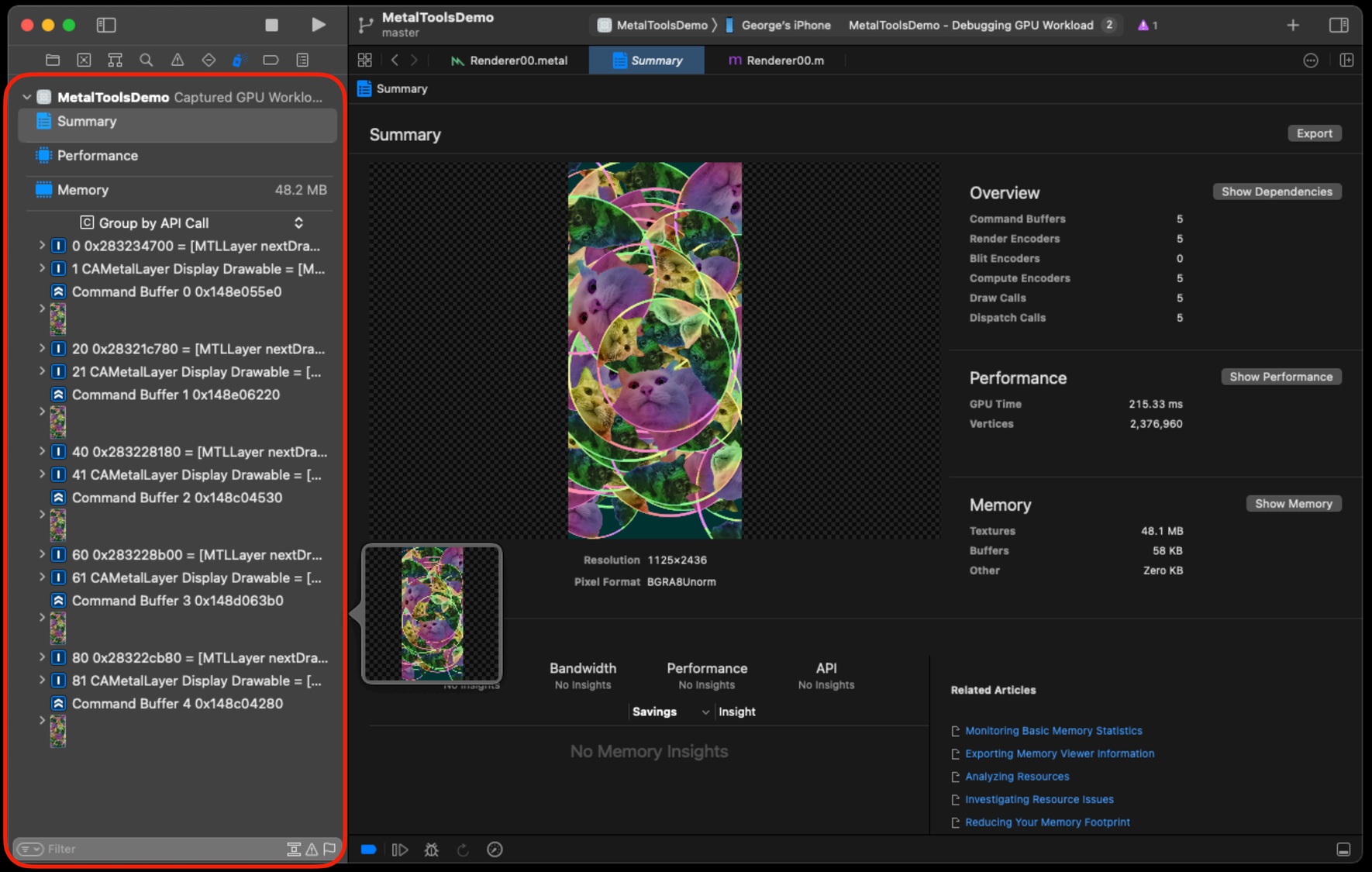


GPU Frame Capture

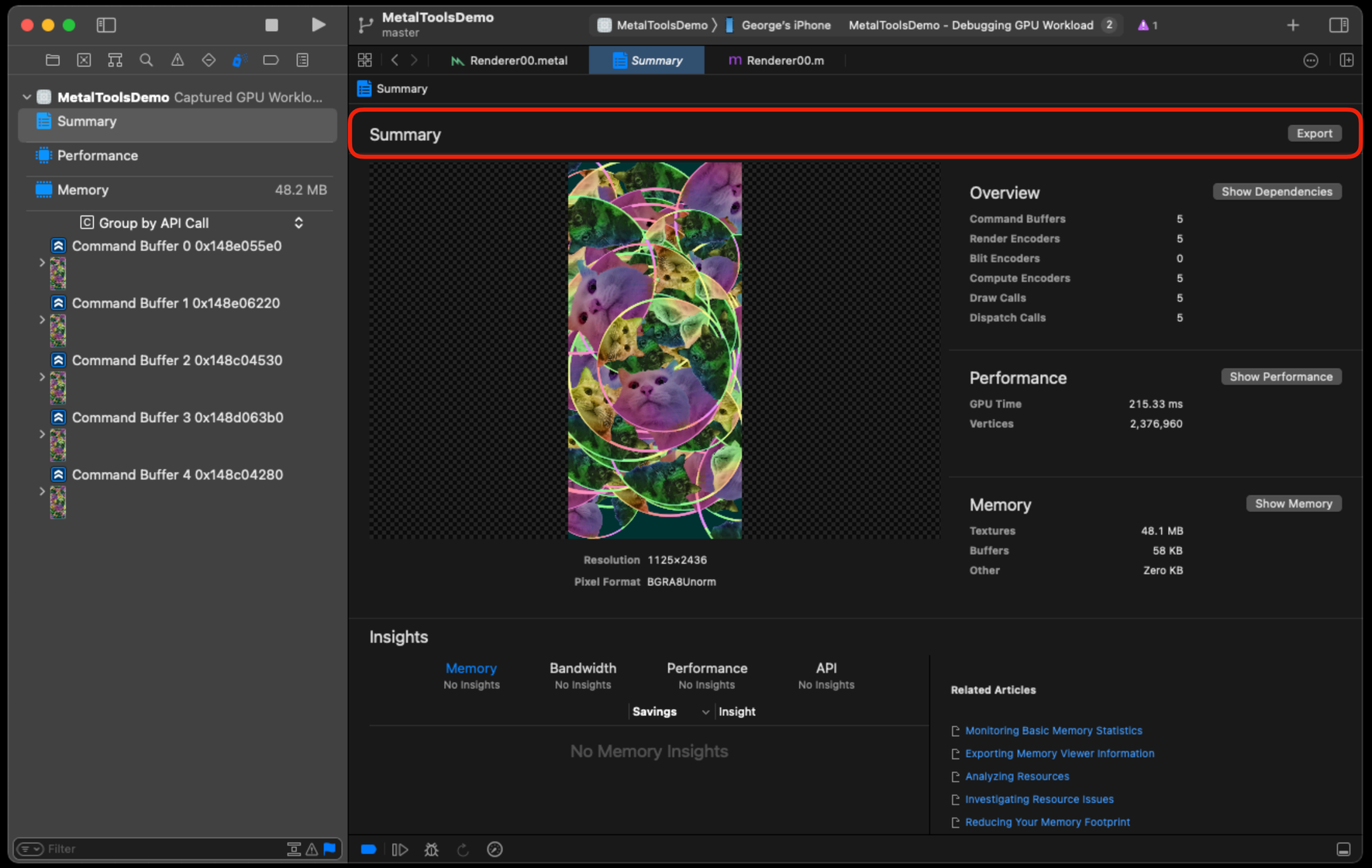




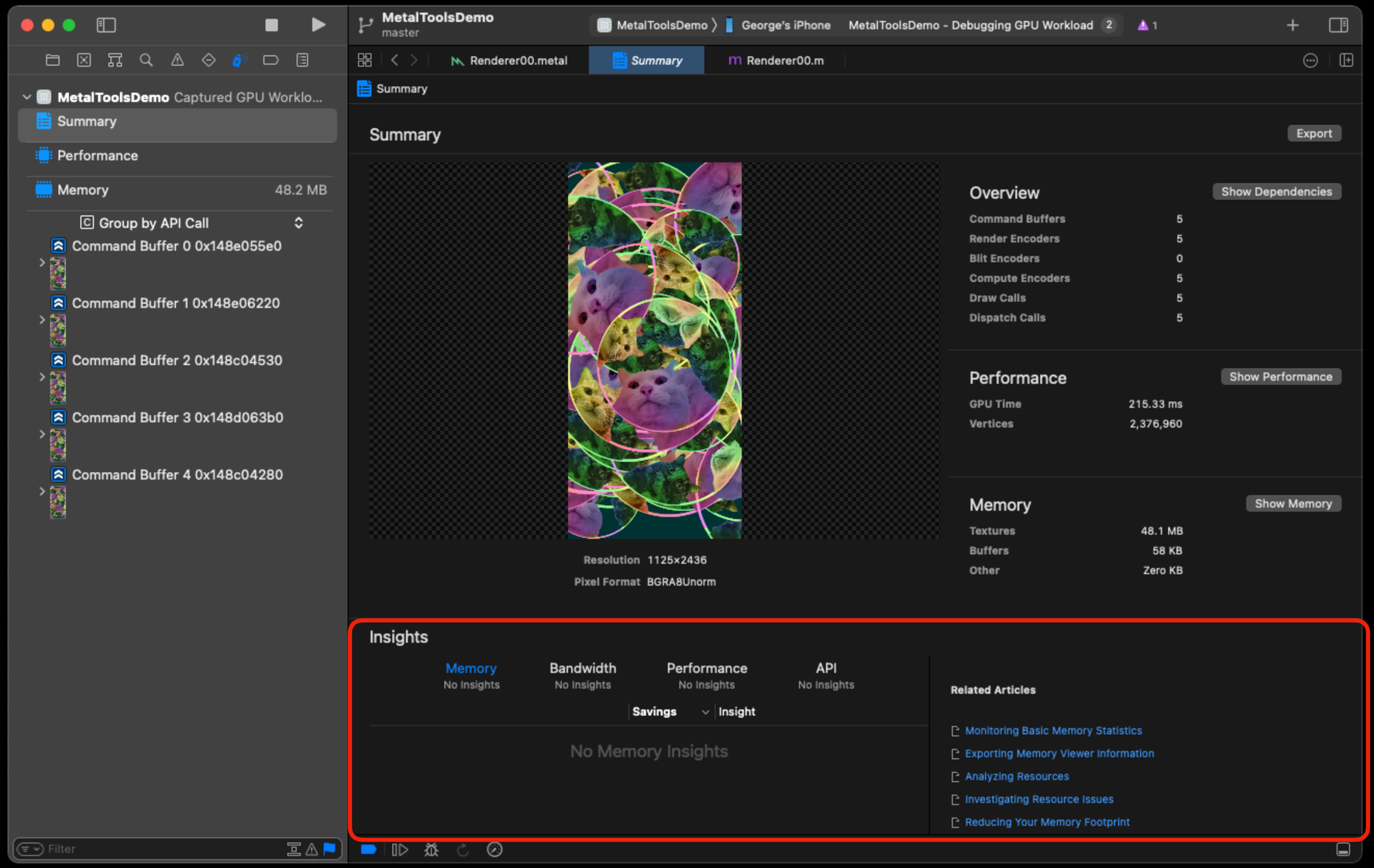
Debug Navigator



Summary: Export



Summary: Insights



Insights

Memory: No Insights | Bandwidth: 12.7 GB | Performance: No Insights | API: No Insights

	Savings	Insight
Render cats	12.7 GB	Coalece Encoders x 1256
Render cats	5.1 MB	Coalece Encoders
Render cats	10.1 MB	Coalece Encoders
Render cats	10.1 MB	Coalece Encoders
Render cats	10.1 MB	Coalece Encoders
Render cats	10.1 MB	Coalece Encoders
Render cats	10.1 MB	Coalece Encoders
Render cats	10.1 MB	Coalece Encoders
Render cats	10.1 MB	Coalece Encoders
Render cats	10.1 MB	Coalece Encoders

Render cats
Draw Calls 1

Encoder 'Render cats' is the root of 1257 encoders that can be coalesced

Your application created separate command encoders which can be combined into a single encoder. By combining these encoders you may reduce your application's load/store bandwidth usage.

Insights

Memory: No Insights | Bandwidth: 268.4 MB | Performance: 1 Insight | API: No Insights

	Savings	Insight
Texture 0x100e34fc0	268.4 MB	Lossless Compression

Texture 0x100e34fc0

Type	2D
Pixel Format	BGRA8Unorm
Mipmap Level	0
Width	8192
Height	8192

Resource "Texture 0x100e34fc0" can't be lossless compressed.

'Texture:0x100e34fc0' opted out of lossless compression because its usage flags include 'ShaderWrite' which prevents lossless compression

Insights

Memory: No Insights | Bandwidth: No Insights | Performance: 1 Insight | API: No Insights

	Count	Insight
fshShader00 (vshShader -> fshShader00)	1 Insight	High float to half ratio

fshShader00

Shader "vshShader" in pipeline "vshShader -> fshShader00" uses a relatively high number of 32-bit floating point operations. (69.78 of Instructions, 68.96 of Shader Cost, 246.67 ms Shader Time)

- For optimal performance, use 16-bit half data types when possible. Avoid 32-bit floating point inputs (textures / buffers). Avoid implicit conversions.

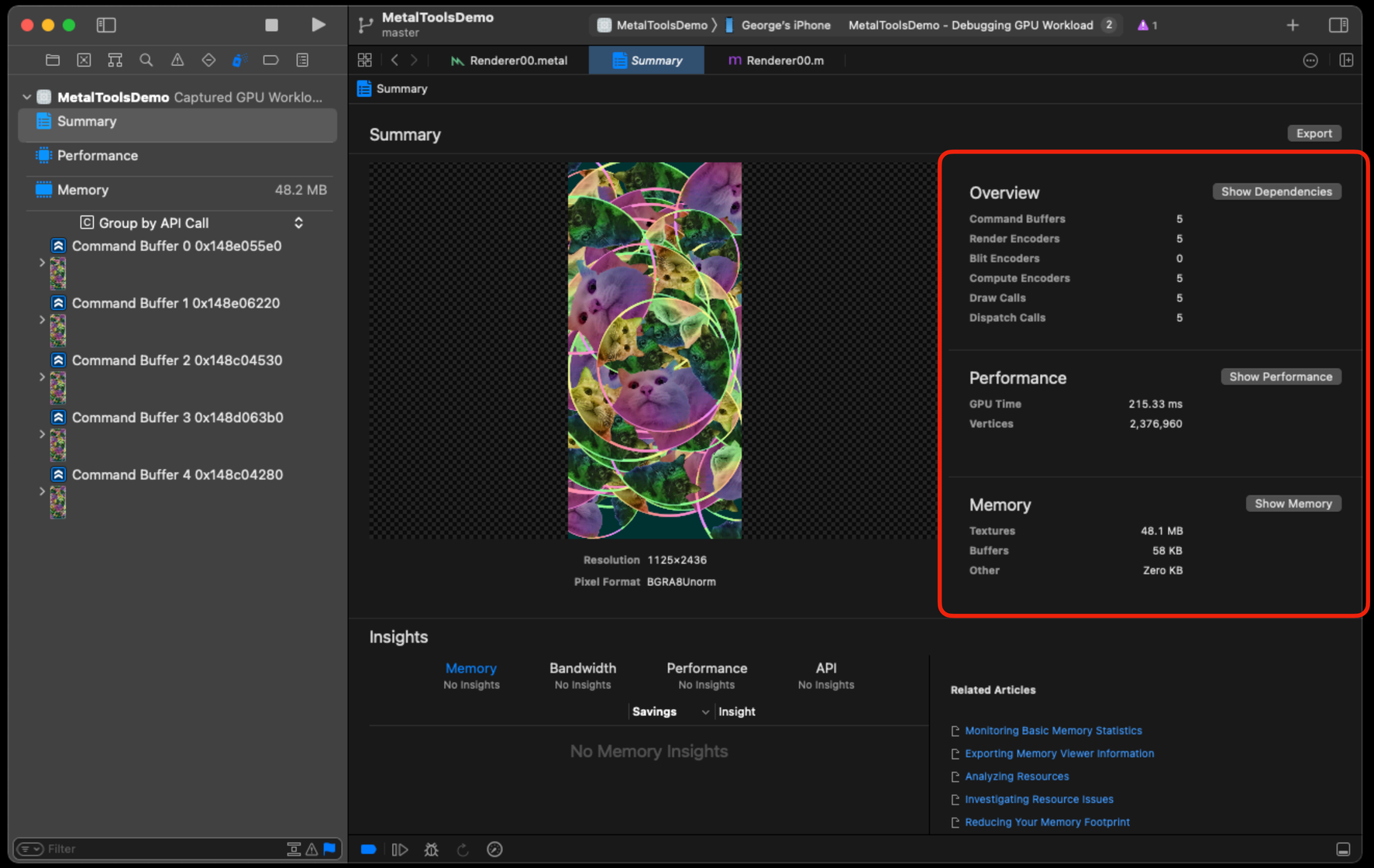
Show Resource

Related Articles

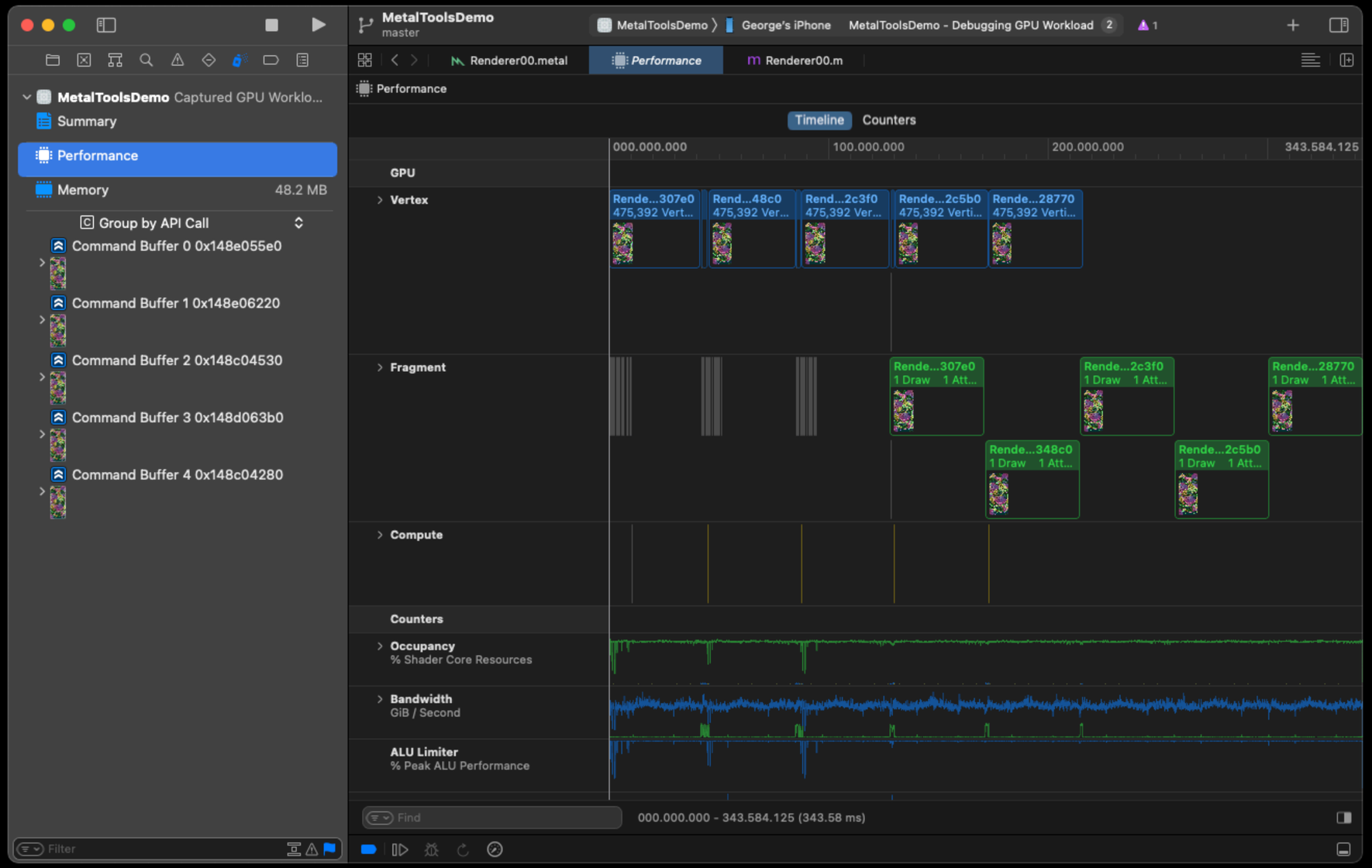
Optimizing Performance with the Shader Profiler

Optimizing Performance with Pipeline Statistics

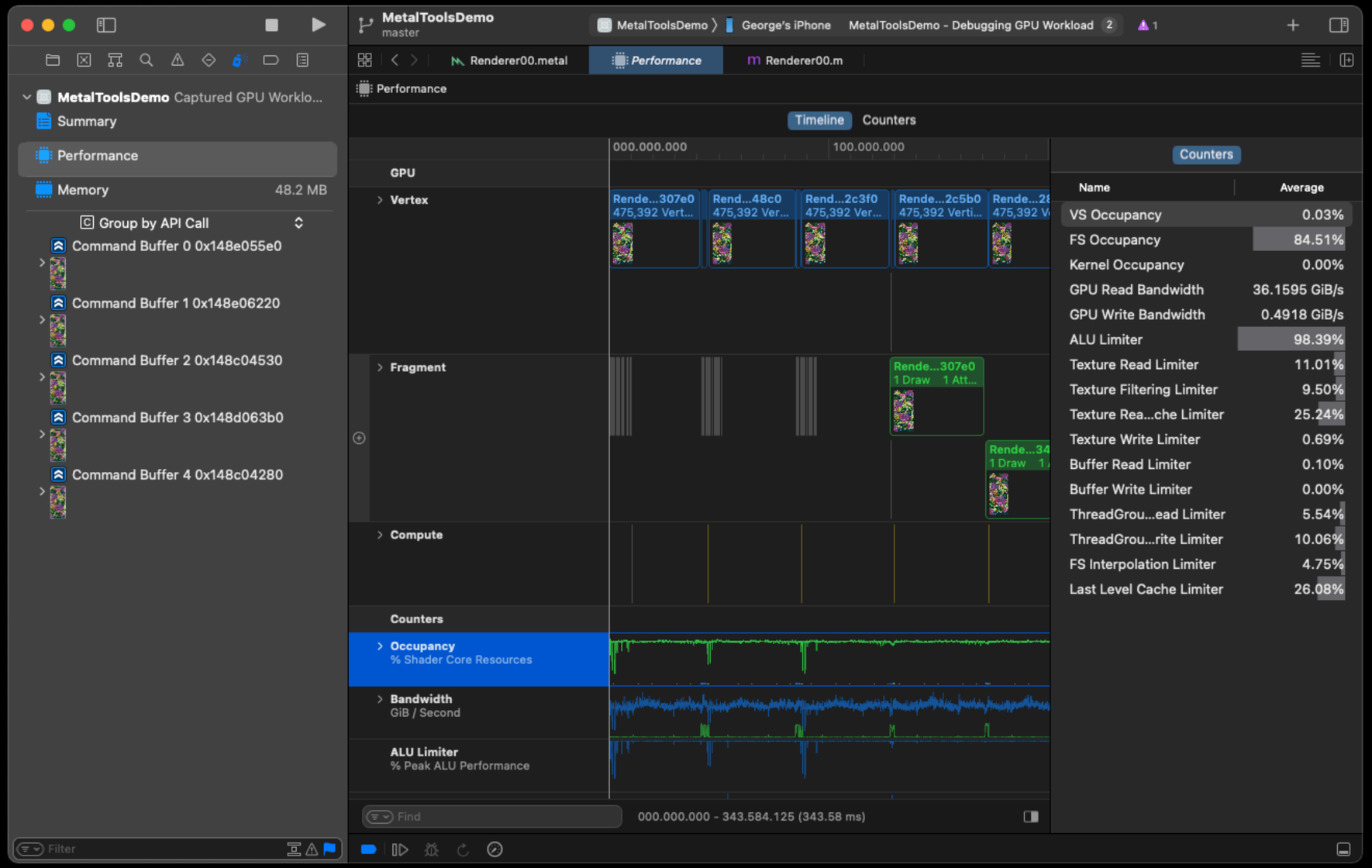
Summary: Overview



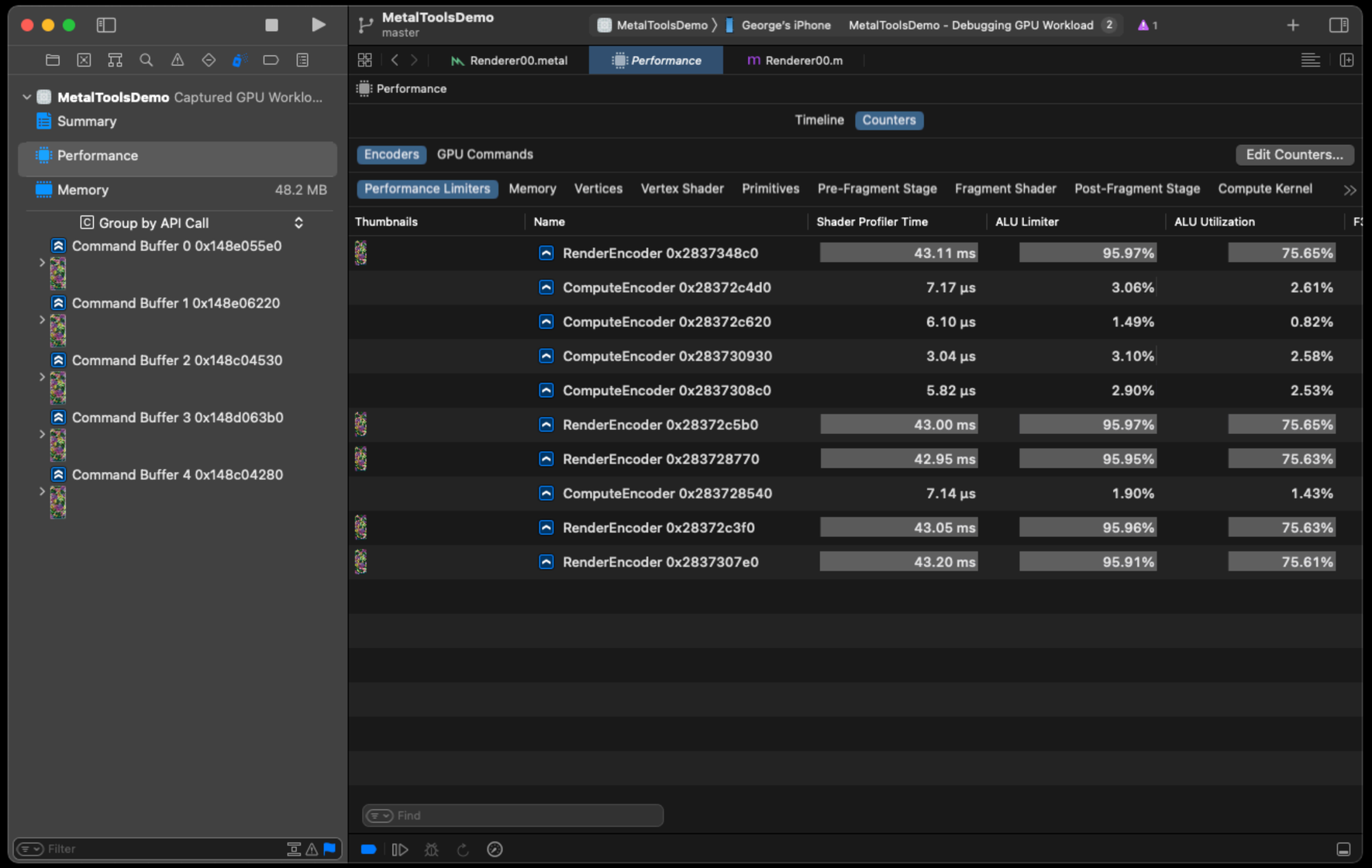
Performance: Timeline



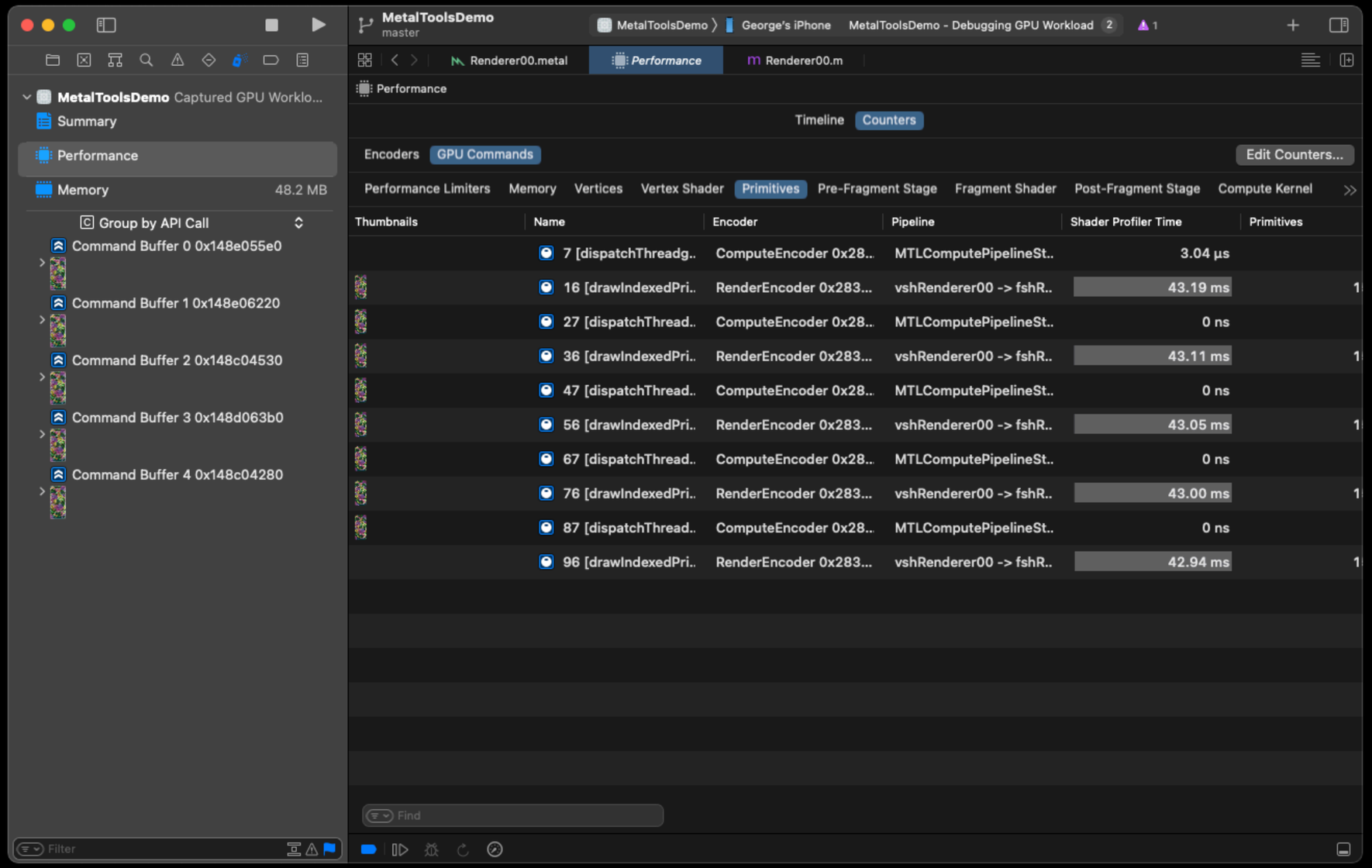
Performance: Details



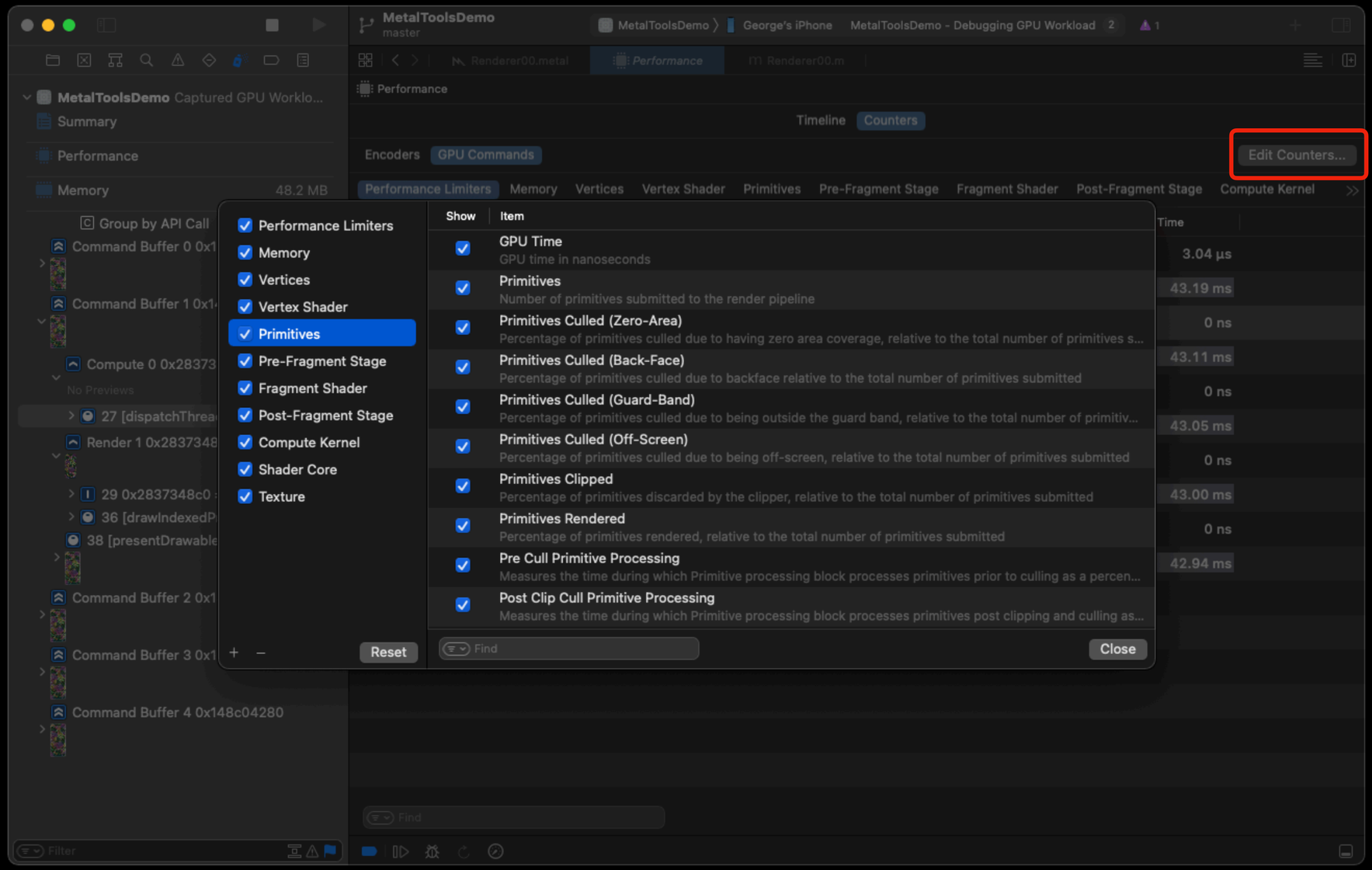
Performance: Counters



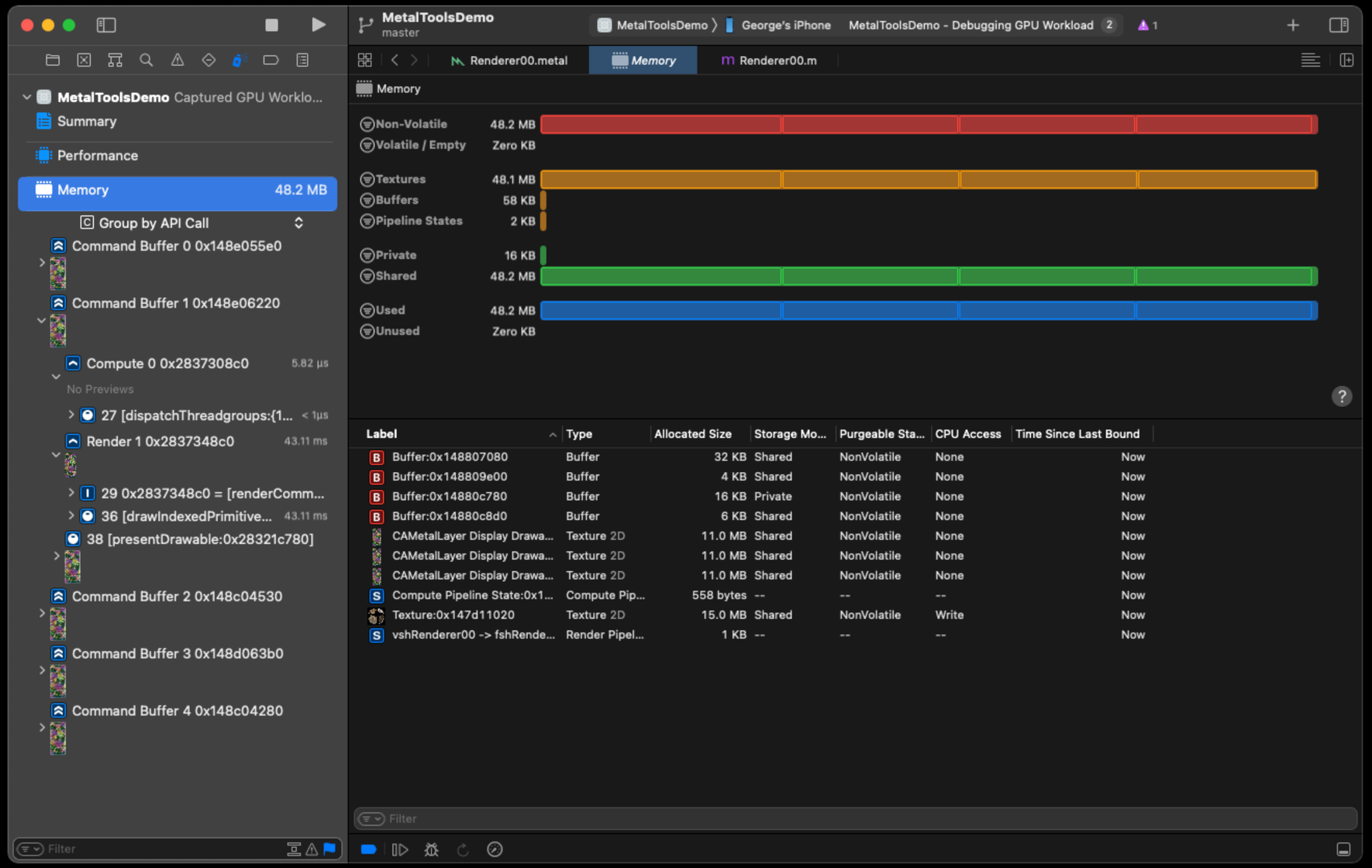
Performance: Counters



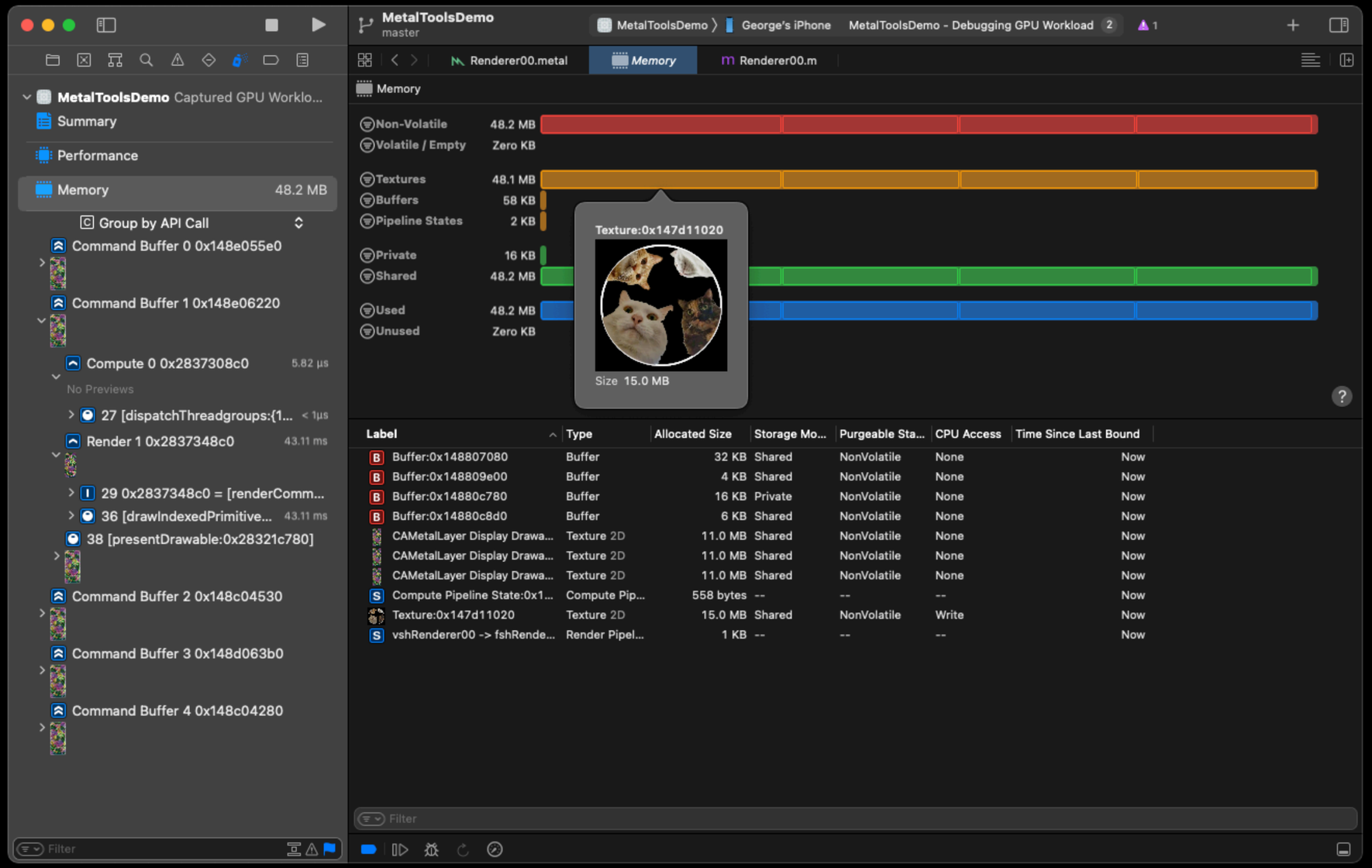
Performance: Edit Counters



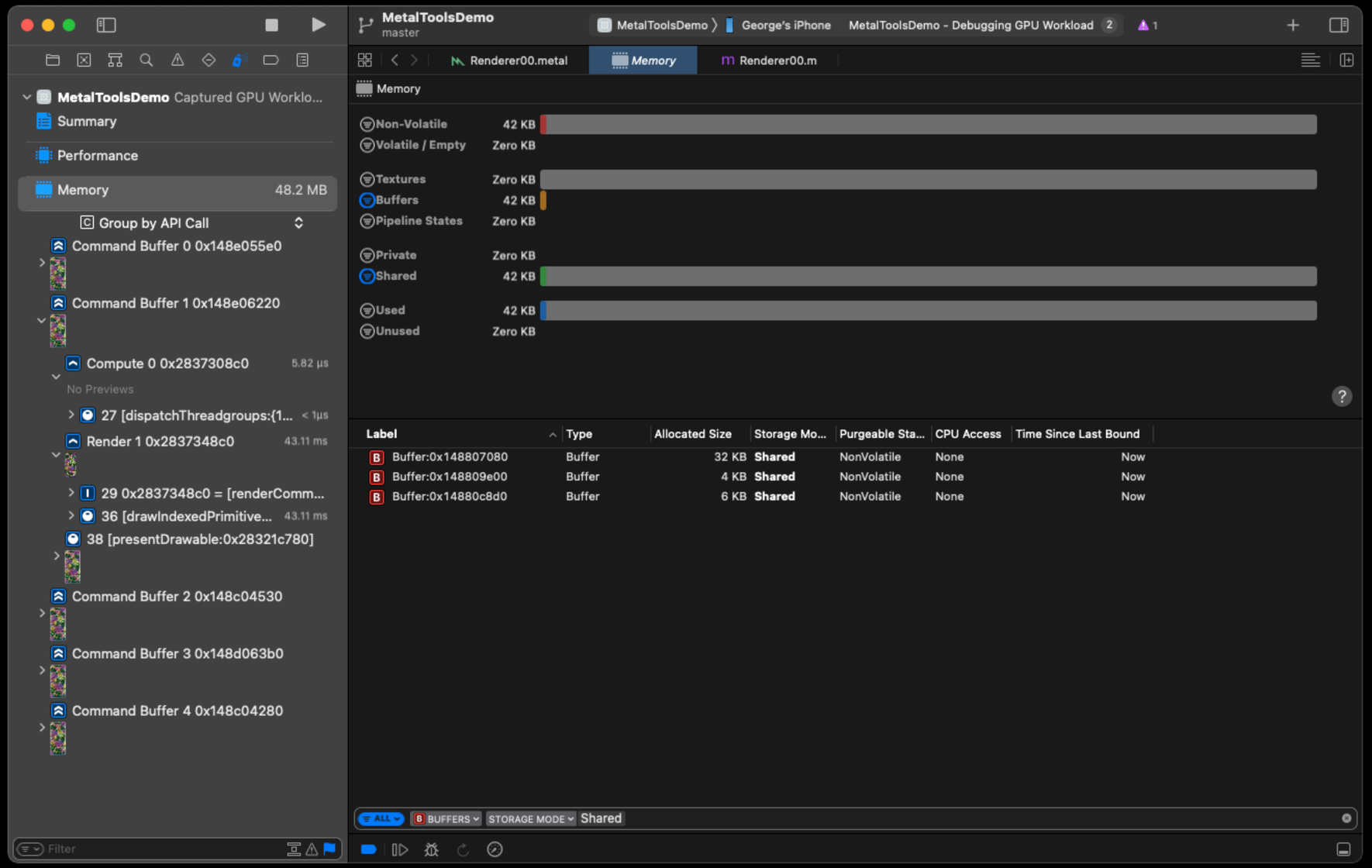
Memory


MetalToolsDemo
master
MetalToolsDemo 〉 George's iPhone MetalToolsDemo - Debugging GPU Workload 2 1
Renderer00.metal
Memory
Renderer00.m
MetalToolsDemo Captured GPU Worklo...
Summary
Performance
Memory 48.2 MB
Group by API Call
Command Buffer 0 0x148e055e0
Command Buffer 1 0x148e06220
Compute 0 0x2837308c0 5.82 µs
No Previews
27 [dispatchThreadgroups:{1... < 1µs
Render 1 0x2837348c0 43.11 ms
29 0x2837348c0 = [renderComm...
36 [drawIndexedPrimitive... 43.11 ms
38 [presentDrawable:0x28321c780]
Command Buffer 2 0x148c04530
Command Buffer 3 0x148d063b0
Command Buffer 4 0x148c04280
Filter
Memory
Non-Volatile 48.2 MB
Volatile / Empty Zero KB
Textures 48.1 MB
Buffers 58 KB
Pipeline States 2 KB
Private 16 KB
Shared 48.2 MB
Used 48.2 MB
Unused Zero KB
Label Type Allocated Size Storage Mo... Purgeable Sta... CPU Access Time Since Last Bound
Buffer:0x148807080 Buffer 32 KB Shared NonVolatile None Now
Buffer:0x148809e00 Buffer 4 KB Shared NonVolatile None Now
Buffer:0x14880c780 Buffer 16 KB Private NonVolatile None Now
Buffer:0x14880c8d0 Buffer 6 KB Shared NonVolatile None Now
CAMetalLayer Display Drawa... Texture 2D 11.0 MB Shared NonVolatile None Now
CAMetalLayer Display Drawa... Texture 2D 11.0 MB Shared NonVolatile None Now
CAMetalLayer Display Drawa... Texture 2D 11.0 MB Shared NonVolatile None Now
Compute Pipeline State:0x1... Compute Pip... 558 bytes -- -- -- Now
Texture:0x147d11020 Texture 2D 15.0 MB Shared NonVolatile Write Now
vshRenderer00 -> fshRende... Render Pipel... 1 KB -- -- -- Now
Filter

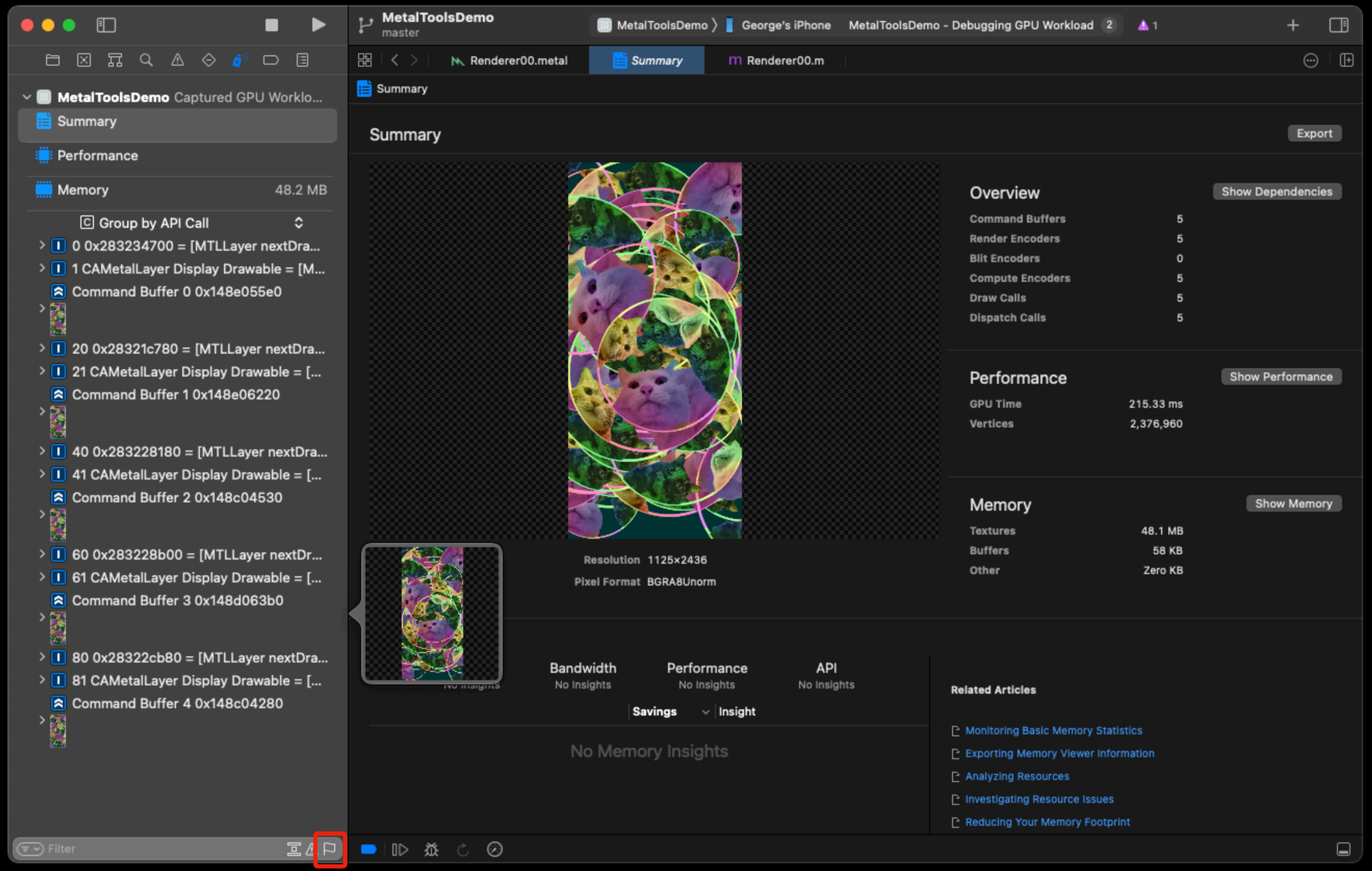
Memory: Preview



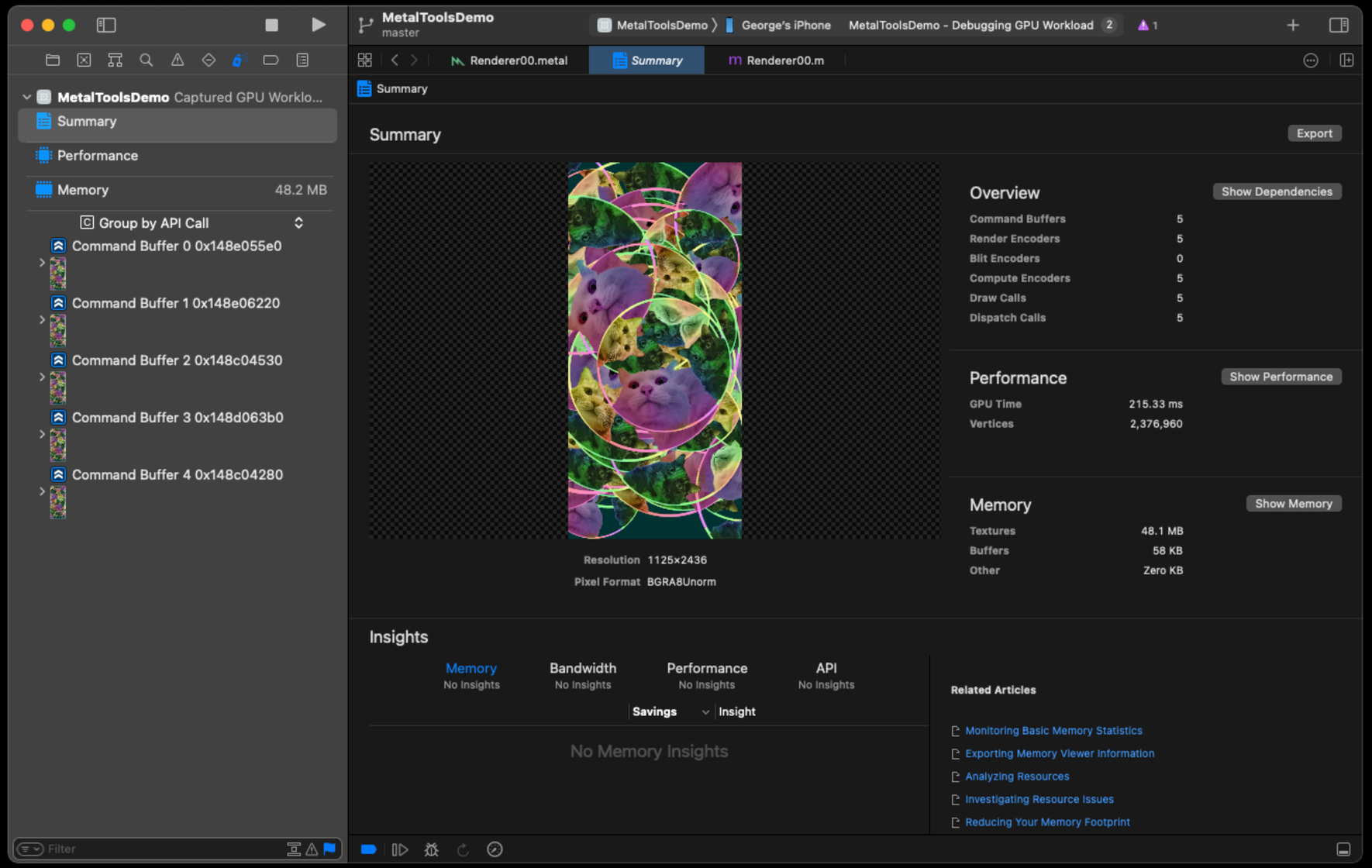
Memory: Filter



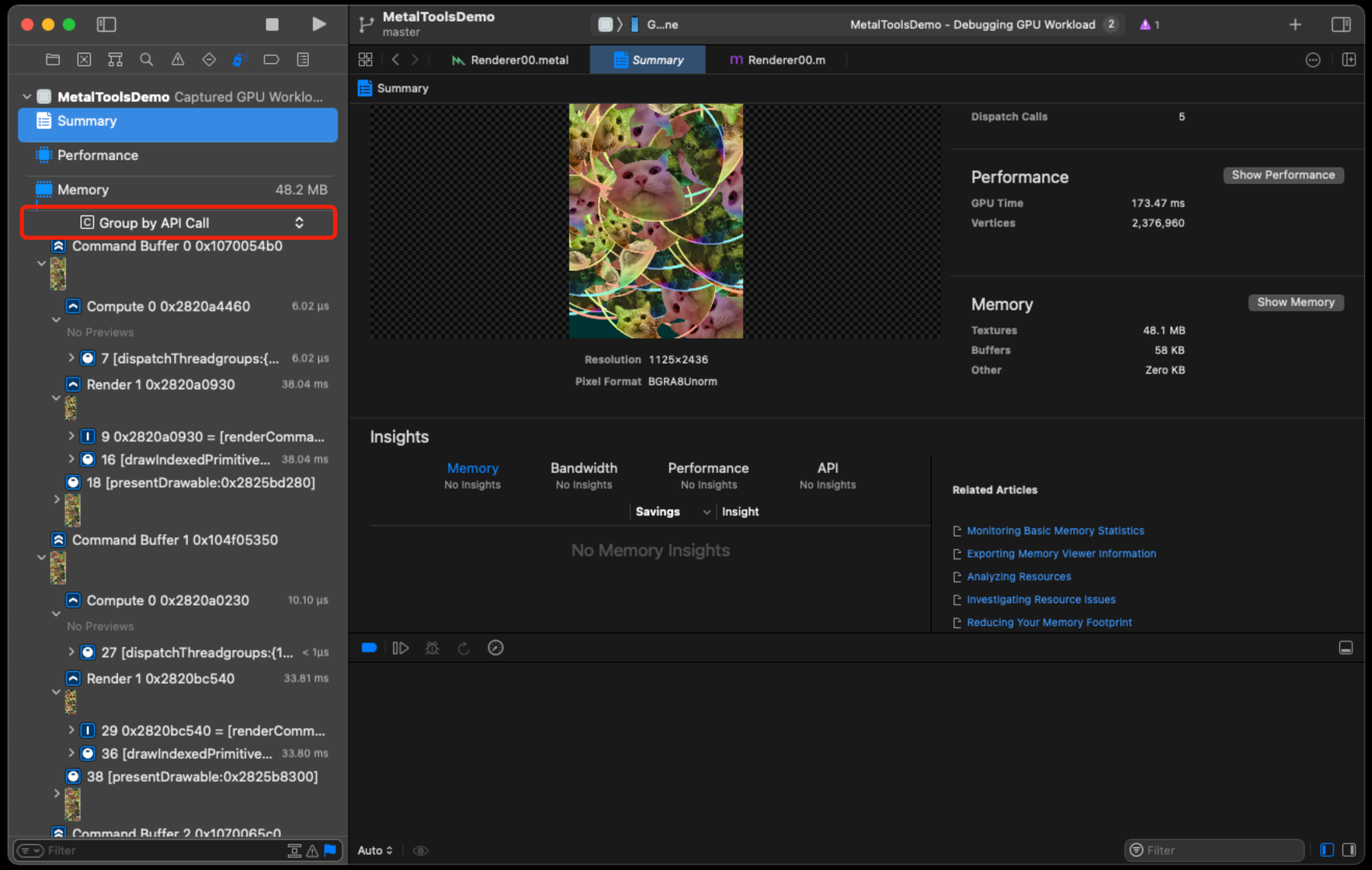
Calls: Show Only Markers And Commands



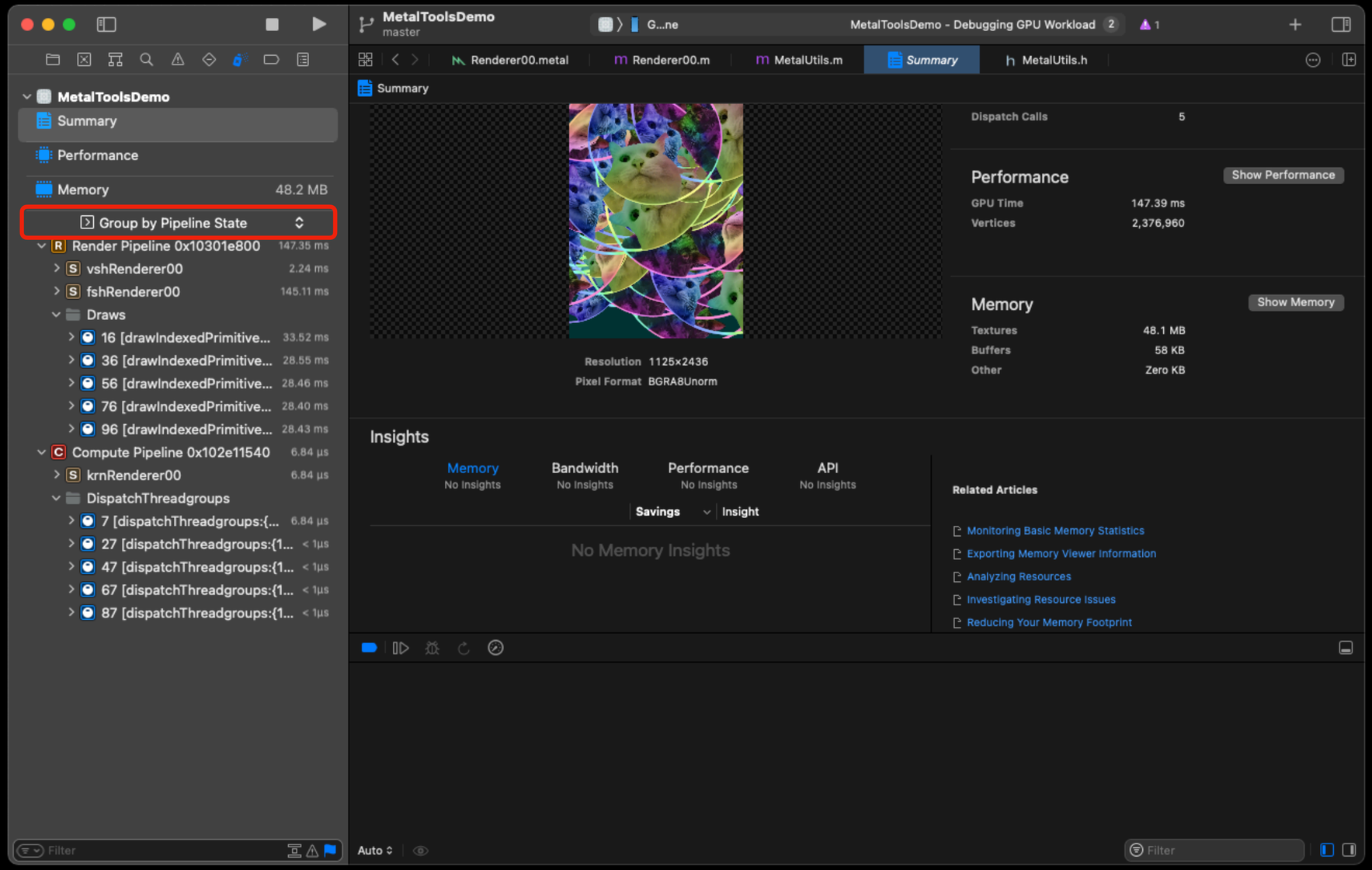
Calls: Show Only Markers And Commands



Calls: Group By API Call



Calls: Group By Pipeline State

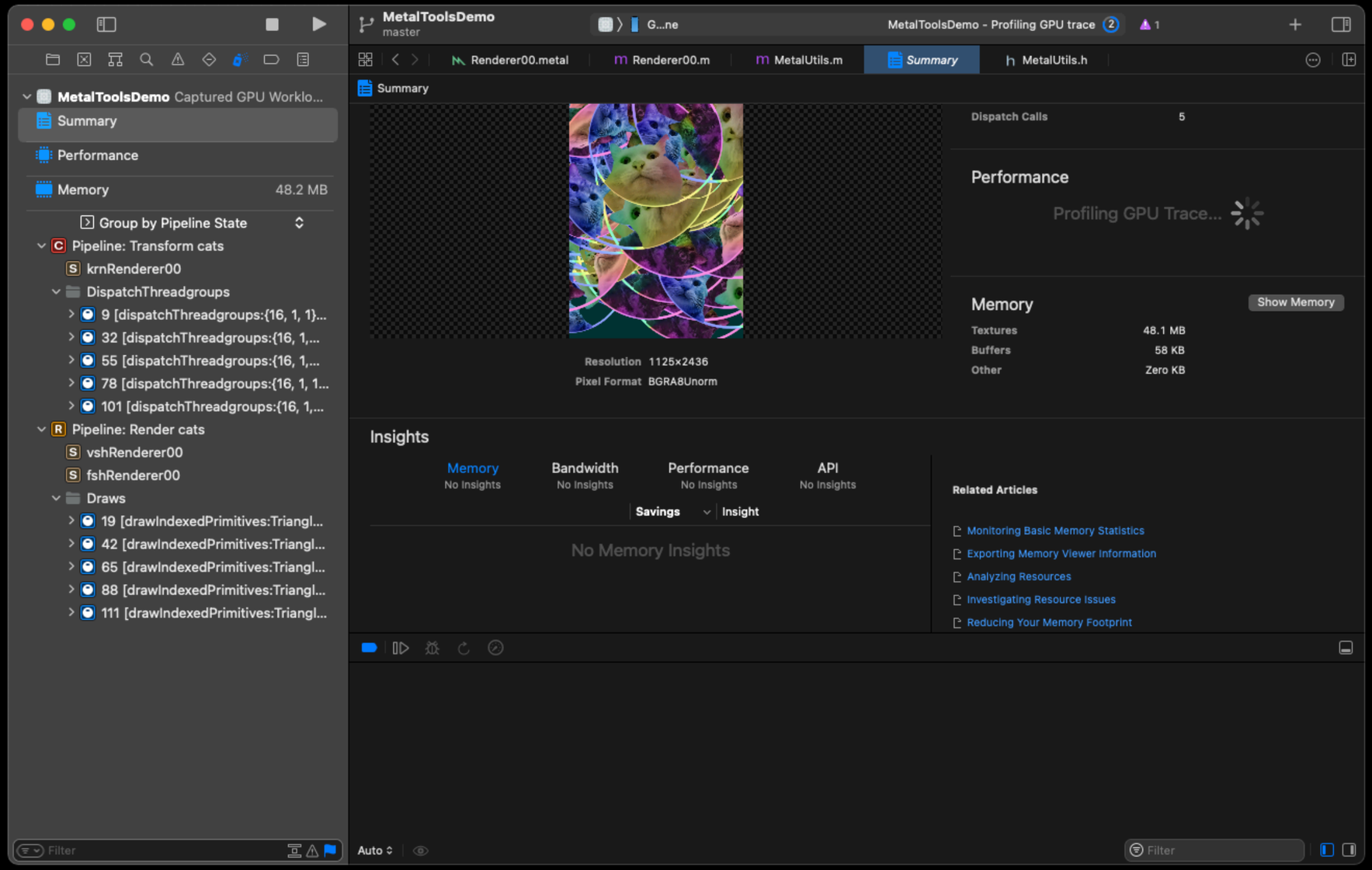


Labels: Pipelines

```
MTLComputePipelineDescriptor *descriptor = [MTLComputePipelineDescriptor new];
descriptor.label = @"label";
```

```
MTLRenderPipelineDescriptor *descriptor = [MTLComputePipelineDescriptor new];
descriptor.label = @"label";
```

Calls: Labels

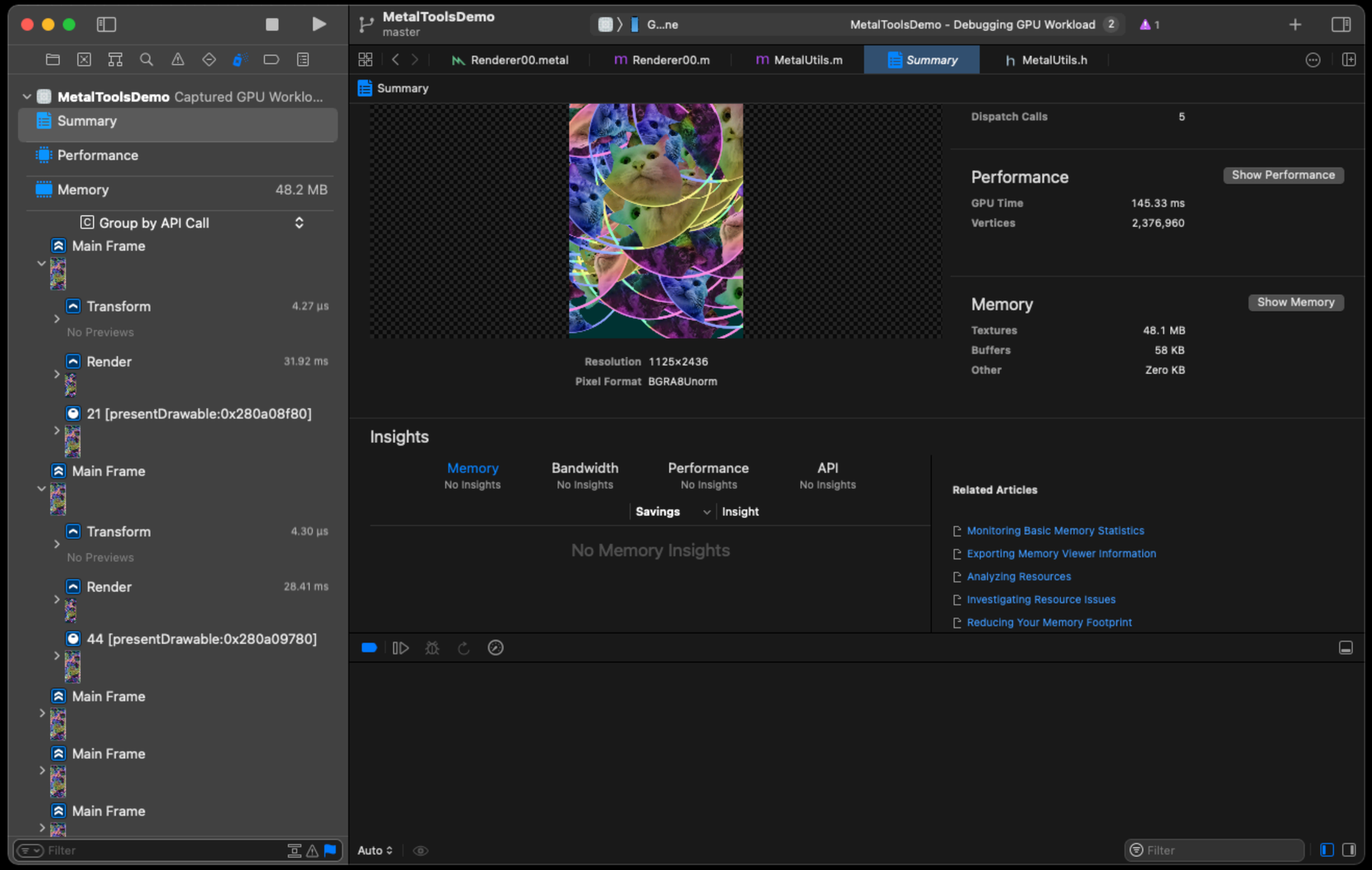


Labels: Command Buffer / Encoder / …

```
// ...
commandBuffer.label = @"label";
```

```
// ...
encoder.label = @"label";
```

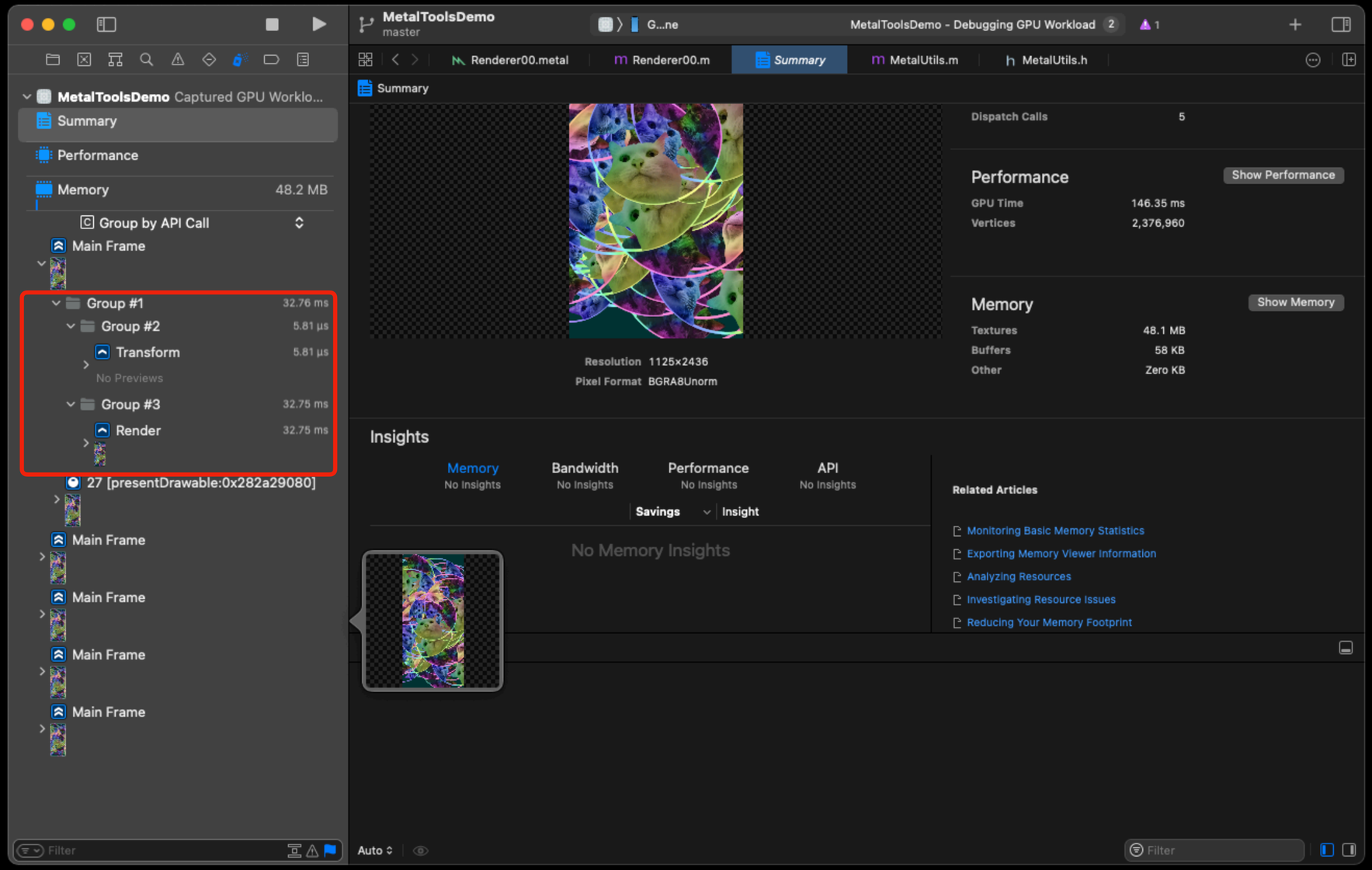
Calls: Labels



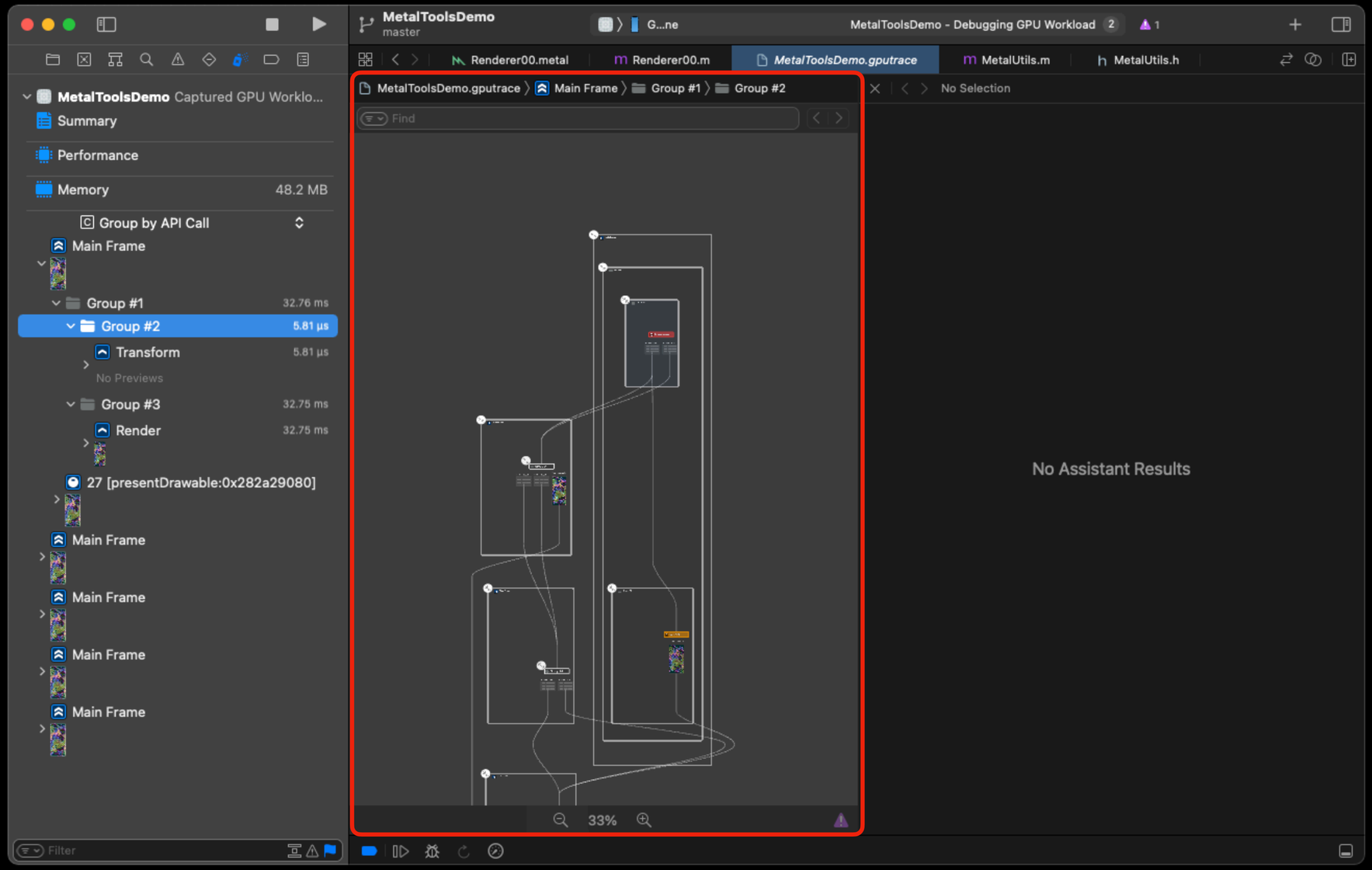
Debug Groups

```
[commandBuffer pushDebugGroup:@"Group #1"];
  [commandBuffer pushDebugGroup:@"Group #2"];
    [self updateTransformsIn:commandBuffer];
  [commandBuffer popDebugGroup];
  [commandBuffer pushDebugGroup:@"Group #3"];
    [self renderIn:commandBuffer];
  [commandBuffer popDebugGroup];
[commandBuffer popDebugGroup];
```

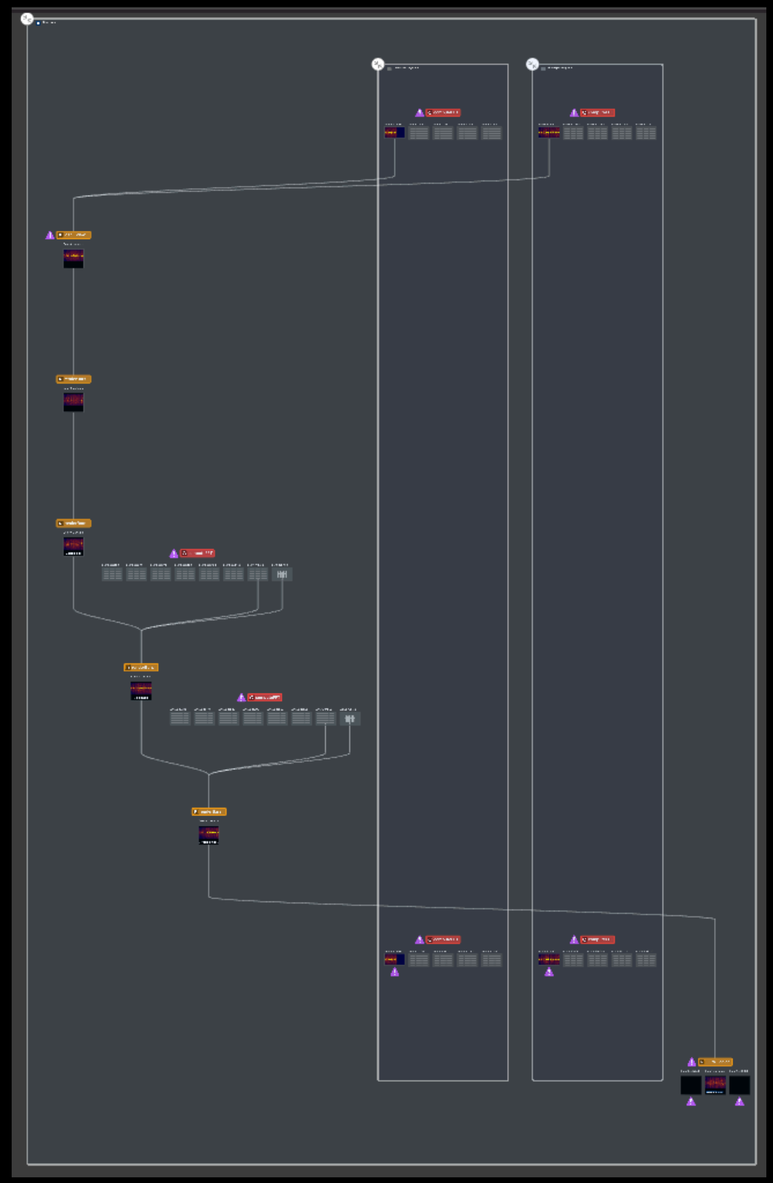
Calls: Labels



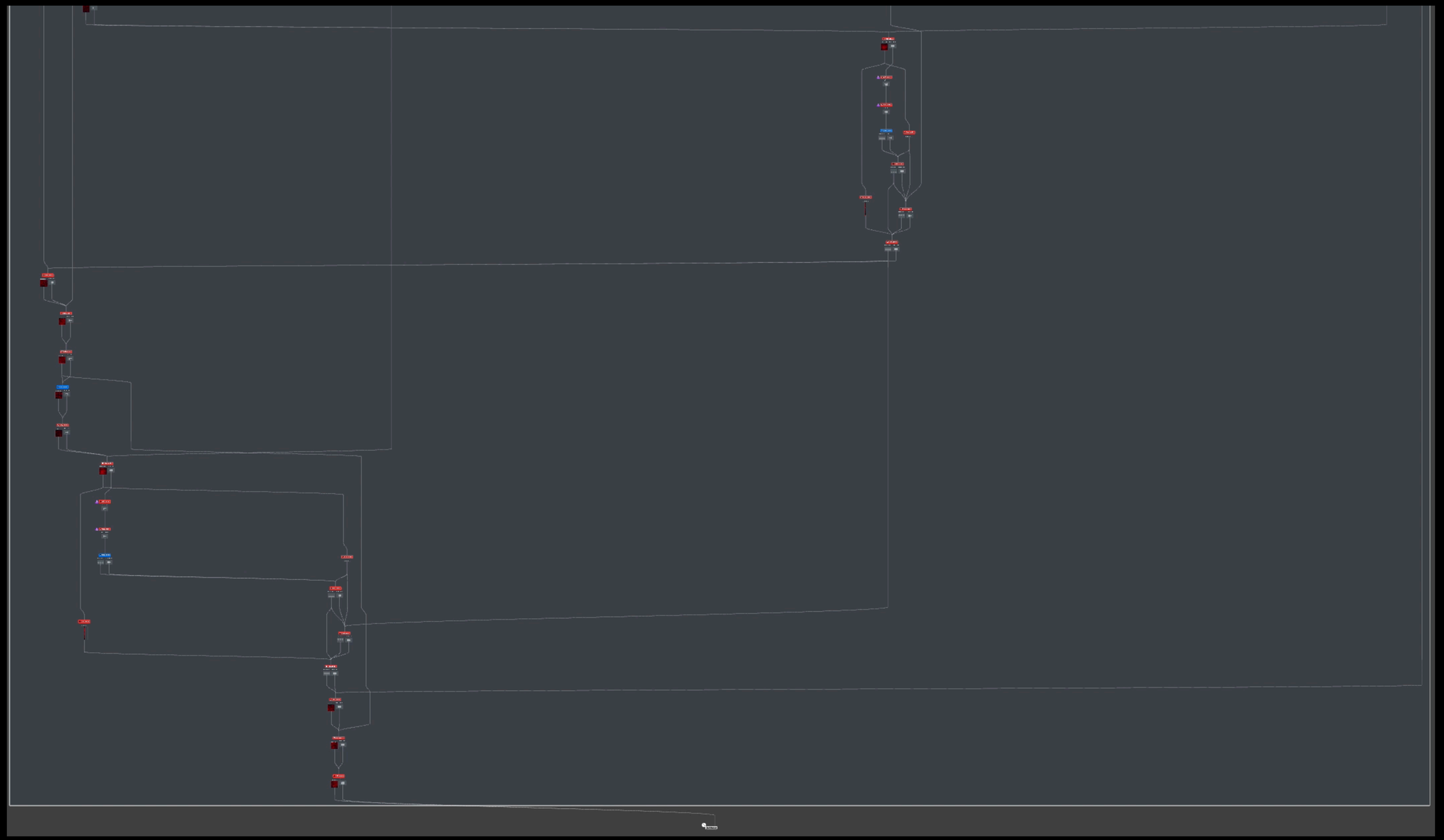
Command Buffer: Dependencies



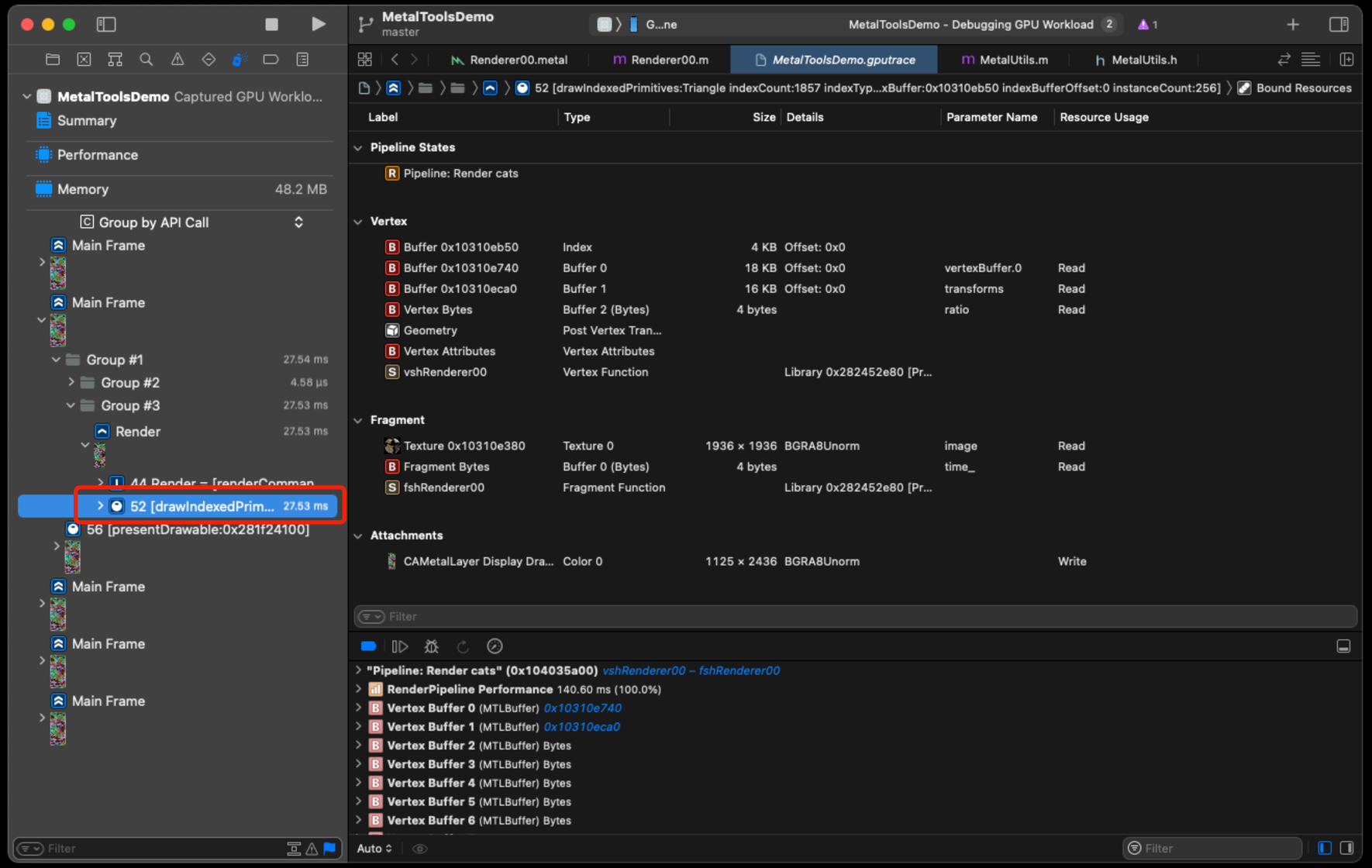
Command Buffer: Dependencies



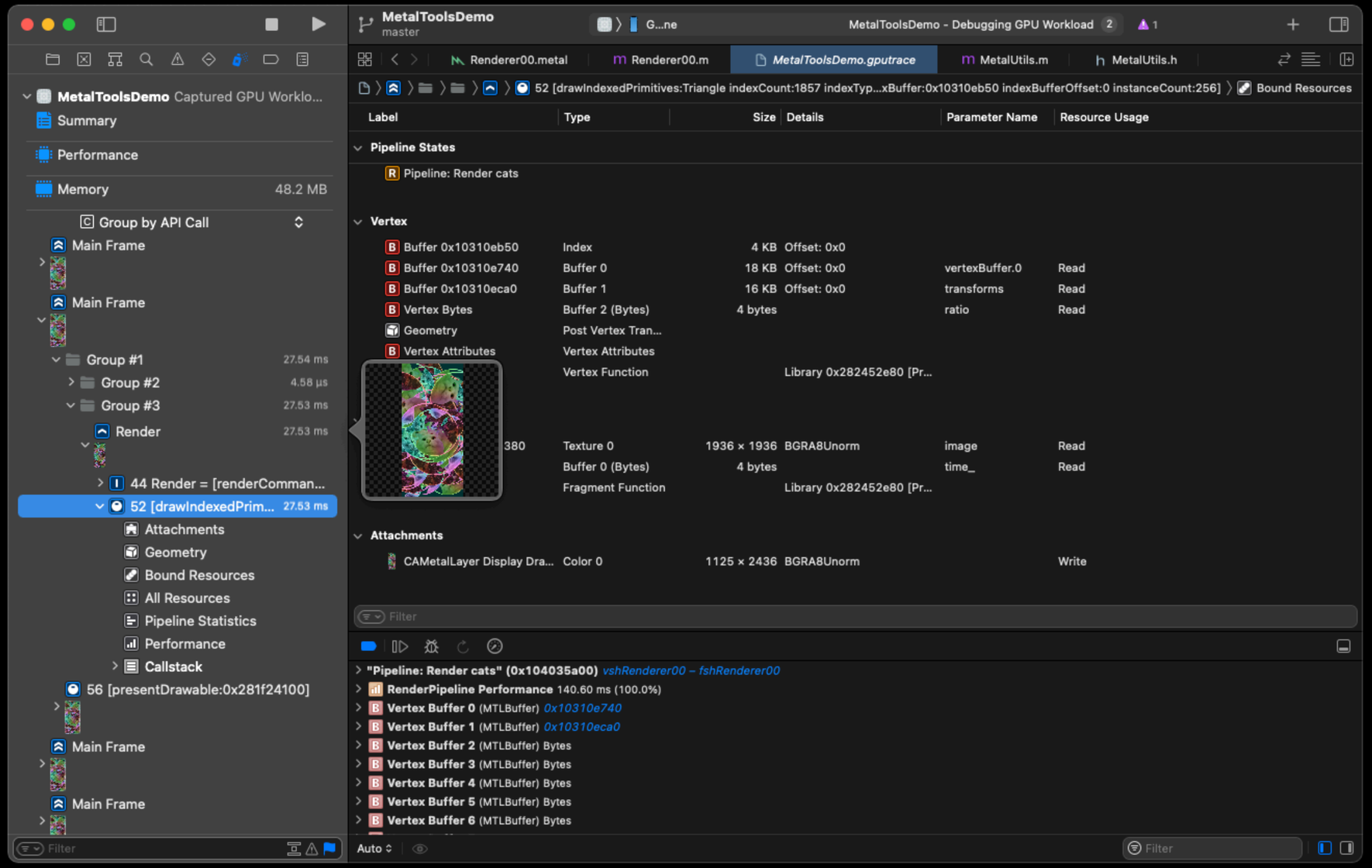
Command Buffer: Dependencies



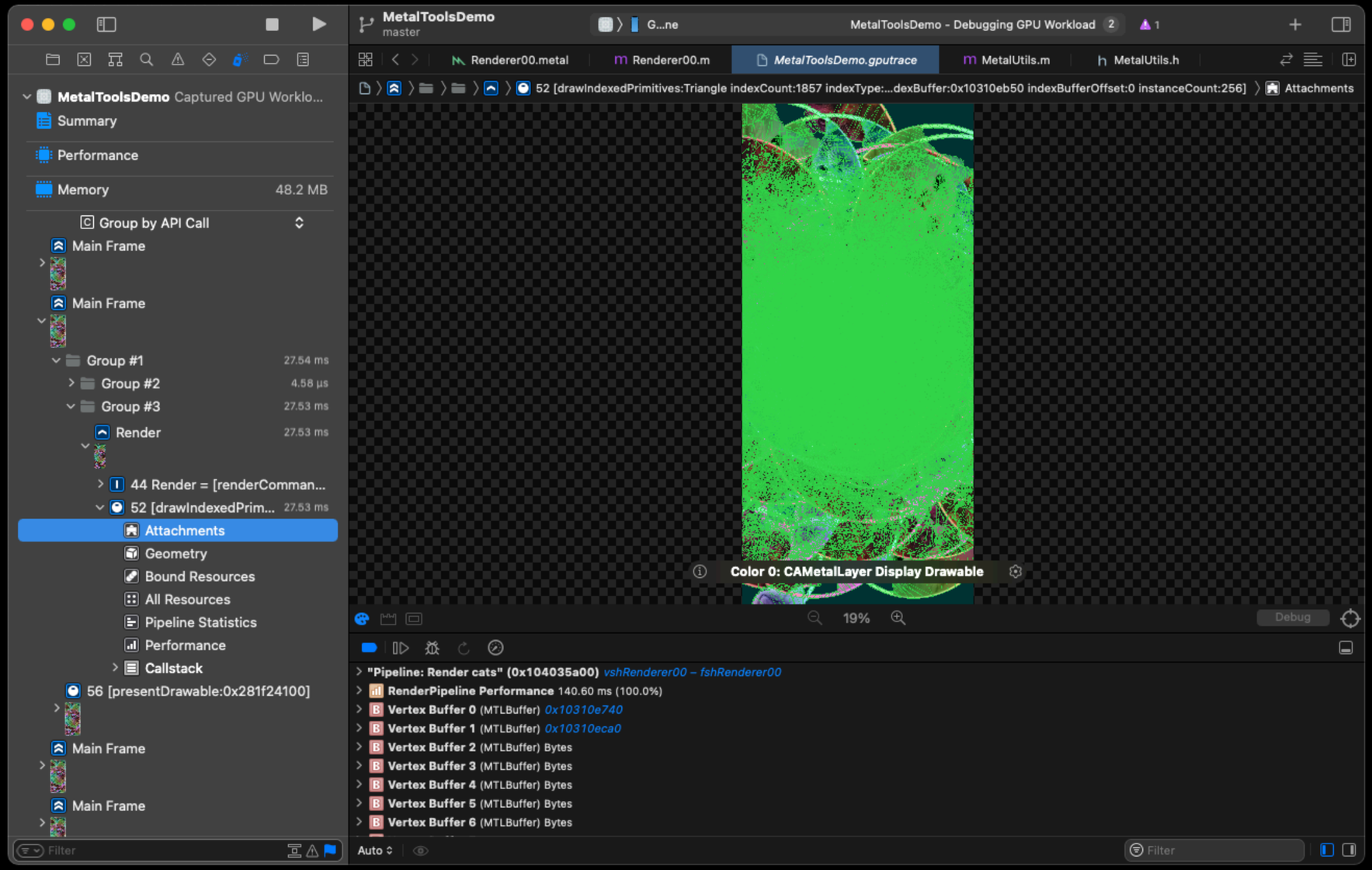
Encoder → Call



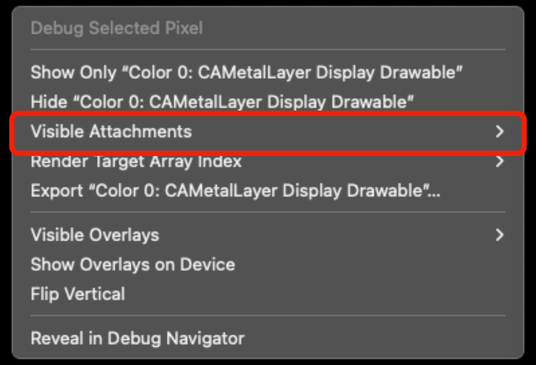
Encoder → Call



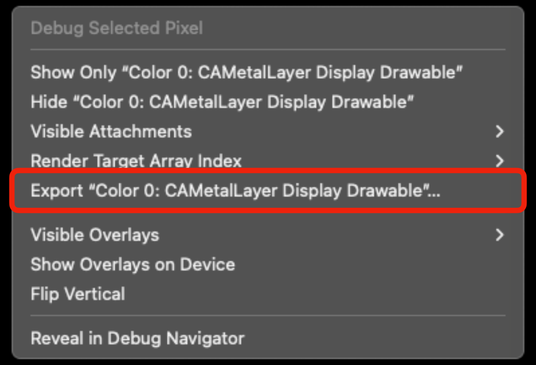
Attachments



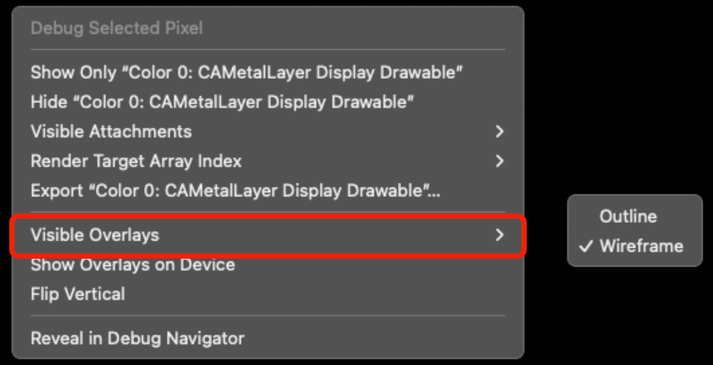
Attachments



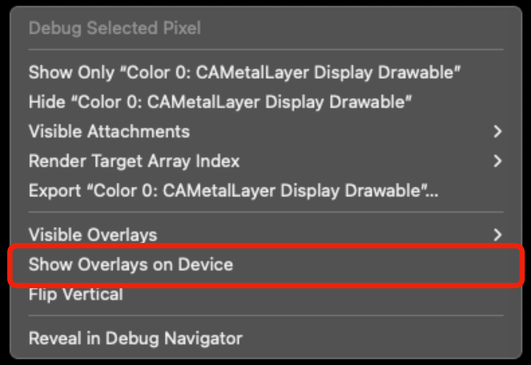
Attachments



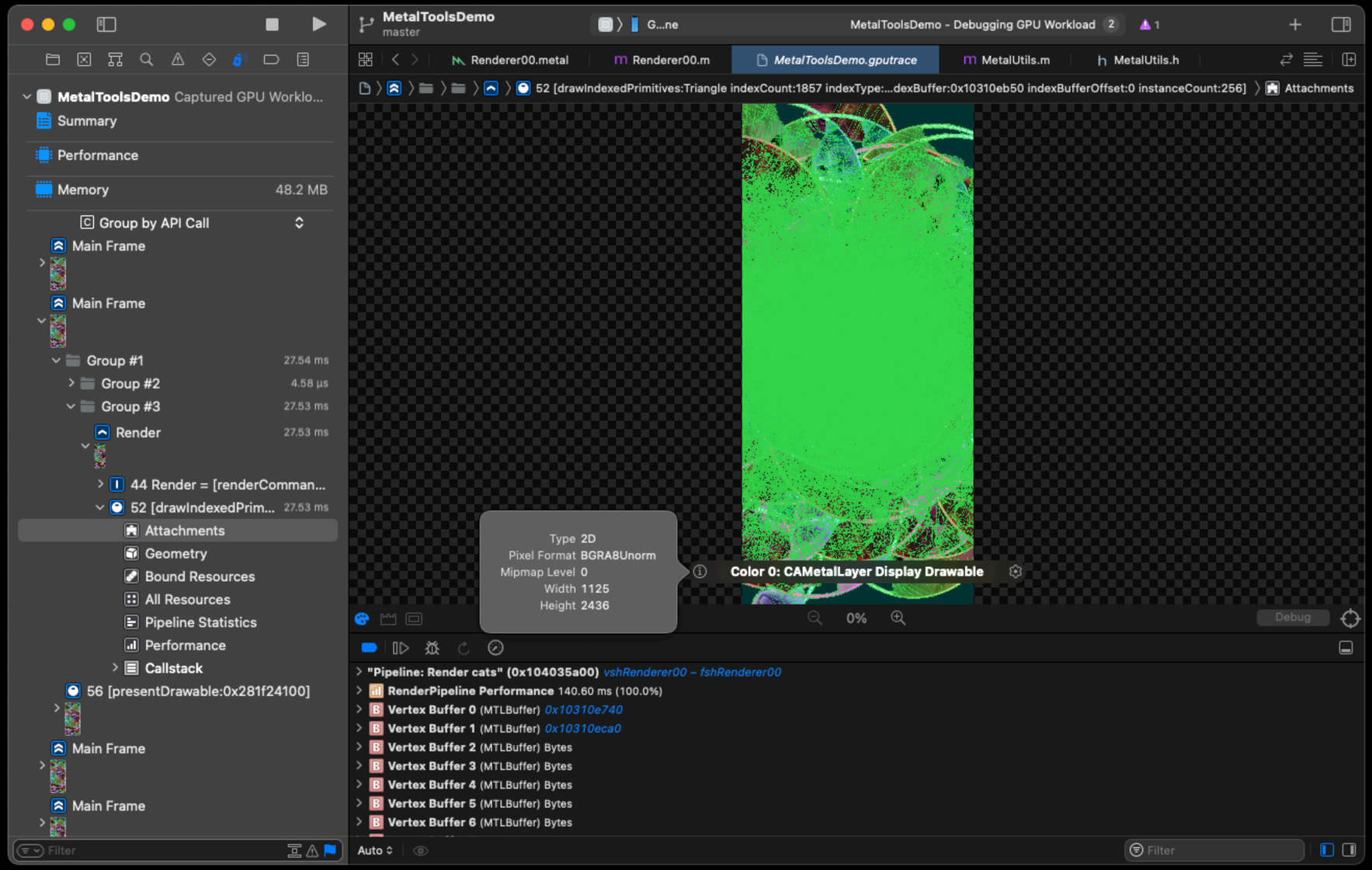
Attachments



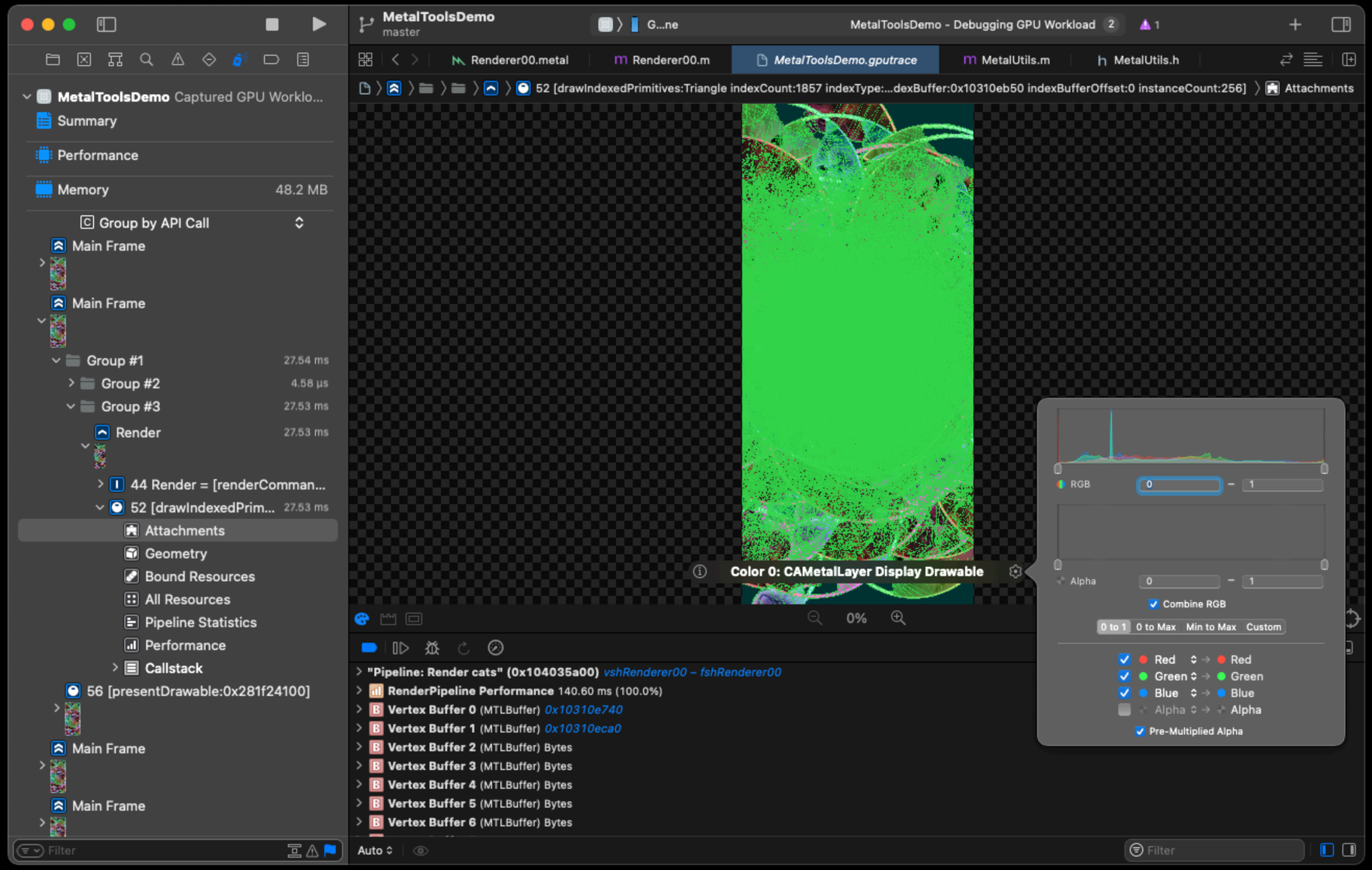
Attachments



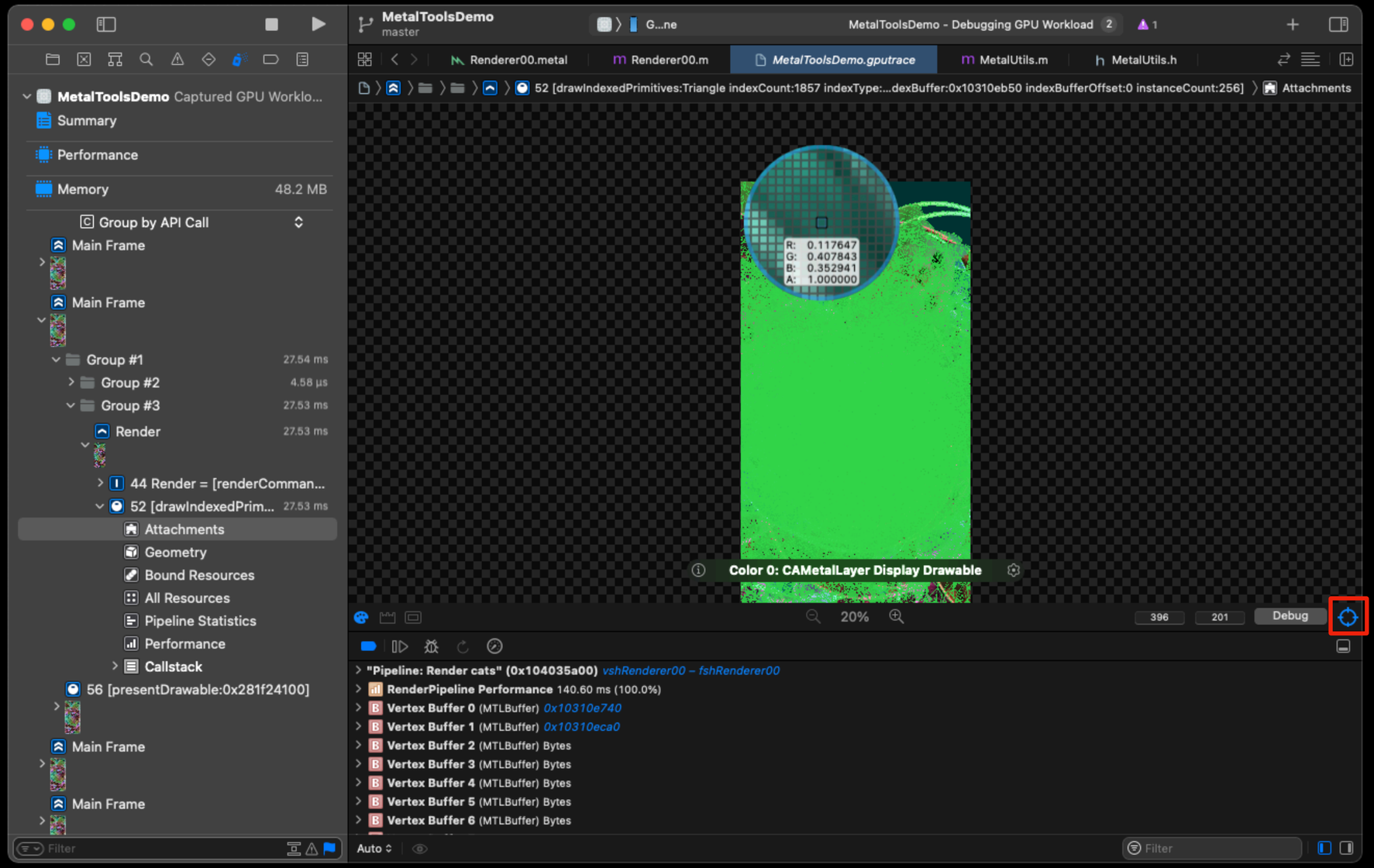
Attachment: Information



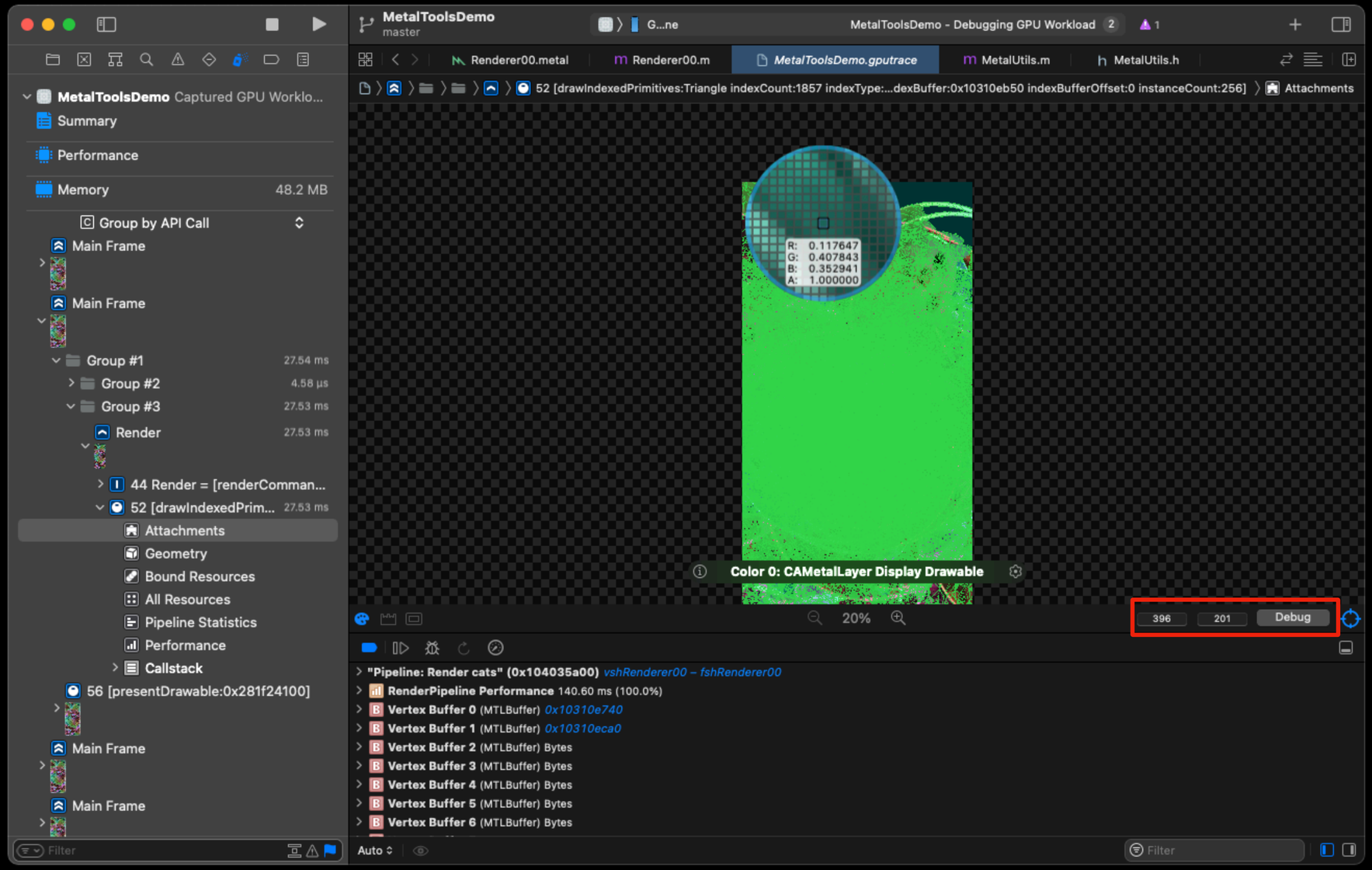
Attachment: Settings



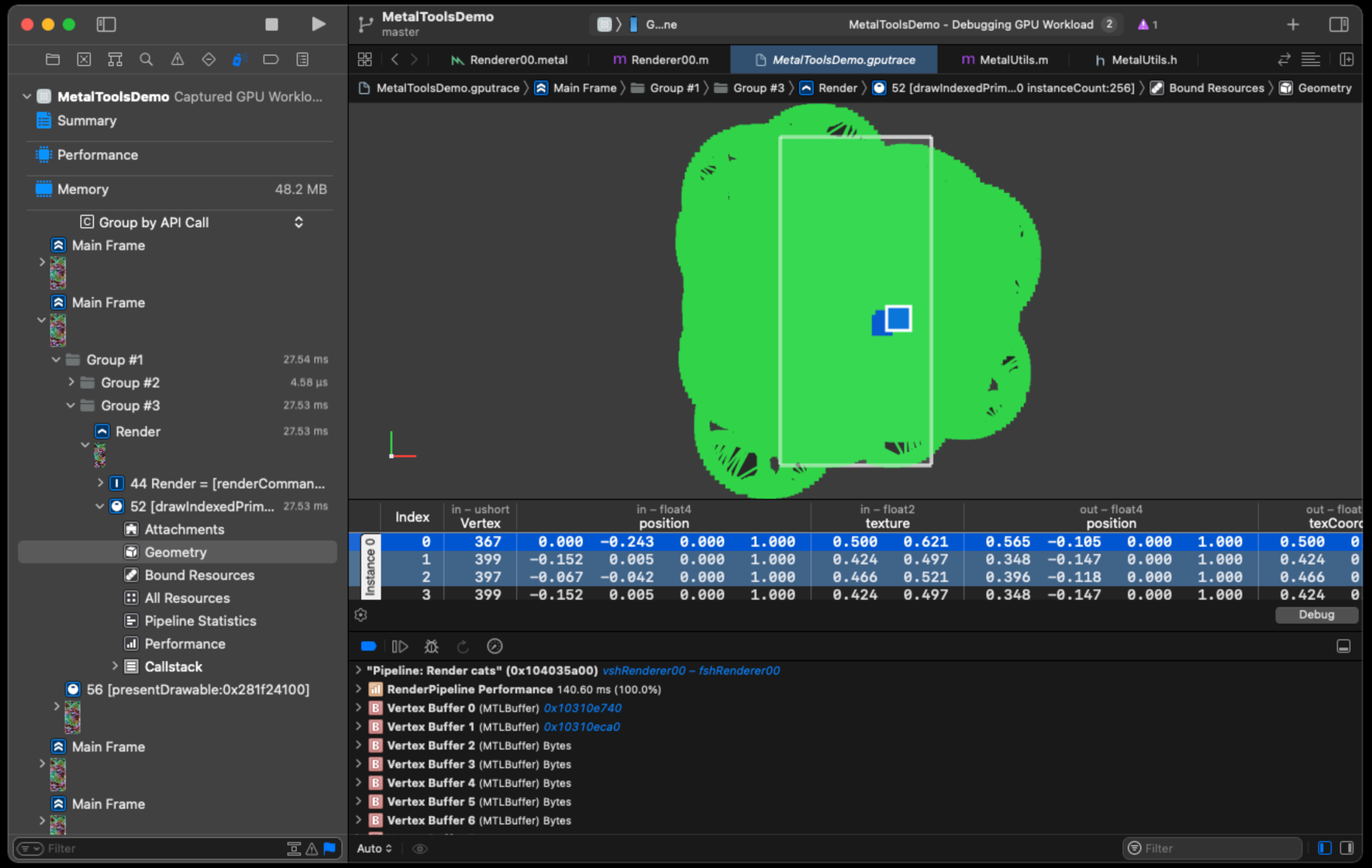
Attachment: Inspect Pixel



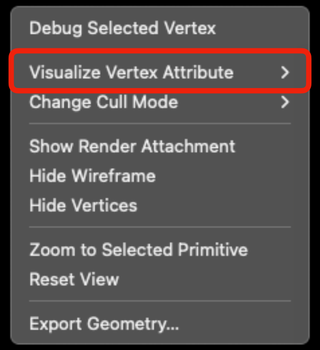
Attachment: Debug



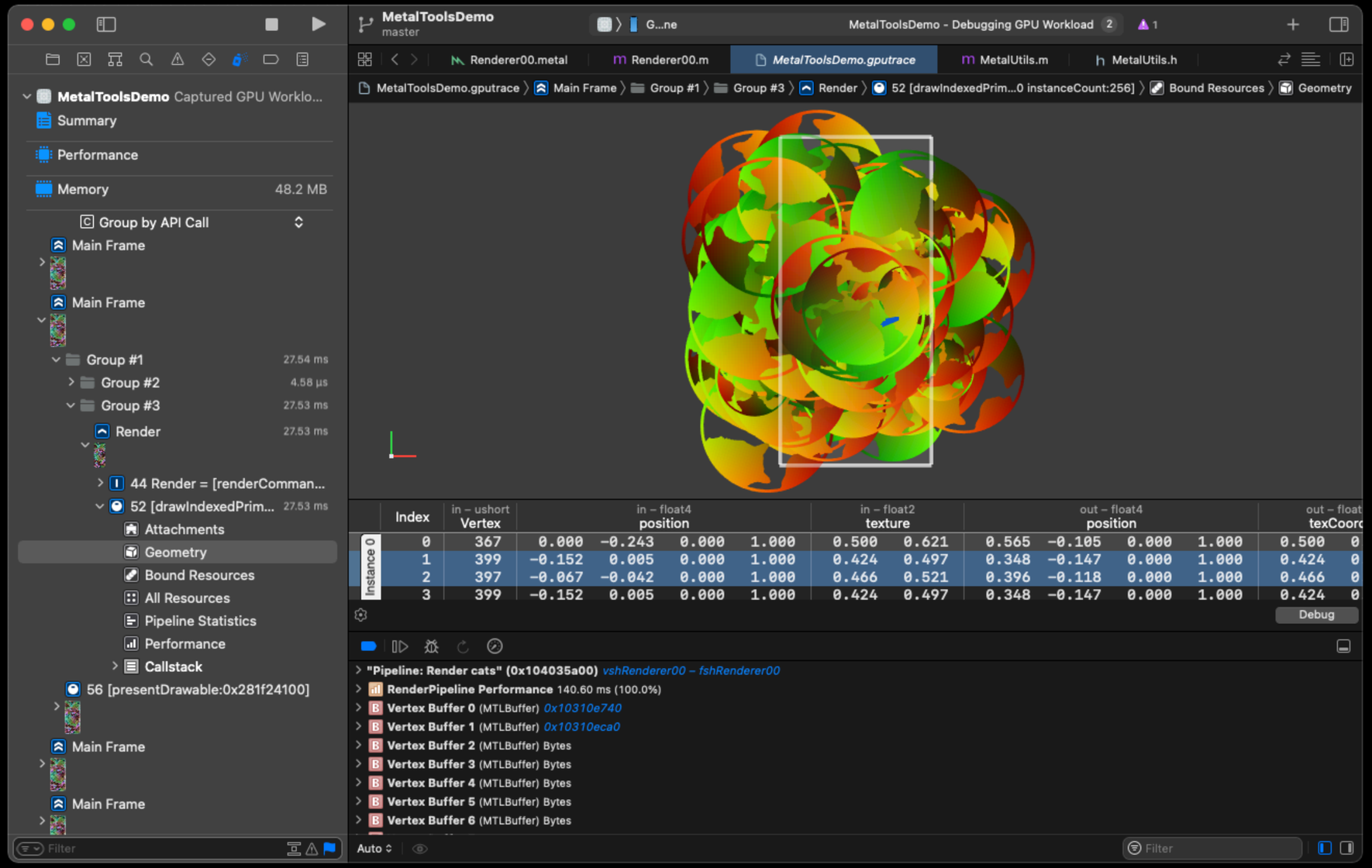
Geometry


MetalToolsDemo
master
MetalToolsDemo - Debugging GPU Workload
Renderer00.metal
Renderer00.m
MetalToolsDemo.gputrace
MetalUtils.m
MetalUtils.h
MetalToolsDemo.gputrace
Main Frame
Group #1
Group #3
Render
52 [drawIndexedPrim...0 instanceCount:256]
Bound Resources
Geometry
MetalToolsDemo Captured GPU Worklo...
Summary
Performance
Memory 48.2 MB
Group by API Call
Main Frame
Main Frame
Group #1 27.54 ms
Group #2 4.58 µs
Group #3 27.53 ms
Render 27.53 ms
44 Render = [renderComman...
52 [drawIndexedPrim... 27.53 ms
Attachments
Geometry
Bound Resources
All Resources
Pipeline Statistics
Performance
Callstack
56 [presentDrawable:0x281f24100]
Main Frame
Main Frame
Index
in – ushort Vertex
in – float4 position
in – float2 texture
out – float4 position
out – float texCoord
Instance 0
0 367 0.000 -0.243 0.000 1.000 0.500 0.621 0.565 -0.105 0.000 1.000 0.500 0
1 399 -0.152 0.005 0.000 1.000 0.424 0.497 0.348 -0.147 0.000 1.000 0.424 0
2 397 -0.067 -0.042 0.000 1.000 0.466 0.521 0.396 -0.118 0.000 1.000 0.466 0
3 399 -0.152 0.005 0.000 1.000 0.424 0.497 0.348 -0.147 0.000 1.000 0.424 0
Debug
"Pipeline: Render cats" (0x104035a00) vshRenderer00 – fshRenderer00
RenderPipeline Performance 140.60 ms (100.0%)
Vertex Buffer 0 (MTLBuffer) 0x10310e740
Vertex Buffer 1 (MTLBuffer) 0x10310eca0
Vertex Buffer 2 (MTLBuffer) Bytes
Vertex Buffer 3 (MTLBuffer) Bytes
Vertex Buffer 4 (MTLBuffer) Bytes
Vertex Buffer 5 (MTLBuffer) Bytes
Vertex Buffer 6 (MTLBuffer) Bytes
Filter
Auto
Filter

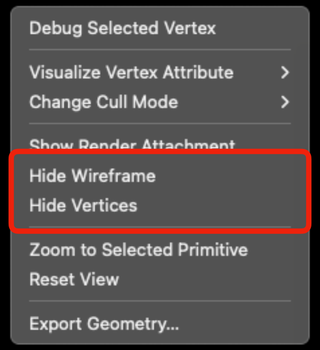
Geometry


Debug Selected Vertex
Visualize Vertex Attribute
Change Cull Mode
Show Render Attachment
Hide Wireframe
Hide Vertices
Zoom to Selected Primitive
Reset View
Export Geometry...

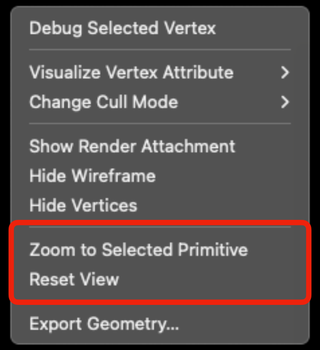
Geometry


MetalToolsDemo
master
MetalToolsDemo - Debugging GPU Workload
Renderer00.metal
Renderer00.m
MetalToolsDemo.gputrace
MetalUtils.m
MetalUtils.h
MetalToolsDemo.gputrace
Main Frame
Group #1
Group #3
Render
52 [drawIndexedPrim...0 instanceCount:256]
Bound Resources
Geometry
MetalToolsDemo Captured GPU Worklo...
Summary
Performance
Memory 48.2 MB
Group by API Call
Main Frame
Main Frame
Group #1 27.54 ms
Group #2 4.58 µs
Group #3 27.53 ms
Render 27.53 ms
44 Render = [renderComman...
52 [drawIndexedPrim... 27.53 ms
Attachments
Geometry
Bound Resources
All Resources
Pipeline Statistics
Performance
Callstack
56 [presentDrawable:0x281f24100]
Main Frame
Main Frame
Index
in – ushort Vertex
in – float4 position
in – float2 texture
out – float4 position
out – float texCoord
Instance 0
0 367 0.000 -0.243 0.000 1.000 0.500 0.621 0.565 -0.105 0.000 1.000 0.500 0
1 399 -0.152 0.005 0.000 1.000 0.424 0.497 0.348 -0.147 0.000 1.000 0.424 0
2 397 -0.067 -0.042 0.000 1.000 0.466 0.521 0.396 -0.118 0.000 1.000 0.466 0
3 399 -0.152 0.005 0.000 1.000 0.424 0.497 0.348 -0.147 0.000 1.000 0.424 0
Debug
"Pipeline: Render cats" (0x104035a00) vshRenderer00 – fshRenderer00
RenderPipeline Performance 140.60 ms (100.0%)
Vertex Buffer 0 (MTLBuffer) 0x10310e740
Vertex Buffer 1 (MTLBuffer) 0x10310eca0
Vertex Buffer 2 (MTLBuffer) Bytes
Vertex Buffer 3 (MTLBuffer) Bytes
Vertex Buffer 4 (MTLBuffer) Bytes
Vertex Buffer 5 (MTLBuffer) Bytes
Vertex Buffer 6 (MTLBuffer) Bytes
Filter
Auto
Filter

Geometry


Debug Selected Vertex
Visualize Vertex Attribute
Change Cull Mode
Show Render Attachment
Hide Wireframe
Hide Vertices
Zoom to Selected Primitive
Reset View
Export Geometry...

Geometry


Debug Selected Vertex
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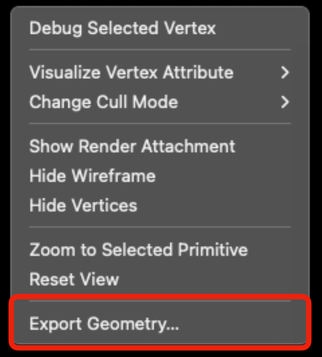
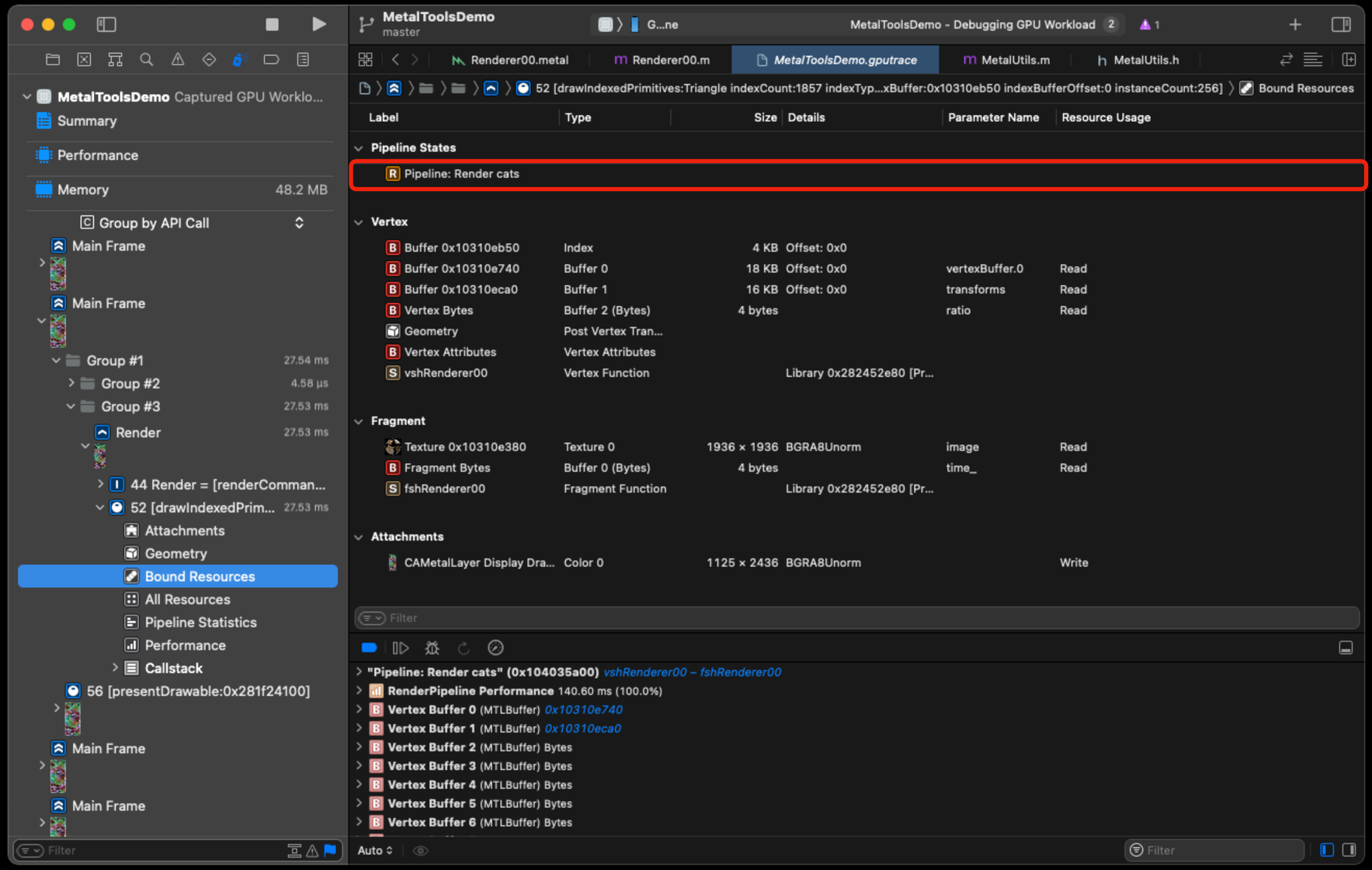
Zoom to Selected Primitive
Reset View
Export Geometry...

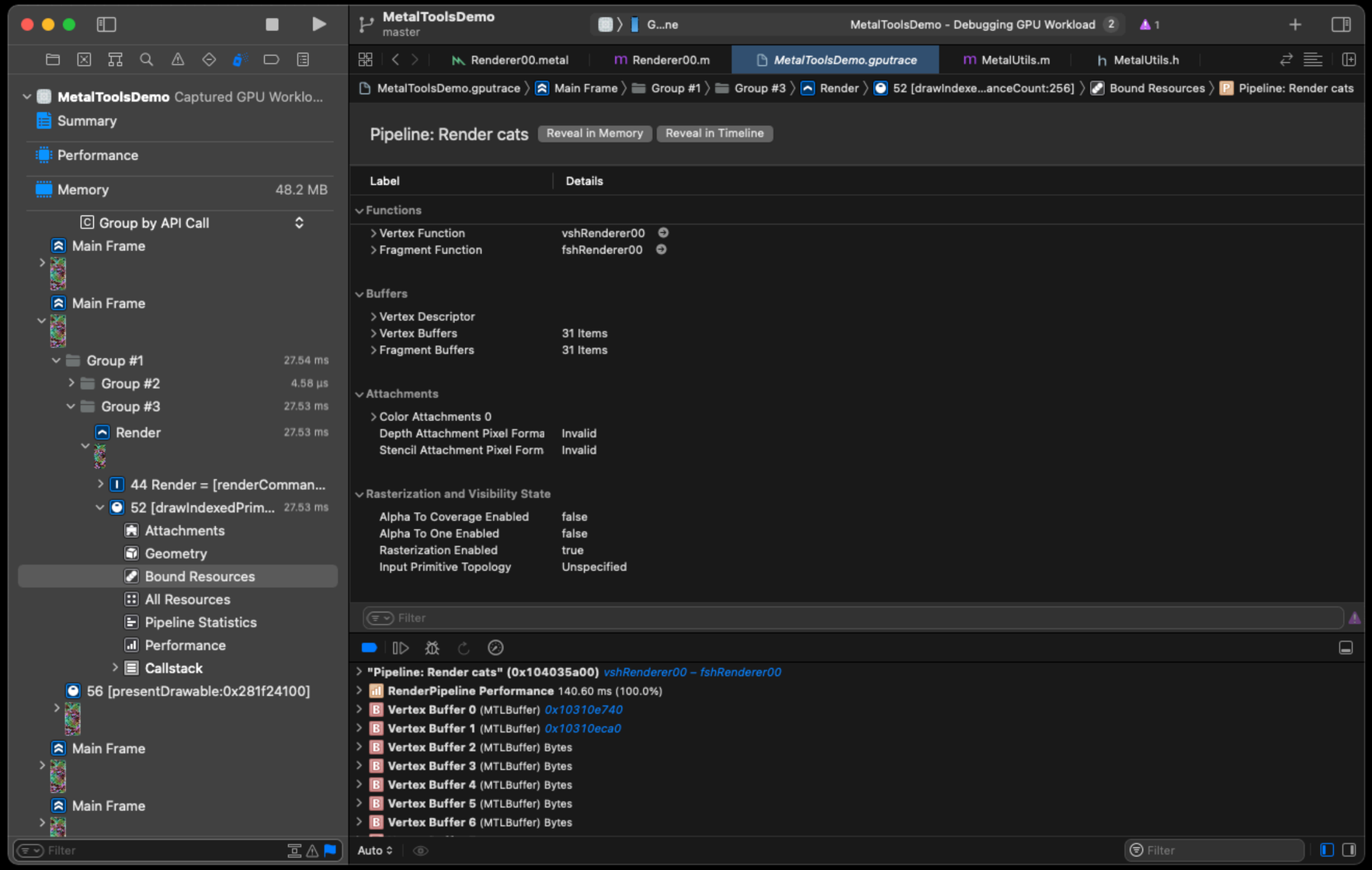
Geometry


Debug Selected Vertex
Visualize Vertex Attribute
Change Cull Mode
Show Render Attachment
Hide Wireframe
Hide Vertices
Zoom to Selected Primitive
Reset View
Export Geometry...

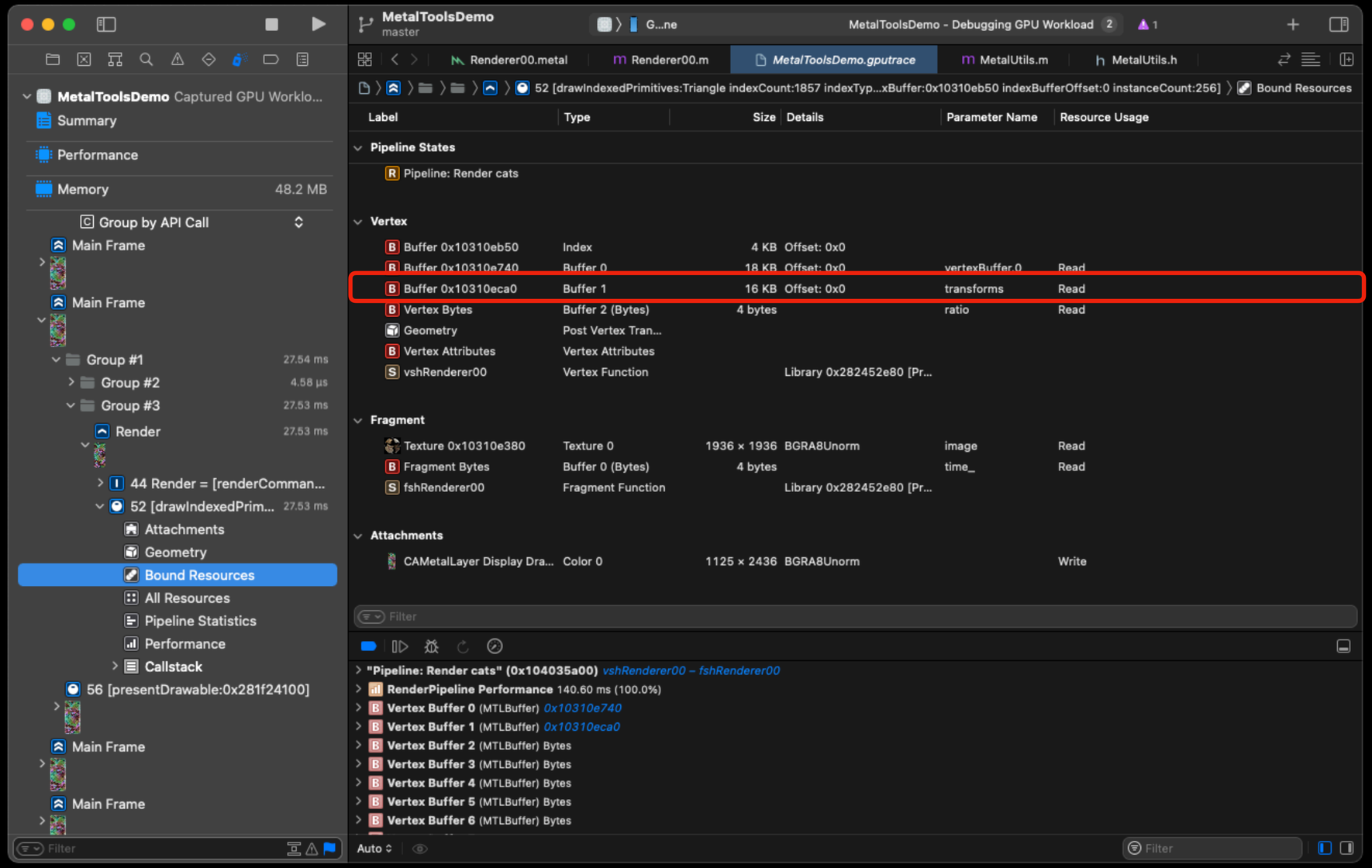
Bound Resources: Pipeline



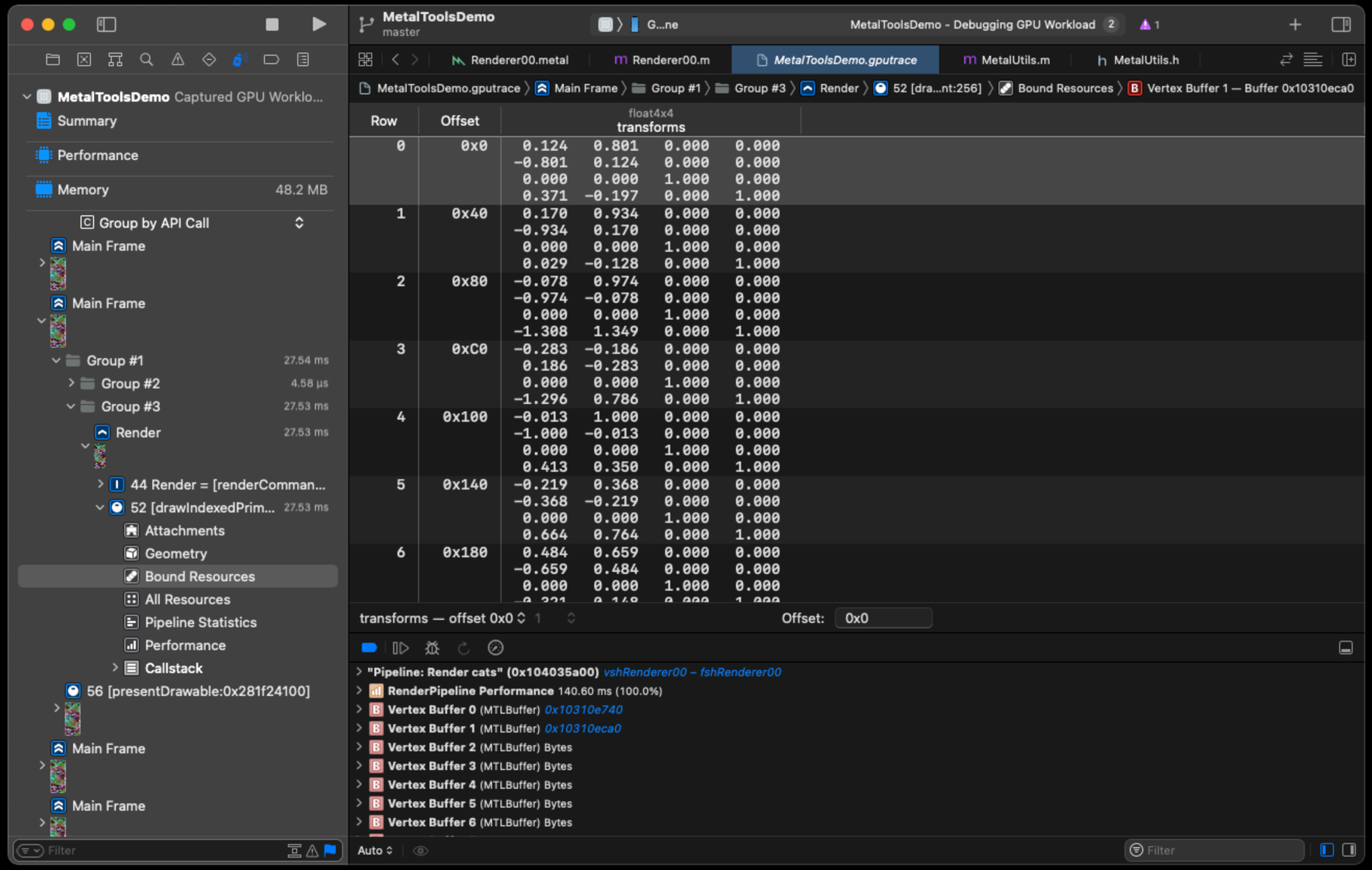
Bound Resources: Pipeline



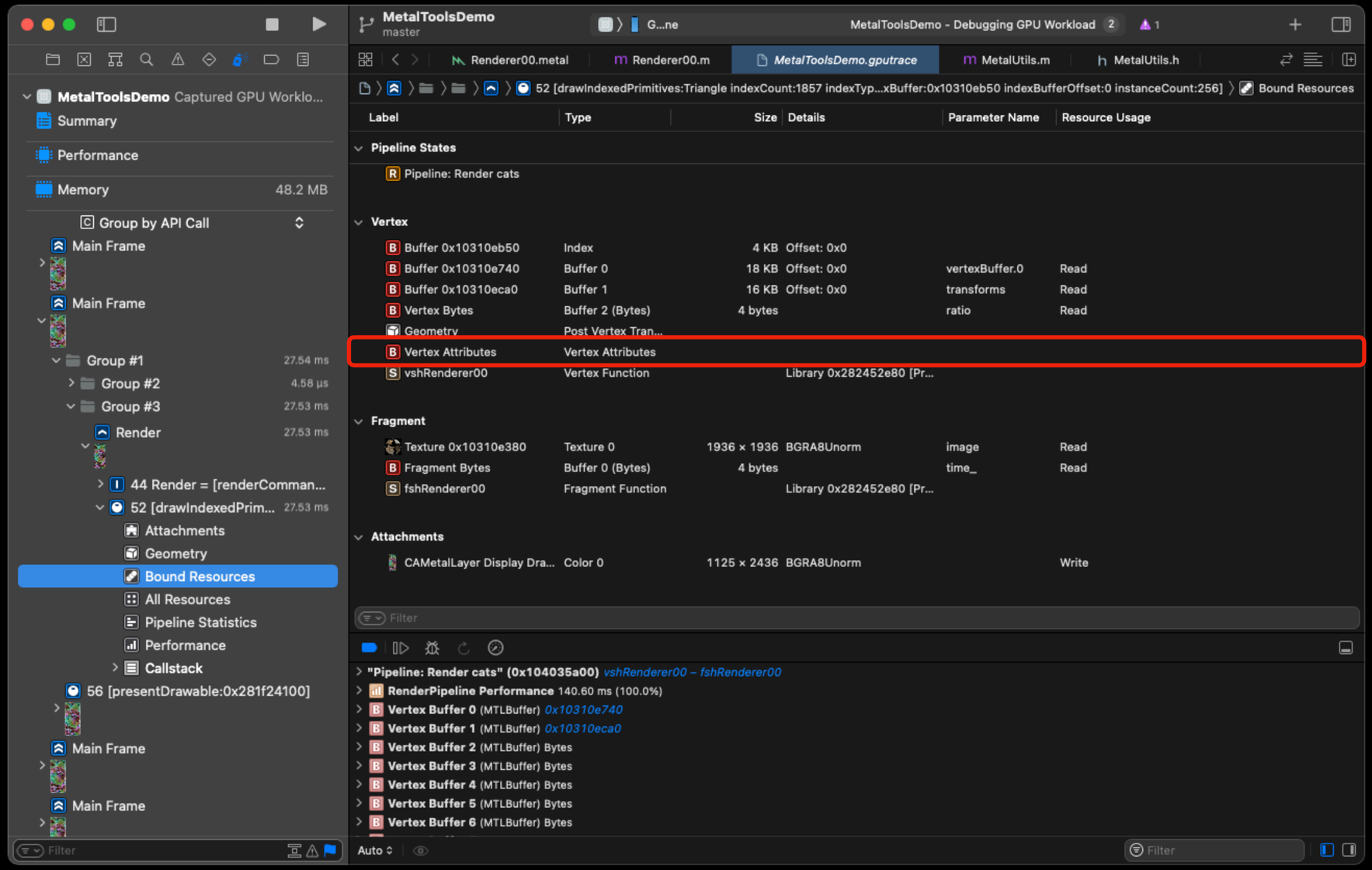
Bound Resources: Buffer



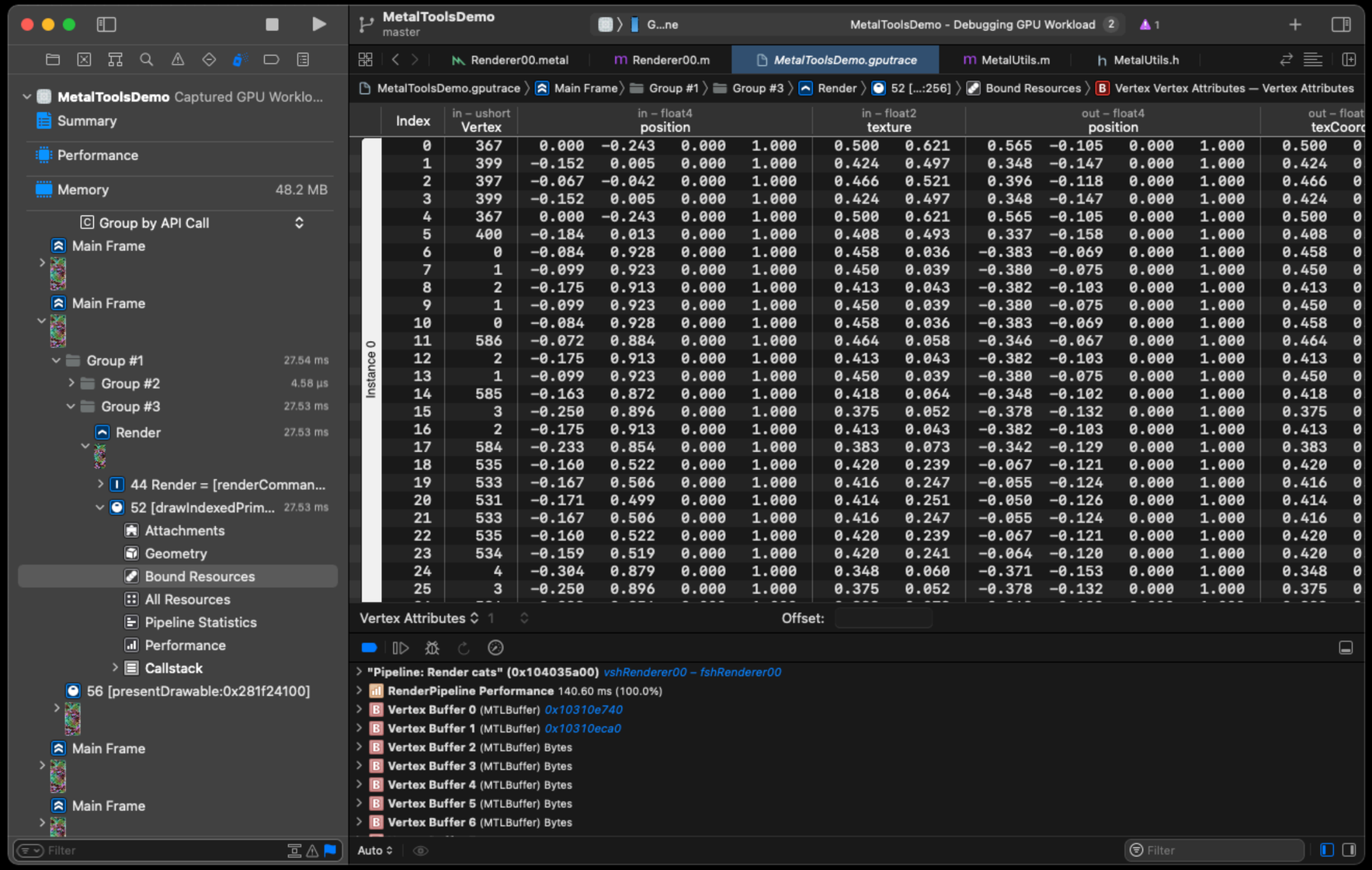
Bound Resources: Buffer



Bound Resources: Vertex Attributes

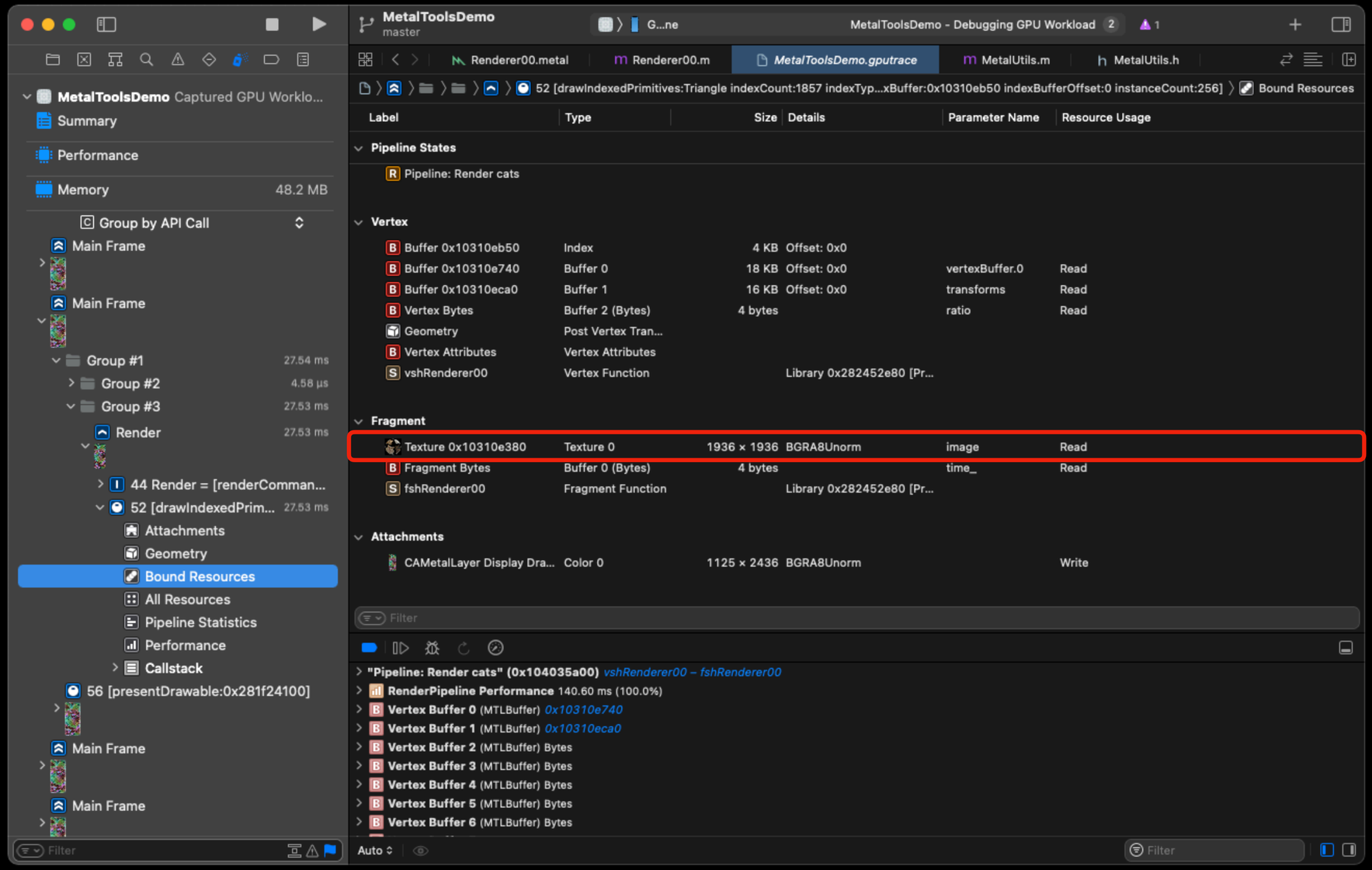


Bound Resources: Vertex Attributes

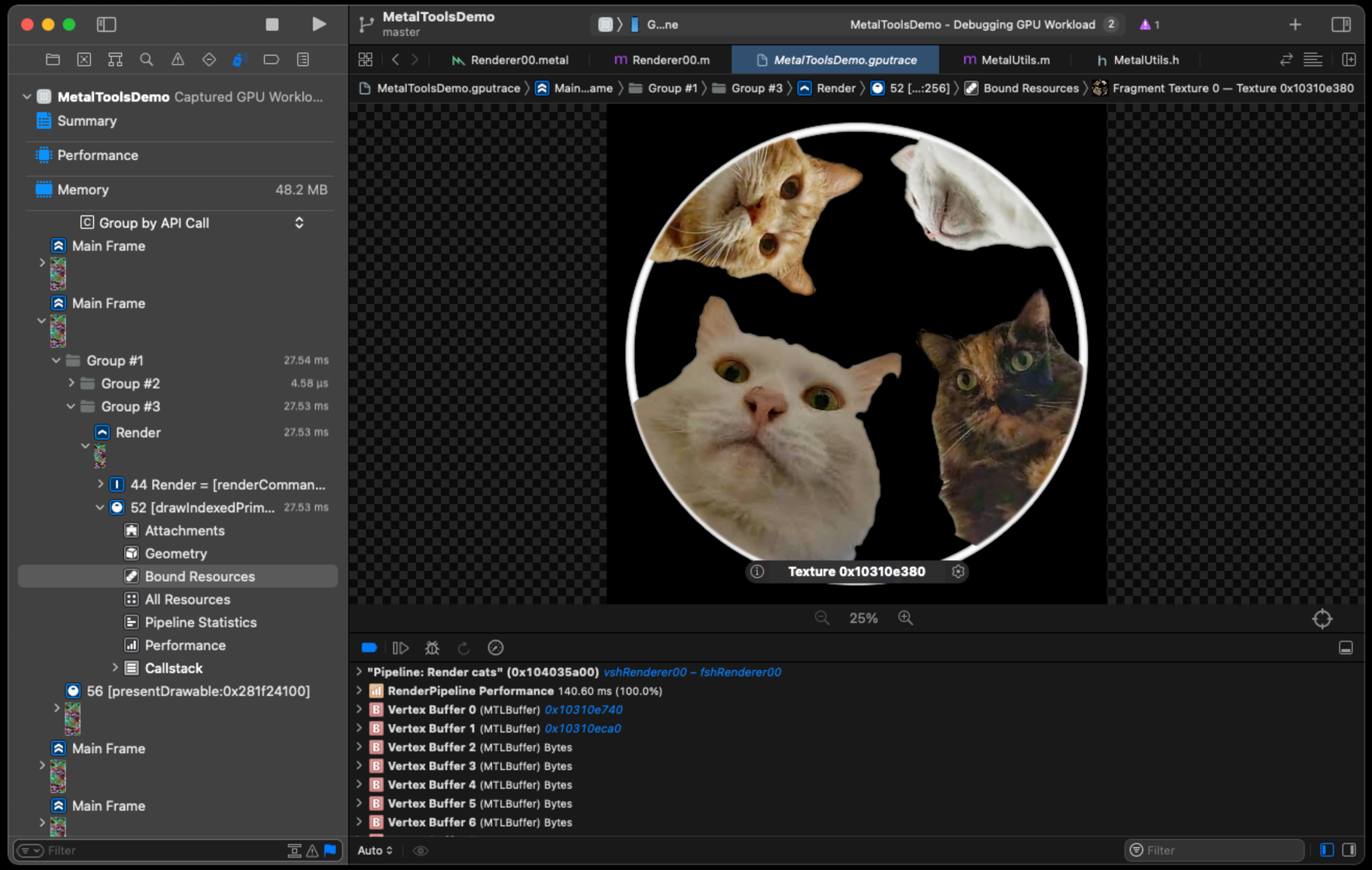


Index	Vertex	position				texture		position				texCoord	
0	367	0.000	−0.243	0.000	1.000	0.500	0.621	0.565	−0.105	0.000	1.000	0.500	0
1	399	−0.152	0.005	0.000	1.000	0.424	0.497	0.348	−0.147	0.000	1.000	0.424	0
2	397	−0.067	−0.042	0.000	1.000	0.466	0.521	0.396	−0.118	0.000	1.000	0.466	0
3	399	−0.152	0.005	0.000	1.000	0.424	0.497	0.348	−0.147	0.000	1.000	0.424	0
4	367	0.000	−0.243	0.000	1.000	0.500	0.621	0.565	−0.105	0.000	1.000	0.500	0
5	400	−0.184	0.013	0.000	1.000	0.408	0.493	0.337	−0.158	0.000	1.000	0.408	0
6	0	−0.084	0.928	0.000	1.000	0.458	0.036	−0.383	−0.069	0.000	1.000	0.458	0
7	1	−0.099	0.923	0.000	1.000	0.450	0.039	−0.380	−0.075	0.000	1.000	0.450	0
8	2	−0.175	0.913	0.000	1.000	0.413	0.043	−0.382	−0.103	0.000	1.000	0.413	0
9	1	−0.099	0.923	0.000	1.000	0.450	0.039	−0.380	−0.075	0.000	1.000	0.450	0
10	0	−0.084	0.928	0.000	1.000	0.458	0.036	−0.383	−0.069	0.000	1.000	0.458	0
11	586	−0.072	0.884	0.000	1.000	0.464	0.058	−0.346	−0.067	0.000	1.000	0.464	0
12	2	−0.175	0.913	0.000	1.000	0.413	0.043	−0.382	−0.103	0.000	1.000	0.413	0
13	1	−0.099	0.923	0.000	1.000	0.450	0.039	−0.380	−0.075	0.000	1.000	0.450	0
14	585	−0.163	0.872	0.000	1.000	0.418	0.064	−0.348	−0.102	0.000	1.000	0.418	0
15	3	−0.250	0.896	0.000	1.000	0.375	0.052	−0.378	−0.132	0.000	1.000	0.375	0
16	2	−0.175	0.913	0.000	1.000	0.413	0.043	−0.382	−0.103	0.000	1.000	0.413	0
17	584	−0.233	0.854	0.000	1.000	0.383	0.073	−0.342	−0.129	0.000	1.000	0.383	0
18	535	−0.160	0.522	0.000	1.000	0.420	0.239	−0.067	−0.121	0.000	1.000	0.420	0
19	533	−0.167	0.506	0.000	1.000	0.416	0.247	−0.055	−0.124	0.000	1.000	0.416	0
20	531	−0.171	0.499	0.000	1.000	0.414	0.251	−0.050	−0.126	0.000	1.000	0.414	0
21	533	−0.167	0.506	0.000	1.000	0.416	0.247	−0.055	−0.124	0.000	1.000	0.416	0
22	535	−0.160	0.522	0.000	1.000	0.420	0.239	−0.067	−0.121	0.000	1.000	0.420	0
23	534	−0.159	0.519	0.000	1.000	0.420	0.241	−0.064	−0.120	0.000	1.000	0.420	0
24	4	−0.304	0.879	0.000	1.000	0.348	0.060	−0.371	−0.153	0.000	1.000	0.348	0
25	3	−0.250	0.896	0.000	1.000	0.375	0.052	−0.378	−0.132	0.000	1.000	0.375	0

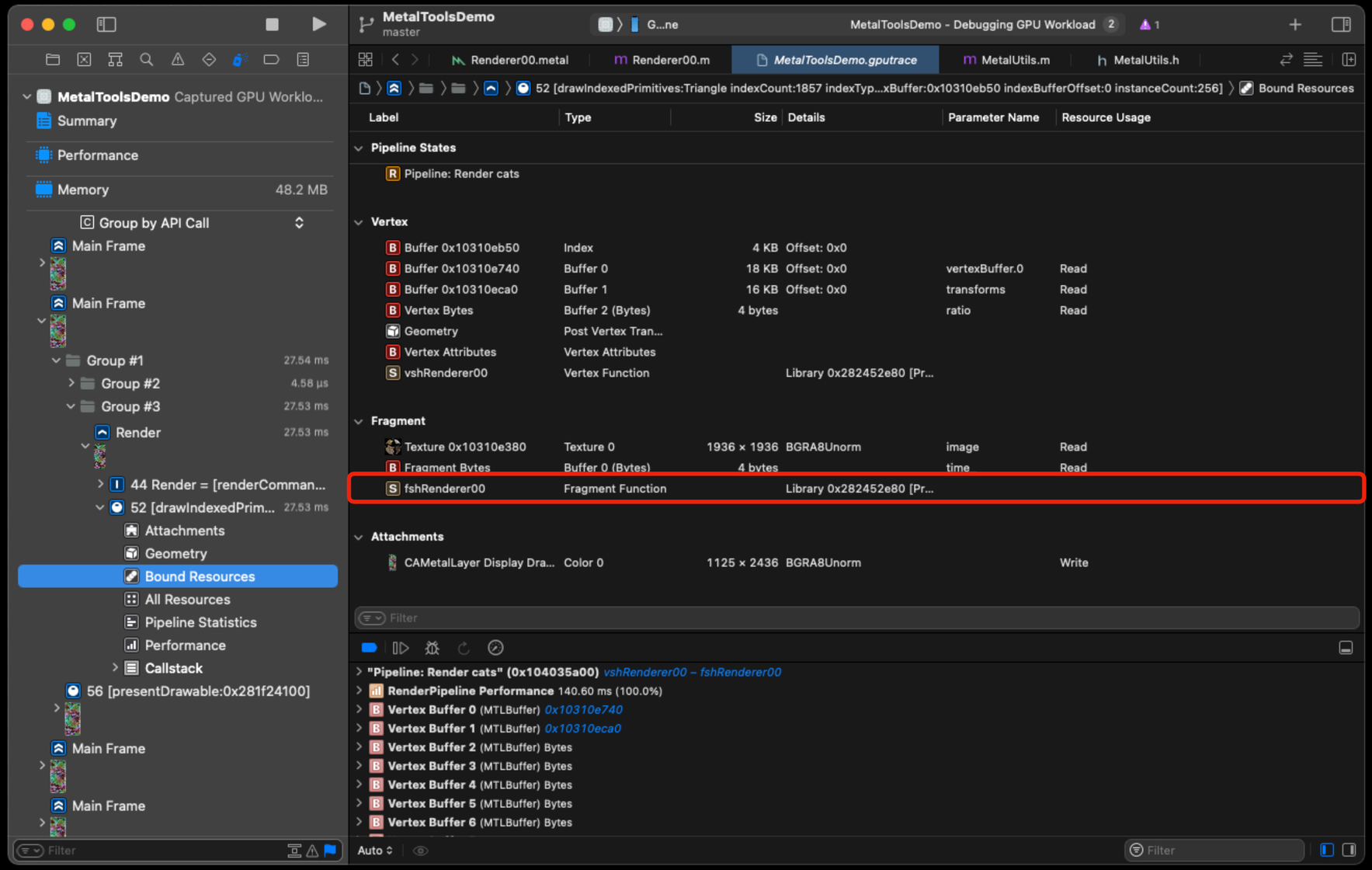
Bound Resources: Texture



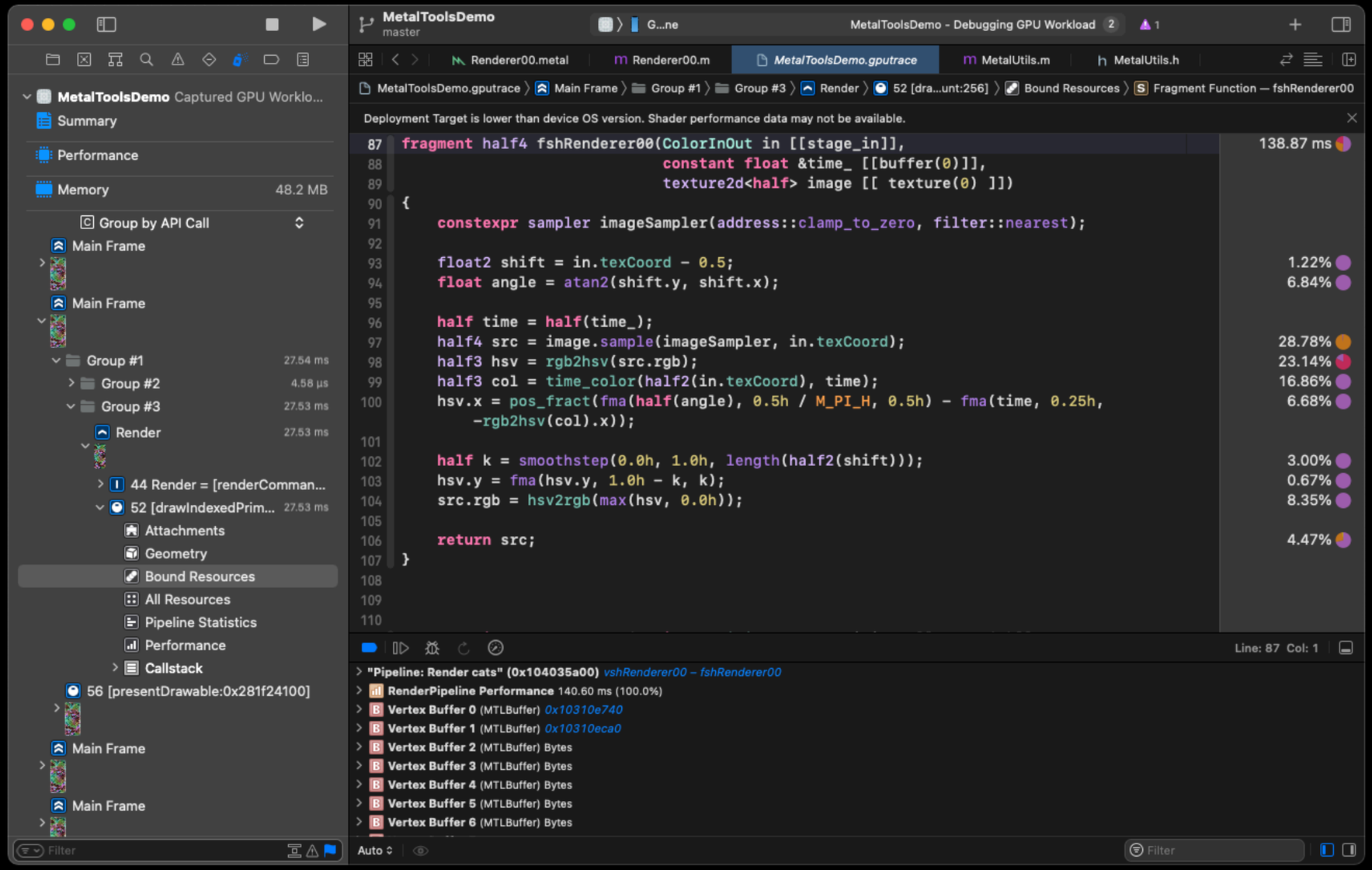
Bound Resources: Texture



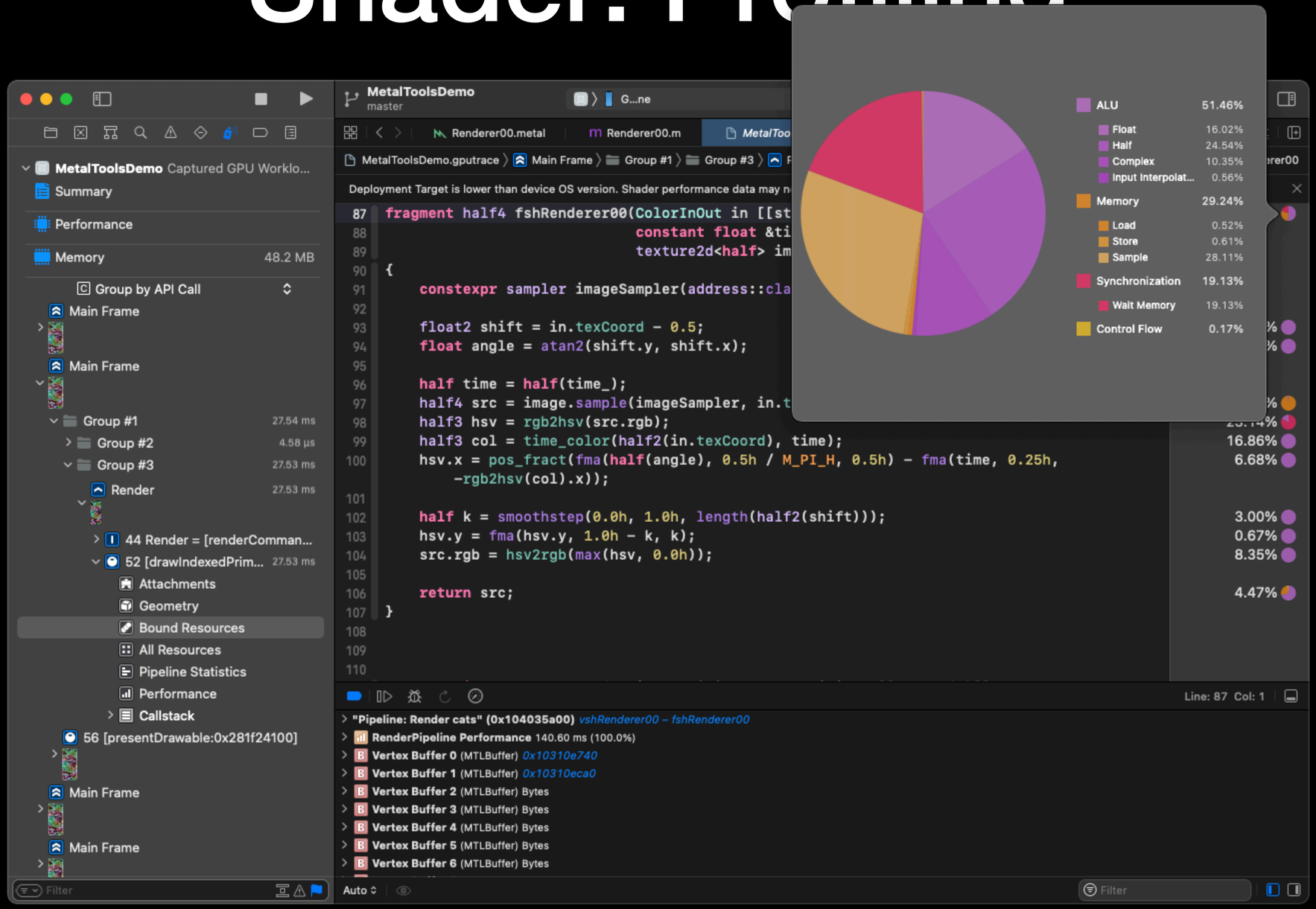
Bound Resources: Shader



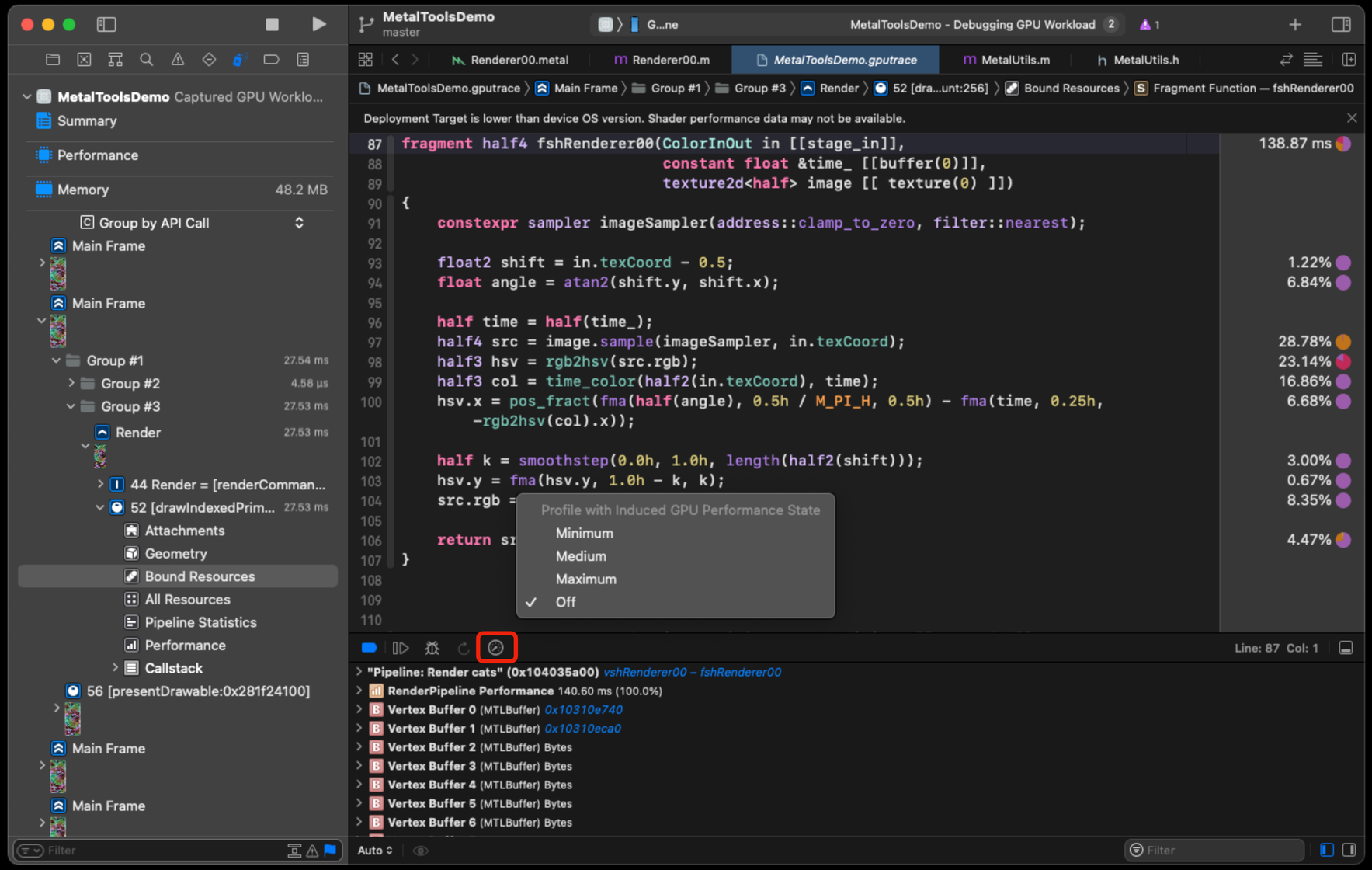
Bound Resources: Shader



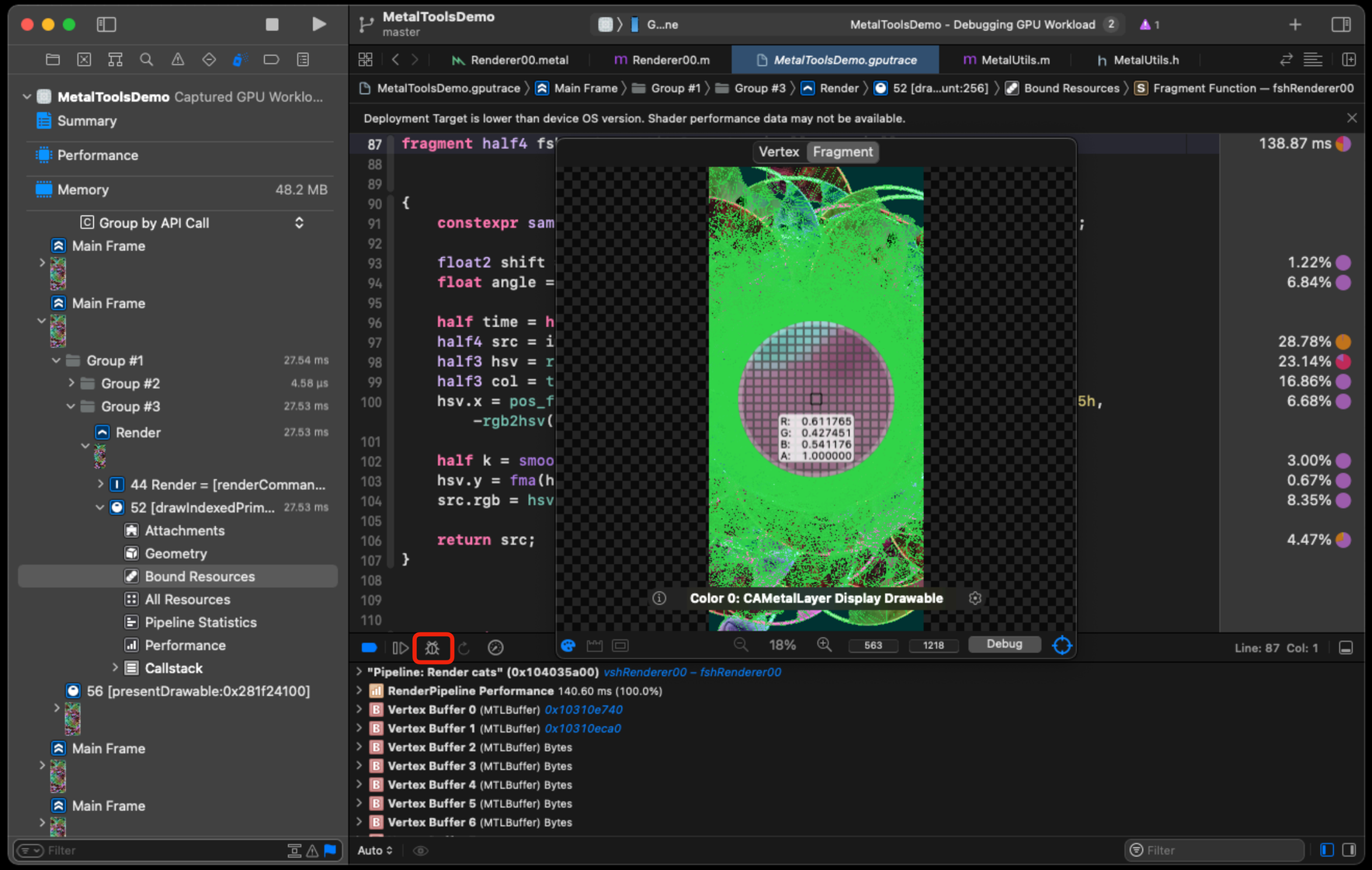
Shader: Profiling



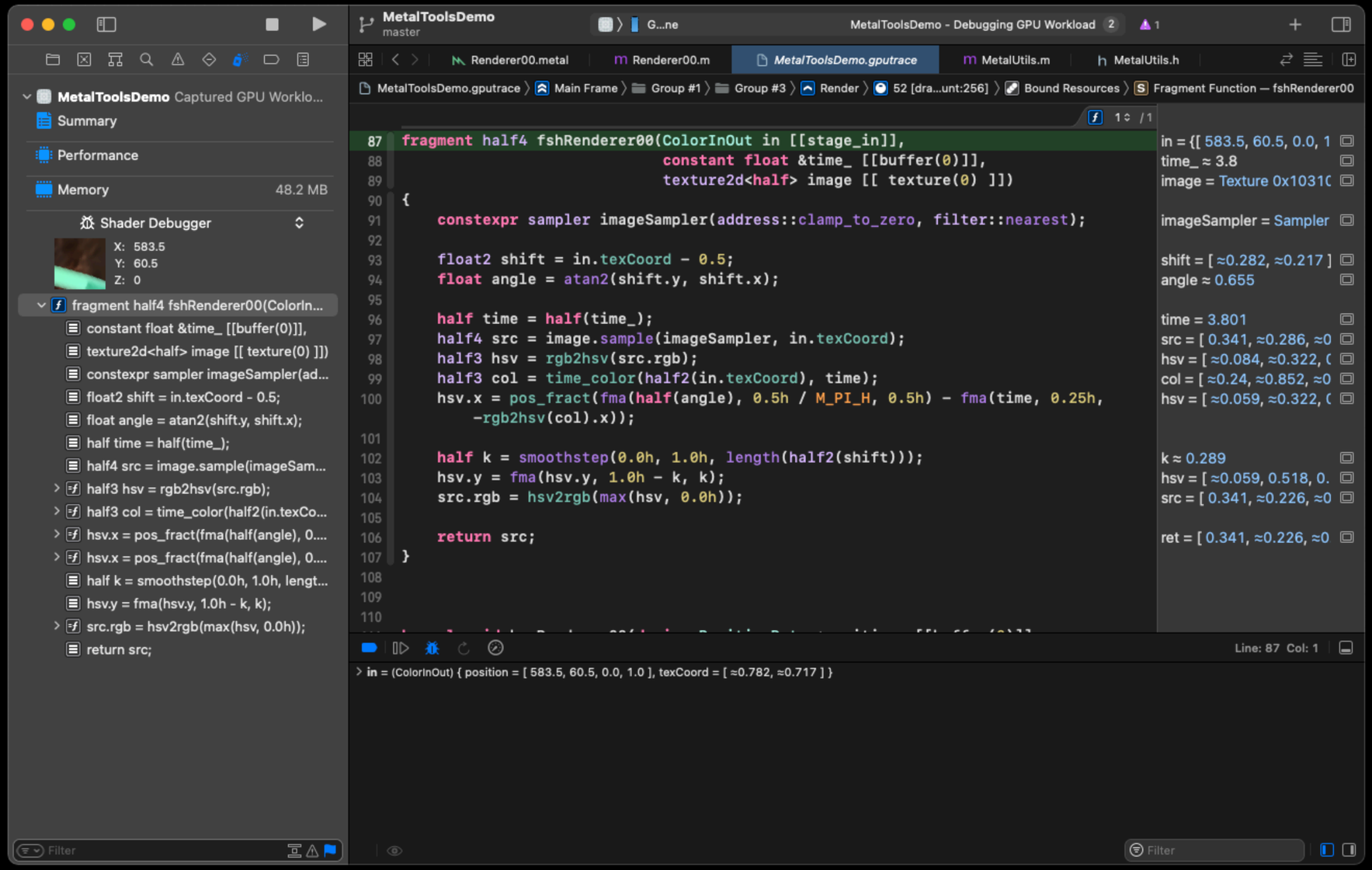
Shader: Profiling



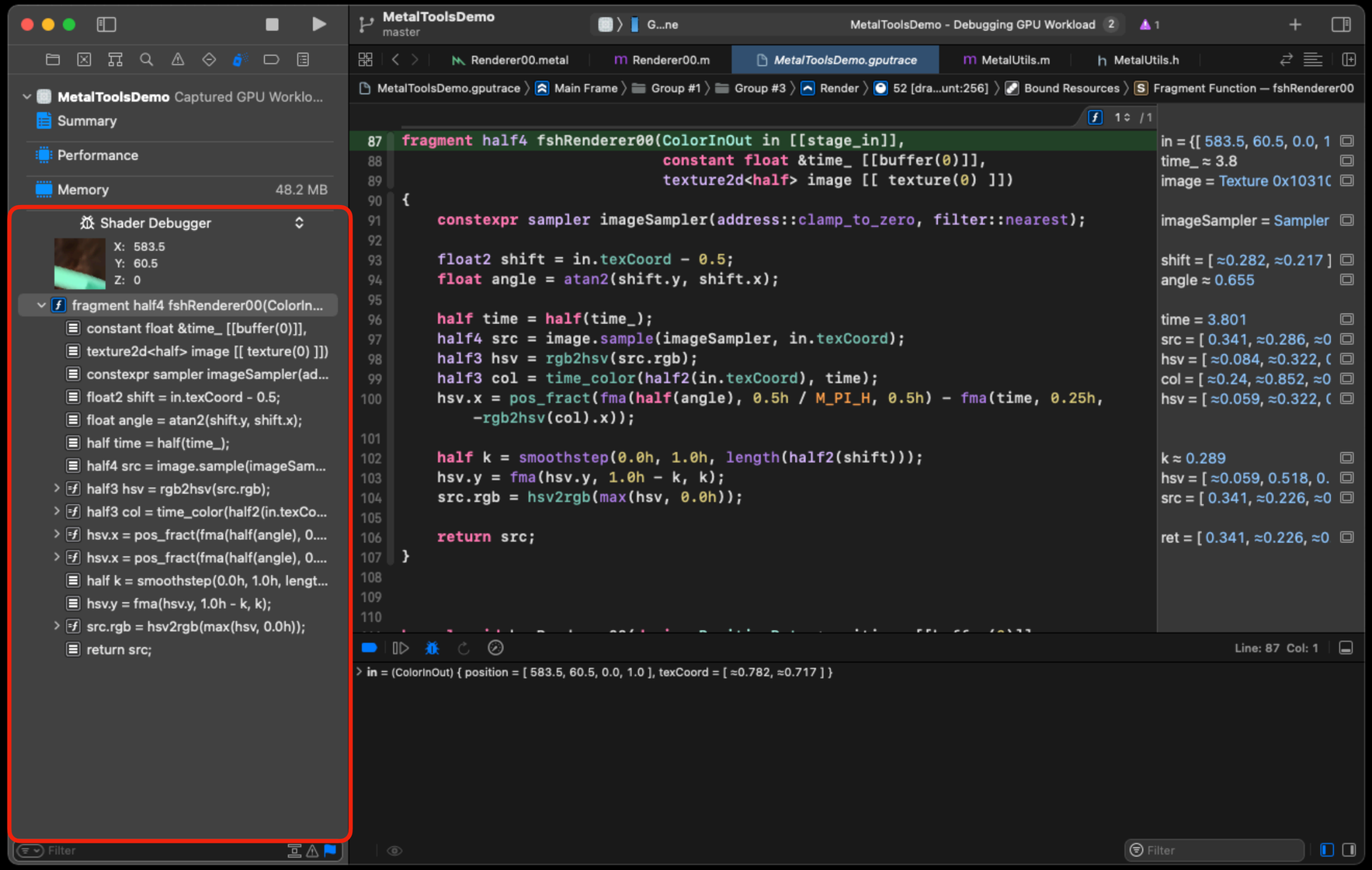
Shader: Debug



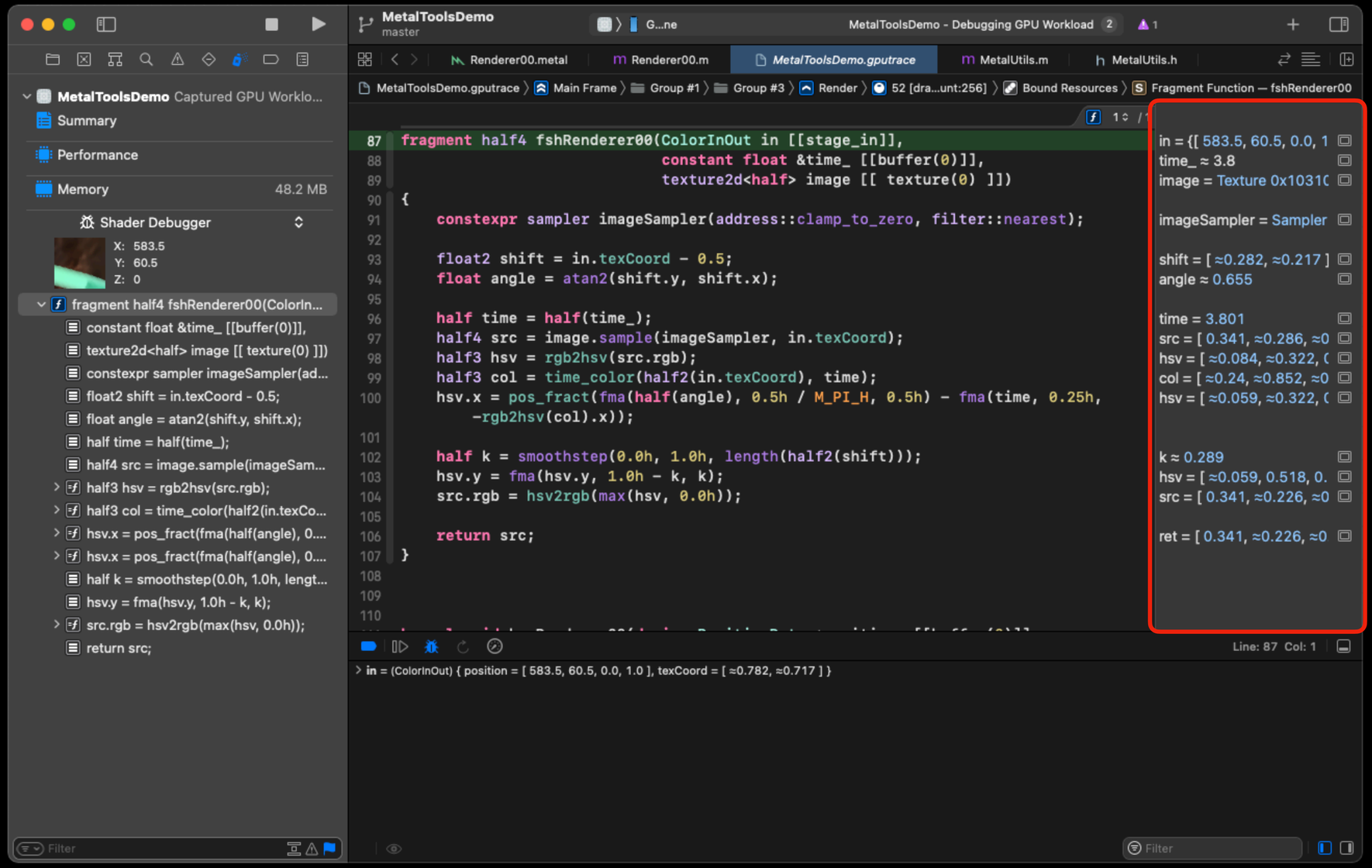
Shader: Debug



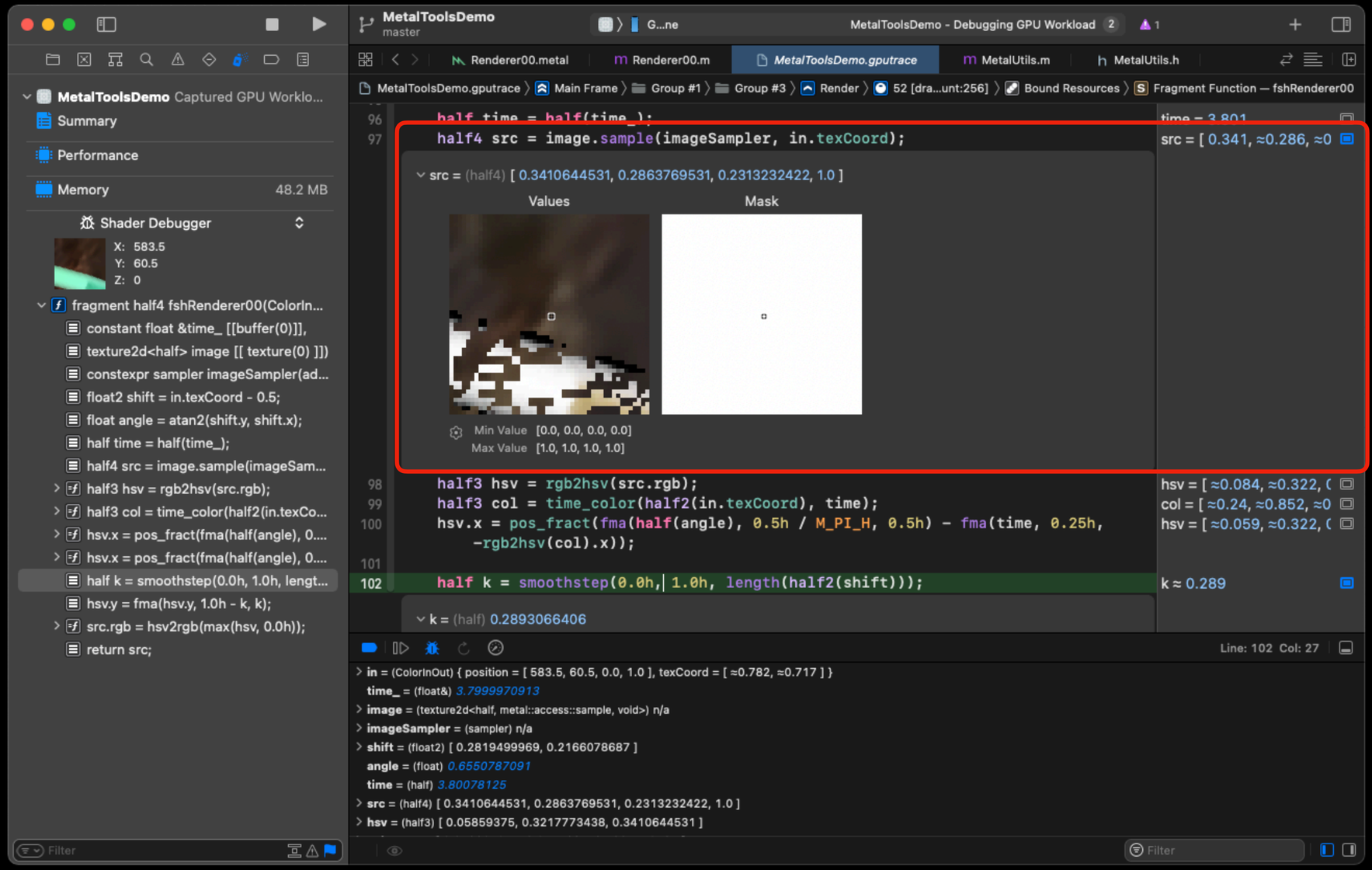
Shader: Debug



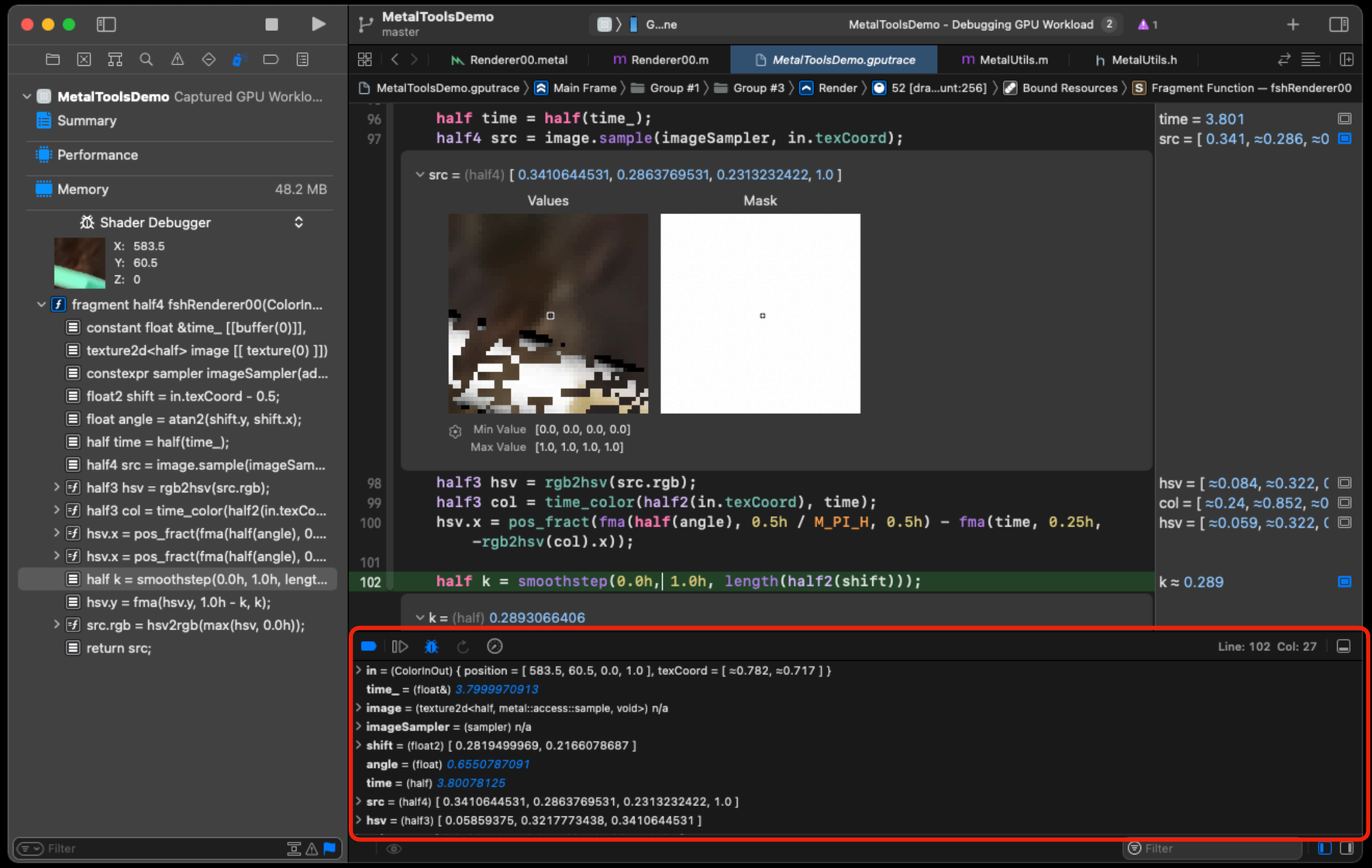
Shader: Debug



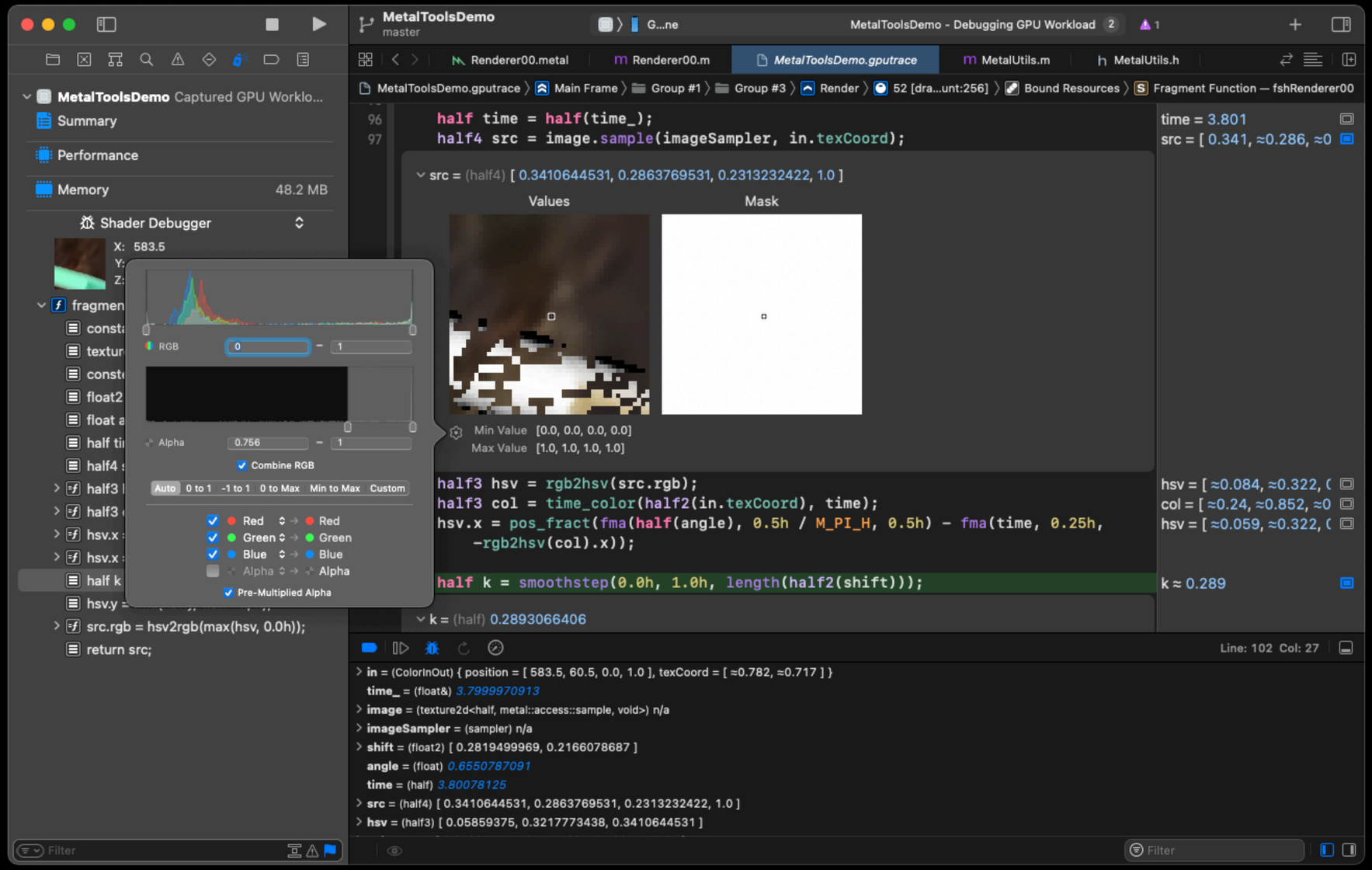
Shader: Debug



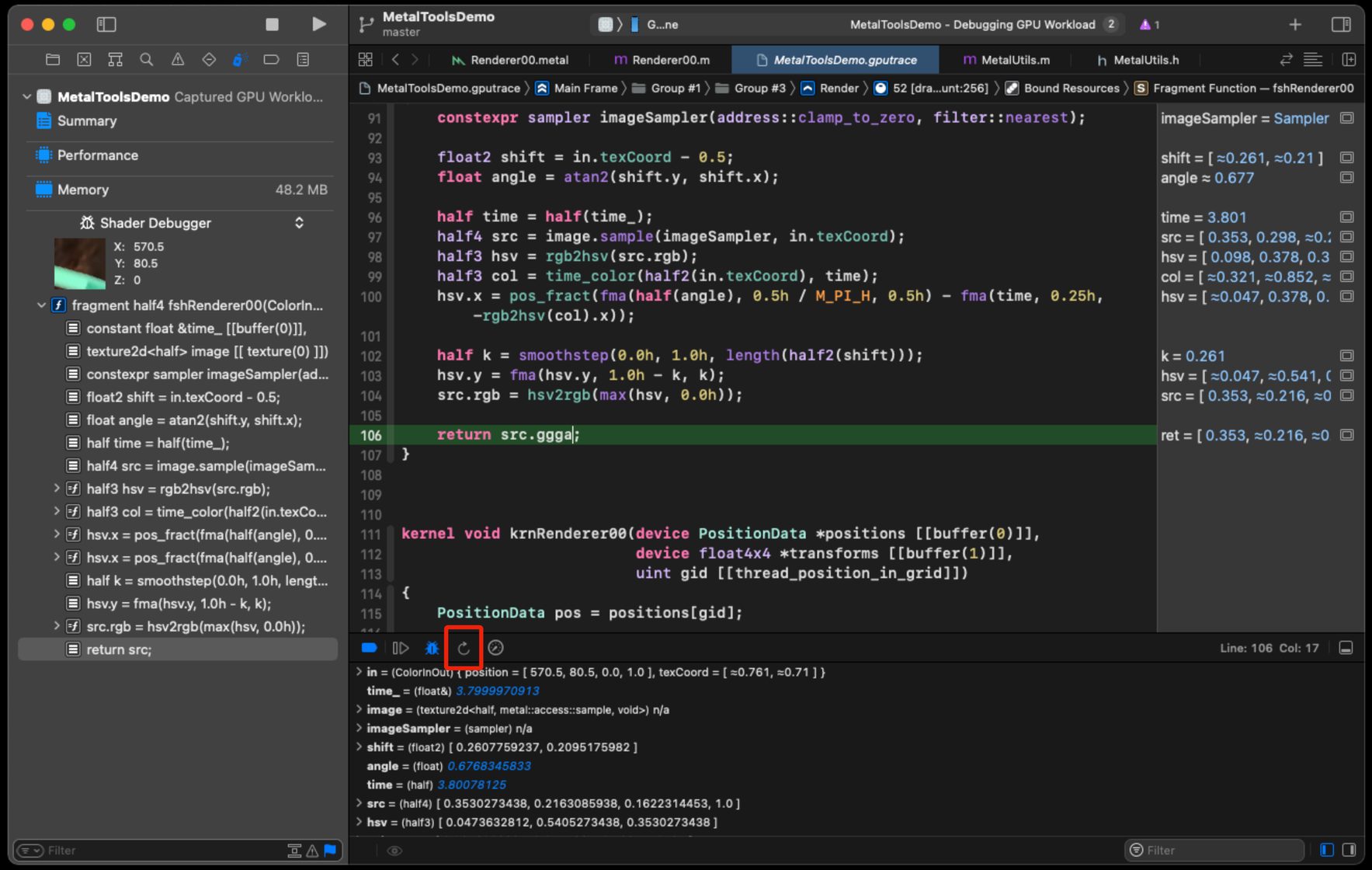
Shader: Debug



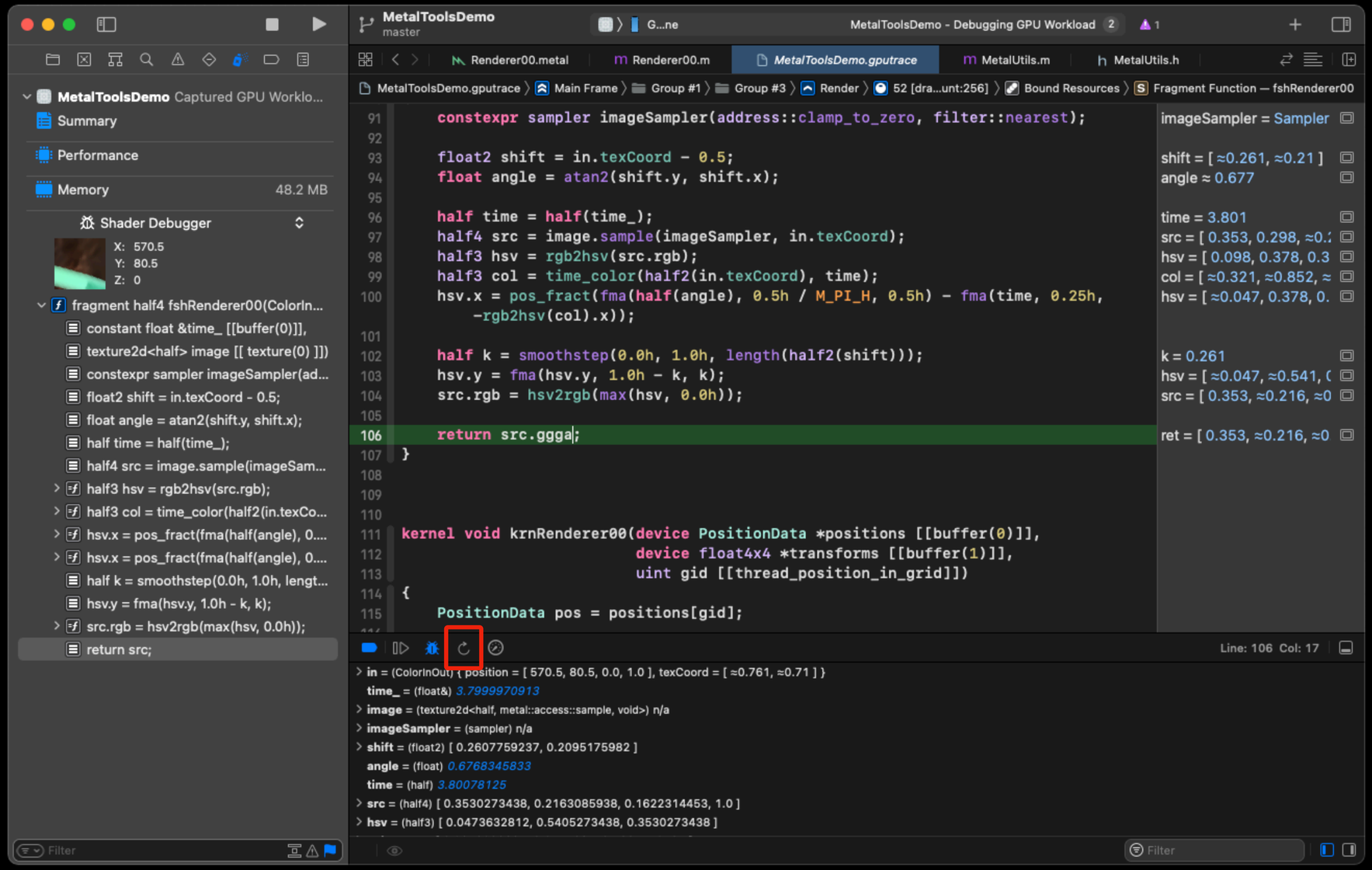
Shader: Debug



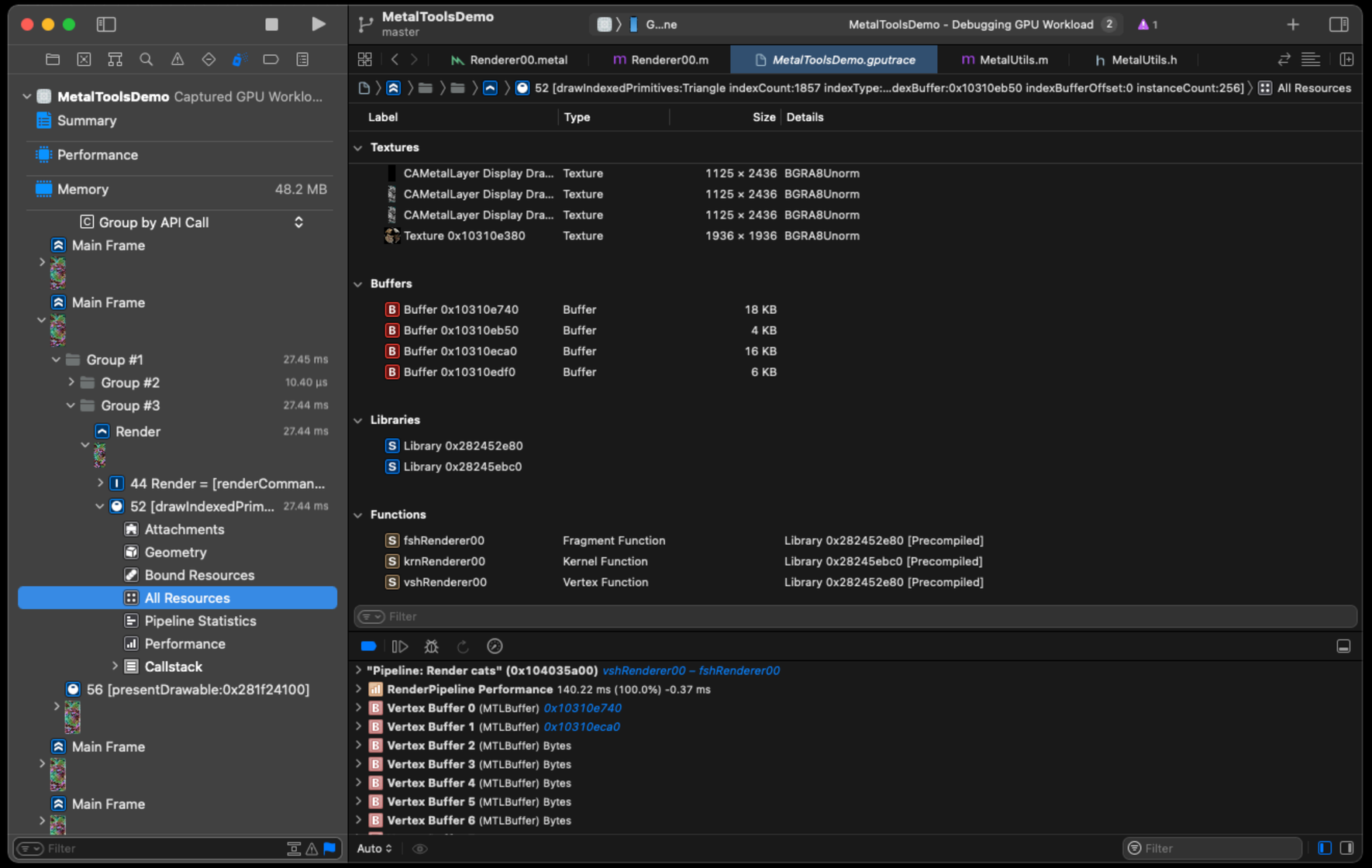
Shader: Edit+Replay



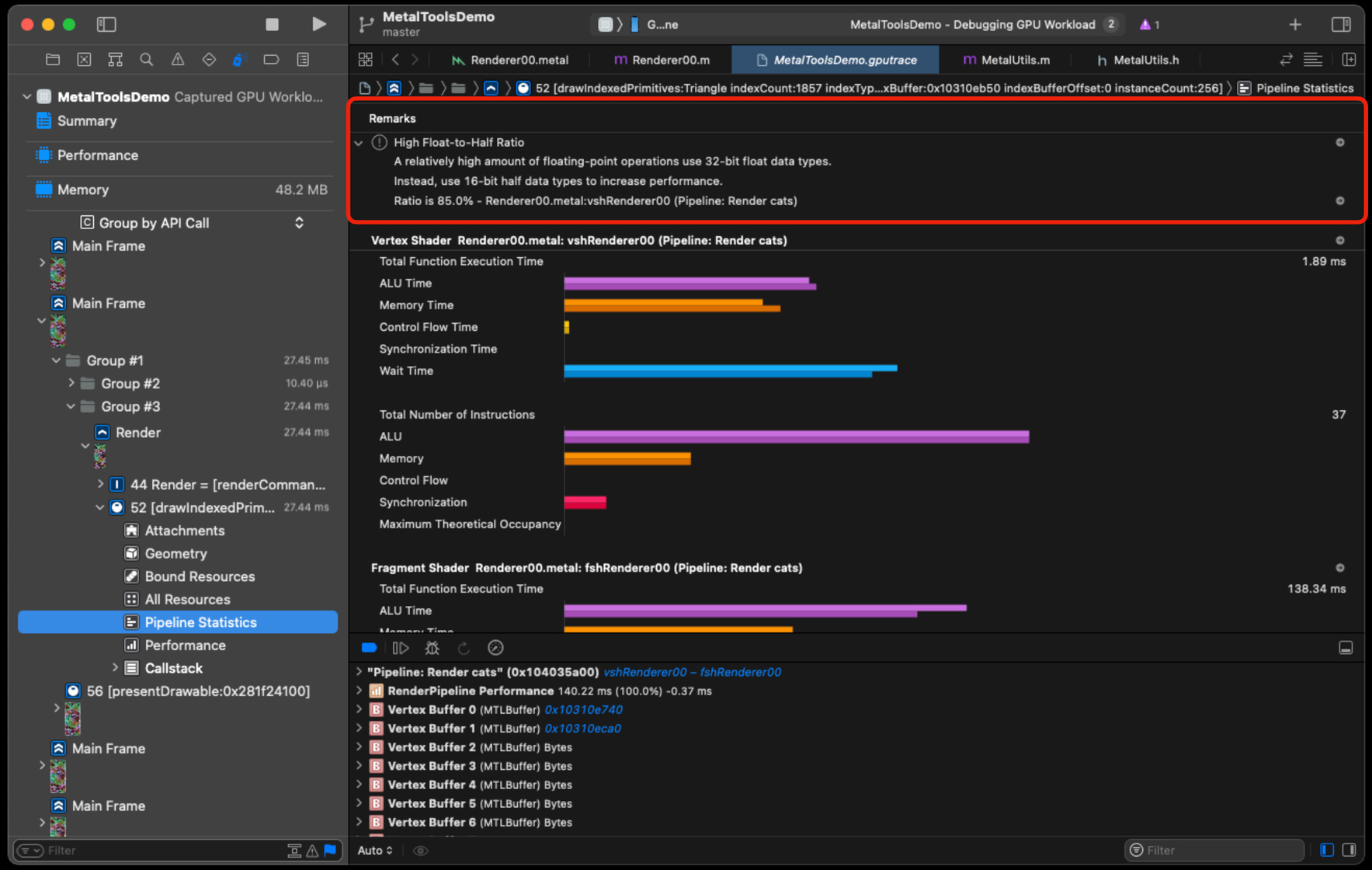
Shader: Edit+Replay



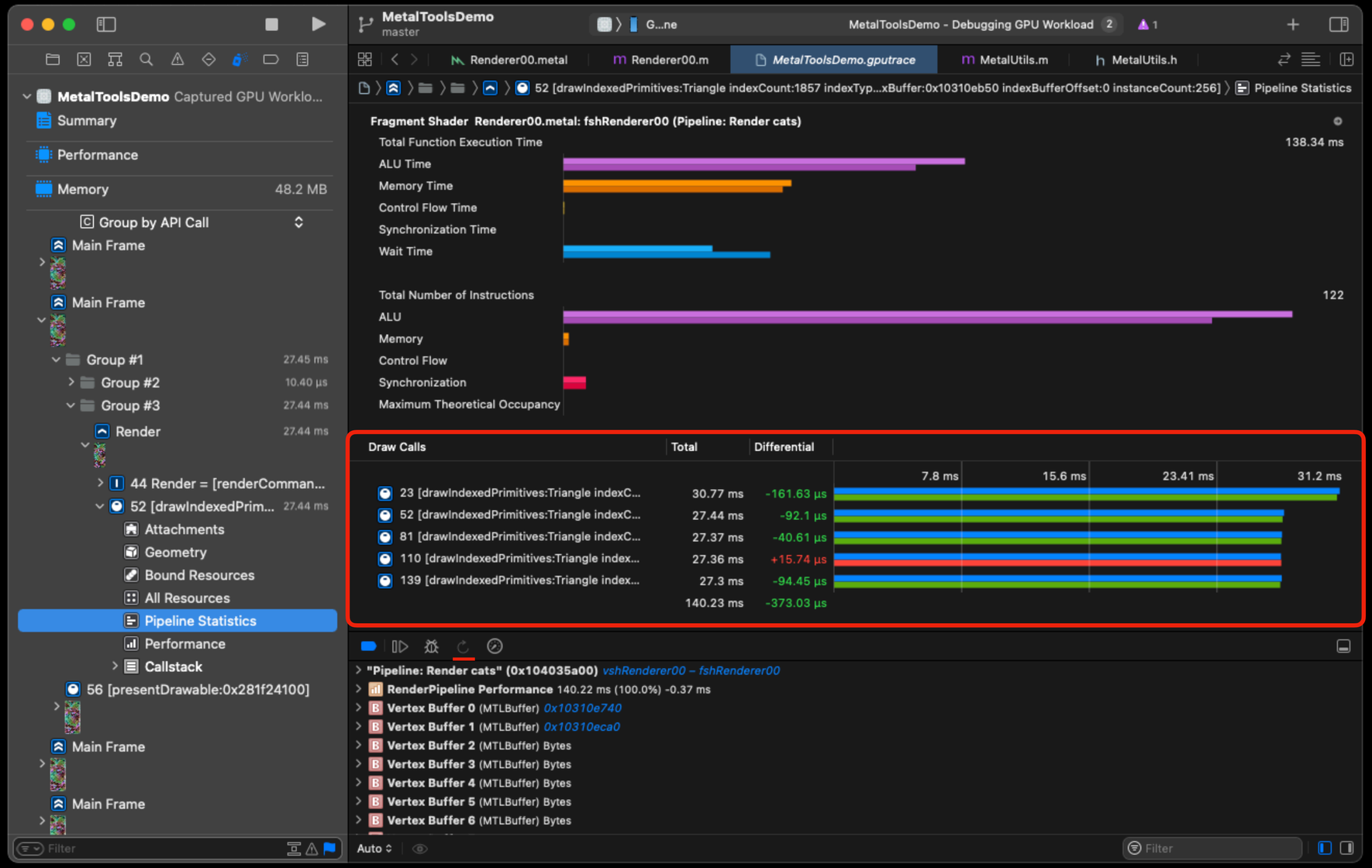
All Resources



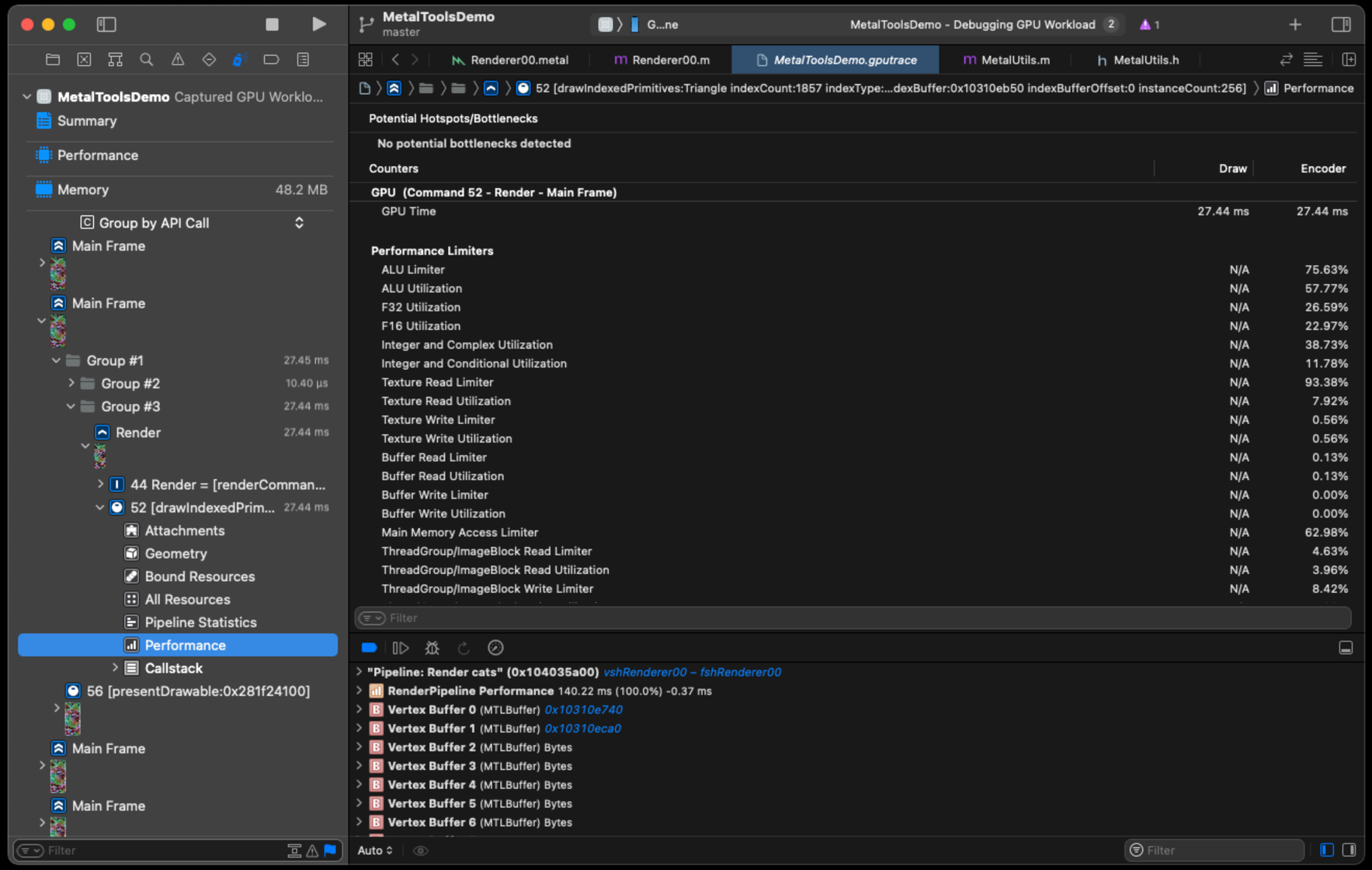
Pipeline Statistics



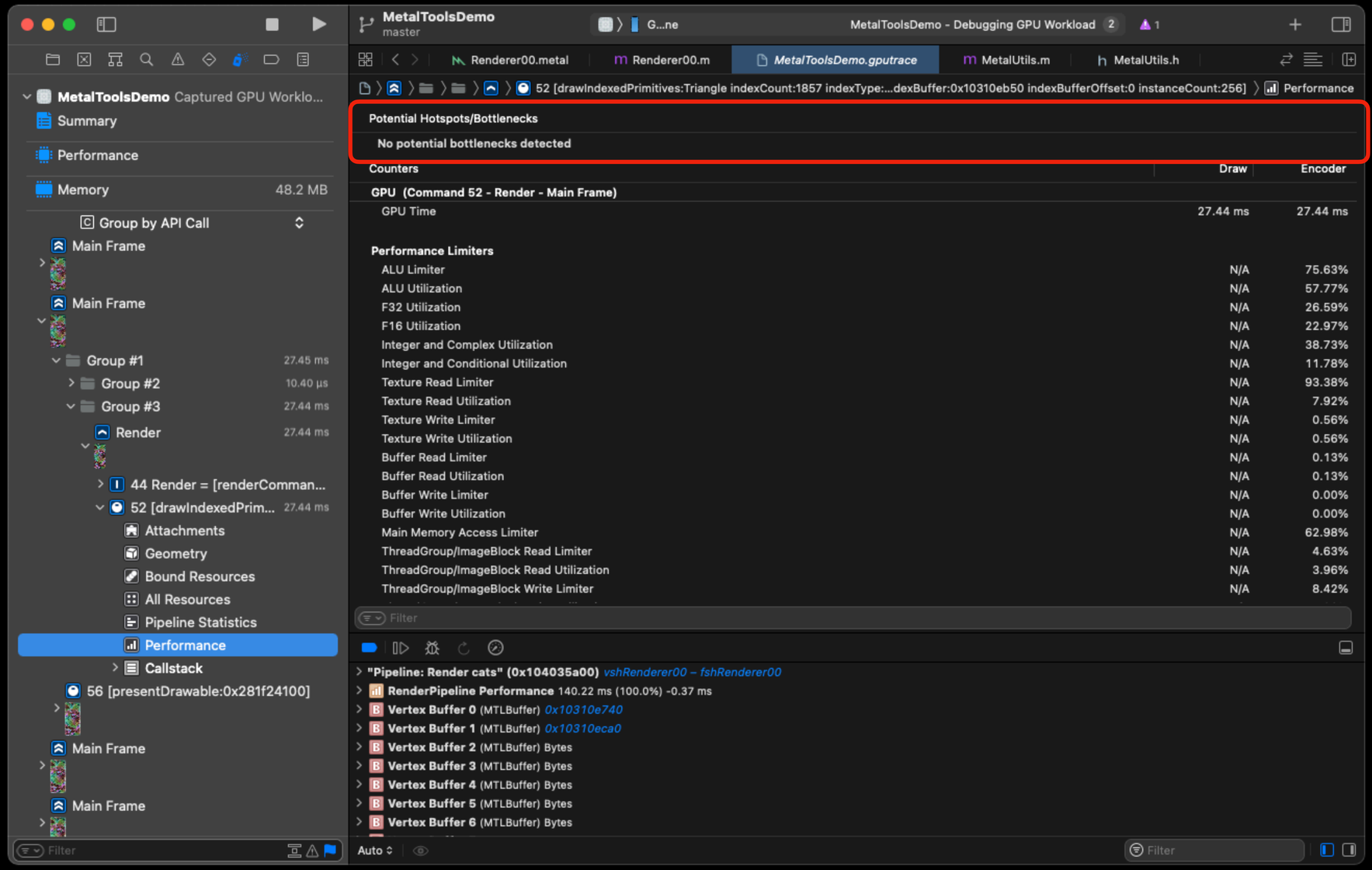
Pipeline Statistics



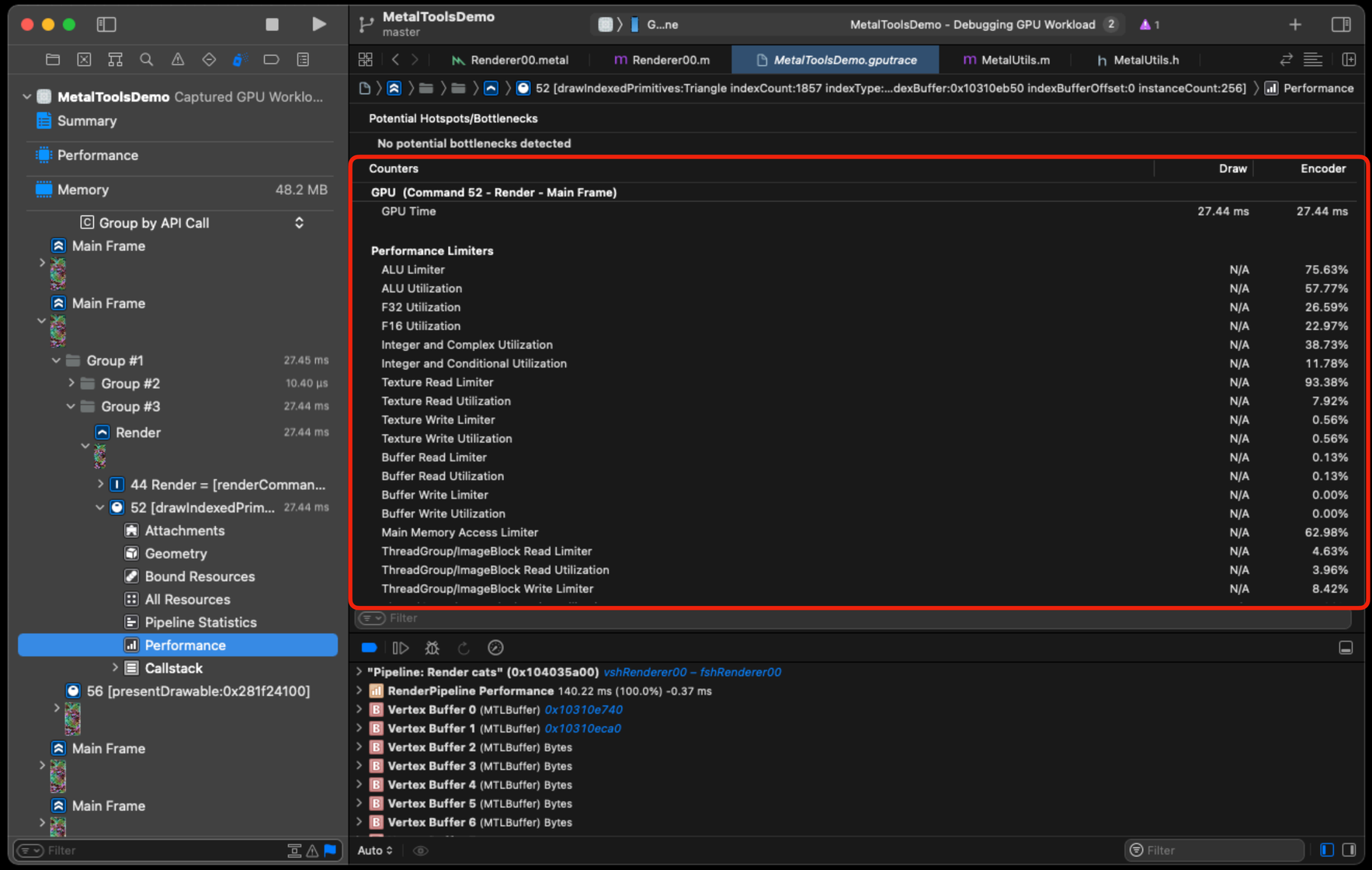
Performance



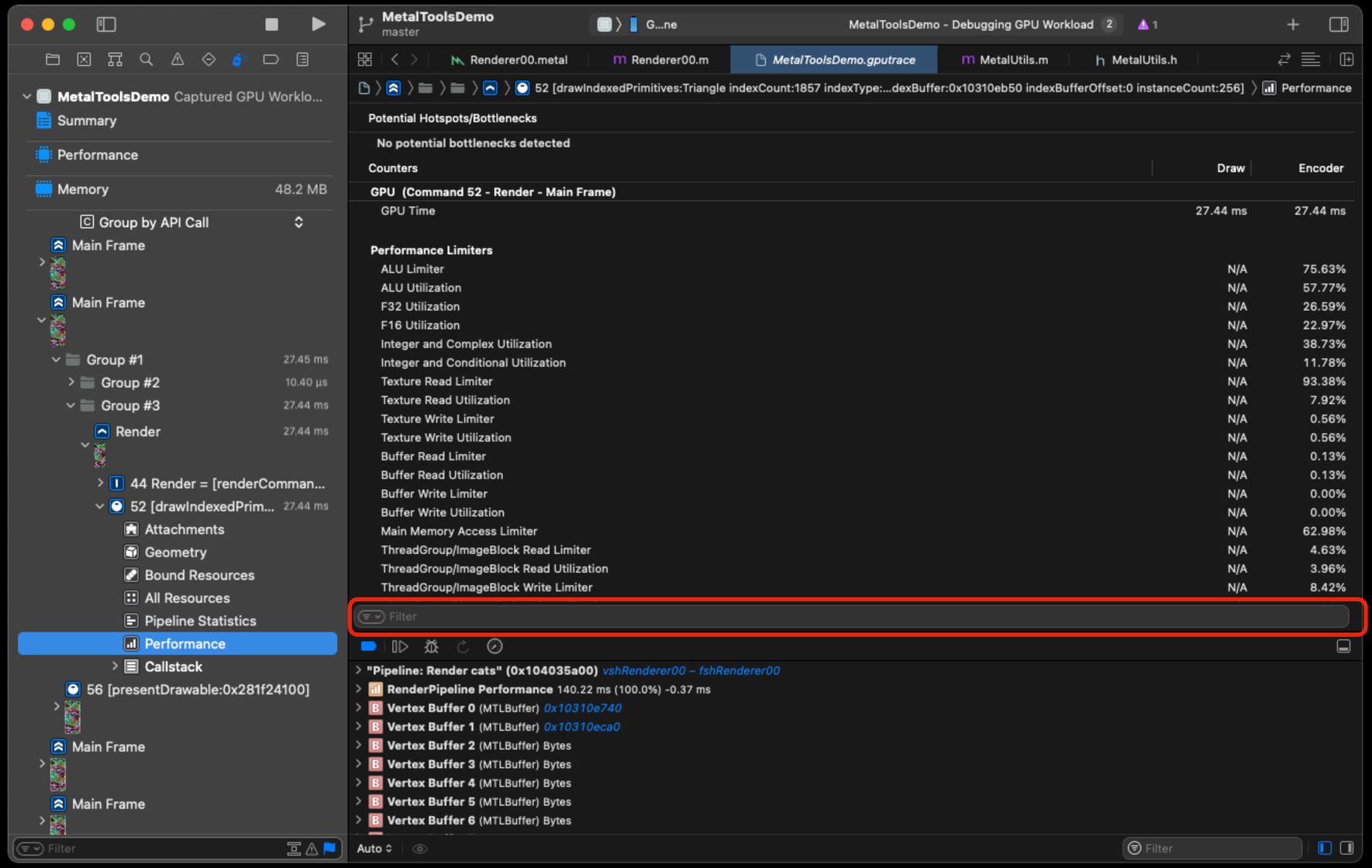
Performance



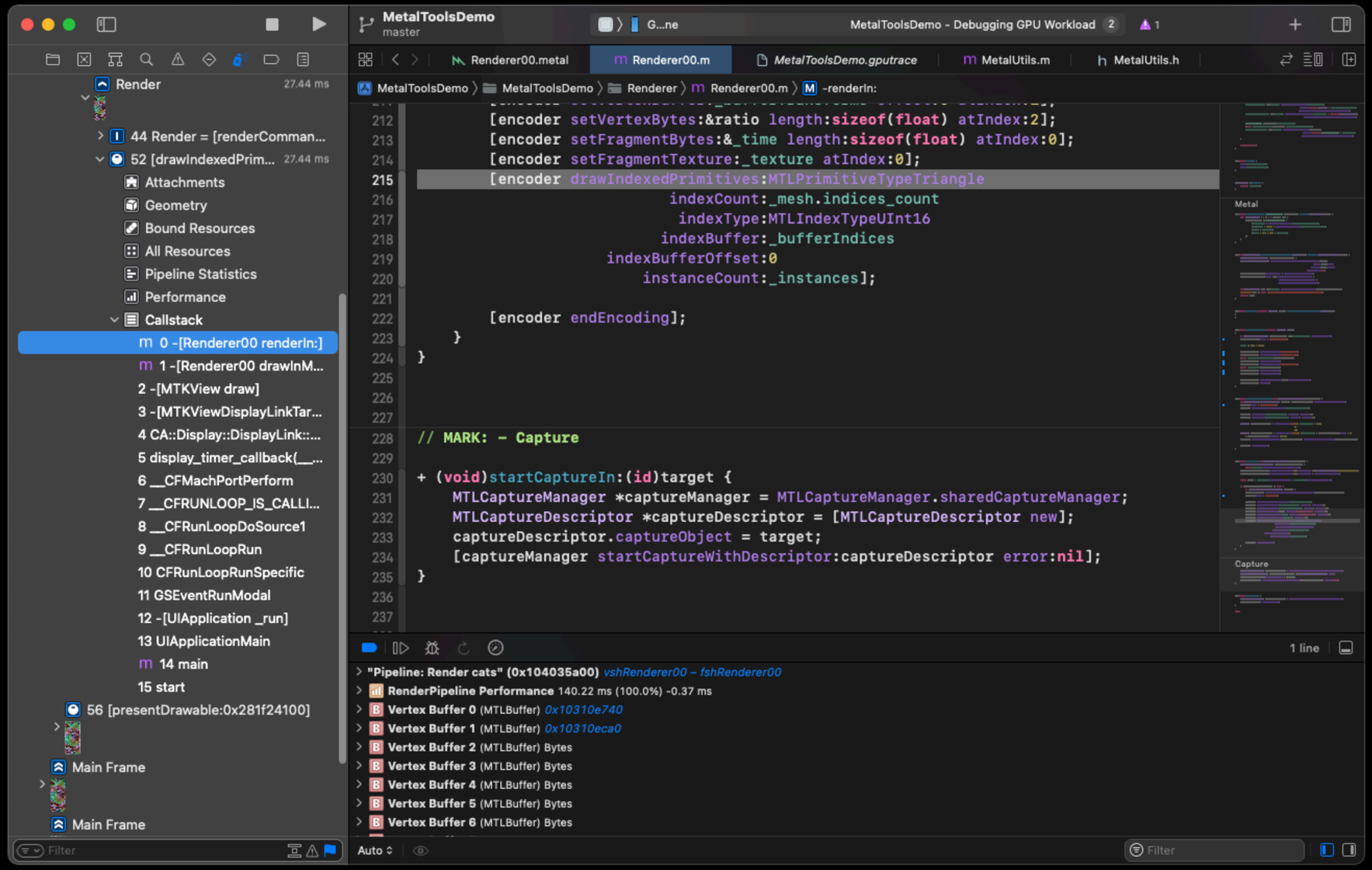
Performance



Performance



Callstack


MetalToolsDemo
master
MetalToolsDemo - Debugging GPU Workload
Renderer00.metal
Renderer00.m
MetalToolsDemo.gputrace
MetalUtils.m
MetalUtils.h
Render 27.44 ms
44 Render = [renderComman...
52 [drawIndexedPrim... 27.44 ms
Attachments
Geometry
Bound Resources
All Resources
Pipeline Statistics
Performance
Callstack
0 -[Renderer00 renderIn:]
1 -[Renderer00 drawInM...
2 -[MTKView draw]
3 -[MTKViewDisplayLinkTar...
4 CA::Display::DisplayLink::...
5 display_timer_callback(__...
6 __CFMachPortPerform
7 __CFRUNLOOP_IS_CALLI...
8 __CFRunLoopDoSource1
9 __CFRunLoopRun
10 CFRunLoopRunSpecific
11 GSEventRunModal
12 -[UIApplication _run]
13 UIApplicationMain
14 main
15 start
56 [presentDrawable:0x281f24100]
Main Frame
Main Frame
[encoder setVertexBytes:&ratio length:sizeof(float) atIndex:2];
[encoder setFragmentBytes:&_time length:sizeof(float) atIndex:0];
[encoder setFragmentTexture:_texture atIndex:0];
[encoder drawIndexedPrimitives:MTLPrimitiveTypeTriangle
indexCount:_mesh.indices_count
indexType:MTLIndexTypeUInt16
indexBuffer:_bufferIndices
indexBufferOffset:0
instanceCount:_instances];
[encoder endEncoding];
}
}
// MARK: - Capture
+ (void)startCaptureIn:(id)target {
MTLCaptureManager *captureManager = MTLCaptureManager.sharedCaptureManager;
MTLCaptureDescriptor *captureDescriptor = [MTLCaptureDescriptor new];
captureDescriptor.captureObject = target;
[captureManager startCaptureWithDescriptor:captureDescriptor error:nil];
}
"Pipeline: Render cats" (0x104035a00) vshRenderer00 – fshRenderer00
RenderPipeline Performance 140.22 ms (100.0%) -0.37 ms
Vertex Buffer 0 (MTLBuffer) 0x10310e740
Vertex Buffer 1 (MTLBuffer) 0x10310eca0
Vertex Buffer 2 (MTLBuffer) Bytes
Vertex Buffer 3 (MTLBuffer) Bytes
Vertex Buffer 4 (MTLBuffer) Bytes
Vertex Buffer 5 (MTLBuffer) Bytes
Vertex Buffer 6 (MTLBuffer) Bytes
Metal
Capture
1 line
Auto
Filter

METAL API

GPU Frame Capture

Simple Capture

```
+ (void)startCaptureIn:(id)target {
    MTLCaptureManager *captureManager = MTLCaptureManager.sharedCaptureManager;
    MTLCaptureDescriptor *captureDescriptor = [MTLCaptureDescriptor new];
    captureDescriptor.captureObject = target;
    [captureManager startCaptureWithDescriptor:captureDescriptor error:nil];
}

+ (void)endCapture {
    MTLCaptureManager *captureManager = MTLCaptureManager.sharedCaptureManager;
    [captureManager stopCapture];
}
```

Scope Capture

```
id<MTLCaptureScope> customScope =
    [[MTLCaptureManager sharedCaptureManager] newCaptureScopeWithDevice:_device];
customScope.label = @"Custom scope";
// ...
[Renderer00 startCaptureIn:customScope];
// ...
[customScope beginScope];
// captured command buffers
[customScope endScope];
// ...
[Renderer00 endCapture];
```

TOOLS DON’T WORK

Manual Solutions

PERFORMANCE

FPS (in code)

FPS (in code)

- Check frame time every frame
- Store time history
- Compute average time with history

FPS: Preparing

```
// Previous timestamp.
CFTimeInterval _prevTime;
// A callback for updating some FPS representation.
FPSUpdater _fpsUpdater;
// A history of time per frames.
double _prevFPS[MaxFPSHistory];
// A size of the history.
NSUInteger _prevFPSNum;
```

FPS: Computing

```
- (void)updateFPS {
  static dispatch_once_t once;

  dispatch_once(&once, ^{
    _prevTime = CACurrentMediaTime() - 1.0 / 60.0;
  });

  CFTimeInterval curTime = CACurrentMediaTime();
  double fps = 1.0 / (curTime - _prevTime);

  double fpsSum = fps;
  int fpsCount = 1;
  for (NSUInteger i = 0; i < _prevFPSNum; ++i) {
    fpsSum += _prevFPS[i];
    ++fpsCount;
  }
  for (int i = (int)_prevFPSNum - 1; i > 0; --i) {
    _prevFPS[i] = _prevFPS[i - 1];
  }
  _prevFPS[0] = fps;
  _prevFPSNum = MIN(_prevFPSNum + 1, MaxFPSHistory);
  _fpsUpdater(fpsSum / fpsCount);
  _prevTime = curTime;
}
```

PERFORMANCE

Command Buffer Profiling

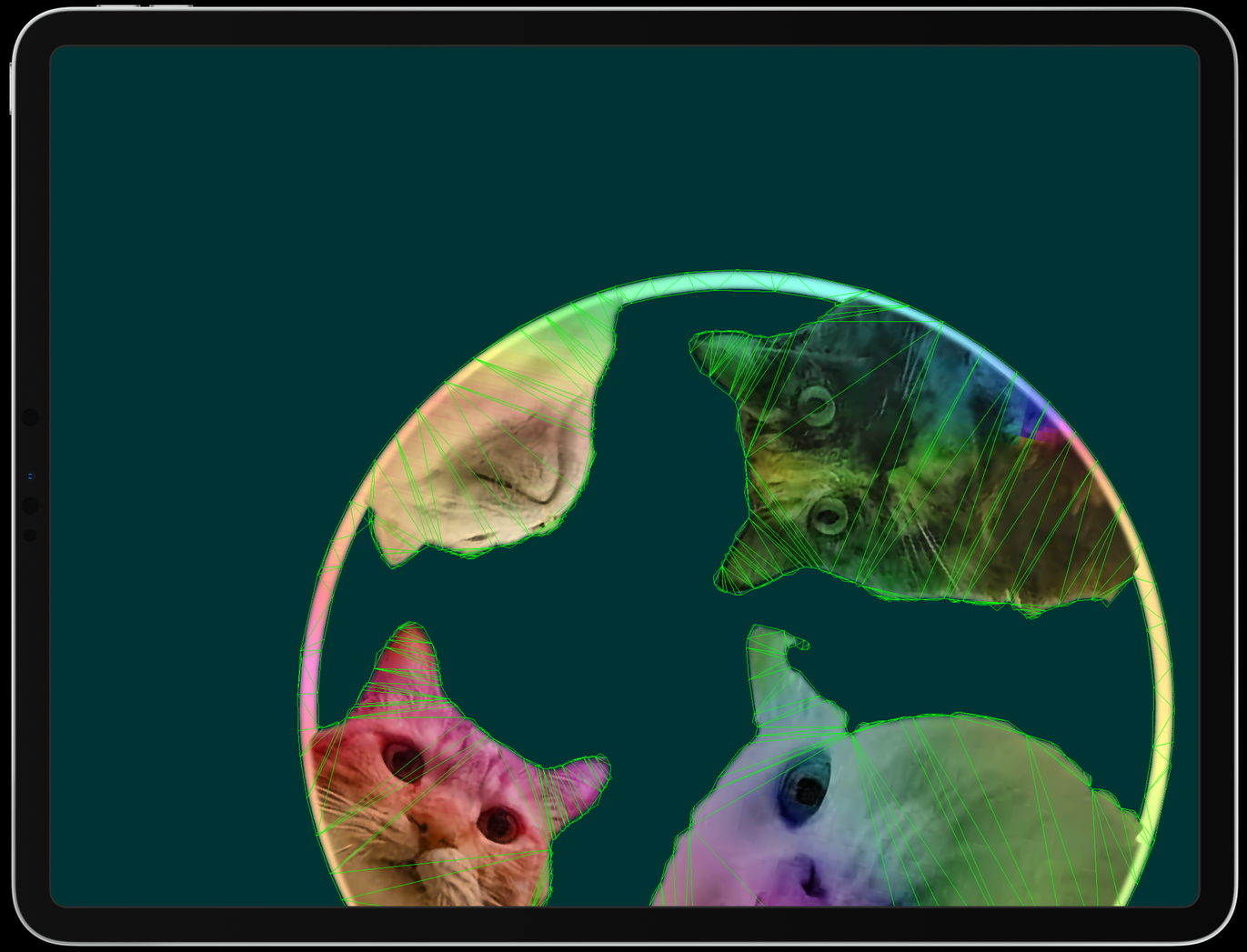
```objc
- (void) foo {
  // ...
  CFTimeInterval startTime = CACurrentMediaTime();
  NSUInteger iterations = 100;
  for (NSUInteger i = 0; i < iterations - 1; ++i) {
    id <MTLCommandBuffer> commandBuffer = [_commandQueue commandBuffer];
    [self renderIn:commandBuffer];
    [commandBuffer commit];
  }
  id <MTLCommandBuffer> commandBuffer = [_commandQueue commandBuffer];
  [self renderIn:commandBuffer];
  [commandBuffer commit];
  [commandBuffer waitUntilCompleted];

  CFTimeInterval curTime = CACurrentMediaTime();
  double fps = (double)iterations / (curTime - startTime);
  // ...

  (void)fps;
}
```

DEBUG SHADERS

Strokes & Fills

GEOMETRY

Wireframe



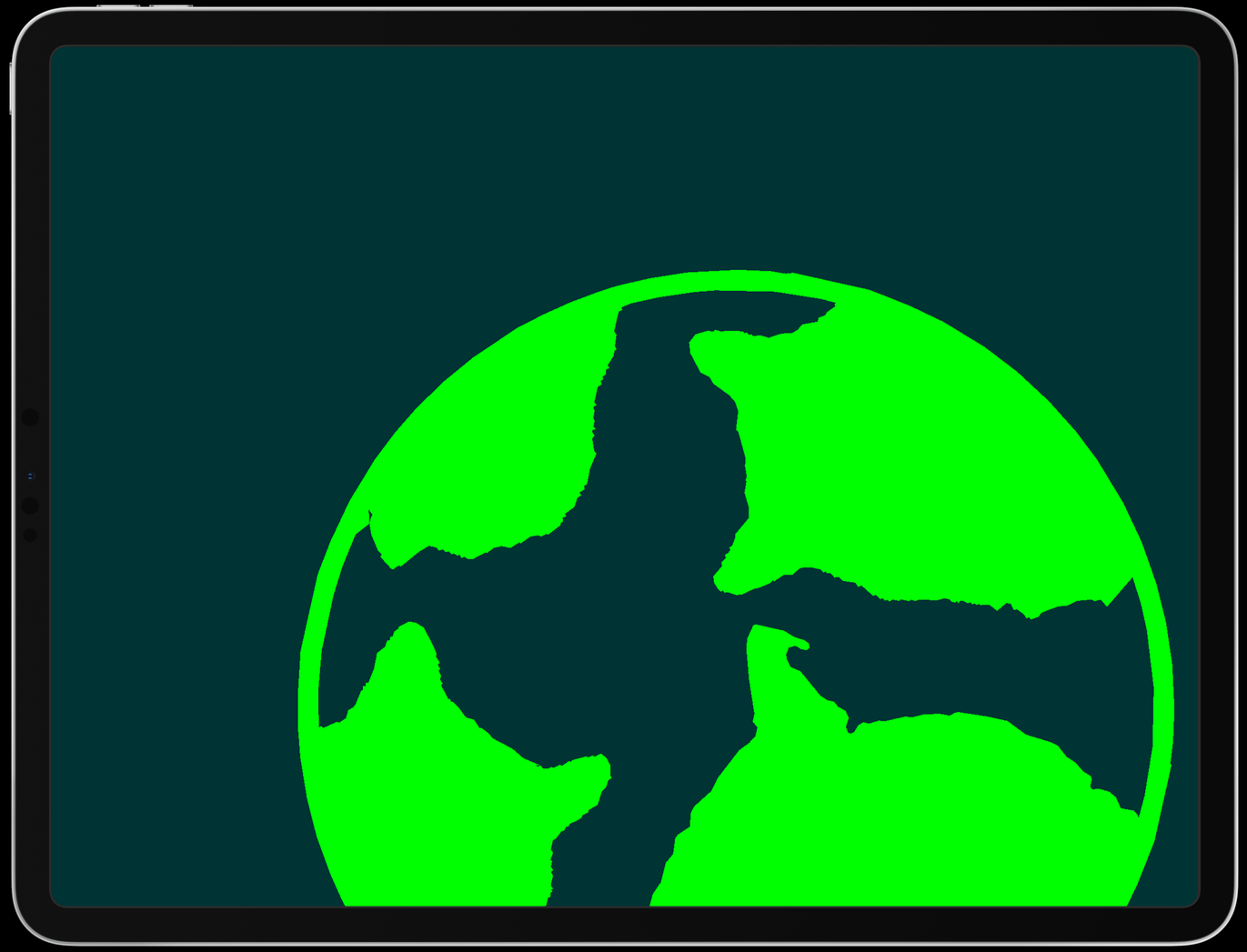
GEOMETRY

Wireframe

```
[encoder setTriangleFillMode:MTLTriangleFillModeLines];
```

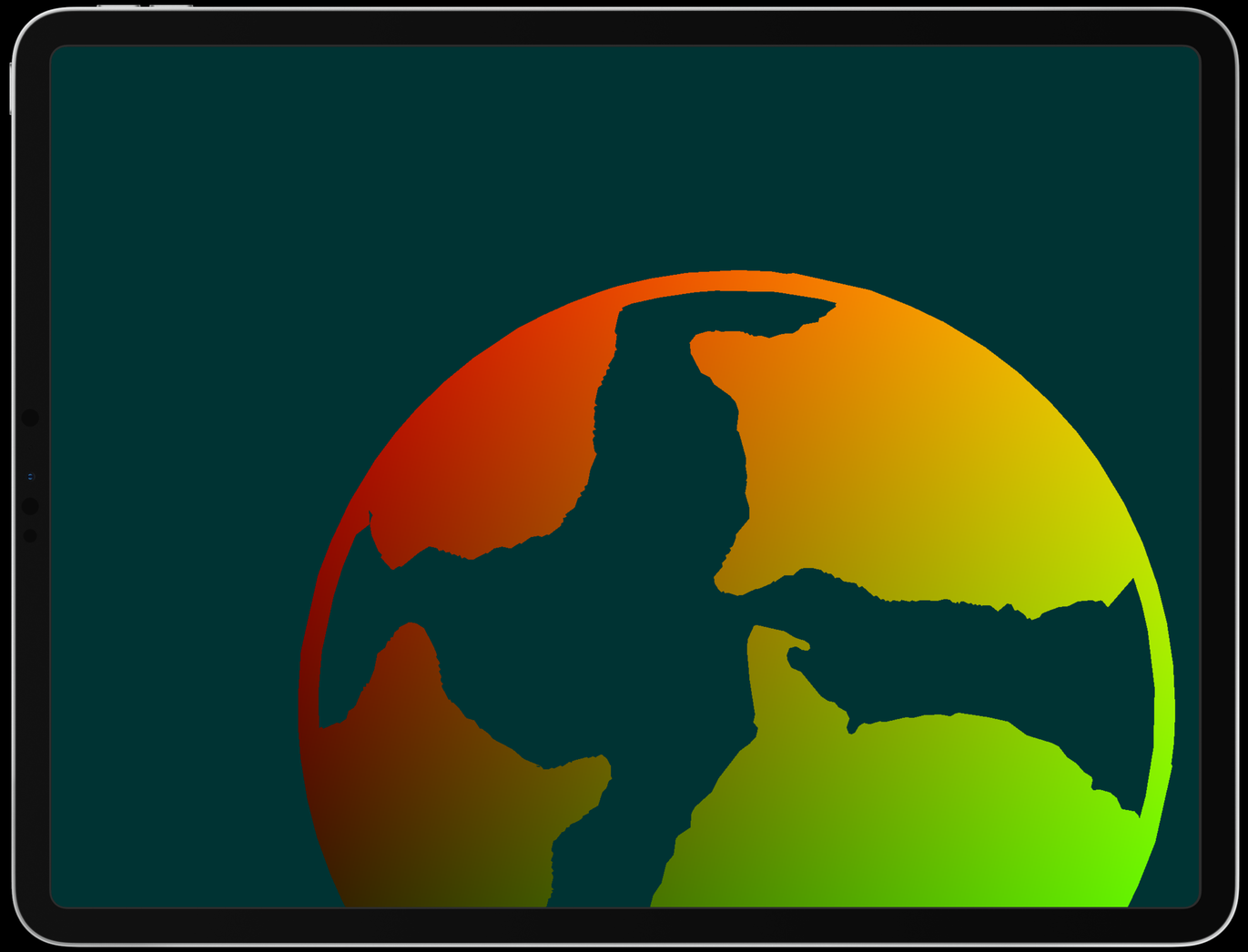
PROCESSED AREA

Color Fill



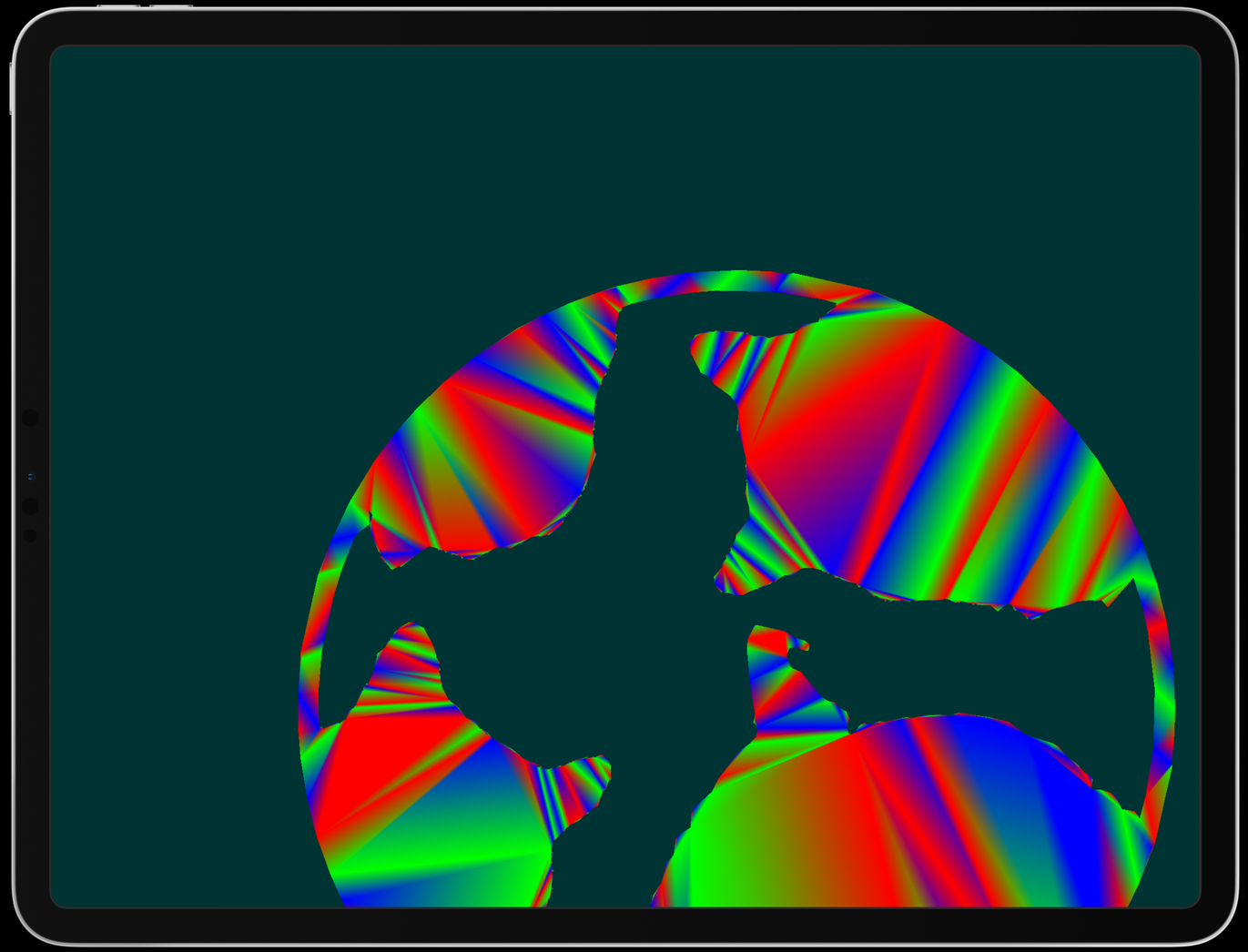
COORDINATES

RG-Fill



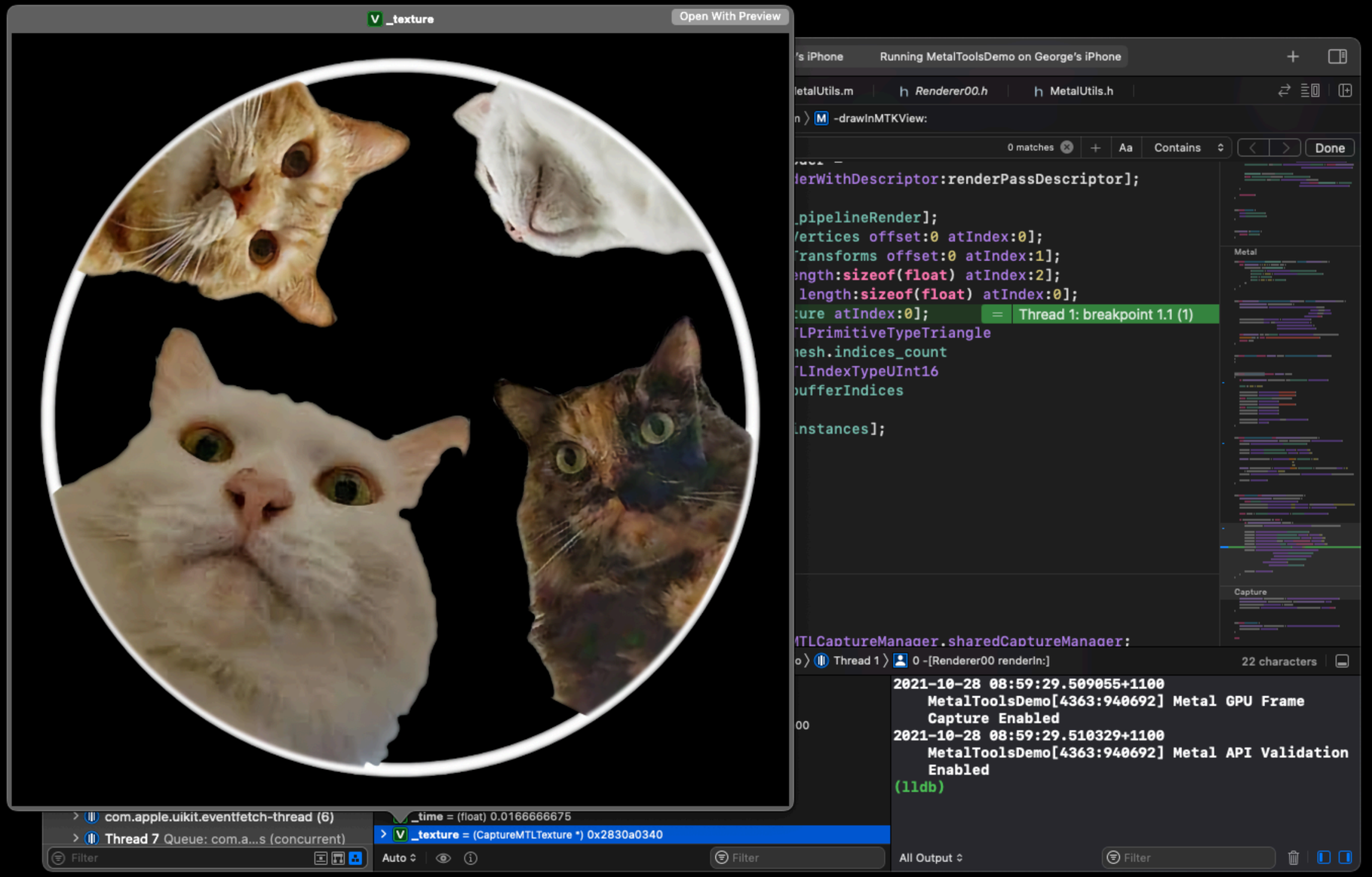
SPECIAL CASES

Special Fills



OFF-SCREEN DEBUGGING

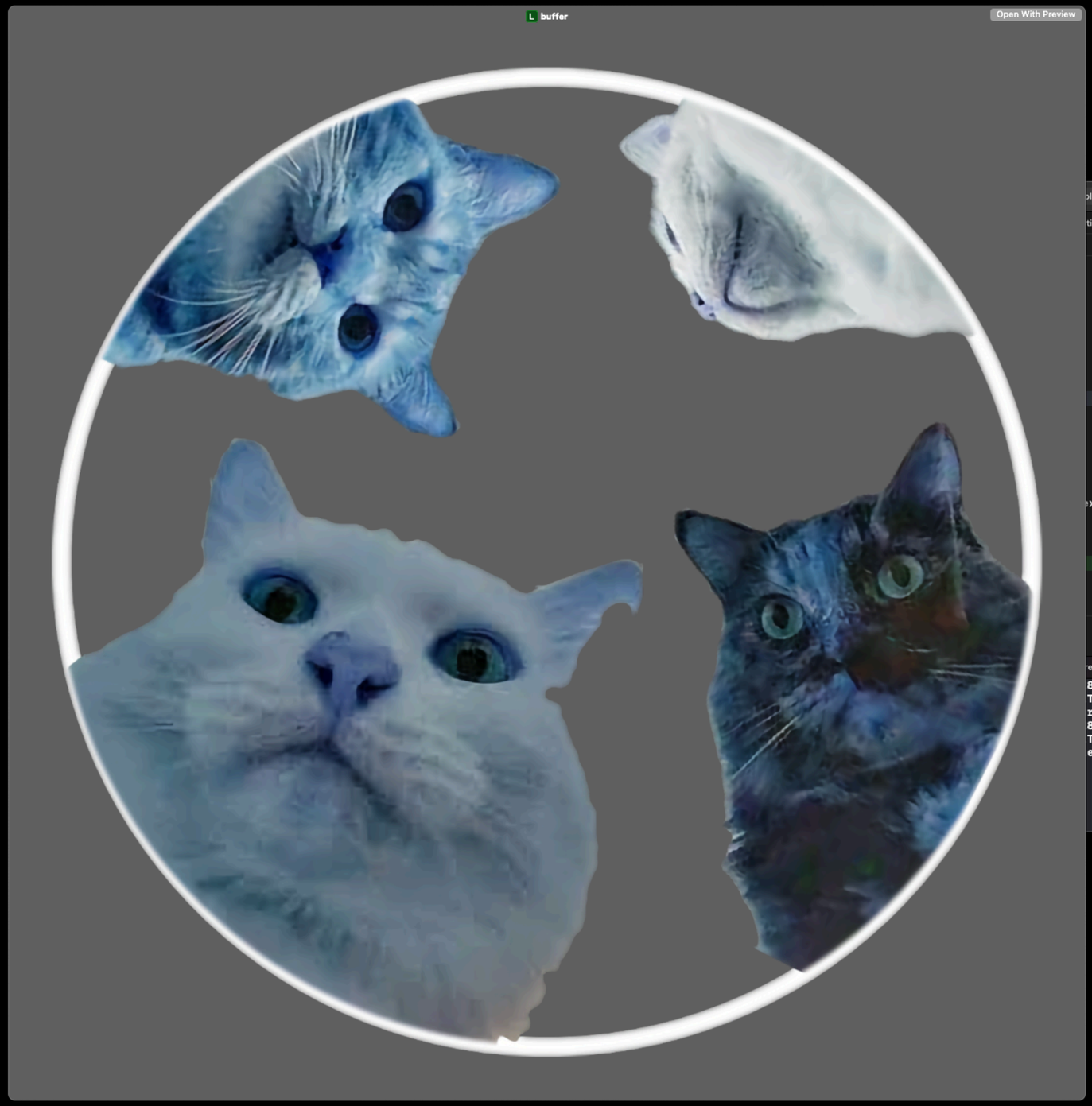
Preview MTLTexture in XCode


_texture
Open With Preview
's iPhone
Running MetalToolsDemo on George's iPhone
MetalUtils.m
Renderer00.h
MetalUtils.h
-drawInMTKView:
0 matches
Aa
Contains
Done
derWithDescriptor:renderPassDescriptor];
_pipelineRender];
Vertices offset:0 atIndex:0];
Transforms offset:0 atIndex:1];
ength:sizeof(float) atIndex:2];
length:sizeof(float) atIndex:0];
ure atIndex:0];
Thread 1: breakpoint 1.1 (1)
TLPrimitiveTypeTriangle
esh.indices_count
TLIndexTypeUInt16
ufferIndices
nstances];
Metal
Capture
MTLCaptureManager.sharedCaptureManager;
Thread 1
0 -[Renderer00 renderIn:]
22 characters
2021-10-28 08:59:29.509055+1100
MetalToolsDemo[4363:940692] Metal GPU Frame Capture Enabled
2021-10-28 08:59:29.510329+1100
MetalToolsDemo[4363:940692] Metal API Validation Enabled
(lldb)
com.apple.uikit.eventfetch-thread (6)
Thread 7 Queue: com.a...s (concurrent)
_time = (float) 0.0166666675
_texture = (CaptureMTLTexture *) 0x2830a0340
Auto
Filter
All Output

OFF-SCREEN DEBUGGING

Download Buffer/Texture

```
+ (vImage_Buffer)bufferOf:(id<MTLTexture>)texture {
  vImage_Buffer buffer = (vImage_Buffer){
    .data = calloc(texture.width * texture.height, 4),
    .width = texture.width,
    .height = texture.height,
    .rowBytes = texture.width * 4
  };

  [texture getBytes:buffer.data
      bytesPerRow:buffer.rowBytes
       fromRegion:MTLRegionMake2D(0, 0, texture.width, texture.height) mipmapLevel:0];

  return buffer;
}
```



olsDemo on George's iPhone
tils.m
MetalUtils.h
Metal
xture.height)
Thread 1: breakpoint 1.1 (1)
Capture
er00 bufferOf:]
Line: 232 Col: 26
8 09:12:52.822537+1100
ToolsDemo[4417:946123] Metal GPU Frame
re Enabled
8 09:12:52.823249+1100
ToolsDemo[4417:946123] Metal API Validation
ed
Filter

THANK YOU

Questions?

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