NVIDIA SYSTEM PROFILING

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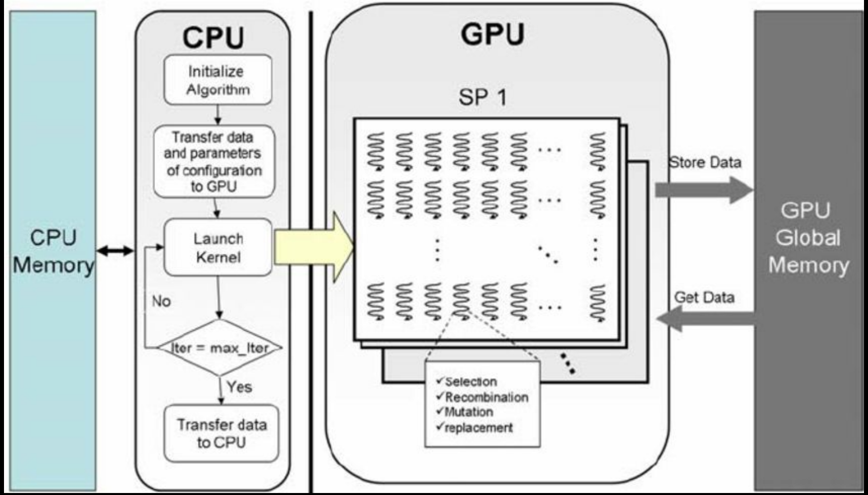
Parallel Pioneers, April 2025

Intro

What is a System?



Stage 1

Transfer data to GPU and allocate device memory

Stage 2

Launch Kernel

Stage 3

CUDA API calls

Stage 4

Repeat until all kernels have executed

Stage 5

Copy all data back to CPU

What is Nsight Systems?

Profiling

A session in which a programmer can collect data about the performance of the application.

Sampling

Collecting the stacks of threads that are active in order to build an understand of the time spent in different kernel functions.

Testing

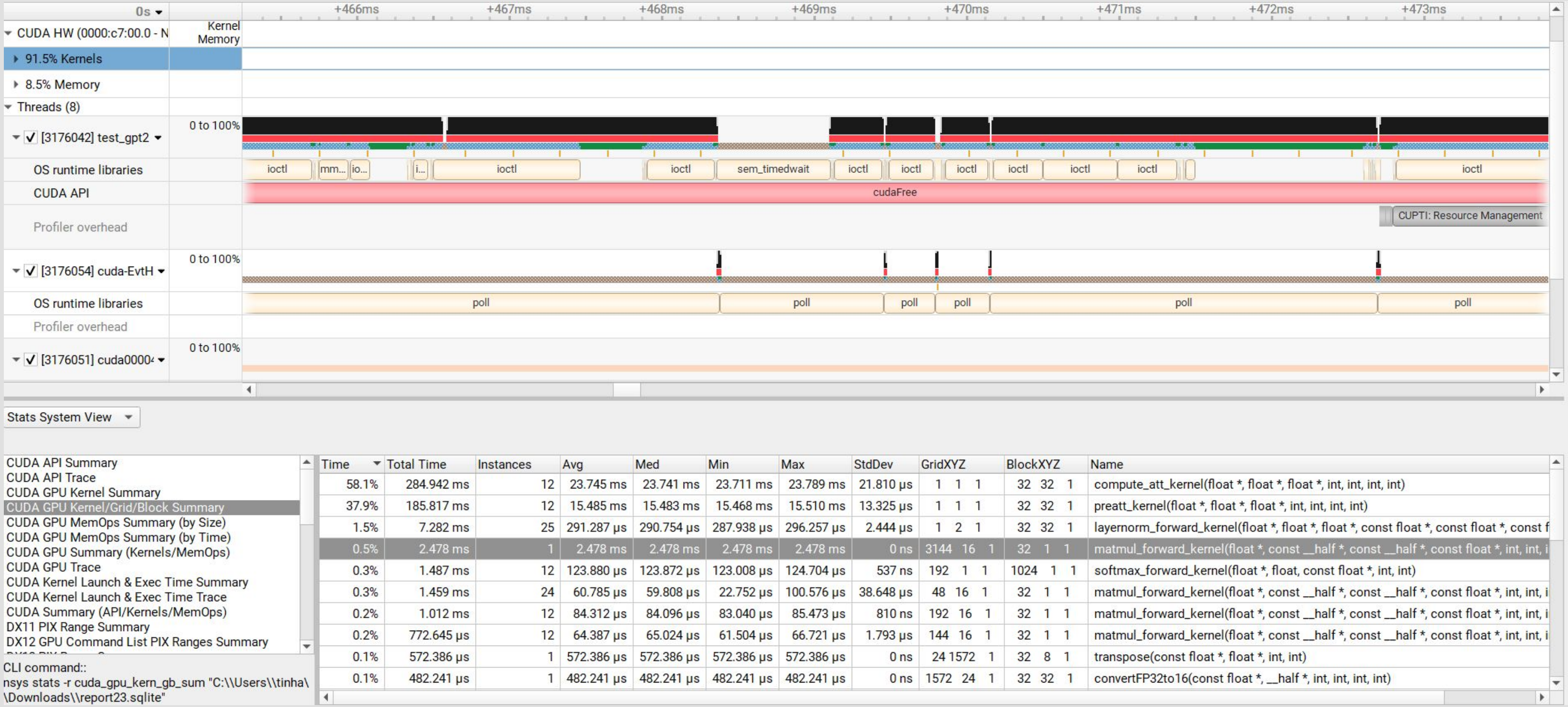
Provides sophisticated information about API functions that have been called and the amount of time spent.

- Overall performance, system level profiling, and analysis
- Shows runtime of Cuda API calls like memcpy and synchronize and kernels
- Helps identify issues across entire systems not just within kernels
- Shows timeline of events

Nsight Systems

- Does GPU kernel level performance analysis
- Allows for more focused profiling of GPU kernels
- Gives detailed metrics of each kernel
- Gives hints of solving bottlenecks

Nsight Compute



CUDA API Summary
CUDA API Trace
CUDA GPU Kernel Summary
CUDA GPU Kernel/Grid/Block Summary
CUDA GPU MemOps Summary (by Size)
CUDA GPU MemOps Summary (by Time)
CUDA GPU Summary (Kernels/MemOps)
CUDA GPU Trace
CUDA Kernel Launch & Exec Time Summary
CUDA Kernel Launch & Exec Time Trace
CUDA Summary (API/Kernels/MemOps)
DX11 PIX Range Summary
DX12 GPU Command List PIX Ranges Summary

CLI command::

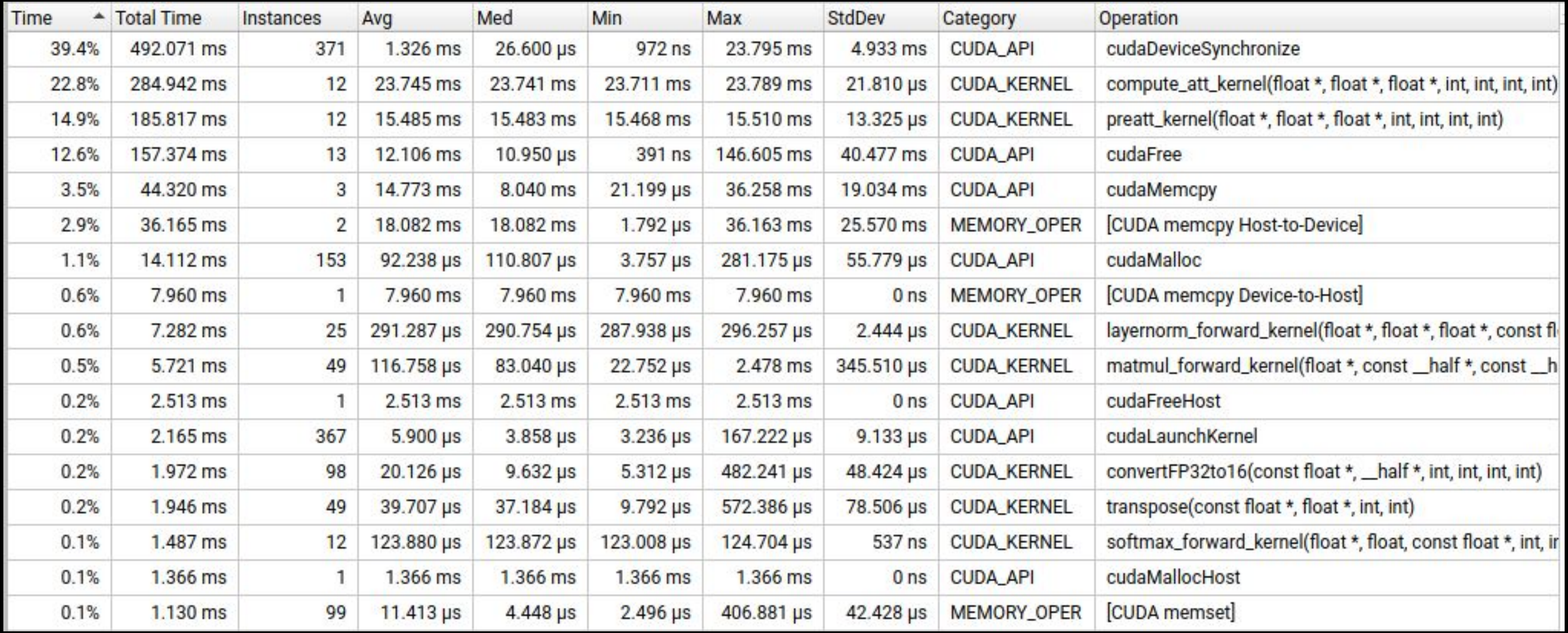
```
nsys stats -r cuda_gpu_kern_gb_sum "C:\\Users\\tinha\
\Downloads\\report23.sqlite"
```

Time	Total Time	Instances	Avg	Med	Min	Max	StdDev	GridXYZ	BlockXYZ	Name
58.1%	284.942 ms	12	23.745 ms	23.741 ms	23.711 ms	23.789 ms	21.810 μs	1 1 1	32 32 1	compute_att_kernel(float *, float *, float *, int, int, int, int)
37.9%	185.817 ms	12	15.485 ms	15.483 ms	15.468 ms	15.510 ms	13.325 μs	1 1 1	32 32 1	preatt_kernel(float *, float *, float *, int, int, int, int)
1.5%	7.282 ms	25	291.287 μs	290.754 μs	287.938 μs	296.257 μs	2.444 μs	1 2 1	32 32 1	layernorm_forward_kernel(float *, float *, float *, const float *, const float *, const f
0.5%	2.478 ms	1	2.478 ms	2.478 ms	2.478 ms	2.478 ms	0 ns	3144 16 1	32 1 1	matmul_forward_kernel(float *, const __half *, const __half *, const float *, int, int, i
0.3%	1.487 ms	12	123.880 μs	123.872 μs	123.008 μs	124.704 μs	537 ns	192 1 1	1024 1 1	softmax_forward_kernel(float *, float, const float *, int, int)
0.3%	1.459 ms	24	60.785 μs	59.808 μs	22.752 μs	100.576 μs	38.648 μs	48 16 1	32 1 1	matmul_forward_kernel(float *, const __half *, const __half *, const float *, int, int, i
0.2%	1.012 ms	12	84.312 μs	84.096 μs	83.040 μs	85.473 μs	810 ns	192 16 1	32 1 1	matmul_forward_kernel(float *, const __half *, const __half *, const float *, int, int, i
0.2%	772.645 μs	12	64.387 μs	65.024 μs	61.504 μs	66.721 μs	1.793 μs	144 16 1	32 1 1	matmul_forward_kernel(float *, const __half *, const __half *, const float *, int, int, i
0.1%	572.386 μs	1	572.386 μs	572.386 μs	572.386 μs	572.386 μs	0 ns	24 1572 1	32 8 1	transpose(const float *, float *, int, int)
0.1%	482.241 μs	1	482.241 μs	482.241 μs	482.241 μs	482.241 μs	0 ns	1572 24 1	32 32 1	convertFP32to16(const float *, __half *, int, int, int, int)

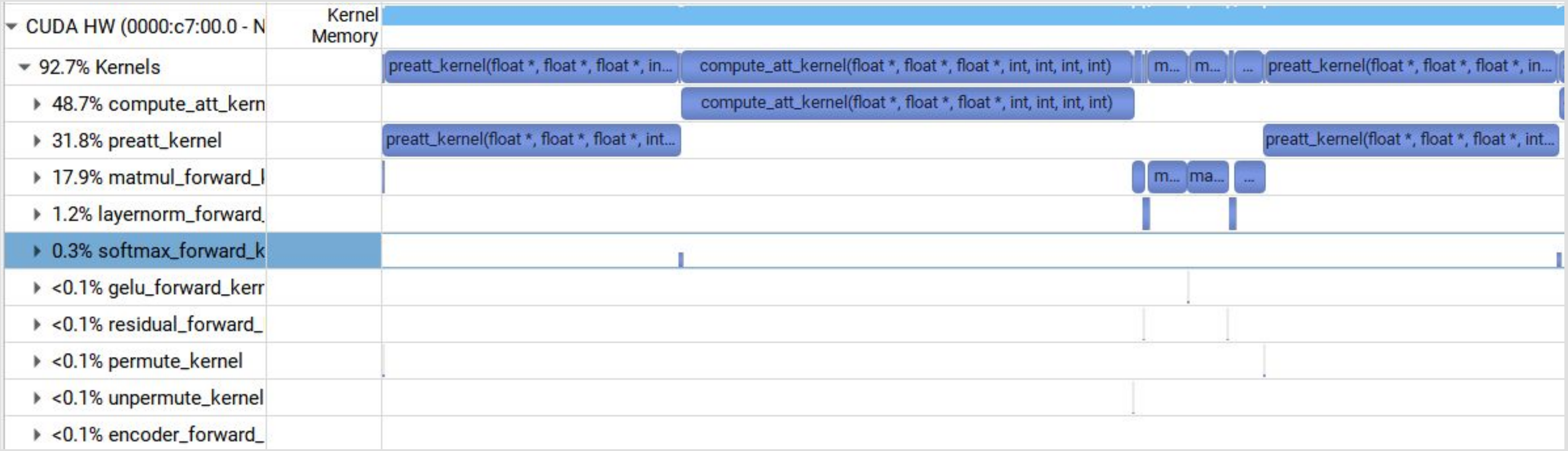
Application Overview

Examples from GPT-2

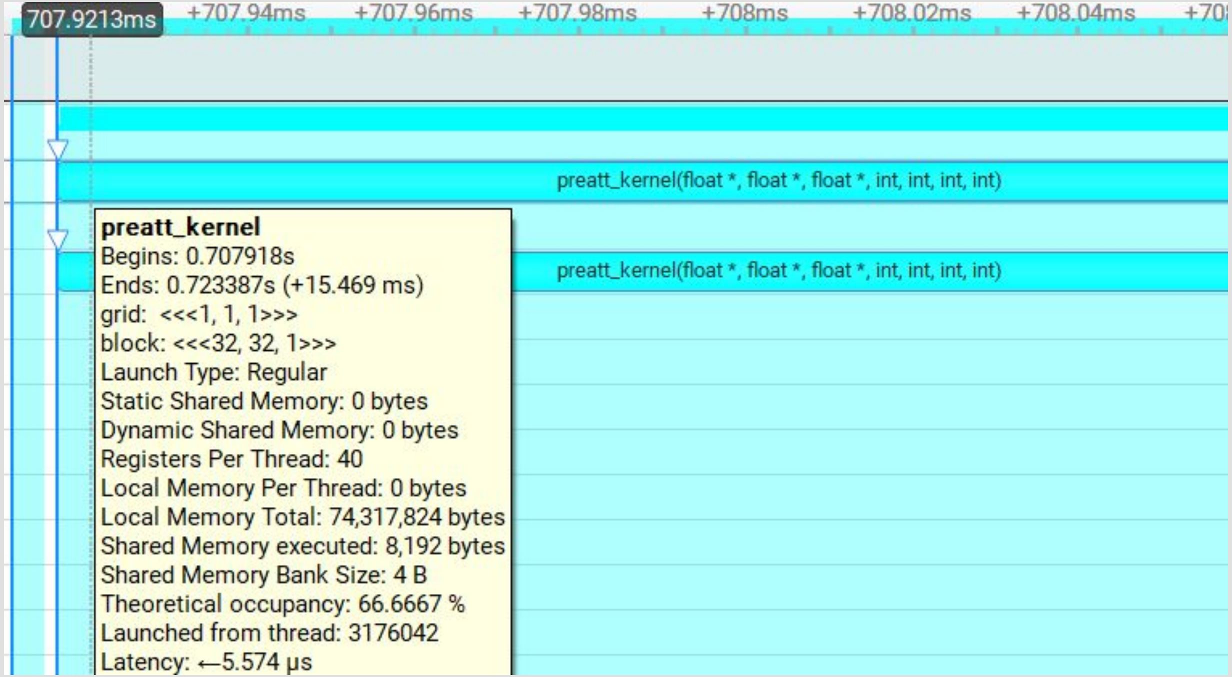
Before M3 optimizations



Time ▲	Total Time	Instances	Avg	Med	Min	Max	StdDev	Category	Operation
39.4%	492.071 ms	371	1.326 ms	26.600 μs	972 ns	23.795 ms	4.933 ms	CUDA_API	cudaDeviceSynchronize
22.8%	284.942 ms	12	23.745 ms	23.741 ms	23.711 ms	23.789 ms	21.810 μs	CUDA_KERNEL	compute_att_kernel(float *, float *, float *, int, int, int, int)
14.9%	185.817 ms	12	15.485 ms	15.483 ms	15.468 ms	15.510 ms	13.325 μs	CUDA_KERNEL	preatt_kernel(float *, float *, float *, int, int, int, int)
12.6%	157.374 ms	13	12.106 ms	10.950 μs	391 ns	146.605 ms	40.477 ms	CUDA_API	cudaFree
3.5%	44.320 ms	3	14.773 ms	8.040 ms	21.199 μs	36.258 ms	19.034 ms	CUDA_API	cudaMemcpy
2.9%	36.165 ms	2	18.082 ms	18.082 ms	1.792 μs	36.163 ms	25.570 ms	MEMORY_OPER	[CUDA memcpy Host-to-Device]
1.1%	14.112 ms	153	92.238 μs	110.807 μs	3.757 μs	281.175 μs	55.779 μs	CUDA_API	cudaMalloc
0.6%	7.960 ms	1	7.960 ms	7.960 ms	7.960 ms	7.960 ms	0 ns	MEMORY_OPER	[CUDA memcpy Device-to-Host]
0.6%	7.282 ms	25	291.287 μs	290.754 μs	287.938 μs	296.257 μs	2.444 μs	CUDA_KERNEL	layernorm_forward_kernel(float *, float *, float *, const fl
0.5%	5.721 ms	49	116.758 μs	83.040 μs	22.752 μs	2.478 ms	345.510 μs	CUDA_KERNEL	matmul_forward_kernel(float *, const __half *, const __h
0.2%	2.513 ms	1	2.513 ms	2.513 ms	2.513 ms	2.513 ms	0 ns	CUDA_API	cudaFreeHost
0.2%	2.165 ms	367	5.900 μs	3.858 μs	3.236 μs	167.222 μs	9.133 μs	CUDA_API	cudaLaunchKernel
0.2%	1.972 ms	98	20.126 μs	9.632 μs	5.312 μs	482.241 μs	48.424 μs	CUDA_KERNEL	convertFP32to16(const float *, __half *, int, int, int, int)
0.2%	1.946 ms	49	39.707 μs	37.184 μs	9.792 μs	572.386 μs	78.506 μs	CUDA_KERNEL	transpose(const float *, float *, int, int)
0.1%	1.487 ms	12	123.880 μs	123.872 μs	123.008 μs	124.704 μs	537 ns	CUDA_KERNEL	softmax_forward_kernel(float *, float, const float *, int, i
0.1%	1.366 ms	1	1.366 ms	1.366 ms	1.366 ms	1.366 ms	0 ns	CUDA_API	cudaMallocHost
0.1%	1.130 ms	99	11.413 μs	4.448 μs	2.496 μs	406.881 μs	42.428 μs	MEMORY_OPER	[CUDA memset]

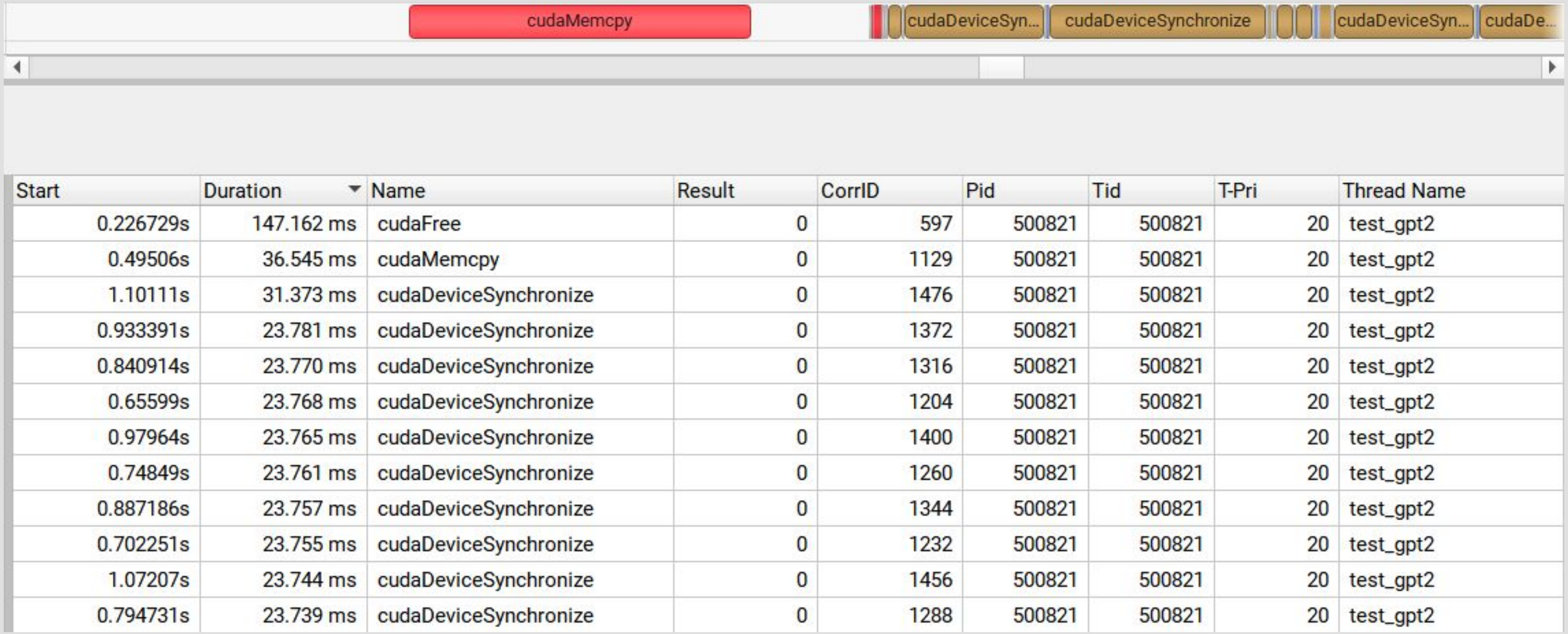

CUDA HW (0000:c7:00.0 - N
Kernel
Memory
92.7% Kernels
48.7% compute_att_kern
31.8% preatt_kernel
17.9% matmul_forward_l
1.2% layernorm_forward
0.3% softmax_forward_k
<0.1% gelu_forward_kerr
<0.1% residual_forward_
<0.1% permute_kernel
<0.1% unpermute_kernel
<0.1% encoder_forward_
preatt_kernel(float *, float *, float *, in...
compute_att_kernel(float *, float *, float *, int, int, int, int)
m...
m...
...
preatt_kernel(float *, float *, float *, in...
compute_att_kernel(float *, float *, float *, int, int, int, int)
preatt_kernel(float *, float *, float *, int...
preatt_kernel(float *, float *, float *, int...
m...
ma...
...

Overall Kernel Runtimes


707.9213ms
+707.94ms
+707.96ms
+707.98ms
+708ms
+708.02ms
+708.04ms
+70
preatt_kernel(float *, float *, float *, int, int, int, int)
preatt_kernel(float *, float *, float *, int, int, int, int)

```
preatt_kernel
Begins: 0.707918s
Ends: 0.723387s (+15.469 ms)
grid:  <<<1, 1, 1>>>
block: <<<32, 32, 1>>>
Launch Type: Regular
Static Shared Memory: 0 bytes
Dynamic Shared Memory: 0 bytes
Registers Per Thread: 40
Local Memory Per Thread: 0 bytes
Local Memory Total: 74,317,824 bytes
Shared Memory executed: 8,192 bytes
Shared Memory Bank Size: 4 B
Theoretical occupancy: 66.6667 %
Launched from thread: 3176042
Latency: ←5.574 µs
```

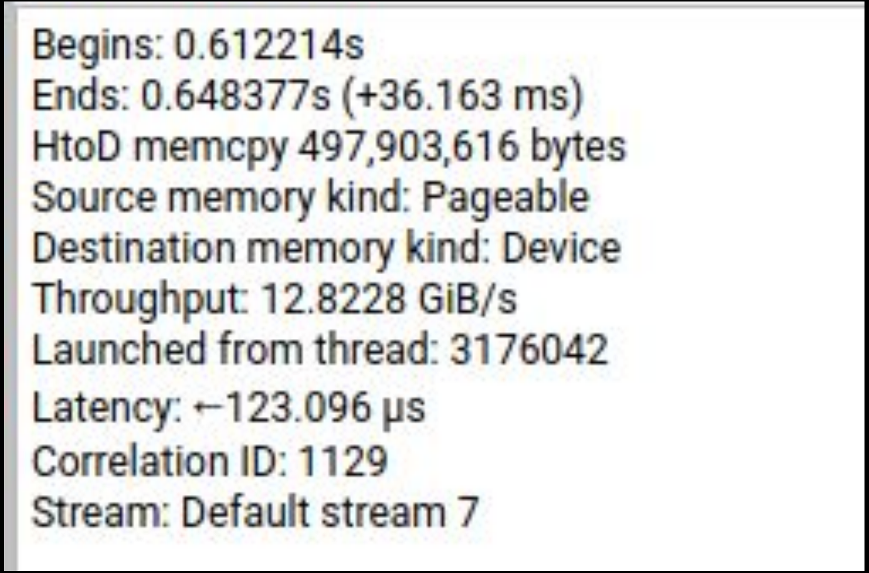
Individual Kernel Breakdown



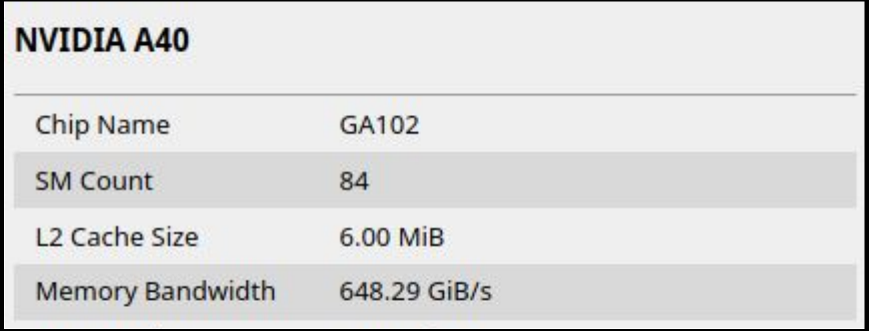
Start	Duration	Name	Result	CorrID	Pid	Tid	T-Pri	Thread Name
0.226729s	147.162 ms	cudaFree	0	597	500821	500821	20	test_gpt2
0.49506s	36.545 ms	cudaMemcpy	0	1129	500821	500821	20	test_gpt2
1.10111s	31.373 ms	cudaDeviceSynchronize	0	1476	500821	500821	20	test_gpt2
0.933391s	23.781 ms	cudaDeviceSynchronize	0	1372	500821	500821	20	test_gpt2
0.840914s	23.770 ms	cudaDeviceSynchronize	0	1316	500821	500821	20	test_gpt2
0.65599s	23.768 ms	cudaDeviceSynchronize	0	1204	500821	500821	20	test_gpt2
0.97964s	23.765 ms	cudaDeviceSynchronize	0	1400	500821	500821	20	test_gpt2
0.74849s	23.761 ms	cudaDeviceSynchronize	0	1260	500821	500821	20	test_gpt2
0.887186s	23.757 ms	cudaDeviceSynchronize	0	1344	500821	500821	20	test_gpt2
0.702251s	23.755 ms	cudaDeviceSynchronize	0	1232	500821	500821	20	test_gpt2
1.07207s	23.744 ms	cudaDeviceSynchronize	0	1456	500821	500821	20	test_gpt2
0.794731s	23.739 ms	cudaDeviceSynchronize	0	1288	500821	500821	20	test_gpt2

CUDA API Call Durations

memory metrics

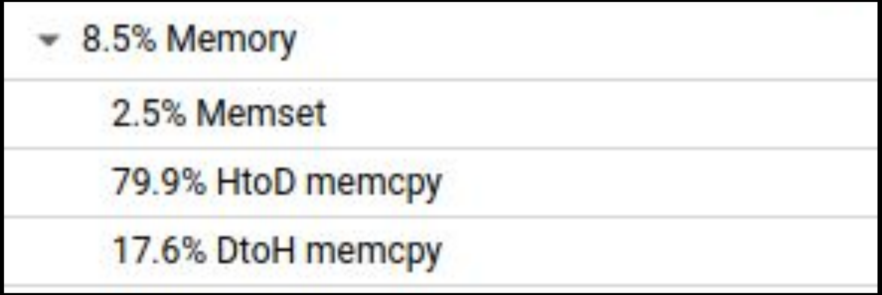


```
Begins: 0.612214s
Ends: 0.648377s (+36.163 ms)
HtoD memcpy 497,903,616 bytes
Source memory kind: Pageable
Destination memory kind: Device
Throughput: 12.8228 GiB/s
Launched from thread: 3176042
Latency: ←123.096 µs
Correlation ID: 1129
Stream: Default stream 7
```



NVIDIA A40

Chip Name	GA102
SM Count	84
L2 Cache Size	6.00 MiB
Memory Bandwidth	648.29 GiB/s



- 8.5% Memory
  - 2.5% Memset
  - 79.9% HtoD memcpy
  - 17.6% DtoH memcpy

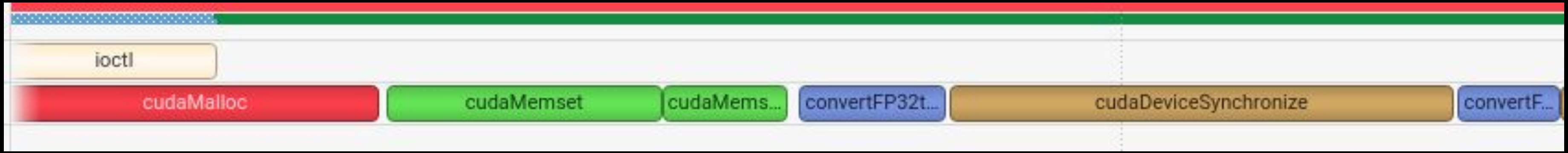
Suspicious Tensor Core Conversions

cudaMalloc 1: 4 microseconds

cudaMalloc 2: 111 microseconds

FP32to16 call 1: 5 microseconds

FP32to16 call 2: 31 microseconds



Solution: Overlapping!

```
cudaMallocAsync 2 //use a stream
cudaMalloc 1
FP32to16 call 1
Synchronize
FP32to16 call 2
```

Questions?

Nsight Compute:
https://developer.nvidia.com/tools-overview/nsight-compute/get-started