Offloading Computation to a GPU with OpenMP

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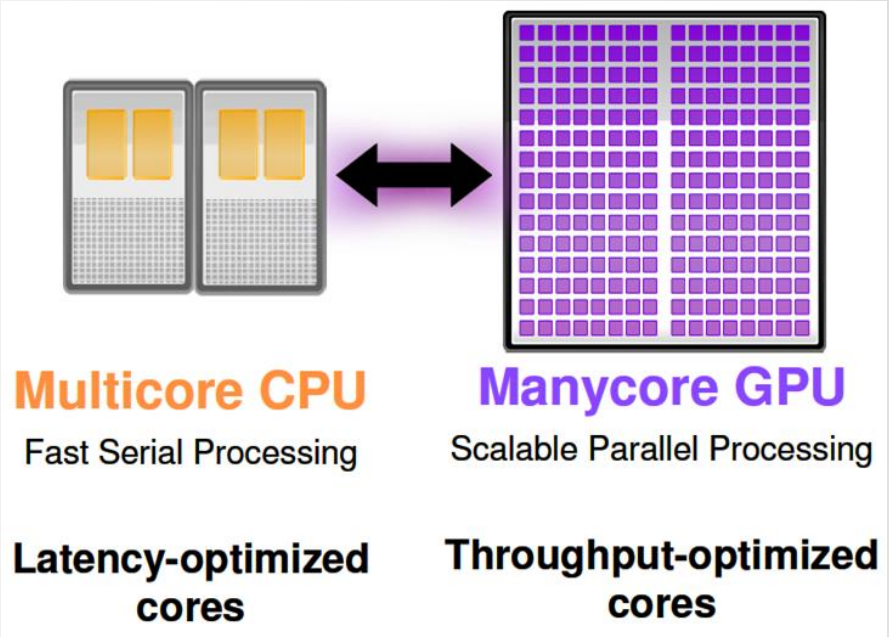
CPUs and GPUs

CPU Threads:

- Heavyweight entities managed by the operating system.
- Context switching saves and restores thread states, and this process can be slow and resource-intensive.
- CPU cores are optimized for minimizing latency for one or two threads at a time.



https://tatourian.blog/2013/09/03/nvidia-gpu-architecture-cuda-programming-environment/

CPUs and GPUs

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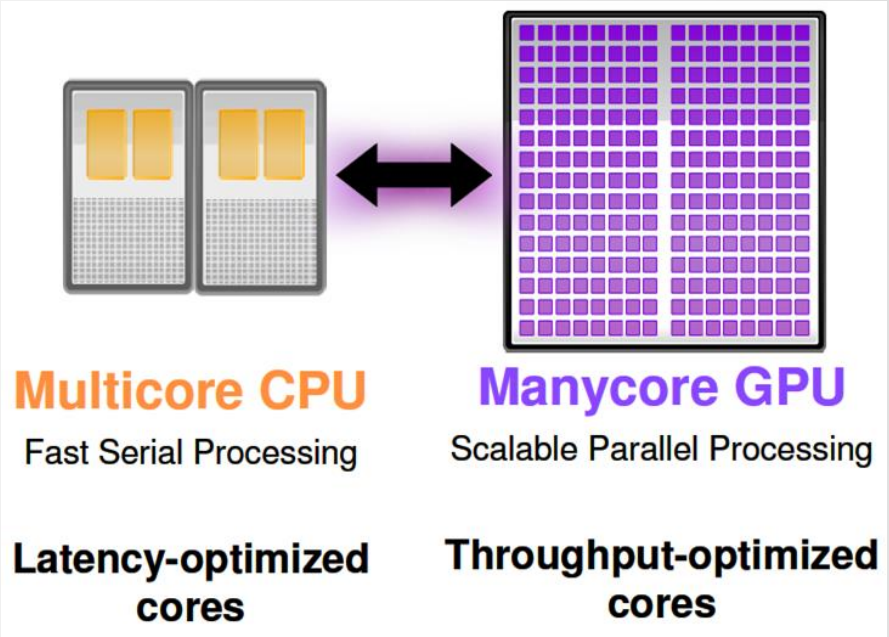
GPU Threads:

- Lightweight and designed for massive parallelism.
- Hundreds of thousands of threads are grouped into warps of 32 threads each.
- Seamless switching between warps when one is waiting, without saving or restoring thread states.
- Each thread has dedicated registers and resources, which remain allocated until execution completes.



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GPU Architecture: Overview

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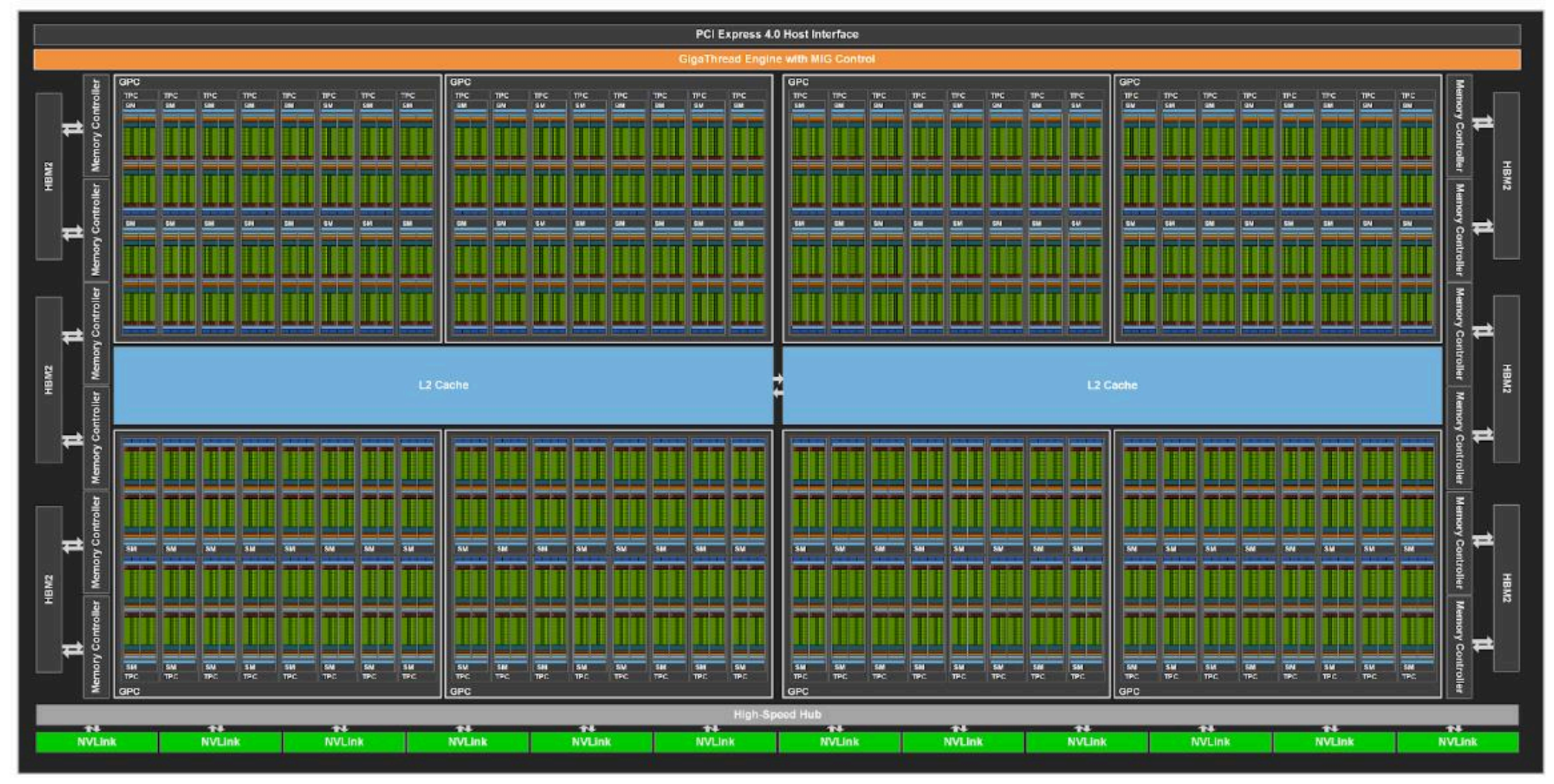

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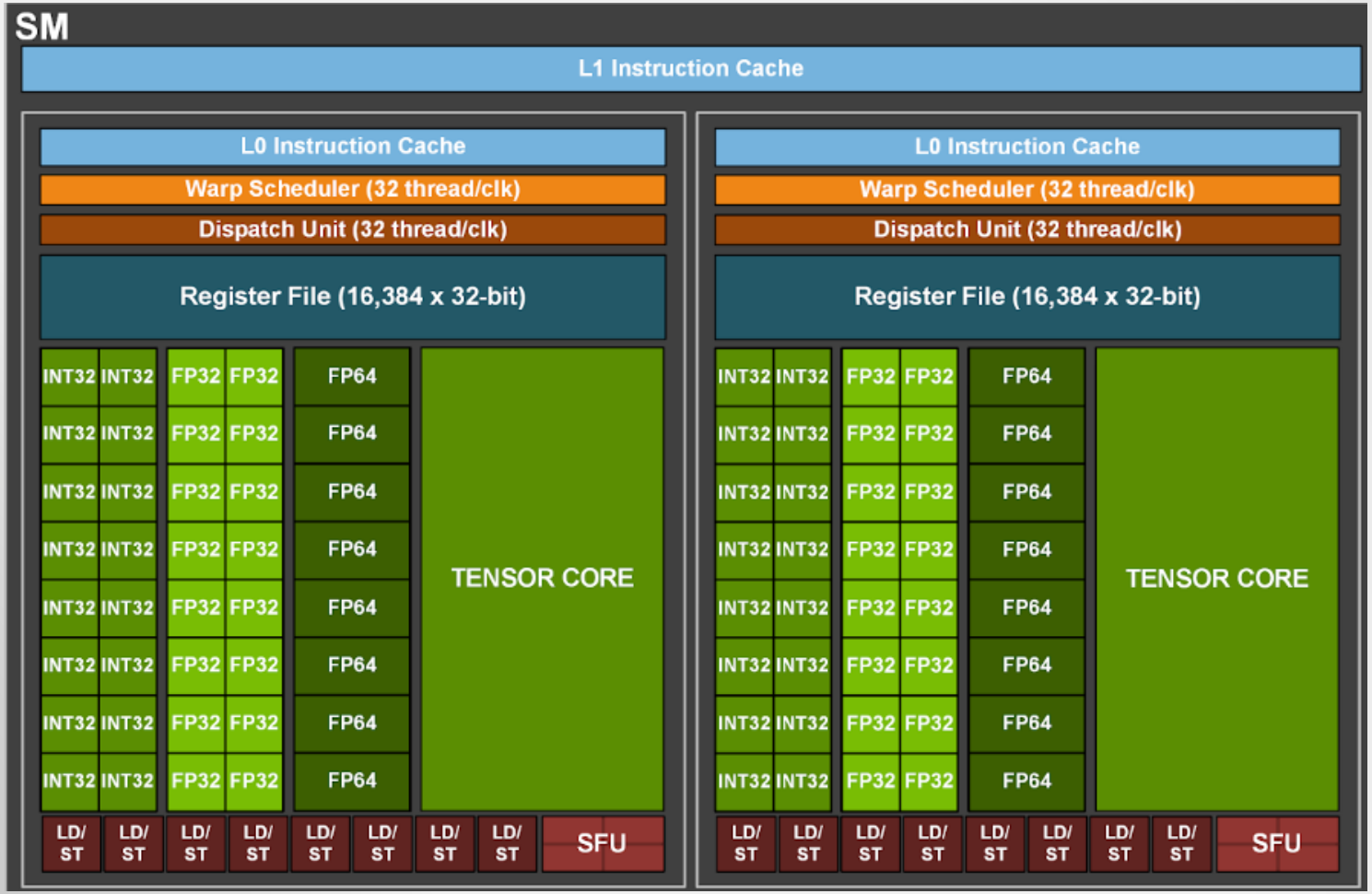
GPU Architecture: Overview



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Programming GPUs: Benefits

High Parallelism: GPUs can execute thousands of threads simultaneously.
High Throughput: Optimized for tasks involving massive data parallelism.
Applications:

- Graphics rendering
- Machine learning
- Scientific simulations

Example: Computing Pi

$$\pi = 4 \int_0^1 \sqrt{1 - x^2}\, dx$$

Numerical Approximation

To compute this integral numerically:

1. Divide the interval $[0, 1]$ into N small intervals of width Δx.

$$\Delta x = \frac{1}{N}$$

2. Approximate the integral using the midpoint rule:

$$\pi \approx 4 \cdot \Delta x \sum_{i=0}^{N-1} \sqrt{1 - (x_i)^2}$$

where:

$$x_i = (i + 0.5) \cdot \Delta x$$

Example: Computing Pi with CUDA

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```
__global__ void integrate_pi(double *d_results, int num_intervals, double step) {
    int idx = blockIdx.x * blockDim.x + threadIdx.x;
    double x, local_sum = 0.0;

    for (int i = idx; i < num_intervals; i += gridDim.x * blockDim.x) {
        x = (i + 0.5) * step;
        local_sum += sqrt(1.0 - x * x) * step;
    }

    d_results[idx] = local_sum;
}
```

Each thread executes this code

ID of the current thread (differentiates the execution from those of other threads"

$$\pi \approx 4 \cdot \Delta x \sum_{i=0}^{N-1} \sqrt{1-(x_i)^2}$$

```
// Launch the kernel
integrate_pi<<<NUM_BLOCKS, THREADS_PER_BLOCK>>>(d_results, num_intervals, step);
```

Kernel launch

Example: Computing Pi with CUDA

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- **Let's work on this CUDA code.**

Thanks

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