CE/CZ 3001:
Advanced Computer Architecture

Module 6: GPU Architecture and CUDA Programming

- GPU architecture and CUDA programming

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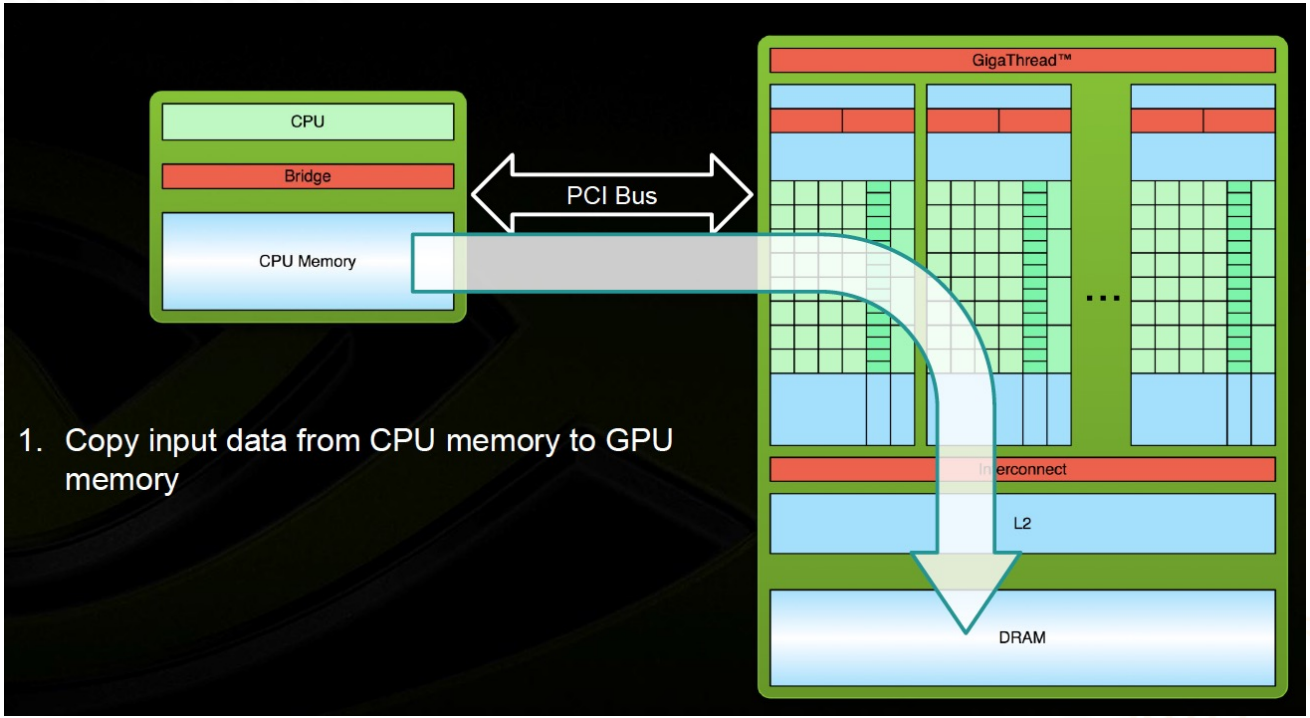
Summary

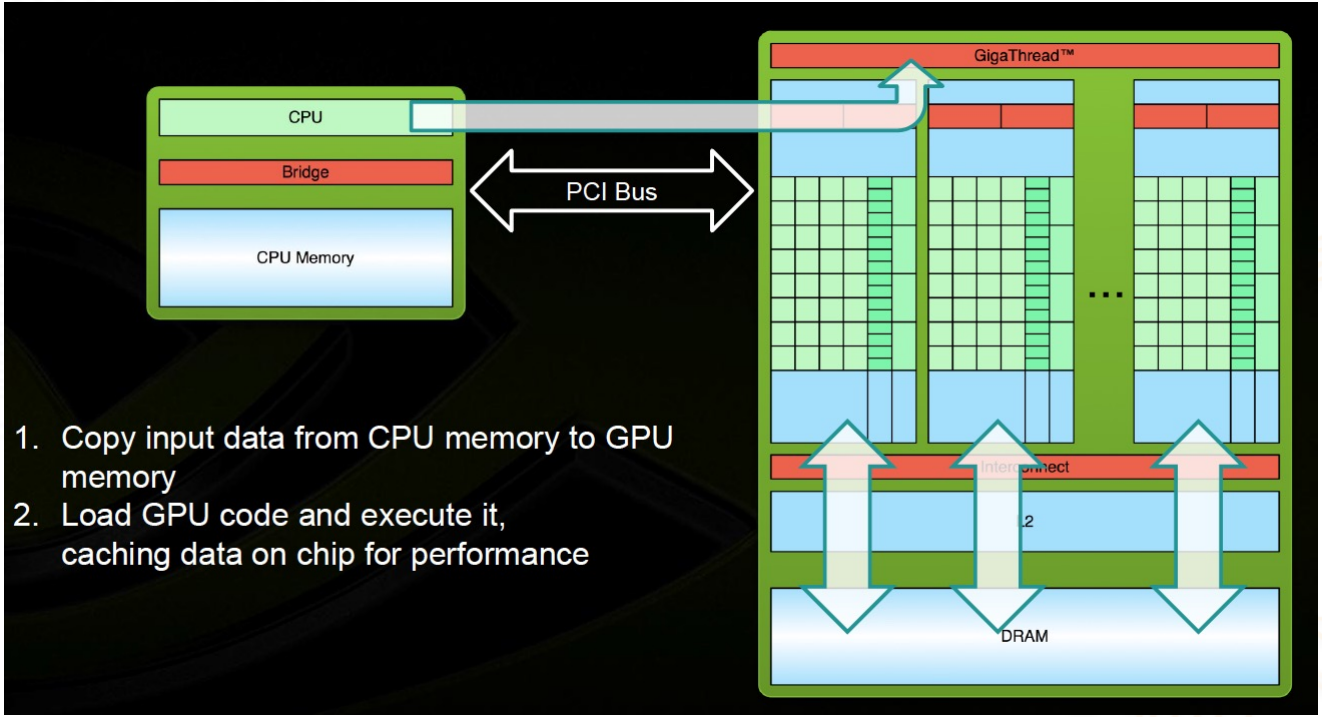
- Basic GPU architectures
- Kernels, threads and thread blocks
- Sync and memory management between host and device
- Data sharing and sync between threads

Simple Processing Flow of Heterogeneous Computing (1)



Acknowledgement: CUDA C/C++ Basics at Nvidia.com

Simple Processing Flow of Heterogeneous Computing (2)



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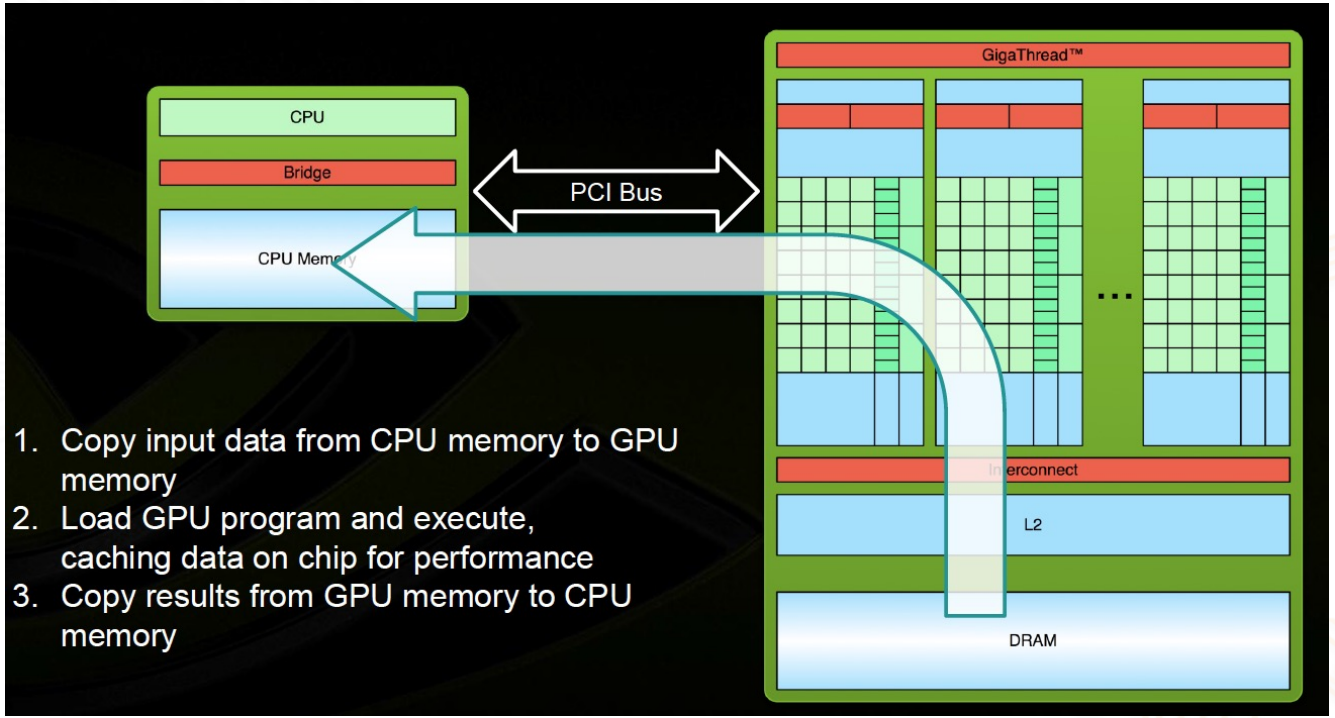
Simple Processing Flow of Heterogeneous Computing (3)



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CUDA programming basics (1)

- Difference between host and device
  - Host CPU
  - Device GPU
- Using __global__ to declare a function as device code
  - Executes on the device
  - Called from the host
- Passing parameters from host code to a device function
- Basic device memory management
  - cudaMalloc()
  - cudaMemcpy()
  - cudaFree()

CUDA programming basics (2)

- Launching parallel threads
  - Launch N blocks with M threads per block with kernel<<<N,M>>>(…);
  - Use blockIdx.x to access block index within grid
  - Use threadIdx.x to access thread index within block

- Allocate elements to threads:
  - int index = threadIdx.x + blockIdx.x * blockDim.x;

- Use __shared__ to declare a variable/array in shared memory
  - Data is shared between threads in a block
  - Not visible to threads in other blocks

- Use __syncthreads() as a barrier
  - Use to prevent data hazards

Excise 1

Which of the following are design philosophies in GPU architecture?

(1) GPUs use massive parallelism to hide stalls

(2) GPUs have many low-latency execution units

(3) GPUs spread the cost of managing an instruction stream across many ALUs

(A) 1 and 2

(B) 1 and 3

(C) 2 and 3

(D) all of the above

Excise 2

If we want to allocate an array of float in the GPU global memory and have the pointer variable device_array to point to the array, what is the correct call to cudamalloc() on the host side?

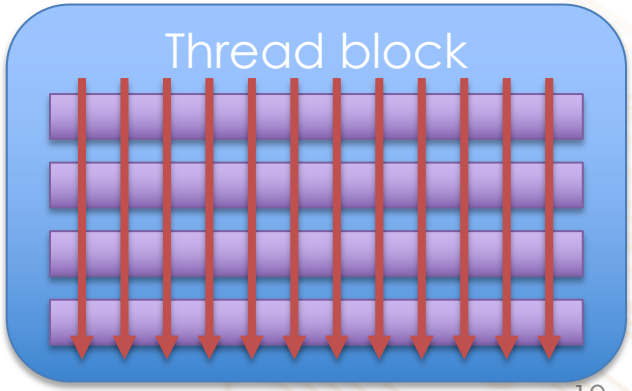
```
// pointers to host & device arrays
float *device_array;
int size = num_bytes * sizeof(float);
```

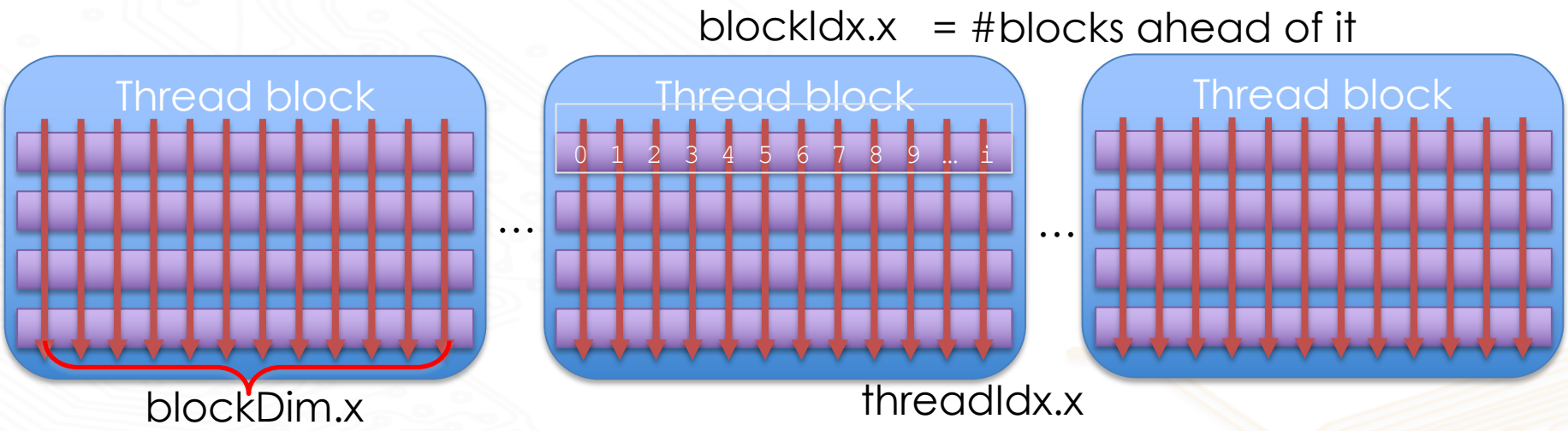
(A) cudaMalloc(device_array, size);
(B) cudaMalloc((void *)device_array, size);
(C) cudaMalloc((void *)&device_array, size);
(D) cudaMalloc((void **)&device_array, size);

Excise 3

We want to use each thread to calculate four output elements of a vector addition. Each thread block processes four sections. All threads in each block will first process a section first, each processing one element. They will then all move to the next section, with each thread processing one more element. This repeats until all four sections are processed. Assume that variable i should be the index for the first element to be processed by a thread. What would be the expression for mapping the thread/block indices to data index of the first element?

(A) i=blockIdx.x*blockDim.x*4 + threadIdx.x;
(B) i=blockIdx.x*threadIdx.x*2;
(C) i=(blockIdx.x*blockDim.x + threadIdx.x)*4;
(D) i=blockIdx.x*blockDim.x*2 + threadIdx.x;






```
Index i for the 1st section/row:
                  i = blockIdx.x*blockDim.x*4 + threadIdx.x;

Index i for the 2nd section/row:
                  i = blockIdx.x*blockDim.x*4 + blockDim.x + threadIdx.x;
Index i for the 3rd section/row:
                  i = blockIdx.x*blockDim.x*4 + blockDim.x*2 + threadIdx.x;
Index i for the 4th section/row:
                  i = blockIdx.x*blockDim.x*4 + blockDim.x*3 + threadIdx.x;

Index i for the 1st section/row of the next block (blockIdx.x increased by 1):
                  i = blockIdx.x*blockDim.x*4 + threadIdx.x;
```

Excise 4

Can we put __syncthreads() in the if-statement as follows?

```
if (t < BLOCK_SIZE / stride) {
    __syncthreads();
    partialSum[t*stride*2] += partialSum[t*stride*2+stride];
}
```

No. Because if there exists control divergence in a warp, the threads which satisfy the if-statement will be in active and wait for the threads which do not satisfy the if-statement forever because these threads are deactivated.

Excise 5

Write some CUDA kernel code in which the threads in the same block transpose the elements of a matrix mat in shared memory in-place. That is, all threads should see that mat[i][j] is swapped with element mat[j][i] after the transposition. You can assume that each block has dimensions dim3(16,16,1). Make your code as efficient in time and space as possible.

```
__shared__ float mat[16][16];

float temp = mat[threadIdx.y][threadIdx.x];
__syncthreads();
mat[threadIdx.x][threadIdx.y] = temp;
__syncthreads();
```