Parallel Computing Workshop

Ms. Kranti Ingale

Prime Minister's Research Fellows (**PMRF**) Scholar

CSE, IIT Madras

Roadmap

- Introduction to GPU
- CUDA Program Flow and CPU-GPU Communication
- Thread organization (Grids, Blocks, Threads, 1D/2D)
- CUDA Memory Model
- CUDA Functions
- CUDA Thrust

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Thread organization (Grids, Blocks, Threads)

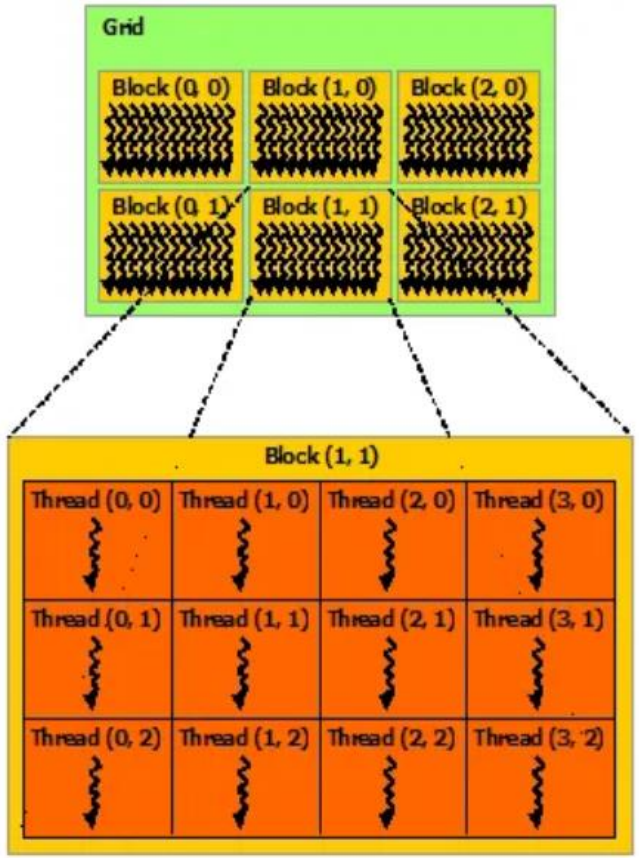
- A kernel (GPU function) is launched as a collection of thread blocks called **Grid**.
- Grid size is defined using the number of blocks.
- For eg. Grid of size 8 contains 8 thread blocks.

Thread organization (Grids, Blocks, Threads)

- **Block** : A thread-block is a 3D array of threads.

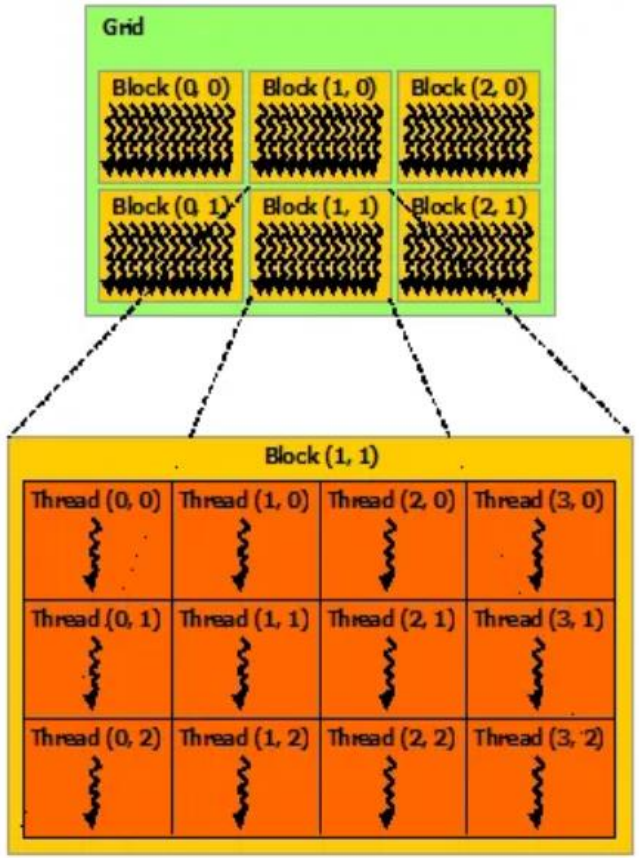
- **Thread :** Single execution unit that runs GPU function (kernel) on GPU.

Standard Variables



- **Dimension of Grid (Number of blocks in the grid)**

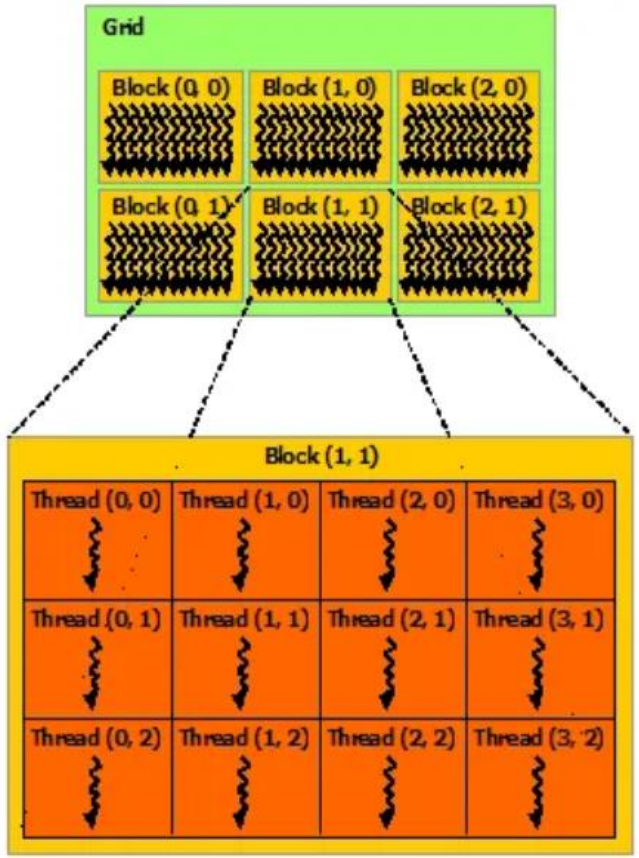
Standard Variables



- **Dimension of Grid (Number of blocks in the grid)**

  gridDim.x : number of blocks in the x dimension of the grid

Standard Variables

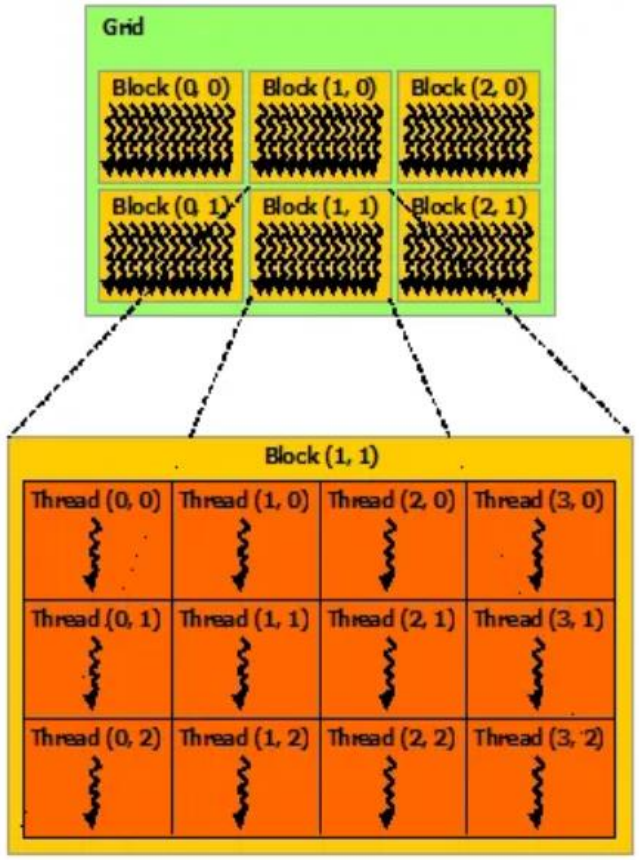


- **Dimension of Grid (Number of blocks in the grid)**

  gridDim.x : number of blocks in the x dimension of the grid

  gridDim.y : number of blocks in the y dimension of the grid

Standard Variables



- **Dimension of Grid (Number of blocks in the grid)**

  gridDim.x : number of blocks in the x dimension of the grid

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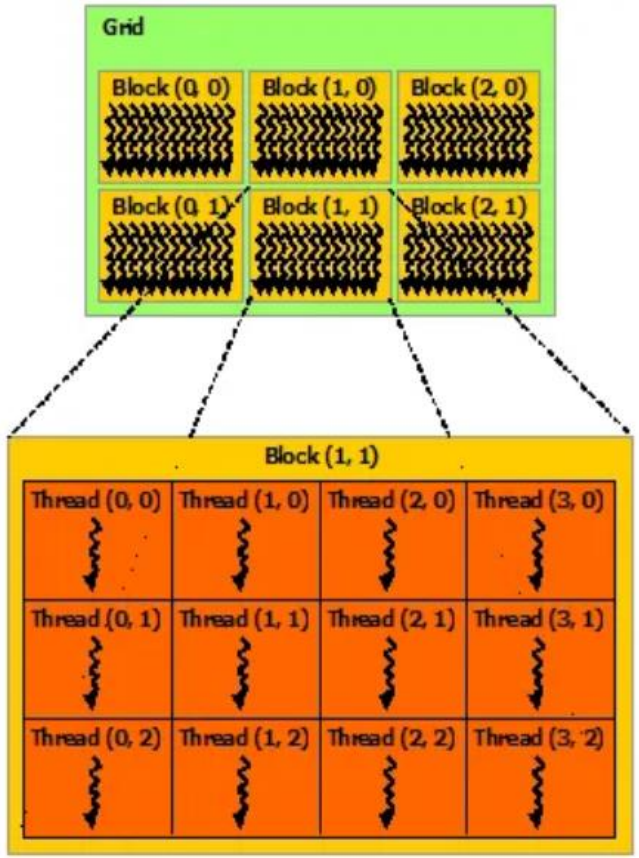
  gridDim.z :number of blocks in the z dimension of the grid

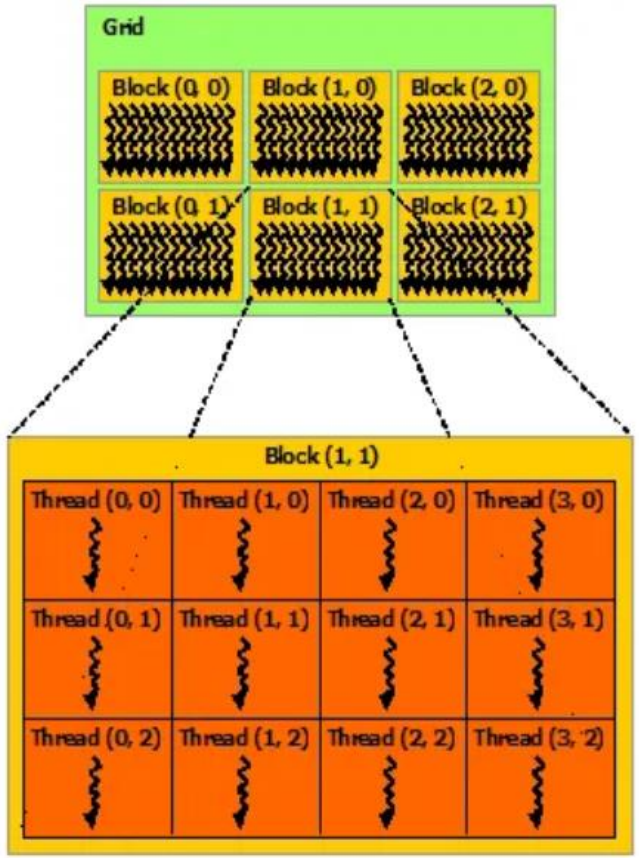
Standard Variables



- **Dimension of block (Number of threads in a block)**

  blockDim.x : number of threads in the x dimension of the block

Standard Variables



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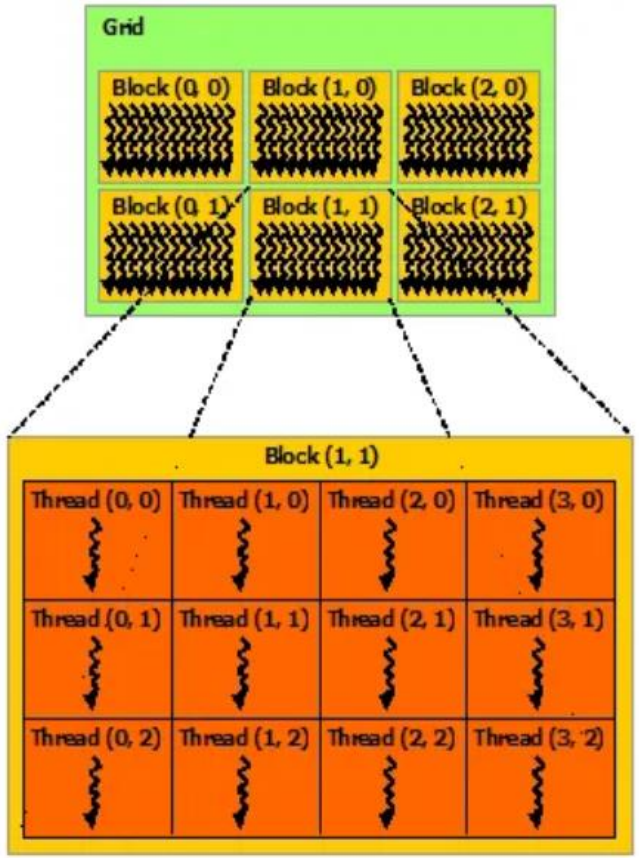

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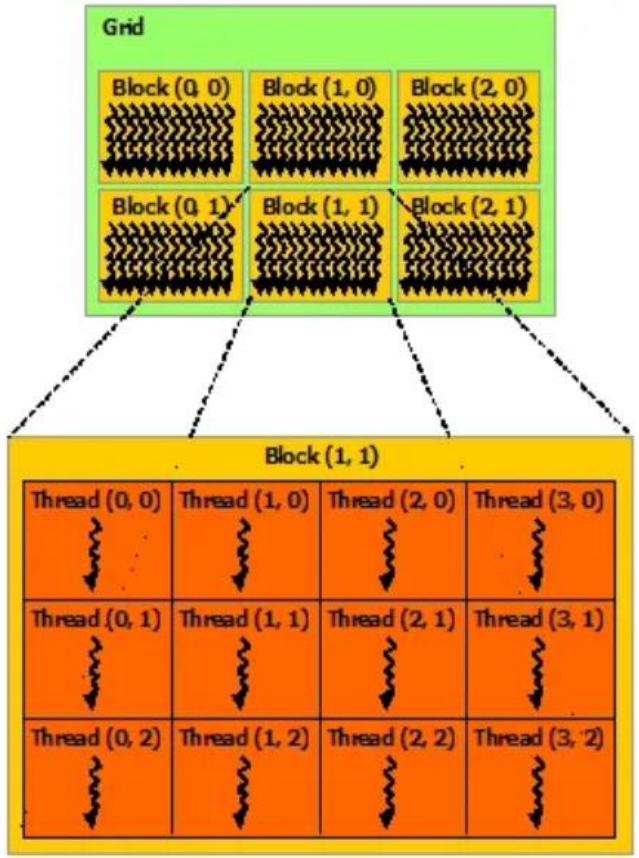
  blockDim.z : number of threads in the z dimension of the block

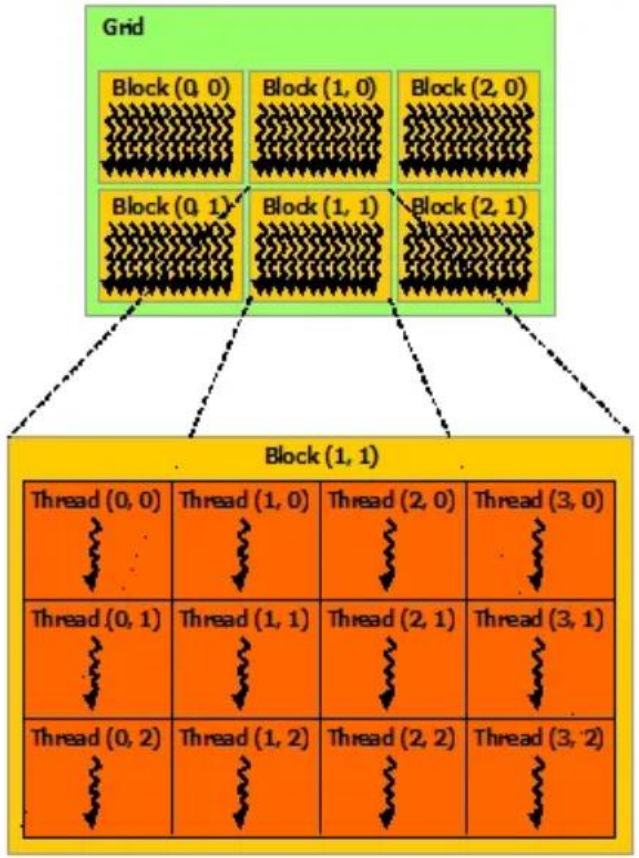
Standard Variables



- **Block Index**

  blockIdx.x : block's index in x dimension

Standard Variables



- **Block Index**

  blockIdx.x : block's index in x dimension

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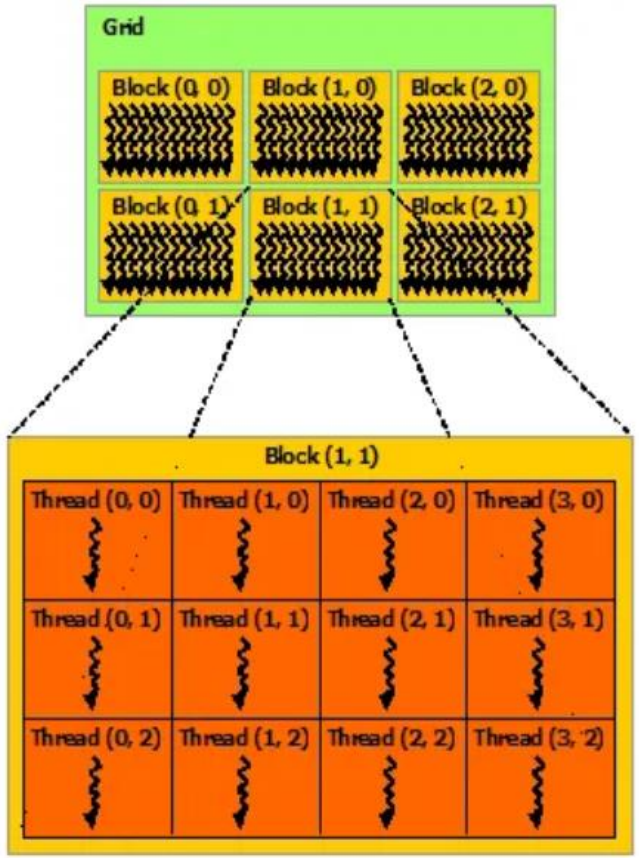

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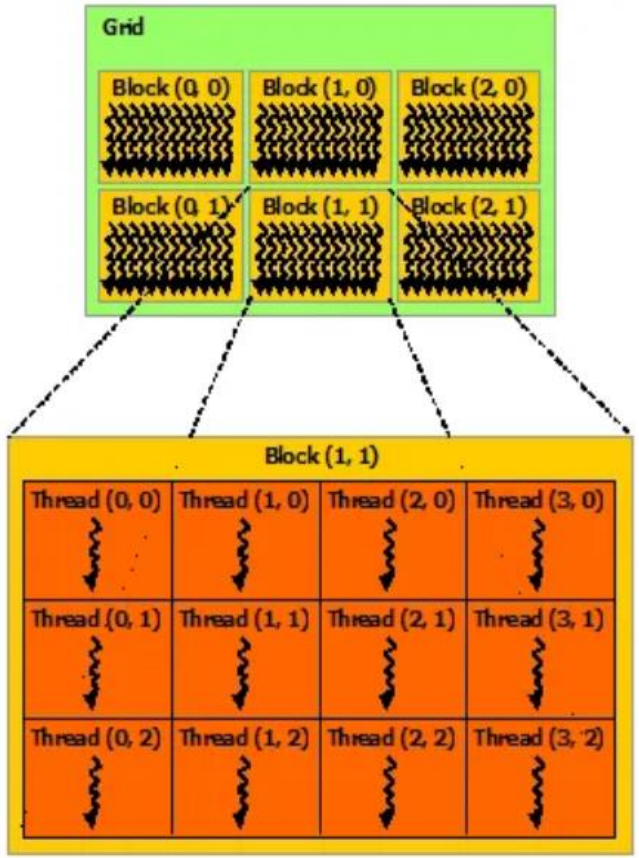
Standard Variables



- **Block Index**

  blockIdx.x : block's index in x dimension

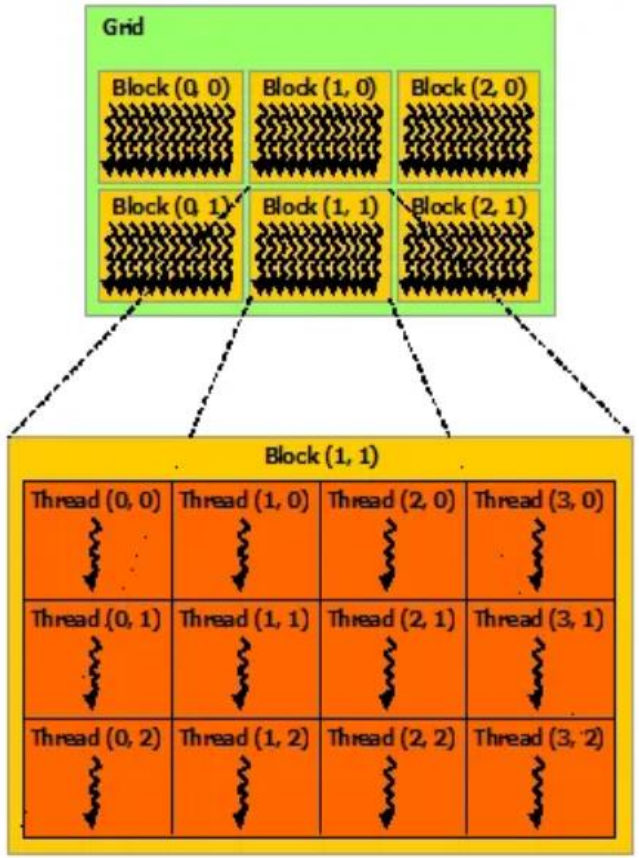
  blockIdx.y : block's index in y dimension

  blockIdx.z : block's index in z dimension

  block (1,0)

  blockIdx.x = 1 , blockIdx.y = 0

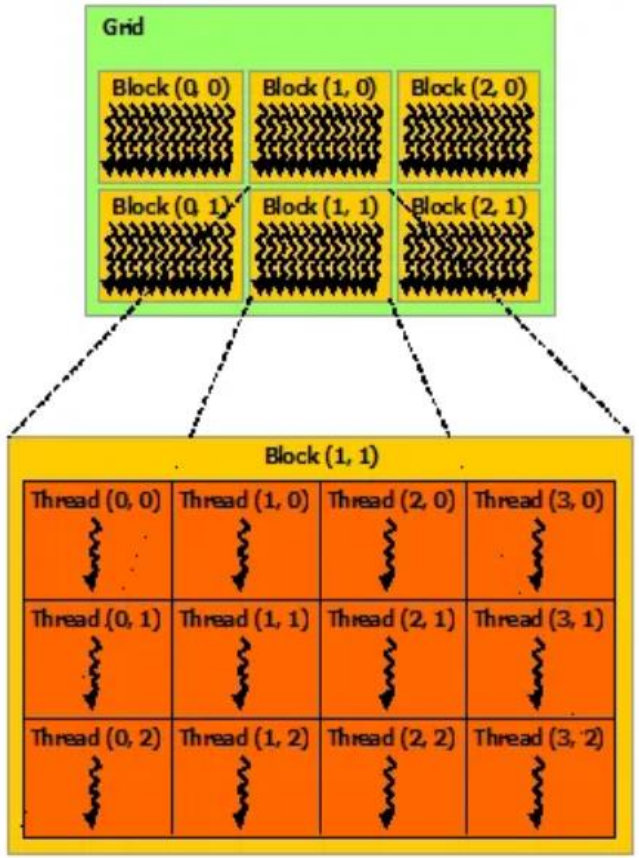
Standard Variables



- **Thread Index**

  threadIdx.x : thread's index in x dimension

Standard Variables



- **Thread Index**

  threadIdx.x : thread's index in x dimension

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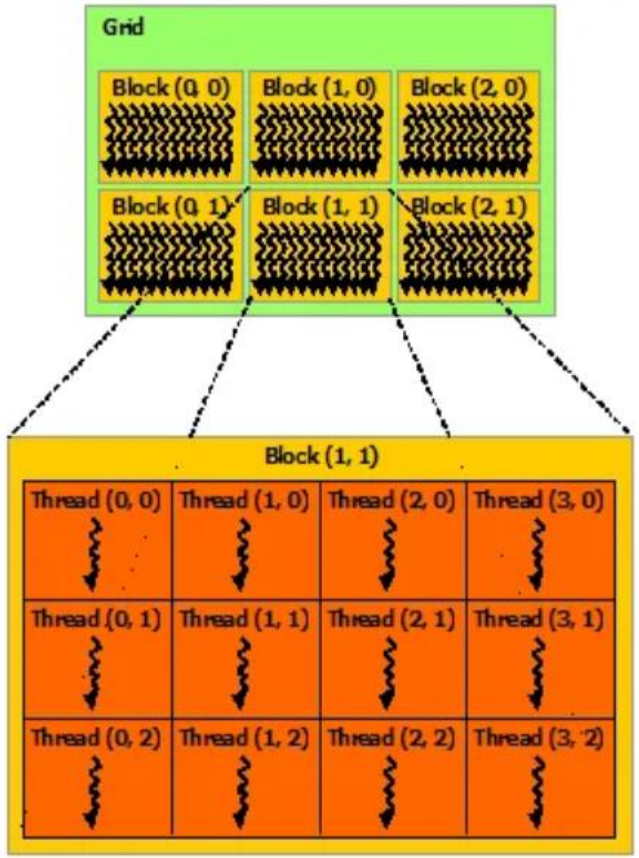

- **Thread Index**

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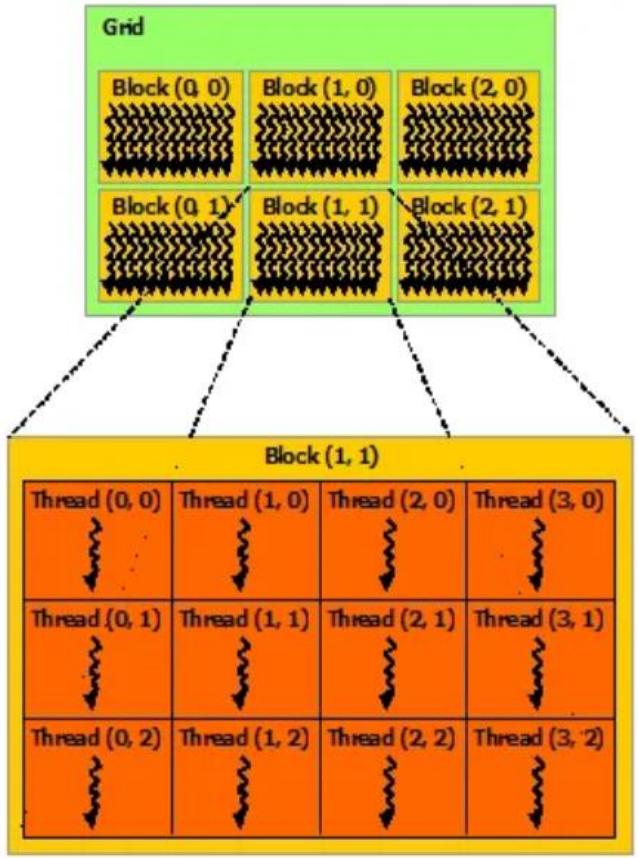


- **Thread Index**

  threadIdx.x : thread's index in x dimension

  threadIdx.y : thread's index in y dimension

  threadIdx.z : thread's index in z dimension

  thread (3,1)

  threadIdx.x = 3 , threadIdx.y = 1

Thread indexing : 1D grid of 1D blocks

- kernel_name<<<numBlocks,threadsPerBlock >>>();

- **dkernel**<<<**3,4**>>>():

  gridDim.x = 3

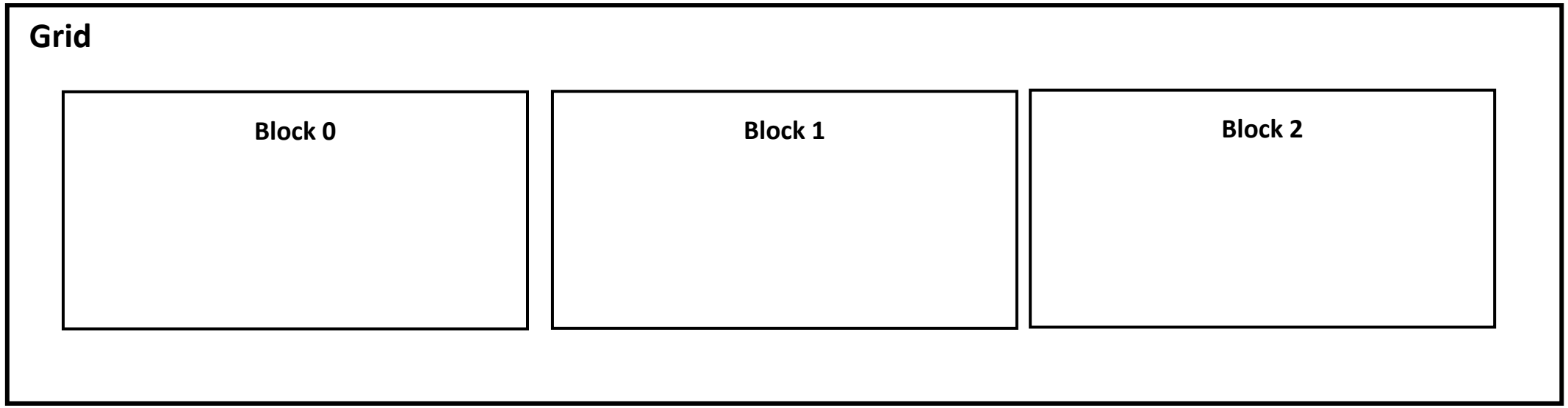
  blockDim.x = 4

Thread indexing : 1D grid of 1D blocks

- dkernel<<<3,4>>>()

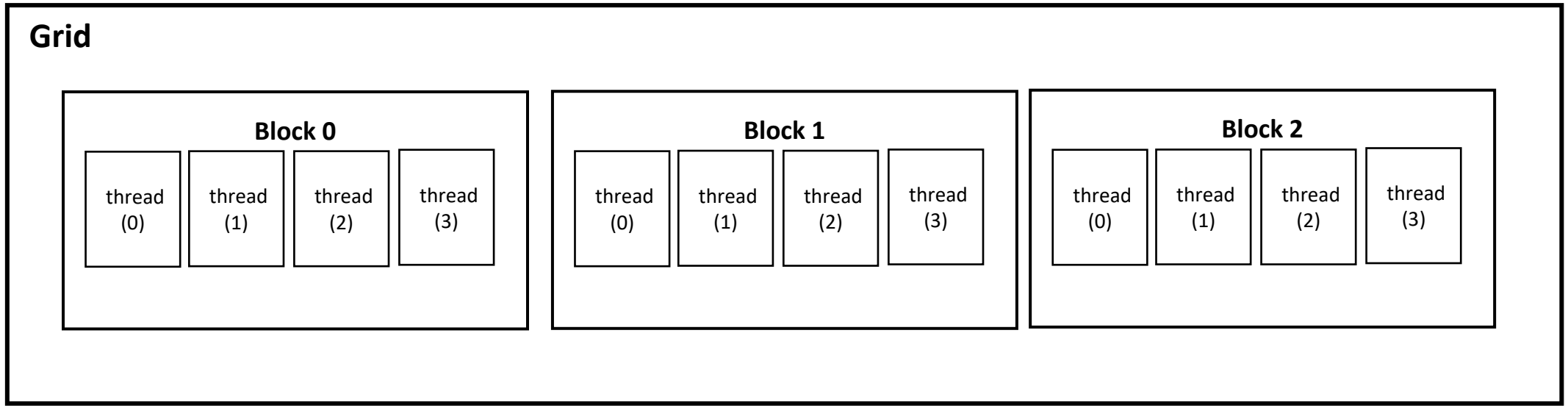
Thread indexing : 1D grid of 1D blocks

- dkernel<<<**3**,4>>>()



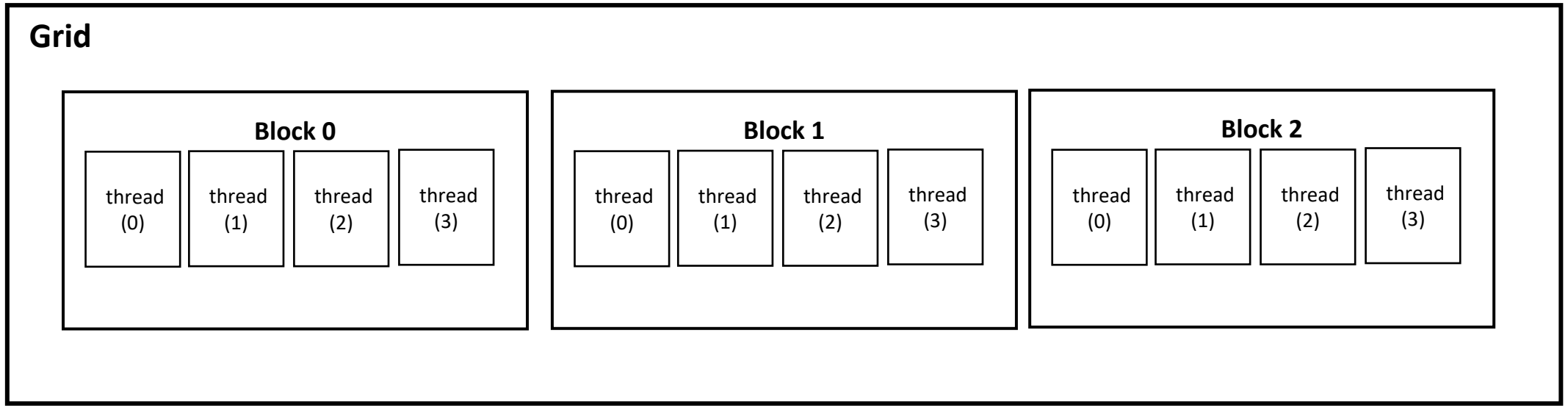
Thread indexing : 1D grid of 1D blocks

- dkernel<<<3,**4**>>>()



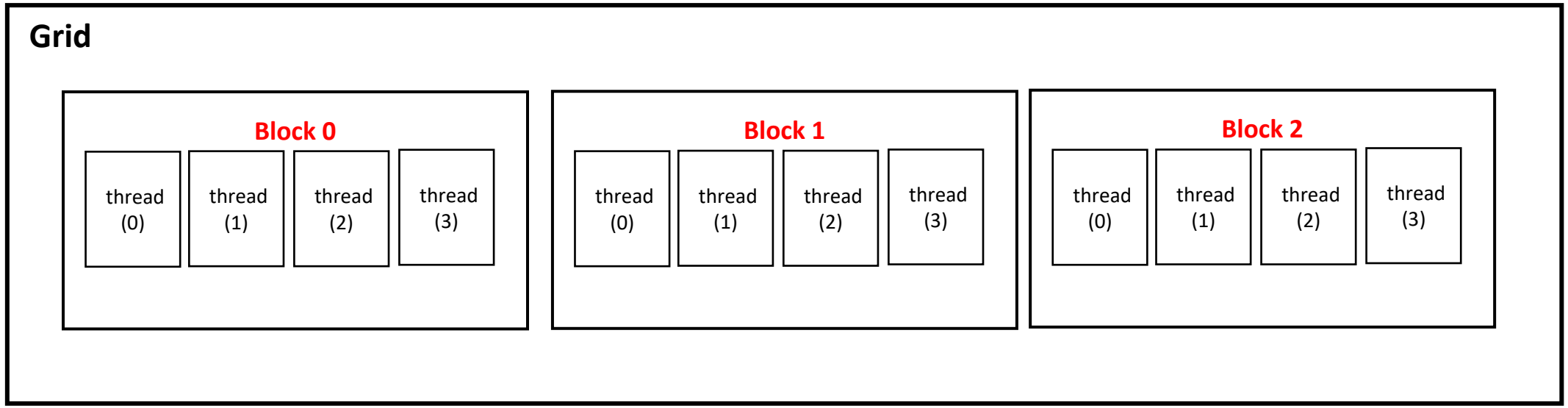
Thread indexing : 1D grid of 1D blocks

- threadId = (blockIdx.x * blockDim.x) + threadIdx.x



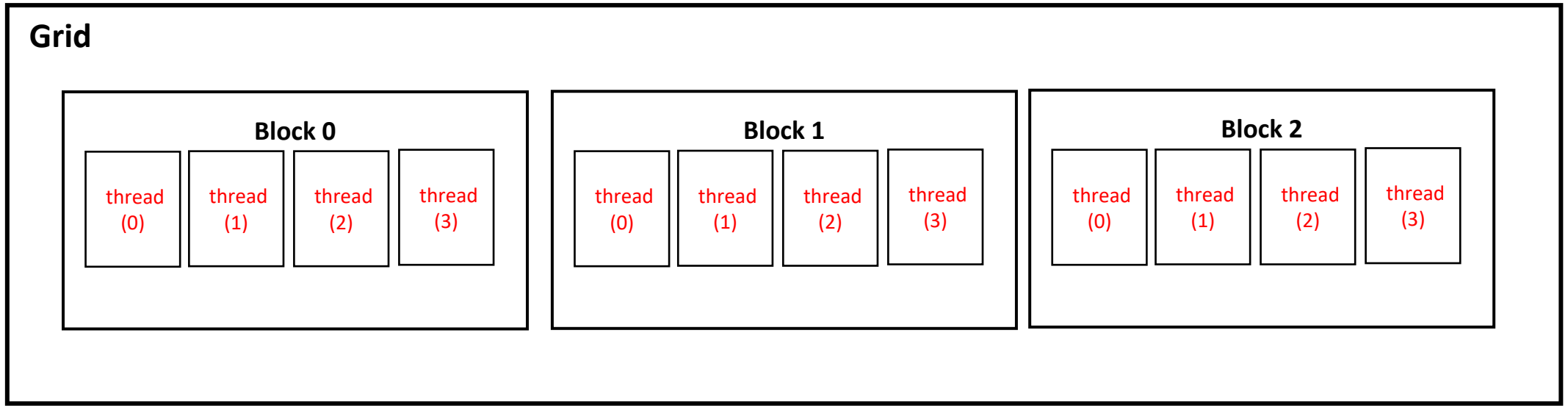
Thread indexing : 1D grid of 1D blocks

- threadId = (**blockIdx.x** * blockDim.x) + threadIdx.x



Thread indexing : 1D grid of 1D blocks

- threadId = (blockIdx.x * blockDim.x) + **threadIdx.x**



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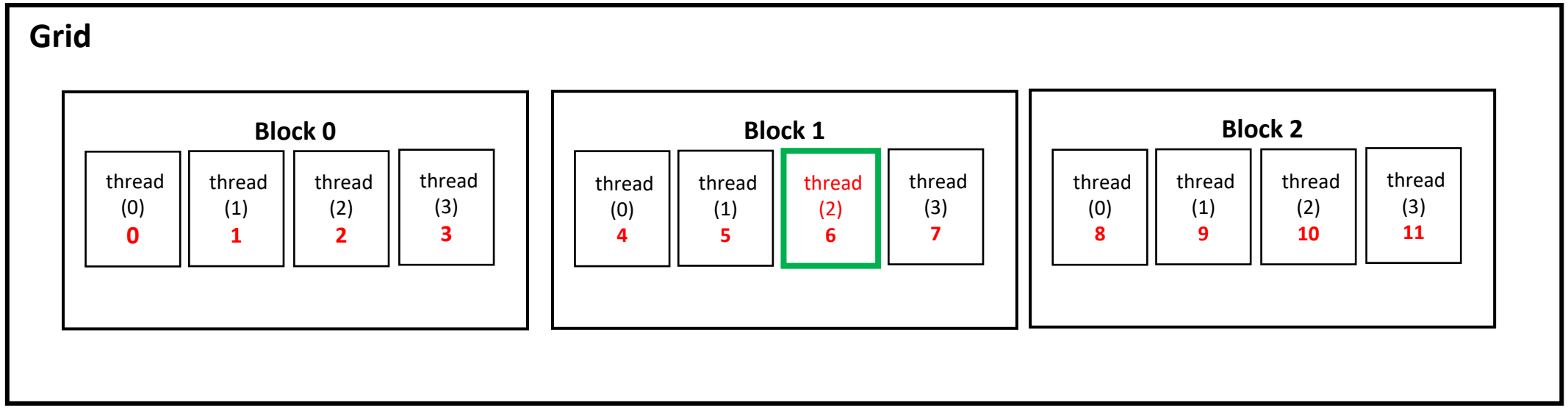
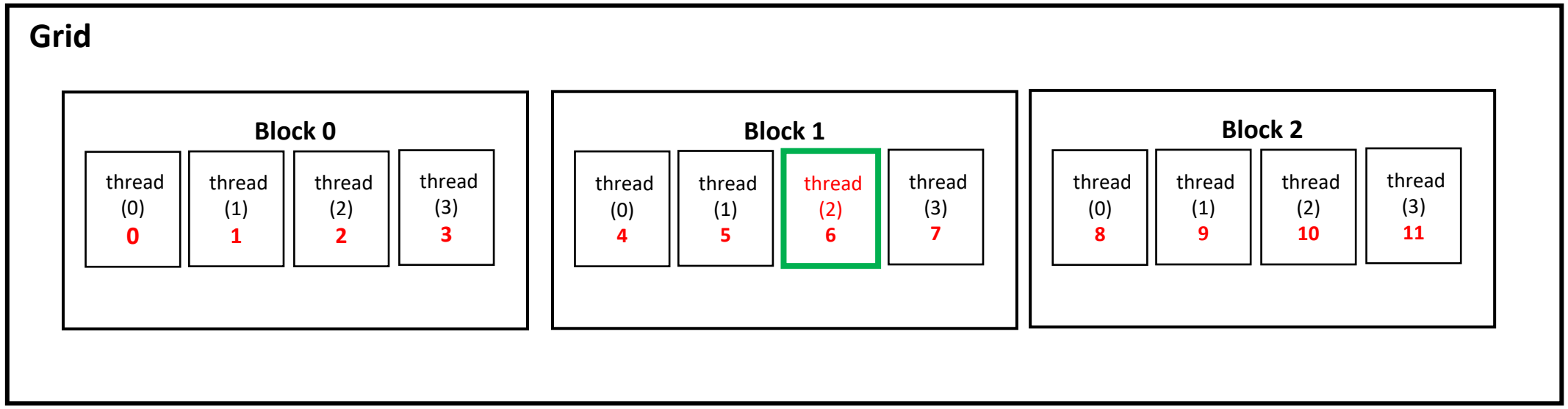


Thread indexing : 1D grid of 1D blocks

- threadId = (blockIdx.x * blockDim.x) + threadIdx.x
- threadId = (1 * 4) + 2 =4+2 = 6



Some examples

- dkernel<<<4,5>>>(A); //kernel launch

```
__global__ void dkernel(int *A)
{
int i=blockIdx.x * blockDim.x + threadIdx.x
A[i]=i;
}
```

Some examples

- dkernel<<<4,5>>>(A); //kernel launch

```
__global__ void dkernel(int *A)
{
int i=blockIdx.x * blockDim.x + threadIdx.x
A[i]=i;
}
```

Output :

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

15 16 17 18 19

Some examples

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```
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{
int i=blockIdx.x * blockDim.x + threadIdx.x
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Some examples

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```
__global__ void dkernel(int *A)
{
int i=blockIdx.x * blockDim.x + threadIdx.x
A[i]=blockDim.x;
}
```

Output :

5

5

5

.. 20 times

Some examples

- dkernel<<<4,5>>>(A); //kernel launch

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__global__ void dkernel(int *A)
{
int i=blockIdx.x * blockDim.x + threadIdx.x
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Some examples

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Output :

0 0 0 0 0 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3

Some examples

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__global__ void dkernel(int *A)
{
int i=blockIdx.x * blockDim.x + threadIdx.x
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Some examples

- dkernel<<<4,5>>>(A); //kernel launch

```
__global__ void dkernel(int *A)
{
int i=blockIdx.x * blockDim.x + threadIdx.x
A[i]=threadIdx.x;
}
```

Output :

0 1 2 3 4 0 1 2 3 4 0 1 2 3 4 0 1 2 3 4

Thread indexing : 1D grid of 2D blocks

- dkernel<<< 1D, 2D>>>();

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- dkernel<<< 1D, 2D>>>();

- dim3 block(N, M, 1); // N= 5 , M=4

Thread indexing : 1D grid of 2D blocks

- dkernel<<<1D, 2D>>>();
- dim3 block(N, M, 1); // N= 5 , M=4
- dkernel<<<(**1,1,1**), (**5,4,1**)>>>();

Thread indexing : 1D grid of 2D blocks

- dkernel<<<(**1,1,1**), (**5,4,1**)>>>();

- gridDim.x = gridDim.y = gridDim.z = 1

Thread indexing : 1D grid of 2D blocks

- dkernel<<<(**1,1,1**), (**5,4,1**)>>>();
- gridDim.x = gridDim.y = gridDim.z = 1
- blockDim.x = 5 , blockDim.y = 4 , blockDim.z = 1

Thread indexing : 1D grid of 2D blocks

- blockIdx.x = blockIdx.y = blockIdx.z = 0

Thread indexing : 1D grid of 2D blocks

- blockIdx.x = blockIdx.y = blockIdx.z = 0

- threadIdx.x = 0 to 4
- threadIdx.y = 0 to 3
- threadIdx.z = 0

Thread indexing : 1D grid of 2D blocks

- unsigned id = threadIdx.x * blockDim.y + threadIdx.y ;
  = (0..4) * 4 + (0..3)

Output :

```
0 1 2 3
4 5 6 7
8 9 10 11
12 13 14 15
16 17 18 19
```

Some examples

- dim3 block(3, 4, 1);
- K<<<1, block>>>();

```
__global__ void dkernel(int *A)
{
 printf("%d\n", threadIdx.x + threadIdx.y);
}
```

Some examples

- dim3 block(3, 4, 1);
- K<<<1, block>>>();

```
__global__ void dkernel(int *A)
{
 printf("%d\n", threadIdx.x + threadIdx.y);
}
```

Output :

0 1 2 1 2 3 2 3 4 3 4 5

Some examples

- dim3 grid(2, 3, 4); dim3 block(5, 6, 7);
- dkernel <<< grid, block>>>();

```
__global__ void dkernel() {
If(threadIdx.x == 0 && blockIdx.x == 0 && threadIdx.y == 0 &&
blockIdx.y == 0 && threadIdx.z == 0 && blockIdx.z == 0)
{
printf("%d %d %d %d %d %d.\n", gridDim.x, gridDim.y, gridDim.z,
blockDim.x, blockDim.y, blockDim.z);
} }
```

Some examples

- dim3 grid(2, 3, 4); dim3 block(5, 6, 7);
- dkernel <<< grid, block>>>();

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__global__ void dkernel() {
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{
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blockDim.x, blockDim.y, blockDim.z);
} }
```

Number of threads launched = 2 *

3 * 4 * 5 * 6 * 7

Some examples

- dim3 grid(2, 3, 4); dim3 block(5, 6, 7);
- dkernel <<< grid, block>>>();

```
__global__ void dkernel() {
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{
printf("%d %d %d %d %d %d.\n", gridDim.x, gridDim.y, gridDim.z,
blockDim.x, blockDim.y, blockDim.z);
} }
```

Number of threads launched = 2 * 3 * 4 * 5 * 6 * 7.

Number of threads in a thread-block = 5 * 6 * 7

Some examples

- dim3 grid(2, 3, 4); dim3 block(5, 6, 7);
- dkernel <<< grid, block>>>();

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__global__ void dkernel() {
If(threadIdx.x == 0 && blockIdx.x == 0 && threadIdx.y == 0 &&
blockIdx.y == 0 && threadIdx.z == 0 && blockIdx.z == 0)
{
printf("%d %d %d %d %d %d.\n", gridDim.x, gridDim.y, gridDim.z,
blockDim.x, blockDim.y, blockDim.z);
} }
```

Number of threads launched = 2 * 3 * 4 * 5 * 6 * 7.

Number of threads in a thread-block = 5 * 6 * 7

Number of thread-blocks in the grid = 2 * 3 * 4

Some examples

- dim3 grid(2, 3, 4); dim3 block(5, 6, 7);
- dkernel <<< grid, block>>>();

```
__global__ void dkernel() {
If(threadIdx.x == 0 && blockIdx.x == 0 && threadIdx.y == 0 &&
blockIdx.y == 0 && threadIdx.z == 0 && blockIdx.z == 0)
{
printf("%d %d %d %d %d %d.\n", gridDim.x, gridDim.y, gridDim.z,
blockDim.x, blockDim.y, blockDim.z);
} }
```

Output:

2 3 4 5 6 7

Thank You