CS/EE 217
GPU Architecture and Parallel Programming

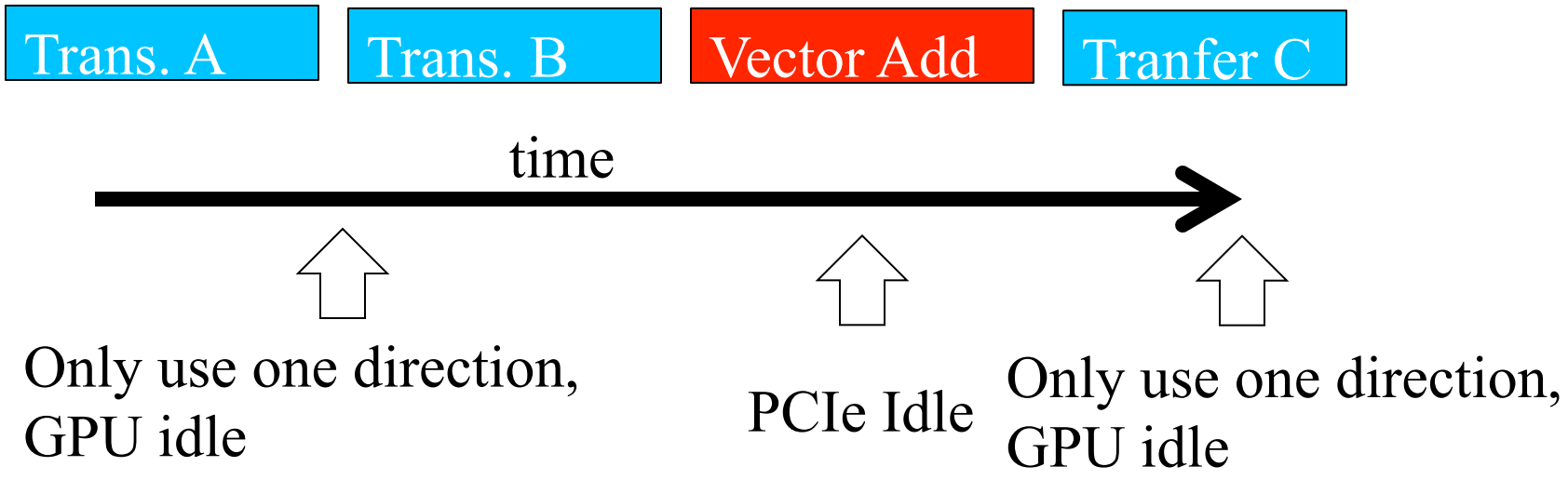
Lecture 17:
Data Transfer and CUDA Streams

Objective

- To learn more advanced features of the CUDA APIs for data transfer and kernel launch
  - Task parallelism for overlapping data transfer with kernel computation
  - CUDA streams

Serialized Data Transfer and GPU computation

- So far, the way we use cudaMemcpy serializes data transfer and GPU computation



Device Overlap

- Some CUDA devices support *device overlap*
  - *Simultaneously execute a kernel while performing a copy between device and host memory*

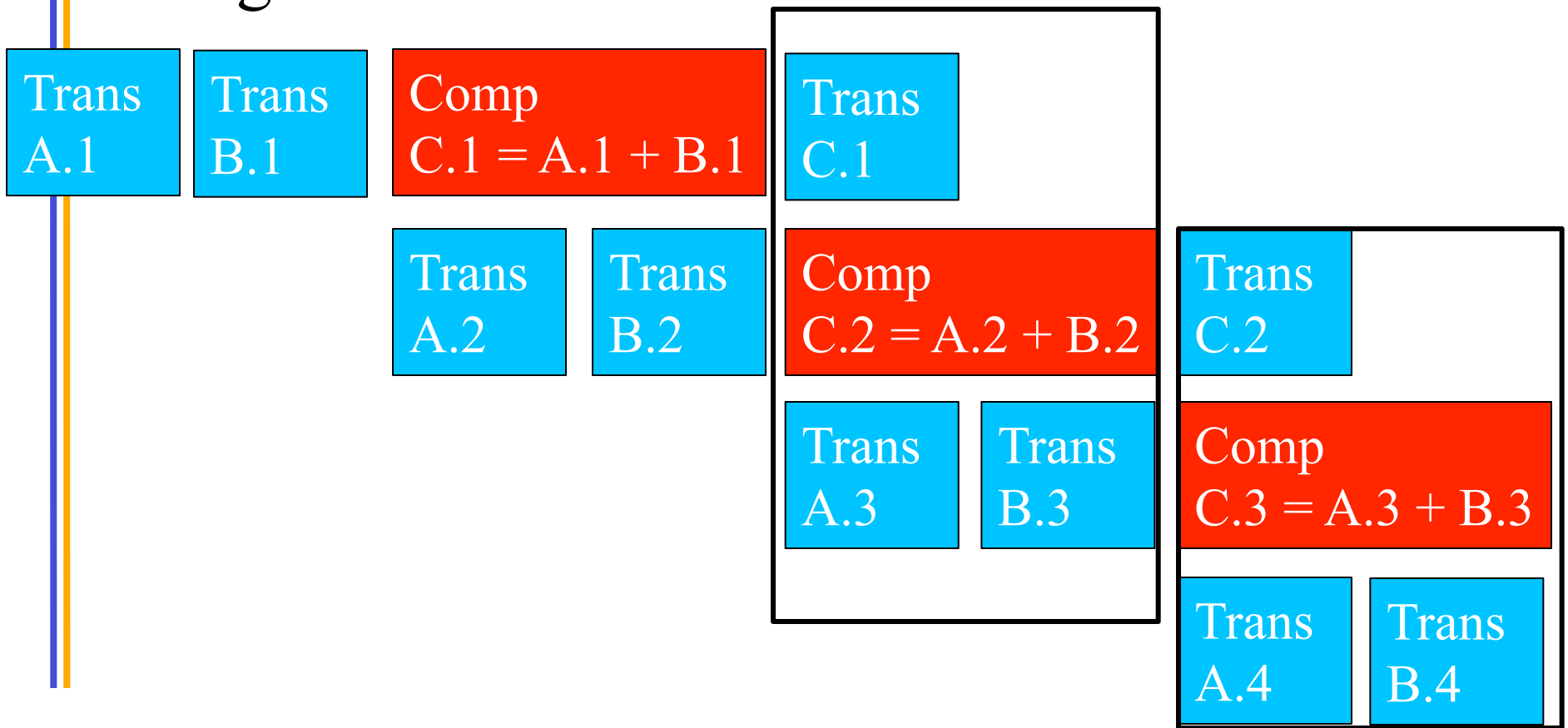
```
int dev_count;
cudaDeviceProp prop;

cudaGetDeviceCount( &dev_count);
for (int i = 0; i < dev_count; i++) {
  cudaGetDeviceProperties(&prop, i);

  if (prop.deviceOverlap) …
```

Overlapped (Pipelined) Timing

- Divide large vectors into segments
- Overlap transfer and compute of adjacent segments

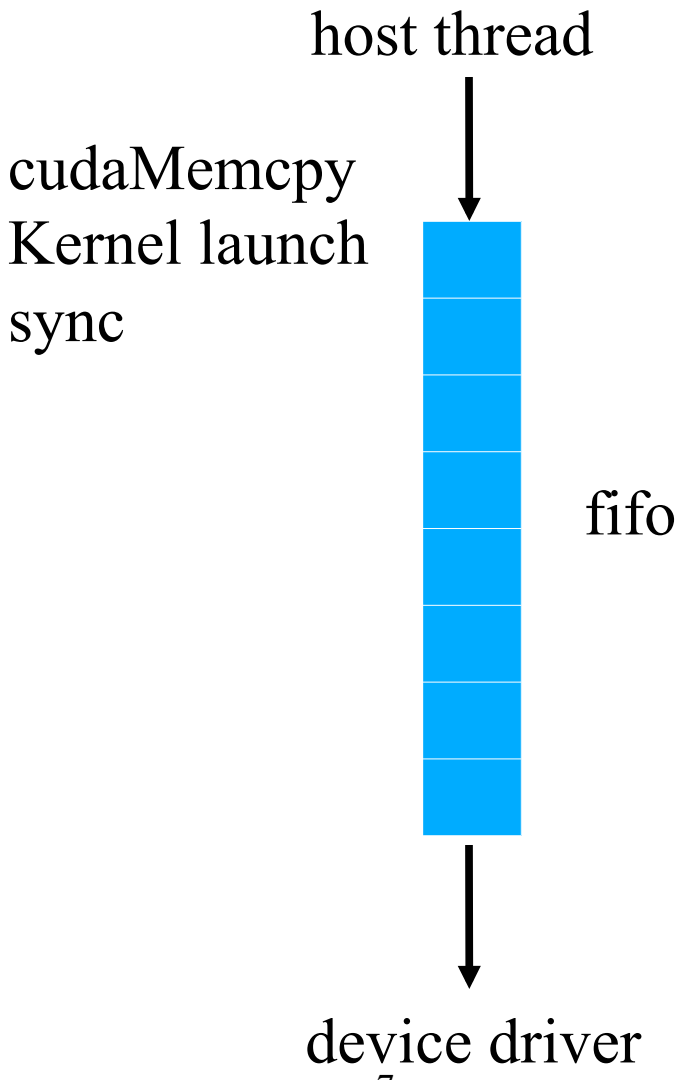


Using CUDA Streams and Asynchronous MemCpy

- CUDA supports parallel execution of kernels and cudaMemcpy with “Streams”
- Each stream is a queue of operations (kernel launches and cudaMemcpy’s)
- Operations (tasks) in different streams can go in parallel
  - “Task parallelism”

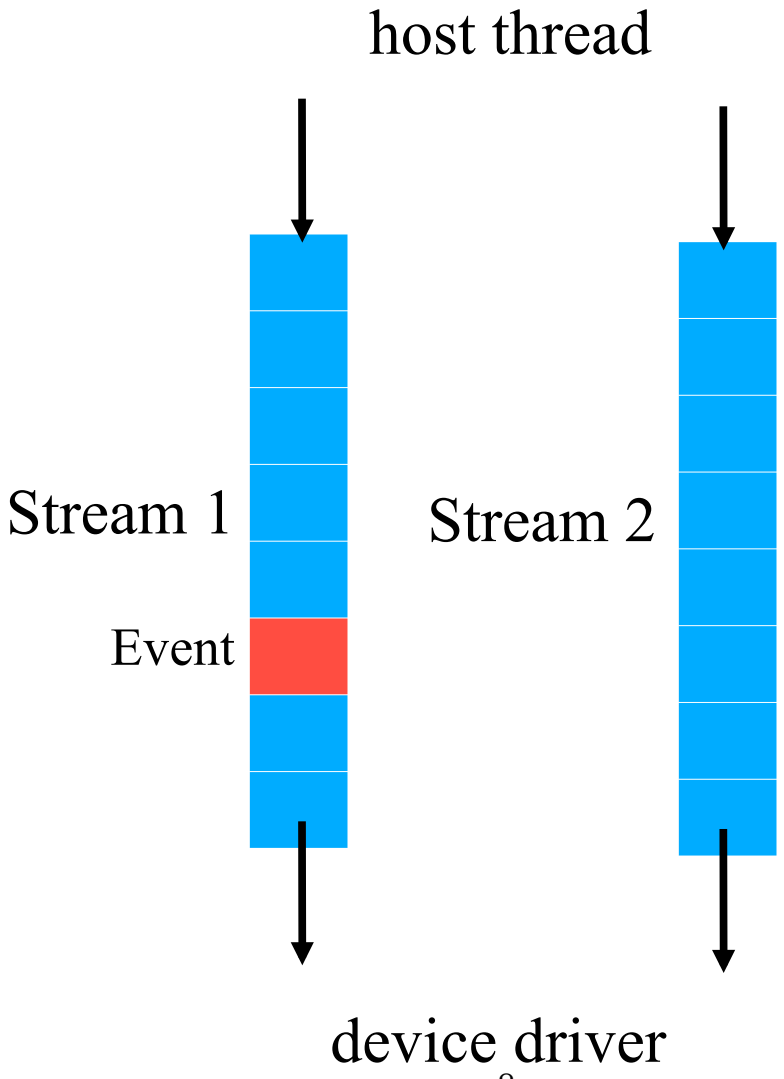
Streams

- Device requests made from the host code are put into a queue
  - Queue is read and processed asynchronously by the driver and device
  - Driver ensures that commands in the queue are processed in sequence. Memory copies end before kernel launch, etc.

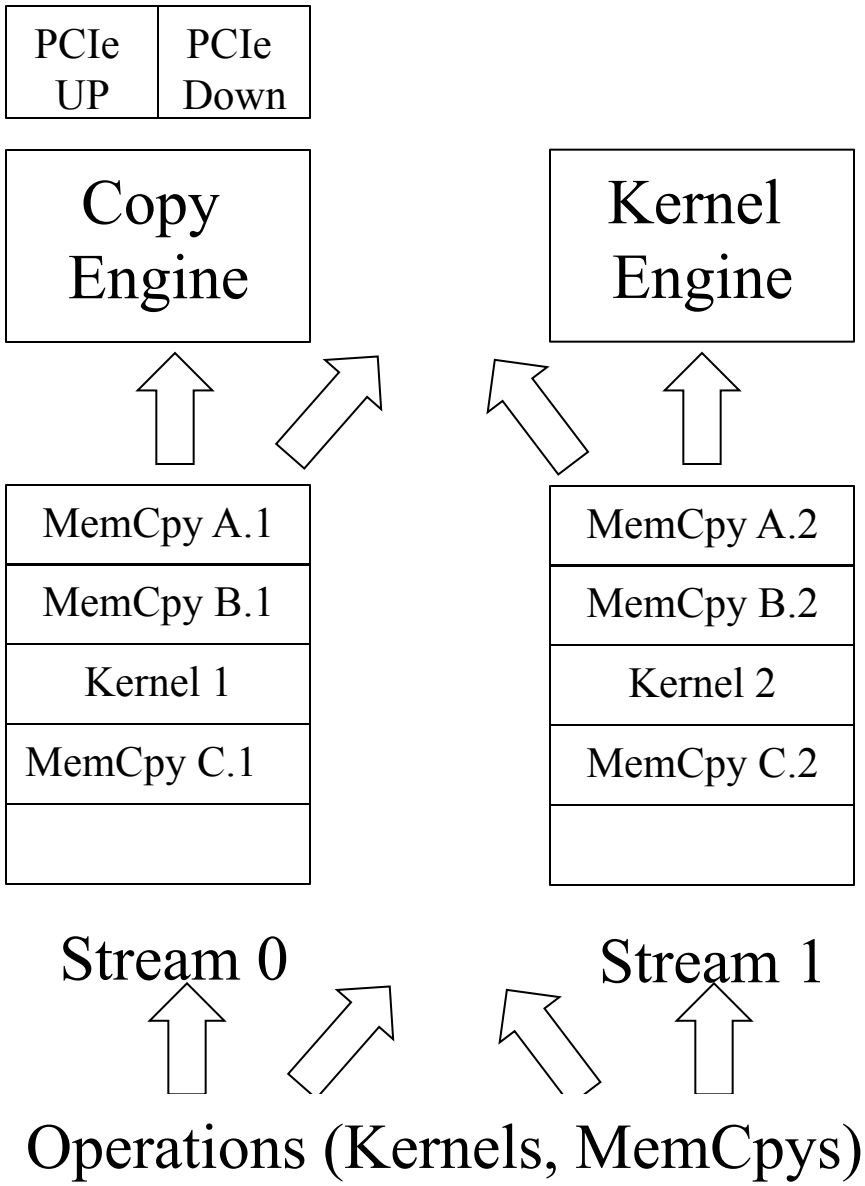


Streams cont.

- To allow concurrent copying and kernel execution, you need to use multiple queues, called "streams"
  - CUDA "events" allow the host thread to query and synchronize with the individual queues.



Conceptual View of Streams



A Simple Multi-Stream Host Code

```
cudaStream_t  stream0, stream1;
cudaStreamCreate( &stream0);
cudaStreamCreate( &stream1);

float *d_A0, *d_B0, *d_C0;  // device memory for stream 0
float *d_A1, *d_B1, *d_C1;  // device memory for stream 1

// cudaMalloc for d_A0, d_B0, d_C0, d_A1, d_B1, d_C1 go here
```

continued

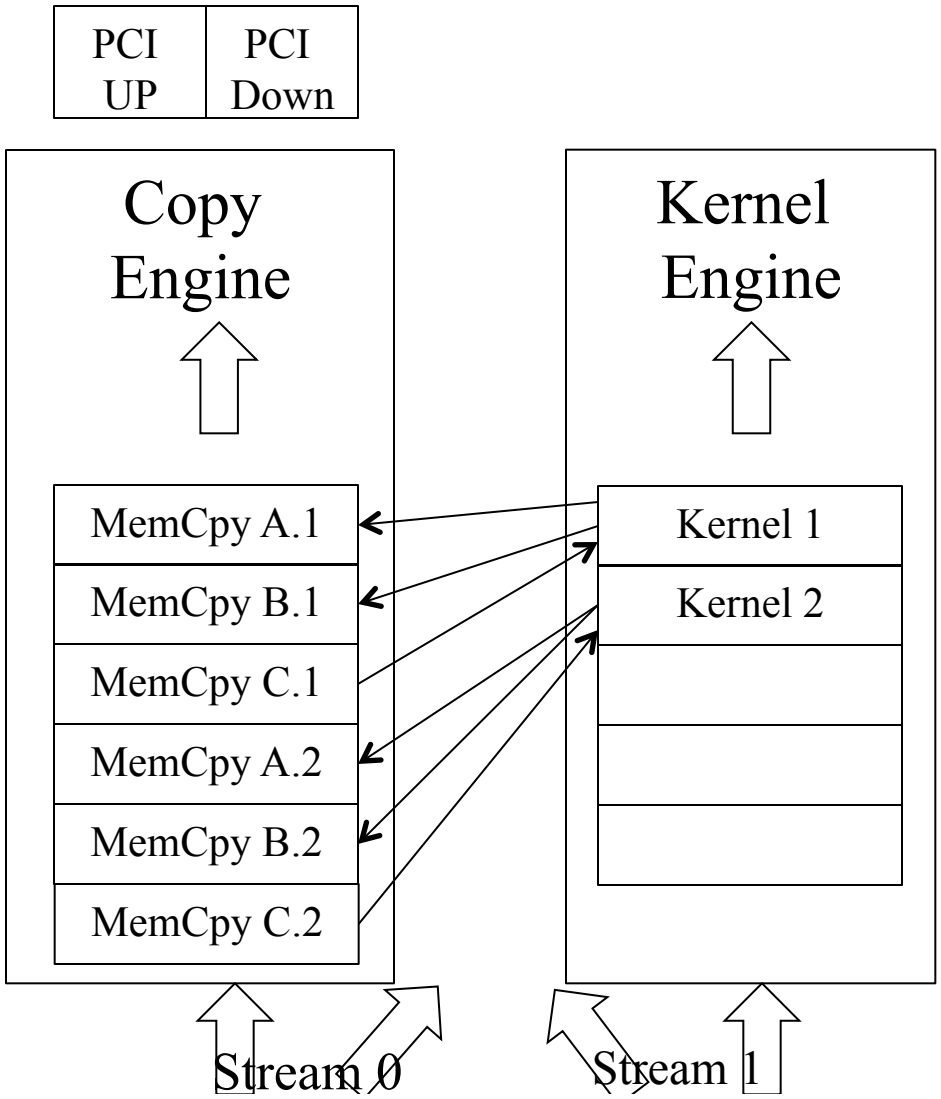
```
for (int i=0; i<n; i+=SegSize*2) {
  cudaMemCpyAsync(d_A0, h_A+i; SegSize*sizeof(float),.., stream0);
  cudaMemCpyAsync(d_B0, h_B+i; SegSize*sizeof(float),.., stream0);
  vecAdd<<<SegSize/256, 256, 0, stream0>>> (…);
  cudaMemCpyAsync(d_C0, h_C+I; SegSize*sizeof(float),.., stream0);
```

A Simple Multi-Stream Host Code (Cont.)

```
for (int i=0; i<n; i+=SegSize*2) {
  cudaMemCpyAsync(d_A0, h_A+i; SegSize*sizeof(float),.., stream0);
  cudaMemCpyAsync(d_B0, h_B+i; SegSize*sizeof(float),.., stream0);
  vecAdd<<<SegSize/256, 256, 0, stream0>>>(d_A0, d_B0, …);
  cudaMemCpyAsync(d_C0, h_C+I; SegSize*sizeof(float),.., stream0);

  cudaMemCpyAsync(d_A1, h_A+i+SegSize;
                                        SegSize*sizeof(float),.., stream1);
  cudaMemCpyAsync(d_B1, h_B+i+SegSize;
                                        SegSize*sizeof(float),.., stream1);
  vecAdd<<<SegSize/256, 256, 0, stream1>>>(d_A1, d_B1, …);
  cudaMemCpyAsync(d_C1, h_C+i+SegSize;
                                        SegSize*sizeof(float),.., stream1);
}
```

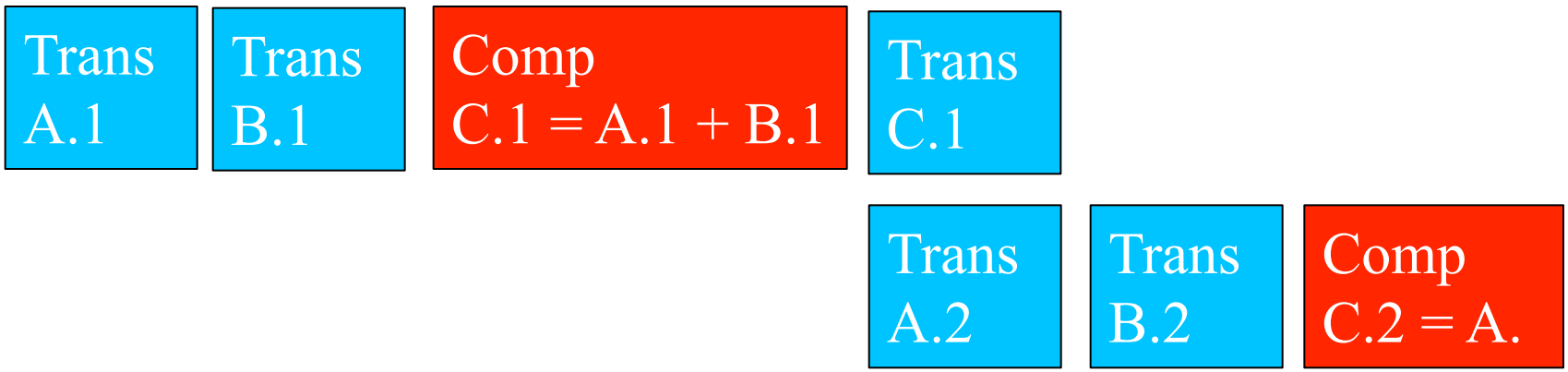
A View Closer to Reality



Operations (Kernels, MemCpys)

Not quite the overlap we want

- C.1 blocks A.2 and B.2 in the copy engine queue

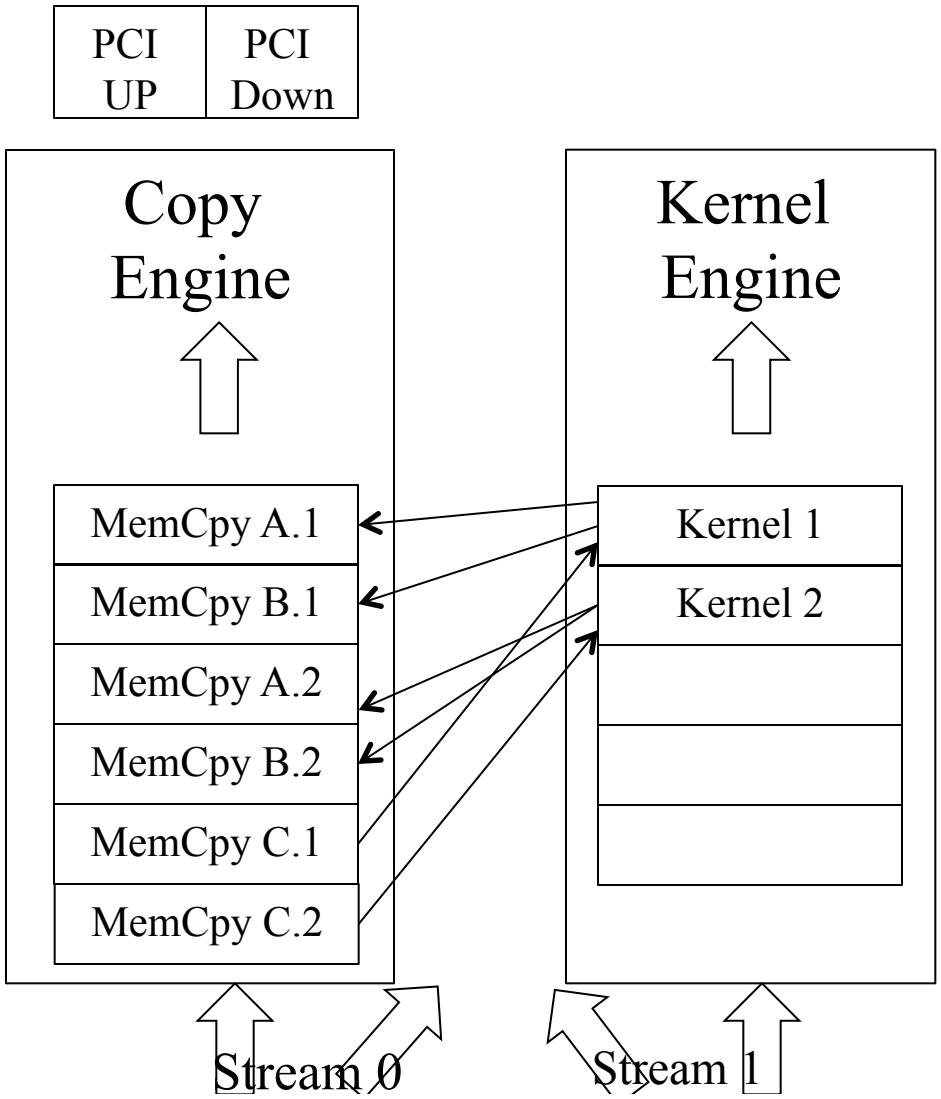


A Better Multi-Stream Host Code (Cont.)

```
for (int i=0; i<n; i+=SegSize*2) {
  cudaMemCpyAsync(d_A0, h_A+i; SegSize*sizeof(float),.., stream0);
  cudaMemCpyAsync(d_B0, h_B+i; SegSize*sizeof(float),.., stream0);
  cudaMemCpyAsync(d_A1, h_A+i+SegSize;
                                  SegSize*sizeof(float),.., stream1);
  cudaMemCpyAsync(d_B1, h_B+i+SegSize;
                                  SegSize*sizeof(float),.., stream1);

  vecAdd<<<SegSize/256, 256, 0, stream0>>>(d_A0, d_B0, …);
  vecAdd<<<SegSize/256, 256, 0, stream1>>>(d_A1, d_B1, …);
  cudaMemCpyAsync(d_C0, h_C+I; SegSize*sizeof(float),.., stream0);
  cudaMemCpyAsync(d_C1, h_C+i+SegSize;
                                  SegSize*sizeof(float),.., stream1);
}
```

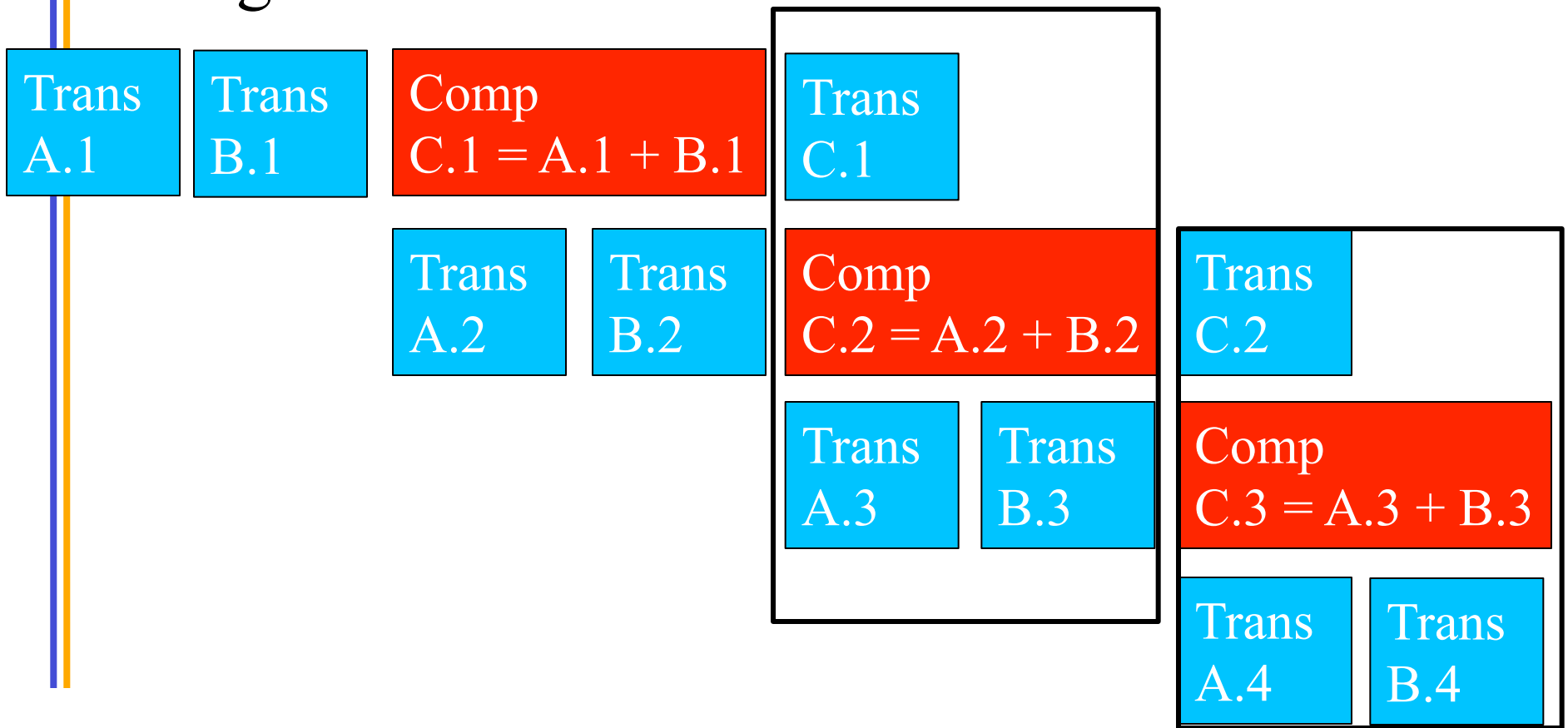
A View Closer to Reality



Operations (Kernels, MemCpys)

Overlapped (Pipelined) Timing

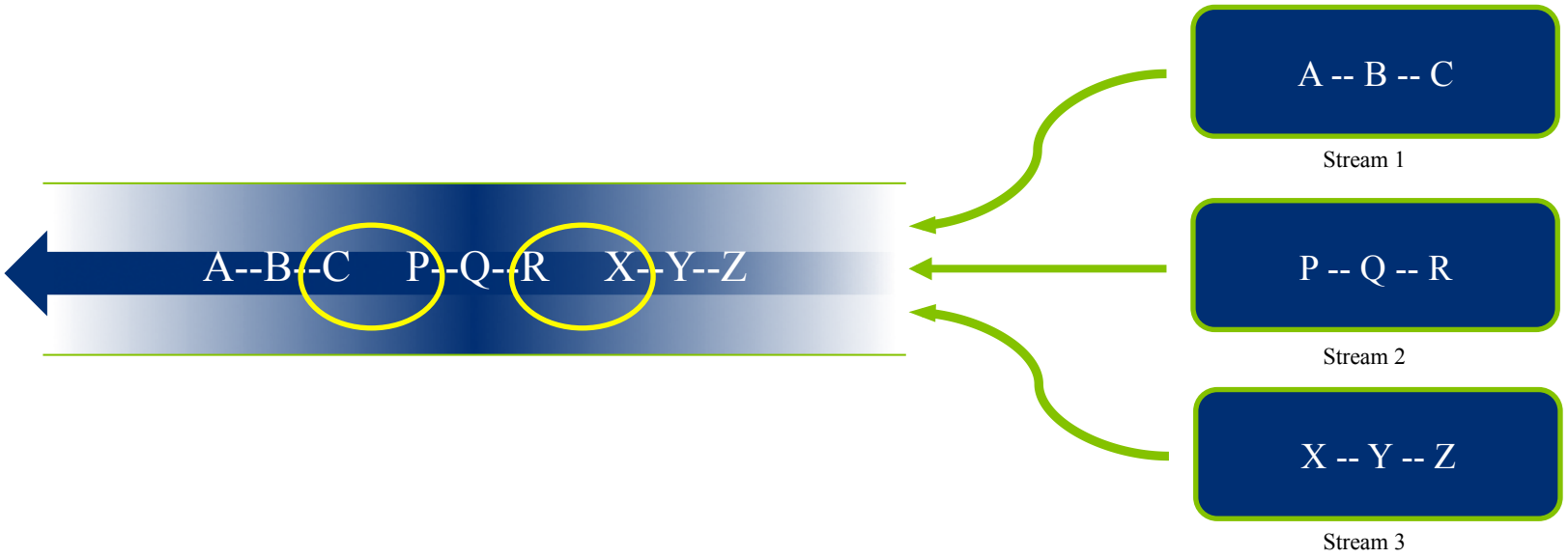
- Divide large vectors into segments
- Overlap transfer and compute of adjacent segments



Hyper Queue

- Provide multiple real queues for each engine
- Allow much more concurrency by allowing some streams to make progress for an engine while others are blocked

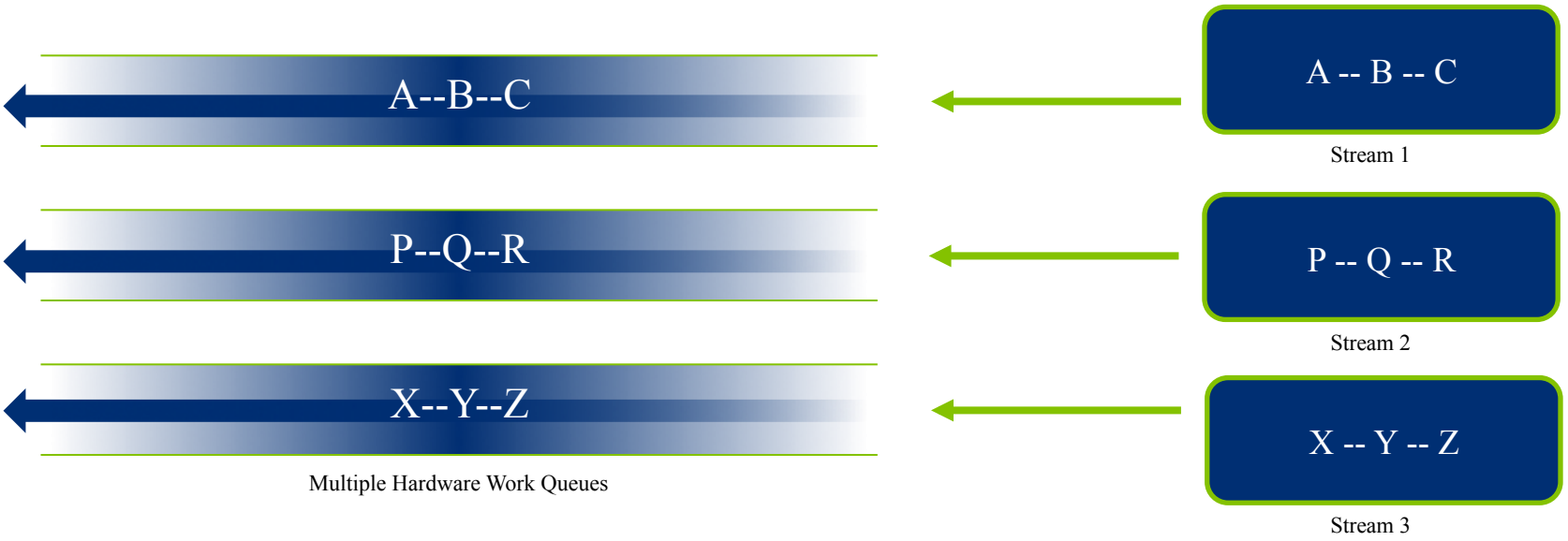
Fermi (and older) Concurrency



Fermi allows 16-way concurrency

- Up to 16 grids can run at once
- But CUDA streams multiplex into a single queue
- Overlap only at stream edges

Kepler Improved Concurrency



Kepler allows 32-way concurrency

- **One work queue per stream**
- **Concurrency at full-stream level**
- **No inter-stream dependencies**

ANY QUESTIONS?

Synchronization

- cudaStreamSynchronize(stream_id)
  - Used in host code
  - Takes a stream identifier parameter
  - Waits until all tasks in the stream have completed

- This is different from cudaDeviceSynchronize()
  - Also used in host code
  - No parameter
  - Waits until all tasks in all streams have completed for current device