Advanced OpenCL by Example

Justin Hensley, Derek Gerstmann &
Takahiro Harada

SIGGRAPHASIA2010
SEOUL

Course Agenda

OpenCL Review

OpenCL Development Tips

OpenGL/OpenCL Interoperability

Rigid body particle simulation
<15 minute Break>
Bullet cloth

Galaxy n-body simulation

Visualization with OpenCL

Slides from tutorial and course

http://sa10.idav.ucdavis.edu

GPU Basics

Architectures meant for **throughput**, not for **single thread**

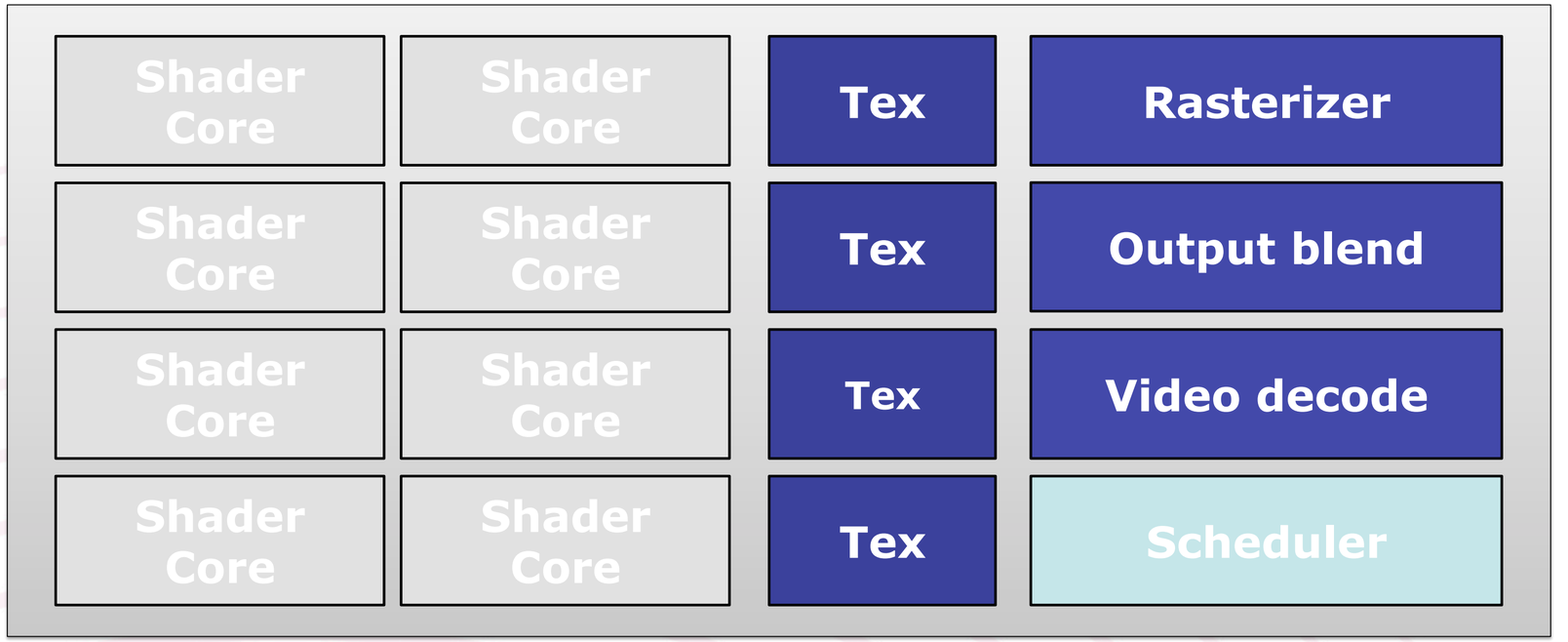
- Not complexity of out-of-order issue
- Nor of multiple issue per core

Rendering is **latency tolerant**

Graphics generates many **parallelizable** tasks

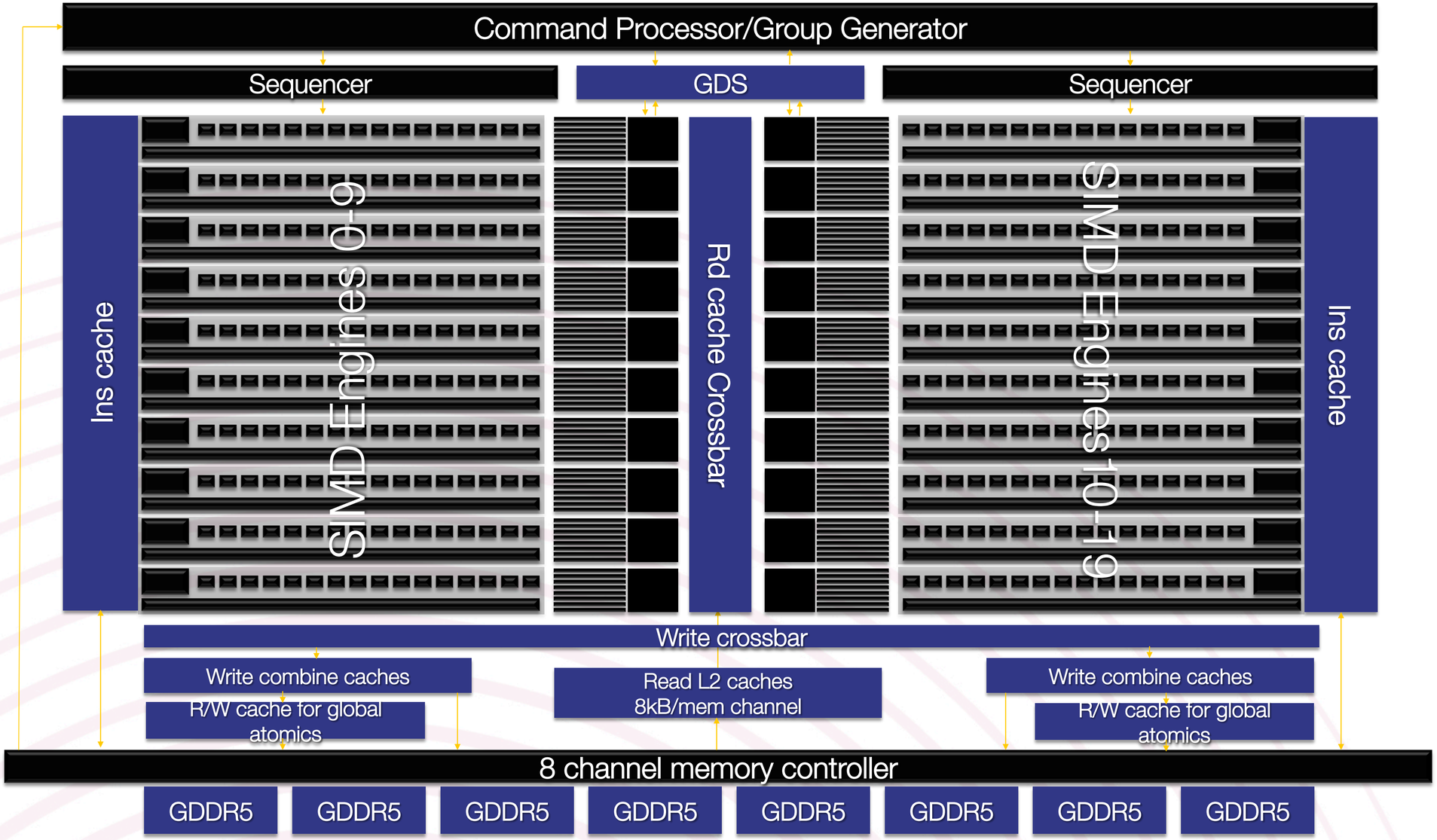
- Therefore much easier to scale

GPU In a nutshell

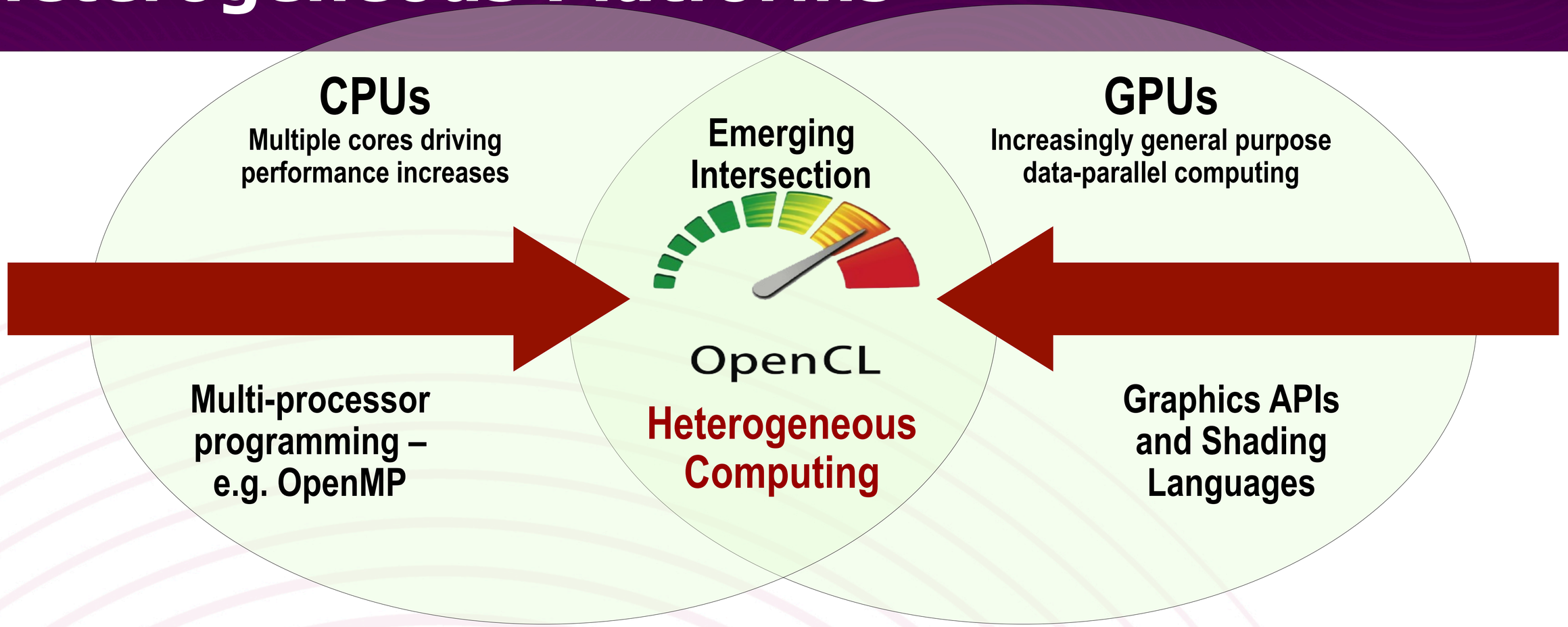


The GPU is a multicore processor optimized for graphics workloads

Modern AMD GPU



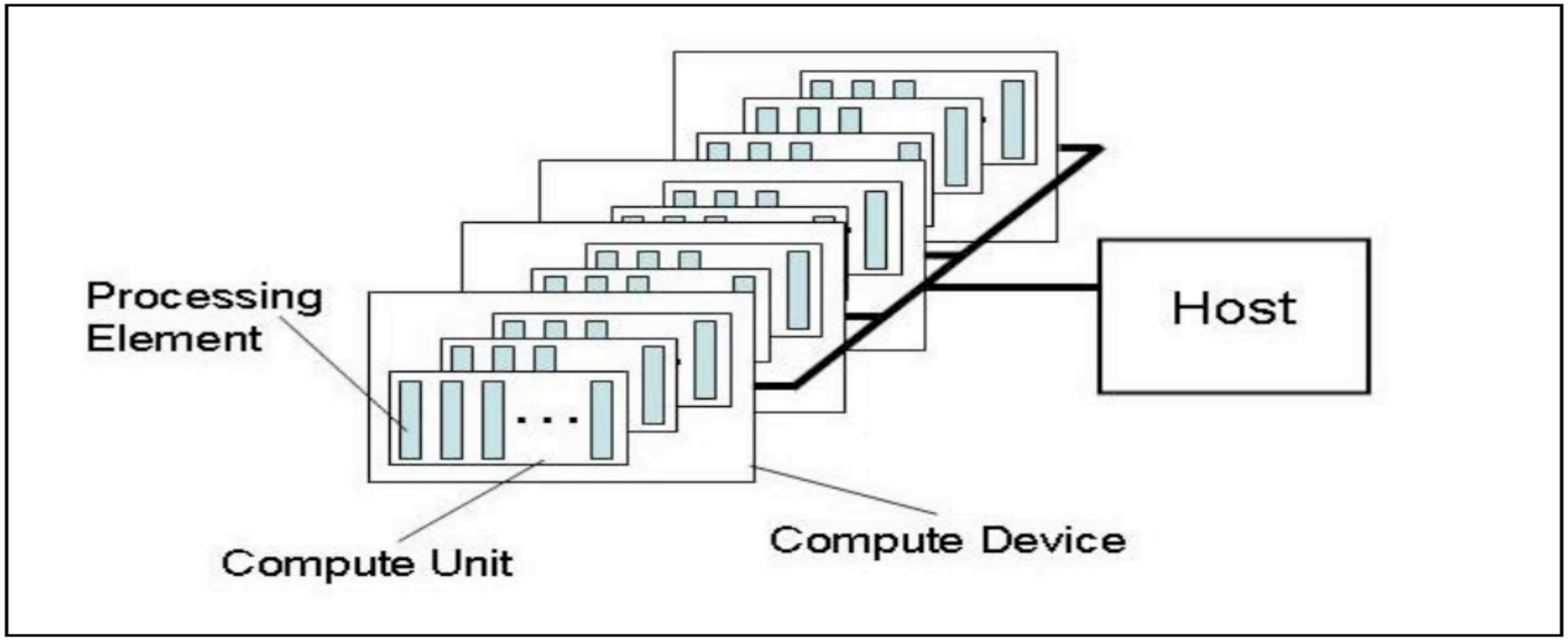
Industry Standard for Programming Heterogeneous Platforms



OpenCL – Open Computing Language

Open, royalty-free standard for portable, parallel programming of heterogeneous parallel computing CPUs, GPUs, and other processors

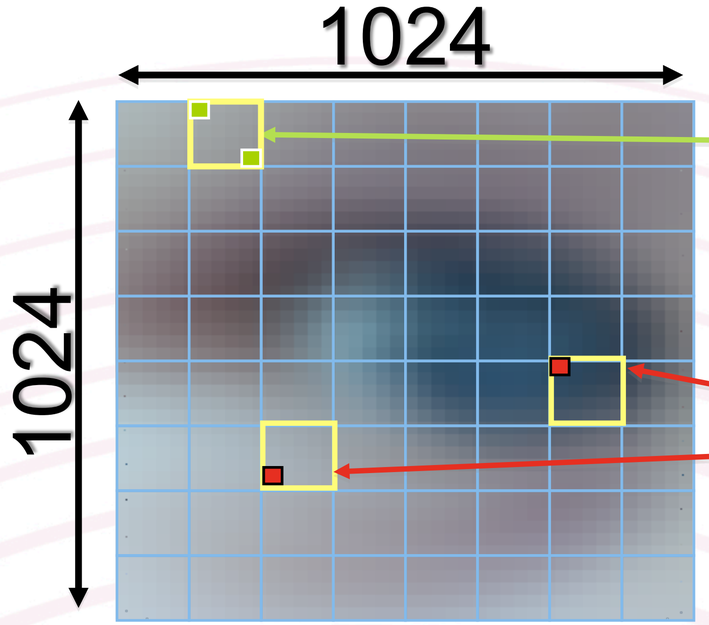
OpenCL Platform Model



- **One Host + one or more Compute Devices**
  - Each Compute Device is composed of one or more Compute Units
    - Each Compute Unit is further divided into one or more Processing Elements

An N-dimension domain of work-items

- Global Dimensions: 1024 x 1024 (whole problem space)
- Local Dimensions: 128 x 128 (work group … executes together)



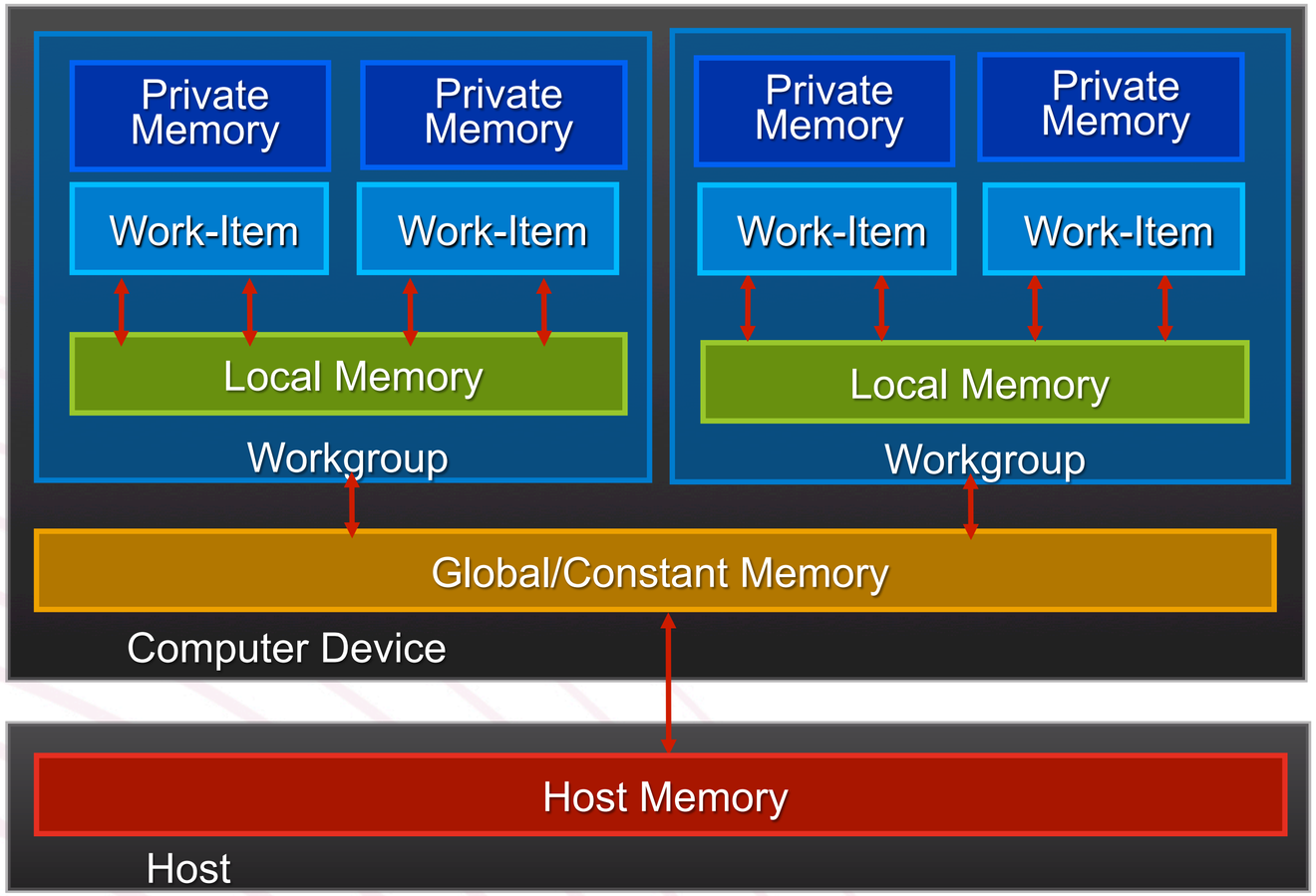
Synchronization between work-items possible only within workgroups: barriers and memory fences

Cannot synchronize outside of a workgroup

- Choose the dimensions that are “best” for your algorithm

OpenCL Memory Model

- **Private Memory**
  - Per work-item
- **Local Memory**
  - Shared within a workgroup
- **Local Global/Constant Memory**
  - Visible to all workgroups
- **Host Memory**
  - On the CPU



- Memory management is explicit

You must move data from host -> global -> local *and* back

OpenCL C Language

- **Derived from ISO C99**
  - No standard C99 headers, function pointers, recursion, variable length arrays, and bit fields
- **Additions to the language for parallelism**
  - Work-items and workgroups
  - Vector types
  - Synchronization
- **Address space qualifiers**
- **Optimized image access**
- **Built-in functions**

OpenCL 1.1 - API

- Thread-safety
  - All API calls, except **clSetKernelArg**, are thread safe
- Sub-buffer objects
  - Create an object that represents a specific region in a buffer object
  - Easy and efficient mechanism to distribute regions of a buffer object across multiple devices
  - OpenCL™ synchronization mechanism ensures modifications to sub-buffer object reflected in appropriate region of parent buffer object

OpenCL 1.1 - API

- User Events
  - **clEnqueue*** commands can wait on event
  - In OpenCL™ 1.0, events can only refer to OpenCL™ commands
  - Need ability to enqueue commands that wait on an external, user defined, event
- Event CallBacks
  - **clSetEventCallbackFn** to register a user callback function
  - called when command identified by event has completed
  - Allows applications to enqueue new OpenCL™ commands based on event state changes in a non-blocking manner

OpenCL 1.1 - Language

- **Implicit Conversions**
  - OpenCL™ 1.0 requires widening for arithmetic operators

```
float4 a, b;
float c;
b = a + c; // c is widened to a float4 vector
           // first and then the add is performed
```

  - OpenCL™ 1.1 extends this feature for all operators
    - relational, equality, bitwise, logical, ternary

OpenCL 1.1 - Language

- **3-component vector data types**
  - And everyone applauds....well almost everyone
- **cl_khr_byte_addressable as core feature**
- **Atomic extensions are now core features**
  - **cl_khr_global_int32_{base | extended}_atomics**
  - **cl_khr_local_int32_{base | extended}_atomics**

OpenCL 1.1 - Language

- **New built-in functions**
  - **get_global_offset**
  - clamp for integer data types
  - **async_work_group_strided_copy**
  - strided async copy of data from global <---> local memory
  - **shuffle** - construct a permutation of elements from 1 or 2 input vectors and a mask

OpenCL 1.1 – OpenCL/OpenGL Sharing

- **Improve performance of OpenCL/ OpenGL interoperability**
  - Portable OpenCL / OpenGL sharing requires
    - a **glFinish** before **clEnqueueAcquireGLObjects**
    - a **clFinish** after **clEnqueueReleaseGLObjects**
  - **glFinish** / **clFinish** are heavyweight APIs

OpenCL 1.1 – OpenCL/OpenGL Sharing

- **Improve performance of OpenCL/ OpenGL interoperability**
  - Create a OpenCL event from an OpenGL sync object
  - Create a OpenGL sync object from a OpenCL event
  - Allows for a finer grained waiting mechanism
    - Use **event_wait_list** argument for events that refer to OpenGL commands to complete
    - Use OpenGL sync APIs to wait for specific OpenCL™ commands to complete