









ND RANGE KERNELS







LEARNING OBJECTIVES

- Learn about the SYCL execution and memory model
- Learn how to enqueue an nd-range kernel functions

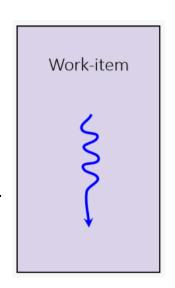








- SYCL kernel functions are executed by work-items
- You can think of a work-item as a thread of execution
- Each work-item will execute a SYCL kernel function from start to end
- A work-item can run on CPU threads, SIMD lanes, GPU threads, or any other kind of processing element

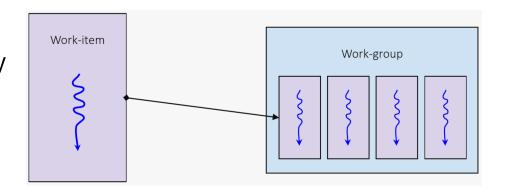








- Work-items are collected together into work-groups
- The size of work-groups is generally relative to what is optimal on the device being targeted
- It can also be affected by the resources used by each work-item



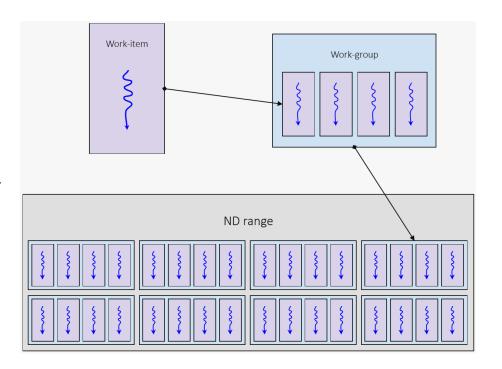








- SYCL kernel functions are invoked within an nd-range
- An nd-range has a number of workgroups and subsequently a number of work-items
- Work-groups always have the same number of work-items

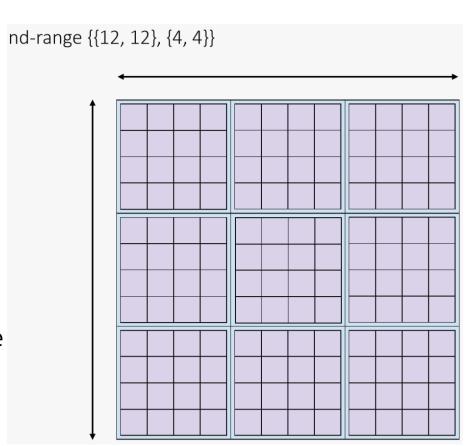








- The nd-range describes an iteration space; how the work-items and work-groups are composed
- An nd-range can be 1, 2 or 3 dimensions
- An nd-range has two components
 - The global-range describes the total number of workitems in each dimension
 - The local-range describes the number of work-items in a work-group in each dimension

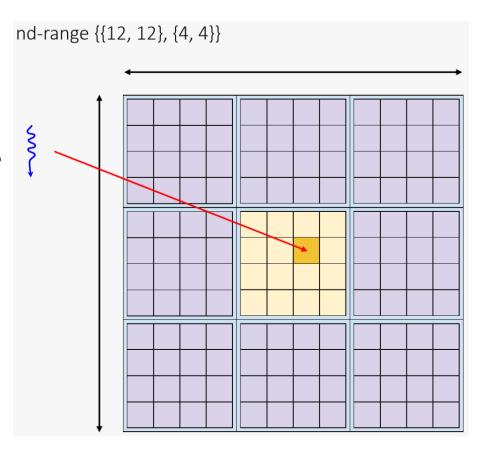






SYCL_{TM}

- Each invocation in the iteration space of an nd-range is a work-item
- Each invocation knows which workitem it is on and can query certain information about its position in the nd-range
- Each work-item has the following:
 - Global range: {12, 12}
 - **Global id**: {5, 6}
 - **Group range**: {3, 3}
 - Group id: {1, 1}
 - **Local range**: {4, 4}
 - Local id: {1, 2}









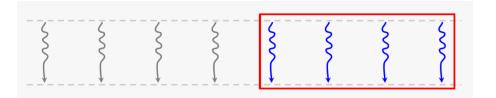
Typically an nd-range invocation SYCL will execute the SYCL kernel function on a very large number of work-items, often in the thousands





SYCL_{TM}

- Multiple work-items will generally execute concurrently
- On vector hardware this is often done in lock-step, which means the same hardware instructions
- The number of work-items that will execute concurrently can vary from one device to another
- Work-items will be batched along with other work-items in the same work-group
- The order work-items and workgroups are executed in is implementation defined

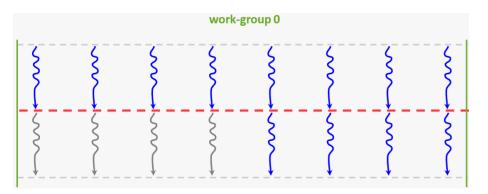








- Work-items in a work-group can be synchronized using a work-group barrier
 - All work-items within a workgroup must reach the barrier before any can continue on

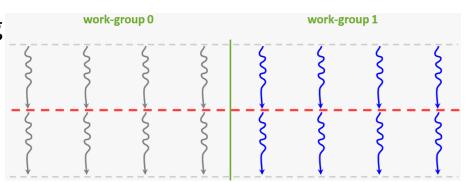








- SYCL does not support synchronizing across all work-items in the nd-range
- The only way to do this is to split the computation into separate SYCL kernel functions

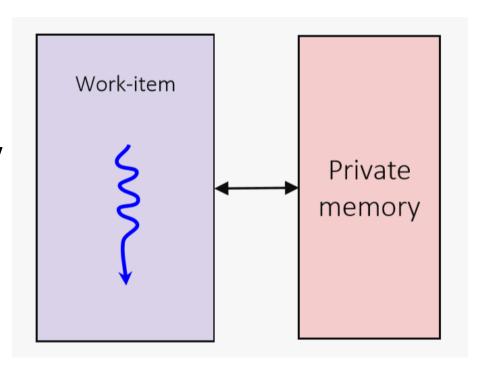




SYCL MEMORY MODEL



- Each work-item can access a dedicated region of private memory
- A work-item cannot access the private memory of another workitem

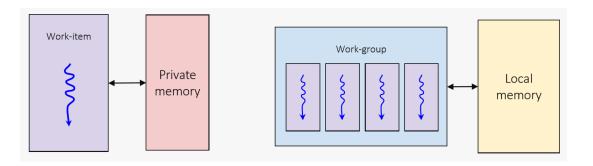






SYCL MEMORY MODEL





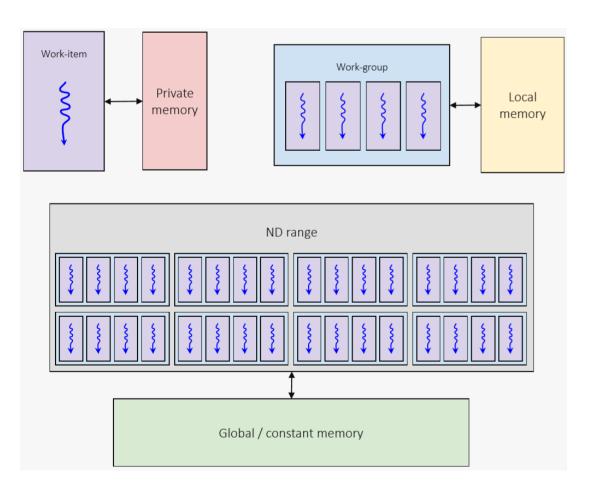
- Each work-item can access a dedicated region of local memory accessible to all work-items in a work-group
- A work-item cannot access the local memory of another workgroup





SYCL MEMORY MODEL





- Each work-item can access a single region of global memory that's accessible to all work-items in a ND-range
- Each work-item can also access a region of global memory reserved as constant memory, which is read-only

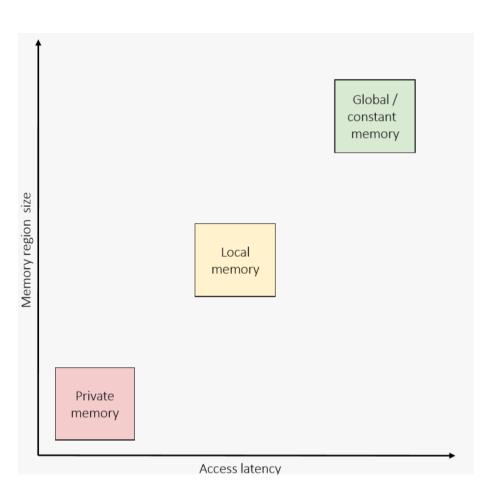








- Each memory region has a different size and access latency
- Global / constant memory is larger than local memory and local memory is larger than private memory
- Private memory is faster than local memory and local memory is faster than global / constant memory









```
SYCL.
```

- Overload taking a range object specifies the global range, runtime decides local range
- An **id** parameter represents the index within the global range
- Overload taking a range object specifies the global range, runtime decides local range
- An **item** parameter represents the global range and the index within the global range

```
cgh.parallel_for<kernel>(range<1>(1024),
   [=](id<1> idx) {
      /* kernel function code */
});
```

```
cgh.parallel_for<kernel>(range<1>(1024),
    [=](item<1> item) {
        /* kernel function code */
});
```







ACCESSING DATA WITH ACCESSORS

- There are a few different ways to access the data represented by an accessor
 - The subscript operator can take an id
 - Must be the same dimensionality of the accessor
 - For dimensions > 1, linear address is calculated in row major
- Nested subscript operators can be called for each dimension taking a size_t
 - E.g. a 3-dimensional accessor: acc[x][y][z] = ...
- A pointer to memory can be retrieved by calling get_pointer
 - This returns a raw pointer to the data









```
buffer<float, 1> bufA(dA.data(), range<1>(dA.size()));
buffer<float, 1> bufB(dB.data(), range<1>(dB.size()));
buffer<float, 1> bufO(dO.data(), range<1>(dO.size()));

gpuQueue.submit([&] (handler &cgh) {
    sycl::accessor inA{bufA, cgh, sycl::read_only};
    sycl::accessor inB{bufB, cgh, sycl::read_only};
    sycl::accessor out{bufO, cgh, sycl::write_only};
    cgh.parallel_for<add>(range<1>(dA.size()),
        [=](id<1> i) {
        out[i] = inA[i] + inB[i];
    });
});
```

 Here we access the data of the accessor by passing in the id passed to the SYCL kernel function.





```
SYCL<sub>TM</sub>
```

```
buffer<float, 1> bufA(dA.data(), range<1>(dA.size()));
buffer<float, 1> bufB(dB.data(), range<1>(dB.size()));
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gpuQueue.submit([&] (handler &cgh) {
    sycl::accessor inA{bufA, cgh, sycl::read_only};
    sycl::accessor inB{bufB, cgh, sycl::write_only};
    sycl::accessor out{bufO, cgh, sycl::write_only};
    cgh.parallel_for<add>(rng, [=](id<3> i) {
        auto ptrA = inA.get_pointer();
        auto ptrO = out.get_pointer();
        auto linearId = i.get_linear_id();

        ptrA[linearId] = ptrB[linearId] + ptrO[linearId];
    });
});
```

- Here we retrieve the underlying pointer for each of the accessors.
- We then access the pointer using the linearized id by calling the get_linear_id member function on the item.
- Again this linearization is calculated in row-major order.





QUESTIONS







EXERCISE

Code_Exercises/Exercise_14_ND_Range_Kernel/source

Implement a SYCL application that will perform a vector add using parallel_for, adding multiple elements in parallel.

