Introduction to SYCL

SYCL Tutorial
IWOCL 2015-05-12

Introduction

- I am
  - Lee Howes
  - Senior staff engineer
  - GPU systems team at Qualcomm
  - Co-spec editor for SYCL and OpenCL
- lhowes@qti.qualcomm.com

Introduction

- This tutorial is a joint effort between Qualcomm, AMD and Codeplay

- As a result, the tutorial is accidentally a trilogy in five parts (with thanks to Douglas Adams):

1. Introduction to SYCL
2. Modern C++ and SYCL
3. SYCL and the Parallel-STL
4. triSYCL: Open source SYCL
5. Hands on with Codeplay's implementation

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Background

- Support for C++ has been a common request for OpenCL

- The weak link between host and kernel code is prone to errors
  - People solve using stub generation and stringification scripts
  - Making this interface strongly typed is a better solution

- The C++ standard is continuing to modernize
  - Well-defined memory model
  - Move towards better concurrency and parallelism definitions

KHRONOS GROUP

What is SYCL™ ?

- We set out to define a standard for OpenCL that addresses these issues

- SYCL
  - Pronounced SICKLE

- Royalty-free, cross platform C++ programming layer
  - Builds on concepts of portability and efficiency

- A Higher Level Model on top of OpenCL

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What is SYCL ?

- **Single source C++**
  - Without language extensions
  - Will build through a standard C++ compiler – though without OpenCL device support

- **Single Source Development Cycle**
  - C++ source contains functions which can be on both host and device
  - Allows to construct reusable templates for algorithms which use OpenCL for acceleration
  - Type safe interaction between host and device code

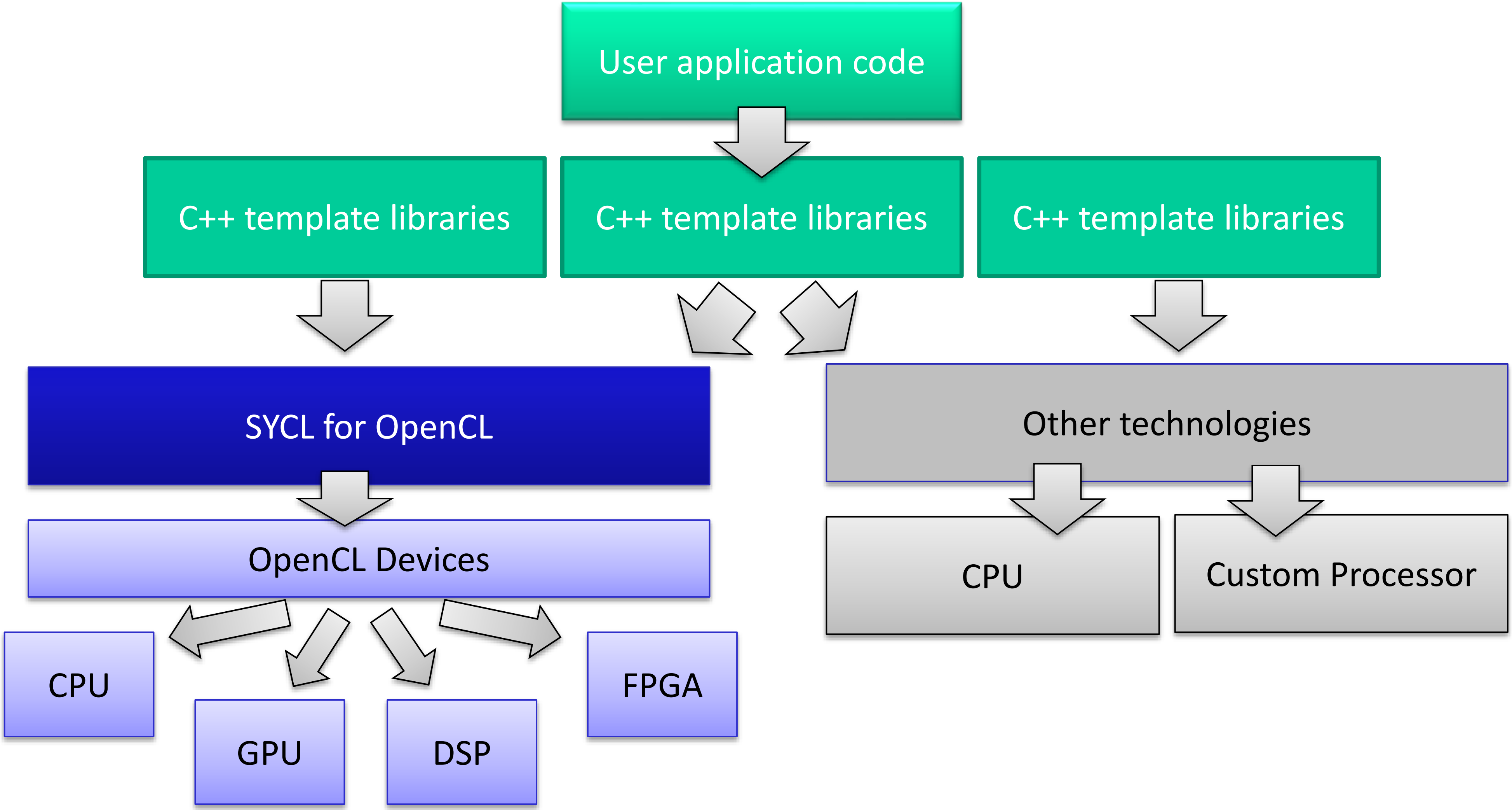
The SYCL™ 1.2 specification

- **Here at IWOCL we are launching the SYCL 1.2 specification**

- **Based on earlier provisional specifications**
  - We have incorporated feedback from developers
  - We have streamlined interfaces to better match standard C++ development
  - We have made consistency fixes with a view to quickly incorporating OpenCL 2.1 features

- **Specifications are available:**
  - https://www.khronos.org/opencl/sycl

Overview


User application code
C++ template libraries
C++ template libraries
C++ template libraries
SYCL for OpenCL
Other technologies
OpenCL Devices
CPU
Custom Processor
CPU
GPU
DSP
FPGA

Shared source

- **Host code and device code in the same flow**
  - Simplifies basic examples

```
#include <CL/sycl.hpp>
#include <iostream>

int main() {
  using namespace cl::sycl;

  int data[1024];  // initialize data to be worked on

  // By including all the SYCL work in a {} block, we ensure
  // all SYCL tasks must complete before exiting the block
  {
    //  create a queue to enqueue work to
    queue myQueue;

    // wrap our data variable in a buffer
    buffer<int, 1> resultBuf(data, range<1>(1024));

    // create a command_group to issue commands to the queue
    myQueue.submit([&](handler& cgh) {
      // request access to the buffer
      auto writeResult = resultBuf.get_access<access::write>(cgh);

      // enqueue a prallel_for task
      cgh.parallel_for<class simple_test>(range<1>(1024), [=](id<1> idx) {
        writeResult[idx] = idx[0];
      });  // end of the kernel function
    });    // end of our commands for this queue
  }        // end of scope, so we wait for the queued work to complete

  // print result
  for (int i = 0; i < 1024; i++)
    std::cout<<"data["<<i<<"] = "<<data[i]<<std::endl;

  return 0;
}
```

Shared source

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Host

Host

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Shared source

- **Host code and device code in the same flow**
  - Simplifies basic examples

- **Device code carries certain restrictions**

Device (bracket marking the device code: the `myQueue.submit` lambda body)

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Shared source

- **Host code and device code in the same flow**
  - Simplifies basic examples

- **Device code carries certain restrictions**

- **The big benefit is the tight type system integration**
  - writeResult here must give access to int
  - Type checks correctly against the cast
  - We'll see this more clearly later

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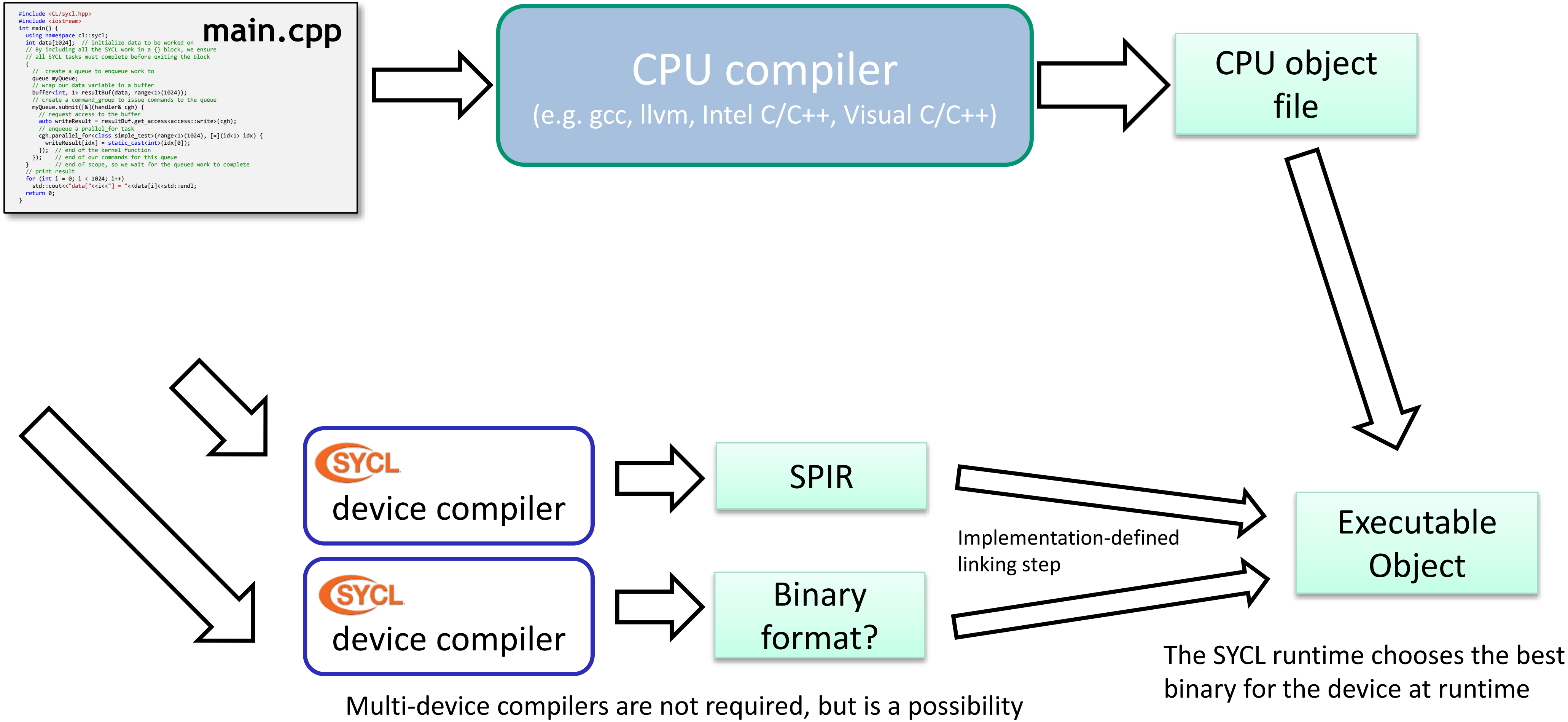
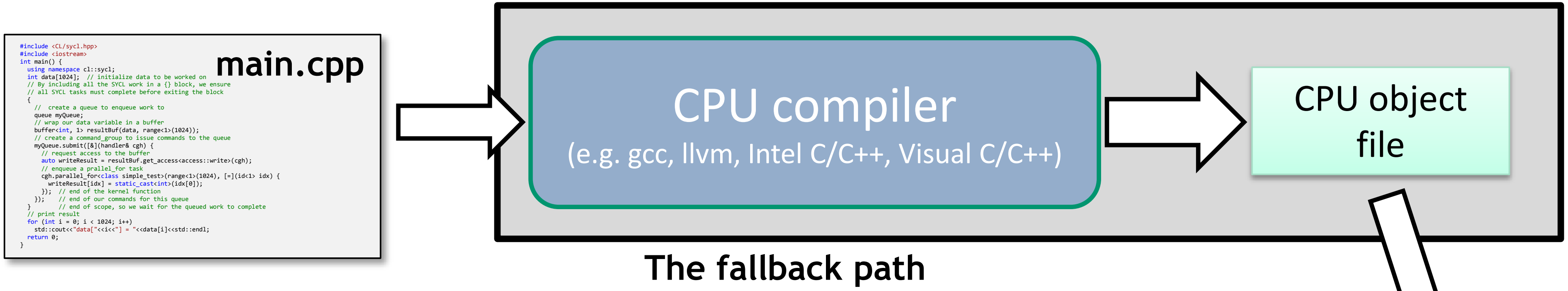
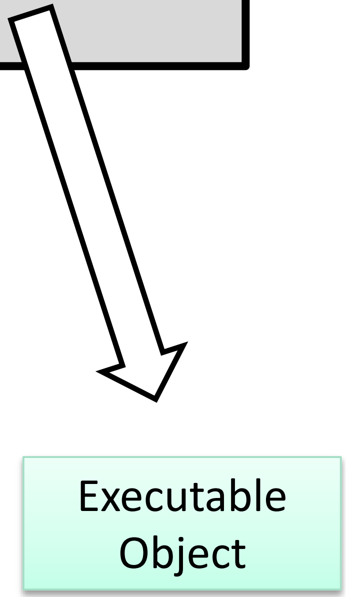
Build Process Overview



Host fallback





- **As it is standard C++ the host compiler path acts as a fallback**
  - Exposed to the SYCL host APIs as a true device with or without an OpenCL runtime
- **Make use of standard C++ compiler optimisations**

Flexible host code

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Flexible host code

- **Defaults to simplify object construction**
  - Default queue here chooses default device, context and platform
- **Type safe buffers**
- **Classes for control where necessary**
  - Context, platform, device
  - Selector classes to choose devices
  - Images
  - Programs and Kernels

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Abstracting tasks through handlers

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Abstracting tasks through handlers

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- Traces ordering of parallel operations within the C++ memory model
- Enables clean scope structure for correctly scheduled object destruction

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Accessors

- **Acquire access to a host buffer via the RAII paradigm**
- **Access falls out of scope at the end of the queue entry**

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Parallel execution

- **OpenCL-style SPMD execution through parallel_for operation**
  - Define an iteration space
- **Pass a function object/lambda**
  - Represents the function executed at each point

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Parallel execution

- **OpenCL-style SPMD execution through parallel_for operation**
  - Define an iteration space
- **Pass a function object/lambda**
  - Represents the function executed at each point
- **Execution index passed in to each iteration**
  - Number of dimensions, style of access well-defined
  - No calling of global built-ins

```
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    [=](id<1> idx) {
      writeResult[idx] = idx[0];
    }); // end of the kernel function
  });    // end of our commands for this queue
}
```

Naming the kernel

- **SYCL does not use language extensions**
- **SYCL does not require a single source compiler**
  - Host code can run through the standard host compiler
- **We need to link host and device code together**
  - This relies on the type of the kernel body object
  - Lambda types are implementation-defined
- **Therefore we have to name them**

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```

Other kernel features

- Vector classes:
  - vec<T, dims>

- Subset of iostream functionality
  - Better type safety than printf

- Full OpenCL maths library support

- C++-style atomic operations

Variations on dispatch

```
auto command_group = [&](handler & cgh) {
cgh.single_task<class kernel_name>(
    [=] () {
      // [kernel code]
    }));
};
```

Very simple single instance
Equivalent to clEnqueueTask

Simple map operation over an iteration space
No local memory, no barriers, no information about the range size

```
class MyKernel;

myQueue.submit( [&](handler & cmdgroup)
{
    auto acc=myBuffer.get_access<read_write>();

    cmdgroup.parallel_for<class MyKernel>(
      range<1>(workItemNo),
      [=] (id<1> index)
      {
        acc[index] = 42.0f;
      });
});
```

Variations on dispatch

```
class MyKernel;

myQueue.submit([&](handler & cmdgroup)
{
    auto acc=myBuffer.get_access<read_write>();

    cmdgroup.parallel_for<class MyKernel>(range<1>(workItemNo),
      [=] (item<1> myItem)
      {
        size_t index = item.get_global();
        acc[index] = 42.0f;
      });
  });
}
```

Adding information about the range
Item carries more information about the iteration space

Adding work-groups
Addition of work-groups allows us to use barriers and communication via local memory

```
auto command_group = [&](handler& cgh) {
  cgh.parallel_for<class example_kernel>(
      nd_range(range(4, 4, 4), range(2, 2, 2)),
      [=](nd_item<3> item) {
        //[kernel code]
        // Internal synchronization
        item.barrier(access::fence_space::global);
        //[kernel code]
      });
};
```

Hierarchical parallelism

- **Better match the developer's intent and thought process**
  - Reduce the need for a developer to mentally slice the execution into work-items
- **Make work-group code explicitly separate from per-work-item code**
  - Ease compiler's job identifying uniform operations and scalar code
- **Make barriers implicit**
  - Loop fission is no longer necessary to map to the CPU
  - More performance portable

```
auto command_group = [&](handler & cgh) {
  // Issue 8 work-groups of 8 work-items each
  cgh.parallel_for_work_group<class example_kernel>(
      range<3>(2, 2, 2), range<3>(2, 2, 2),
    [=](group<3> myGroup) {

      //[workgroup code]
      int myLocal;  // this variable shared between workitems

      private_memory<int> myPrivate(myGroup);

      parallel_for_work_item(myGroup, [=](item<3> myItem) {
        //[work-item code]
        myPrivate(myItem) = 0;
      });

      parallel_for_work_item(myGroup, [=](item<3> myItem) {
        //[work-item code]
        output[myGroup.get_local_range()*myGroup.get()+myItem]
          = myPrivate(myItem);
      });
      //[workgroup code]
    });
});
```

Remainder of the tutorial

- **Ronan Keryell - Modern C++ and SYCL**

- **Ruyman Reyes - SYCL for Parallel STL**
  - SYCL is standard C++ and is intended to underpin OpenCL-based implementations of developing C++ concurrency features

- **Ronan Keryell - triSYCL: open source SYCL runtime**
  - SYCL is standard C++ and triSYCL implements it entirely on the CPU

- **Ruyman Reyes and Maria Rovatsou - Hands on with SYCL**
  - A hands on tutorial on top of a virtual machine