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SYCL/DPC++ – An Introduction

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Goal of this talk

1. Give you a feel of SYCL/DPCPP
2. Tease you enough so you want to play with SYCL during the Hands-on[1]
3. Question are welcomed!

[1] Or at least watch me going through some examples... on Exclusive Hardware!

Introduction

What programming model to use to target GPU?

- Parallel STL
- OpenMP (pragma based)
- CUDA[2] / HIP[3] / OpenCL[4] (low level)
- Kokkos, raja, OCCA (high level, abstraction layer, academic project)
- SYCL (high level) / DPCPP[5]

[2] Compute Unified Device Architecture
[3] Heterogeneous-Compute Interface
[4] Open Computing Language
[5] Data Parallel C++

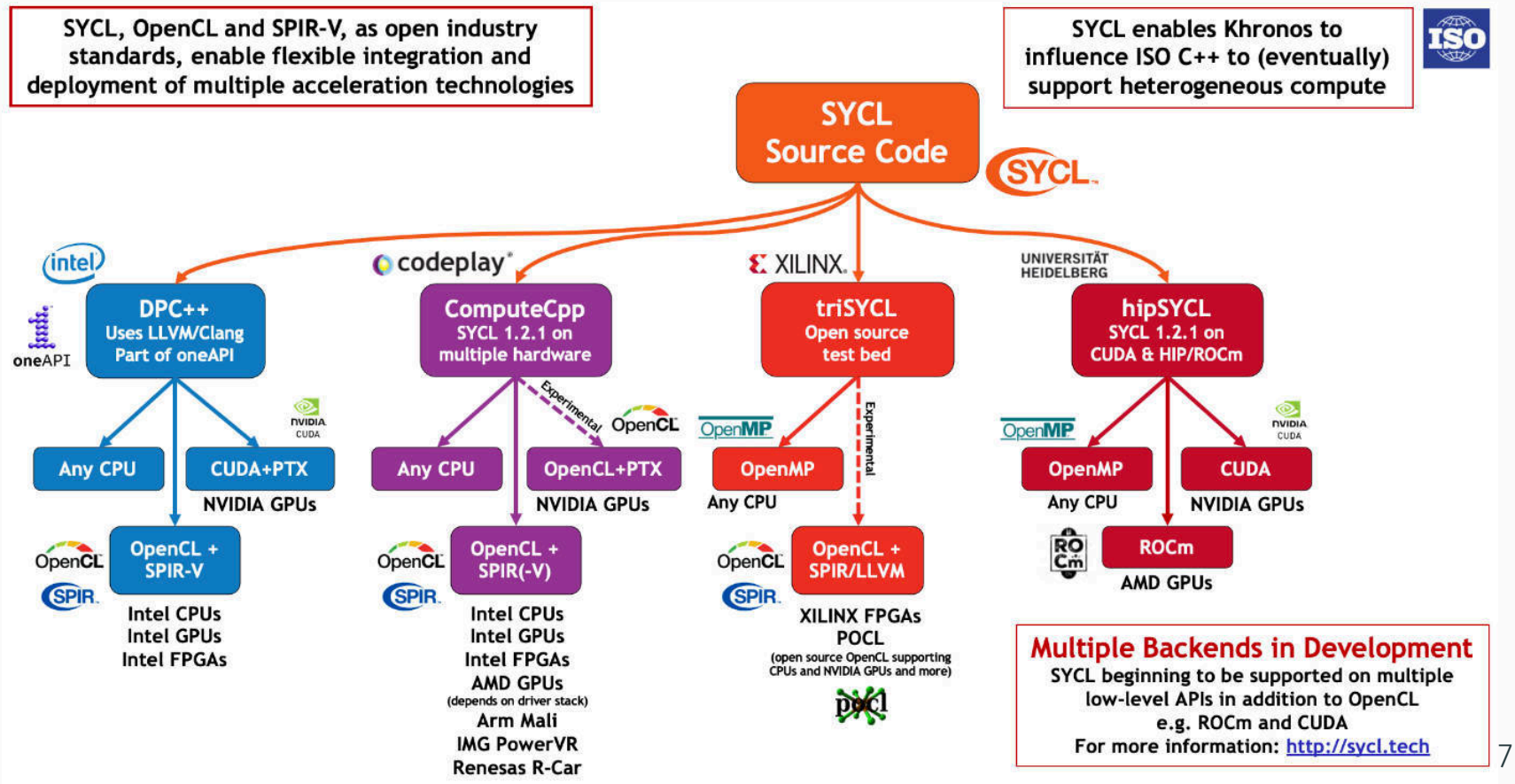
What is SYCL™?

1. Target C++ programmers (template, lambda)
   - No language extension
   - No pragmas
   - No attribute
2. Borrow lot of concept from battle tested OpenCL (platform, device, work-group, range)
3. Single Source (two compilation pass)
4. Implicit data-transfer
5. SYCL is a Specification developed by the Khronos Group (OpenCL, SPIR, Vulkan, OpenGL)

- The current stable SYCL specification is 1.2.
- SYCL 2020 is expected to be approved at the end of the years[6].

[6] https://www.khronos.org/registry/SYCL/specs/sycl-2020-provisional.pdf

SYCL Implementation



[7]

[7] Credit: Khronos groups (*https://www.khronos.org/sycl/*)

What is DPCPP[10]?

- Intel implementation of SYCL[8]
- The name of the SYCL-aware Intel compiler[9]

[8] Obvious from the name isn't it?
[9] So you don't need to pass `-fsycl`
[10] Data Parallel C++: *https://github.com/intel/llvm/releases*

DPCPP (and the associated ecosystem)

DPCPP a high potential SYCL implementation

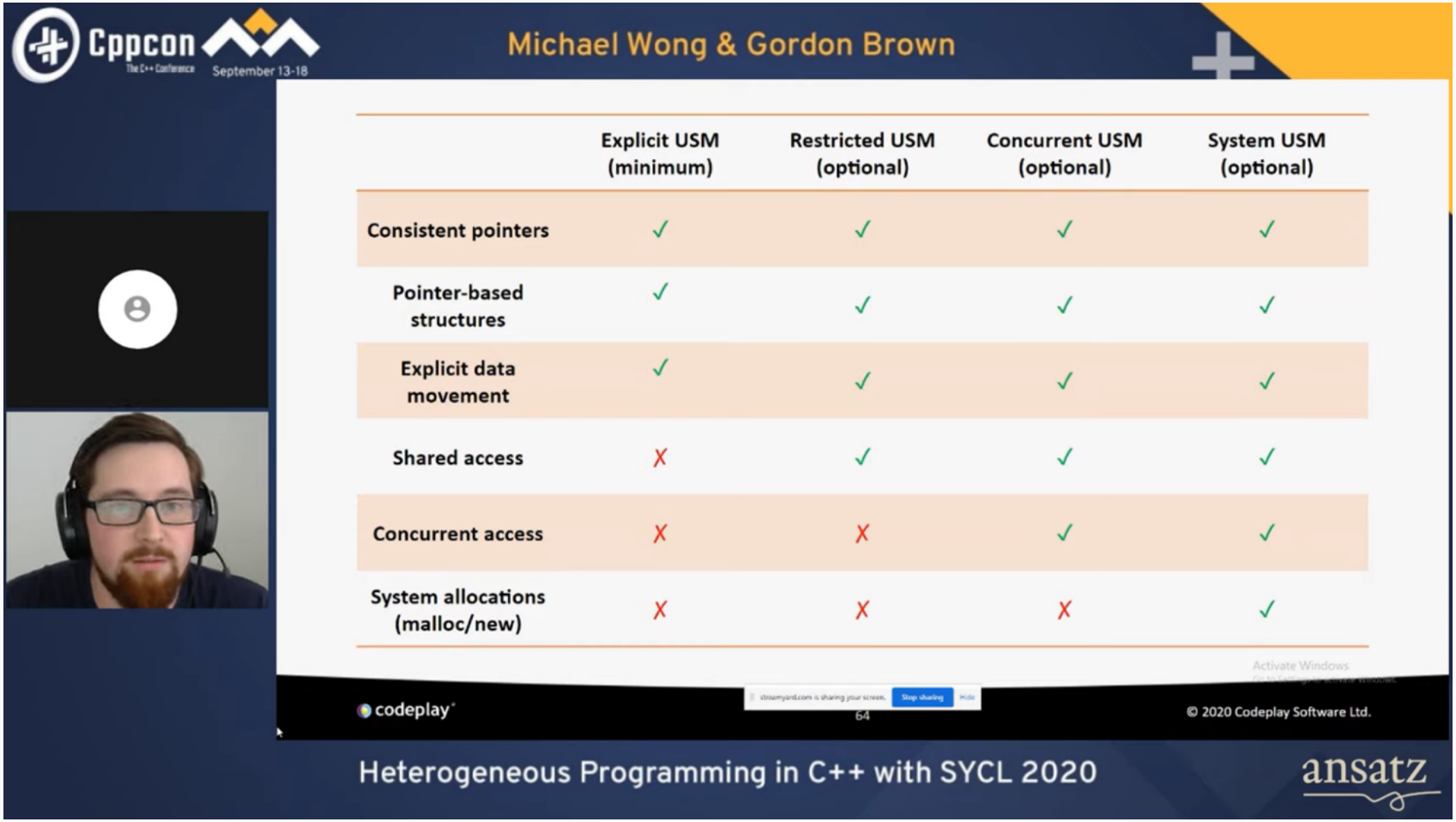
DPCPP implement the SYCL Standard + extension[11]

- Unnamed Lambda
- Unified Shared Memory
- Reduction
- Magic introspection function
- Explicit SIMD

Many of DPCPP extension are now merged in the new SYCL2020 standard!

[11] *https://github.com/intel/llvm/tree/sycl/sycl/doc/extensions*

A note on USM


Cppcon
The C++ Conference
September 13-18
Michael Wong & Gordon Brown
Explicit USM (minimum)
Restricted USM (optional)
Concurrent USM (optional)
System USM (optional)
Consistent pointers
Pointer-based structures
Explicit data movement
Shared access
Concurrent access
System allocations (malloc/new)
codeplay
64
© 2020 Codeplay Software Ltd.
Heterogeneous Programming in C++ with SYCL 2020
ansatz

Interoperability

- SYCL2020: with Native programming model (OpenCL, Cuda, ...)
  - Creating sycl Buffer with `cl_men`
  - Creating sycl Kernel from Opencl Kernel
- DPCPP: With OpenMP. Not yet memory compatibly. But on the pipeline[12]

[12] *https://software.intel.com/content/www/us/en/develop/documentation/oneapi-programming-guide/top/software-development-process/composability/c-c-openmp-and-dpc-composability.html*

DPCT: CUDA to DPCPP translator[14]

1. This is not a CUDA to DPCPP source to source compiler[13].
2. "Tool Assisted Porting", not part of th
3. `module load dpct` on JLSE

[13] It's a little more complex than a perl script

[14] *https://software.intel.com/content/www/us/en/develop/documentation/oneapi-programming-guide/top/software-development-process/migrating-code-to-dpc/migrating-from-cuda-to-dpc.html*

oneMKL[15]

> *oneMKL interfaces are an open-source implementation of the oneMKL Data Parallel C++ (DPC++) interface according to the oneMKL specification. It works with multiple devices (back-ends) using device-specific libraries underneath.*

`https://github.com/oneapi-src/oneMKL`

[15] `https://software.intel.com/content/www/us/en/develop/tools/oneapi/components/onemkl.html`

Vtunes / Advisor / iprof

1. Lot of profiler available for SYCL/DPCPP
2. iprof [16], will trace the underlying back-end calls

```
$ iprof ./4_buffer
Running on Intel(R) Gen12LP HD Graphics NEO
A[ 0 ] = 0

== OpenCL ==
API calls | 1 Hostnames | 1 Processes | 1 Threads

                    Name |      Time | Time(%) | Calls |  Average |
          clBuildProgram | 112.49ms |  97.69% |     1 | 112.49ms |
          clCreateBuffer |   1.50ms |   1.30% |     1 |   1.50ms |
clEnqueueNDRangeKernel | 584.20us |   0.51% |     1 | 584.20us |
                   Total | 115.15ms | 100.00% |     4 |

[...]
```

[16] For iprof `module load iprof`

Theory

First thing first: λ !

Constructs a closure: an unnamed function object capable of capturing variables in scope.

Lambda Hello World[17]

```
1  int main() {
2    //[] -> Capture;  [=] capture by value, [&] capture by reference
3    //() -> Parameter
4    //{} -> Body
5    [](){};
6    return 0;
7  }
```

```
1  void printVector(vector<int> v) {
2      const offset = 0;
3      // lambda expression to print vector
4      for_each(v.begin(), v.end(), [=](int i) {
5          cout << offset + i << endl;
6      });
7  }
```

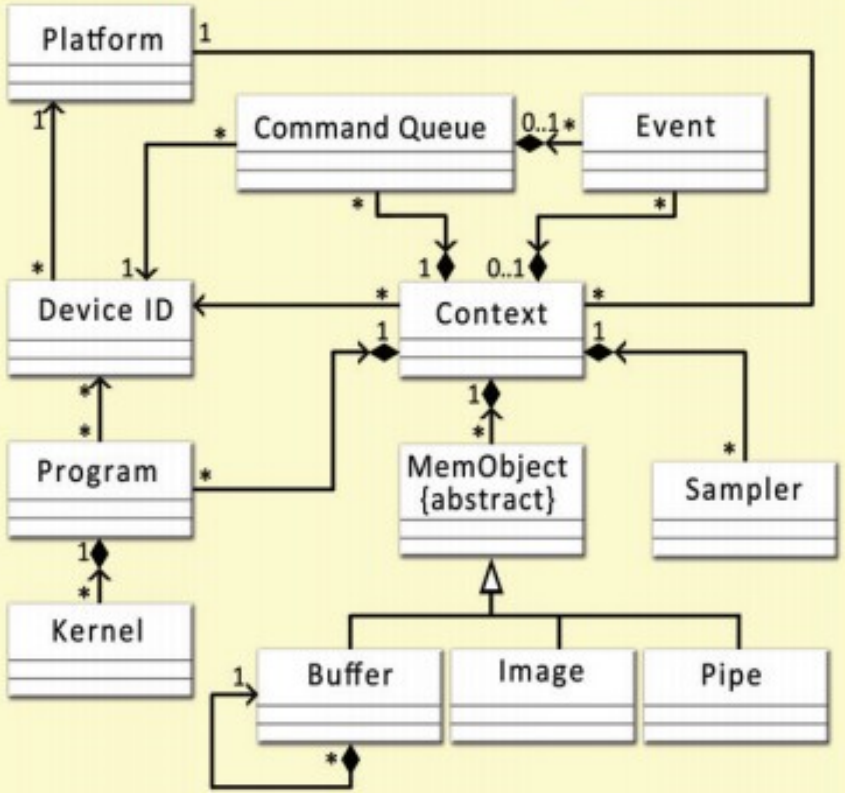
[17] Yes, it look like APL

A picture is worth a thousand words[18]

OpenCL Class Diagram

The figure below describes the OpenCL specification as a class diagram using the Unified Modeling Language[1] (UML) notation. The diagram shows both nodes and edges which are classes and their relationships. As a simplification it shows only classes, and no attributes or operations.

Annotations	
Relationships	
abstract classes	{abstract}
aggregations	♦
inheritance	△
relationship navigability	^
Cardinality	
many	*
one and only one	1
optionally one	0..1
one or more	1..*



[1] Unified Modeling Language (http://www.uml.org/) is a trademark of Object Management Group (OMG).

[18] and this is a UML diagram so maybe more!

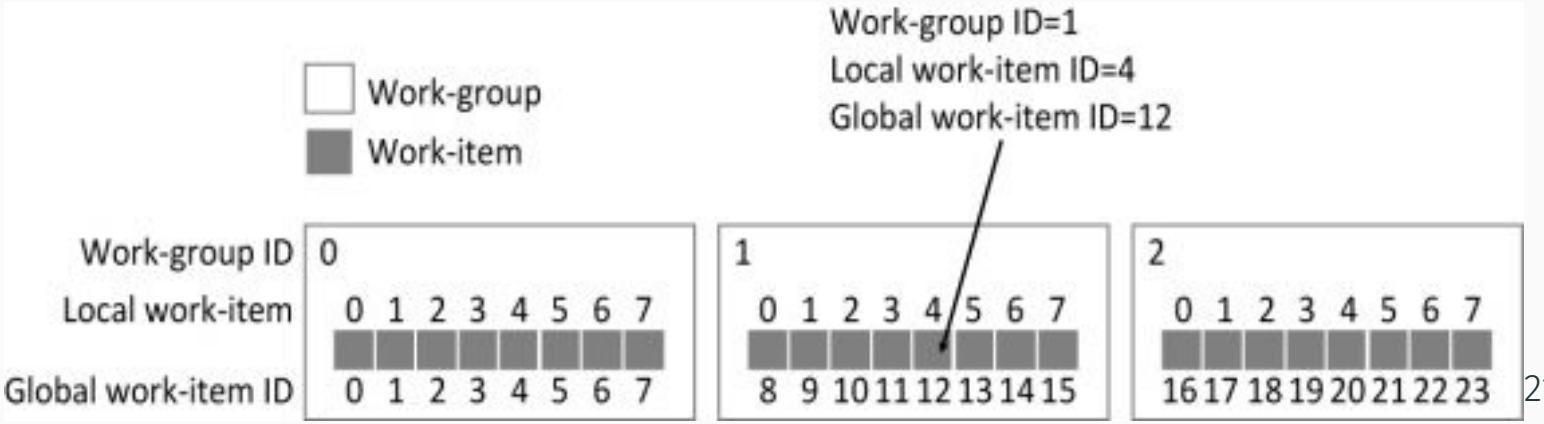
Memory management: SYCL innovation

1. Buffers encapsulate your data
2. Accessors describe how you access those data
3. Buffer destruction will cause synchronization

- Or you can also use Unified shared memory

Implicit Loop

- A Kernel is invoked once for each work item [19]
- local work size Work items are grouped into a work group [20]
- The total number of all work items is specified by the global work size



[21]

[19] similar to *MPI_rank*
[20] similar to *pragma omp simdlen/safelen*
[21] Credit The OpenCL Programming Book by Fixstars

Implicit Loop: Example!

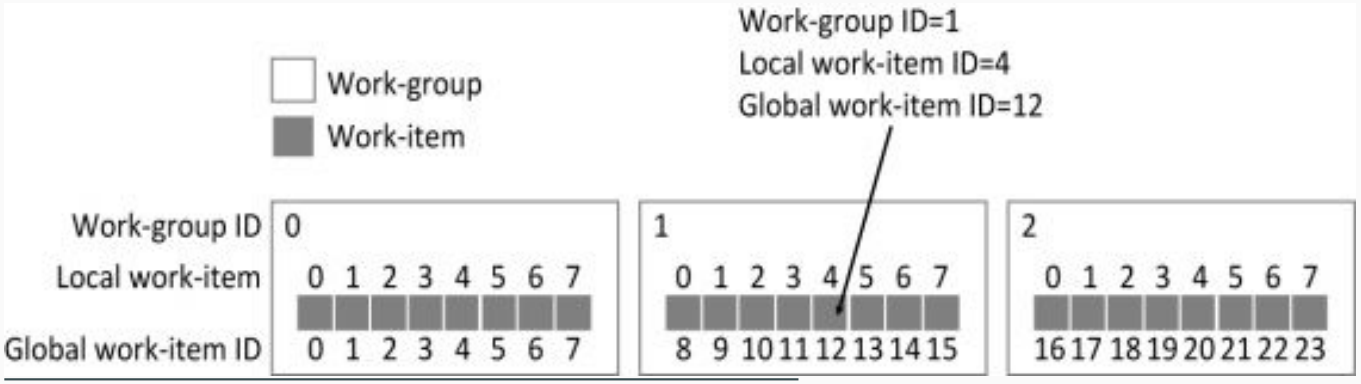
```
global_work_size = 24 ; local_work_size = 8
```

SYCL / Opencl / CUDA

```
parallel_for<global_work_size,local_work_size>(mykernel);
```

OpenMP[22]

```
# wG = work_group ; wC = work_item
for (wG_id=0; wG_id++; wG_id < (global_work_size / local_work_size)
    for (local_wI_id=0; local_wI_id++; local_wI_id < local_work_size)
        global_wI_id = local_wI_id + wG_id*local_wG_size
```



[22] Using chunking / tilling / vectorization technique

SYCL Example

```
1   std::vector<int> A(global_range);
2   {
3     sycl::buffer<sycl::cl_int, 1> bufferA(A.data(), A.size());
4     sycl::queue myQueue;
5     myQueue.submit([&](sycl::handler &cgh) {
6       auto accessorA = bufferA.get_access<sycl::access::mode::write>(cgh);
7       cgh.parallel_for<class hello_world>(
8         sycl::range<1>(global_range),
9         [=](sycl::id<1> idx) { accessorA[idx] = idx[0];}
10      );
11    });
12  }
```

Teasing: SYCL Explicit SIMD Example

```
1    q.submit([&](handler &cgh) {
2         auto PA = bufa.get_access<access::mode::read>(cgh);
3         auto PB = bufb.get_access<access::mode::read>(cgh);
4         auto PC = bufc.get_access<access::mode::write>(cgh);
5         cgh.parallel_for<class Test>(
6             GlobalRange * LocalRange, [=](id<1> i) SYCL_ESIMD_KERNEL {
7               using namespace sycl::INTEL::gpu;
8               unsigned int offset = i * VL * sizeof(float);
9               simd<float, VL> va = block_load<float, VL>(PA, offset);
10              simd<float, VL> vb = block_load<float, VL>(PB, offset);
11              simd<float, VL> vc = va + vb;
12              block_store(PC, offset, vc);
13            });
14      });
```

”Pro” tips

1. Queue creation are expensive. Try to reuse the queue[23]
2. The easiest way to achieved parallel execution of kernel, is to use mutiple queue.
3. You need also to pass ID around, sometime it can be tedious. dpcpp provide an extension to emulate OpenCL `get_global_id()`
4. Use compatibility and USM to ease the porting

[23] You already pass `mpi_com_world` around, just do the same things.

Conclusion

Conclusion

1. For better or worth, SYCL is C++
2. Many vendors (Intel, Nvidia, AMD) and hardware (CPU, GPU, FPGA) supported
3. Implicit data-movement by default (Buffer / Accessors concepts)

Lot of goods resources online

1.2.1 Spec

1. *https://www.khronos.org/registry/SYCL/specs/sycl-1.2.1.pdf*
2. *https://www.khronos.org/files/sycl/sycl-121-reference-card.pdf*

Examples

1. *https://github.com/alcf-perfengr/sycltrain*
2. *https://github.com/codeplaysoftware/computecpp-sdk/tree/master/samples*
3. *https://github.com/jeffhammond/dpcpp-tutorial*

Documentations (oneline and books)

1. *https://sycl.tech/*
2. Mastering DPC++ for Programming of Heterogeneous Systems using C++ and SYCL (ISBN 978-1-4842-5574-2)

Q&A

Thank you! Do you have any questions?

Hands-on

```
ssh a_real_name@login.jlse.anl.gov
git clone https://github.com/alcf-perfengr/sycltrain
./sycltrain/presentation/2020_10_21_COE/fetch_a_node.yarrow.sh # Or
↪  iris.sh
cd ./sycltrain/presentation/2020_10_21_COE/
source env.jlse.rc
cd 9_sycl_of_hell
make
```