oneAPI

Cross-Architecture Programming for Accelerated Compute, Freedom of Choice for Hardware

Intel® DPC++ Compatibility Tool

March 2022

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All information provided in this deck is subject to change without notice.
Contact your Intel representative to obtain the latest Intel product specifications and roadmaps.

Agenda

- Intel® DPC++ Compatibility Tool overview
- vecAdd Migration Example
- Project migration (Rodinia NW)

Intel® DPC++ Compatibility Tool

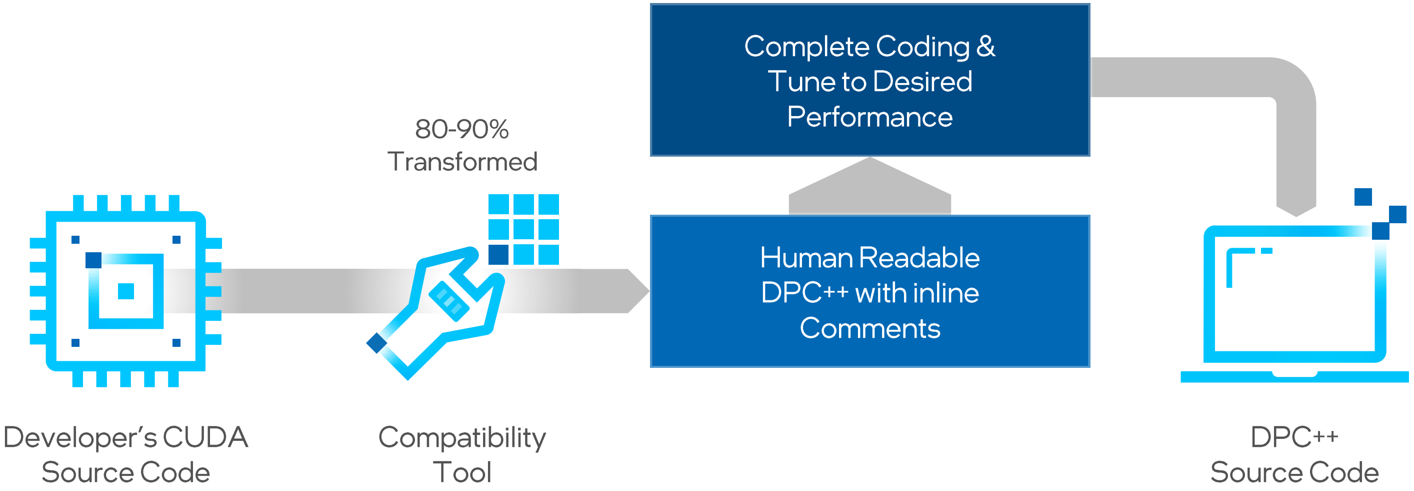
Minimizes Code Migration Time

Assists developers migrating code written in CUDA to DPC++ once, generating **human readable** code wherever possible

~80-90% of code typically migrates automatically

Inline comments are provided to help developers finish porting the application

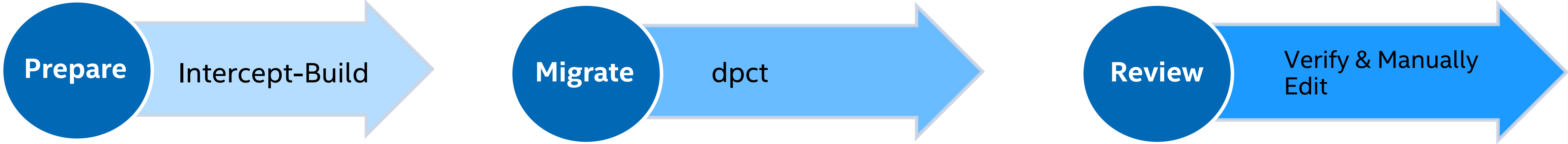
Intel DPC ++ Compatibility Tool Usage Flow



Complete Coding & Tune to Desired Performance
80-90% Transformed
Human Readable DPC++ with inline Comments
Developer's CUDA Source Code
Compatibility Tool
DPC++ Source Code

Intel® DPC++ Compatibility Tool

Migration of Large Code Bases



Prepare

Intercept-Build

Migrate

dpct

Review

Verify & Manually Edit

1. Create a compilation database file

   intercept-build make

2. Migrate your source to DPC++
   dpct -p compile_commands.json
   -in-root=$PROJ_DIR
   -out-root=dpcpp_out *.cu

3. Verify the source for correctness and fix not migrated parts

https://tinyurl.com/intel-dpcpp-compatibility-tool

Migration example

```
#include <cuda.h>

#define VECTOR_SIZE 4
__global__ void VectorAddKernel (float *A, float *B, float *C)
{
  A[threadIdx.x] = threadIdx.x + 1.0f;
  B[threadIdx.x] = threadIdx.x + 1.0f;
  C[threadIdx.x] = A[threadIdx.x] + B[threadIdx.x];
}


int main()
{


  float *d_A, *d_B, *d_C;
  cudaMalloc(&d_A, VECTOR_SIZE*sizeof(float));
  cudaMalloc(&d_B, VECTOR_SIZE*sizeof(float));
  cudaMalloc(&d_C, VECTOR_SIZE*sizeof(float));



  VectorAddKernel<<<1, VECTOR_SIZE>>>(d_A, d_B, d_C);



  float Result[VECTOR_SIZE] = { };
  cudaMemcpy(Result, d_C,VECTOR_SIZE*sizeof(float),cudaMemcpyDeviceToHost);

  cudaFree(d_A);
  cudaFree(d_B);
  cudaFree(d_C);
}
```

Header files

Kernel

Mem alloc

Kernel call

Mem copy

Mem free

```
#include <CL/sycl.hpp>
#include <dpct/dpct.hpp>
#define VECTOR_SIZE 4
void VectorAddKernel (float *A, float *B, float *C, sycl::nd_item<3> item_ct1)
{
  A[item_ct1.get_local_id(2)] = item_ct1.get_local_id(2) + 1.0f;
  B[item_ct1.get_local_id(2)] = item_ct1.get_local_id(2) + 1.0f;
  C[item_ct1.get_local_id(2)] = A[item_ct1.get_local_id(2)] + B[item_ct1.get_local_id(2)];
}


int main()
{
  dpct::device_ext &dev_ct1 = dpct::get_current_device();
  sycl::queue &q_ct1 = dev_ct1.default_queue();

  float *d_A, *d_B, *d_C;
  d_A = sycl::malloc_device<float>(VECTOR_SIZE, q_ct1);
  d_B = sycl::malloc_device<float>(VECTOR_SIZE, q_ct1);
  d_C = sycl::malloc_device<float>(VECTOR_SIZE, q_ct1);

  q_ct1.submit([&](sycl::handler &cgh){
    cgh.parallel_for(sycl::nd_range(sycl::range(1, 1, VECTOR_SIZE),
      sycl::range(1, 1, VECTOR_SIZE)), [=](sycl::nd_item<3> item_ct1) {
      VectorAddKernel(d_A, d_B, d_C, item_ct1);
    });
  });


  float Result[VECTOR_SIZE] = { };
  q_ct1.memcpy(Result, d_C, VECTOR_SIZE * sizeof(float)).wait();

  sycl::free(d_A, q_ct1);
  sycl::free(d_B, q_ct1);
  sycl::free(d_C, q_ct1);
}
```

tinyurl.com/cuda-sycl-equivalence

intel.

Queue Selection

```
/// Util function to get the defualt queue of current device in
/// dpct device manager.
static inline cl::sycl::queue &get_default_queue() {
  return dev_mgr::instance().current_device().default_queue();
}
```

```
cl::sycl::queue &default_queue() { return *_default_queue; }
```

```
 device_ext(const cl::sycl::device &base) : cl::sycl::device(base) {
#ifdef DPCT_USM_LEVEL_NONE
    _default_queue = new cl::sycl::queue(base, exception_handler);
#else
    _default_queue = new cl::sycl::queue(base, exception_handler,
                                         cl::sycl::property::queue::in_order());
#endif
    _queues.insert(_default_queue);
    _saved_queue = _default_queue;
  }
```

General Best Known Methods (BKMs)

- Migrate Incrementally
  - If you see *dpct* generate multiple errors when migrating a long list of CUDA source files in one run, do it one-by-one
- Check that dpct recognized the input code as “valid”
  - default C++ std, macro definitions and include paths
- Start with a clean project - “make clean” before running “intercept-build make”

oneAPI Development Example

ZUSE INSTITUTE BERLIN

ZIB ported *EasyWave* application from CUDA to DPC++ delivering performance across multi-architectures

- Ported EasyWave written in CUDA to Data Parallel C++ efficiently using the Intel® DPC++ Compatibility Tool
- Achieved strong performance across Intel CPU, GPU and FPGA architectures, and within 5% of CUDA performance on Nvidia P100

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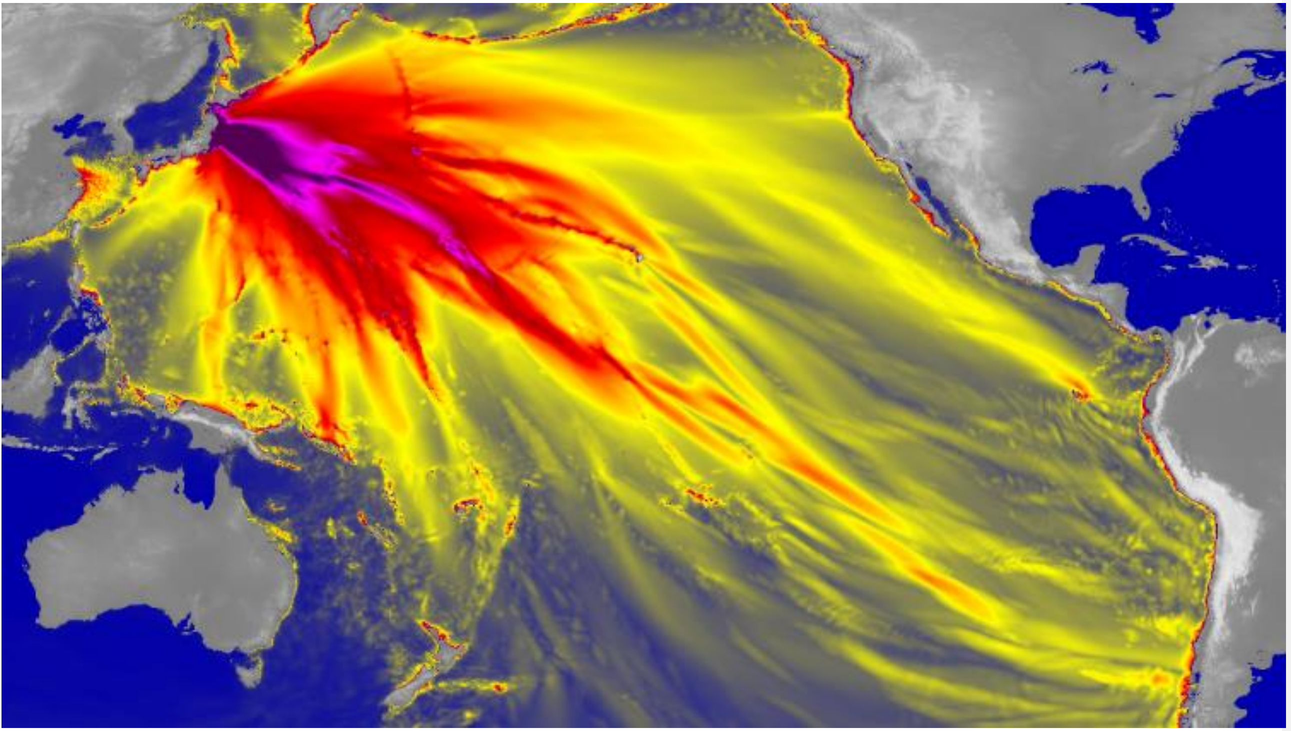


Visualization of EasyWave tsunami simulation application
Courtesy Zuse Institute Berlin (ZIB)

Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy.

easyWave - A Tsunami Simulations Application

Getting Started on DevCloud

- devcloud.intel.com
- qsub -I -l nodes=1:gpu:ppn=2 -d .
- sycl-ls (control devices via SYCL_DEVICE_FILTER)
- Compile and run simple vecAdd code
- export SYCL_PI_TRACE=1
- export SYCL_DEVICE_FILTER=level_zero

Demo

Pre-requisites on your own system:

- Get the latest oneAPI Base Toolkit:

  https://software.intel.com/content/www/us/en/develop/tools/oneapi/base-toolkit/download.html

- Set the environment, e.g. source /opt/intel/oneapi/setvars.sh

or use Intel DevCloud devcloud.intel.com

- git clone https://github.com/oneapi-src/oneAPI-samples.git
- cd oneAPI-samples/Tools/Migration/
- dpct --help

NOTE: You need to have CUDA* headers available to migrate the code

vecAdd

- *cd vector-add-dpct/src*
- *dpct --cuda-include-path=/home/u136312/include vector_add.cu*

```
NOTE: Could not auto-detect compilation database for file 'vector_add.cu' in '/home/u136312/oneAPI-samples/Tools/Migration/vector-add-dpct/src' or any parent directory.
The directory "dpct_output" is used as "out-root"
Processing: /home/u136312/oneAPI-samples/Tools/Migration/vector-add-dpct/src/vector_add.cu
/home/u136312/oneAPI-samples/Tools/Migration/vector-add-dpct/src/vector_add.cu:32:14: warning: DPCT1003:0: Migrated API does not return error code. (*, 0) is inserted. You may need to rewrite this code.
    status = cudaMemcpy(Result, d_C, VECTOR_SIZE*sizeof(float), cudaMemcpyDeviceToHost);
             ^
Processed 1 file(s) in -in-root folder "/home/u136312/oneAPI-samples/Tools/Migration/vector-add-dpct/src"

See Diagnostics Reference to resolve warnings and complete the migration:
https://software.intel.com/content/www/us/en/develop/documentation/intel-dpcpp-compatibility-tool-user-guide/top/diagnostics-reference.html
```

- File vector_add.dp.cpp is generated in dpct_output directory

vecAdd

- *dpct --cuda-include-path=/home/u136312/include --enable-ctad --out-root=test1 vector_add.cu*

  diff dpct_output/vector_add.dp.cpp test1/vector_add.dp.cpp

```
32,33c32,33
<       cgh.parallel_for(sycl::nd_range<3>(sycl::range<3>(1, 1, VECTOR_SIZE),
<                                          sycl::range<3>(1, 1, VECTOR_SIZE)),
---
>       cgh.parallel_for(sycl::nd_range(sycl::range(1, 1, VECTOR_SIZE),
>                                       sycl::range(1, 1, VECTOR_SIZE)),
```

- *dpct --cuda-include-path=/home/u136312/include --enable-ctad --out-root=test2 --keep-original-code vector_add.cu*

```
/* DPCT_ORIG __global__ void VectorAddKernel(float* A, float* B, float* C)*/
void VectorAddKernel(float *A, float *B, float *C, sycl::nd_item<3> item_ct1)
{
/* DPCT_ORIG     A[threadIdx.x] = threadIdx.x + 1.0f;*/
    A[item_ct1.get_local_id(2)] = item_ct1.get_local_id(2) + 1.0f;
/* DPCT_ORIG     B[threadIdx.x] = threadIdx.x + 1.0f;*/
    B[item_ct1.get_local_id(2)] = item_ct1.get_local_id(2) + 1.0f;
/* DPCT_ORIG     C[threadIdx.x] = A[threadIdx.x] + B[threadIdx.x];*/
    C[item_ct1.get_local_id(2)] =
        A[item_ct1.get_local_id(2)] + B[item_ct1.get_local_id(2)];
}  ...
  /* DPCT_ORIG     cudaMalloc(&d_A, VECTOR_SIZE*sizeof(float));*/
      d_A = sycl::malloc_device<float>(VECTOR_SIZE, q_ct1);
  /* DPCT_ORIG     cudaMalloc(&d_B, VECTOR_SIZE*sizeof(float));*/
      d_B = sycl::malloc_device<float>(VECTOR_SIZE, q_ct1);
  /* DPCT_ORIG     cudaMalloc(&d_C, VECTOR_SIZE*sizeof(float));*/
      d_C = sycl::malloc_device<float>(VECTOR_SIZE, q_ct1);

  /* DPCT_ORIG     VectorAddKernel<<<1, VECTOR_SIZE>>>(d_A, d_B, d_C);*/
      q_ct1.submit([&](sycl::handler &cgh) {
```

Rodinia NW

- *cd ~/dpct_demo/oneAPI-samples/Tools/Migration/rodinia-nw-dpct*

- *make clean*

1. *intercept-build make*

```
cat compile_commands.json
[
  {
    "command": "nvcc -c  -o needleman_wunsch_cu -D__CUDACC__=1 src/needle.cu",
    "directory": "/home/u136312/oneAPI-samples/Tools/Migration/rodinia-nw-dpct",
    "file": "/home/u136312/oneAPI-samples/Tools/Migration/rodinia-nw-dpct/src/needle.cu"
  }
]
```

clang.llvm.org/docs/JSONCompilationDatabase.html

2. *dpct --cuda-include-path=/home/u136312/include -p compile_commands.json --in-root=. --out-root=migration*

```
warning: DPCT1065:0: Consider replacing sycl::nd_item::barrier() with sycl::nd_item::barrier(sycl::access::fence_space::local_space) for better
performance if there is no access to global memory.

…

warning: DPCT1003:0: Migrated API does not return error code. (*, 0) is inserted. You may need to rewrite this code.

warning: DPCT1043:1: The version-related API is different in SYCL. An initial code was generated, but you need to adjust it.

warning: DPCT1009:2: SYCL uses exceptions to report errors and does not use the error codes. The original code was commented out and a
warning string was inserted. You need to rewrite this code.

…

warning: DPCT1049:5: The workgroup size passed to the SYCL kernel may exceed the limit. To get the device limit, query
info::device::max_work_group_size. Adjust the workgroup size if needed.
```

tinyurl.com/dpct-project-migration-linux

Rodinia NW

- *cp Makefile migration/*
- Replace the CUDA configurations in that new `Makefile` with the following for use with DPC++:

```
CXX = dpcpp
TARGET = needleman_wunsch_dpcpp
SRCS = src/needle.dp.cpp
DEPS = src/needle_kernel.dp.cpp src/needle.h
```

- Compilation out-of-box fails with an error similar to the following:

```
error: assigning to 'int' from incompatible type 'typename info::param_traits<info::device,
(device)4143U>::return_type' (aka 'basic_string<char>’)
```

- Need to address warnings first

Addressing Warnings in Migrated Code

warning: DPCT1003:0: Migrated API does not return error code. (*, 0) is inserted. You may need to rewrite this code.

warning: DPCT1043:1: The version-related API is different in SYCL. An initial code was generated, but you need to adjust it.

warning: DPCT1009:2: SYCL uses exceptions to report errors and does not use the error codes. The original code was commented out and a warning string was inserted. You need to rewrite this code.

- remove unnecessary code processing error codes
- need to update the code with correct SYCL device API

needle.dp.cpp

```
int version = 0;
int err_code = 999;
/* ...dpct generated comments... */
err_code = (version = dpct::get_current_device().get_info<sycl::info::device::version>(), 0);
if (err_code != 0)
/* ...dpct generated comments... */
    printf("Error \\"%s\\" checking driver version: %s.\\n",
    "cudaGetErrorName not supported" /*cudaGetErrorName(err_code)*/,
    "cudaGetErrorString not supported" /*cudaGetErrorString(err_code)*/);
else
    printf("CUDA driver version: %d.%d\n", version/1000, version%1000/10);
```

```
std::string version = dpct::get_current_device().get_info<sycl::info::device::version>();
printf("SYCL device version: %s\n", version.c_str());
```

Addressing Warnings in Migrated Code

Check warning DPCT1049:

```
 /*
DPCT1049:5: The workgroup size passed to the SYCL kernel may exceed the limit.
To get the device limit, query info::device::max_work_group_size. Adjust the
workgroup size if needed.
*/
        q_ct1.submit([&](sycl::handler &cgh) {
            sycl::range<2> temp_range_ct1(17 /*BLOCK_SIZE+1*/,
                                          17 /*BLOCK_SIZE+1*/);
            sycl::range<2> ref_range_ct1(16 /*BLOCK_SIZE*/, 16 /*BLOCK_SIZE*/);
```

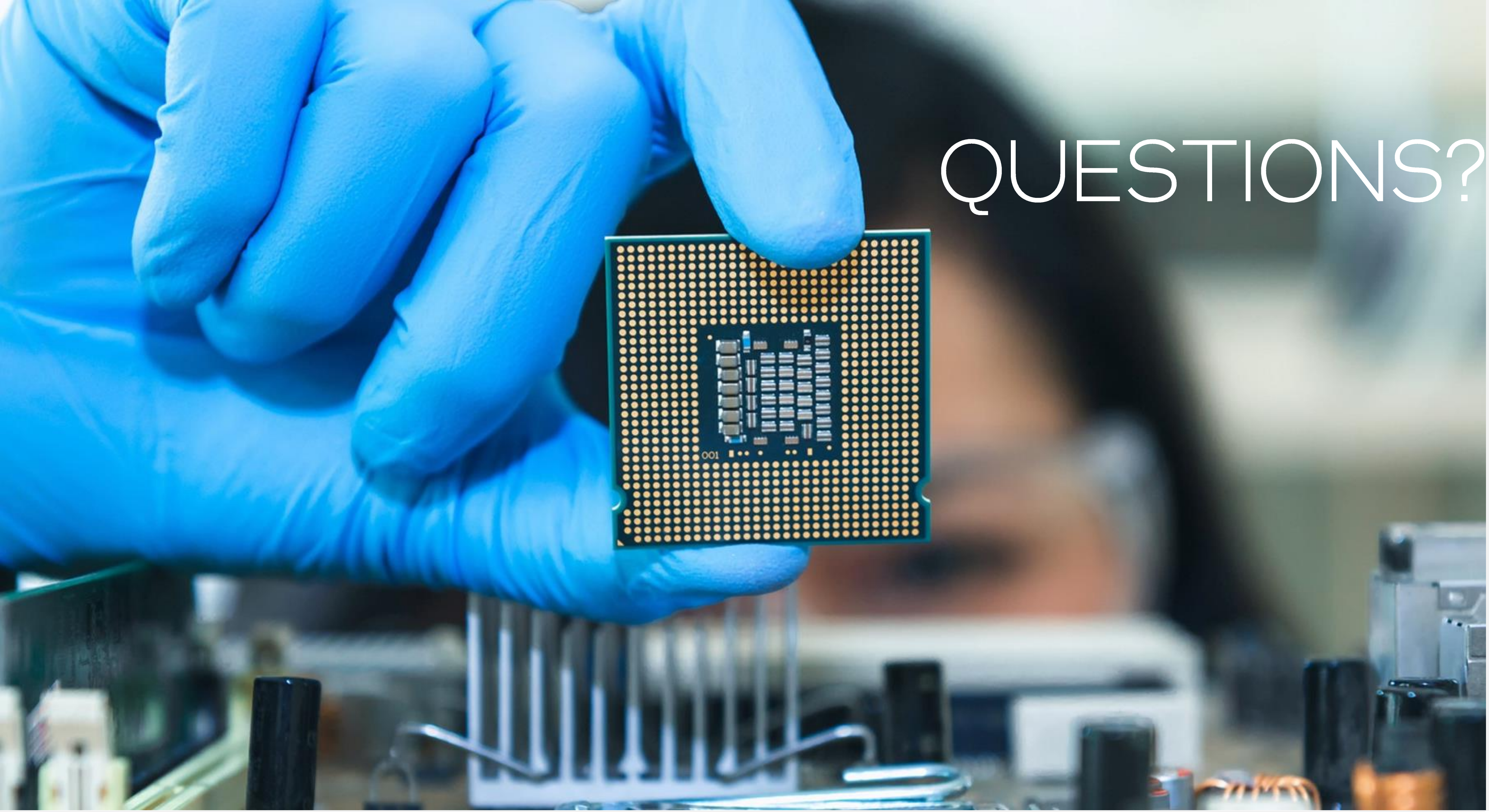
Once migration is completed, compile DPC++ code and run via make commands:

- *make*
- *make run*
- *./needleman_wunsch_dpcpp 4096 16*

```
WG size of kernel = 128
Start Needleman-Wunsch
Processing top-left matrix
Processing bottom-right matrix
```

Case Studies

- https://www.oneapi.io/events/devcon2021isc/
  - https://www.oneapi.io/event-sessions/experiences-with-adding-sycl-support-to-gromacs/
  - https://www.oneapi.io/event-sessions/application-optimization-with-cache-aware-roofline-model-and-intel-oneapi-tools/
  - https://www.oneapi.io/event-sessions/porting-namd-oneapi-dpc/
  - https://www.oneapi.io/event-sessions/evaluating-cuda-portability-with-hipcl-dpct/
- https://www.hlrn.de/doc/display/PUB/Joint+NHR@ZIB+-+INTEL+++oneAPI+Workshop
  - easyWave - A Tsunami Simulations Application
  - Ginkgo – a sparse linear algebra library for OneAPI Hardware



QUESTIONS?

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