HLRS Workshop September 2023

Intel® Distribution for GDB*

A Cross-Architecture Application Debugger

Pascal Bähr

pascal.rene.baehr@intel.com

Agenda

- Why Intel® Distribution for GDB*?
- Key features
- System Requirements Overview
- DPC++ Linux* Demo
- Debugging Multi-Tile GPU
- C++: Debugging OpenMP* offload
- Other Debug Capabilities
- Demo: CLI on Linux
- Demo: Visual Studio Code via SSH

Why Intel® Distribution for GDB*?

Overview

- Companion tool to Intel compilers and libraries
- Cross-architecture debugging
- Unified debugging experience for oneAPI ecosystem
  - C, C++, SYCL, OpenMP, or Fortran
- Debug parallel and threaded applications
  - Single session for CPU and GPU code
  - Capable of handling thousands of threads simultaneously

Key features

- Command line debugging on the same machine: `gdb-oneapi`
- IDE Integration – Visual Studio, Visual Studio Code
  - 2 machines required: CPU host and GPU target
- Device support:

Multi-node debugging	MPI applications	Not supported
Multi-thread debugging	On the same GPU	Supported
Multi-user debugging	On the same GPU	Not supported; GPU is blocked by the debugger
Multi-target debugging	debug GPU and CPU code in the same session	Supported

Windows*

Language Support

- Data Parallel C++ (DPC++)
- C \ C++
- Fortran
- OpenMP

IDE Support

- Microsoft Visual Studio 2022*
- Visual Studio Code *

OS Support

- Windows* 10, 64-bit
- Windows* 11, 64-bit

GPUs

- Intel® Arc™ Series

CPUs

- Intel® Core™ Processor family
- Intel® Xeon® Processor family
- Intel® Xeon® Scalable Performance processors

FPGA

- Emulation device only

[Intel® Distribution for GDB* Release Notes]
[Intel® Distribution for GDB* System Requirements]

Linux*

Language Support

- Data Parallel C++ (DPC++)
- C \ C++
- Fortran
- OpenMP

IDE Support

- Eclipse * (native)
- Visual Studio Code *

OS Support

- Ubuntu* 20.04, 22.04
- SLES* 15
- RHEL* 8, 9

GPUs

- Intel® Arc™ Series
- Intel® Data Center GPU Flex Series
- Intel® Data Center GPU Max

CPUs

- Intel® Core™ Processor family
- Intel® Xeon® Processor family
- Intel® Xeon® Scalable Performance processors

FPGA

- Emulation device only

Intel® Distribution for GDB* Release Notes
Intel® Distribution for GDB* System Requirements

Other Debug Capabilities

oneAPI Debug Tools and Variables

- Specified level of tracing for SYCL Plugin Interface:
  - `SYCL_PI_TRACE={1,2,-1}`
- GPU backends:
  - Profiling Tools Interfaces for GPU (PTI GPU) - [Level Zero Tracer ze_tracer]
  - Intercept Layer for OpenCL - [How to Use the Intercept Layer for OpenCL™ Applications]
- OpenMP Offload:
  - `LIBOMPTARGET_DEBUG={-1, 1, 2, 3}`
- Compiler options – more options are available Fortran!
- Clang Sanitizers, valgrind etc

Useful Links

- Basic:
  - Documentation & Code Samples
  - Intel® Distribution for GDB* Release Notes
  - Intel® Distribution for GDB* System Requirements
- Advanced:
  - oneAPI Debug Tools at Intel® oneAPI Programming Guide
  - Get Started with OpenMP* Offload to GPU for the Intel® oneAPI DPC/C++ Compiler and Intel® Fortran Compiler

DPC++ Linux* Demo (Command Line)

Array Transform Sample

- Prerequisites:
  - Get Started Guide to configure the debugger
- Clone **oneAPI-samples**:

```
git clone https://github.com/oneapi-src/oneAPI-samples.git
cd oneAPI-samples/Tools/ApplicationDebugger/array-transform
```

- Set oneAPI environment:

```
source /opt/intel/oneapi/setvars.sh
```

Array Transform Sample

- Enable i915 debug support in kernel persistently:
  - Requires sudo!
  - `cat /etc/default/grub`
  - Make sure your `GRUB_CMDLINE_LINUX_DEFAULT` contains:

```
i915.debug_eu=1 drm.debug=0xa i915.enable_hangcheck=0
i915.debugger_timeout_ms=0
```

- Enable i915 debug support in Kernel:
  - `cat /sys/class/drm/card*/prelim_enable_eu_debug`
  - Make sure the output is `1`

Diagnostics Utility

- For the default oneAPI installation:
  - `python3 /opt/intel/oneapi/diagnostics/latest/diagnostics.py --filter debugger_sys_check –force`
- Expected output:

```
Checks results:

==================================================================================
Check name: debugger_sys_check
Description: This check verifies if the environment is ready to use gdb (Intel(R) Distri
bution for GDB*).
Result status: PASS
Debugger found.
libipt found.
libiga found.
i915 debug is enabled.
Environmental variables correct.
==================================================================================

1 CHECK: 1 PASS, 0 FAIL, 0 WARNINGS, 0 ERRORS
```

Array Transform Sample on CPU

- Build:

```
icpx -fsycl -g -O0 array-transform.cpp -o array-transform
```

- Run:

```
ONEAPI_DEVICE_SELECTOR=*:cpu ./array-transform
```

- Run under the debugger:

```
ONEAPI_DEVICE_SELECTOR=*:cpu gdb-oneapi --args ./array-transform
```

Array Transform Sample on GPU

- Build:

```
icpx -fsycl -g -O0 array-transform.cpp -o array-transform
```

- Run:

```
ONEAPI_DEVICE_SELECTOR=level_zero:gpu gdb-oneapi ./array-transform
```

- Enable debugging:

```
export ZET_ENABLE_PROGRAM_DEBUGGING=1
export IGC_EnableGTLocationDebugging=1
```

- Run under the debugger:

```
ONEAPI_DEVICE_SELECTOR=level_zero:gpu gdb-oneapi --args ./array-transform
```

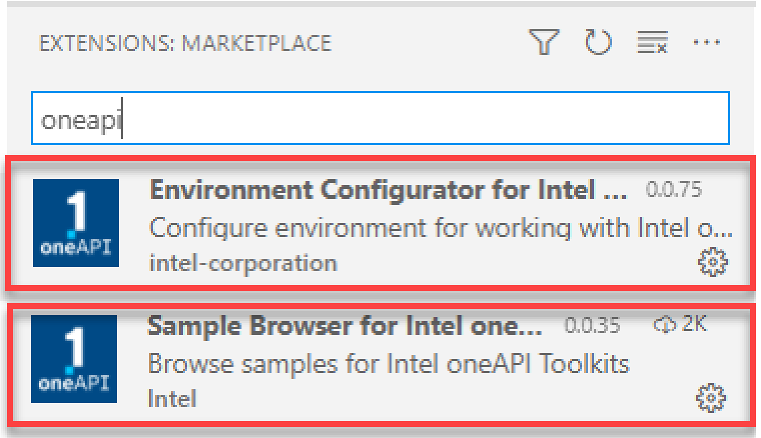
Debugging on GPU

- `info inferiors` - make sure you are on GPU now
- `info threads` - inspect threads
- `thread 2.<Thread_number>:<SIMD_lane>` - switching between threads
- `info locals` - print local threads variables
- `disassemble` - see disassemble
- `set scheduler-locking step` - step to the next

DPC++ Linux* Demo (Visual Studio Code - Remote)

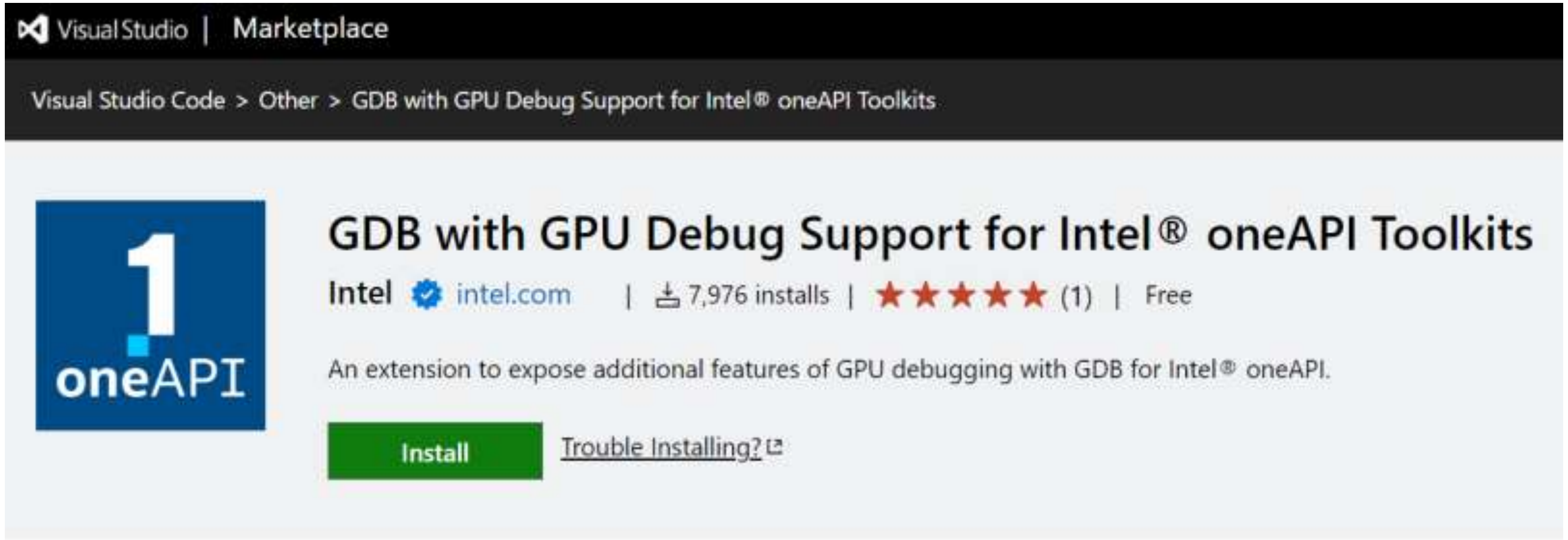
Setting up VS Code

- Prerequisites:
  - Get Started Guide to configure the debugger for remote debugging
  - Setup oneAPI environment on target machine
- Install oneAPI extensions for VSC on remote
- Install **oneAPI-samples** via sample browser:



Visual Studio Code – oneAPI GDB extension

- Install and [setup the oneAPI Debug extension for VS Code]



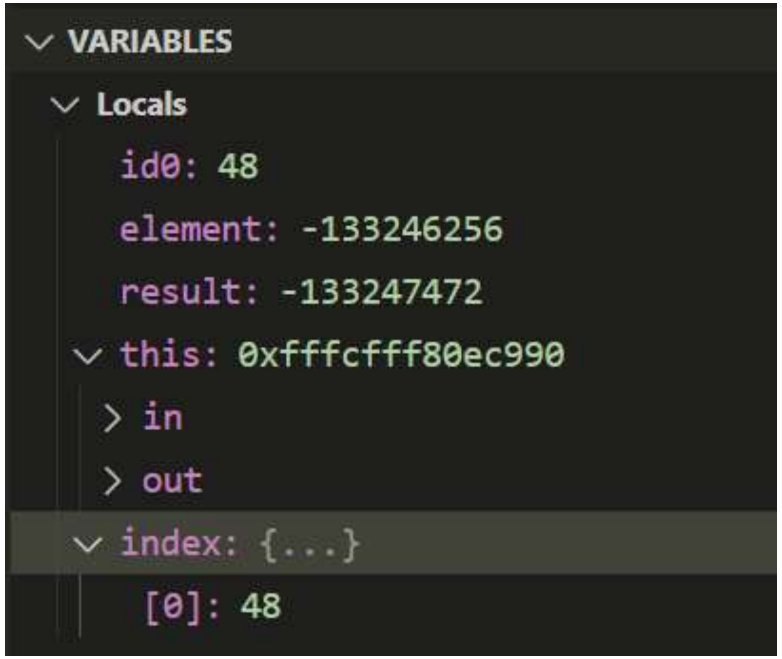
Visual Studio Code – oneAPI GDB extension

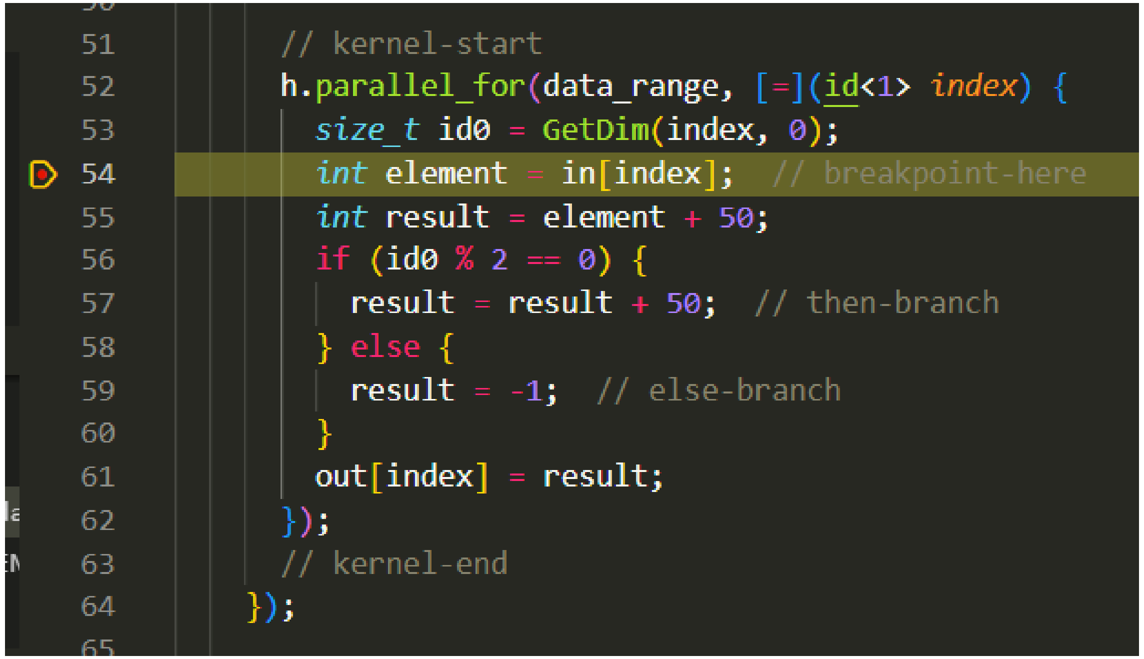
- Generate and setup a launch configuration
- Set environment variables
  - For debugging
  - For execution on GPU

```json
"environment": [
    {
        "name": "ZET_ENABLE_PROGRAM_DEBUGGING",
        "value": "1"
    },
    {
        "name": "IGC_EnableGTLocationDebugging",
        "value": "1"
    },
    {
        "name": "ONEAPI_DEVICE_SELECTOR",
        "value": "*:gpu"
    }
],
```

Visual Studio Code – oneAPI GDB extension

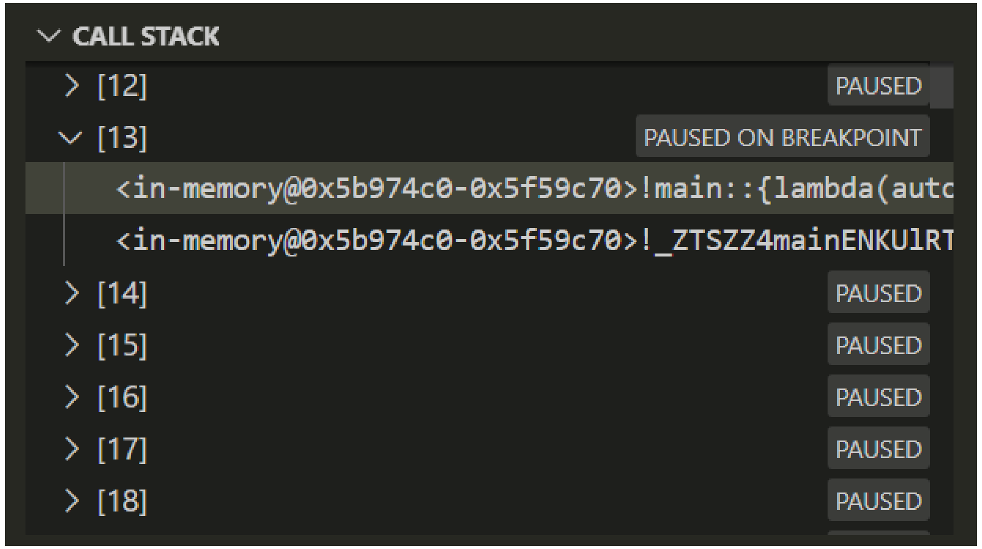
- Inspect variables





Visual Studio Code – oneAPI GDB extension

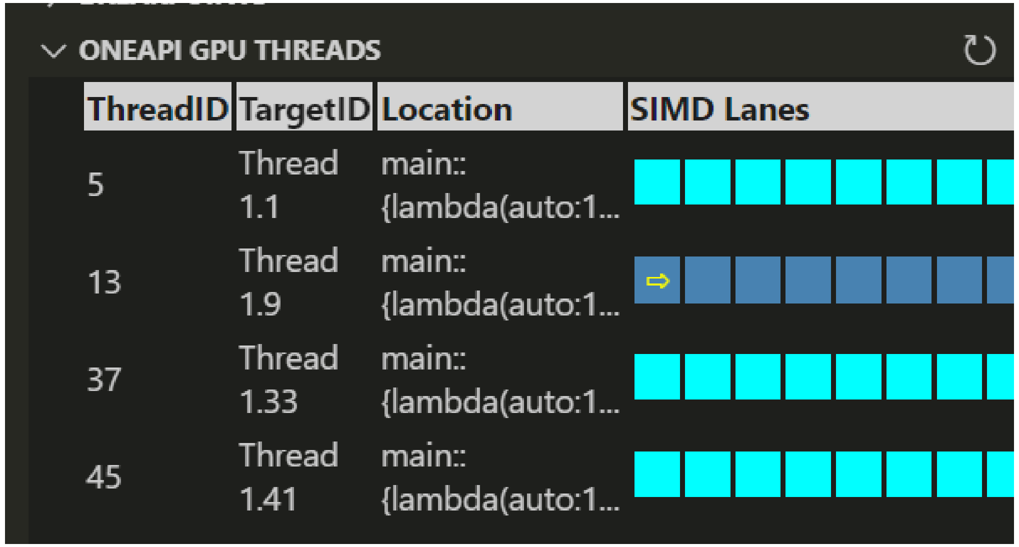
- Inspect call stack




```
    // kernel-start
    h.parallel_for(data_range, [=](id<1> index) {
      size_t id0 = GetDim(index, 0);
      int element = in[index];  // breakpoint-here
      int result = element + 50;
      if (id0 % 2 == 0) {
        result = result + 50;  // then-branch
      } else {
        result = -1;  // else-branch
      }
      out[index] = result;
    });
    // kernel-end
  });
```

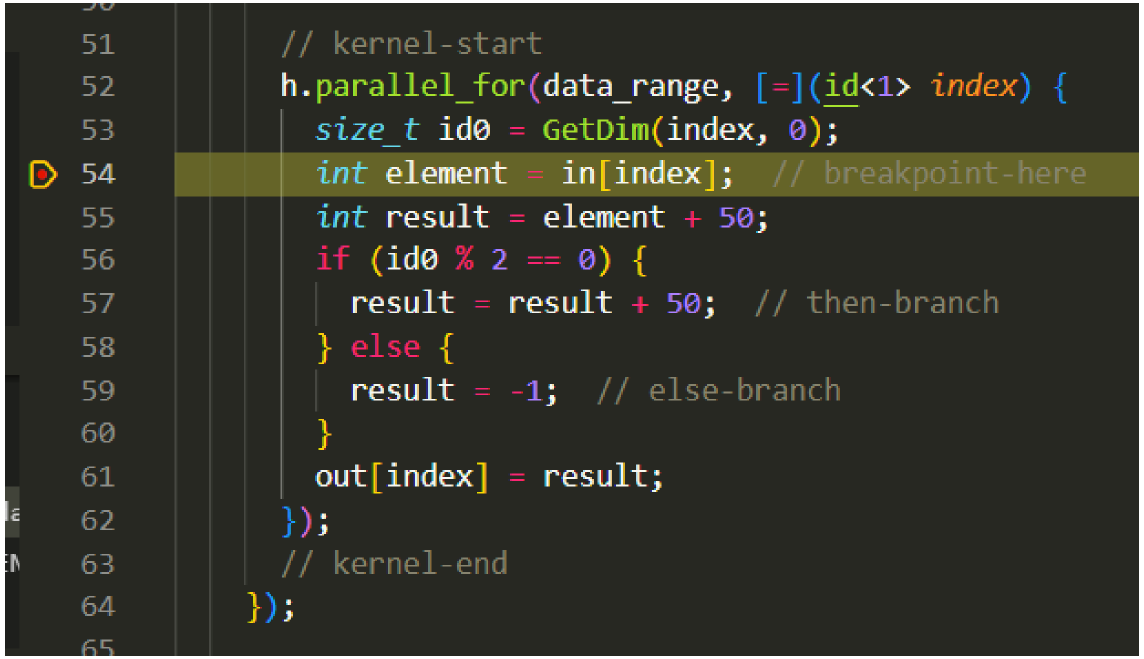
Visual Studio Code – oneAPI GDB extension

- Inspect GPU threads and SIMD Lanes



ONEAPI GPU THREADS

ThreadID	TargetID	Location	SIMD Lanes
5	Thread 1.1	main:: {lambda(auto:1...	
13	Thread 1.9	main:: {lambda(auto:1...	⇨
37	Thread 1.33	main:: {lambda(auto:1...	
45	Thread 1.41	main:: {lambda(auto:1...	



```
// kernel-start
h.parallel_for(data_range, [=](id<1> index) {
  size_t id0 = GetDim(index, 0);
  int element = in[index];  // breakpoint-here
  int result = element + 50;
  if (id0 % 2 == 0) {
    result = result + 50;  // then-branch
  } else {
    result = -1;  // else-branch
  }
  out[index] = result;
});
// kernel-end
});
```

Visual Studio Code – oneAPI GDB extension

- Inspect GPU threads and SIMD Lanes

SELECTED LANE

Lane Number:	0
Thread Workgroup:	x:0,y:0,z:0
Work item Global Id:	x:48,y:0,z:0
Work item Local Id:	x:48,y:0,z:0
Execution Mask:	0xffff
Hit Lanes Mask:	0xffff
SIMD Width:	16

```
    // kernel-start
    h.parallel_for(data_range, [=](id<1> index) {
      size_t id0 = GetDim(index, 0);
      int element = in[index];  // breakpoint-here
      int result = element + 50;
      if (id0 % 2 == 0) {
        result = result + 50;  // then-branch
      } else {
        result = -1;  // else-branch
      }
      out[index] = result;
    });
    // kernel-end
  });
```

Debugging Multi-Tile GPU

ZE_AFFINITY_MASK

Value	Behavior
0, 1	all devices and sub-devices are reported (same as default)
0	only device 0 is reported; with all its sub-devices
1	only device 1 is reported as device 0; with all its sub-devices
0.0	only device 0, sub-device 0 is reported as device 0
1.1	only device 1 is reported as device 0; with its sub-devices 1 and 2 reported as sub-devices 0 and 1, respectively
0.2, 1.3, 1.0, 0.3	both device 0 and 1 are reported; device 0 reports sub-devices 2 and 3 as sub-devices 0 and 1, respectively; device 1 reports sub-devices 0 and 3 as sub-devices 0 and 1, respectively; the order is unchanged.

Selecting Different Devices

- $ gdb-oneapi --args ./array-transform

```
(gdb) info devices
  Location    Sub-device   Vendor Id   Target Id   Cores   Device Name
  [3a:00.0]   -            0x8086      0x0bd5      1024    Intel(R) Graphics [0x0bd5]
* [9a:00.0]   -            0x8086      0x0bd5      1024    Intel(R) Graphics [0x0bd5]
```

- $ ZE_AFFINITY_MASK=0.0 gdb-oneapi --args ./array-transform

```
(gdb) info devices
  Location    Sub-device   Vendor Id   Target Id   Cores   Device Name
* [9a:00.0]   -            0x8086      0x0bd5      512     Intel(R) Graphics [0x0bd5]
```

- $ ZE_AFFINITY_MASK=1.0 gdb-oneapi --args ./array-transform

```
(gdb) info devices
  Location    Sub-device   Vendor Id   Target Id   Cores   Device Name
* [3a:00.0]   -            0x8086      0x0bd5      512     Intel(R) Graphics [0x0bd5]
```

Debugging OpenMP* Offload (C++)

Matmul build and run

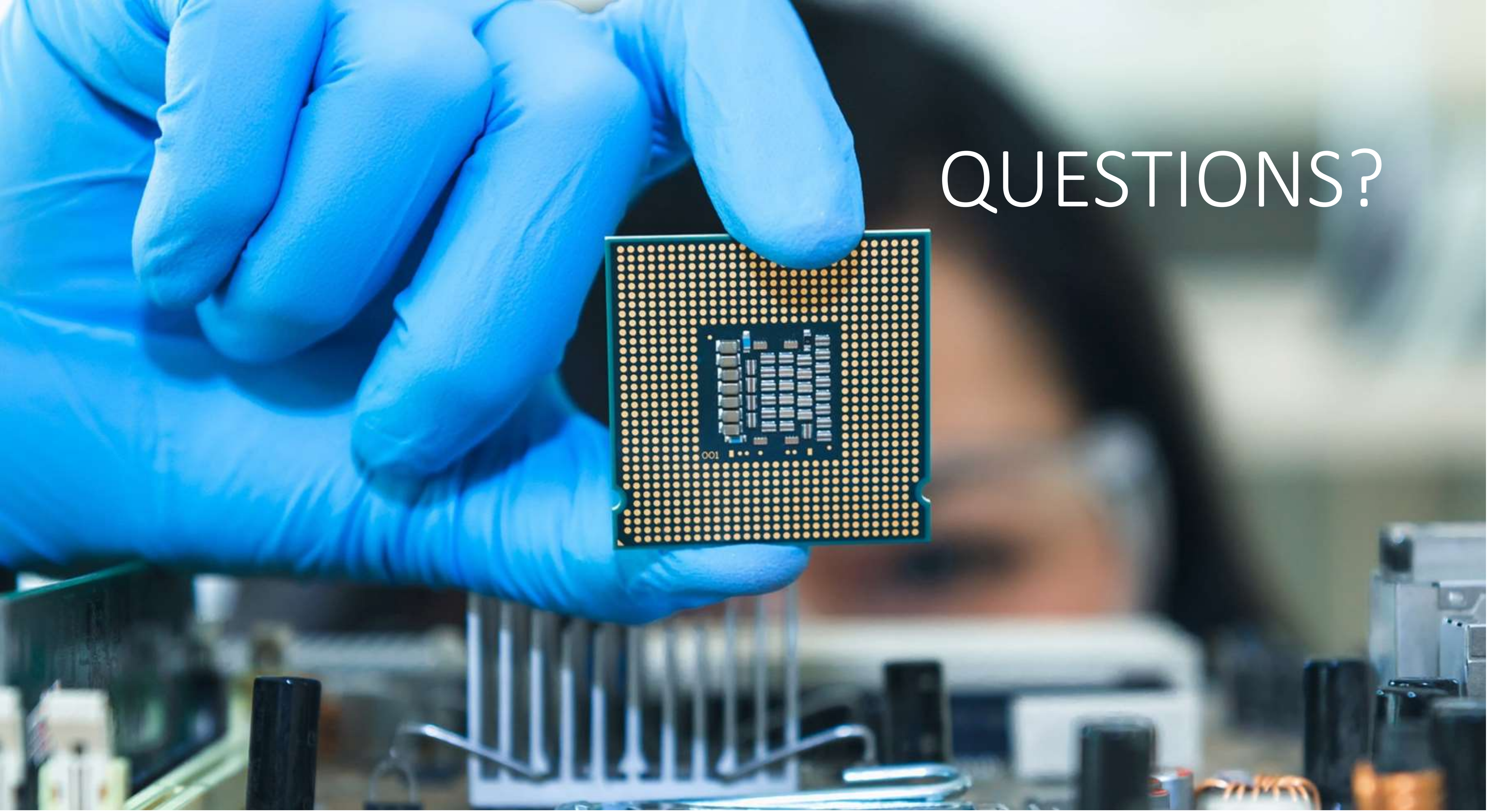
- Build :
  - `icpx -O0 -g -fiopenmp -fopenmp-targets=spir64 matmul_offload.cpp -o matmul_debug`
- Disable device optimizations:

```
export ZET_ENABLE_PROGRAM_DEBUGGING=1
export IGC_EnableGTLocationDebugging=1
```

- Set up offloading:
  - `export OMP_TARGET_OFFLOAD="MANDATORY"`
- Debug :
  - `gdb-oneapi ./matmul_debug`

[Get Started with OpenMP* Offload to GPU for the Intel® oneAPI DPC/C++ Compiler and Intel® Fortran Compiler]()

QUESTIONS?



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