ATPESC 21

Intel® VTune Profiler and Intel® Advisor Hands on in Intel® DevCloud

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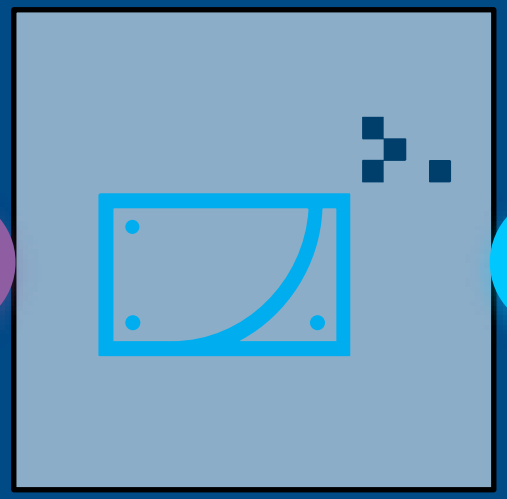
Agenda

1. **Intel® DevCloud Setup**
   Information on starting a GPU node in DevCloud.
2. **Workload Description**
   Overview of MandelbrotOMP sample and changes.
3. **Intel VTune Profiler Server Setup**
   Brief explanation on setting up Intel VTune Profiler Server in the DevCloud node.
4. **Demo**
   Running the sample in the DevCloud with Intel Advisor and Intel VTune Profiler.

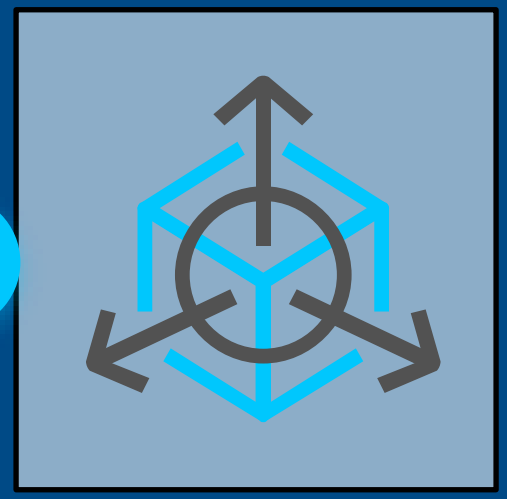
Workflow

Log into an Intel® **DevCloud** GPU node and configure the **MandelbrotOMP** sample

Run Intel Advisor: **Offload Advisor** to estimate performance on Gen9 GT2 GPU



Run Intel Advisor: **GPU Roofline** on offloaded implementation to visualize GPU performance



Run Intel VTune Profiler: **GPU Hotspots** for deeper insights into GPU kernels and device metrics

DevCloud Setup

- Log into DevCloud via ssh
- Start interactive gpu node:

```
$ qsub -I -l
nodes=1:gpu:ppn=2
```

- Create MandelbrotOMP sample:

https://github.com/oneapi-src/oneAPI-samples

- Start Intel VTune Profiler Server in second ssh terminal

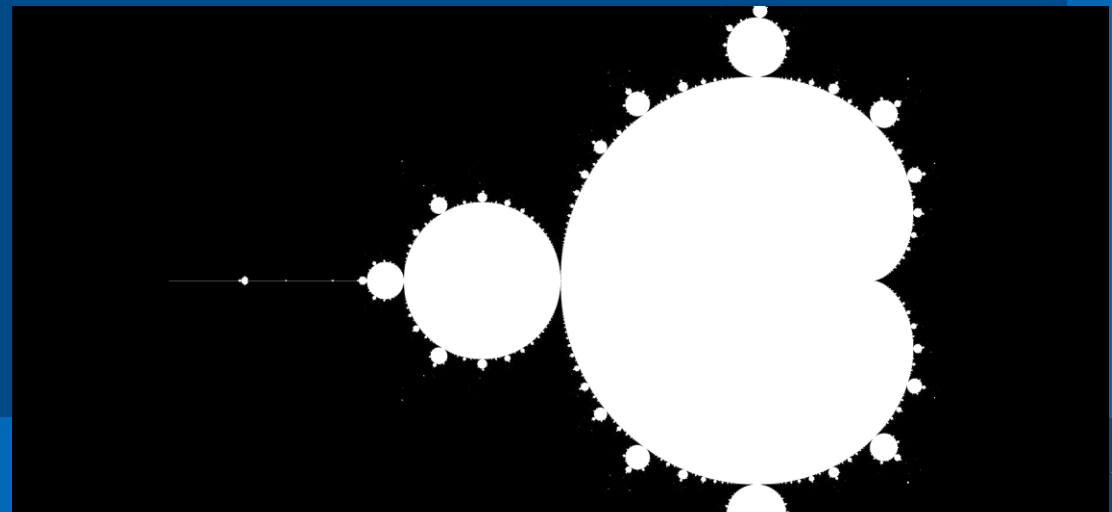
DevCloud Setup

Intel DevCloud provides a free environment for testing the latest Intel CPUs and GPUs. Intel oneAPI toolkits are already installed and set up for use.

To create a DevCloud account, follow these steps:
https://www.intel.com/content/www/us/en/forms/idz/devcloud-enrollment/oneapi-request.html

MandelbrotOMP

- This sample runs one or all of four algorithms for generating a Mandelbrot image. Each algorithm has an increasing level of optimization, from a serial implementation to using OpenMP for parallelization and simd vectorization.
- Github link: https://github.com/oneapi-src/oneAPI-samples/tree/master/DirectProgramming/C%2B%2B/CombinationalLogic/MandelbrotOMP



MandelbrotOMP with GPU Offload

- To help demonstrate the capabilities of Intel Offload Advisor, we added a fifth function to use OpenMP offload to a GPU target:

- src/mandelbrot.cpp
  - Copy the `omp_mandelbrot (..)` function and rename to `offload_mandelbrot (..)`
  - Change #pragma omp parallel for schedule to:
    - `#pragma omp target teams distribute \`

```
   parallel for simd collapse(2) \
map(from:output[0:width*height])
map(to:height,width,xstep,ystep,max_depth)
```

- src/mandelbrot.hpp
  - Copy the `omp_mandelbrot (..)` function and rename to `offload_Mandelbrot (..)`

MandelbrotOMP with GPU Offload

- Add a fifth option to enable the new offload_mandelbrot function

- src/main.cpp
  - Change the `max_depth` from 100 to 5000
  - Add variable `offload_time` to
    - ```
      double serial_time,
      omp_simd_time,
      omp_parallel_time,
      omp_both_time;
      ```
  - Add section for offload_mandelbrot under `printf("\nRunning all tests\n")`
  - Add case 5 with offload_Mandelbrot to switch (option)
  - Not using PERF_NUM
      ```

MandelbrotOMP Makefile

- Change options to use OpenMP offload capability
  - Change compiler from icpc to icpx
  - Remove qopenmp from CFLAGS and LIBFLAGS and add: `-fiopenmp -fopenmp-targets=spir64`
  - Add `-g -D__INTEL_COMPILER` to CFLAGS

Intel® VTune Profiler Server Setup

- Follow the instructions in the online Intel VTune Profiler Performance Analysis Cookbook: https://software.intel.com/content/www/us/en/develop/documentation/vtune-cookbook/top/configuration-recipes/using-vtune-server-with-vs-code-intel-devcloud.html
- After setting up the ssh terminal for the DevCloud GPU node, open a new terminal and run:
  - `$ ssh -L 127.0.0.1:55001:127.0.0.1:55001 devcloud`
  - `$ ssh -L 127.0.0.1:55001:127.0.0.1:55001 <node>`
  - `$ vtune-backend --web-port=55001 --enable-server-profiling`
- Copy the URL provided into the browser to start the Intel VTune Profiler GUI

Demo

- Running the sample in the DevCloud with Intel Advisor and Intel VTune Profiler.

Demo Steps

- Example screenshots and commands from the demo follow

Log into Intel® DevCloud GPU Node

- Follow the instructions on slide 4 to open a ssh terminal for an interactive GPU node on DevCloud. This node uses Intel processor codenamed Coffee Lake and has an integrated Gen9 GT2 GPU.
- `qsub -I -l nodes=1:gpu:ppn=2`

Intel® Advisor: Offload Advisor

- Run the following Intel Advisor CLI commands on the parallel OpenMP implementation of MandelbrotOMP (option 3) to estimate the performance benefits of offloading to a Gen9 GT2 GPU:

- `advisor --collect=survey --project-dir=./parallel_mandel --stackwalk-mode=online --static-instruction-mix -- /home/uxxxxx/MandelbrotOMP/release/Mandelbrot 3`
- `advisor --collect=tripcounts --project-dir=./parallel_mandel --flop --target-device=gen9_gt2 -- /home/uxxxxx/MandelbrotOMP/release/Mandelbrot 3`
- `advisor --collect=projection --project-dir=./ parallel_mandel --config=gen9_gt2 --no-assume-dependencies`

Package Results and copy to local system

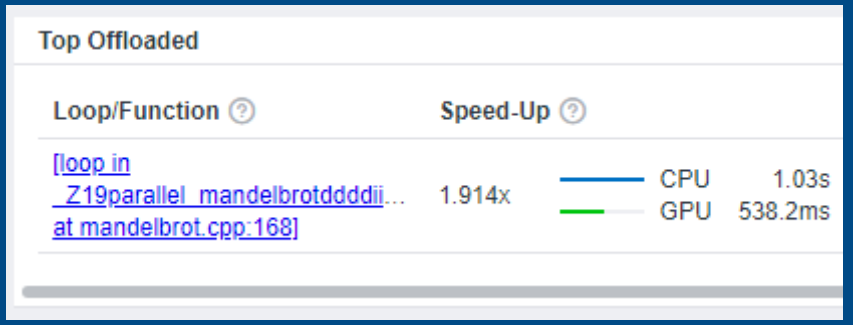
- Package the Intel Advisor project on the DevCloud node and copy to your local system with Advisor 2021.3 installed:

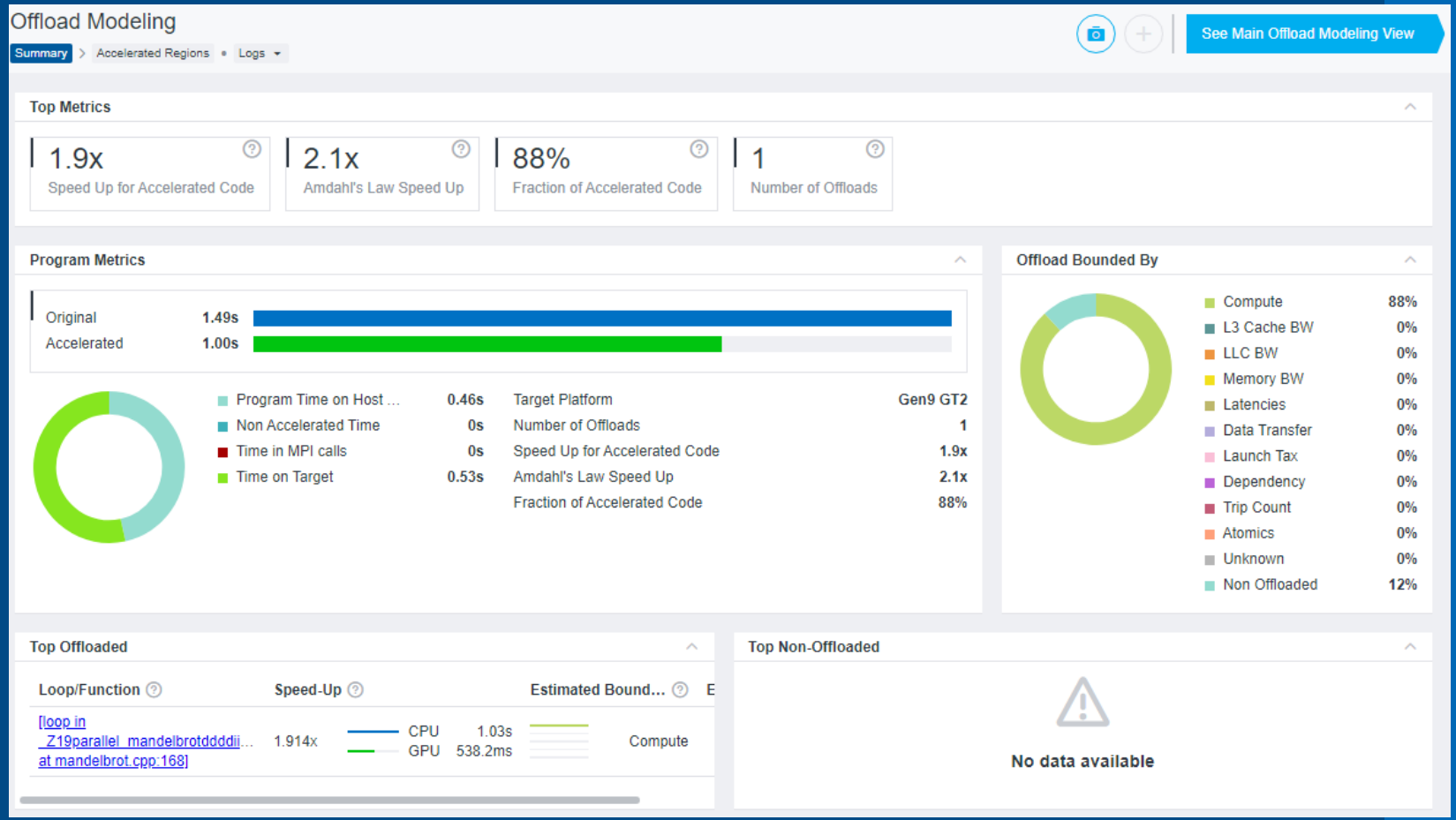
```
advisor --snapshot --project-dir=./parallel_mandel --pack --cache-sources --cache-binaries -- ./parallel_mandel_snapshot
```

View Offload Advisor Results

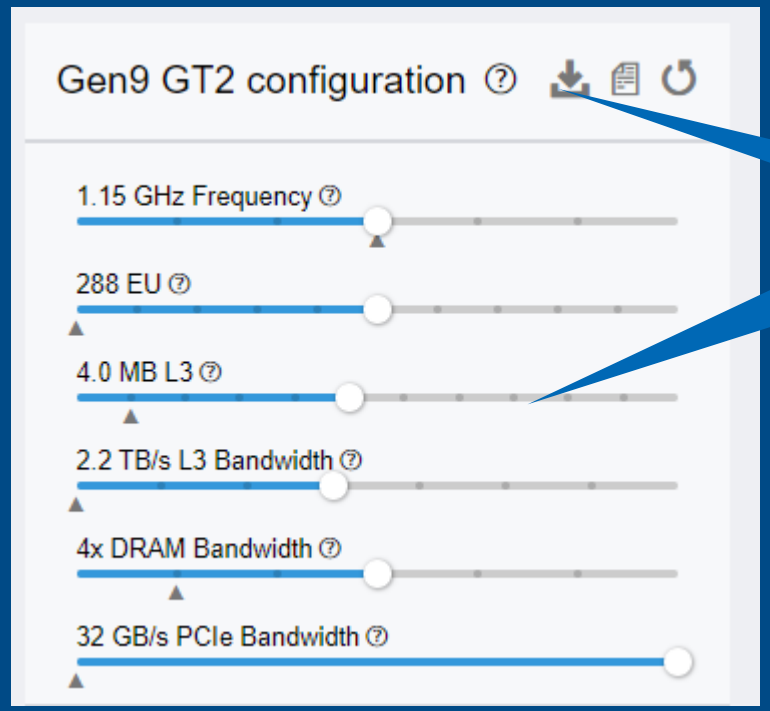
This report shows that a speed up of 1.9x can be gained by offloading the loops.

The loop is expected to run for 538.2ms on the GPU.





Explore different GPU Configurations



Reconfigure GPU settings to a hypothetical new GPU

Then save custom config to scalers.toml

Rerun projection

advisor --collect=projection --project-dir=./parallel_mandel --custom-config=scalers.toml --no-assume-dependencies

View how we are running compared to system max

- Use Intel® Advisor CLI to generate a GPU Roofline report on the offload implementation (option 5):

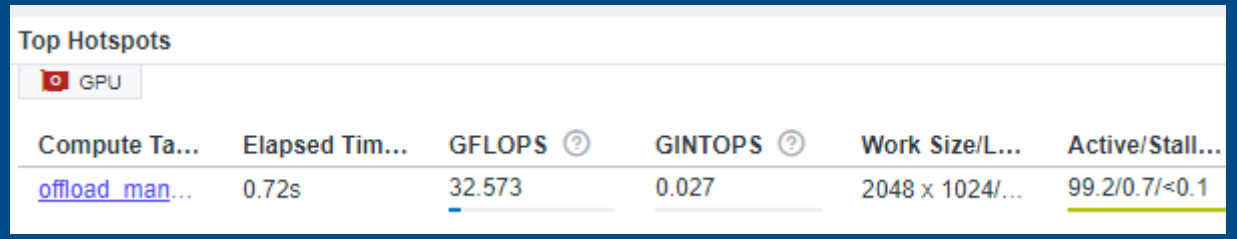
- `advisor --collect=survey --project-dir=./offload_mandel --profile-gpu -- /home/uxxxxx/MandelbrotOMP/release/Mandelbrot 5`
- `advisor --collect=tripcounts --project-dir=./offload_mandel --flop --profile-gpu -- /home/uxxxxx/MandelbrotOMP/release/Mandelbrot 5`
- `advisor -report=roofline -gpu -project-dir=./offload_mandel --report-output=./gpu_roofline.html`

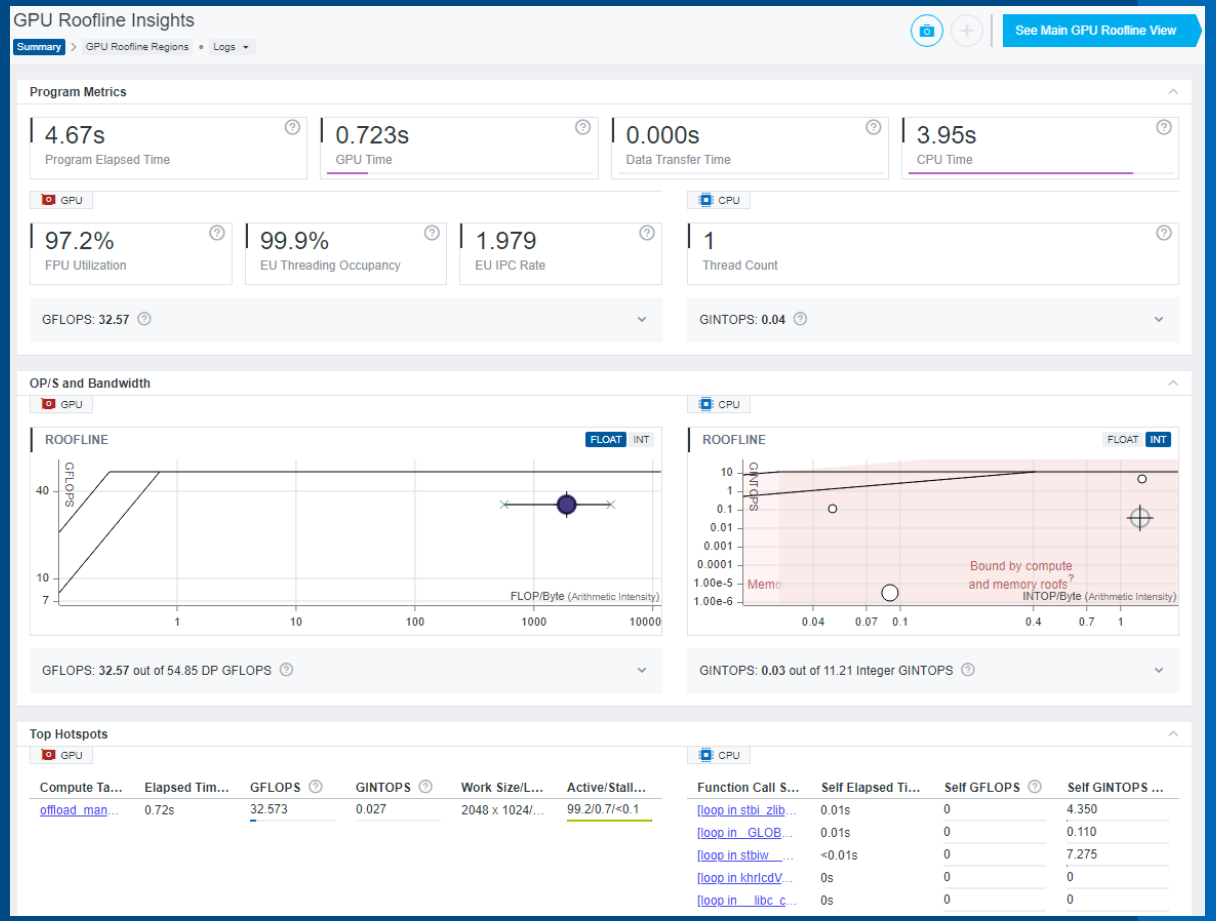
- Create a snapshot for download to the local GUI:

- `advisor --snapshot --project-dir=./offload_mandel --pack --cache-sources --cache-binaries -- ./offload_mandel_snapshot`

GPU Roofline

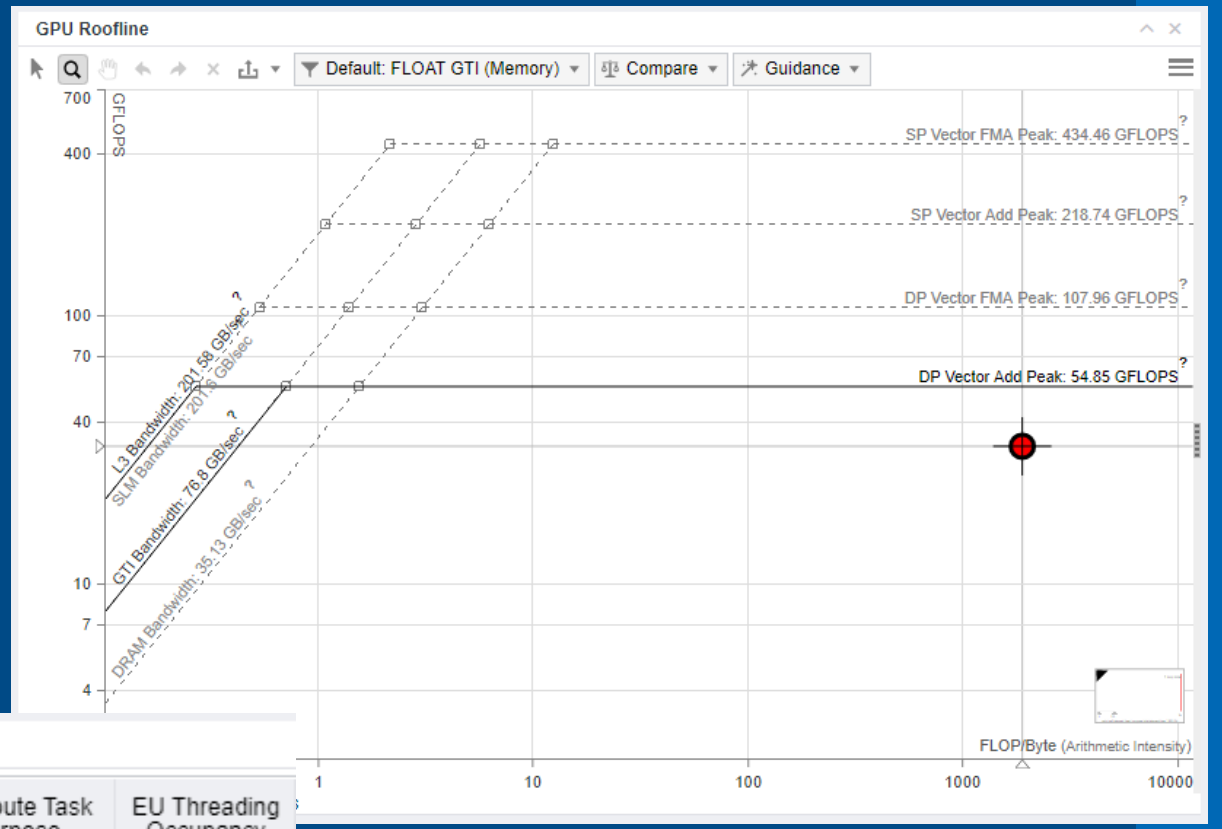
- The overall elapsed time of 4.67s is much higher in the offloaded version than the parallel CPU implementation (1.49s). But the compute task has a speed-up:
  - From 1.03s in parallel_mandelbrot to 0.72s in offload_Mandelbrot. Not quite hitting the estimate of 538.2ms.
  - Nearly 4s is spent on the CPU





GPU Roofline continued

- The offload task appears to be bounded by the DP Vector Add Peak. Otherwise, it appears to make good use of the GPU.
  - EU Array is 99.2% active, and the threading occupancy is almost 100%
  - There is an unknown task consuming 3.951s of CPU time with 100% idle GPU time.



GPU

Compute Task	Elapsed Time	GPU Compute Performance	EU Array			Compute Task Purpose	EU Threading Occupancy
			Active	Stalled	Idle		
[Outside any task]	3.951s	0.000	0.0%	0.0%	100.0%	[Unknown]	0.0%
zeCommandListAppendMemoryCopy	0.000s	0.000	0.0%	0.0%	100.0%	Transfer In	0.0%
zeCommandListAppendBarrier	0.000s	0.000	0.0%	0.0%	100.0%	Synchroniz...	0.0%
offload_mandelbrotompoffloading:266	0.723s	32.573	99.2%	0.7%	0.0%	Compute	99.9%

Intel VTune Profiler: GPU Hotspots
command-line

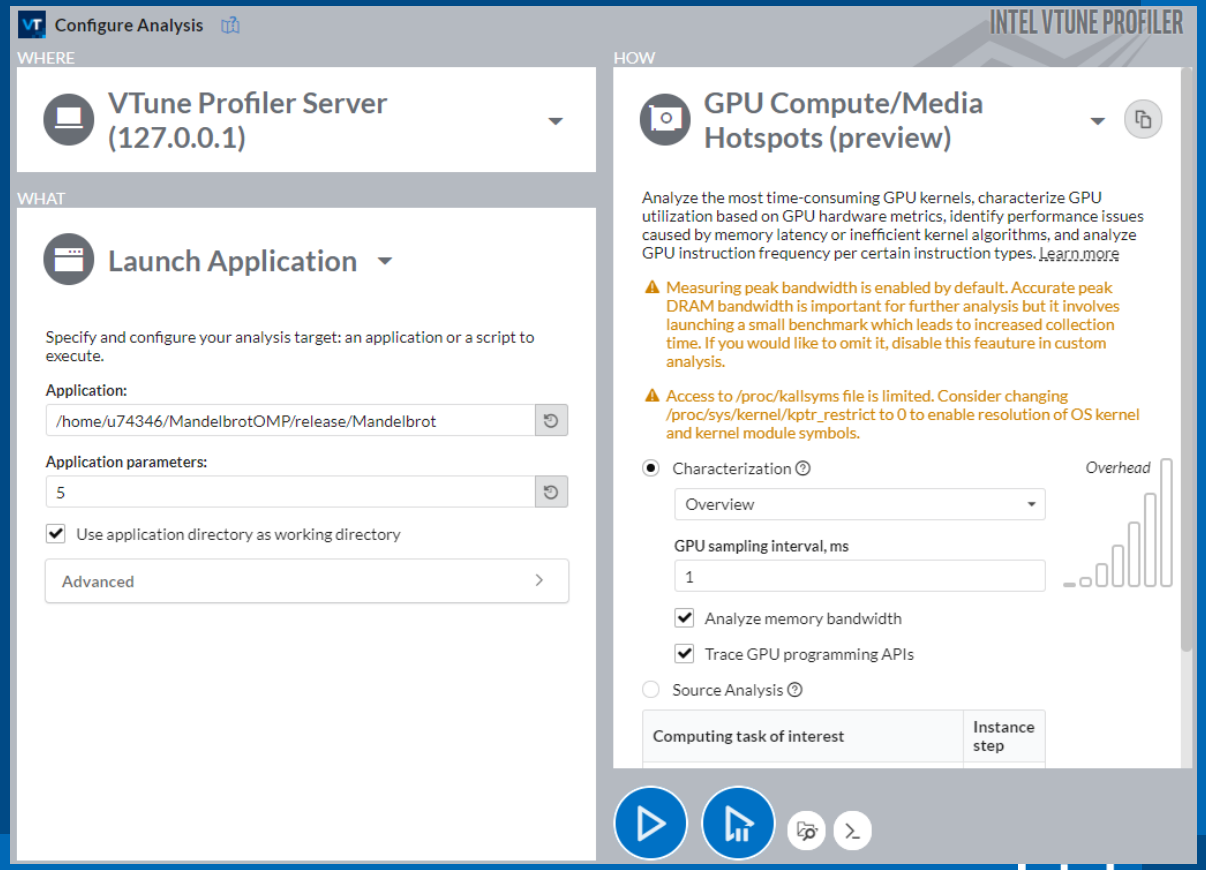
- Running gpu-hotspots on the command-line
- vtune –collect gpu-hotspots ./Mandelbrot 5

- Generating a report Elapsed Time: 4.386s
- GPU Time: 0.682s
- EU Array Stalled/Idle: 0.8%
- GPU L3 Bandwidth Bound: 0.3%
- Hottest GPU Computing Tasks Bound by GPU L3 Bandwidth
- Computing Task Total Time
- ---------- ----------
- Sampler Busy: 0.0%
- Hottest GPU Computing Tasks with High Sampler Usage
- Computing Task Total Time
- ---------- ----------
- FPU Utilization: 96.3%
- Hottest GPU Computing Tasks with High FPU Utilization

Copy result directory to local system

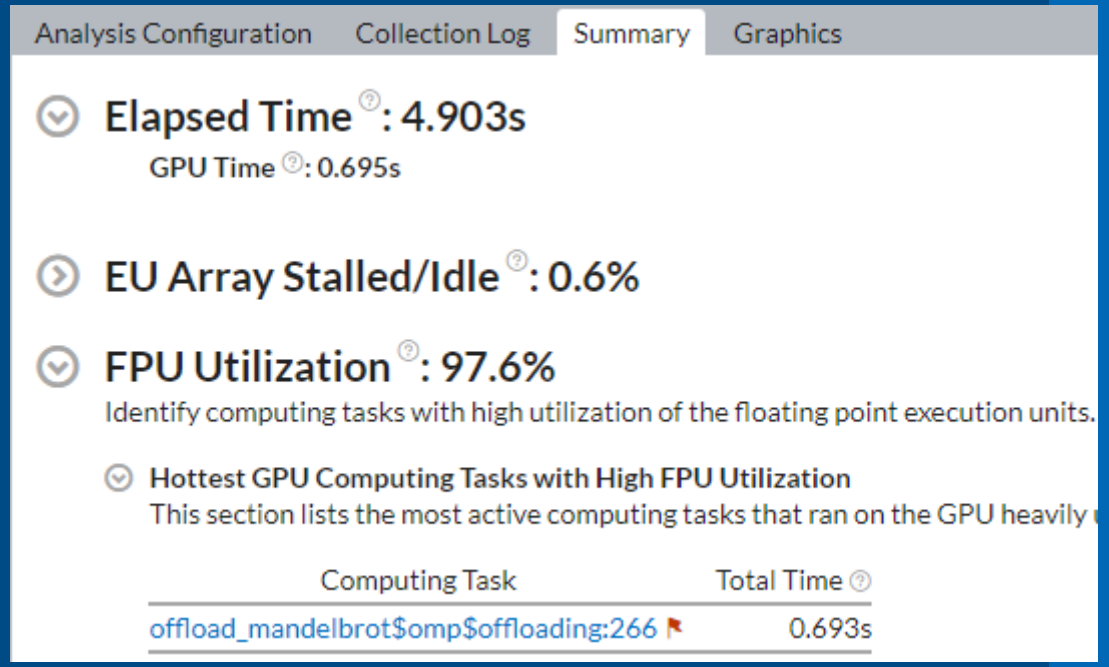
Intel VTune Profiler: GPU Hotspots

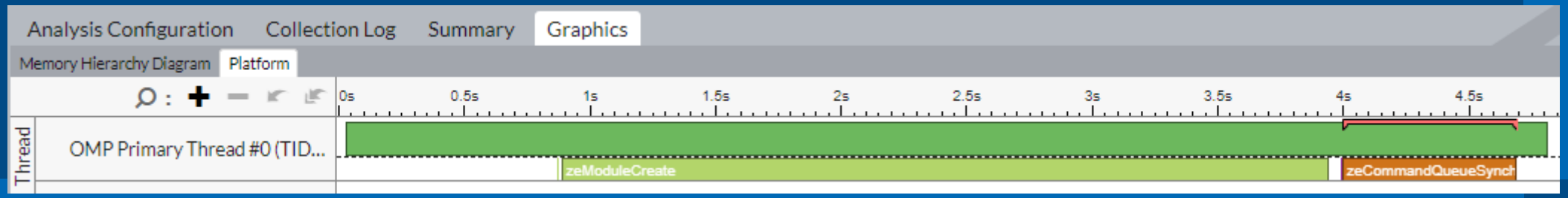
- Once the Intel VTune Profiler is running with the vtune-backend command, open the URL in the browser for the GUI.
  - Set the application to /home/uxxxxx/MandelbrotOMP/release/Mandelbrot and set the application parameter to 5.
  - Run the GPU Compute/Media Hotspots analysis type



GPU Hotspots

- The Summary tab shows that although only a small percentage of the overall elapsed time is spent on the GPU, the offload task performs well on the GPU.
- The Graphics tab doesn't indicate any major problems. Under the Platform sub-tab, there is an OpenMP task called zeModuleCreate that runs for about 3.5s. That explains the high CPU utilization time.





Summary

- You can use Advisor and VTune GUI & CLI to run the collection and to generate the reports.
- Advisor and VTune provides several analysis types to profile GPU workload.
- Each analysis type provides specific insights

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Notice revision #20110804

Backup

Set up system for GPU analysis

- To collect GPU hardware metrics on Linux, you need
  - run the collection as root

  or
  - set /proc/sys/dev/i915/perf_stream_paranoid to 0
  - have read/write access to /dev/dri/card* and /dev/dri/renderD* files
- Optional: To collect information about DMA packets on Linux, you need
  - enable CONFIG_DRM_I915_LOW_LEVEL_TRACEPOINTS option for i915 kernel module
  - have read/write access to debugFS

VTune Profiler documentation: Set Up Sytem for GPU Analysis

Compiler Switches for Performance Analysis

-gline-tables-only -fdebug-info-for-profiling	Enable generating debug information for GPU analysis of a DPC++ or OpenMP applications. This information is necessary for source-assembly mapping for GPU kernels. Intel oneAPI DPC++ Compiler and Intel C++ Compiler
-debug offload	Enable generating debug information for GPU analysis of OpenMP application. This information is necessary for source-assembly mapping offload regions. Intel Fortran Compiler
-parallel-source-info=2	Enable source location emission when OpenMP or auto-parallelism code is generated. `2` is the level of source location emission that tells the compiler to emit path, file, routine name, and line information. Intel C++ Compiler and Intel Fortran Compiler

VTune Profiler documentation:

- Compiler Switches for Performance Analysis on Linux* Targets
- Debug Information for Linux* Application Binaries


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