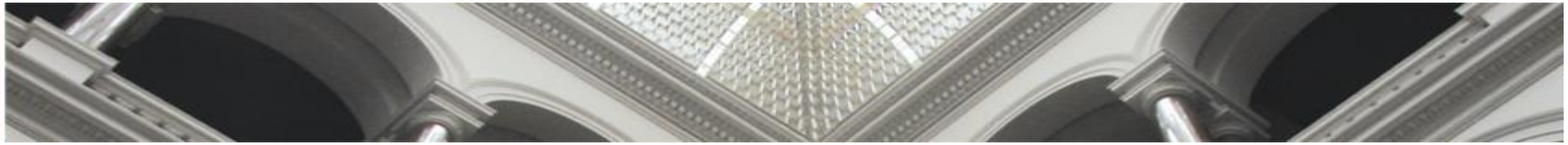
Technische Universität Berlin

OpenMP Accelerator Offloading using OpenCL with SPIR-V

Daniel Schürmann | AES | Lightning Talk



OpenMP Accelerator Offloading

#pragma omp target

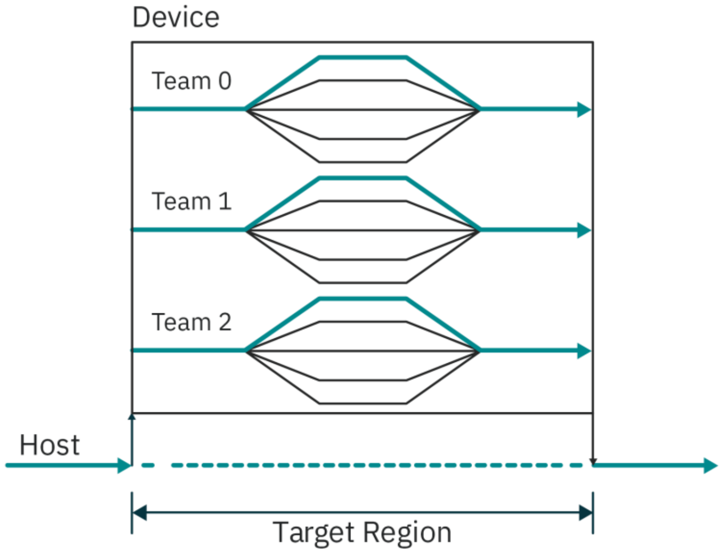
- map code section to a device

#pragma omp teams

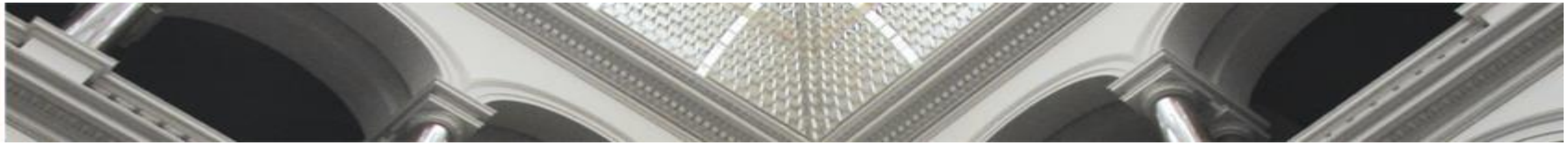
- create a league of independent thread teams

#pragma omp distribute

- distribute loop over the thread teams

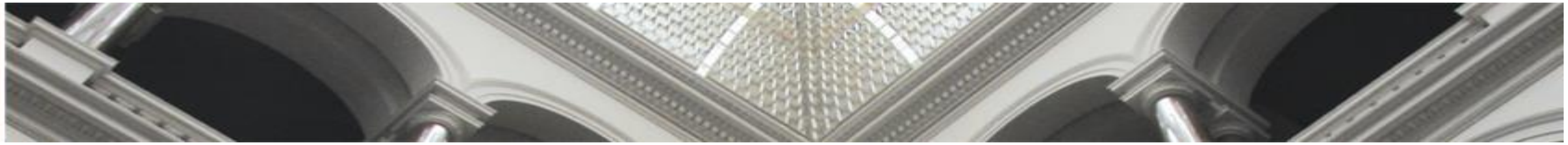


```
#pragma omp target teams distribute parallel for
for (int i = 0; i < n; ++i) {
  A[i] = B[i] + C[i]
}
```



Problem

- GPUs offer high performance and efficiency, but are difficult to program
- Working implementations exist for NVPTX/Cuda and Intel Xeon Phi.
- Specification is available since 2 years but there is no sight of support for OpenCL devices.



Idea & Motivation

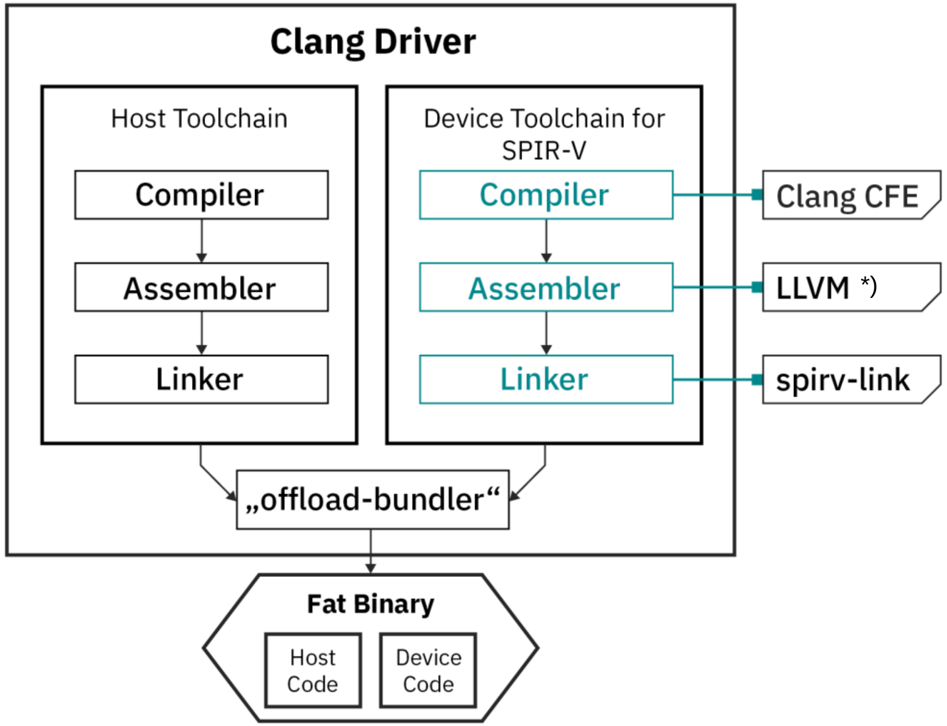
Enable all OpenCL 2.1 devices to be targeted by OpenMP accelerator offloading:

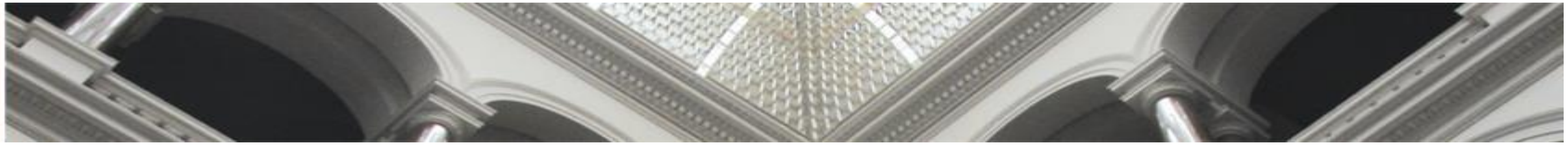
- simplify the parallel programming of heterogeneous systems
- easily convert existing scalar code for GPUs
- potential target for libraries/programming languages to provide single-source GPGPU capabilities

Implementation: Clang Driver

- Selects Toolchain for each target
- spirv-link from Khronos Group spirv-tools

*) Uses LLVM-backend from Nicholas Wilson





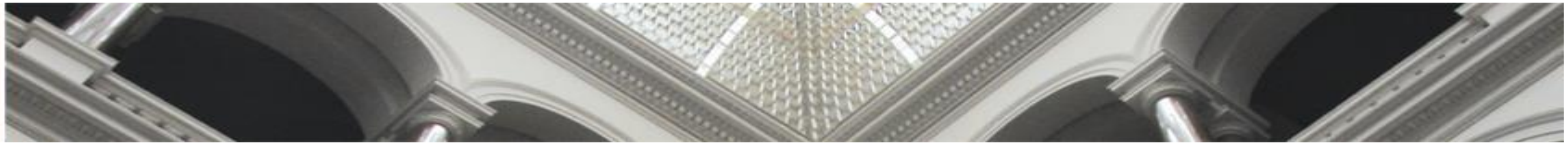
Implementation: #pragma omp parallel

```
#pragma omp target
{
<some code goes here>

  #pragma omp parallel
  {

  …

  }
<some code goes here>
}
```



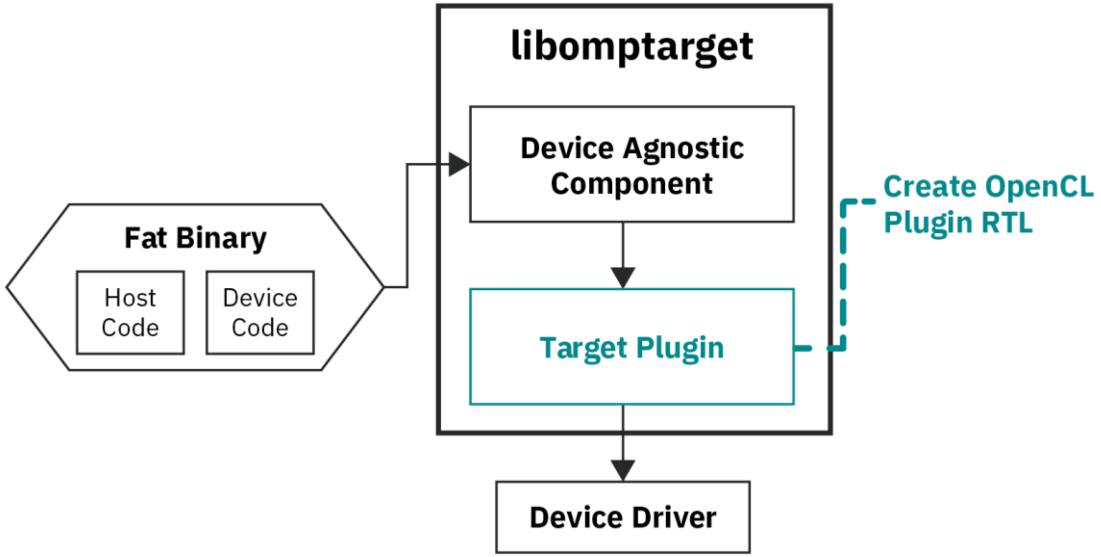
Implementation: #pragma omp parallel

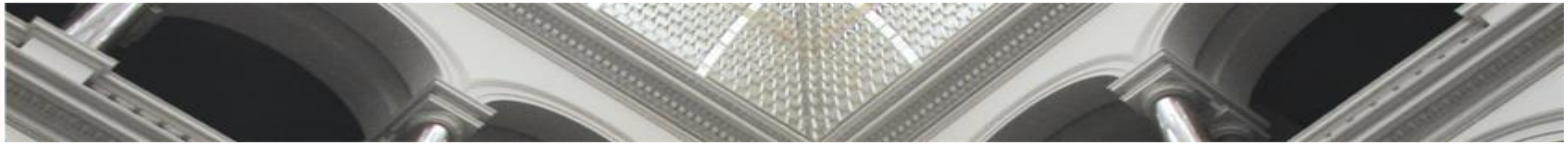
```
#pragma omp target
IF (thread_idx == 0)
<some code goes here>

  #pragma omp parallel
(copy shared variables to local memory)
ENDIF
  Call inlined parallel function
IF (thread_idx == 0)
(copy shared variables back)
<some code goes here>
```

Implementation: Run-Time Library

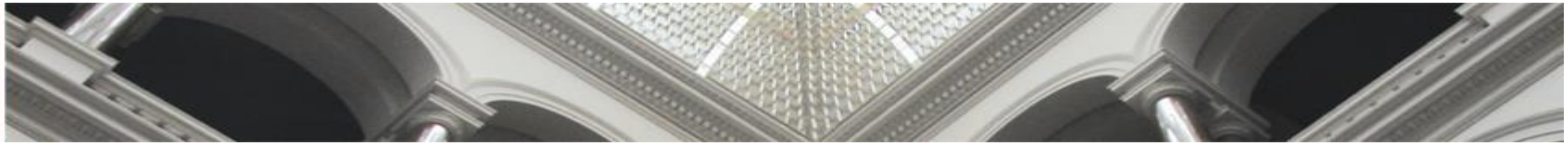
Write a run-time plugin for OpenMP to offload device code to the GPU





Benchmark: LULESH

- Livermore Unstructured Lagrangian Explicit Shock Hydrodynamics Benchmark
- Models hydrodynamics as representing a typical scientific application
- Studies behavior of fluid flow when subject to forces
- Implementations: CUDA, OpenCL, OpenMP, MPI, serial for various targets



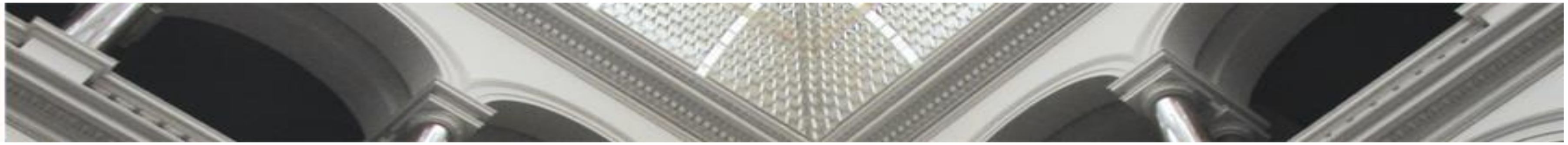
Benchmark: LULESH

Challenge 1: missing #pragma omp declare target

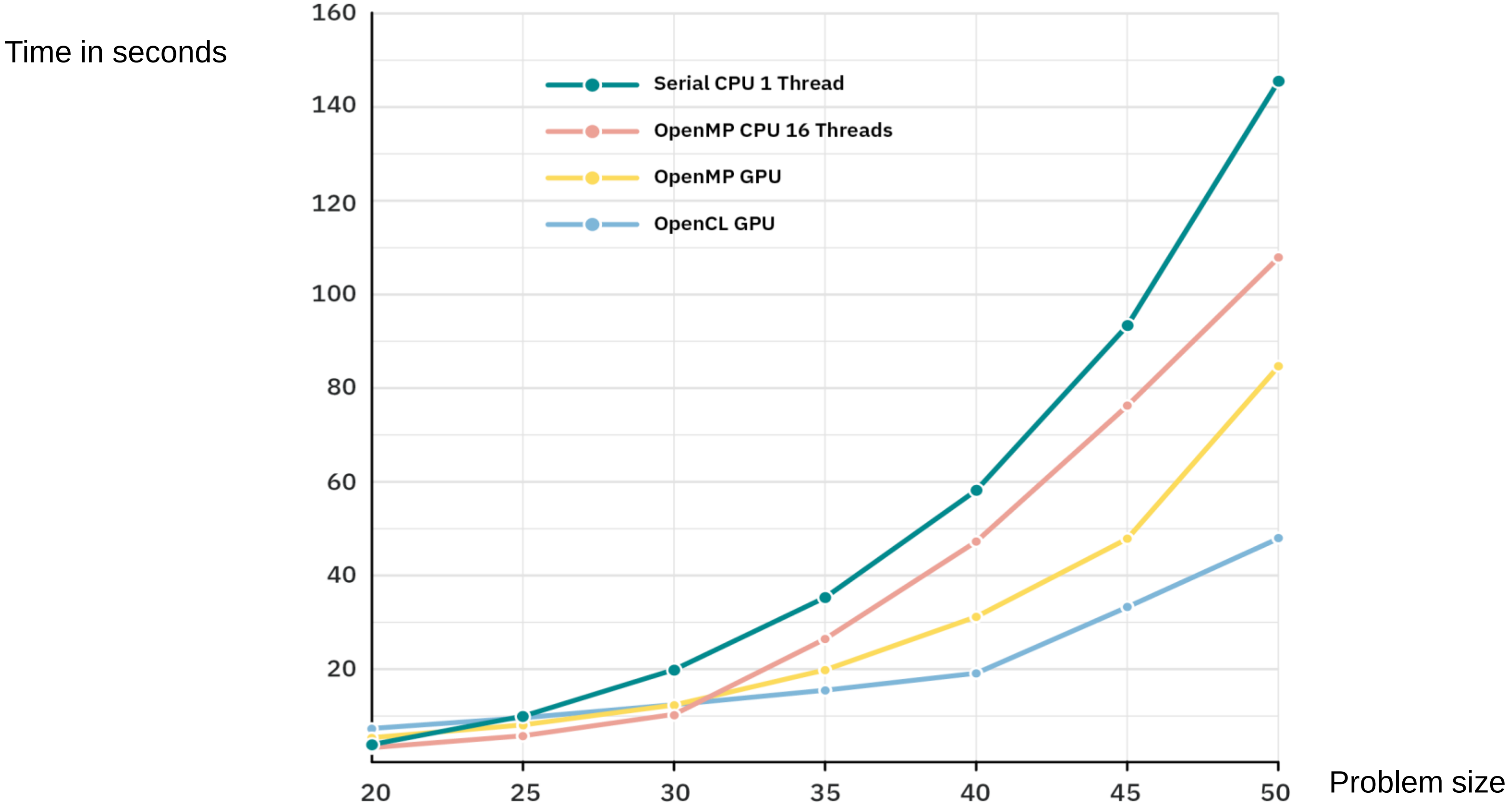
- Declares a function definition to be available on the device
- Solution: Inline everything! ☺

Challenge 2: Math Functions

- LULESH uses functions included by <math.h>
- Solution: Use Itanium name mangling to use OpenCL library functions



Benchmark: LULESH

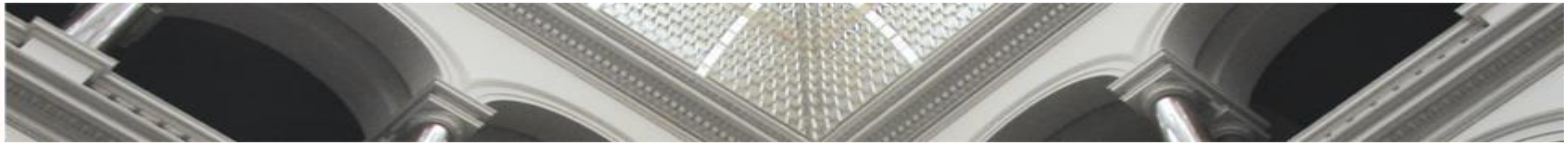


System:
CPU: AMD Ryzen 1700
GPU: AMD Radeon RX 560

Benchmark: Mandelbrot

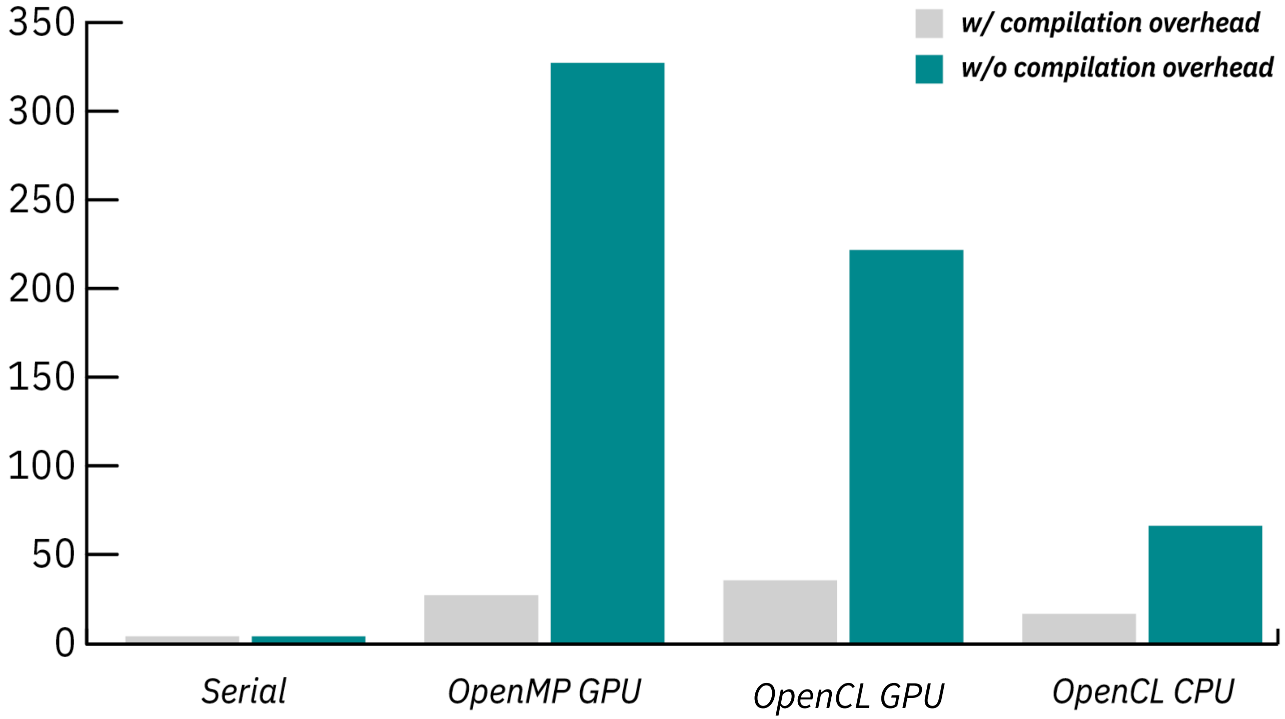
- Offloaded version benchmarked on AMD Radeon RX 560
- Scalar version benchmarked on AMD Ryzen 1700
- Resolution: 3840x2160

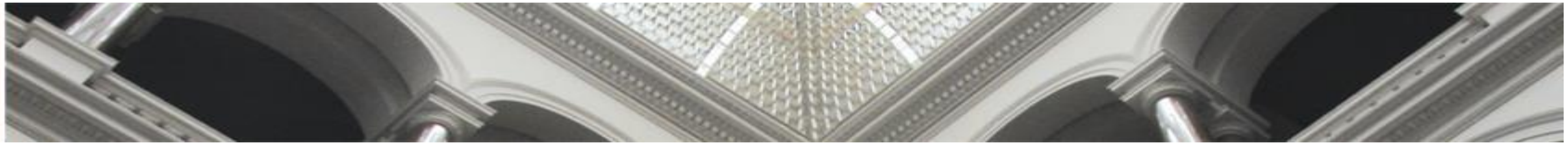
```
#pragma omp target teams map(from:output[0:width*height]) thread_limit(width*heigth)
#pragma omp distribute parallel for collapse(2)
for (int j = 0; j < height; j++) {
  for (int i = 0; i < width; ++i) {
    float x = x0 + i * dx;
    float y = y0 + j * dy;
    …
```



Benchmark: Mandelbrot

Speed-up compared to serial implementation

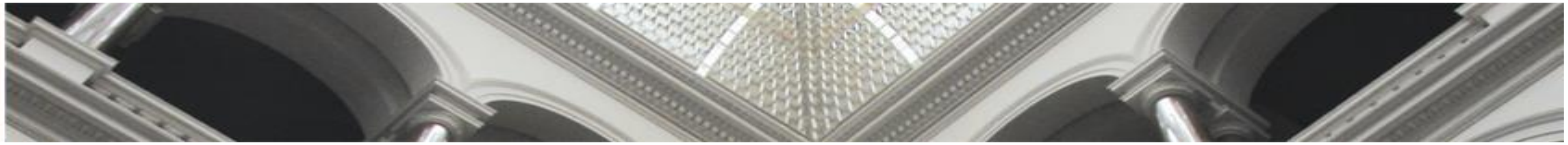




Conclusion & Future Work

- We could demonstrate the functionality & efficiency of the approach
- SPIR-V linker available
- OpenCL C library functions available

- No optimizations are enabled yet
- Reduction clause not implemented
- OpenMP library functions not available



Source Code Available

- Clang:

  https://github.com/daniel-schuermann/clang

- LLVM:

  https://github.com/thewilsonator/llvm/tree/compute

- OpenMP:

  https://github.com/daniel-schuermann/openmp