CHAPEL-ON-HSA: TOWARDS SEAMLESS ACCELERATION OF CHAPEL PROGRAMS USING HSA

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OUTLINE

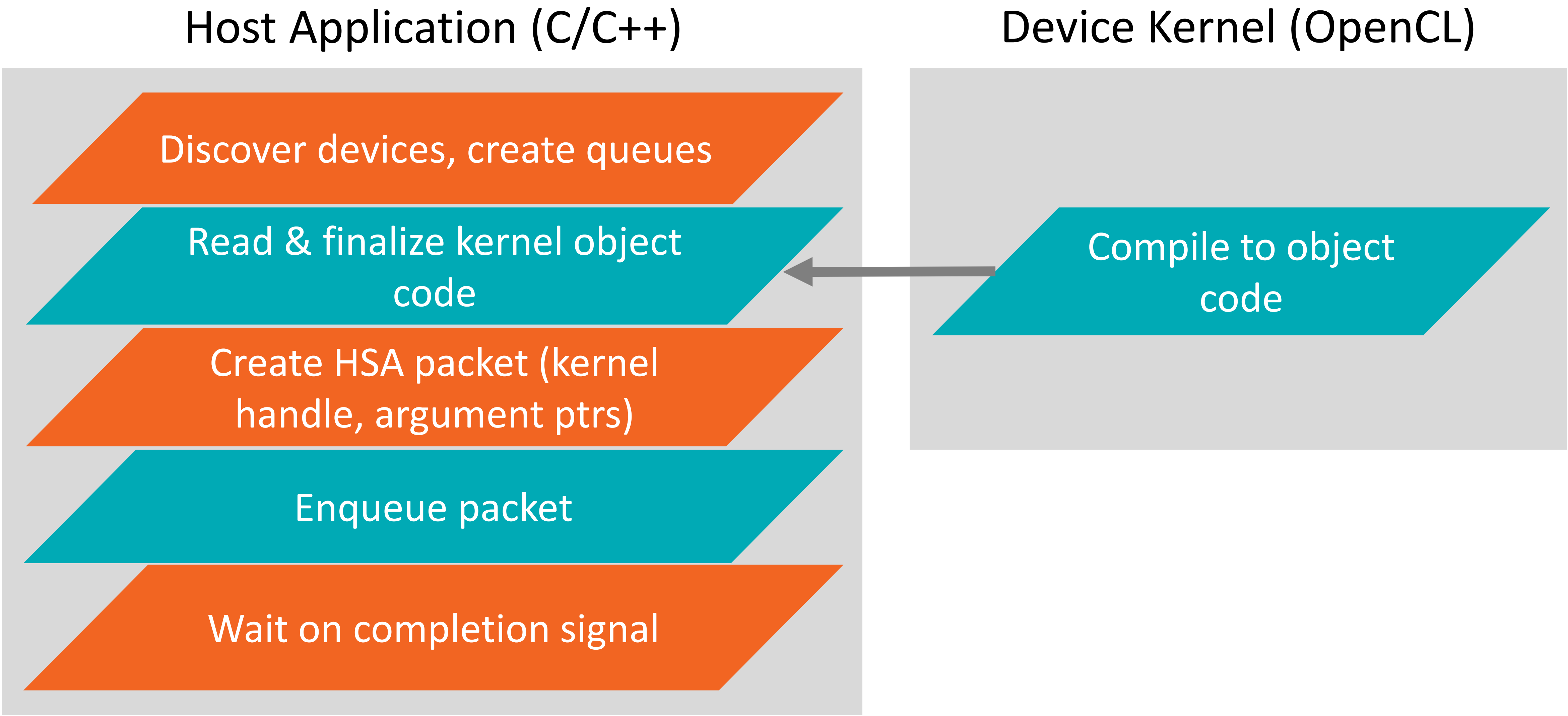
- Heterogeneous System Architecture (HSA)
- Exposing GPUs in Chapel – GPU sublocales
- Reduction
- Foralls
- Future Plans

THE HETEROGENEOUS SYSTEM ARCHITECTURE (HSA)

OPEN STANDARD PLATFORM SPECIFICATION

- Enables efficient, portable management of heterogeneous systems
- Shared address space abstraction
  - No explicit data movement
  - Single pointer across all devices
- Fast user-mode task dispatch
  - Shared memory queues for user-space direct packet enqueue
  - Fast user-space synchronization
- Multi-device support: GPUs, DSPs, FPGAs, NICs, PIM, etc.
  - A single task dispatch packet format across all devices
- Pre-emptive context-switching
- Open-source implementation
- Support for multiple higher-level languages

EXECUTING A GPU KERNEL



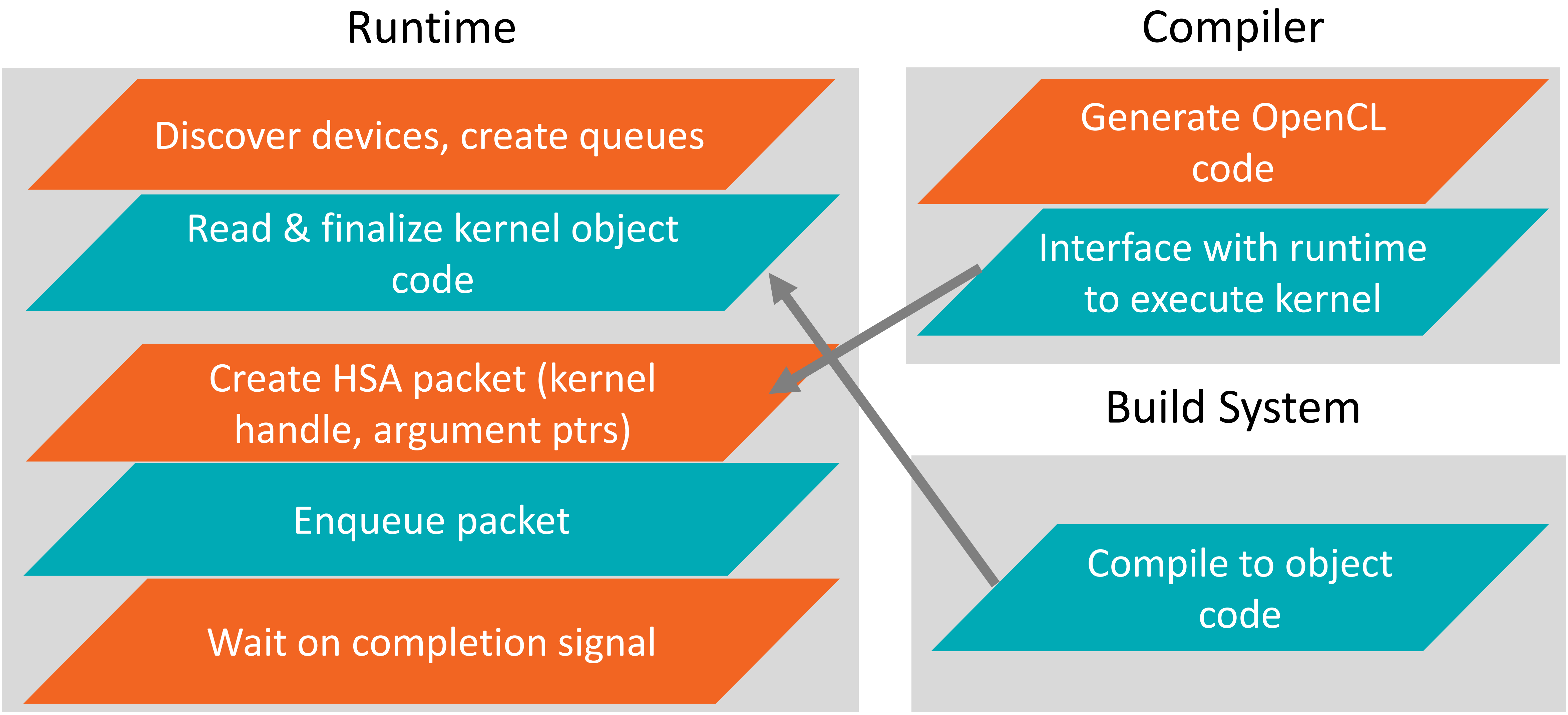
CHAPEL + HSA

GPU OFFLOAD CAPABILITY FOR DATA-PARALLEL CONSTRUCTS

- Native single-source GPU execution support
- Expose GPU execution capabilities in the language
  - Expose GPU as a sublocale
  - New “HSA” hierarchical locale with CPU and GPU sublocales
  - Any operation executed *on* a GPU sublocale gets executed on a GPU

```
on Locales[0] do {
    var A: [1..3] int = (1,2,3);
    on (Locales[0]:LocaleModel).GPU do {
       //Data-parallel constructs
       var sum = + reduce A;
   }
}
```

GPU EXECUTION IN CHAPEL



COMPILER MODIFICATIONS

CODE GENERATION AND KERNEL EXECUTION

- Parse
- Create Task Functions
- Parallel Transforms
- Optimizations
- C-Codegen

COMPILER MODIFICATIONS

AMD

Parse

- Insert new Chapel block for GPU offload
- Conditional execution of GPU code if sublocale is GPU

Create Task Functions

- Create new task functions for GPU blocks

Create GPU Functions

- Bundle core GPU executable in a new GPU function
- Maintain unique ids
- Capture arguments and bundle into 1 parameter

Parallel Transforms

Optimizations

C-Codegen

- Generate OpenCL code for GPU functions in .cl file
- Use runtime enqueue calls to enqueue functions using ids

OFFLOADING NODE-LOCAL REDUCTIONS

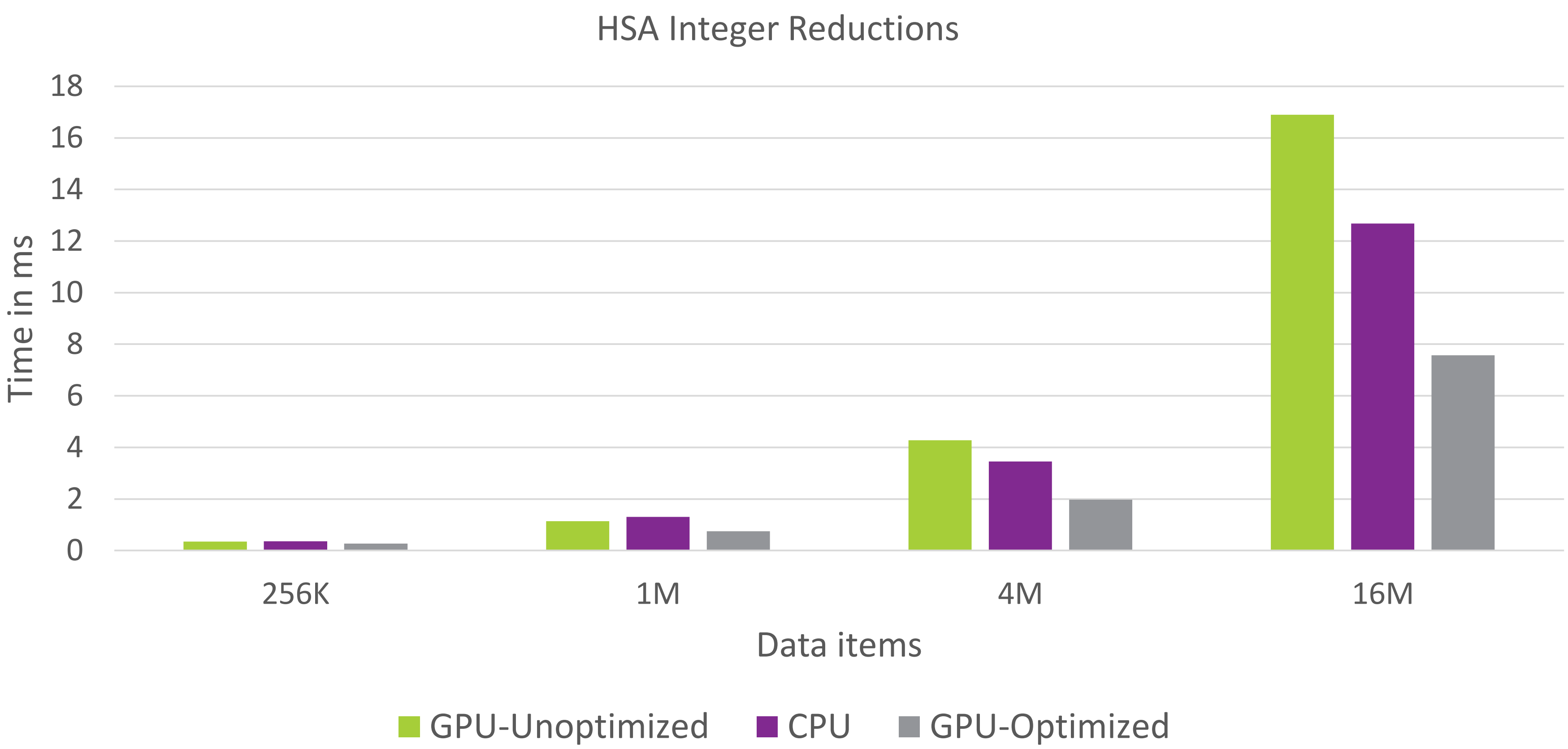
- Predefined reduction operators to reduce aggregate expressions to a single result

```
var A: [1..3] int = (1,2,3);
var sum = + reduce A;
```

- CPU reductions are pre-defined in the ChapelReduce module
- Similarly, we use precompiled OpenCL kernels
  - Separate OpenCL kernel for every <operator, data-type> pair
- Parser replaces a reduction expression with a call to the Chapel runtime routine
- GPU reductions are tricky!
  - Multiple calls to the kernels followed by processing on the CPU
  - Runtime orchestrates execution of multiple kernels
  - Direct translation of CPU code not appropriate

REDUCTION RESULTS

A10-7850K WITH RADEON™ R7 SERIES (4 CPU CORES @3.7 GHZ, 512 GPU CORES@720MHZ)



OFFLOADING NODE-LOCAL FORALLS

Data-parallelism

```
var A: [1..256] int;
forall i in {1..256} do
   A[i] = i;
```

CPU task-parallelism

```
var A: [1..256] int;
coforall j in {1..4} do {
   const lo = 1+(i–1)*64;
   const hi = lo + 63;
   for i in {lo..hi}
      A[i] = i;
}
```

4 tasks in parallel
Each task does 64 serial iterations

GPU thread-parallelism

```
var A: [1..256] int;
size_t i = get_global_id(0)
   A[i] = i;
```

256 work-items in parallel
4 workgroups
Each workgroup has 64 workitems

OFFLOADING NODE-LOCAL FORALLS

- Bundle the loop body in a new GPU-targeted function
- Estimate work-items and work group size
- Replace loop variables with OpenCL calls to obtain thread id
- Insert OpenCL specific keywords(“kernel”, “global”)
- Emit kernel code in .cl file

COMPILER

- Build system compiles the kernels to a GPU ISA using a llvm-based tool-chain

BUILD

- Kernel execution requests are sent to the runtime using the kernel-id

RUNTIME

FUTURE WORK

- Multi-node reductions and coforalls
- Multi-dimensional arrays
- Expose workgroup based resources
  - Local memory
  - Barriers
- Benchmarking
- Testing

Thank You!

We Are Hiring!

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Interns, Co-ops, Post-docs

(Fall 2016, Spring 2017,…)

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