



Vortex Open GPU Research Platform

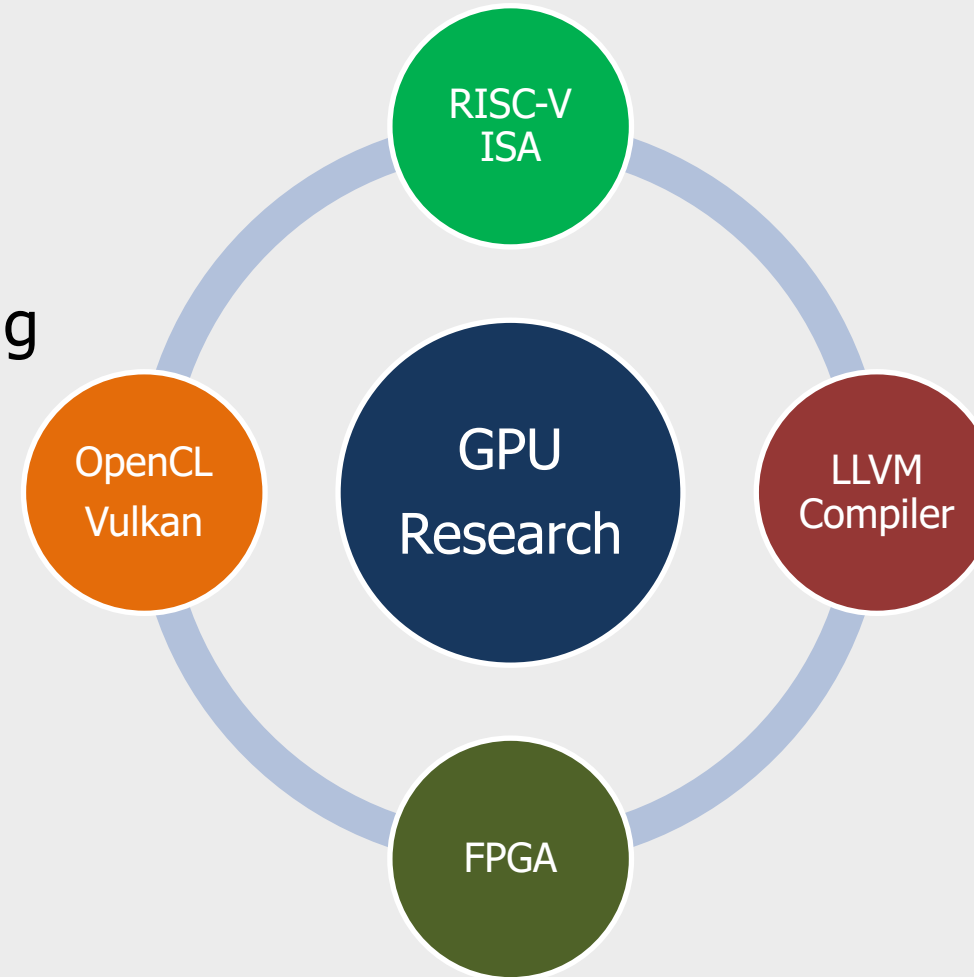


Georgia Tech College of Computing
Center for Research into
Novel Computing Hierarchies

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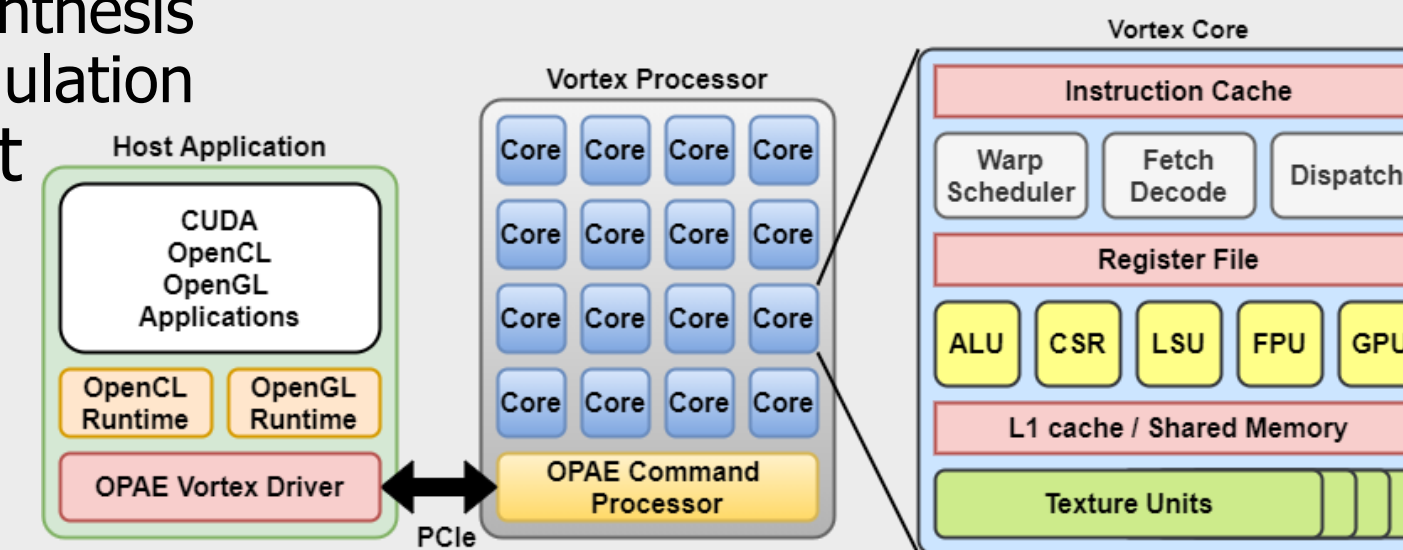
Motivation

- Research in GPU Hardware Architecture
 - Hardware research beyond simulation
 - A robust framework for prototyping
 - Lack of open-source full-system GPU
- The advent of RISC-V
 - Open ISA for accessibility
 - Frozen ISA for compatibility
 - Extensible ISA for customization
 - Ideal for architecture research!
- The advent of RISC-V
 - Large-scale RTL designs now possible
 - What about complex GPU designs?



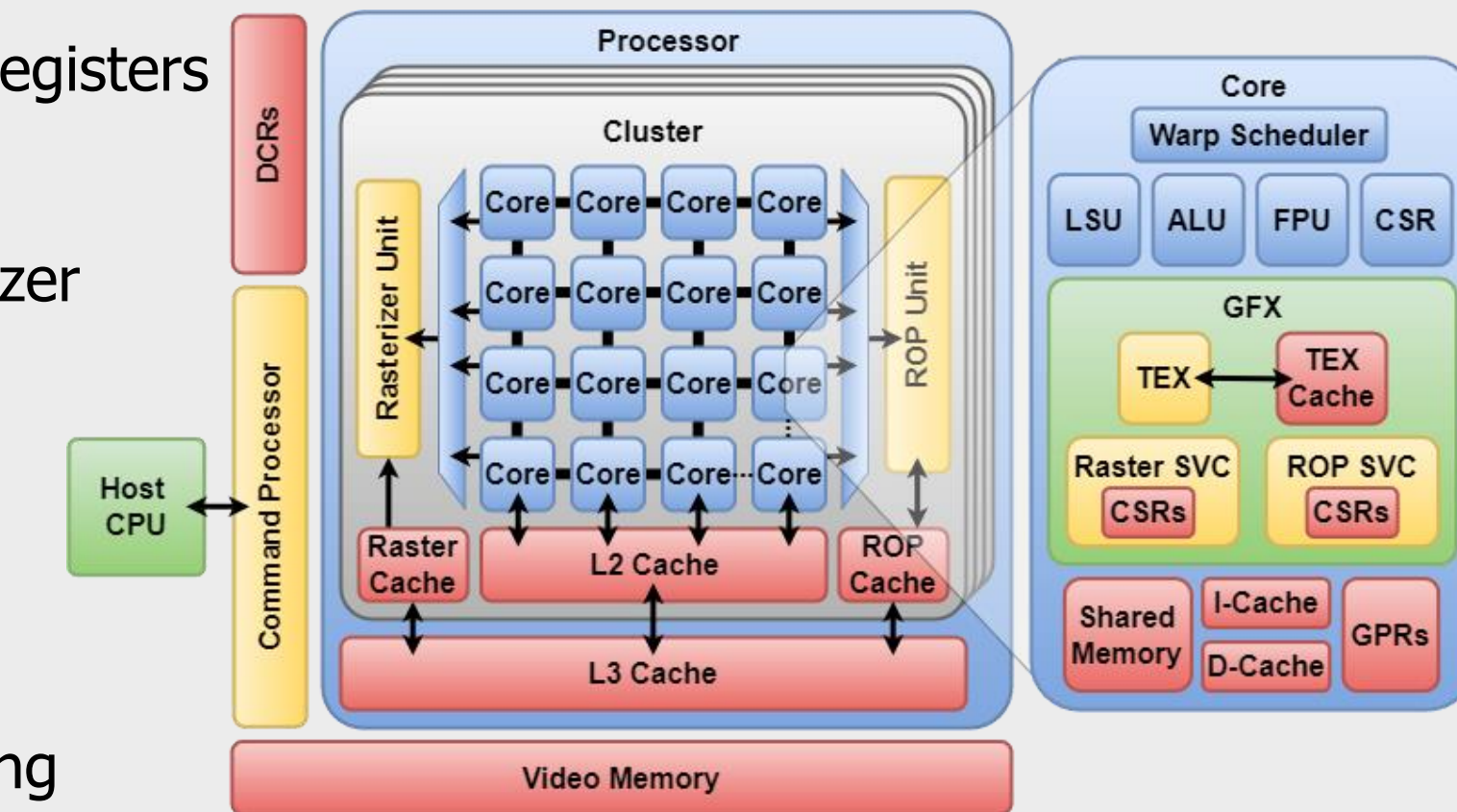
Vortex System Architecture

- Open-source Toolchain
 - POCL: OpenCL Compiler
 - OPAE: FPGA Driver API
 - Verilator: RTL simulation
 - Yosys: FPGA Synthesis
 - Gem5: CAS Simulation
- Software Support
 - OpenCL
 - CUDA
 - OpenGL
 - Vulkan
- Hardware
 - Configurable multi-core SIMT architecture
 - PCIe host-device interface
 - Up to 32-cores @ 230 Mhz



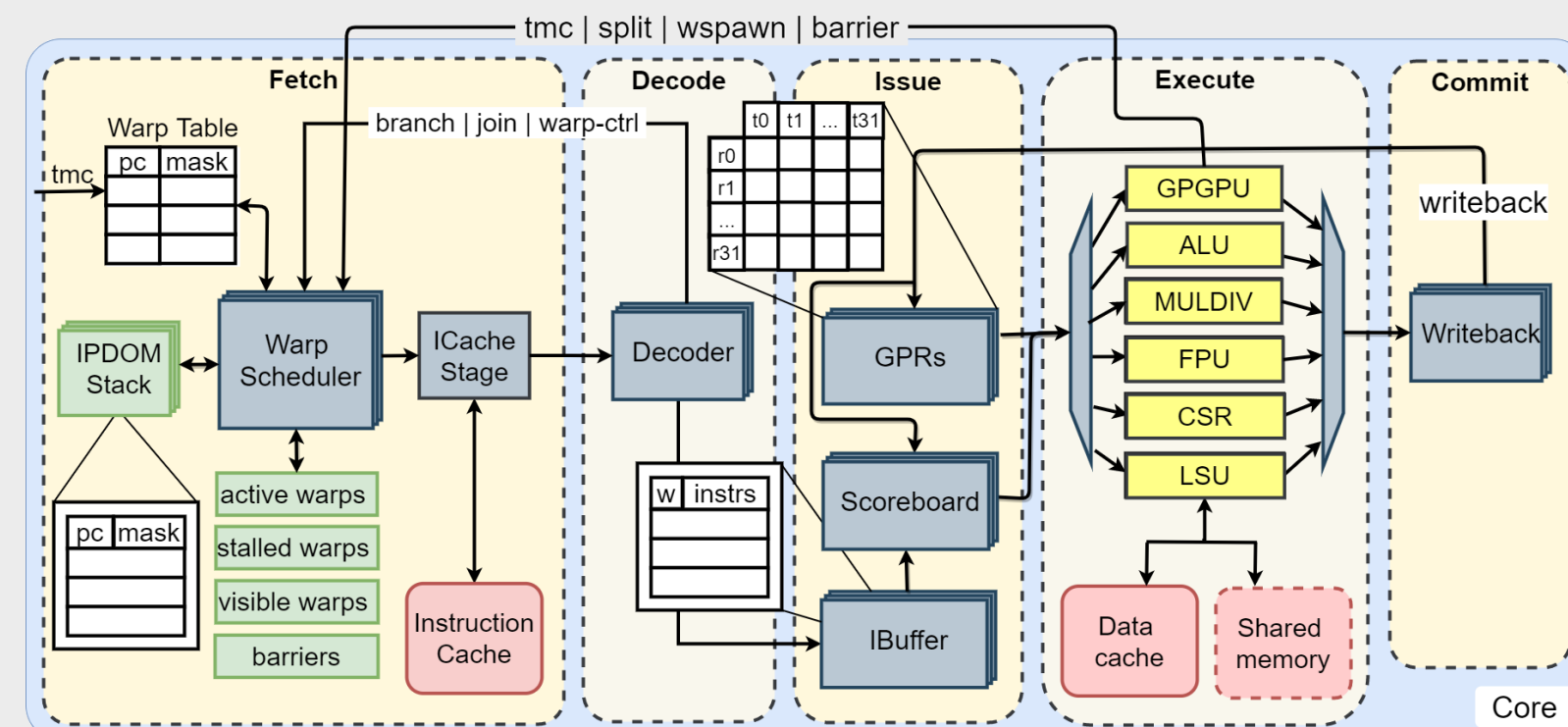
Vortex Processor Microarchitecture

- Command Processor
 - CPU-GPU communication
- DCRs
 - Configuration registers
 - CPU driven
- Raster Unit
 - Triangle rasterizer
 - Tile-based
- ROP Unit
 - Depth/Stencil
 - Blending
 - Logic Op
- Texture Unit
 - Texture sampling



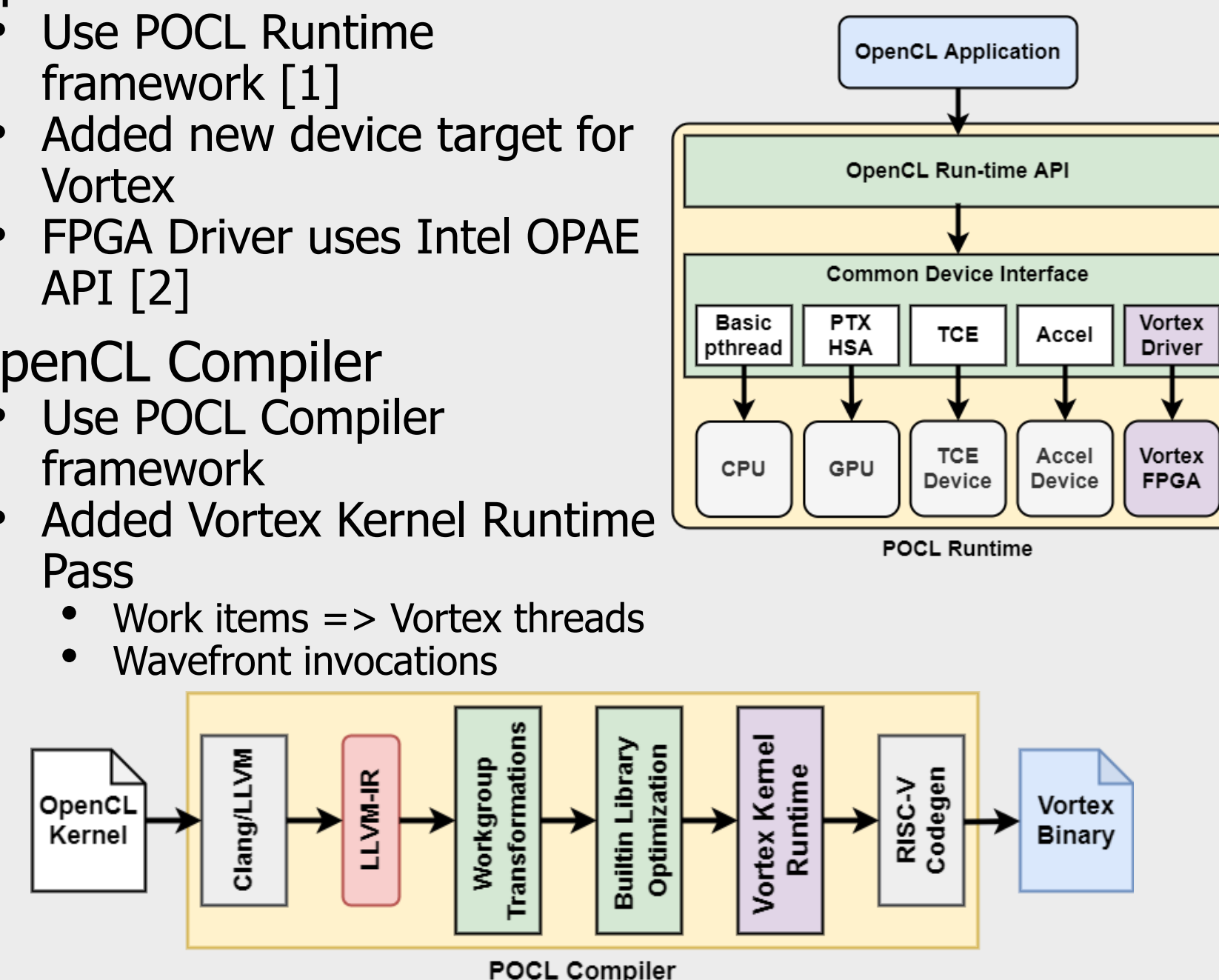
Vortex Single Core Microarchitecture

- Five-stage RISC-V Pipeline
 - In-order issue, out-of-order commit
 - Warp scheduler
 - Per-thread general-purpose register file
 - Per-wavefront instruction buffer
 - GPGPU Unit



OpenCL Software Stack

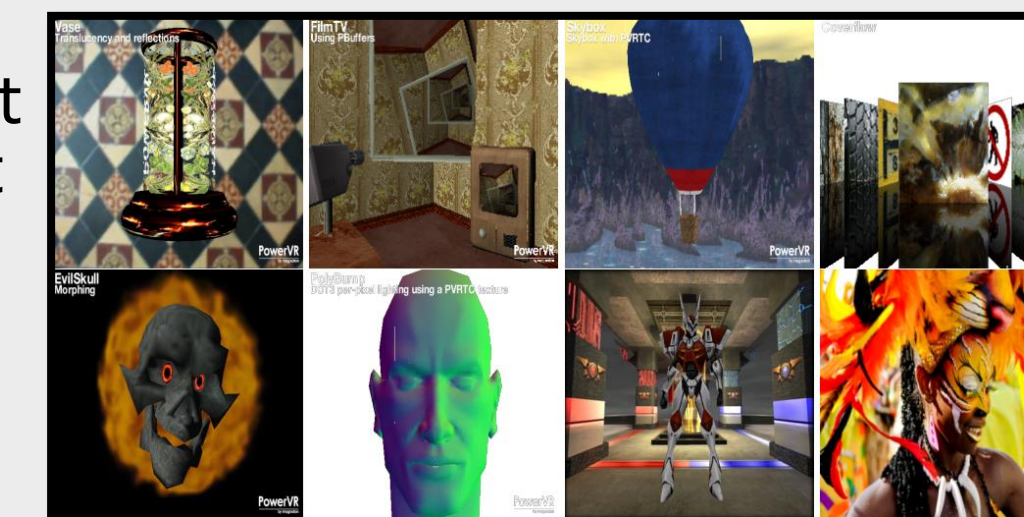
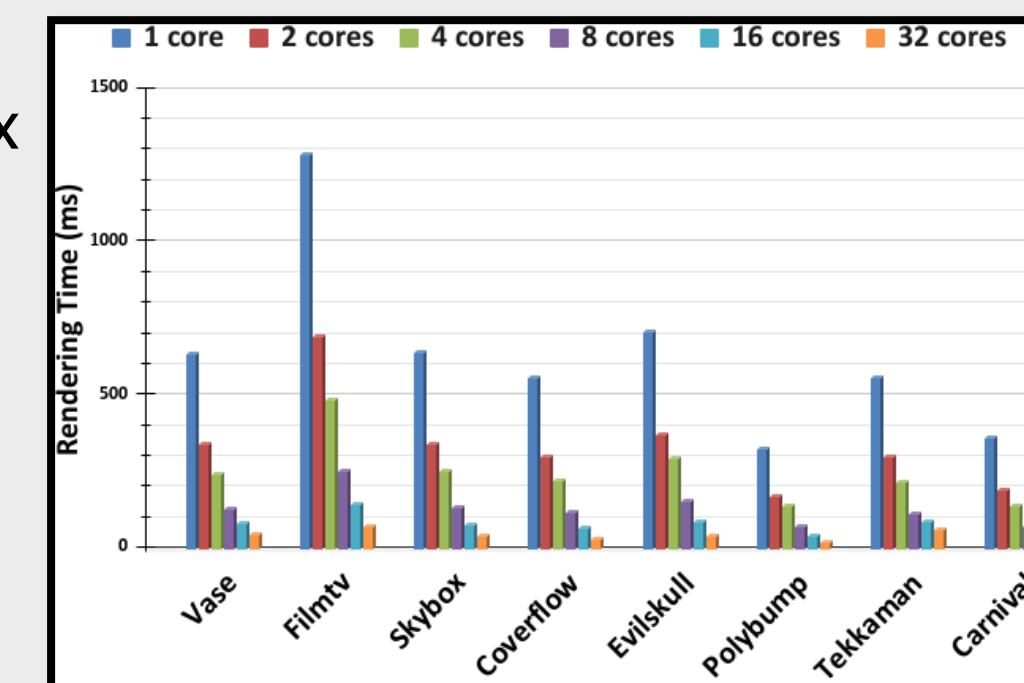
- OpenCL Runtime
 - Use POCL Runtime framework [1]
 - Added new device target for Vortex
 - FPGA Driver uses Intel OPAE API [2]
- OpenCL Compiler
 - Use POCL Compiler framework
 - Added Vortex Kernel Runtime Pass
 - Work items => Vortex threads
 - Wavefront invocations



[1] Pekka Jääskeläinen et al "pocl: A Performance-Portable OpenCL Implementation"
[2] Open Programmable Acceleration Engine: <https://opae.github.io>

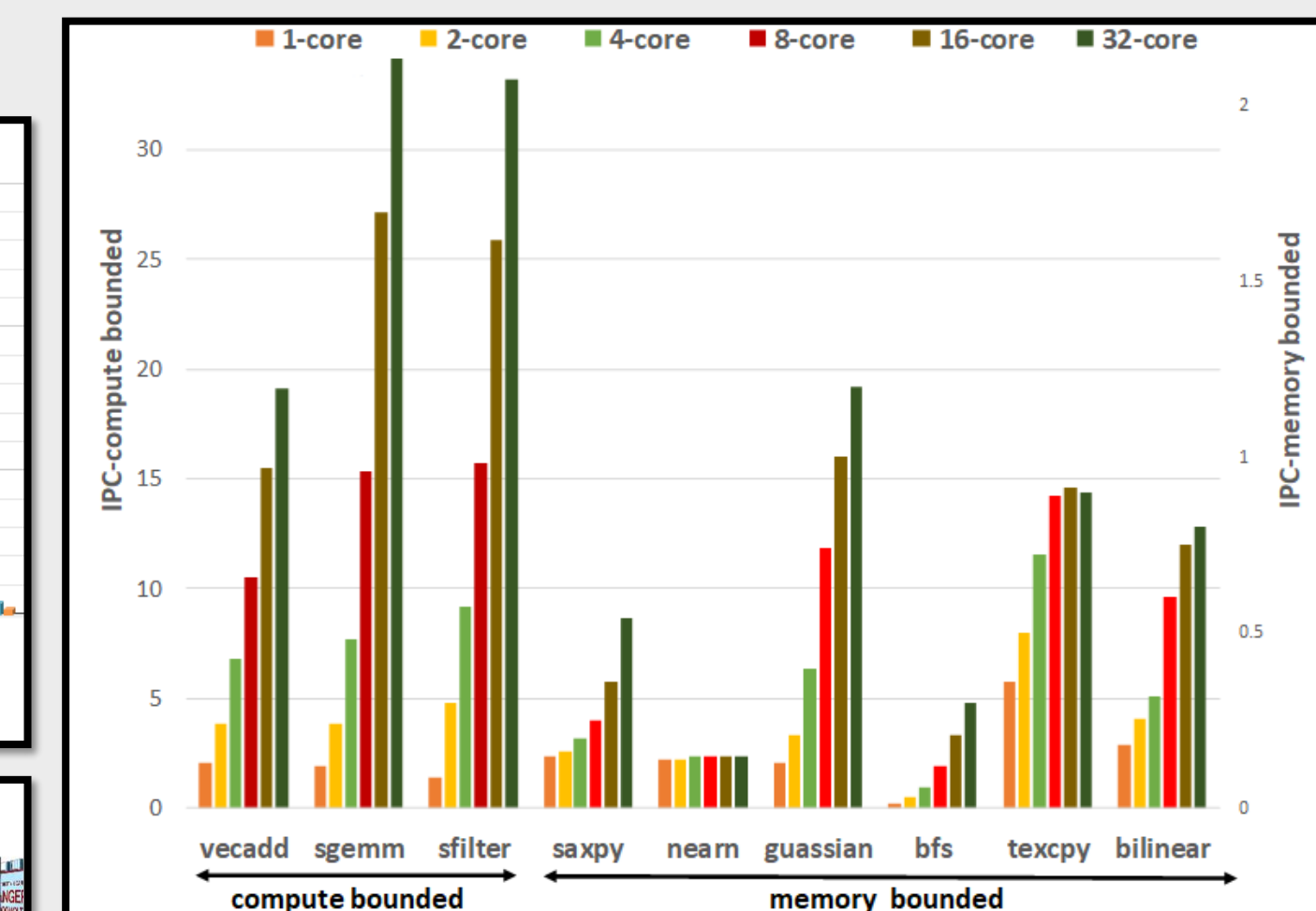
Graphics Benchmark

- Evaluation Setup
 - Intel PAC Stratix 10 FPGA
 - Intel Xeon E5-1650 3.5 Ghz CPU



- FPGA Performance
 - 32 GPU cores
 - 1 Rasterizer unit
 - 4 render output units
 - 8 texture units
 - Texture Fill Rate: 7.4 GTexels/s
 - Pixel Fill Rate: 3.7 GPixels/s

GPGPU Benchmark



- Evaluation Setup
 - Intel PAC Arria 10 FPGA
 - Intel Xeon E5-1650 3.5 GHz CPU
- OpenCL Performance
 - Rodinia benchmark
 - Compute vs. memory bound
 - Scaling across many applications
 - Throughput: 29 Gflops