

CUDA 6.0
Performance Report

April 2014



CUDA 6 Performance Report

- **CUDART** CUDA Runtime Library
- **cuFFT** Fast Fourier Transforms Library
- **cuBLAS** Complete BLAS Library
- **cuSPARSE** Sparse Matrix Library
- **cuRAND** Random Number Generation (RNG) Library
- **NPP** Performance Primitives for Image & Video Processing
- **Thrust** Templated Parallel Algorithms & Data Structures
- **math.h** C99 floating-point Library

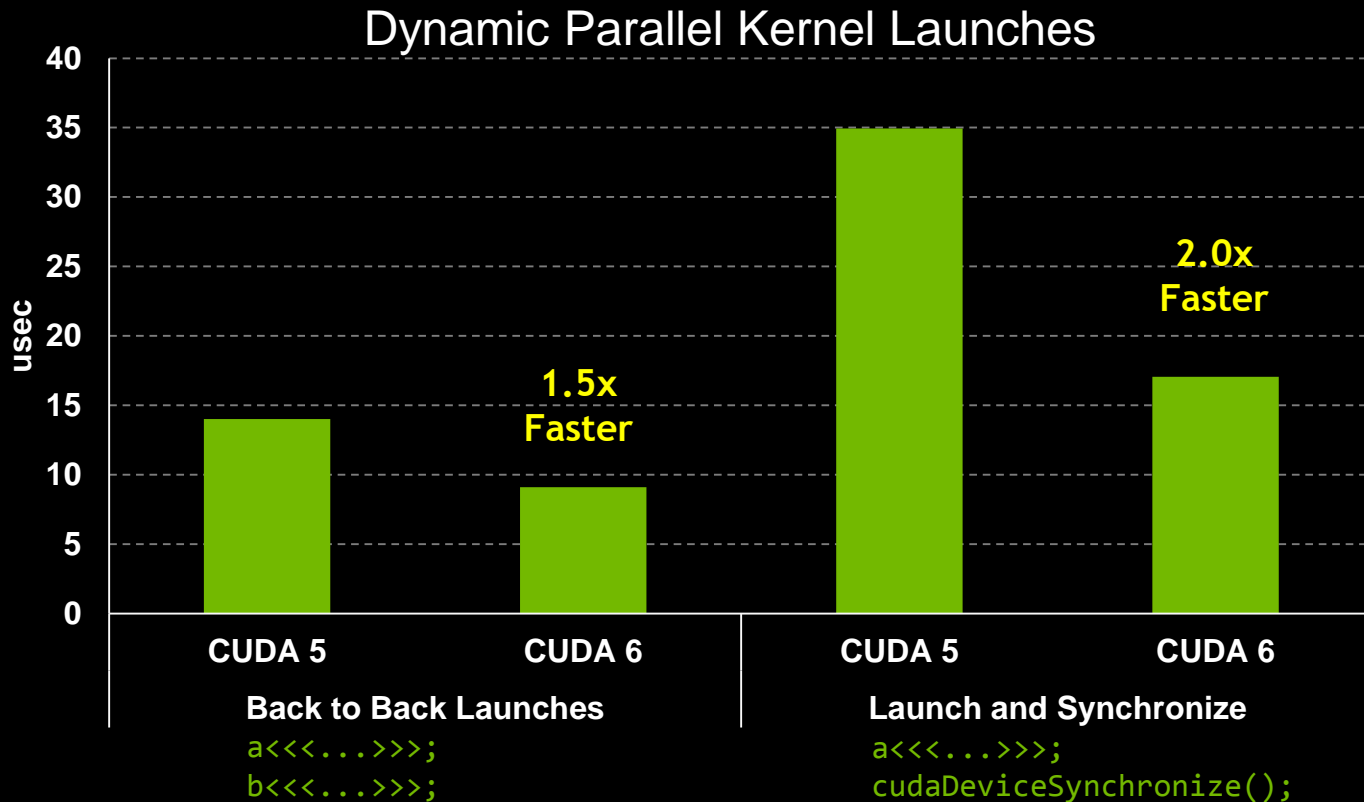
Included in the CUDA Toolkit (free download):

developer.nvidia.com/cuda-toolkit

For more information on CUDA libraries:

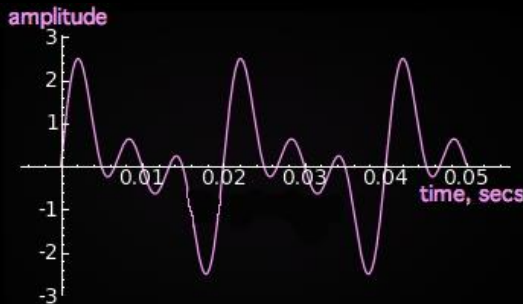
developer.nvidia.com/gpu-accelerated-libraries

CUDA 6: 2x Faster GPU Kernel Launches



cuFFT: Multi-dimensional FFTs

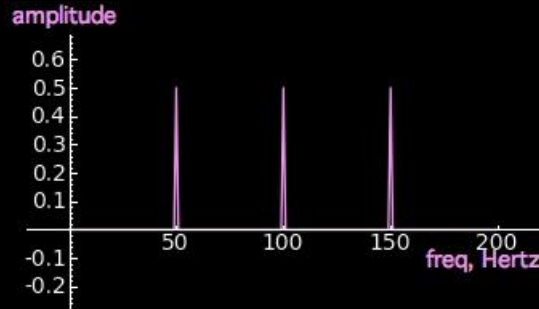
- Real and complex
- Single- and double-precision data types
- 1D, 2D and 3D batched transforms
- Flexible input and output data layouts
- **New in CUDA 6** ● XT interface supports dual-GPU cards (Tesla K10, GeForce GTX690, ...)



$$F(x) = \sum_{n=0}^{N-1} f(n) e^{-j2\pi(x\frac{n}{N})}$$



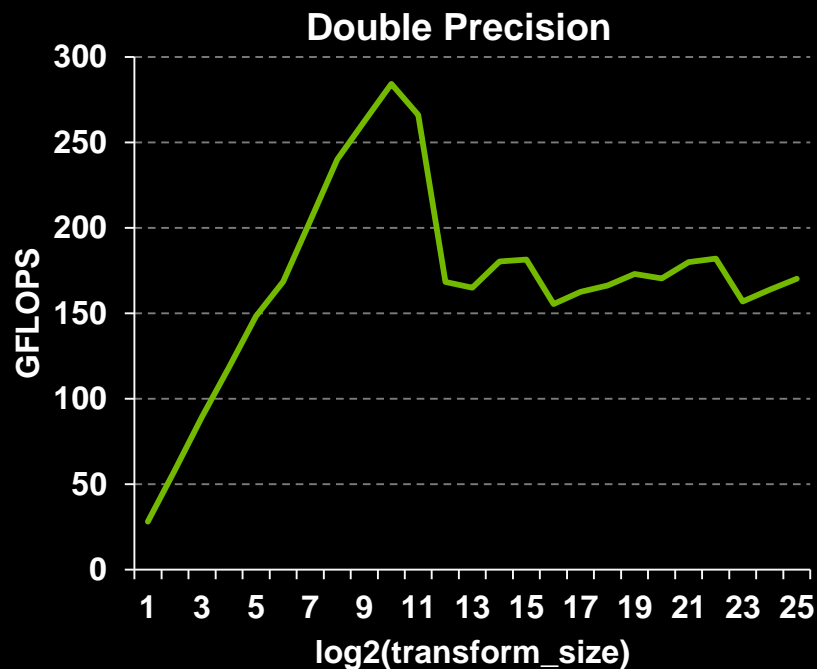
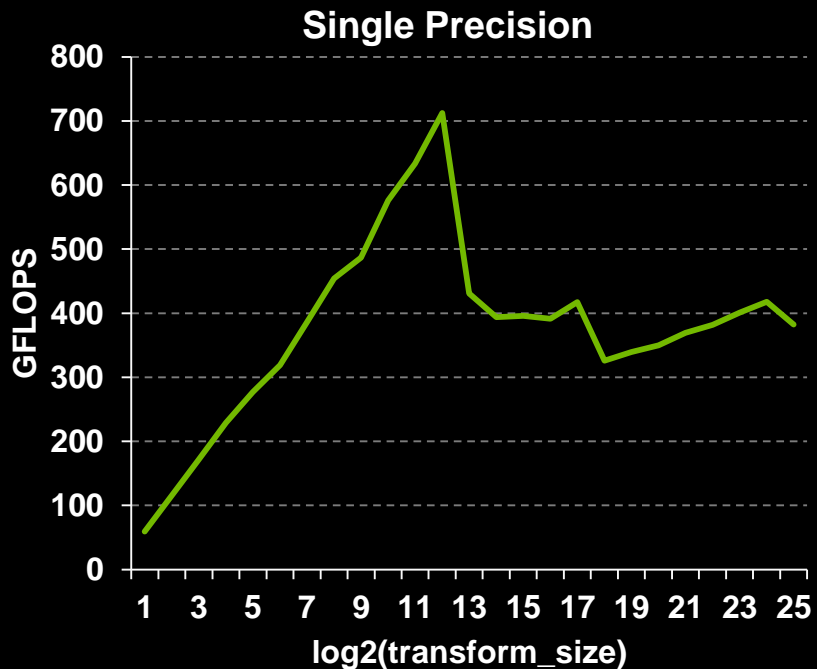
$$f(n) = \frac{1}{N} \sum_{x=0}^{N-1} F(x) e^{j2\pi(x\frac{n}{N})}$$



cuFFT: up to 700 GFLOPS

1D Complex, Batched FFTs

Used in Audio Processing and as a Foundation for 2D and 3D FFTs

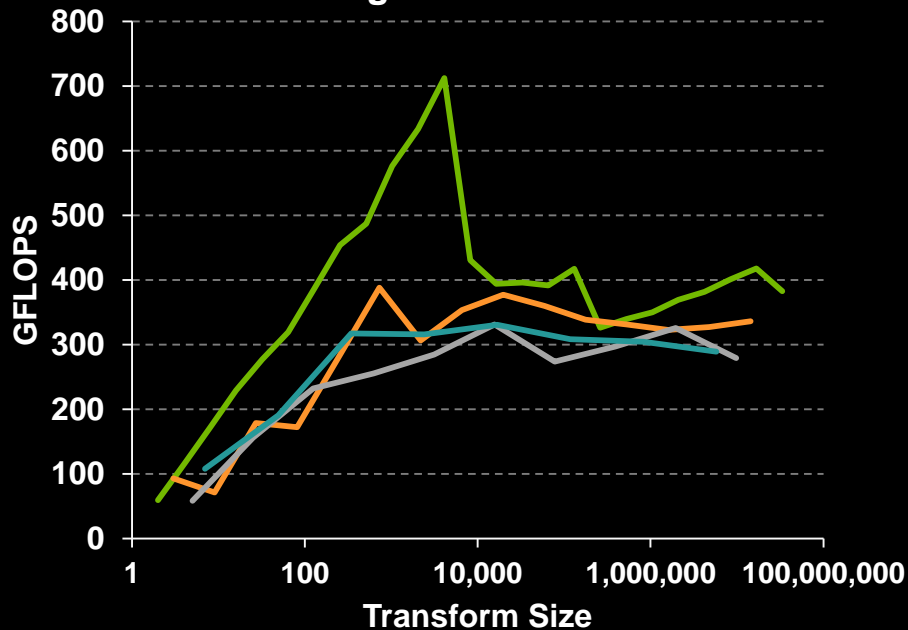


cuFFT: Consistently High Performance

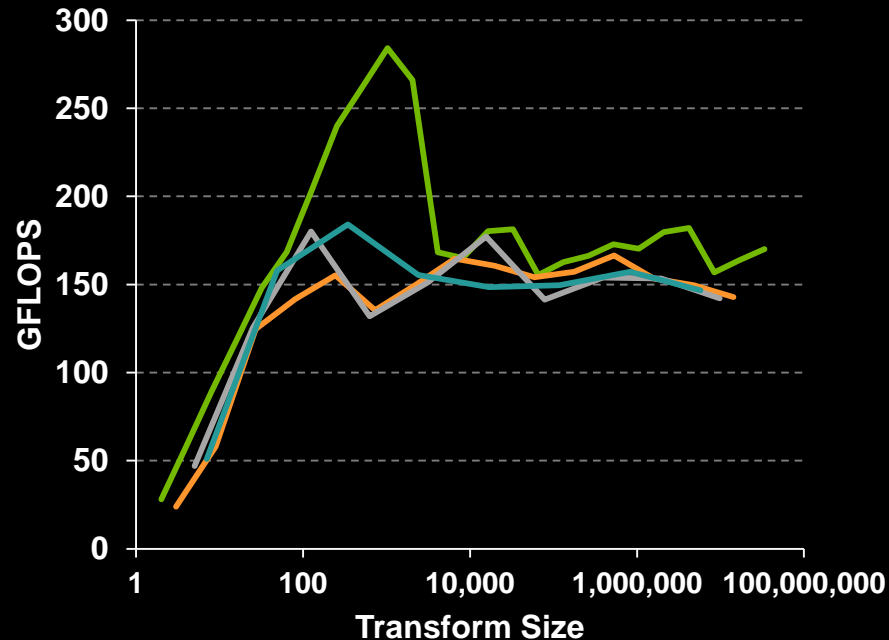
1D Complex, Batched FFTs

Used in Audio Processing and as a Foundation for 2D and 3D FFTs

Single Precision



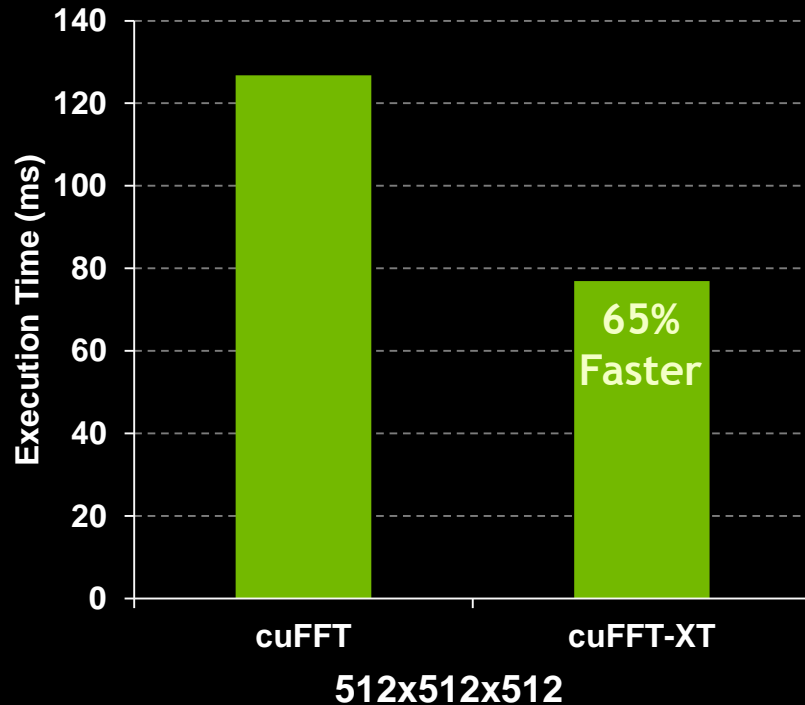
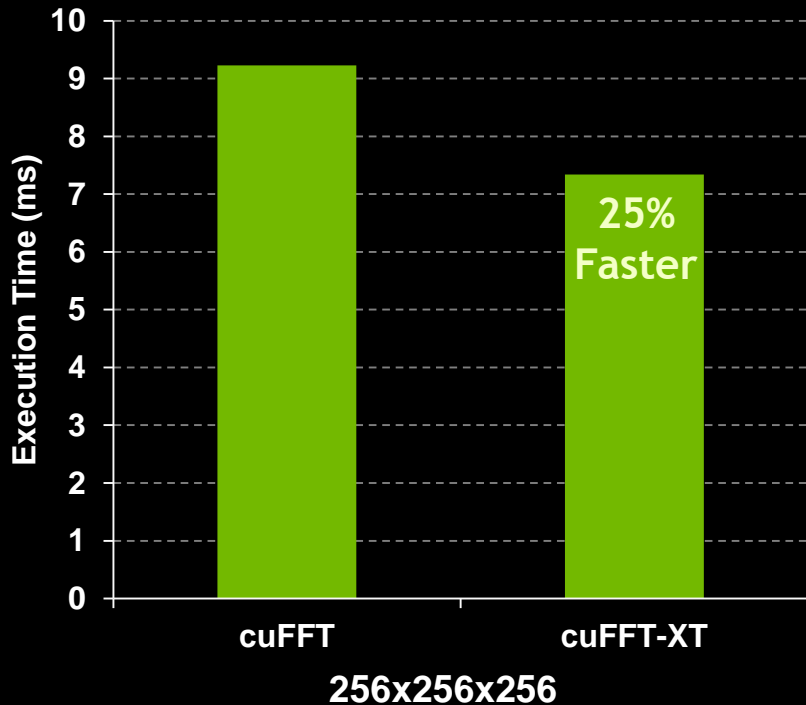
Double Precision




— Powers of 2 — Powers of 3 — Powers of 5 — Powers of 7

New in
CUDA 6

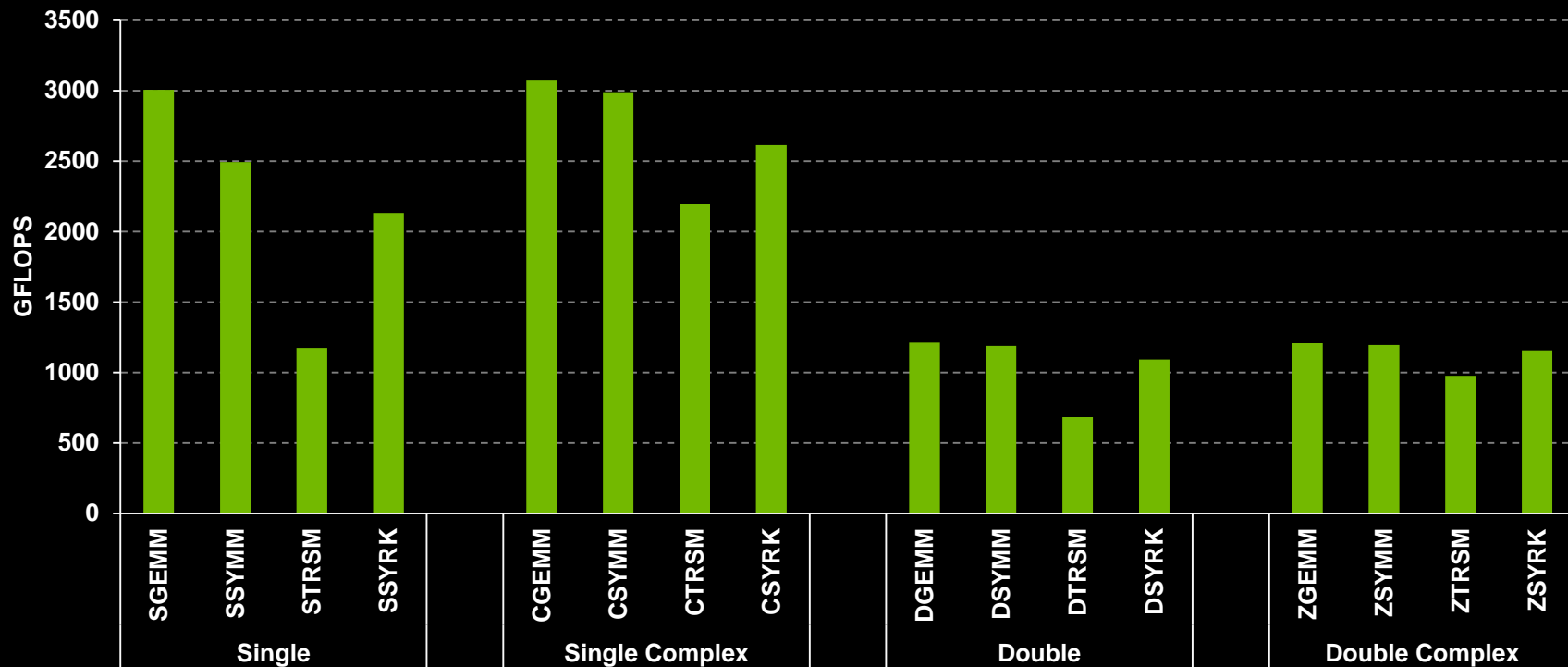
cuFFT-XT: Boosts Performance on K10



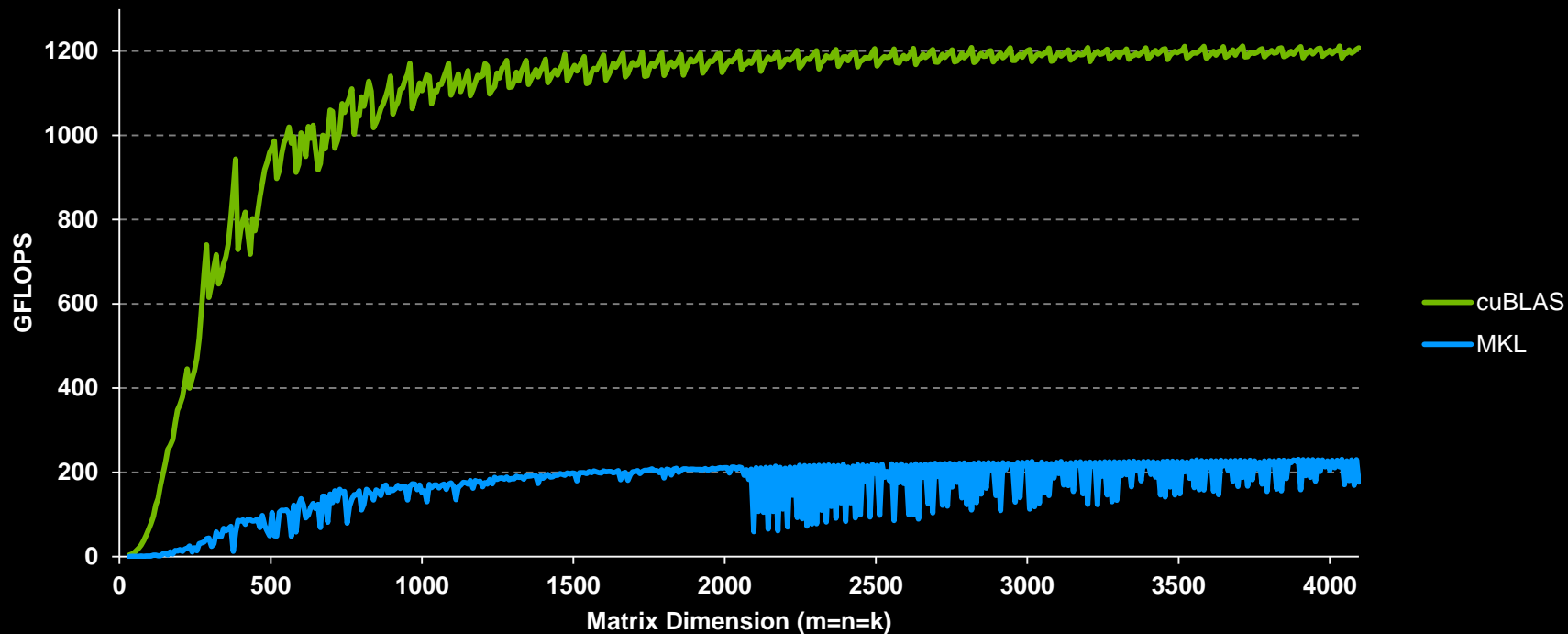
cuBLAS: Dense Linear Algebra on GPUs

- Complete BLAS implementation plus useful extensions
 - Supports all 152 standard routines for single, double, complex, and double complex
 - Host and device-callable interface
-  XT Interface for Level 3 BLAS
 - Distributed computations across multiple GPUs
 - Out-of-core streaming to GPU, no upper limit on matrix size
 - “Drop-in” BLAS intercepts CPU BLAS calls, streams to GPU

cuBLAS: >3 TFLOPS single-precision
>1 TFLOPS double-precision

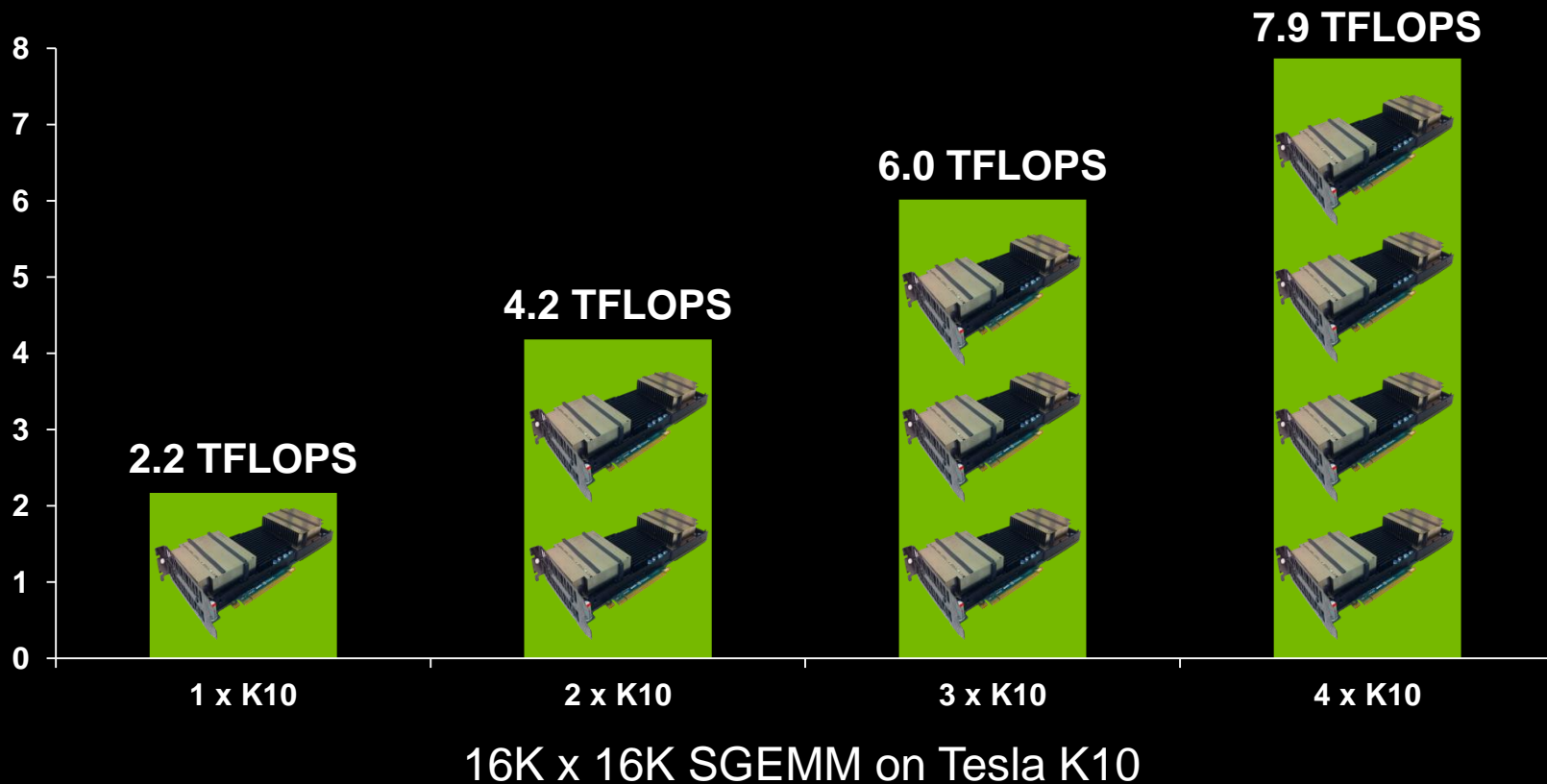


cuBLAS: ZGEMM 5x Faster than MKL



New in
CUDA 6

cuBLAS-XT: Multi-GPU Performance Scaling



cuSPARSE: Sparse linear algebra routines

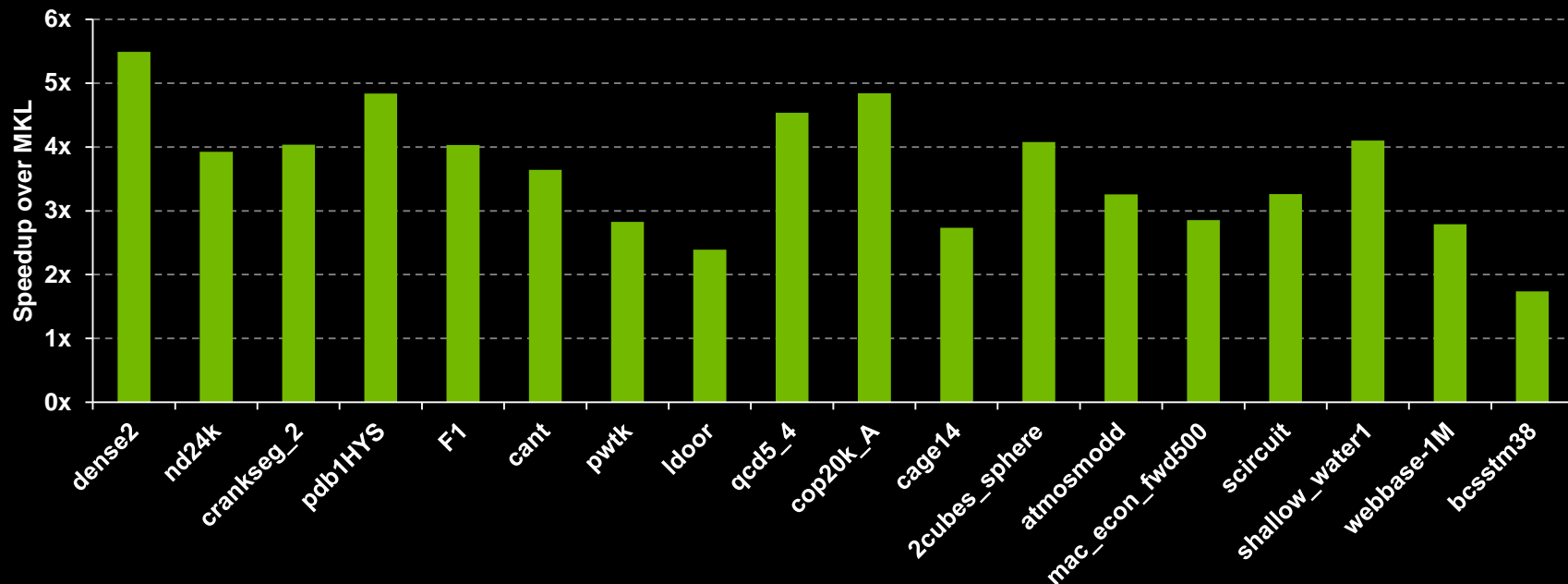
- Optimized sparse linear algebra BLAS routines - matrix-vector, matrix-matrix, triangular solve
- Support for variety of formats (CSR, COO, block variants)
- Many improvements to triangular solvers, Incomplete-LU, and Cholesky preconditioners

New in
CUDA 6

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \alpha \begin{bmatrix} 1.0 & & & \\ 2.0 & 3.0 & & \\ & & 4.0 & \\ 5.0 & & 6.0 & 7.0 \end{bmatrix} \begin{bmatrix} 1.0 \\ 2.0 \\ 3.0 \\ 4.0 \end{bmatrix} + \beta \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix}$$

cuSPARSE: 5x Faster than MKL

Sparse Matrix x Dense Vector (SpMV)



- Average of s/c/d/z routines
- cuSPARSE 6.0 on K40m, ECC ON, input and output data on device
- MKL 11.0.4 on Intel IvyBridge 12-core E5-2697 v2 @ 2.70GHz
- Matrices obtained from: <http://www.cise.ufl.edu/research/sparse/matrices/>

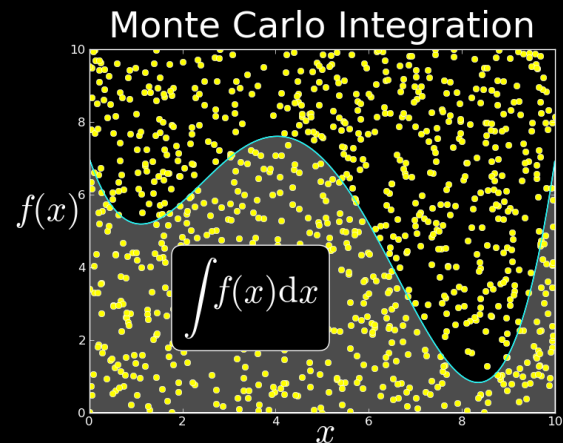
cuRAND: Random Number Generation

- Generating high quality random numbers in parallel is hard
 - Don't do it yourself, use a library!

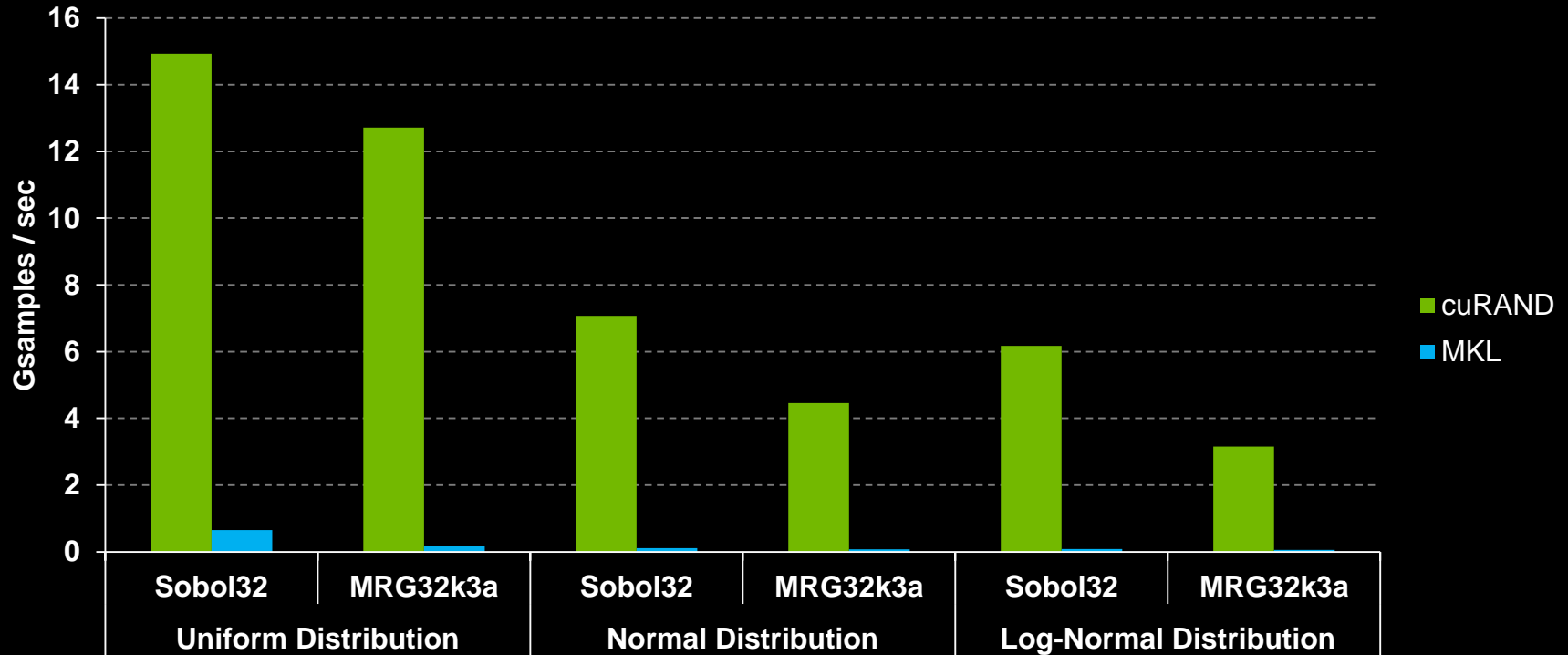
- Pseudo- and Quasi-RNGs
- Supports several output distributions
- Statistical test results in documentation

New in
CUDA 6

- Mersenne Twister 19937

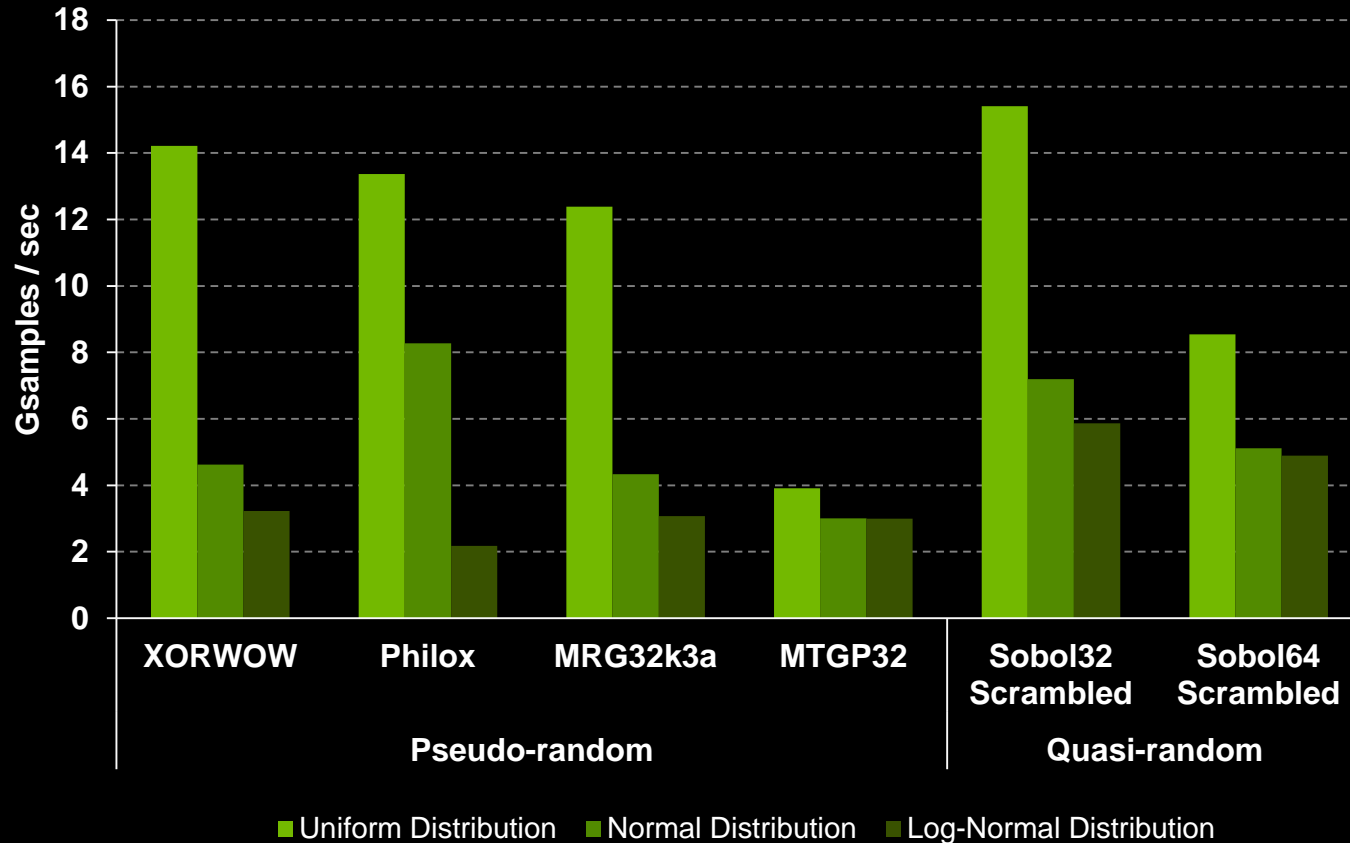


cuRAND: Up to 75x Faster vs. Intel MKL



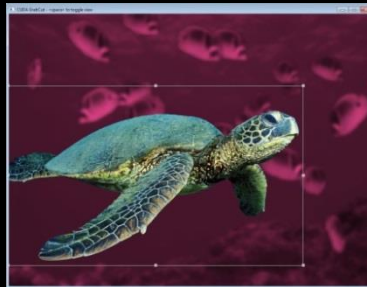
- cuRAND 6.0 on K40c, ECC ON, double-precision input and output data on device
- MKL 11.0.1 on Intel SandyBridge 6-core E5-2620 @ 2.0 GHz

cuRAND: High Performance RNGs



NPP: NVIDIA Performance Primitives

- Over **5000** image and signal processing routines:
color transforms, geometric transforms, move operations, linear filters, image & signal statistics, image & signal arithmetic, JPEG building blocks, image segmentation
- **New in CUDA 6** Over 500 new routines, including:
median filter, BGR/YUV conversion, 3D LUT color conversion, improvements to JPEG primitives, plus many more



NPP Speedup vs. Intel IPP



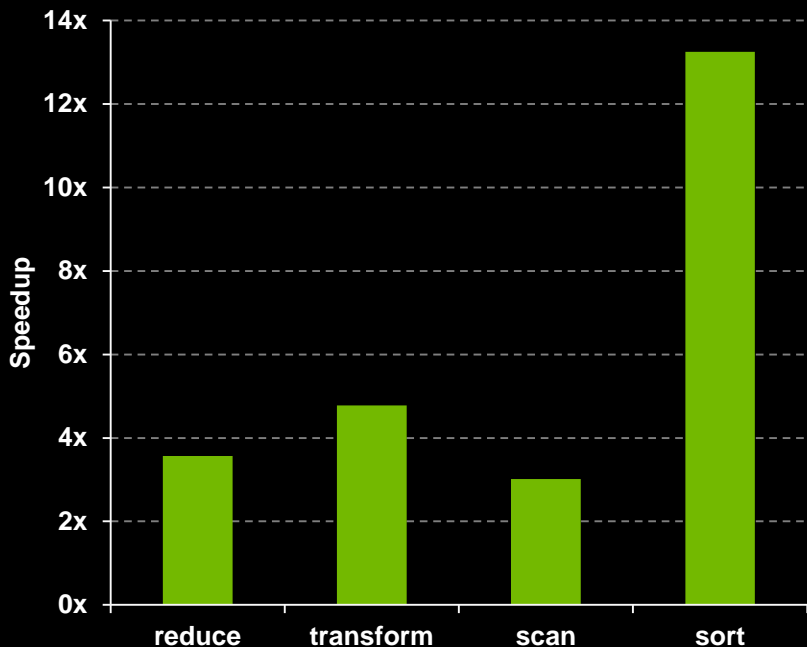


CUDA C++ Template Library

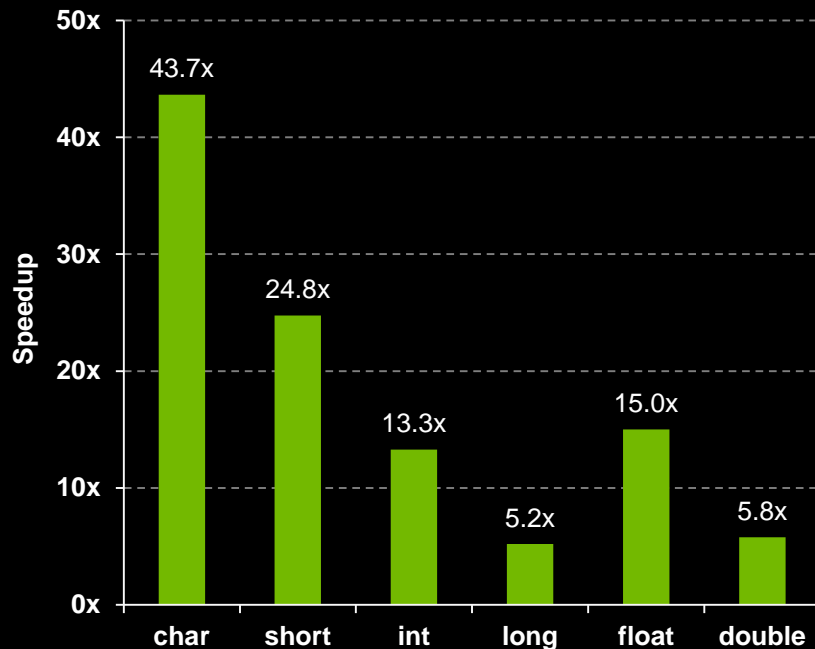
- Template library for CUDA C++
 - Host and Device Containers that mimic the C++ STL
 - Optimized Algorithms for sort, reduce, scan, etc.
 - OpenMP Backend for portability
- Also available on github: [thrust.github.com](https://github.com/rapidsai/thrust)
- Allows applications and prototypes to be built *quickly*

Thrust Performance vs. Intel TBB

Thrust vs. TBB on 32M integers



Thrust Sort vs. TBB on 32M samples



- Thrust v1.7.1 on K40m, ECC ON, input and output data on device
- TBB 4.2 on Intel IvyBridge 12-core E5-2697 v2 @ 2.70GHz

math.h: C99 floating-point library + extras

CUDA math.h is **industry proven, high performance, accurate**

- **Basic:** +, *, /, 1/, sqrt, FMA (all IEEE-754 accurate for float, double, all rounding modes)
- **Exponentials:** exp, exp2, log, log2, log10, ...
- **Trigonometry:** sin, cos, tan, asin, acos, atan2, sinh, cosh, asinh, acosh, ...
- **Special functions:** lgamma, tgamma, erf, erfc
- **Utility:** fmod, remquo, modf, trunc, round, ceil, floor, fabs, ...
- **Extras:** rsqrt, rcbrt, exp10, sinpi, sincos[pi], cospi, erfinv, erfcinv, normcdf[inv],...

New in
CUDA 6

- Over 80 new SIMD instructions
 - Useful for video processing: `_v*2`, `_v*4`
- Cylindrical bessel: `cyl_i{0,1}`
- 1/hypotenuse: `rhypot`