GPU VSIPL: High Performance VSIPL Implementation for GPUs

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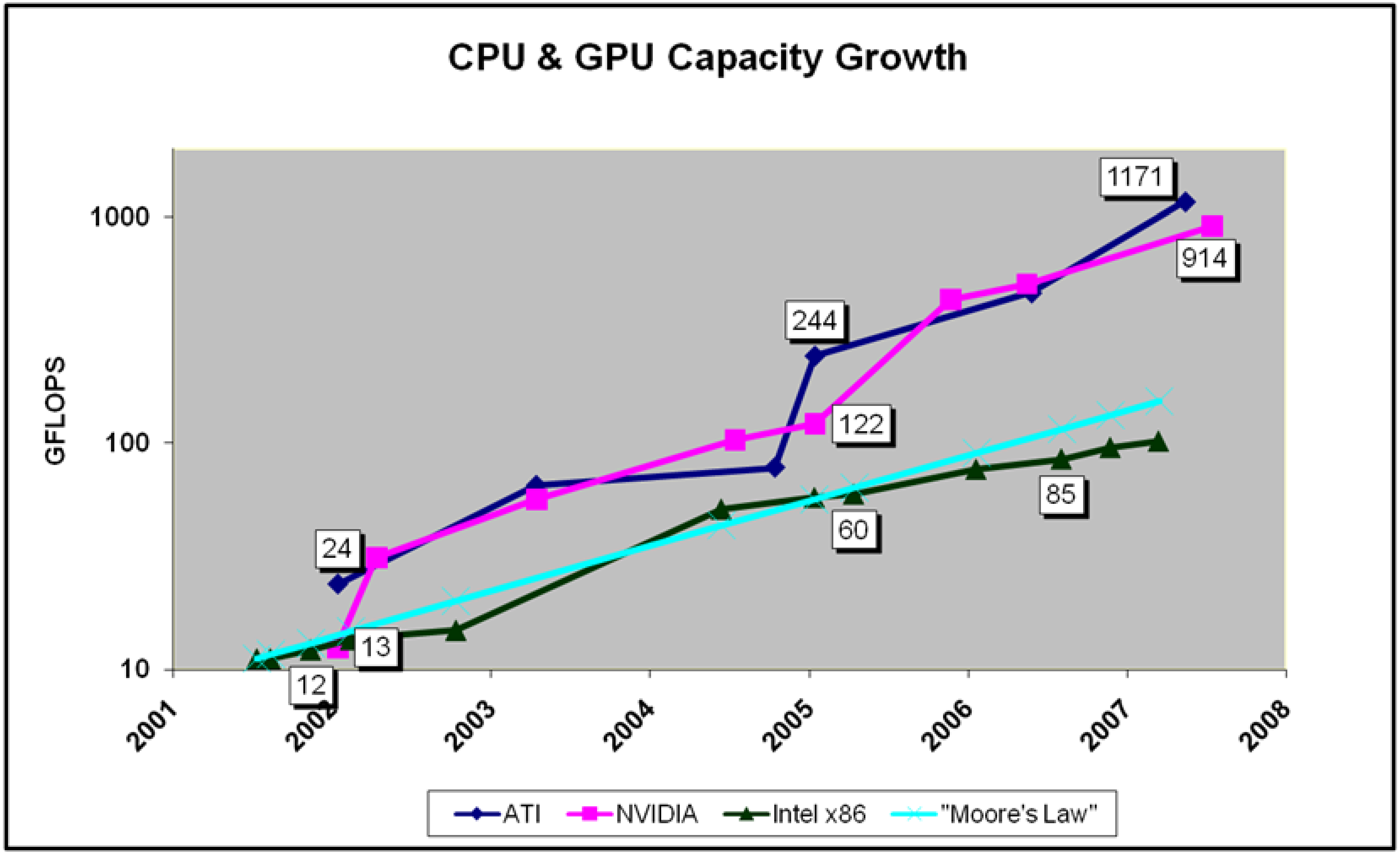
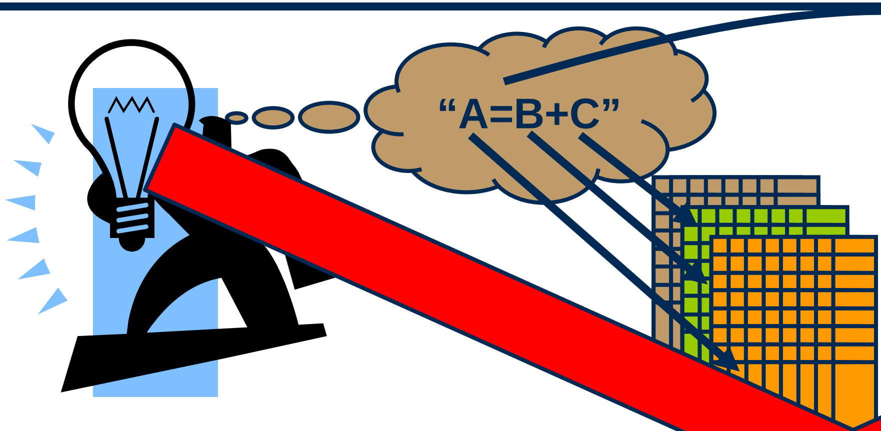
Signal Processing on Graphics Processors

- GPUs original role: turn 3-D polygons into 2-D pixels…
- …Which also makes them cheap & plentiful source of FLOPs
  - Leverages volume & competition in entertainment industry
  - Primary role highly parallel, very regular
  - Typically <$500 drop-in addition to standard PC
- Outstripping CPU capacity, and growing more quickly
  - Peak theoretical ~1TFlop
  - Power draw: 280GTX = 200W Q6600 = 100W
  - Still making improvements in market app with more parallelism, so growth continues

GPU/CPU Performance Growth



GPGPU (Old) Concept of Operations




```
void main(float2 tc0 : TEXCOORD0,
          out float4 col : COLOR,
       uniform samplerRECT
       uniform sample             )
{
      col            ECT (B, tc0) +
                   ECT (C, tc0);
```

- Arrays ➔ Textures
- Render polyg   the same pixel dimensio   utput texture
- Exec   fragment program to perform desired ca   ion
- Mo   e data from output buffer to desired texture

Now we have compute-centric programming models…
… But they require expertise to fully exploit

VSIPL - Vector Signal Image Processing Library

- Portable API for linear algebra, image & signal processing
- Originally sponsored by DARPA in mid ’90s
- Targeted embedded processors – portability primary aim
- Open standard, Forum-based
- Initial API approved April 2000

- Functional coverage
  - Vector, Matrix, Tensor
  - Basic math operations, linear algebra, solvers, FFT, FIR/IIR, bookkeeping, etc

VSIPL & GPU: Well Matched

- VSIPL is great for exploiting GPUs
  - High level API with good coverage for dense linear algebra
  - Allows non experts to benefit from hero programmers
  - Explicit memory access controls
  - API precision flexibility
- GPUs are great for VSIPL
  - Improves prototyping by speeding algorithm testing
  - Cheap addition allows more engineers access to HPC
  - Large speedups without needing explicit parallelism at application level

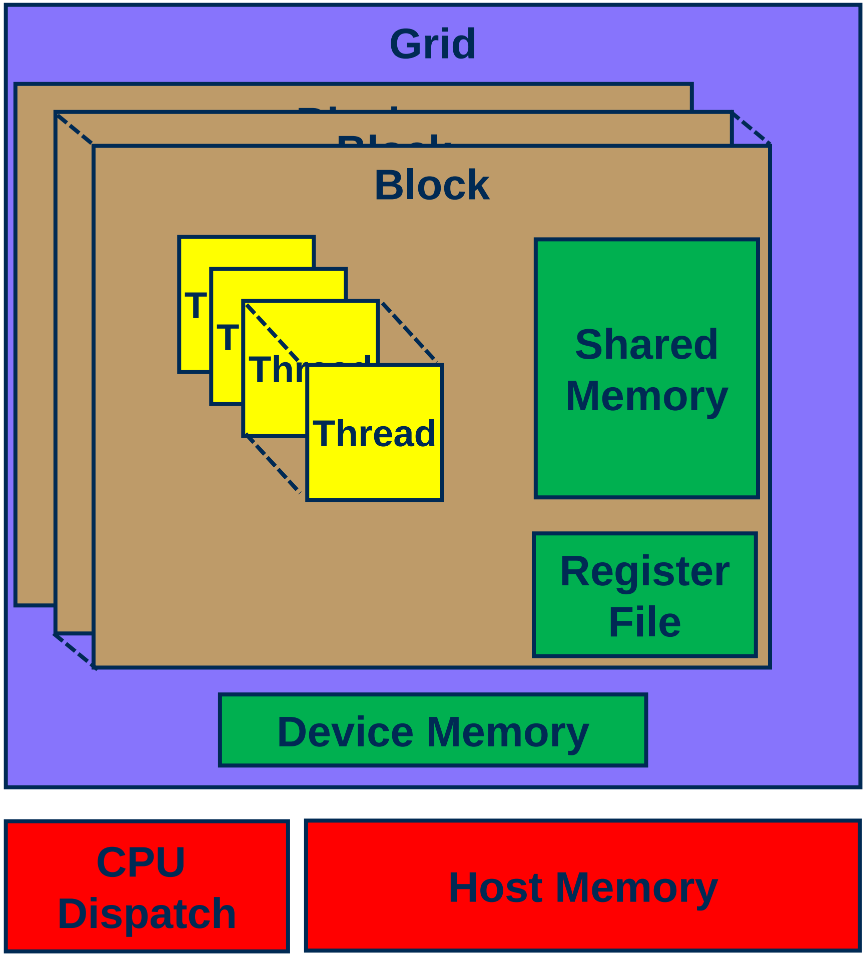
GPU-VSIPL Implementation

- Full, compliant implementation of VSIPL Core-Lite Profile
- Fully encapsulated CUDA backend
  - Leverages CUFFT library
  - All VSIPL functions accelerated
- Core Lite Profile:
  - Single precision floating point, some basic integer
  - Vector & Sxalar, complex & real support
  - Basic elementwise, FFT, FIR, histogram, RNG, support
  - Full list: http://www.vsipl.org/coreliteprofile.pdf

- Also, some matrix support, including vsip_fftm_f

CUDA Programming & Optimization

CUDA Programming Model

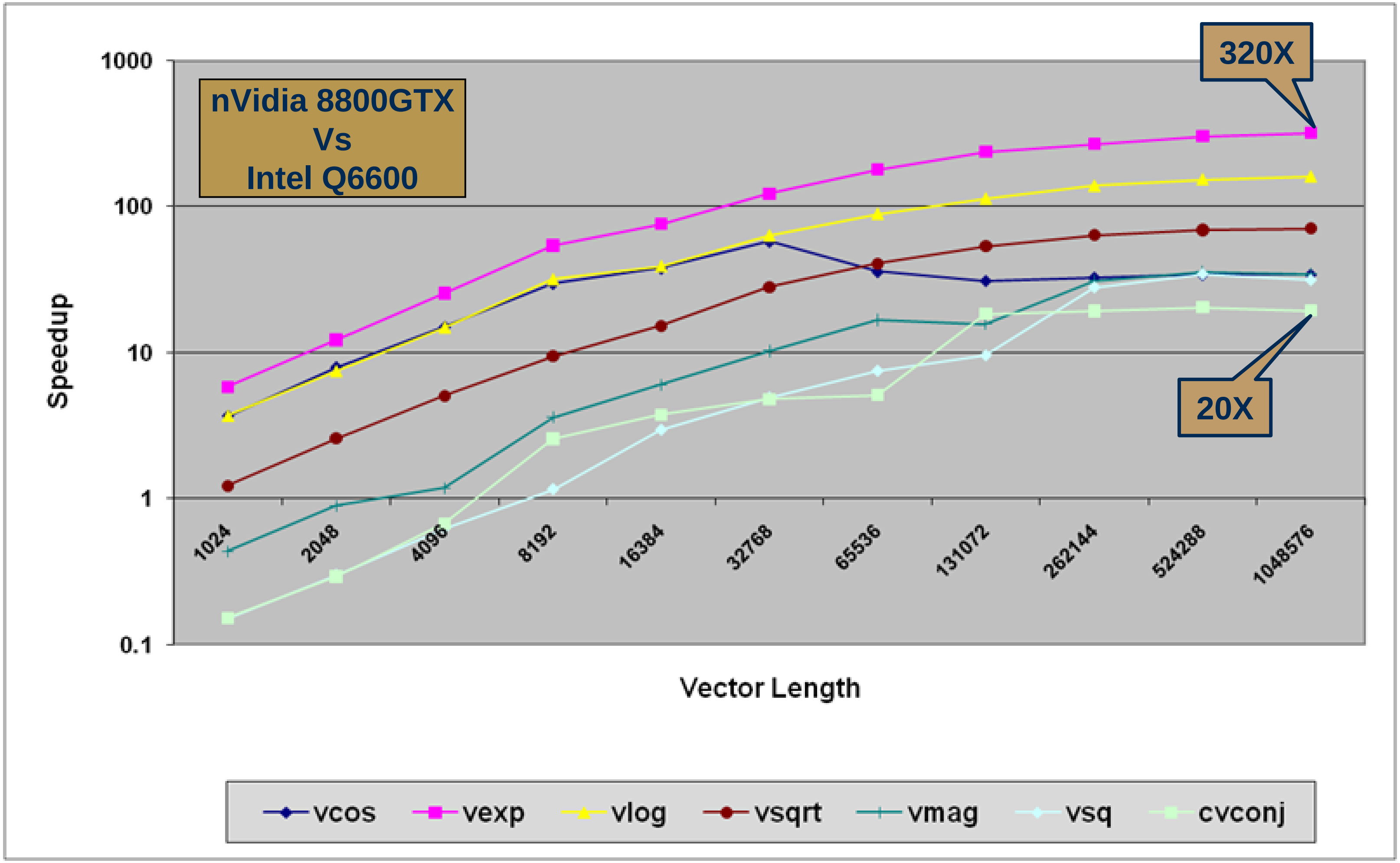


CUDA Optimization Considerations

- Maximize occupancy to hide memory latency
- Keep lots of threads in flight
- Carefully manage memory access to allow coalesce & avoid conflicts
- Avoid slow operations (*e.g* integer multiply for indexing)
- Minimize synch barriers
- Careful loop unrolling
- Hoist loop invariants
- Reduce register use for greater occupancy

- "*GPU Performance Assessment with the HPEC Challenge*" – Thursday PM

GPU VSIPL Speedup: Unary



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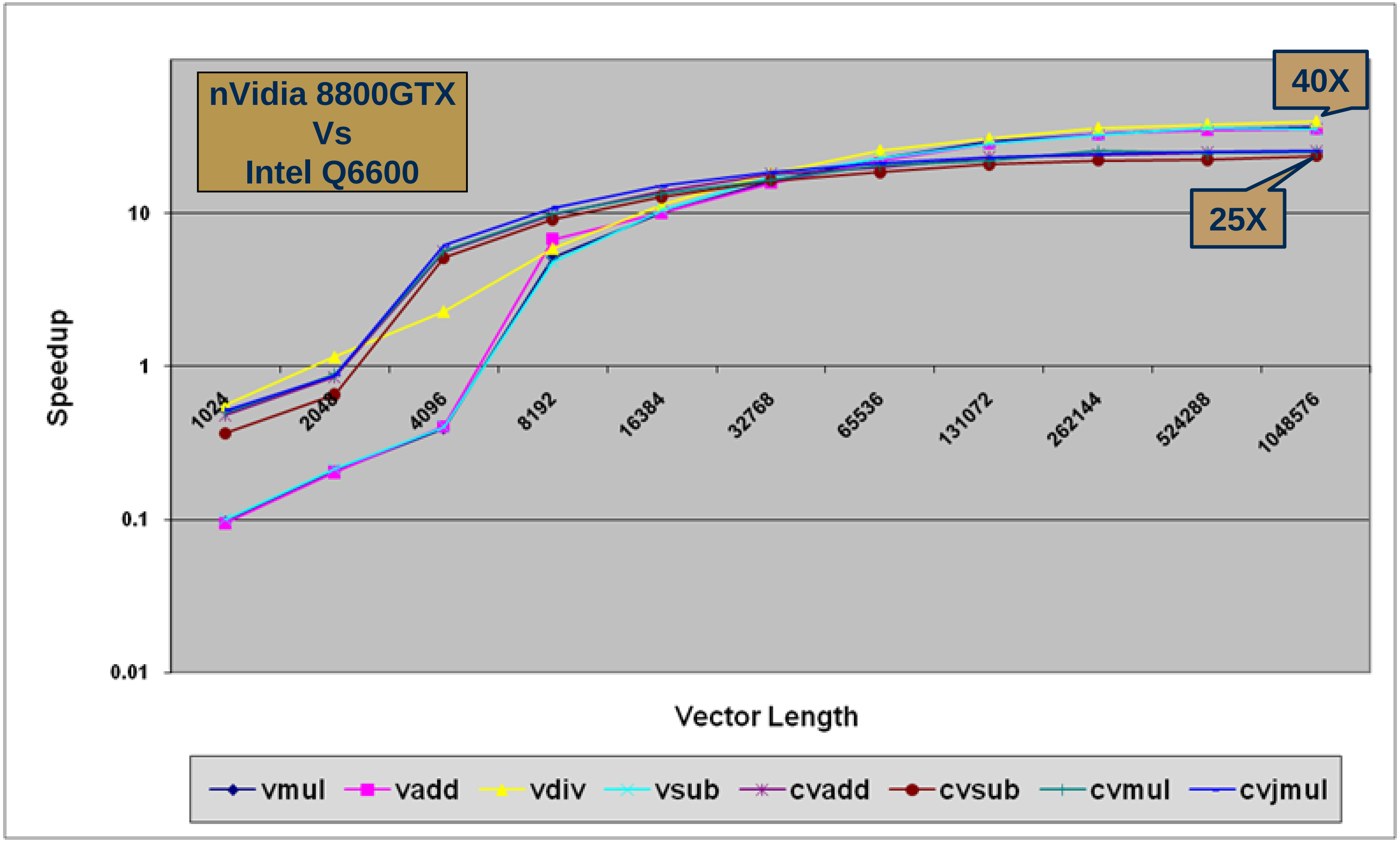
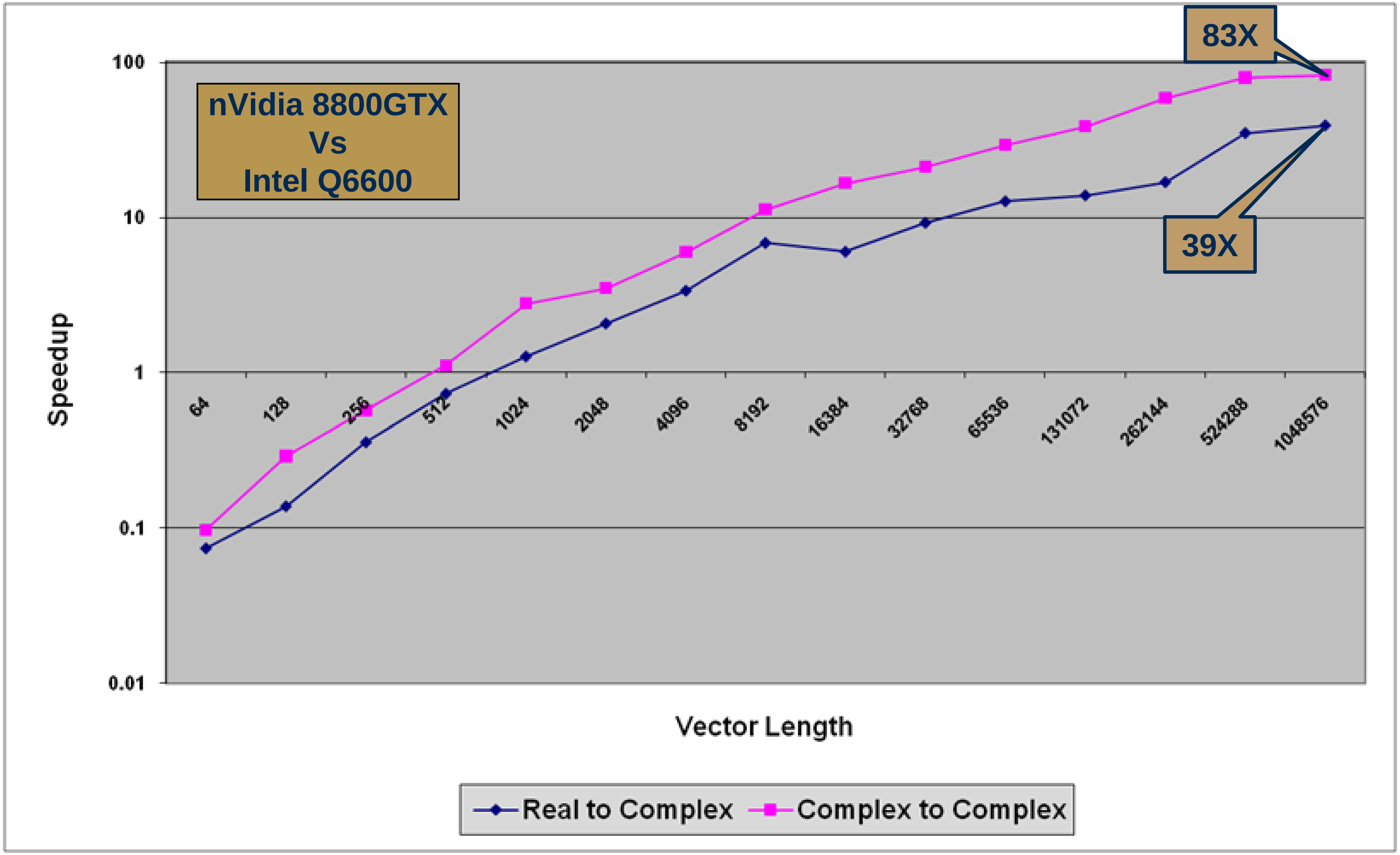
GPU VSIPL Speedup: Binary



GPU VSIPL Speedup: FFT



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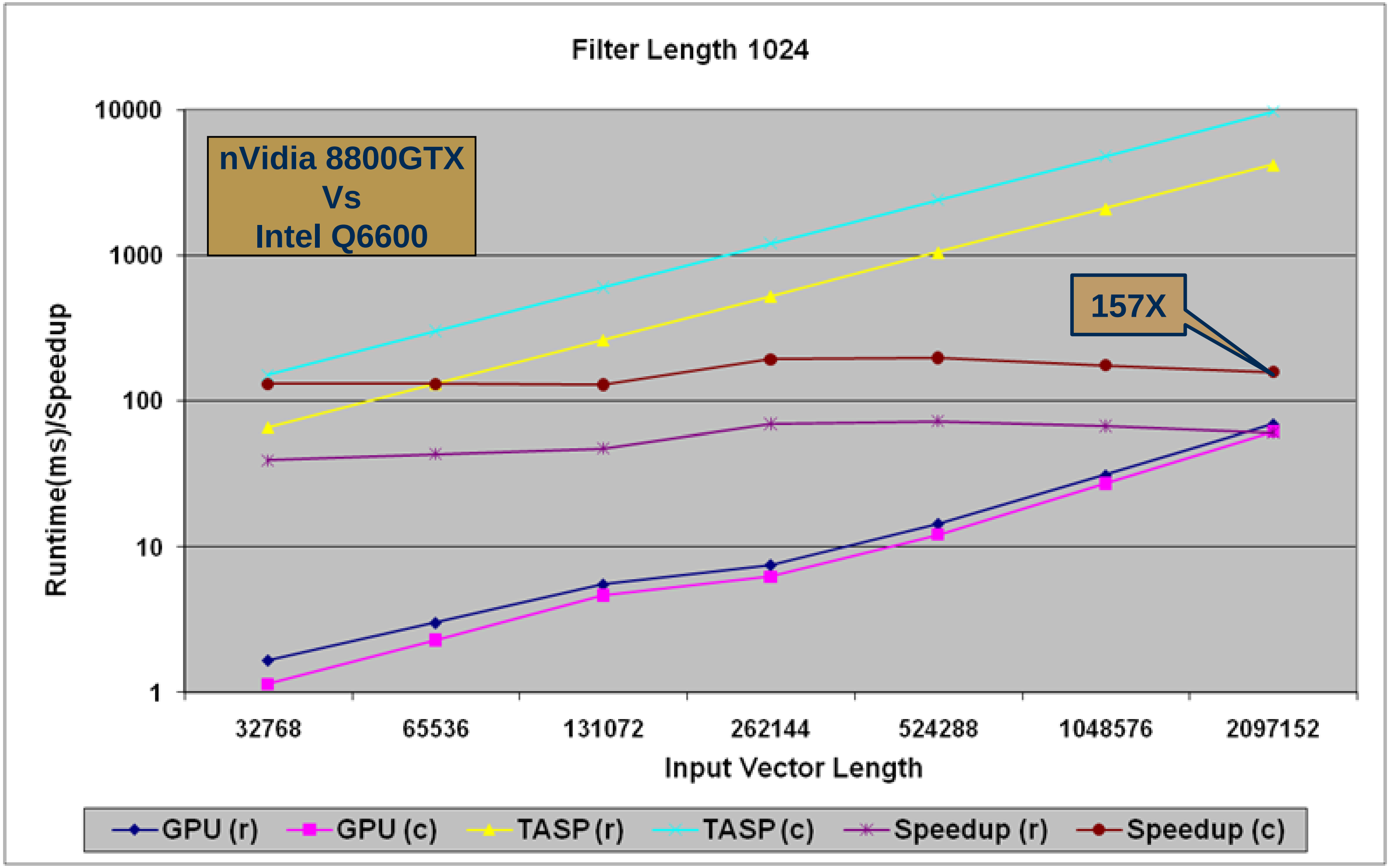
GPU VSIPL Speedup: FIR



Application Example: Range Doppler Map

- **Simple Range/Doppler data visualization application demo**
- **Intro app for new VSIPL programmer**
- **59x Speedup TASP → GPU-VSIPL**
- **No changes to source code**

Section	9800GX2 Time (ms)	Q6600 Time (ms)	Speedup
Admit	8.88	0	0
Baseband	67.77	1872.3	28
Zeropad	23.18	110.71	5
Fast time FFT	47.25	5696.3	121
Multiply	8.11	33.92	4
Fast Time FFT^{-1}	48.59	5729.04	118
Slow time FFT, 2x CT	12.89	3387	263
log10 $\lvert . \rvert^2$	22.2	470.15	21
Release	54.65	0	0
Total:	293.52	17299.42	59

GPU-VSIPL: Future Plans

- Expand matrix support
- Move toward full Core Profile
- More linear algebra/solvers
- VSIPL++
- Double precision support

Conclusions

- GPUs are fast, cheap signal processors
- VSIPL is a portable, intuitive means to exploit GPUs
- GPU-VSIPL allows easy access to GPU performance without becoming an expert CUDA/GPU programer
- 10-100x speed improvement possible with no code change

- Not yet released, but unsupported previews may show up at: http://gpu-vsipl.gtri.gatech.edu