CUDA-x86

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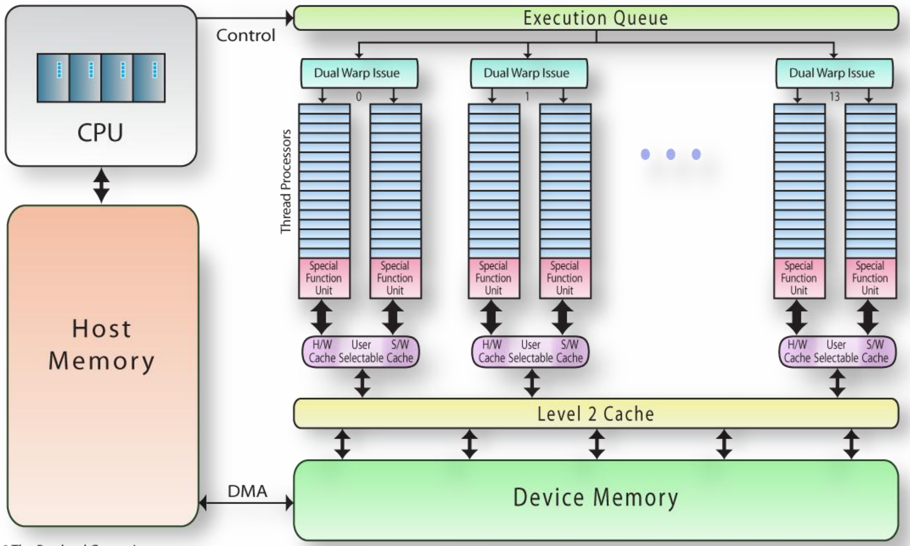
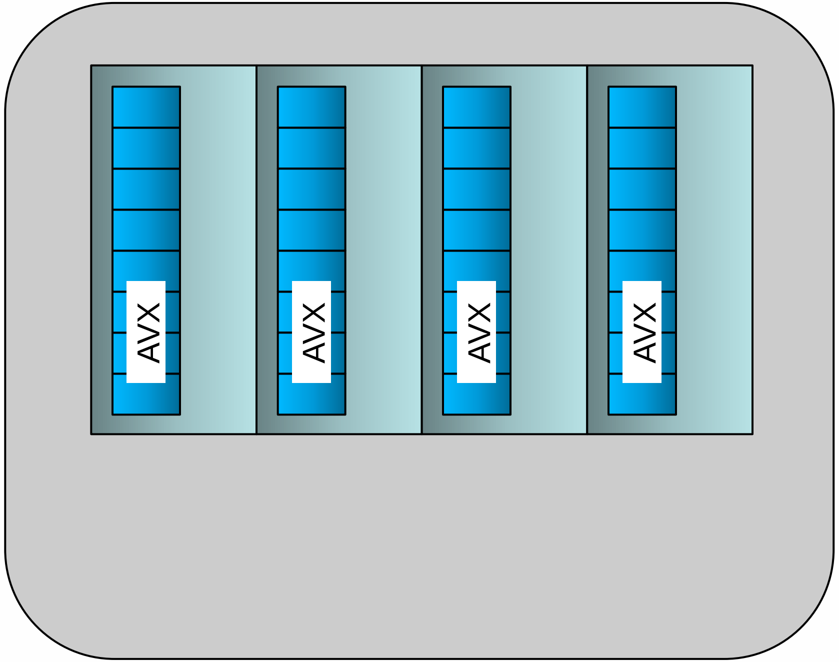
CUDA C for GPUs




```
cudaMalloc(&A,bytes);
cudaMemcpy(A,data,bytes);
...
sgemm<<<dim3(m/16,n/16),dim3(16,16)>>>
           (A,la,B,lb,C,lc);
...

__global__ void sgemm( float *A, int la,
    float* B, int lb, float* C, int lc )
{
    int tx=threadIdx.x, ty=threadIdx.y;
    int i = blockIdx.x*16+tx;
    int j = blockIdx.y*16+ty;
    float Cij = C[i+j*lc];
    __shared__ float Ab[16][16];
    __shared__ float Bb[16][16];
    for(int kb=0; kb<lc; kb+=16){
        Ab[tx][ty] = A[i+la*(kb+ty)];
        Bb[tx][ty] = B[kb+tx+lb*(j)];
        __syncthreads();
        for(int k=0; k<16; ++k)
            Cij += Ab[tx][k]*Bb[k][ty];
        __syncthreads();
    }
    C[i+j*lc] = Cij;
}
```

CUDA C for Multi-core




```
cudaMalloc(&A,bytes);
cudaMemcpy(A,data,bytes);
...
sgemm<<<dim3(m/16,n/16),dim3(16,16)>>>
           (A,la,B,lb,C,lc);
...

__global__ void sgemm( float *A, int la,
    float* B, int lb, float* C, int lc )
{
    int tx=threadIdx.x, ty=threadIdx.y;
    int i = blockIdx.x*16+tx;
    int j = blockIdx.y*16+ty;
    float Cij = C[i+j*lc];
    __shared__ float Ab[16][16];
    __shared__ float Bb[16][16];
    for(int kb=0; kb<lc; kb+=16){
        Ab[tx][ty] = A[i+la*(kb+ty)];
        Bb[tx][ty] = B[kb+tx+lb*(j)];
        __syncthreads();
        for(int k=0; k<16; ++k)
            Cij += Ab[tx][k]*Bb[k][ty];
        __syncthreads();
    }
    C[i+j*lc] = Cij;
}
```

PGI®

- C, C++, Fortran Compilers
- Optimizing, Vectorizing, Parallelizing
- Graphical debugger, profiler
- AMD and Intel, 32-bit and 64-bit
- PGI Unified Binary
- Linux, Apple OS/X, Microsoft Windows
- PGI Visual Fortran in Visual Studio
- CUDA Fortran
- PGI Accelerator Programming Model

C Matrix Sum

```
nbytes = N*M*sizeof(float);
A = (float*)malloc( nbytes );
B = (float*)malloc( nbytes );
.../* fill A and B */
MyMadd( A, B, N, M );
.../* continue using A and B */
free( A );
free( B );
....

void MyMadd( float* A, float* B, int N, int M ){
 int i,j;
 for( j = 0; j < N; ++j )
   for( i = 0; i < M; ++i )
     A[i+j*M] += B[i+j*M];
}
```

CUDA C Matrix Sum

```
cudaMalloc((void**)&dA, nbytes );
cudaMalloc((void**)&dB, nbytes );
cudaMemcpy( dA, A, nbytes, cudaMemcpyHostToDevice);
cudaMemcpy( dB, B, nbytes, cudaMemcpyHostToDevice);
/* ... other stuff ... */
GPUMadd<<< dim3(N/64,M/4,1), dim3(64,4,1) >>>
    (dA, dB, N, M );
/* ... more uses of dA, dB ... */
cudaFree( dA );
cudaFree( dB );
....
__global__ void GPUMadd(float* A,float* B,int N,int M){
 int  j = threadIdx.y + blockIdx.y*blockDim.y;
   int  i = threadIdx.x + blockIdx.x*blockDim.x;
     A[i+j*M] += B[i+j*M];
}
```

Parallel Structure of the Kernel

thread block 0,0

0,0	A[i+j*M] += B[i+j*M]
0,1	A[i+j*M] += B[i+j*M]
0,2	A[i+j*M] += B[i+j*M]
0,4	A[i+j*M] += B[i+j*M]
0,5	A[i+j*M] += B[i+j*M]
0,6	A[i+j*M] += B[i+j*M]
0,7	A[i+j*M] += B[i+j*M]
0,8	A[i+j*M] += B[i+j*M]
0,9	A[i+j*M] += B[i+j*M]
⋮	
3,62	A[i+j*M] += B[i+j*M]
3,63	A[i+j*M] += B[i+j*M]

thread block 1,0

0,0	A[i+j*M] += B[i+j*M]
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⋮	
3,62	A[i+j*M] += B[i+j*M]
3,63	A[i+j*M] += B[i+j*M]

• • •

thread block N/64,M/4

0,0	A[i+j*M] += B[i+j*M]
0,1	A[i+j*M] += B[i+j*M]
0,2	A[i+j*M] += B[i+j*M]
0,4	A[i+j*M] += B[i+j*M]
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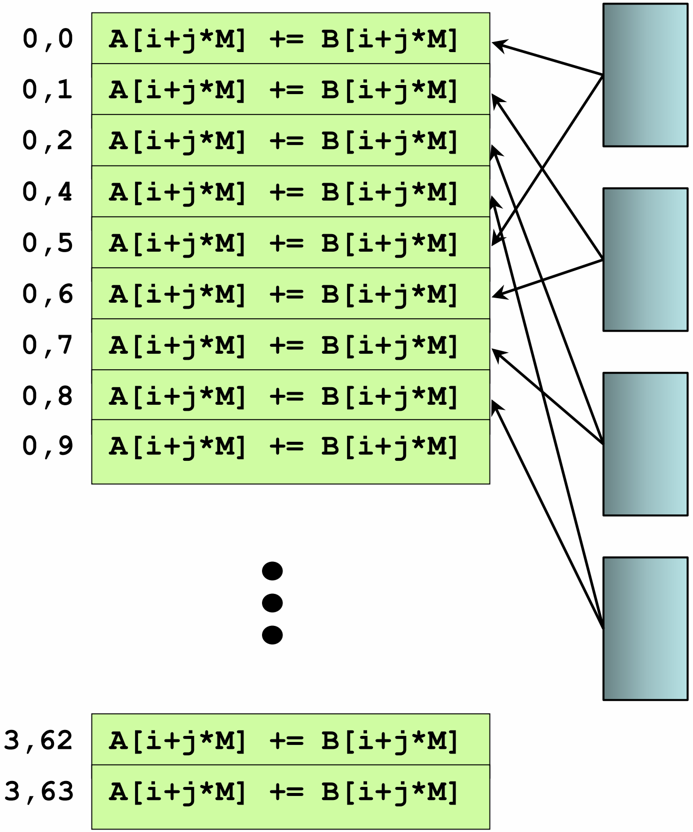
3,63	A[i+j*M] += B[i+j*M]

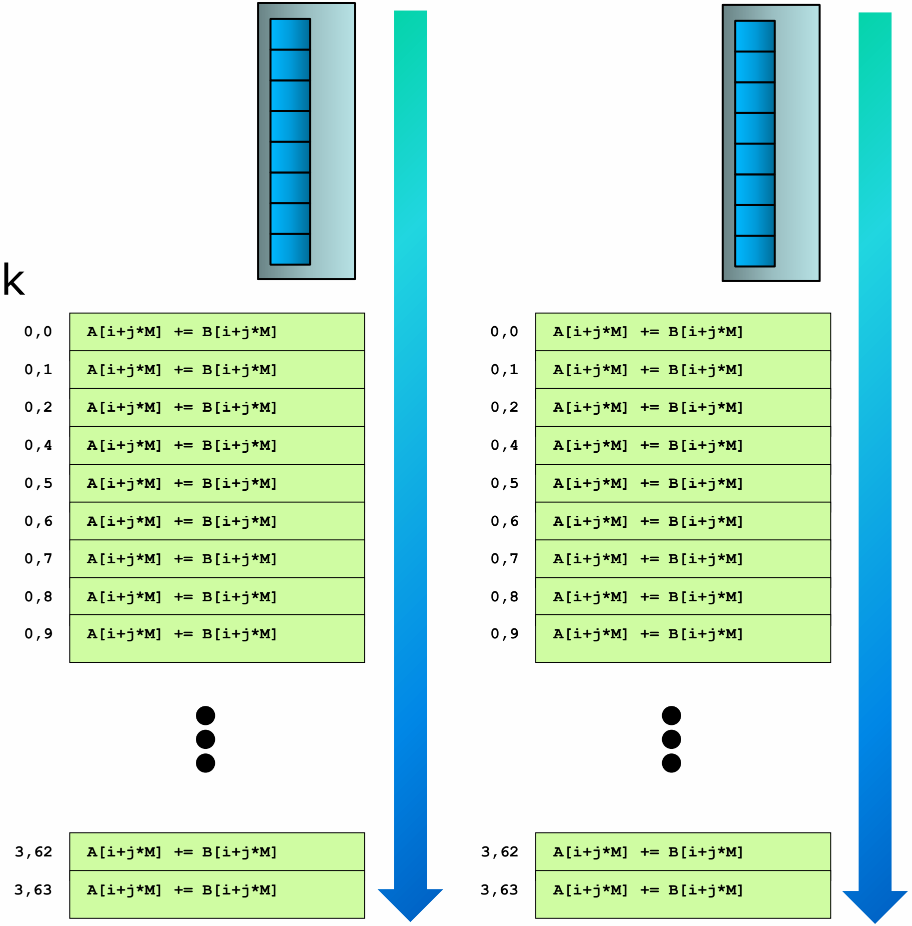
Phase 1: Emulation

- Each CUDA thread becomes a task
- x86 threads share the tasks
- `__syncthreads()` becomes task barrier
- Full functionality
- Full debugger support
- Parallelism between threads in block
- Blocks executed sequentially
- CUDA Fortran emulation mode



Phase 2: Optimization

- Each CUDA thread block becomes a task
- One X86 thread executes each task
- Vectorize the thread indices
- **`__shared__`** becomes local to task
- **`__syncthreads()`** comes for free
- Parallelism between thread blocks



Phase 3: Unification

- PGI Unified Binary technology
- Generate both x86 host code AND NVIDIA device code for kernels
- Choose at runtime which code to run

0,0	A[i+j*M] += B[i+j*M]
0,1	A[i+j*M] += B[i+j*M]
0,2	A[i+j*M] += B[i+j*M]
0,4	A[i+j*M] += B[i+j*M]
0,5	A[i+j*M] += B[i+j*M]
0,6	A[i+j*M] += B[i+j*M]
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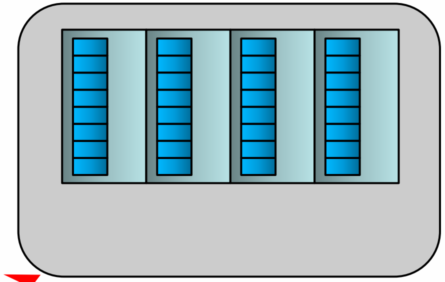
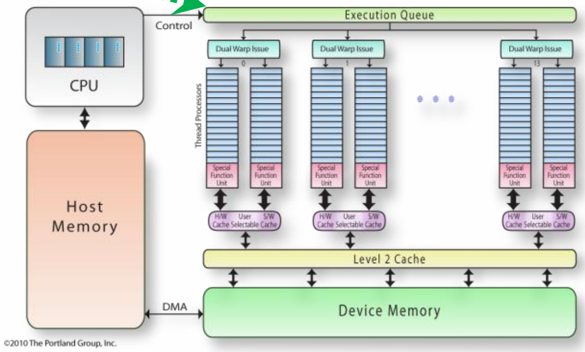
⋮

3,62	A[i+j*M] += B[i+j*M]
3,63	A[i+j*M] += B[i+j*M]





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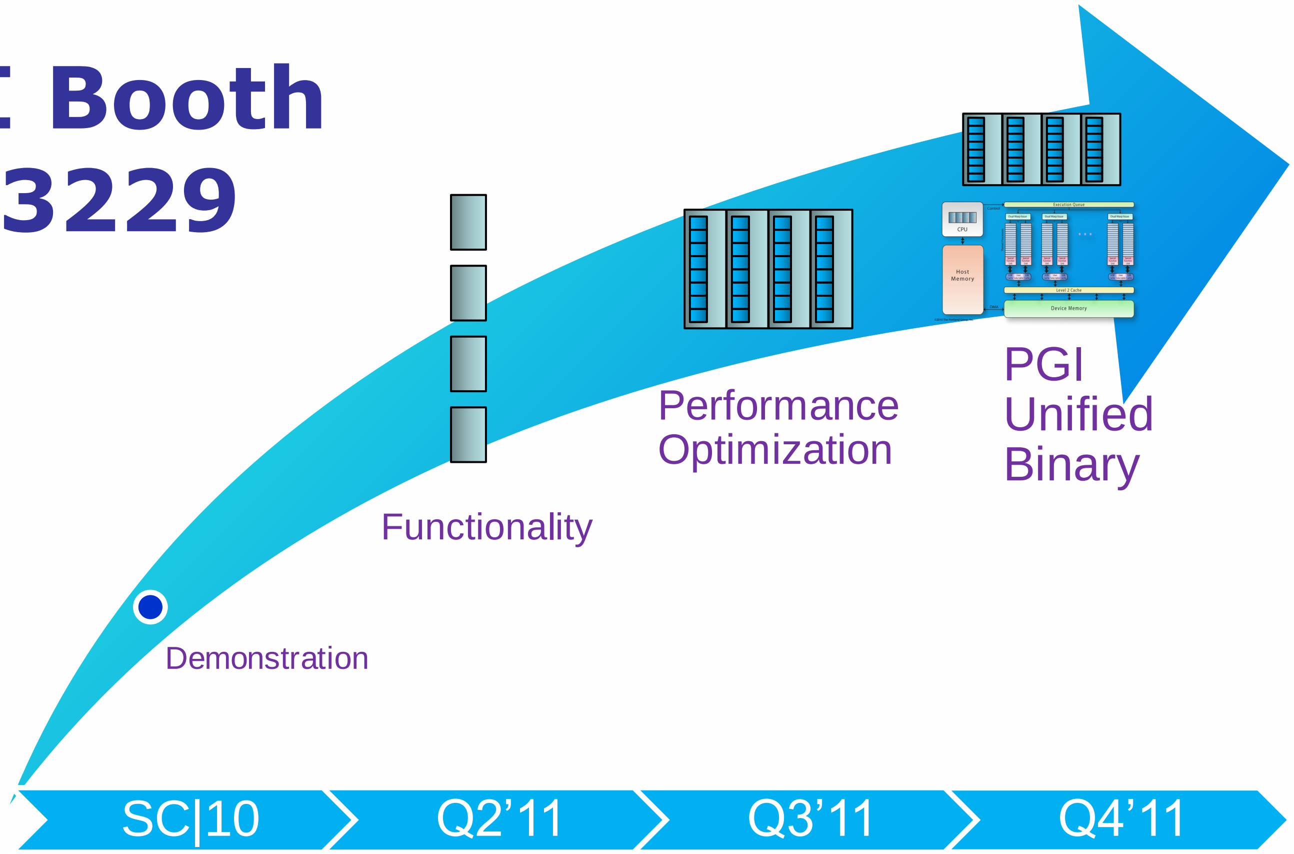

More information at www.pgroup.com/cuda_x86.htm