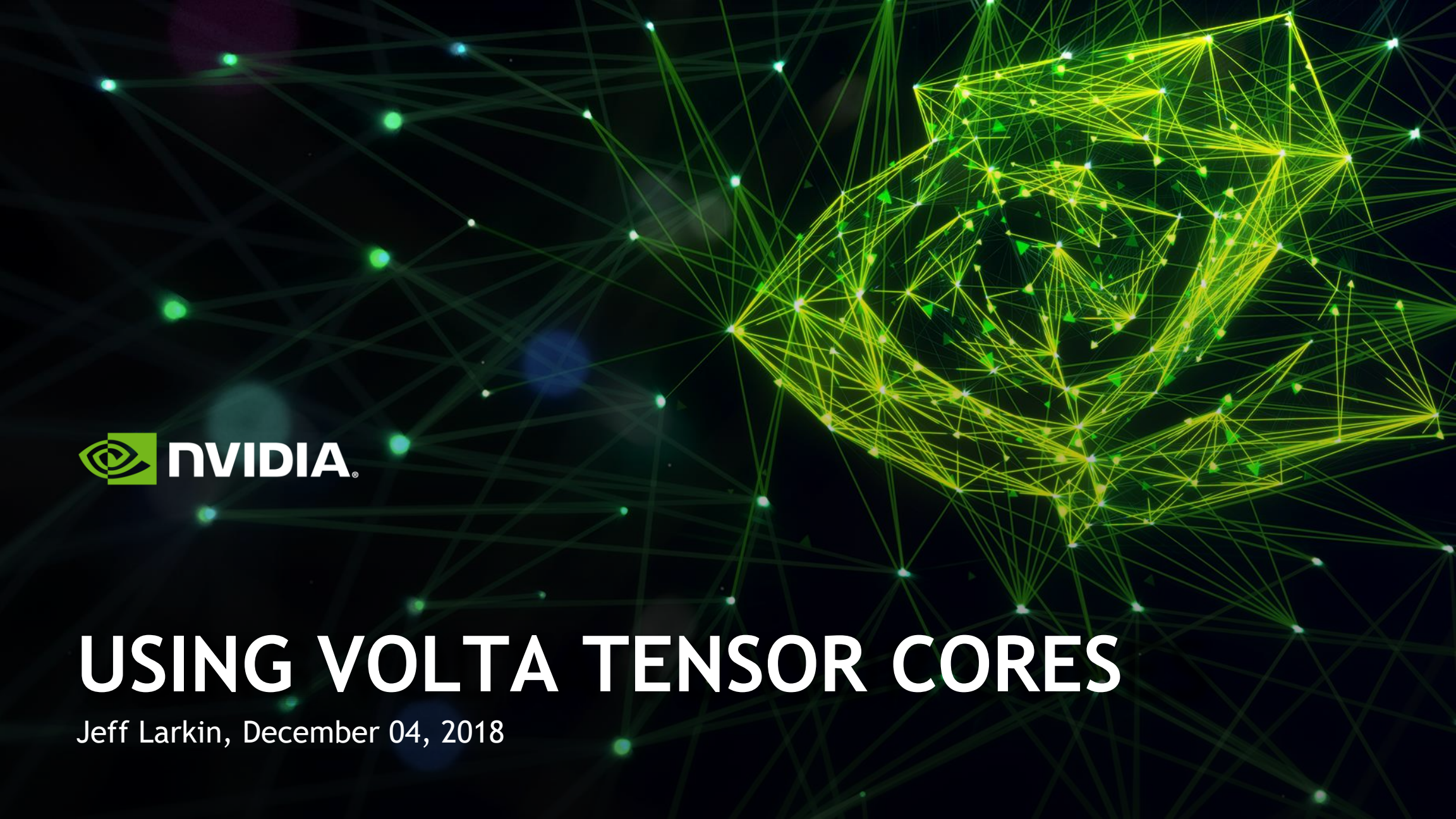
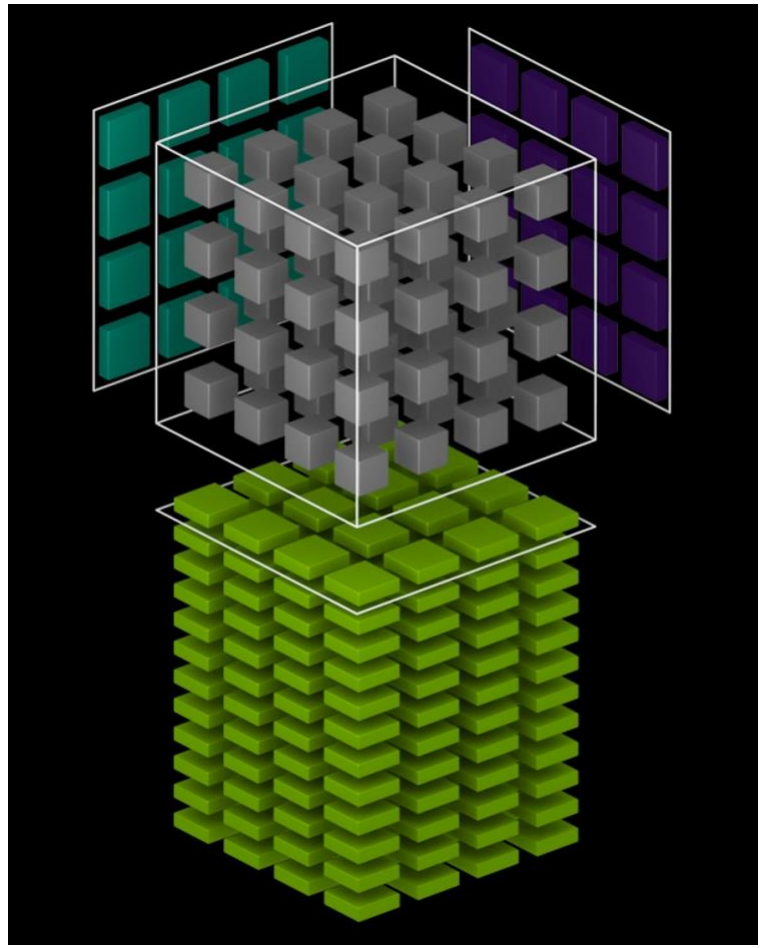


USING VOLTA TENSOR CORES

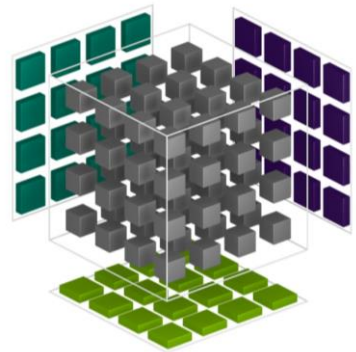
Jeff Larkin, December 04, 2018

VOLTA TENSOR CORE



TENSOR CORE

Mixed Precision Matrix Math
4x4 matrices



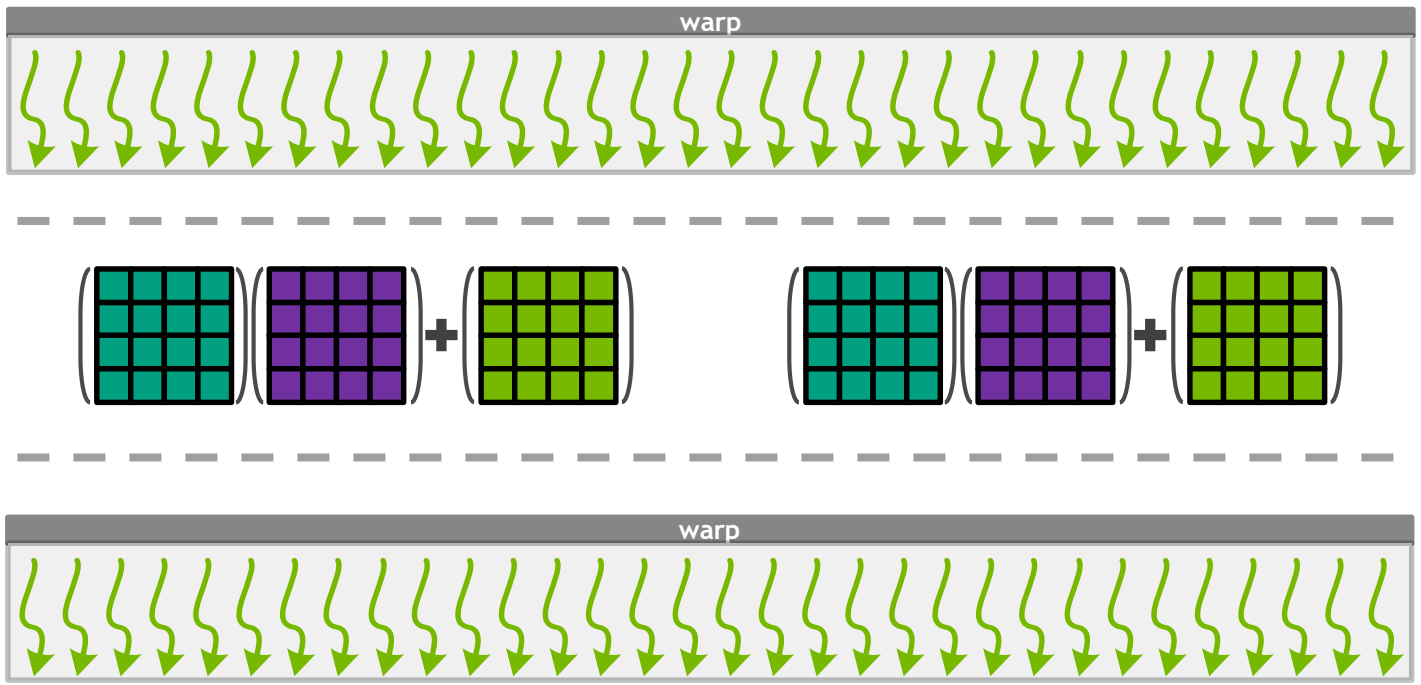
$$D = \begin{pmatrix} A_{0,0} & A_{0,1} & A_{0,2} & A_{0,3} \\ A_{1,0} & A_{1,1} & A_{1,2} & A_{1,3} \\ A_{2,0} & A_{2,1} & A_{2,2} & A_{2,3} \\ A_{3,0} & A_{3,1} & A_{3,2} & A_{3,3} \end{pmatrix} \begin{pmatrix} B_{0,0} & B_{0,1} & B_{0,2} & B_{0,3} \\ B_{1,0} & B_{1,1} & B_{1,2} & B_{1,3} \\ B_{2,0} & B_{2,1} & B_{2,2} & B_{2,3} \\ B_{3,0} & B_{3,1} & B_{3,2} & B_{3,3} \end{pmatrix} + \begin{pmatrix} C_{0,0} & C_{0,1} & C_{0,2} & C_{0,3} \\ C_{1,0} & C_{1,1} & C_{1,2} & C_{1,3} \\ C_{2,0} & C_{2,1} & C_{2,2} & C_{2,3} \\ C_{3,0} & C_{3,1} & C_{3,2} & C_{3,3} \end{pmatrix}$$

FP16 or FP32 | FP16 | FP16 | FP16 or FP32

$$D = AB + C$$

TENSOR CORE COORDINATION

Full Warp 16x16 Matrix Math

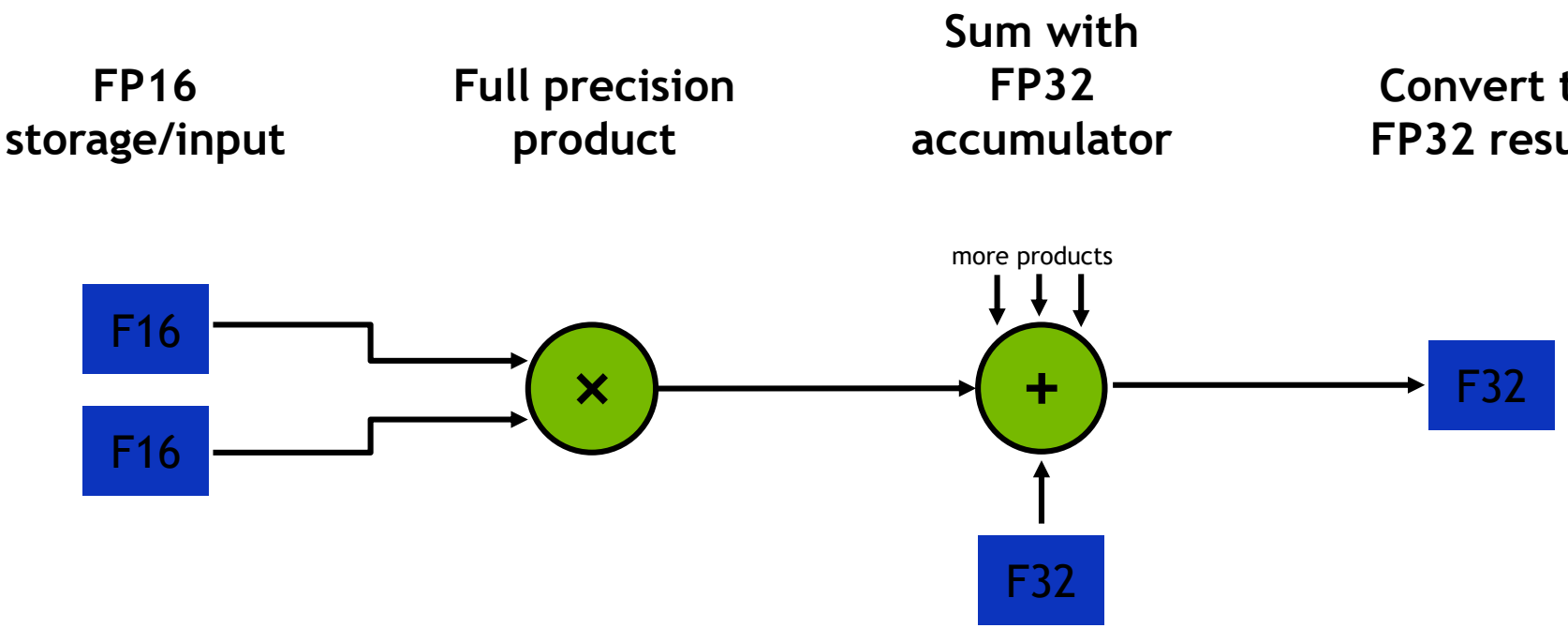


Warp-synchronizing operation for cooperative matrix math

Aggregate Matrix Multiply and Accumulate for **16x16** matrices

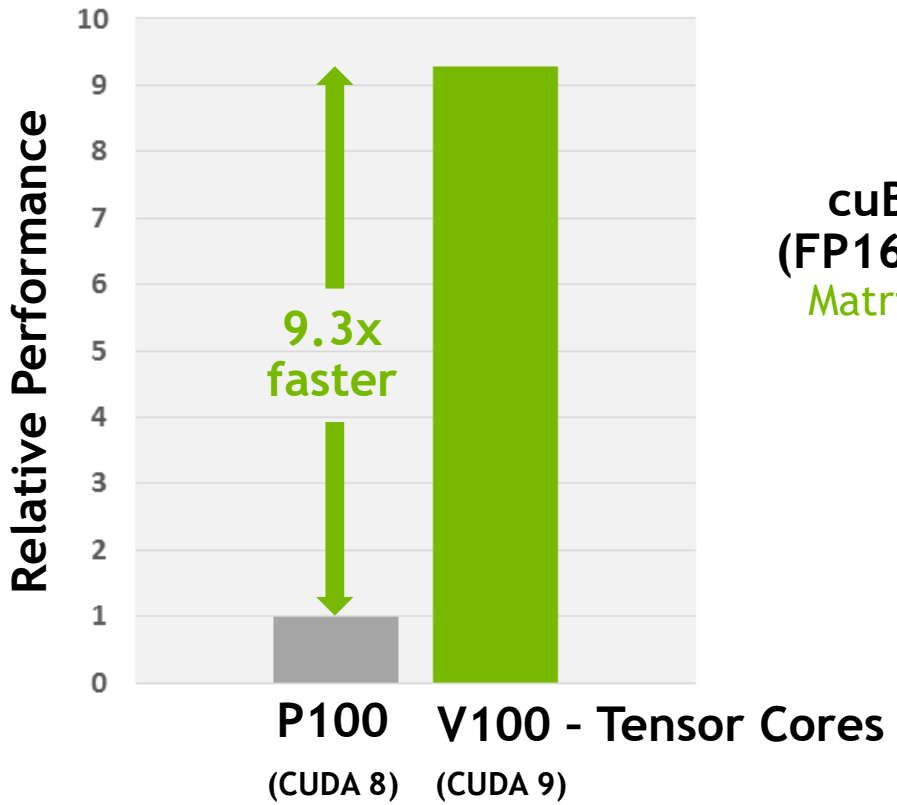
Result distributed across warp

VOLTA TENSOR OPERATION



Also supports FP16 accumulator mode for inferencing

A GIANT LEAP FOR DEEP LEARNING



cuBLAS Mixed Precision
(FP16 input, FP32 compute)
Matrix Multiply (M=N=K=2048)

V100 measured on pre-production hardware.

USING TENSOR CORES

NVIDIA cuDNN, cuBLAS, TensorRT

Volta Optimized Frameworks and Libraries

```
__device__ void tensor_op_16_16_16(
    float *d, half *a, half *b, float *c)
{
  wmma::fragment<matrix_a, …> Amat;
  wmma::fragment<matrix_b, …> Bmat;
  wmma::fragment<matrix_c, …> Cmat;

  wmma::load_matrix_sync(Amat, a, 16);
  wmma::load_matrix_sync(Bmat, b, 16);
  wmma::fill_fragment(Cmat, 0.0f);

  wmma::mma_sync(Cmat, Amat, Bmat, Cmat);

  wmma::store_matrix_sync(d, Cmat, 16,
                          wmma::row_major);
}
```

CUDA C++

Warp-Level Matrix Operations

TENSOR CORES FROM CUBLAS

CUBLAS provides an extended BLAS interface for mixed precisions

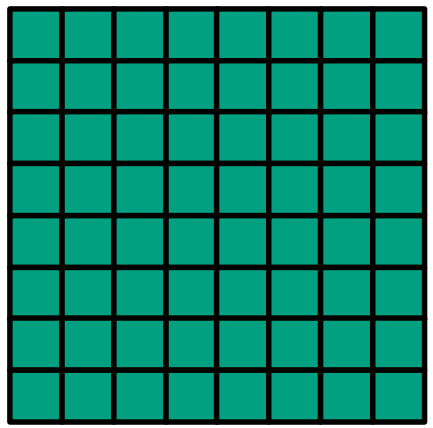
cublasGemmEx(), cublasGemmBatchedEx(), and cublasGemmStridedBatchedEx() all accept FP16 data types for Tensor Core use.

Some solvers are also available in an Ex form.

See https://docs.nvidia.com/cuda/cublas/index.html#cublas-GemmEx

CUDA TENSOR CORE PROGRAMMING

New WMMA datatypes



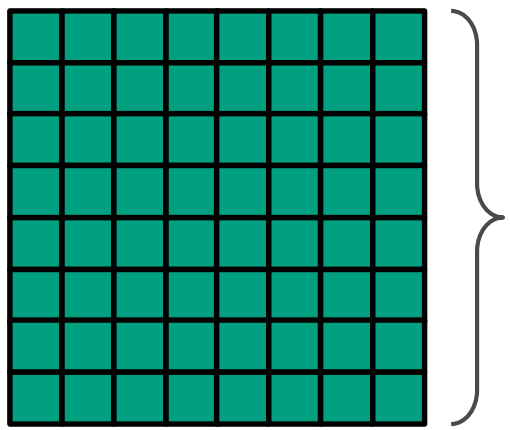
Per-Thread fragments to hold components of matrices for use with Tensor Cores

```
wmma::fragment<matrix_a, …> Amat;
```

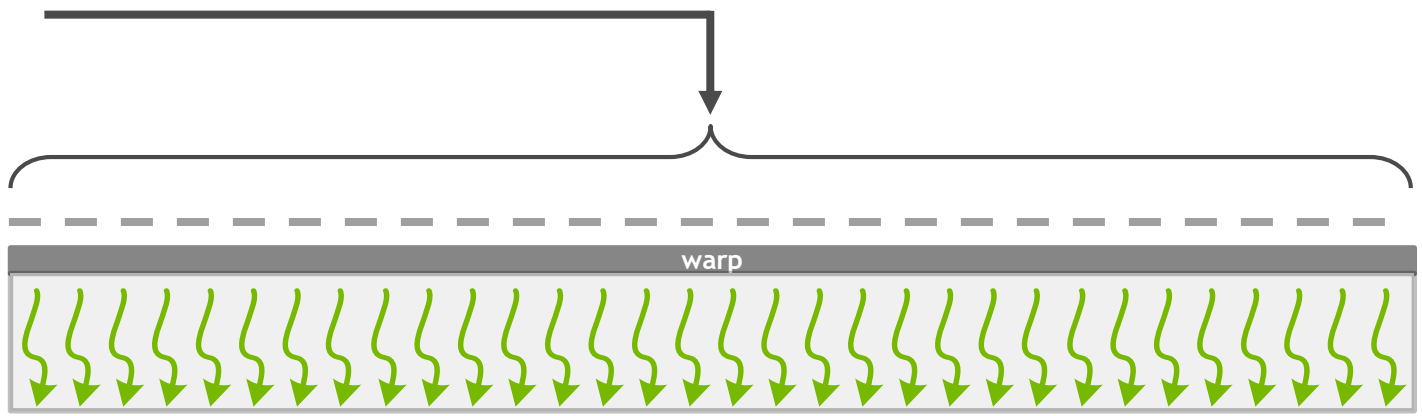
CUDA TENSOR CORE PROGRAMMING

New WMMA load and store operations

Warp-level operation to fetch components of matrices into fragments



```
wmma::load_matrix_sync(Amat, a, stride);
```

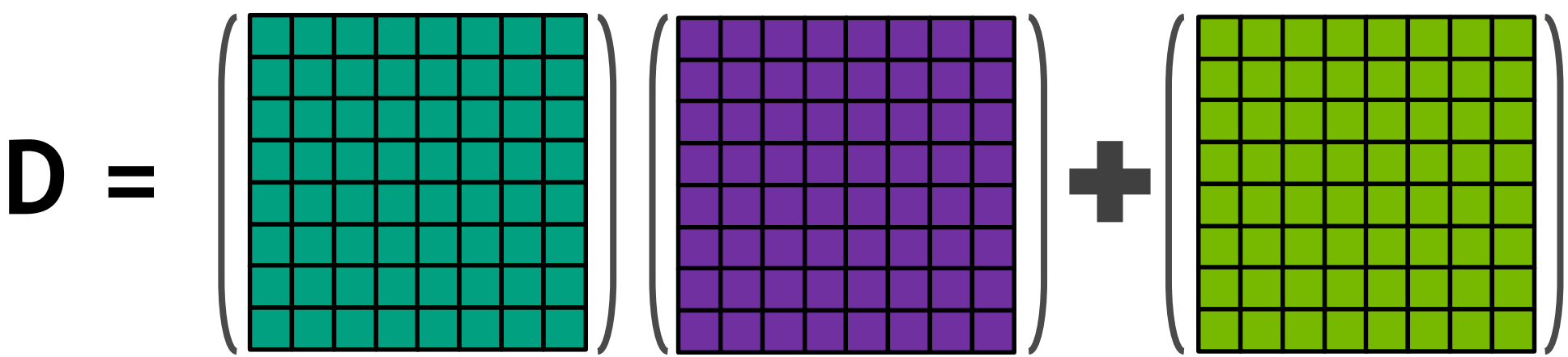


CUDA TENSOR CORE PROGRAMMING

New WMMA Matrix Multiply and Accumulate Operation

Warp-level operation to perform matrix multiply and accumulate

```
wmma::mma_sync(Dmat, Amat, Bmat, Cmat);
```

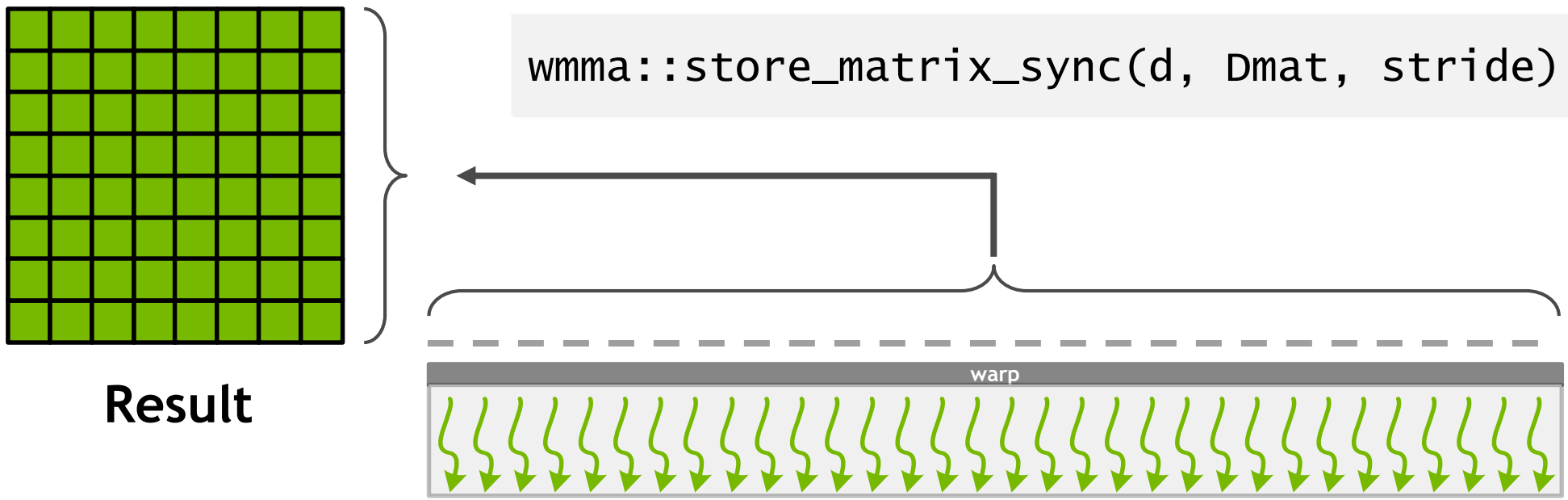


CUDA TENSOR CORE PROGRAMMING

New WMMA load and store operations

Warp-level operation to fetch components of matrices into fragments

```
wmma::store_matrix_sync(d, Dmat, stride);
```



TENSOR CORE EXAMPLE


```
__device__ void tensor_op_16_16_16(
    float *d, half *a, half *b, float *c)
{
  wmma::fragment<matrix_a, …> Amat;
  wmma::fragment<matrix_b, …> Bmat;
  wmma::fragment<matrix_c, …> Cmat;

  wmma::load_matrix_sync(Amat, a, 16);
  wmma::load_matrix_sync(Bmat, b, 16);
  wmma::fill_fragment(Cmat, 0.0f);

  wmma::mma_sync(Cmat, Amat, Bmat, Cmat);

  wmma::store_matrix_sync(d, Cmat, 16,
                          wmma::row_major);
}
```

CUDA C++

Warp-Level Matrix Operations