NanoJPEG CUDA

Parallelization of a JPEG Decompression Library on a CUDA GPGPU

Lorenzo CHIOLA, s287911

Politecnico di Torino

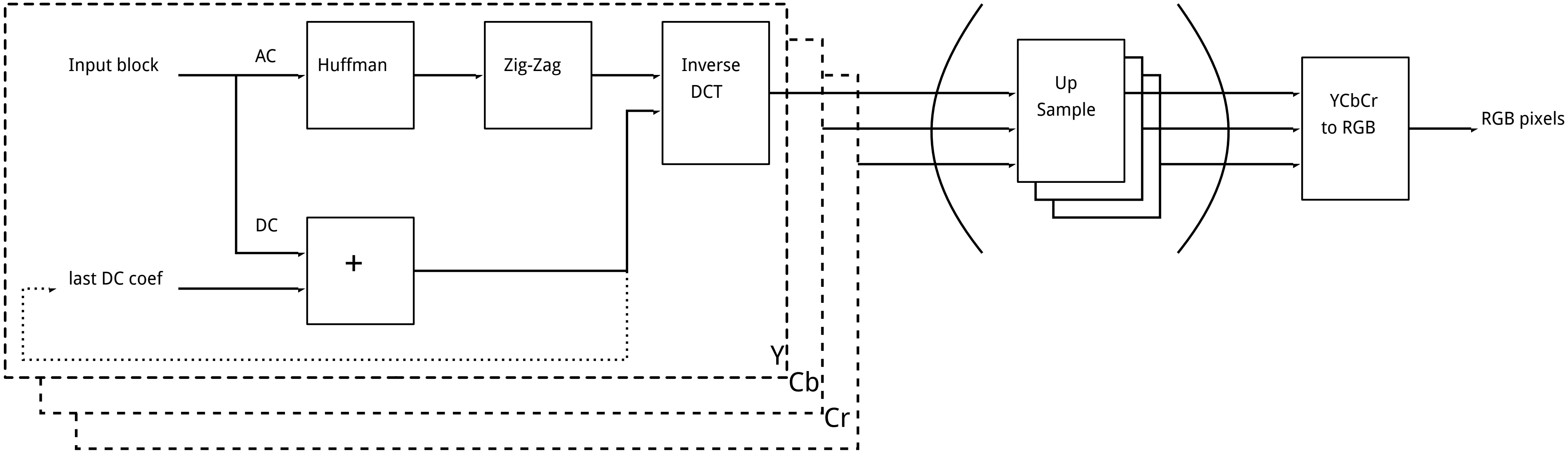
JPEG/JFIF Format

- JPEG: Image Compression
  choice of **color spaces**
  choice of **compression quality**
  choice of **subsampling**
- JFIF: Container Format
  choice of **sections** (some are mandatory)
  progressive JPEG

JPEG Compression Overview

- 8x8 px blocks
- Chroma Subsampling
- DCT: Dual Cosine Transform
- Huffman Encoding
- Separate DC component

JPEG Compression Flow



JFIF (JPEG File Interchange Format)

- **SOF** (Start Of Frame)

  Width, height, color space...

- **DHT** (Define Huffman Table)

  Huffman code tree. Y DC, Y AC, Cb/Cr DC, Cb/Cr AC

- **DQT** (Define Quantization Table)

  Separate for Y and Cb, Cr

- **DRI** (Define Restart Interval)

  DC DPCM restart component

- (Start of) **Scan**

  Actual data: 8x8 blocks

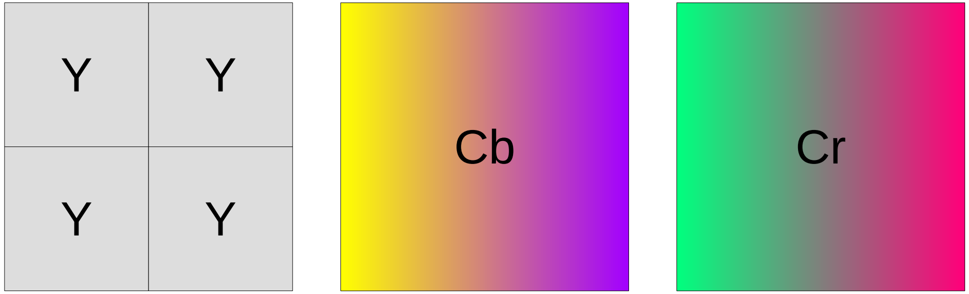
JFIF Scan

- **8x8 Blocks** grouped into MCUs (Minimum Coded Units)

```
RGB:            {R, G, B},   {R, G, B},   …
YcbCr 4:4:4:    {Y, Cb, Cr}, {Y, Cb, Cr}, …
```

- **Chroma Subsampling** (less chrominance information)

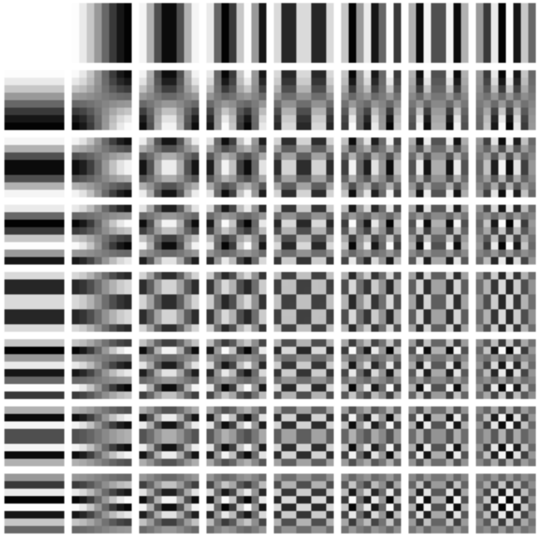
```
YcbCr 4:2:2:    {Y, Y, Cb, Cr},         {Y, Y, Cb, Cr},         …
YcbCr 4:2:0:    {Y, Y, Y, Y, Cb, Cr}, {Y, Y, Y, Y, Cb, Cr}, …
```

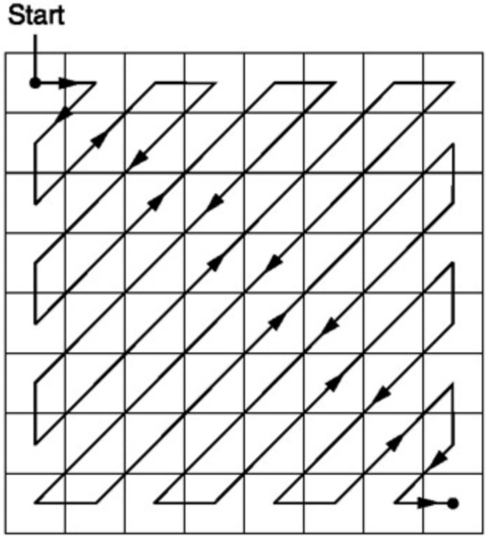


JFIF Scan: Blocks

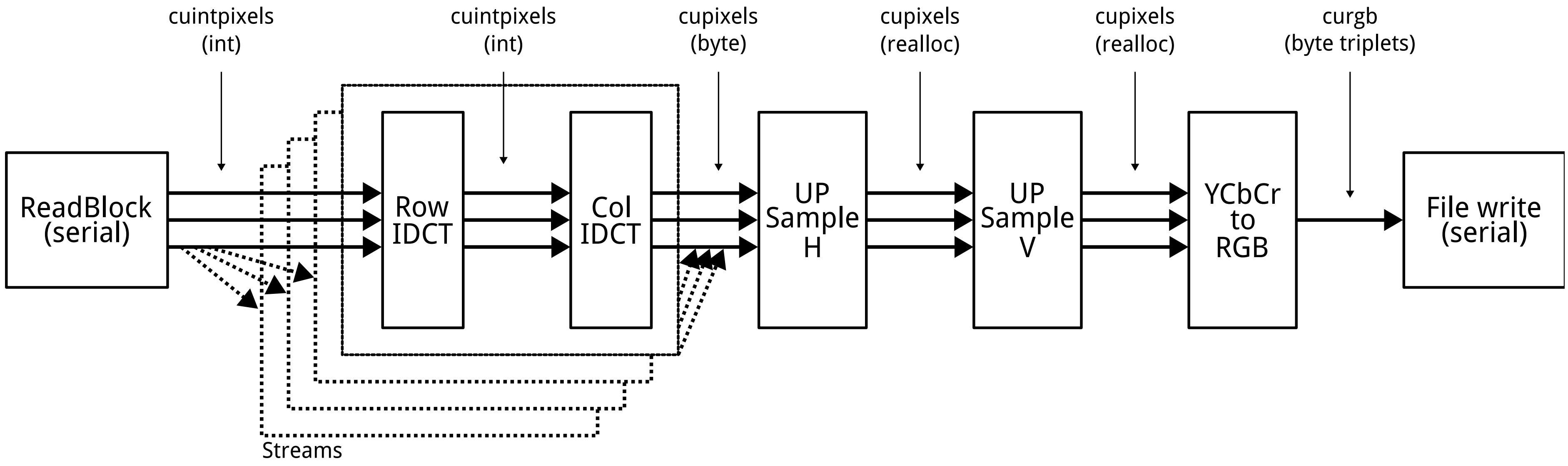
- **DC coefficient** (zero frequency: cell [0, 0])
  Differential Pulse Code Modulation (DPCM)

- **AC coefficient** (the other 63 cells)
  Zig-Zag order: from low to high frequency
  Huffman encoded

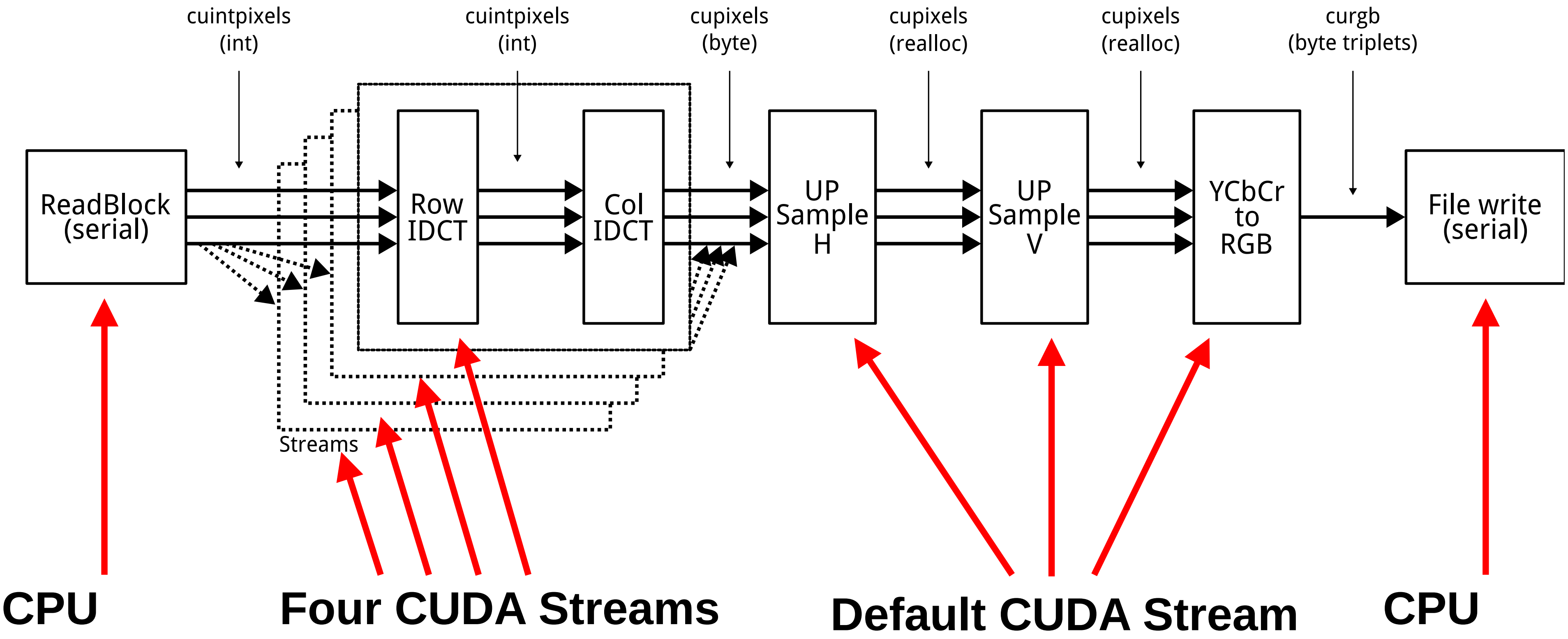




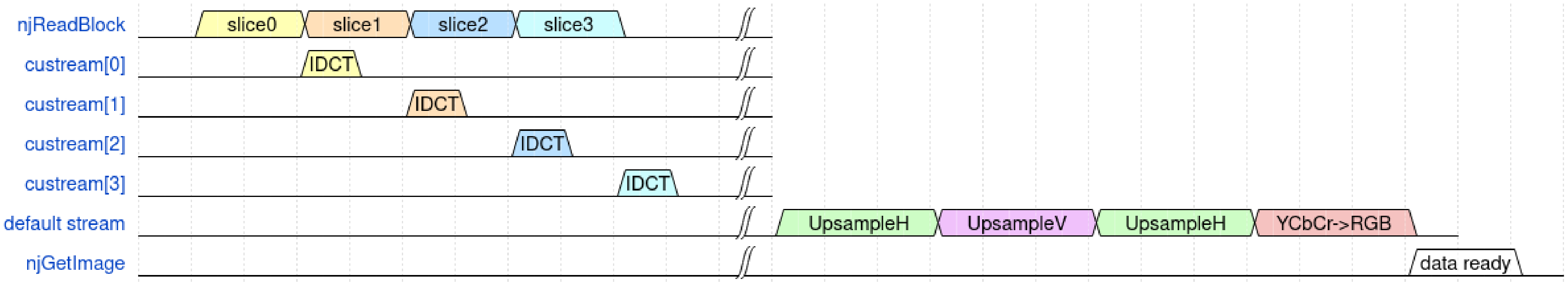
NanoJPEG CUDA Data Flow



Streamed Execution

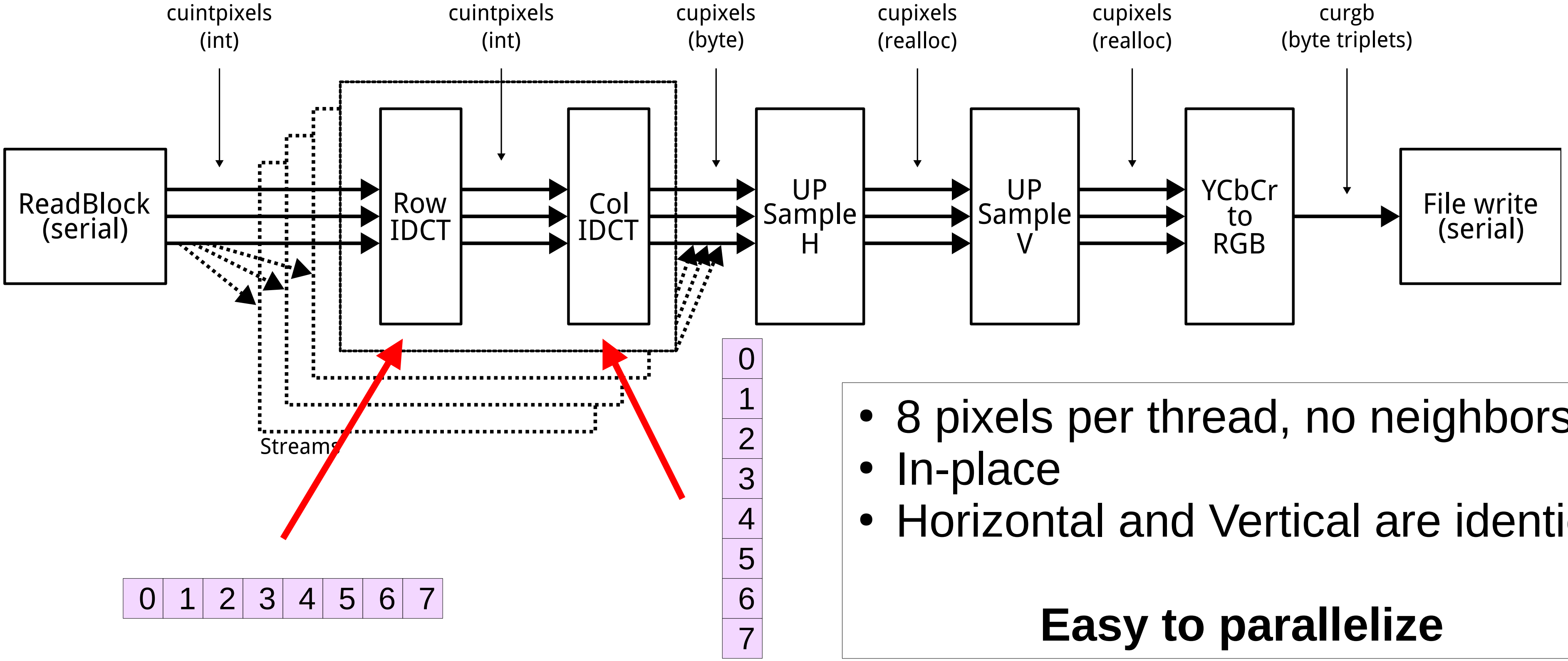


Streamed Execution



- Few CUDA cores: 1 SM / 128 Threads
- Disk I/O bound workload

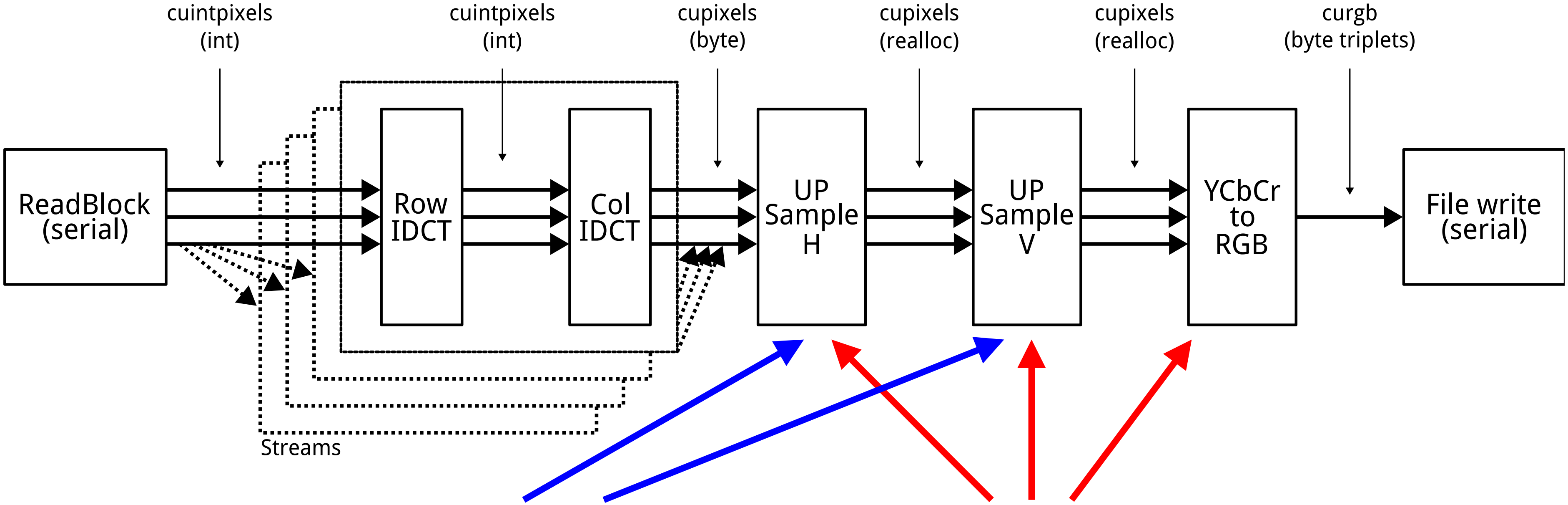
Inverse Discrete Cosine Transform (IDCT)



- 8 pixels per thread, no neighbors
- In-place
- Horizontal and Vertical are identical

Easy to parallelize

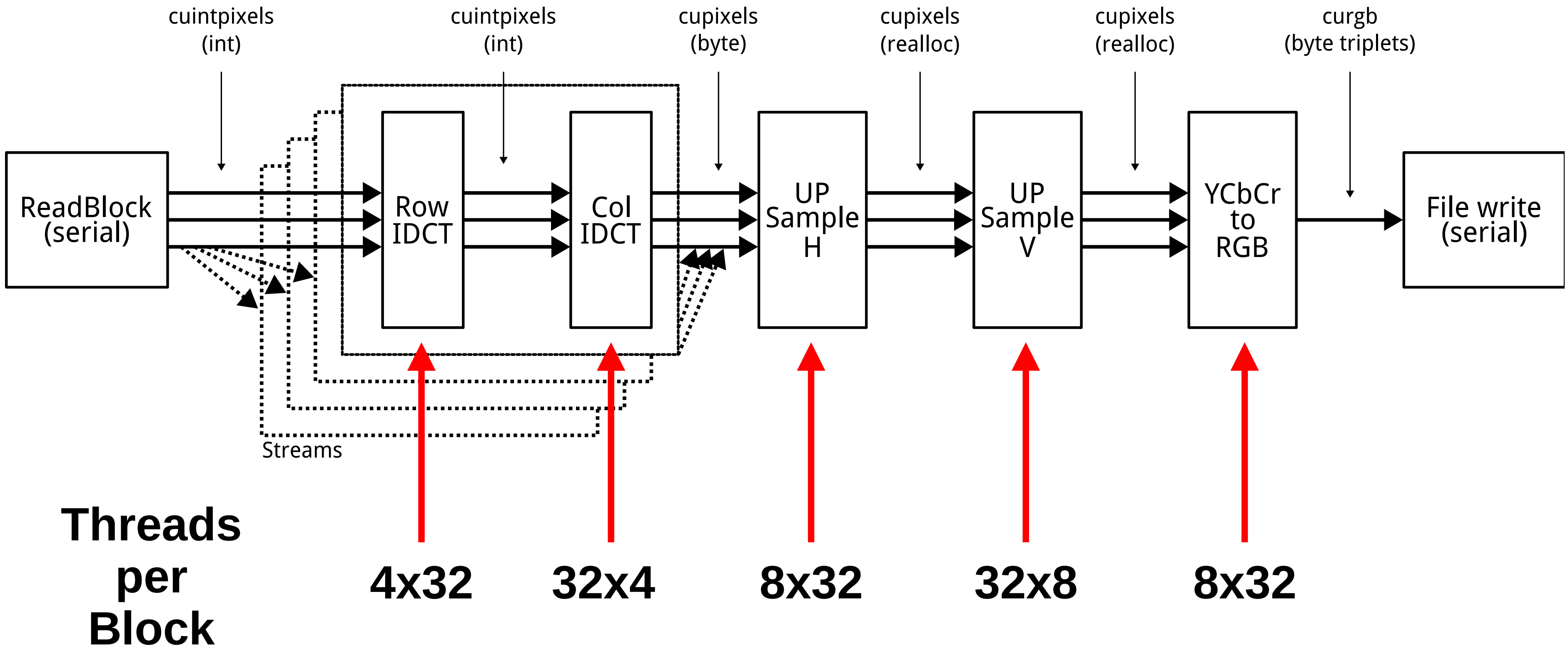
Upsampling, RGB Conversion



Interdependent pixels

8/16 pixel in per thread
16 pixel out per thread

CUDA Grids


cuintpixels (int)
cuintpixels (int)
cupixels (byte)
cupixels (realloc)
cupixels (realloc)
curgb (byte triplets)
ReadBlock (serial)
Row IDCT
Col IDCT
UP Sample H
UP Sample V
YCbCr to RGB
File write (serial)
Streams
Threads per Block
4x32
32x4
8x32
32x8
8x32

NanoJPEG CUDA Performance

- Advantageous for big images (on Jetson Nano)
  1 Megapixel: GPU **on par** with single-thread CPU
  8 Megapixel: GPU **40% faster** than single-thread CPU
- Pro: elaboration in parallel with disk read
- Problems: elaboration is faster than disk I/O (bottleneck)

Performance must be evaluated
for any particular CPU + GPU + DISK combination