Multiplexed imaging with Nchannels beams

```
μm = 10^-6;
μs = 10^-6;
ms = 10^-3;
ns = 10^-9;
mm = 10^-3;
kHz = 10^3;
Mbps = 10^6;
min = 60;
hour = 3600;
mmps = 10^-3;

L = 10 mm; (*Size of the whole sample*)
Δz = 0.5 μm; (*spatial sampling in z*)
Tline = 62.5 μs; (*Time per scanned line*)
Tlaser = 12.5 ns; (*Laser pulse repetition period*)
tFPGA = 6.25 ns; (*Clock of the FPGA*)

Nchannels = 16; (*Number of laser beams*)
Nbits = 4; (*Number of bits per pixel*)
NpixWidth = 400; (*Number of pixels per line*)
NpixHeight = 25; (*Number of lines per frame,
per channel. The total lines in a frame is Nchannels*NpixHeight *)
Ntiles = 50 × 50; (*Number of tiles*)
Nframes = 10 000; (*Number of frames*)
FIFOOUTdepth = 131 071;
BWacquisition = Nchannels * Nbits NpixWidth / Tline; (*Acquisition bandwidth for Nchannels*)
BWreading = 250. Mbps; (*Bandwidth for transfering the FIFO
 data from the FPGA to the computer (experimentally measured) *)
tWholeSampleNoPause = Ntiles * Nframes * NpixHeight * Tline;
```

Block imaging - the acquisition of each frame starts immediately after the previous frame. Then the acquisition is stopped to wait till the PC finishes reading the FIFO

con: stopping and re-starting the z-stage could take several ms and could be non-deterministic

```
tFillUp = Nchannels * Nbits * FIFOOUTdepth / (BWacquisition - BWreading);
(*Time to fill up the FIFO*)
tEmpty = Nchannels * Nbits * FIFOOUTdepth / BWreading; (*Time to empty a full FIFO*)

NmaxLines = 1200.; (*Max number of lines successfully read from the PC
 before overflowing (?) the FPGA FIFO OUT. Determined experimentally*)
NmaxFrames = NmaxLines / NpixHeight; (*Number of frames in a block (whole sample)*)
Npause = Ntiles * Nframes / NmaxFrames; (*Total time pausing (whole sample)*)
tPause = 0.5 * tEmpty (*Time pausing per block*)
dtWholeSampleBlock = Npause * tPause ;
(*Total additional time added by pausing (whole sample) *)
tWholeSampleBlock = tWholeSampleNoPause + dtWholeSampleBlock;
(*Total imaging time (whole sample)*)
tPerFrameBlock = NpixHeight * Tline; (*Time to image a frame*)
tPerBlock = tPerFrameBlock NmaxFrames; (*Time to image a block*)
ZstageSpeedBlock = Δz / tPerFrameBlock; (*Speed of the z-stage*)
```

```
0.0167771
```

```
Grid[{{"#", "PARAMETER", "VALUE" , "UNITS", "COMMENTS"},
  {"1", "FIFO depth", FIFOOUTdepth , "elements"},
  {"2", "Acquisition bandwidth", BWacquisition / Mbps, "Mbps", "Calculated. Exact"},
  {"3", "Reading bandwidth", BWreading / Mbps, "Mbps", "Measured"},
  {"4", "Time to fill up the FIFO", tFillUp / ms, "ms"},
  {"5", "Time to empty a full FIFO",
   tEmpty / ms, "ms", "> time to pause the acquisition"},
  {"6", "# lines per block", NmaxLines, "-", "Rought approx"},
  {"7", "# frames per block", NmaxFrames, "-"},
  {"8", "Time imaging per block", tPerBlock / ms, "ms",
   "Longer than #4. Probably the FIFO's BW measurement is off"},
  {"9", "Time pausing per block", tPause / ms, "ms", "Probably a fraction of #5"},
  {"10", "Total pausing time (whole sample)", dtWholeSampleBlock / hour, "hour"},
  {"11", "Total imaging time(whole sample)", tWholeSampleBlock / hour,
   "hour", "Without considering the shifting in XY and the VT cutting"},
  {"12", "Speed z-stage", ZstageSpeedBlock / mmps, "mm/s"}}, Frame → All]
```

#	PARAMETER	VALUE	UNITS	COMMENTS
1	FIFO depth	131071	elements	
2	Acquisition bandwidth	409.6	Mbps	Calculated. Exact
3	Reading bandwidth	250.	Mbps	Measured
4	Time to fill up the FIFO	52.5598	ms	
5	Time to empty a full FIFO	33.5542	ms	> time to pause the acquisition
6	# lines per block	1200.	-	Rought approx
7	# frames per block	48.	-	
8	Time imaging per block	75.	ms	Longer than #4. Probably the FIFO's BW measurement is off
9	Time pausing per block	16.7771	ms	Probably a fraction of #5
10	Total pausing time (whole sample)	2.42724	hour	
11	Total imaging time(whole sample)	13.2779	hour	Without considering the shifting in XY and the VT cutting
12	Speed z-stage	0.32	mm/s	

Interleaved imaging - After acquiring a frame, the code waits for number of RS swings so that the PC finish reading the FIFO. The z-stage runs continuously

```
NwaitLinesPerFrame = 15;(*Wait for this amount of RS swings between frames*)
tWaitPerFrame = NwaitLinesPerFrame * Tline;(*Waiting time after each frame*)
tPerFrameInterleaved = NpixHeight * Tline + tWaitPerFrame;(*Time to image a frame*)
BWacquisitionInterleaved = (NpixHeight * Nchannels * Nbits * NpixWidth) / tPerFrameInterleaved;
(*Because of multiplexing, only NpixHeight lines have to be scanned in each frame*)
dtWholeSampleInterleaved = Ntiles * Nframes * tWaitPerFrame;
(*Total additional time from waiting (whole sample)*)
tWholeSampleInterleaved = tWholeSampleNoPause + dtWholeSampleInterleaved;
(*Total imaging time (whole sample)*)
ZstageSpeedInterleaved = Δz / tPerFrameInterleaved;(*Speed of the z-stage*)
```

```
Grid[{{"#", "PARAMETER", "VALUE", "UNITS", "COMMENTS"},
  {"1", "FIFO depth", FIFOOUTdepth , "elements"},
  {"2", "# waiting lines between frame", NwaitLinesPerFrame,
   "-", "Increase till #4 close to the measured value"},
  {"3", "Imaging time per frame", tPerFrameInterleaved / ms , "ms"},
  {"4", "Interleaved imaging bandwidth",
   BWacquisitionInterleaved / Mbps, "Mbps", "Of course lower than without waiting"},
  {"5", "Total pausing time (whole sample)", dtWholeSampleInterleaved / hour, "hour"},
  {"6", "Total imaging time(whole sample)", tWholeSampleInterleaved / hour, "hours"},
  {"7", "Speed z-stage", ZstageSpeedInterleaved / mmps, "mm/s"}}, Frame → All]
```

#	PARAMETER	VALUE	UNITS	COMMENTS
1	FIFO depth	131071	elements	
2	# waiting lines between frame	15	-	Increase till #4 close to the measured value
3	Imaging time per frame	2.5	ms	
4	Interleaved imaging bandwidth	256.	Mbps	Of course lower than without waiting
5	Total pausing time (whole sample)	6.51042	hour	
6	Total imaging time(whole sample)	17.3611	hours	
7	Speed z-stage	0.2	mm/s	