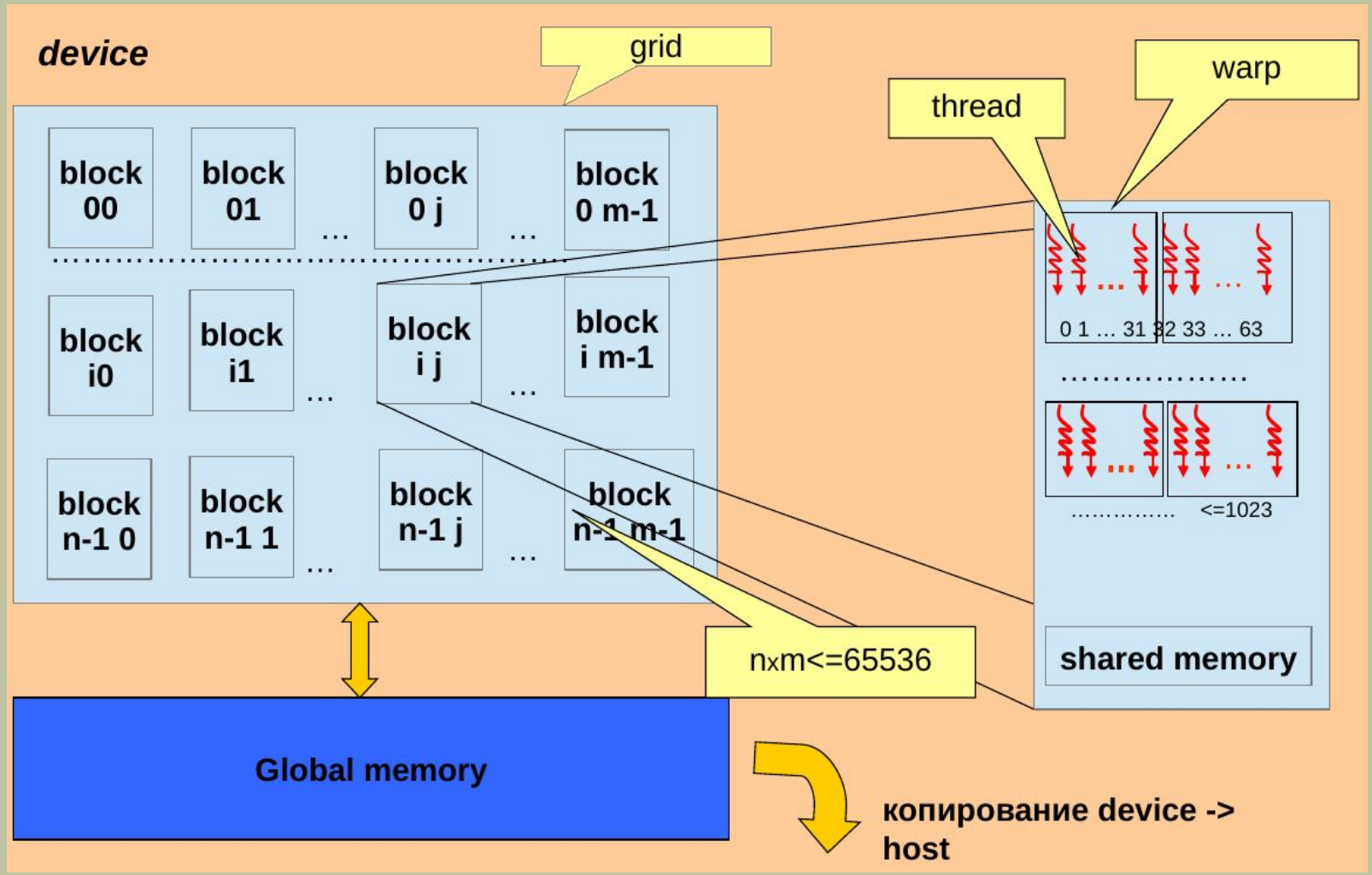
Лекция 5

- Объединение нитей в блоки и варпы.
- Оптимальная конфигурация нитей.
- Иерархия памяти.


device
grid
block 00
block 01
block 0 j
block 0 m-1
block i0
block i1
block i j
block i m-1
block n-1 0
block n-1 1
block n-1 j
block n-1 m-1
nxm<=65536
thread
warp
0 1 ... 31 32 33 ... 63
<=1023
shared memory
Global memory
копирование device -> host

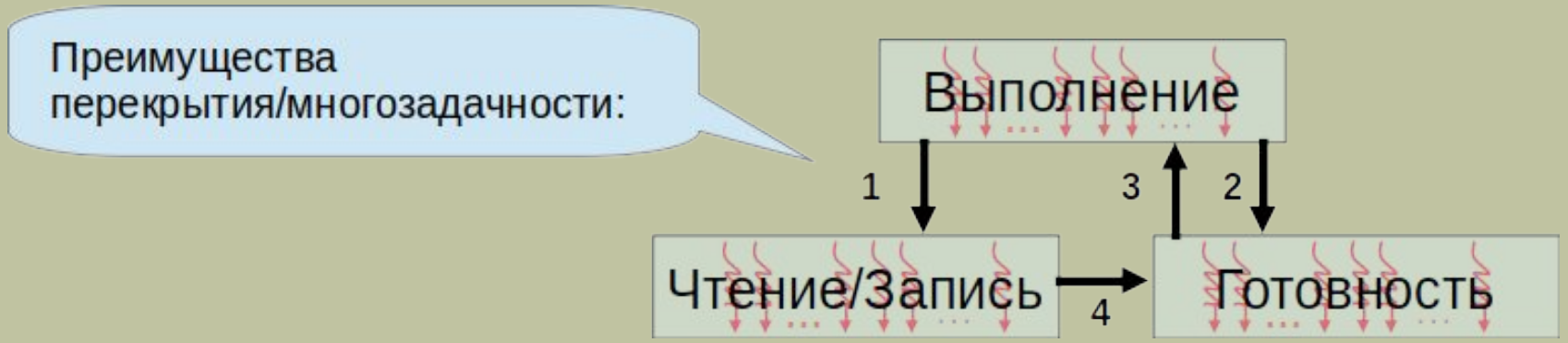
```
#include <stdio.h>
#include <stdlib.h>

  global    void gShowIdx() {
 int idx = blockIdx.x * blockDim.x + threadIdx.x;
 int warp idx = threadIdx.x / warpSize;
 int lane idx = threadIdx.x % warpSize;
 printf(" %5d\t%5d\t %2d\t%2d\n",
          idx, blockIdx.x, warp_idx, lane_idx);
}
```

```
int main(int argc, char** argv){
 if(argc < 3){
  fprintf(stderr,
        "USAGE: <prog> <threads_per_block> <num_of_blocks>\n");
   return -1;
 }

 int threads per block=atoi(argv[1]);
 int num_of_blocks=atoi(argv[2]);

 gShowIdx<<<num_of_blocks, threads_per_block>>>();
 cudaDeviceSynchronize();

 return 0;
}
```

```
./lab4a 64 2 | sort -g -k1,1 -k2,2
-k4,4 > stat.txt
```

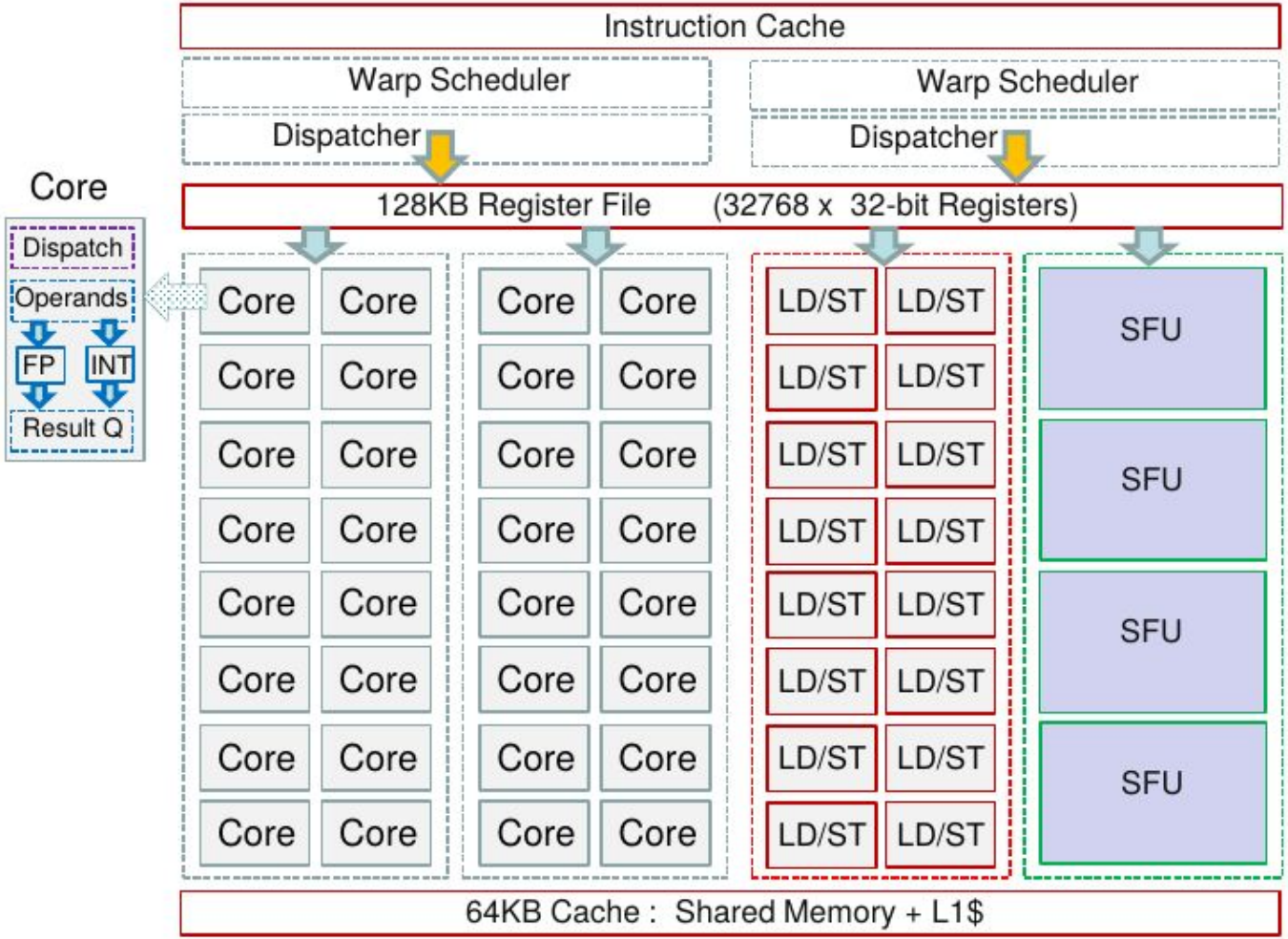
Idx	*blk*	*wrp*	*lane*
0	0	0	0
1	0	0	1
2	0	0	2
.....			
30	0	0	30
31	0	0	31
32	0	1	0
33	0	1	1
34	0	1	2
.....			
62	0	1	30
63	0	1	31
64	1	0	0
65	1	0	1
.....			
95	1	0	31
96	1	1	0
97	1	1	1
.....			
127	1	1	31

Оптимальное количество нитей в блоках
(сокрытие латентности)



Кол-во варпов % 32 ==0 && Кол-во варпов / 32 > 1

Кол-во блоков >= Кол-во мультипроцессоров


Instruction Cache
Warp Scheduler
Warp Scheduler
Dispatcher
Dispatcher
Core
Dispatch
Operands
FP
INT
Result Q
128KB Register File (32768 x 32-bit Registers)
Core
LD/ST
SFU
64KB Cache : Shared Memory + L1$

```
Detected 1 CUDA Capable device(s)
Device 0: "NVIDIA GeForce RTX 2060"
 CUDA Driver Version / Runtime Version          12.0 / 11.1
 CUDA Capability Major/Minor version number:    7.5
……..
 (30) Multiprocessors, ( 64) CUDA Cores/MP:     1920 CUDA Cores
……..
 Memory Clock rate:                             7001 Mhz
 Memory Bus Width:                              192-bit
 L2 Cache Size:                                 3145728 bytes
……..
 Total amount of constant memory:               65536 bytes
 Total amount of shared memory per block:       49152 bytes
 Total shared memory per multiprocessor:        65536 bytes
 Total number of registers available per block: 65536
 Warp size:                                     32
 Maximum number of threads per multiprocessor:  1024
 Maximum number of threads per block:           1024
```

```
Detected 2 CUDA Capable device(s)
Device 0: "GeForce GTX 1050"
 CUDA Driver Version / Runtime Version          9.1 / 9.1
 CUDA Capability Major/Minor version number:    6.1
……
 ( 5) Multiprocessors, (128) CUDA Cores/MP:     640 CUDA Cores
……..
 Memory Clock rate:                             3504 Mhz
 Memory Bus Width:                              128-bit
 L2 Cache Size:                                 1048576 bytes
……
 Total amount of constant memory:               65536 bytes
 Total amount of shared memory per block:       49152 bytes
 Total number of registers available per block: 65536
 Warp size:                                     32
 Maximum number of threads per multiprocessor:  2048
 Maximum number of threads per block:           1024
……..
```

https://docs.nvidia.com/cuda/archive/11.2.0/cuda-c-programming-guide/index.html#compute-capabilities

Table 15. Technical Specifications per Compute Capability

	Compute Capability												
Technical Specifications	**3.5**	**3.7**	**5.0**	**5.2**	**5.3**	**6.0**	**6.1**	**6.2**	**7.0**	**7.2**	**7.5**	**8.0**	**8.6**
Warp size	32												
Maximum number of resident blocks per SM	16		32								16	32	16
Maximum number of resident warps per SM	64										32	64	48
Maximum number of resident threads per SM	2048										1024	2048	1536
Number of 32-bit registers per SM	64 K	128 K	64 K										
Maximum number of 32-bit registers per thread block	64 K				32 K	64 K		32 K			64 K		
Maximum number of 32-bit registers per thread	255												

```
__global__ void gSum(int* a, int *b){
 int i=threadIdx.x+blockIdx.x*blockDim.x;
 a[i]+=b[i];
}
```

```
int N=1<<atoi(argv[1]);
int num_threads=atoi(argv[2]);
int num_blocks=N/num_threads;
```

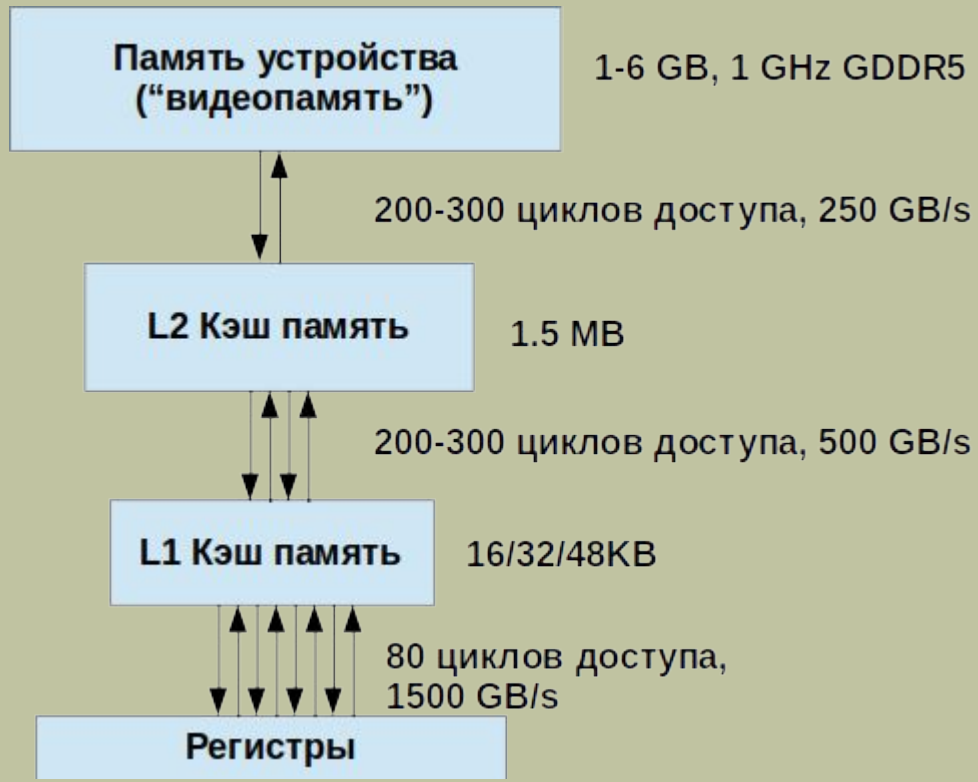
```
gSum<<<num_blocks, num_threads>>>(a,b);
 cudaDeviceSynchronize();
 CUDA_CHECK_RETURN(cudaGetLastError());
```

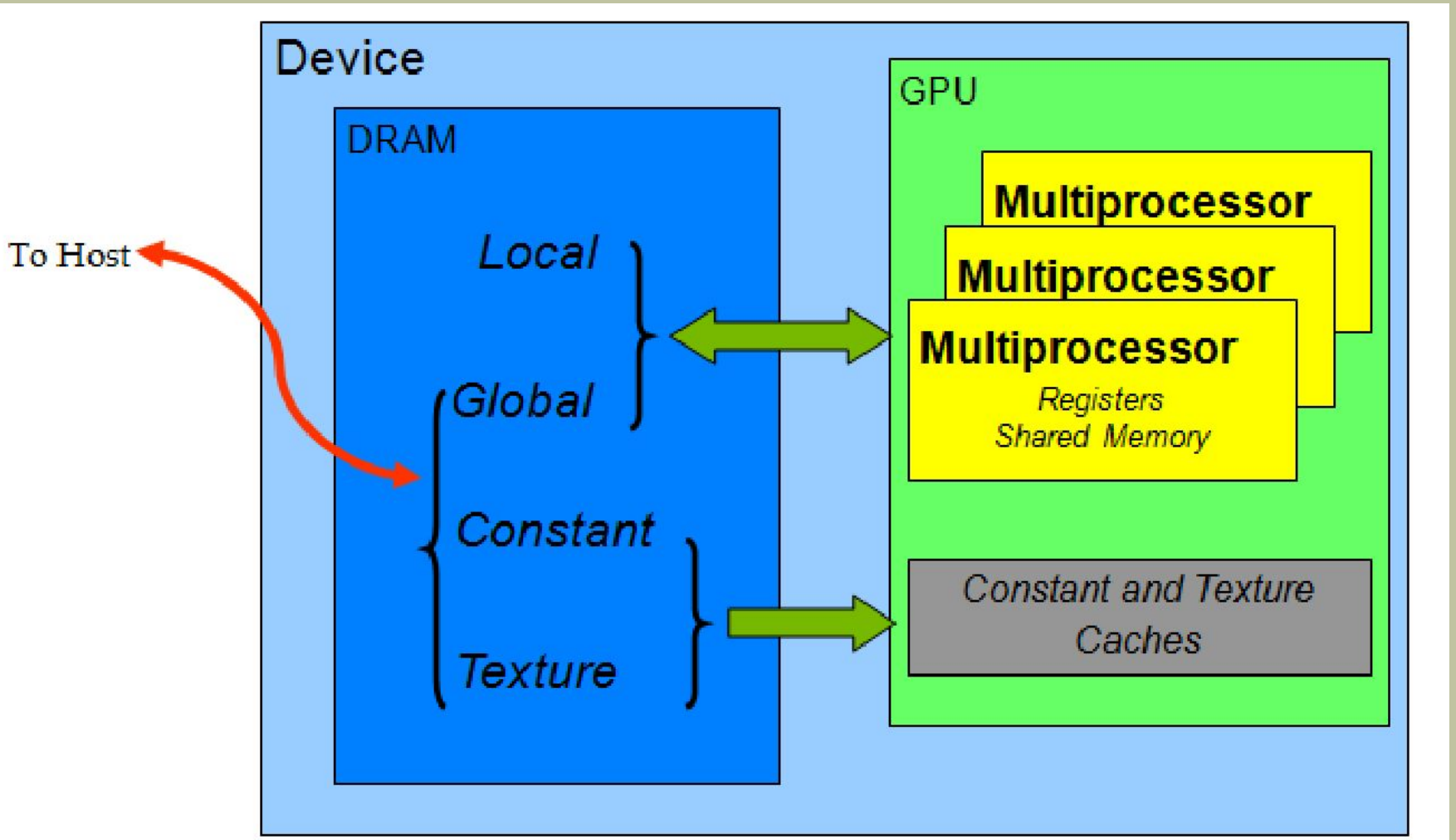
```
/Lab4 # ncu --target-processes all -k gSum ./lab4 20   32
```

```
  gSum(int *, int *), 2023-Feb-20 17:05:19, Context 1, Stream 7
    Section: GPU Speed Of Light Throughput
    ----------------------------------------
    Duration                    usecond         69.38
    ----------------------------------------


    Section: Occupancy
    ----------------------------------------
    Theoretical Occupancy       %               50
    Achieved Occupancy          %            33.63
……..
```

```
/Lab4 # ncu --target-processes all -k gSum ./lab4 20   64
```

```
gSum(int *, int *), 2023-Feb-20 17:05:19, Context 1, Stream 7
  Section: GPU Speed Of Light Throughput
  ----------------------------------------
  Duration                    usecond         42.78
  ----------------------------------------


  Section: Occupancy
  ----------------------------------------
  Theoretical Occupancy       %                 100
  Achieved Occupancy          %               79.17
```


Память устройства
(“видеопамять”)
1-6 GB, 1 GHz GDDR5
200-300 циклов доступа, 250 GB/s
L2 Кэш память
1.5 MB
200-300 циклов доступа, 500 GB/s
L1 Кэш память
16/32/48KB
80 циклов доступа,
1500 GB/s
Регистры


Device
DRAM
Local
Global
Constant
Texture
To Host
GPU
Multiprocessor
Multiprocessor
Multiprocessor
Registers
Shared Memory
Constant and Texture
Caches

```
#define DUMMY_LENGTH 102

__global__ void gInit(int* a, int* b){
 int i=threadIdx.x+blockIdx.x*blockDim.x;
 int dummy[DUMMY_LENGTH];
 for(int j=0;j<DUMMY_LENGTH;j++)
   dummy[j]=j%2+1;

 a[i]=dummy[DUMMY_LENGTH-2]*i;
 b[i]=dummy[DUMMY_LENGTH-1]*i+1;
}
```

быдло-код 😜

```
/PGP-2023> nvprof -m local_memory_overhead ./lab4 20 32
```

```
Invocations  Metric Name  Metric Description
                                        Min       Max       Avg
Device "GeForce GTX 1050 (0)"
Kernel: gInit(int*, int*)
    1     local_memory_overhead  Local Memory Overhead
                                     98.11%    98.11%    98.11%
Kernel: gSum(int*, int*)
    1    local_memory_overhead  Local Memory Overhead
                                      0.00%     0.00%     0.00%
```

Type	Time(%)	Time	Calls	Avg	Min	Max	Name
GPU activities:	83.15%	**4.3196ms**	1	**4.3196ms**	**4.3196ms**	**4.3196ms**	gInit(int*, int*)
	4.67%	242.60us	1	**242.60us**	**242.60us**	**242.60us**	gSum(int*, int*)

```
#define DUMMY_LENGTH 101
```

```
/PGP-2023> nvprof -m local_memory_overhead ./lab4 20 32
```

```
Invocations  Metric Name  Metric Description
                                        Min        Max        Avg
Device "GeForce GTX 1050 (0)"
Kernel: gInit(int*, int*)
    1     local_memory_overhead  Local Memory Overhead
                                     0.00%    0.00%    0.00%
Kernel: gSum(int*, int*)
    1     local_memory_overhead  Local Memory Overhead
                                     0.00%     0.00%    0.00%
```

Type	Time(%)	Time	Calls	Avg	Min	Max	Name
GPU activities:	16.67%	**173.67us**	1	**173.67us**	**173.67us**	**173.67us**	gInit(int*, int*)
	23.26%	**242.25us**	1	**242.25us**	**242.25us**	**242.25us**	gSum(int*, int*)