

1. GPU정보 확인하기

(a) `srun --partition=shpc --gres=gpu:4 nvidia-smi`

```
shpc136@login1:~$ srun --partition=shpc --gres=gpu:4 nvidia-smi
Wed May 17 16:27:15 2023
```

NVIDIA-SMI 470.57.02 Driver Version: 470.57.02 CUDA Version: 11.4									
GPU	Name	Persistence-M	Bus-Id	Disp.A	Volatile Uncorr.	ECC			
Fan	Temp	Perf	Pwr:Usage/Cap	Memory-Usage	GPU-Util	Compute M.	MIG	M.	M.
0	NVIDIA TITAN RTX	Off	00000000:18:00.0	Off	0%	Default	N/A		
41%	45C	P0	60W / 280W	0MiB / 24220MiB			N/A		
1	NVIDIA TITAN RTX	Off	00000000:3B:00.0	Off	1%	Default	N/A		
43%	38C	P0	56W / 280W	0MiB / 24220MiB			N/A		
2	NVIDIA TITAN RTX	Off	00000000:86:00.0	Off	0%	Default	N/A		
40%	34C	P0	56W / 280W	0MiB / 24220MiB			N/A		
3	NVIDIA TITAN RTX	Off	00000000:AF:00.0	Off	0%	Default	N/A		
32%	32C	P0	23W / 280W	0MiB / 24220MiB			N/A		

GPU	GI	CI	PID	Type	Process name	GPU Memory
ID	ID	ID				Usage
No running processes found						

계산노드에 설치된 GPU 4개의 상태를 알 수 있음

(GPU 이름, driver version, Memory-usage, GPU-util, 온도, 전력소비 및 GPU에서 돌아가는 process의 정보 등등)

`srun --partition=shpc --gres=gpu:4 nvidia-smi -q`

```
shpc136@login1:~$ srun --partition=shpc --gres=gpu:4 nvidia-smi -q
srun: job 592485 queued and waiting for resources
srun: job 592485 has been allocated resources

=====NVSMI LOG=====

Timestamp                               : Wed May 17 16:31:48 2023
Driver Version                           : 470.57.02
CUDA Version                             : 11.4

Attached GPUs                             : 4
GPU 00000000:18:00.0
  Product Name                           : NVIDIA TITAN RTX
  Product Brand                           : Titan
  Display Mode                             : Disabled
  Display Active                           : Disabled
  Persistence Mode                         : Disabled
  MIG Mode
    Current                               : N/A
    Pending                               : N/A
  Accounting Mode                         : Disabled
  Accounting Mode Buffer Size              : 4096
  Driver Model
    Current                               : N/A
    Pending                               : N/A
  Serial Number                           : 1324419071623
  GPU UUID                                : GPU-aeab102-5e5a-8389-2f2b-40f5ac9d2017
  Minor Number                             : 0
  VBIOS Version                           : 90.02.2E.00.0C
  MultiGPU Board                           : No
  Board ID                                : 0x1800
  GPU Part Number                          : 900-1G150-2500-000
  Module ID                                : 0
  Inforom Version                          : 0
```

계산노드에 설치된 4개의 GPU에 대해 더 상세한 정보에 대해 알 수 있음

(Product Name, Product Brand, Display Mode, Display Active, Persistence Mode, MIG Mode, Accounting Mode, Accounting Mode Buffer Size, Driver Model, Serial Number, GPU UUID, PCI 등등)

srunk --partition=shpc --gres=cpu:4 clinfo

```
shpc136@login1:~$ srunk --partition=shpc --gres=cpu:4 clinfo
srunk: job 592541 queued and waiting for resources
srunk: job 592541 has been allocated resources
slurmstepd: error: couldn't chdir to '/home/n8/shpc136': No such file or directory: going to /tmp instead
slurmstepd: error: couldn't chdir to '/home/n8/shpc136': No such file or directory: going to /tmp instead
Number of platforms
Platform Name      NVIDIA CUDA
Platform Vendor    NVIDIA Corporation
Platform Version    OpenCL 3.0 CUDA 11.4.94
Platform Profile    FULL_PROFILE
Platform Extensions cl_khr_global_int32_base_atomics cl_khr_global_int32_ext
_khr_byte_addressable_store cl_khr_icd cl_khr_gl_sharing cl_nv_compiler_options cl_nv_device_attribute_query
Platform Host timer resolution
Platform Extensions function suffix

Platform Name      NVIDIA CUDA
Number of devices  4
Device Name        NVIDIA TITAN RTX
Device Vendor      NVIDIA Corporation
Device Vendor ID   0x10de
Device Version      OpenCL 3.0 CUDA
Driver Version      470.57.02
Device OpenCL C Version
Device Type        GPU
Device Topology (NV)
Device Profile      FULL_PROFILE
Device Available    Yes
Compiler Available  Yes
Linker Available    Yes
Max compute units   72
Max clock frequency 1770MHz
Compute Capability (NV)
Device Partition    (core)
  Max number of sub-devices
Supported partition types
Max work item dimensions
Max work item sizes
Max work group size
Preferred work group size multiple
Warp size (NV)      32
Max sub-groups per work group
Preferred / native vector sizes
char                1 / 1
short               1 / 1
```

계산 노드 GPU 4개를 할당 받아 OpenCL 플랫폼과 디바이스에 대한 자세한 정보가 표시됨.

(플랫폼 이름, 버전, 지원하는 OpenCL버전, 디바이스 이름, 타입, 메모리 크기 등등)

(b) 모델명 : NVIDIA TITAN RTX, 노드당 GPU 개수 : 4개

(c) GPU 메모리 크기 : 24220MiB

(d) Max power limit : 320W, Max SM clock speed : 2100MHz

(e) Max work item dimension : 3, Max work item size : 1024X1024X64, Max work group size : 1024

2. Matrix Multiplication with OpenCL

(a) 병렬화 방식 :

1. Output Matrix의 크기인 $M * N$ 스레드에 할당
2. global memory coalescing을 위해 커널 인덱스 공간을 $\{N, M\}$ 으로 함
3. local(shared) memory를 활용하기 위해 타일링 적용

(b) matmul.c에 대한 설명

1. matmul_initialize : 커널 코드 실행에 필요한 객체 생성

- clGetPlatformIDs : 플랫폼 개수와 ID 얻어오기
- clGetDeviceIDs : 디바이스 개수와 ID 얻어오기
- clCreateContext : 컨텍스트 생성
- clCreateCommandQueue : 커맨드큐 생성
- clCreateProgramWithSource : 소스 코드로부터 프로그램 오브젝트 만들기
- clBuildProgram : 프로그램 빌드
- clCreateKernel : 커널 오브젝트 만들기
- clCreateBuffer : 버퍼 오브젝트 만들기

2. matmul : 커널코드 실행

- clEnqueueWriteBuffer : 버퍼 쓰기
- clSetKernelArg : 커널 인자 설정
- clEnqueueNDRangeKernel : 커널 실행
- clEnqueueReadBuffer : 버퍼 읽기

3. matmul_finalize : 메모리 leaking 방지를 위해 활용이 끝난 메모리 free

- clReleaseMemobject: 버퍼 free
- clReleaseKernel : 커널 free
- clReleaseProgram : 프로그램 free
- clReleaseCommandQueue : 커맨드큐 free
- clReleaseContext : 컨텍스트 free

4. 그 외 API

- clGetplatforminfo : OpenCL 플랫폼 정보
- clGetdeviceinfo : OpenCL 디바이스 정보
- clGetProgramBuildInfo : OpenCL 프로그램빌드 정보

(c) 최적화에 따른 성능 실험($M=N=K=4096$)

1. Naïve한 OpenCL 적용 : 140GFlops
2. Global Memory Coalescing : 1160GFlops
3. Local (shared) Memory Tiling : 1450GFlops