# COALESCED GLOBAL MEMORY

# LEARNING OBJECTIVES

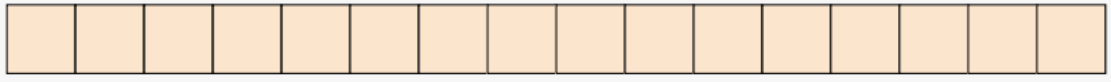
- Learn about coalesced global memory access
- Learn about the performance impact
- Learn about row-major vs column-major
- Learn about SoA vs AoS

# COALESCED GLOBAL MEMORY

- Reading from and writing to global memory is generally very expensive.
- It often involves copying data across an off-chip bus.
    - This means you generally want to avoid unnecessary accesses.
- Memory access operations is done in chunks.
    - This means accessing data that is physically close together in memory is more efficient.

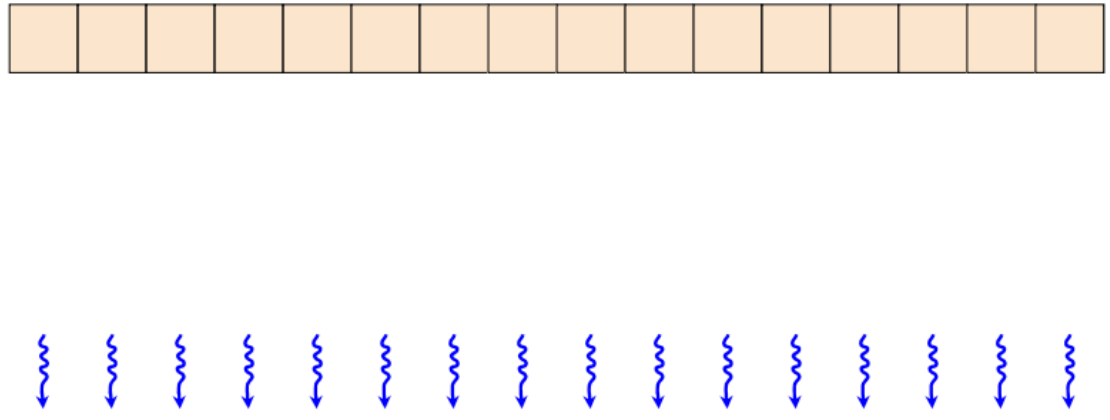
# COALESCED GLOBAL MEMORY

```
float data[size];
```



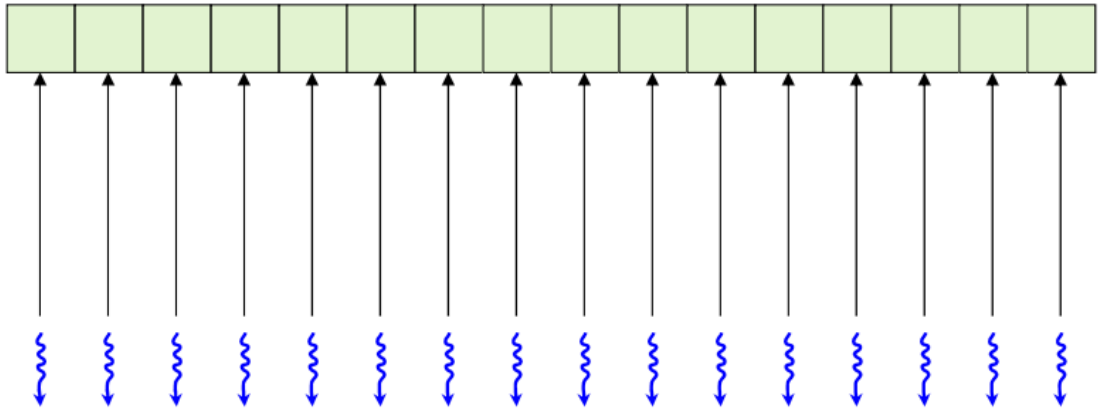
# COALESCED GLOBAL MEMORY

```
float data[size];

...

f(a[globalId]);
```



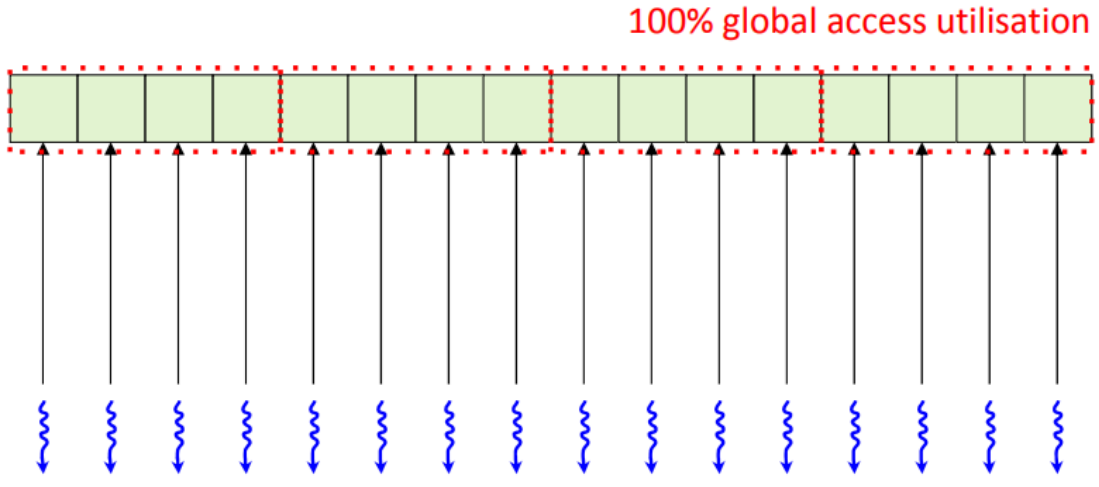
# COALESCED GLOBAL MEMORY

```
float data[size];

...

f(a[globalId]);
```



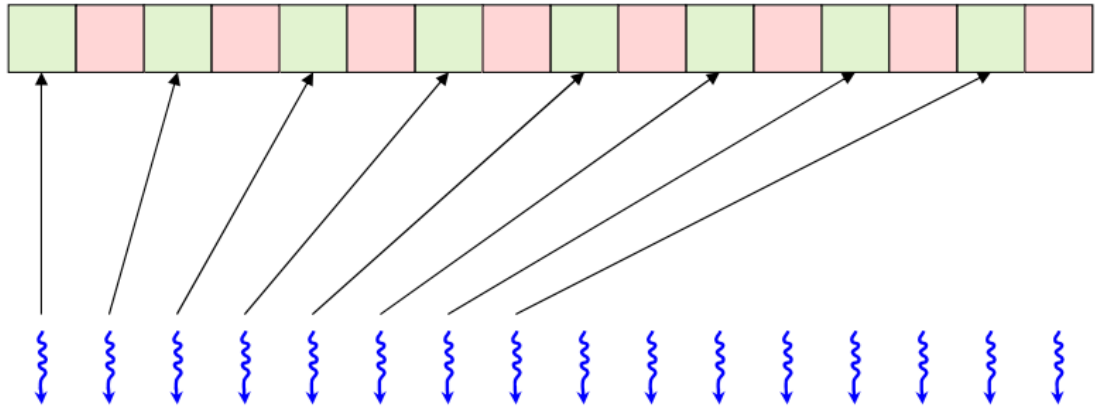
# COALESCED GLOBAL MEMORY

```
float data[size];

...

f(a[globalId]);
```



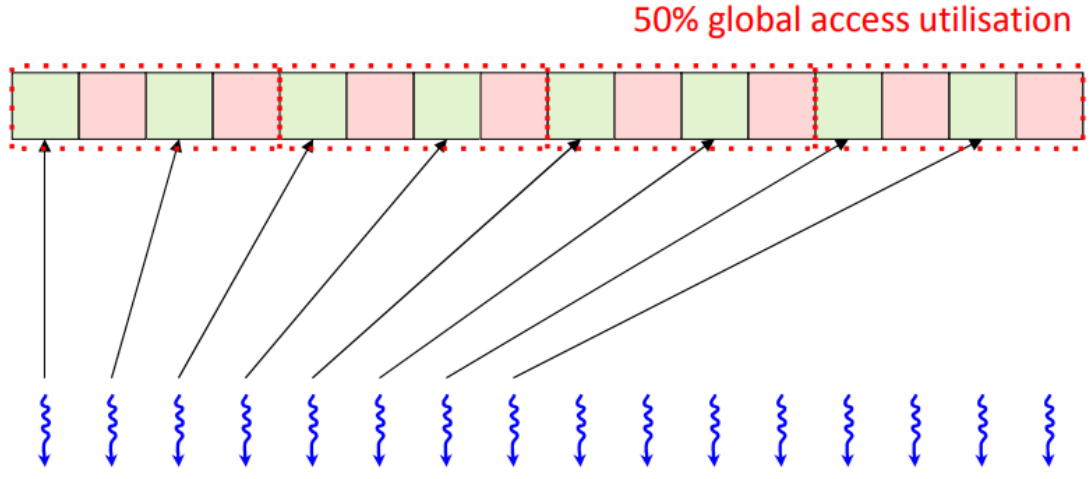
# COALESCED GLOBAL MEMORY

```
float data[size];

...

f(a[globalId * 2]);
```



# COALESCED GLOBAL MEMORY

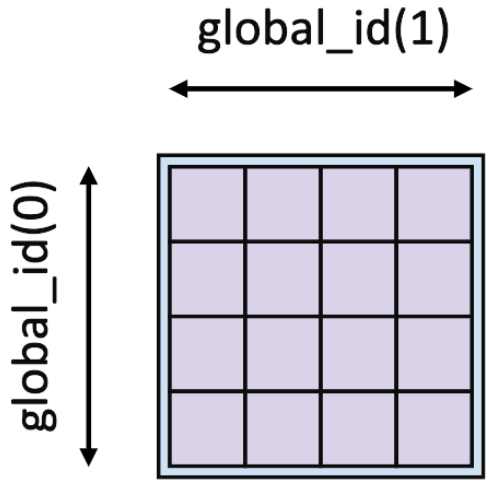
```
float data[size];

...

f(a[globalId * 2]);
```



# ROW-MAJOR VS COLUMN-MAJOR

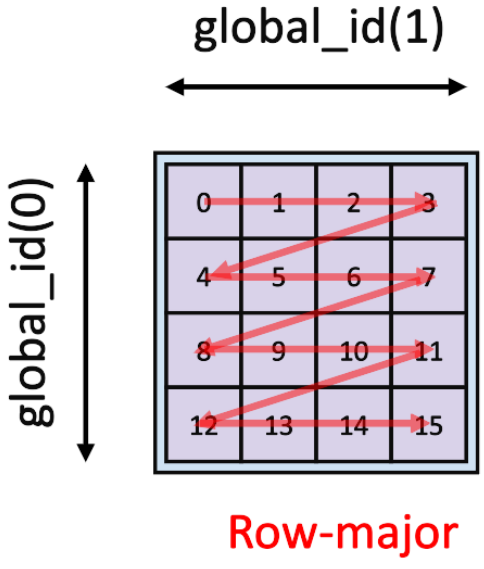
- Coalescing global memory access is particularly important when working in multiple dimensions.
- This is because when doing so you have to convert from a position in 2d space to a linear memory space.
- There are two ways to do this; generally referred to as row-major and column-major.

# ROW-MAJOR VS COLUMN-MAJOR



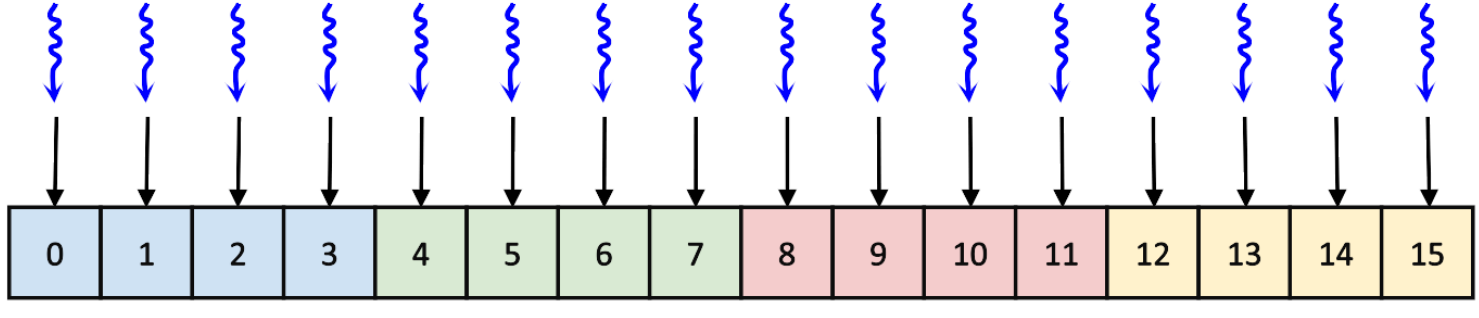

Row-major

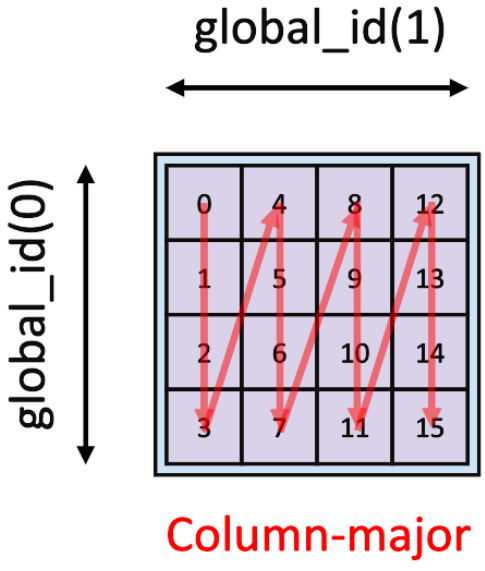
```
auto id0 = get_global_id(0);

auto id1 = get_global_id(1);

auto linearId = (id0 * 4) + id1;

a[linearId] = f();
```




Row-major

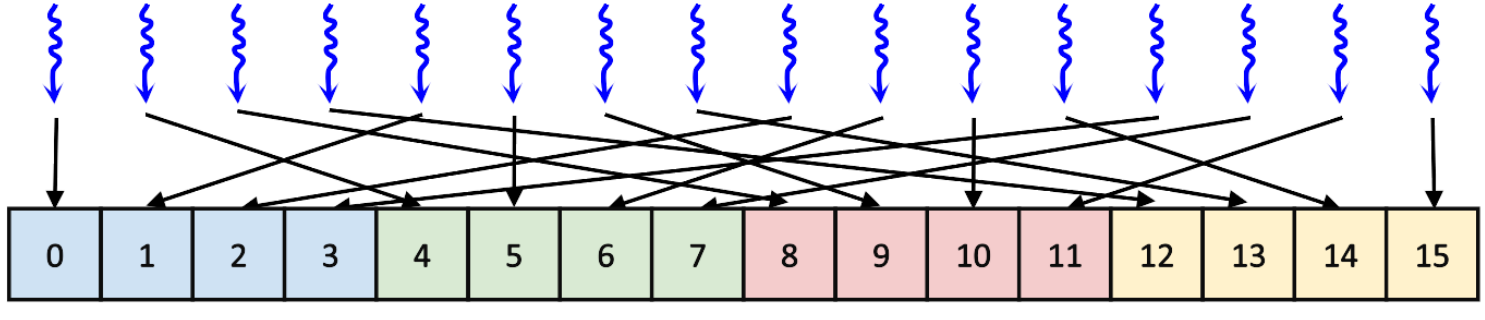
```
auto id0 = get_global_id(0);
auto id1 = get_global_id(1);
auto linearId = (id0 * 4) + id1;
a[linearId] = f();
```






Column-major

```
auto id0 = get_global_id(0);

auto id1 = get_global_id(1);

auto linearId = (id1 * 4) + id0;

a[linearId] = f();
```

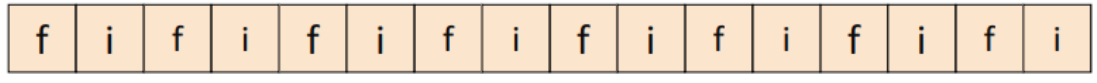


# AOS VS SOA

- Another area this is a factor is when composing data structures.
- It's often instinctive to have struct representing a collection of data and then have an array of this - often referred to as Array of Structs (AoS).
- But for data parallel architectures such as a GPU it's more efficient to have sequential elements of the same type stored contiguously in memory - often referred to as Struct of Arrays (SoA).

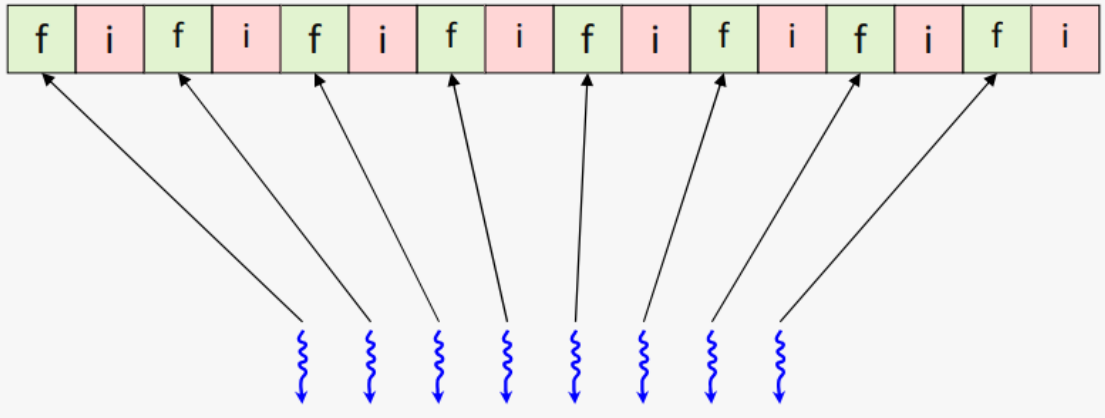
# AOS VS SOA

```
struct str {
  float f;
  int i;
};

str data[size];
```



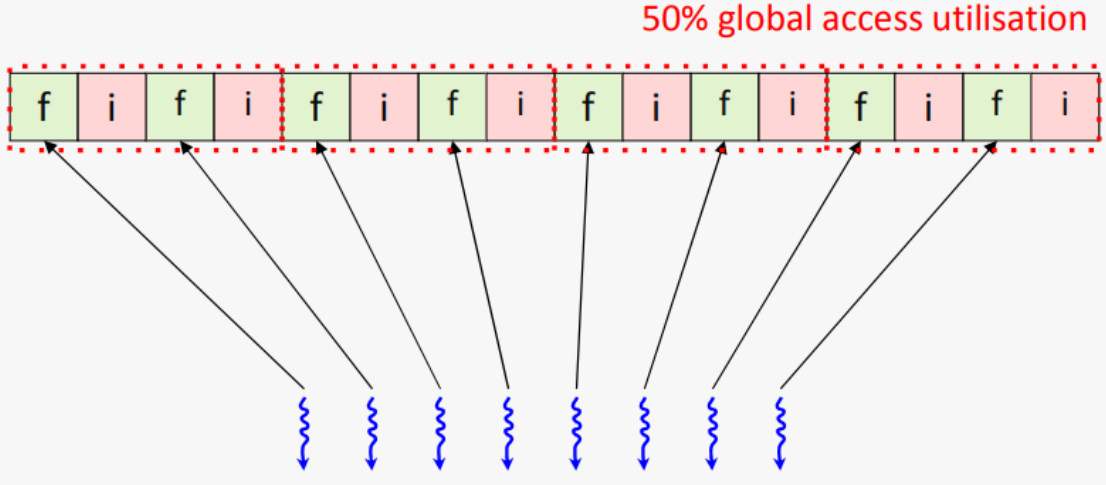
# AOS VS SOA

```
struct str {
  float f;
  int i;
};

str data[size];

...



f(a[globalId].f);
```



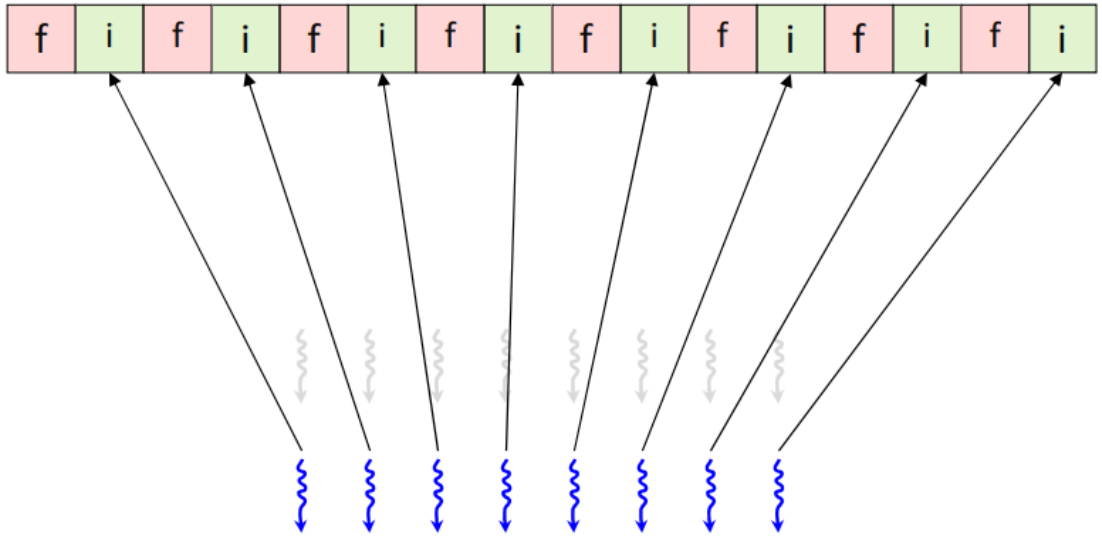
# AOS VS SOA

```
struct str {
  float f;
  int i;
};

str data[size];

...



f(a[globalId].f);
```



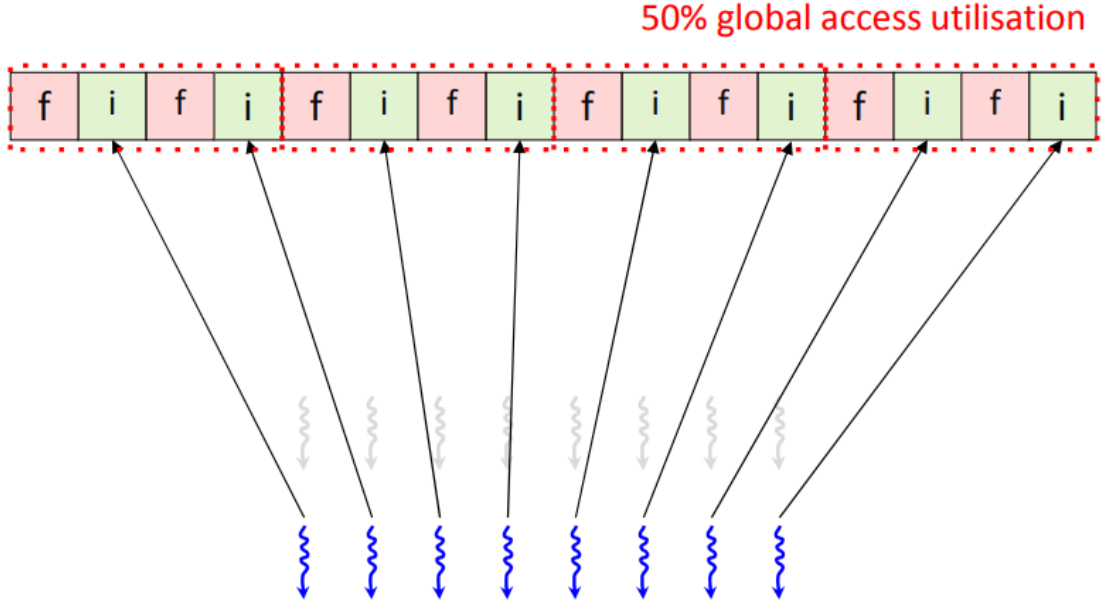
# AOS VS SOA

```
struct str {
  float f;
  int i;
};

str data[size];

...



f(a[globalId].f);

f(a[globalId].i);
```



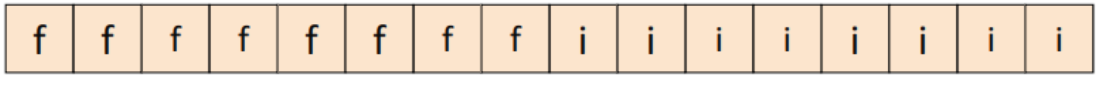
# AOS VS SOA

```
struct str {
  float f;
  int i;
};

str data[size];

...



f(a[globalId].f);

f(a[globalId].i);
```



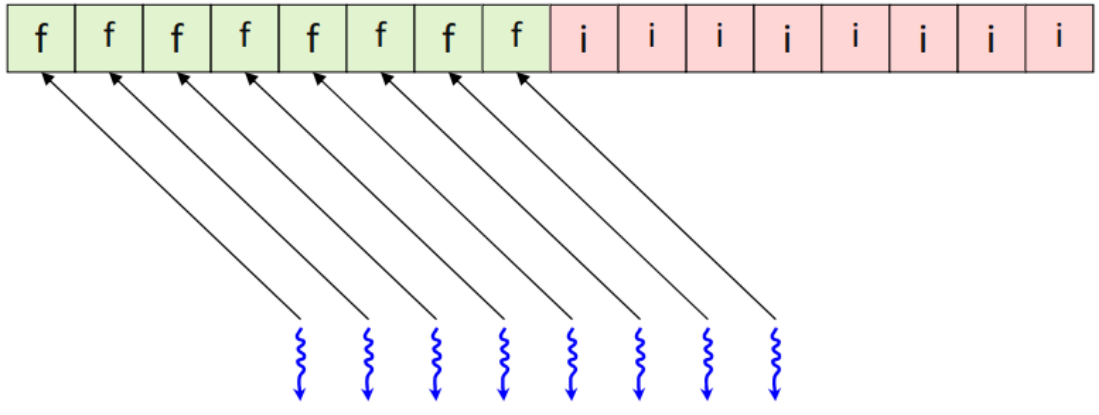
# AOS VS SOA

```
struct str {
  float fs[size];
  int is[size];
};

str data;
```



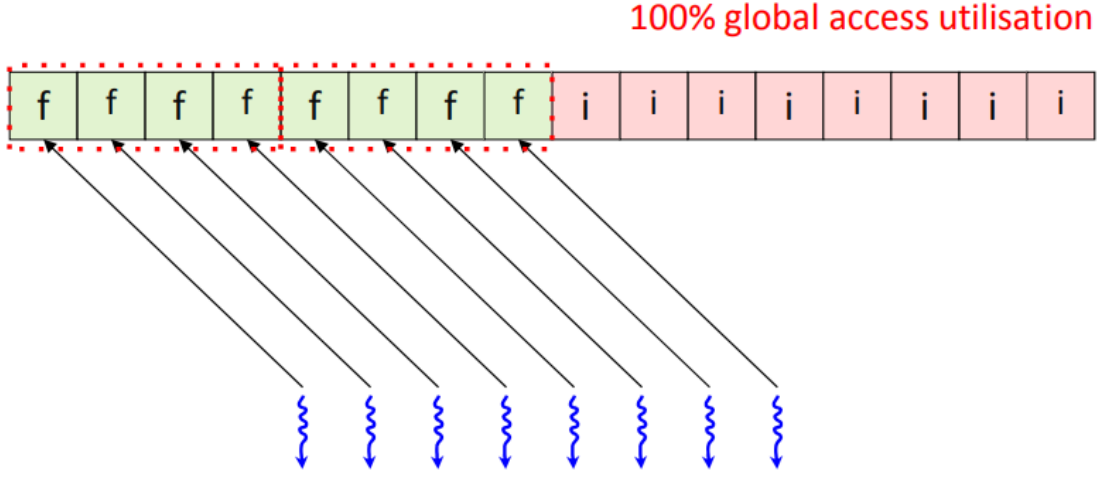
# AOS VS SOA

```
struct str {
  float fs[size];
  int is[size];
};

str data;

...



f(a[0].fs[globalId]);
```



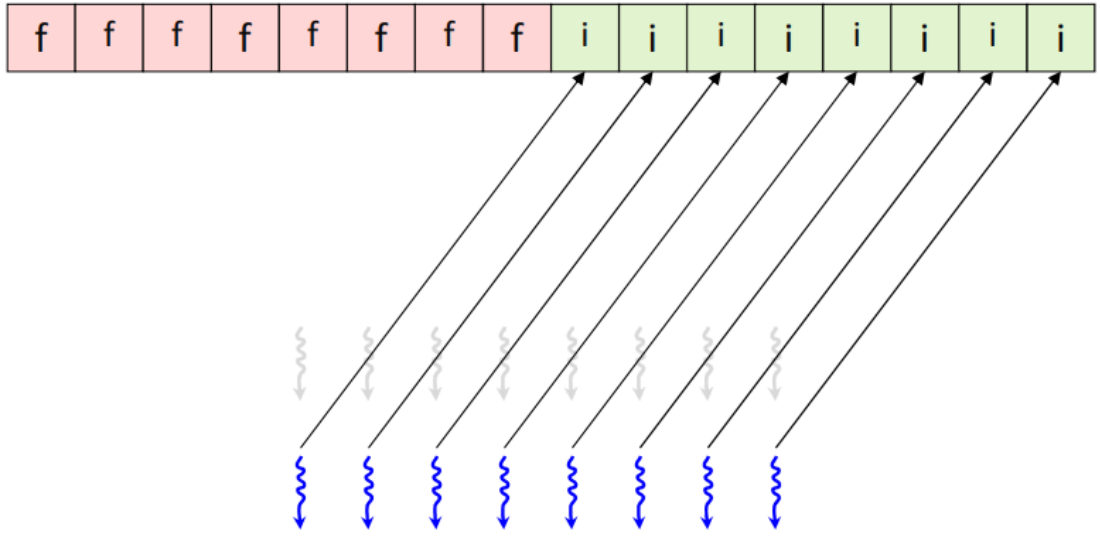
# AOS VS SOA

```
struct str {
  float fs[size];
  int is[size];
};

str data;

...



f(a[0].fs[globalId]);
```



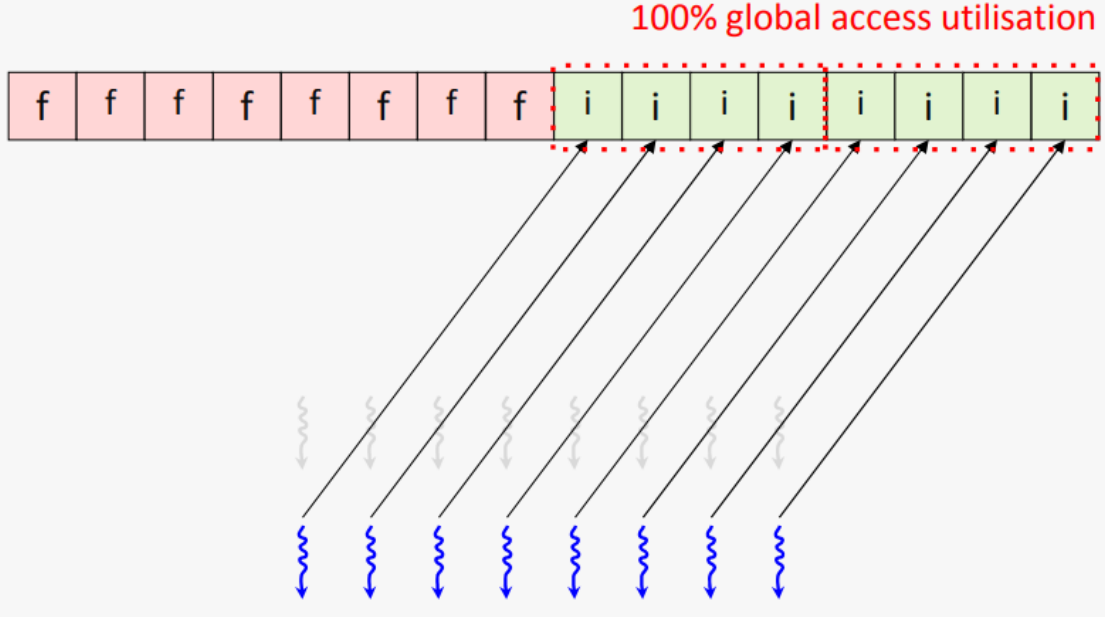
# AOS VS SOA

```
struct str {
  float fs[size];
  int is[size];
};

str data;

...



f(a[0].fs[globalId]);

f(a[0].is[globalId]);
```



# AOS VS SOA

```
struct str {
  float fs[size];
  int is[size];
};

str data;

...



f(a[0].fs[globalId]);

f(a[0].is[globalId]);
```



# COALESCED IMAGE CONVOLUTION PERFORMANCE

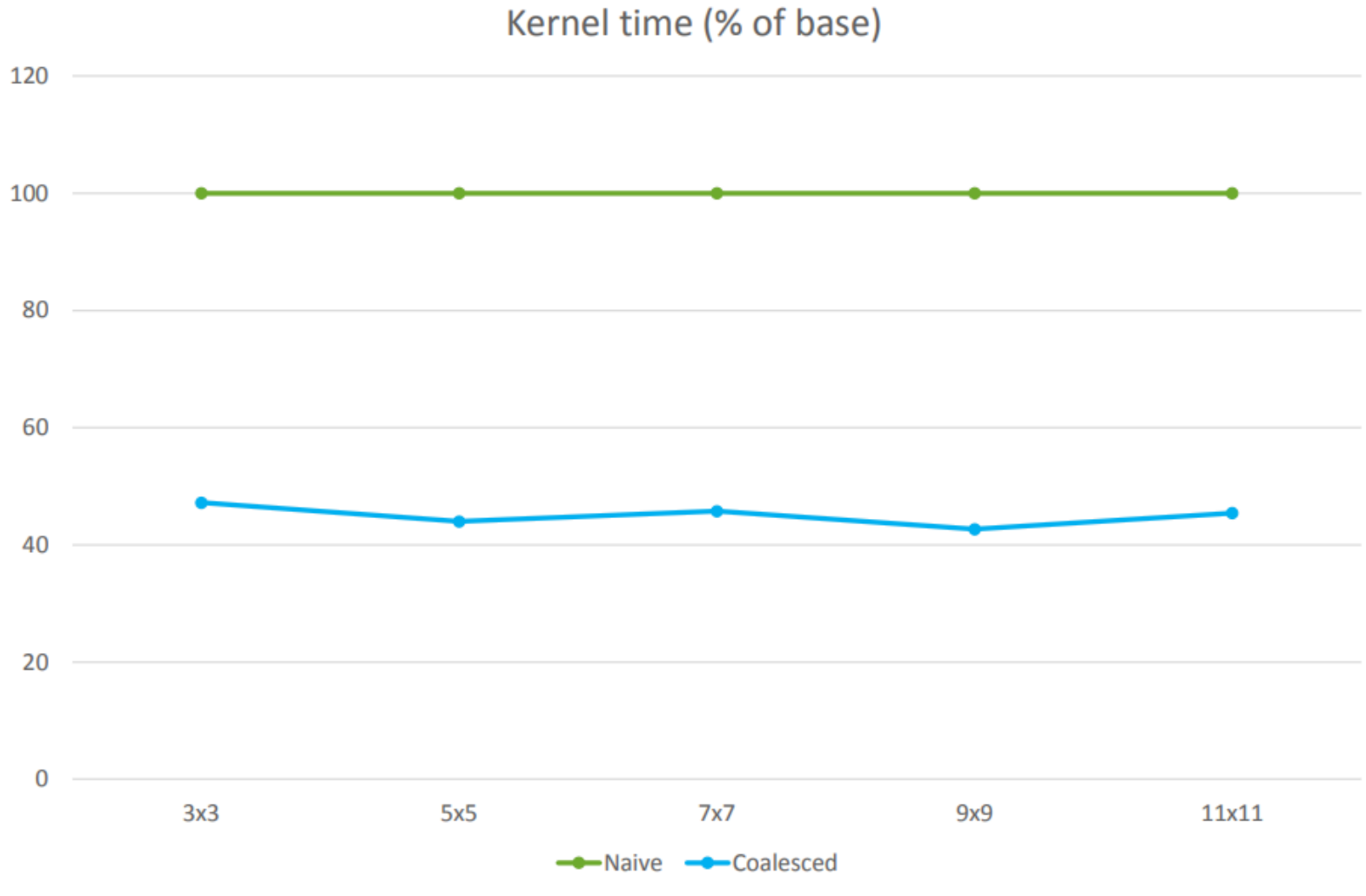



Image conv

512x512 source image

Intel HD Graphics 530

# VEC TYPES

```
auto f4 = sycl::float4{1.0f, 2.0f, 3.0f, 4.0f}; // {1.0f, 2.0f, 3.0f, 4.0f}
```

```
auto f2 = sycl::float2{2.0f, 3.0f}; // {2.0f, 3.0f}
auto f4 = sycl::float4{1.0f, f2, 4.0f}; // {1.0f, 2.0f, 3.0f, 4.0f}
```

```
auto f4 = sycl::float4{0.0f};  // {0.0f, 0.0f, 0.0f, 0.0f}
```

- A `vec` can be constructed with any combination of scalar and vector values which add up to the correct number of elements.
- A `vec` can also be constructed from a single scalar in which case it will initialize every element to that value.

# VEC OPERATORS

```
auto f4a = sycl::float4{1.0f, 2.0f, 3.0f, 4.0f}; // {1.0f, 2.0f, 3.0f, 4.0f}

auto f4b = sycl::float4{2.0f}; // {2.0f, 2.0f, 2.0f, 2.0f}

auto f4r = f4a * f4b; // {2.0f, 4.0f, 6.0f, 8.0f}
```

- The `vec` class provides a number of operators such as `+`, `-`, `*`, `/` and many more, which perform the operation elemeent-wise.

# VEC SIZES

```
sycl::int2
sycl::int3 (N.B sizeof(int3) == sizeof(int4))
sycl::int4
sycl::int8
sycl::int16
```

- Vectors can be made from all char, integer or floating point types.
- Using vector types:
  - Can make code more readable
  - Can give better memory access patterns.

# QUESTIONS

# EXERCISE

Code_Exercises/Exercise_16_Coalesced_Global_Memory/source

Try inverting the dimensions when calculating the linear address in memory and measure the performance.