Fachpraktikum Parallele Programmierung, Wintersemester 2024/25

1. Aufgabe: Bild-Filter

*Norbert Baumstark, Johannes Becker, Stefan Butz*

# Aufgabenstellung

Es sollten zwei Filter zur Bearbeitung von JPEG-Bildern erstellt werden:

* Ein Filter, der ein Farbbild in Graustufen umrechnet.
* Ein Weichzeichner-Filter, der durch Durchschnittsbildung mit umliegenden Pixeln einen Unschärfeeffekt erzeugt. Der Filter soll sowohl Graustufen- als auch Farbbilder sowie verschiedene Randgrößen unterstützen.

Es sollten die Zeiten für die Berechnung sowie den Speichertransfer analysiert und dokumentiert werden.

# Verzeichnisstruktur

Auf der obersten Verzeichnisebene befinden sich drei Dateien:

* ein Makefile,
* ein Python-Skript download\_images.py, welches einige Beispielbilder aus dem Web lädt, welche ihrer Größe wegen nicht beigefügt sind,
* ein Python-Skript perform\_measurements.py, welches alle Messungen ausführt.

Es gibt folgende Unterverzeichnisse:

* src/ enthält den Quellcode der beiden Kernels sowie die beiden Header-Dateien jpeg.h (eine objektorientierte Schnittstelle zu libjpeg) und util.h (zwei ASSERT-Makros sowie die Funktion cudaInit, die durch einmaligen Aufruf von cudaFree(0) dafür sorgt, dass zum Zeitpunkt der Messungen der Treiber bereits initialisiert ist).
* analysis/: enthält ein Jupyter-Notebook zur Auswertung der Messergebnisse. Dieses diente der Analyse sowie der Erstellung von Tabellen und Diagrammen für die vorliegende Dokumentation.
* doc/ enthält die vorliegende Dokumentation.
* images/ enthält Bilddateien, die für die Messungen verwendet werden, außerdem ein Python-Skript, mit dem die ebenfalls enthaltene Datei info.json erstellt wurde, welche Informationen über die Bilddateien enthält, insbesondere die Bildgrößen.
* nvidia/ enthält das mit den CUDA-Entwicklungstools mitgelieferte Beispielprogramm deviceQuery, welches Geräteinformationen über die GPU ausgibt.
* images\_from\_web/ wird von ./download\_images.py angelegt und dient der Ablage der Beispielbilder aus dem Web.
* bin/ wird ggf. von make angelegt und dient als Zielverzeichnis für die Objektdateien sowie die ausführbaren Binärdateien.
* images-out/ wird ggf. von perform\_measurements.py angelegt und dient der Ablage der Output-Bilddateien.
* measurements/ wird ggf. von perform\_measurements.py angelegt und dient der Ablage der Geräteinformationen und Messergebnisse.

In den abgegebenen Dateien sind die Messergebnisse enthalten, die dieser Dokumentation zugrunde liegen.

# Aufruf

Wenn gewünscht, können zunächst durch

./download\_images.py

die zusätzliche Beispielbilder aus dem Web nachgeladen werden. Nach Erstellen der ausführbaren Dateien durch

make

startet man durch

./perform\_measurements.py

die Messungen. Gegebenenfalls sind die Parameter im Makefile auf die verwendete Architektur und im Python-Skript der Pfad zum Python-Interpreter anzupassen.

Das Python-Skript perform\_measurements.py ermittelt zunächst die Geräteinformationen durch Aufruf von bin/deviceQuery und erstellt dann mittels des Tools nsys von NVIDIA Laufzeitprofile für bin/01\_grayscale und bin/02\_blur. Den beiden Binarys wird durch Kommandozeilenargumente Eingabe- und Ausgabedatei mitgeteilt; 02\_blur erhält als erstes Kommandozeilenargument zusätzlich die zu verwendende Margin. Es wird also für jedes der Beispielbilder aufgerufen:

* bin/01\_grayscale
* sowie bin/02\_blur jeweils einmal mit den Margins 1, 2 und 3.

In einem Unterverzeichnis von measurements/, das den aktuellen Zeitstempel als Namen trägt, werden abgelegt:

* die Geräteinformationen als Textdatei,
* jeweils der Output von nsys als Textdatei,
* die aus dem Output extrahierten für diese Aufgabe relevanten Messergebnisse als JSON-Datei.

Im Unterverzeichnis measurements/[Zeitstempel]/temp/ legt nsys temporäre Dateien ab.

Die Binarys können wie folgt direkt aufgerufen werden:

bin/01\_grayscale input.jpg output.jpg

bin/02\_blur 2 input.jpg output.jpg („2“ spezifiziert hier eine Margin von 2).

Die Aufrufe von nsys, welche perform\_measurements.py vornimmt, haben dementsprechend folgende Form:

nsys profile --stats=true \  
--output measurements /[Zeitstempel]/temp/report%n \  
bin/01\_grayscale input.jpg output.jpg

bzw.

nsys profile --stats=true \  
--output measurements /[Zeitstempel]/temp/report%n \  
bin/02\_blur 2 input.jpg output.jpg

# Der Programmcode: Umwandlung in Graustufen – 01\_grayscale.cu

Jeder Thread bearbeitet genau ein Pixel. Der Grauwert wird als Linearkombination von Rot-, Blau- und Gelbwert gebildet.

\_\_global\_\_ void RgbToGrayscale(

unsigned char \*inputImage, unsigned char \*outputImage,

int width,int height

) {

int x = blockIdx.x \* blockDim.x + threadIdx.x;

int y = blockIdx.y \* blockDim.y + threadIdx.y;

int idx = y \* width + x;

if (x < width && y < height) {

int rgb\_idx = idx \* 3;

unsigned char r = inputImage[rgb\_idx];

unsigned char g = inputImage[rgb\_idx + 1];

unsigned char b = inputImage[rgb\_idx + 2];

unsigned char gray = static\_cast<unsigned char>(

0.299f \* r + 0.587f \* g + 0.114f \* b

);

outputImage[idx] = gray;

}

}

Entsprechend wird die Anzahl der Blöcke auf Grundlage der Bildgröße berechnet; der Aufruf des Kernels geschieht wie folgt:

dim3 blockSize(16, 16);

dim3 gridSize(

(width + blockSize.x - 1) / blockSize.x,

(height + blockSize.y - 1) / blockSize.y

);

RgbToGrayscale<<<gridSize, blockSize>>>(

dInputImage, dOutputImage, width, height

);

Um zufällige Messfehler zu reduzieren, ruft main() den Filter 16mal auf.

# Der Programmcode: Weichzeichnen – 02\_blur.cu

Es bearbeitet jeder Thread genau einen Farbkanal genau eines (Output-)Pixels. Die Anzahl der Threads entspricht also der Anzahl der Kanäle (3 für Farbbilder, 1 für Graustufenbilder) mal der Anzahl der Pixel. Die verwendeten Blöcke sind dreidimensional, wobei die z-Komponente den zu bearbeitenden Farbkanal kodiert. Zur Weichzeichnung wird der Durchschnittswert aller Pixel berechnet, die in x- oder in y-Richtung höchstens um die Margin vom Outputpixel entfernt sind.

\_\_global\_\_ void Blur(

unsigned char \*inputImage, unsigned char \*outputImage,

int width, int height,

int channels, int margin

) {

int x = blockIdx.x \* blockDim.x + threadIdx.x;

int y = blockIdx.y \* blockDim.y + threadIdx.y;

int channel = threadIdx.z;

if (x < width && y < height) {

int startX = max(x - margin, 0);

int endX = min(x + margin, width);

int startY = max(y - margin, 0);

int endY = min(y + margin, height);

float v = 0;

for (int i = startY; i < endY; i++) {

for (int j = startX; j < endX; j++) {

v += inputImage[(i \* width + j) \* channels + channel];

}

}

float n = (endX - startX) \* (endY - startY);

outputImage[(y \* width + x) \* channels + channel] = v / n;

}

}

Der Aufruf des Kernels erfolgt entsprechend folgendermaßen:

dim3 blockSize(16, 16, channels);

dim3 gridSize(

(width + blockSize.x - 1) / blockSize.x,

(height + blockSize.y - 1) / blockSize.y

);

Blur<<<gridSize, blockSize>>>(

dInputImage, dOutputImage, width, height, channels, margin

);

Auch hier ruft main() den Filter 16mal auf, um zufällige Messfehler zu reduzieren.

# Vorgehen bei den Messungen

Wir haben bei dieser Aufgabe Zeitmessungen sowohl mittels CUDA-Events als auch mit dem Tool nsys von NVIDIA ausprobiert. Die Ergebnisse stimmten weitgehend überein. Für die Einsendung haben wir uns dazu entschlossen, die Ergebnisse von nsys zu dokumentieren. (In anderen Aufgaben verwenden wir CUDA-Ereignisse.)

Aus von nsys erstellten Reports extrahieren wir die Laufzeitinformationen zu

* der Startdauer des Kernels („cudaLaunchKernel“),
* der Zeit für den Transfer vom Host zum Device („CUDA memcpy Host-to-Device“),
* der Ausführungszeit des Kernels,
* der Zeit für den Transfer vom Device zum Host („CUDA memcpy Device-to-Host“).

# Eingabedaten

Als Eingabedaten verwenden wir farbige Beispielbilder verschiedener Größe. Tabelle X gibt einen Überblick.

# Hardware

|  |  |  |  |
| --- | --- | --- | --- |
| Bild | Breite | Höhe | Pixel |
| 01\_small.jpg | 100 | 100 | 10000 |
| toledo01.jpg | 320 | 214 | 68480 |
| toledo02.jpg | 640 | 428 | 273920 |
| toledo03.jpg | 800 | 535 | 428000 |
| toledo04.jpg | 1024 | 685 | 701440 |
| 02\_medium.jpg | 1200 | 675 | 810000 |
| toledo05.jpg | 1280 | 857 | 1096960 |
| toledo06.jpg | 2560 | 1713 | 4385280 |
| 03\_large.jpg | 5616 | 3744 | 21026304 |
| toledo07.jpg | 13226 | 8852 | 117076552 |

Tabelle 1. Die für die Messungen verwendeten Bilddateien.

Die Messungen wurden auf folgenden Geräten durchgeführt:

* NVIDIA Jetson Xavier NX 16 GB in einem Seeed Studio reComputer J2022;  
  GPU gemäss Datenblatt: 384-core NVIDIA Volta GPU with 48 Tensor Cores,  
  CPU gemäss Datenblatt: 6-core NVIDIA Carmel ARM v8.2 64-bit CPU 6MB L2 + 4MB L3.
* NVIDIA Tesla V100-SXM2-32GB,

funkel.fernuni-hagen.de.

Die Ausgaben von deviceQuery für die einzelnen Geräte finden sich in Anhang A.

# Messergebnisse

Abbildung 1 zeigt die Zeiten für den Transfer der Daten vom Host zum Device in Abhängigkeit von der Bildgröße, d.h. der Anzahl Pixels. Wie zu erwarten ist, ist die Transferzeit einigermaßen linear in der Anzahl der Pixels.

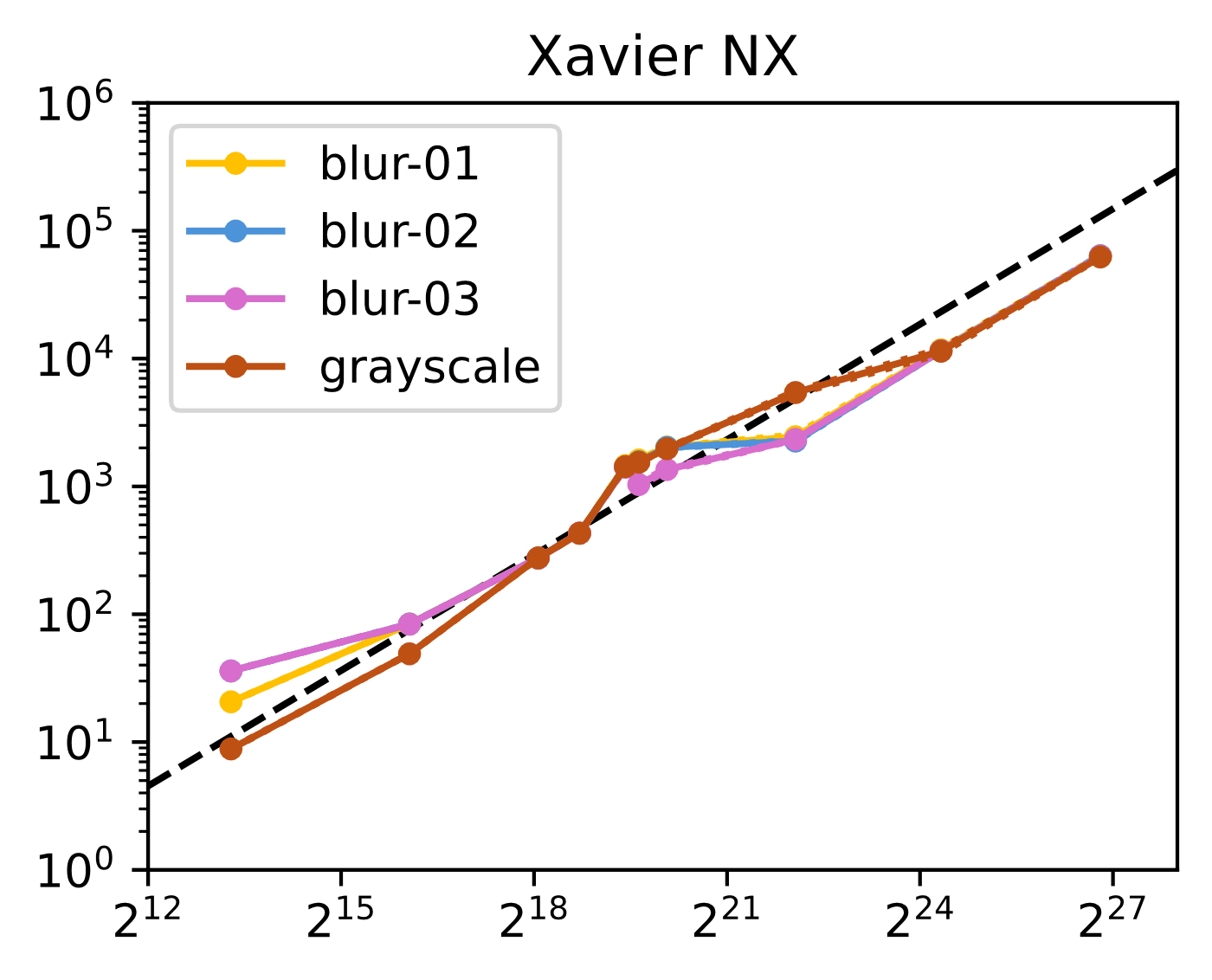
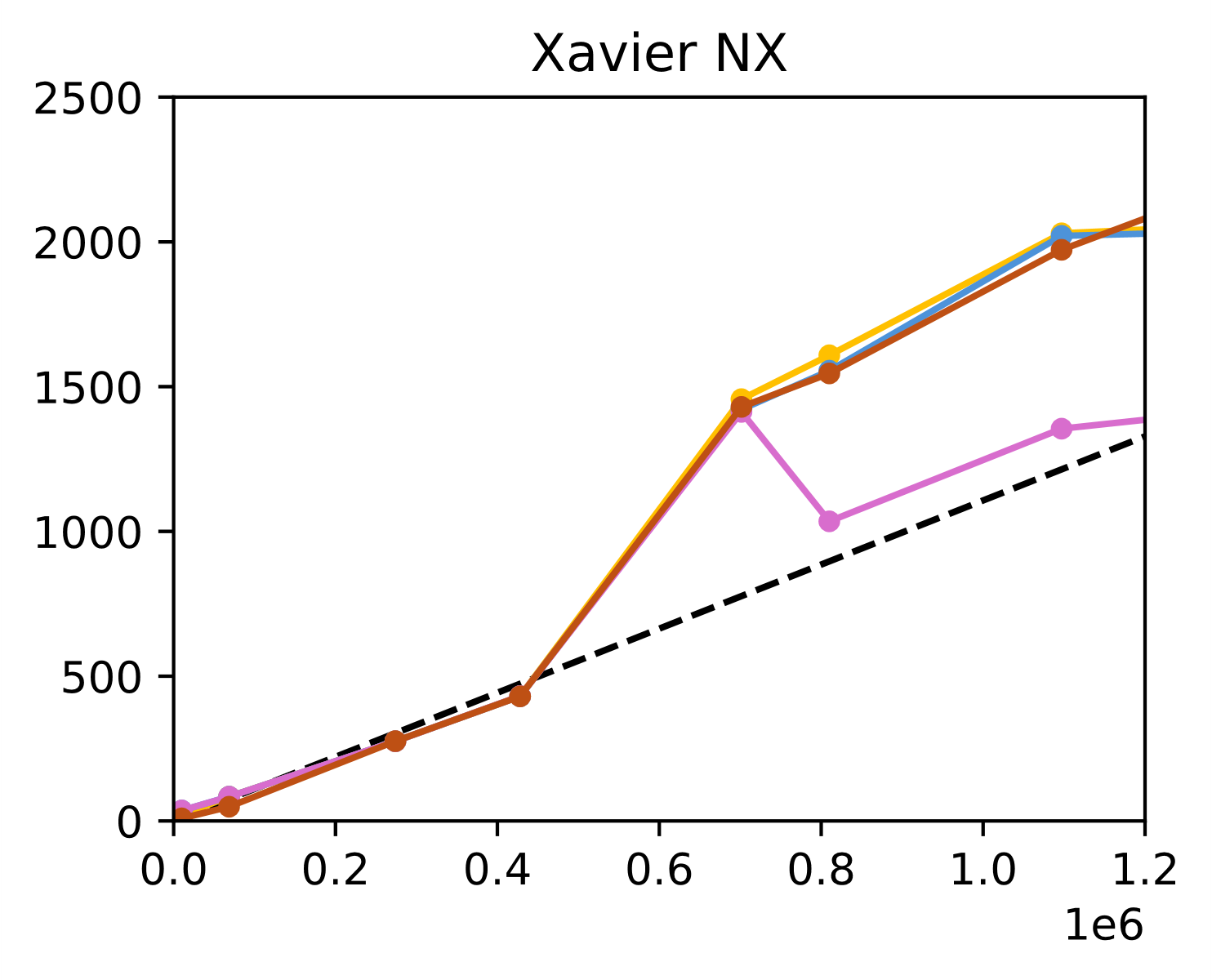


Abbildung 1. Arithmetische Mittel der Zeiten für den Transfer der Daten vom Host zum Device, in Abhängigkeit von der Bildgröße. Die horizontale Achse stellt die Anzahl Pixel dar. Auf der vertikalen Achse ist jeweils die mittlere Transferzeit in Mikrosekunden (µs) abgetragen. Das linke Diagramm zeigt die Werte für die Bilder mit bis zu 1.2 Millionen Pixeln, mit linear skalierten Achsen. Das rechte Diagramm zeigt alle Werte, mit logarithmisch skalierten Achsen. Die gepunkteten Kurven im rechten Diagramm (kaum erkennbar) zeigen das 90%-Konfidenzband. Die gestrichelte schwarze Gerade zeigt eine „gefittete“ Gerade mit Achsenabschnitt 0, d.h. eine ideale lineare Laufzeit.

Abbildung 2 zeigt die Transferzeiten in umgekehrter Richtung, d.h. vom Device zum Host. Auch hier zeigt sich eine im Wesentlichen lineare Abhängigkeit. Bei der Umwandlung in Grauwerte sind die Transferzeiten nun wesentlich kürzer als bei den Weichzeichnungsfiltern. Dies überrascht nicht, da jeweils nur ein Drittel der Datenmenge zu übertragen ist.

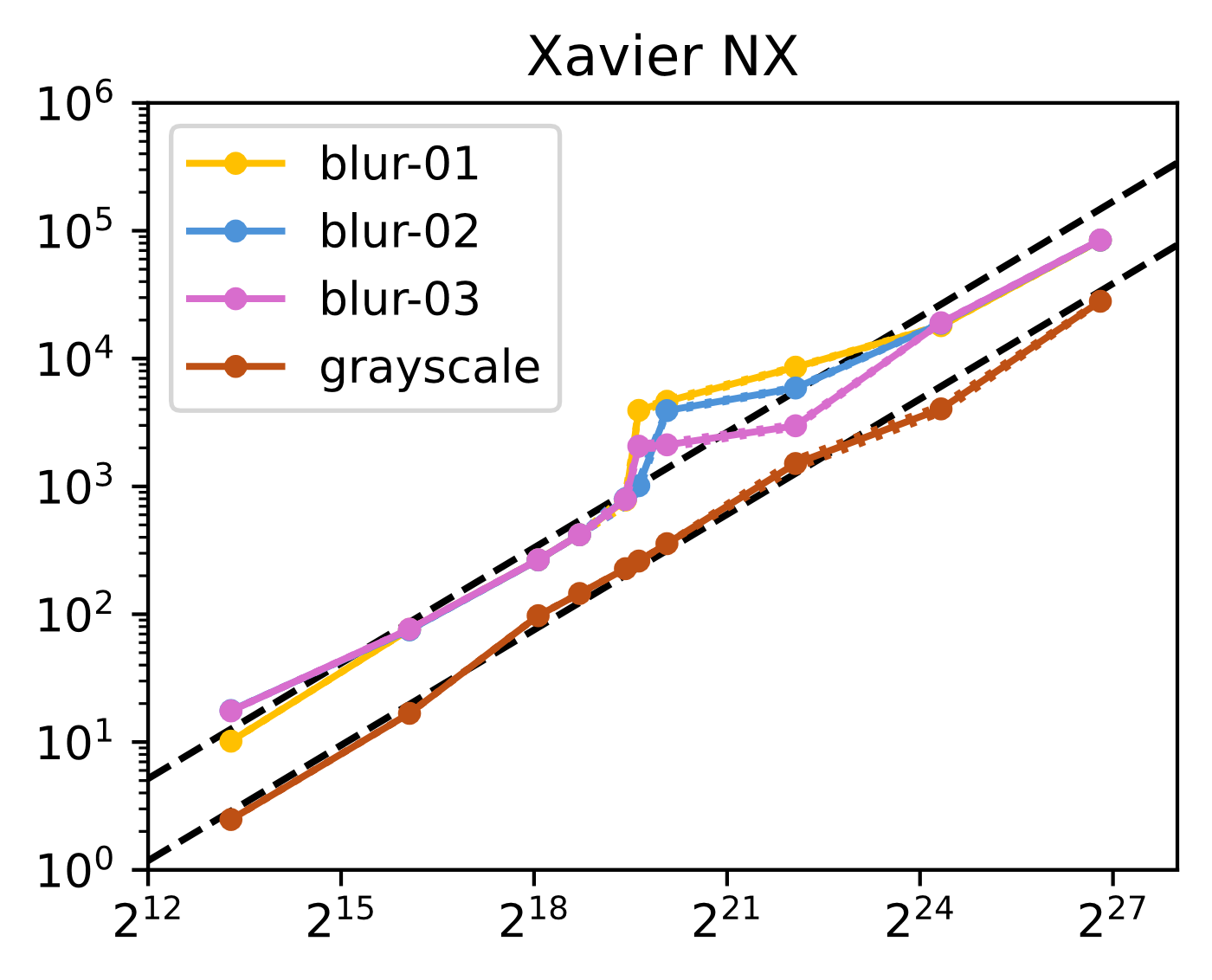
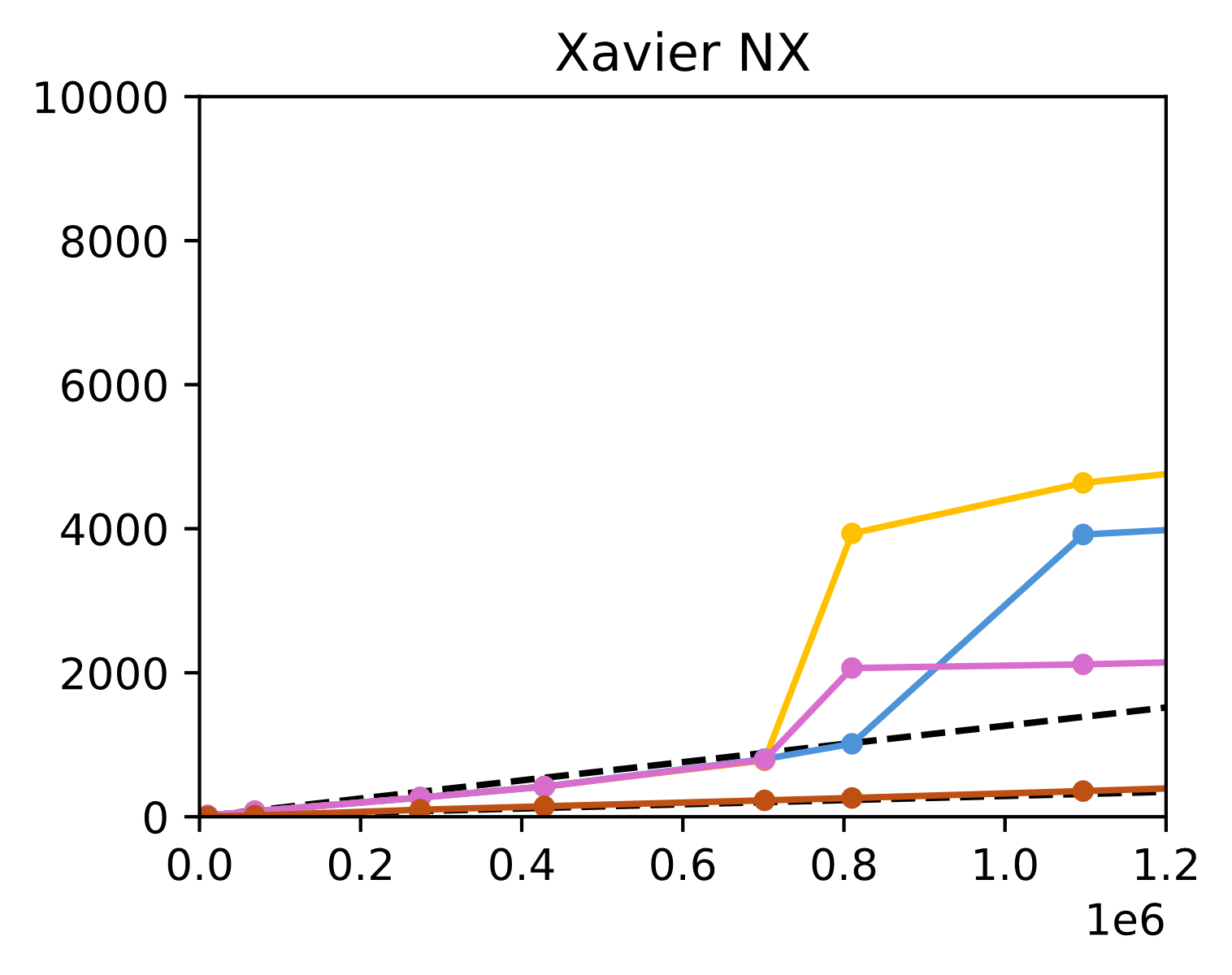


Abbildung 2. Arithmetische Mittel der Zeiten für den Transfer der Daten vom Device zum Host, in Abhängigkeit von der Bildgröße. Die horizontale Achse stellt wieder die Anzahl Pixel dar, die vertikalen Achse die mittlere Transferzeit in Mikrosekunden (µs). Das linke Diagramm zeigt die Werte für die Bilder mit bis zu 1.2 Millionen Pixeln, mit linear skalierten Achsen. Das rechte Diagramm zeigt alle Werte, mit logarithmisch skalierten Achsen. Die gepunkteten Kurven im rechten Diagramm zeigen das 90%-Konfidenzband. Aufgrund der unterschiedlichen Datenmengen wurden nun für die Umwandlung in Graustufen und den Weichzeichnungsfilter zwei unterschiedliche Geraden mit Achsenabschnitt 0 gefittet.

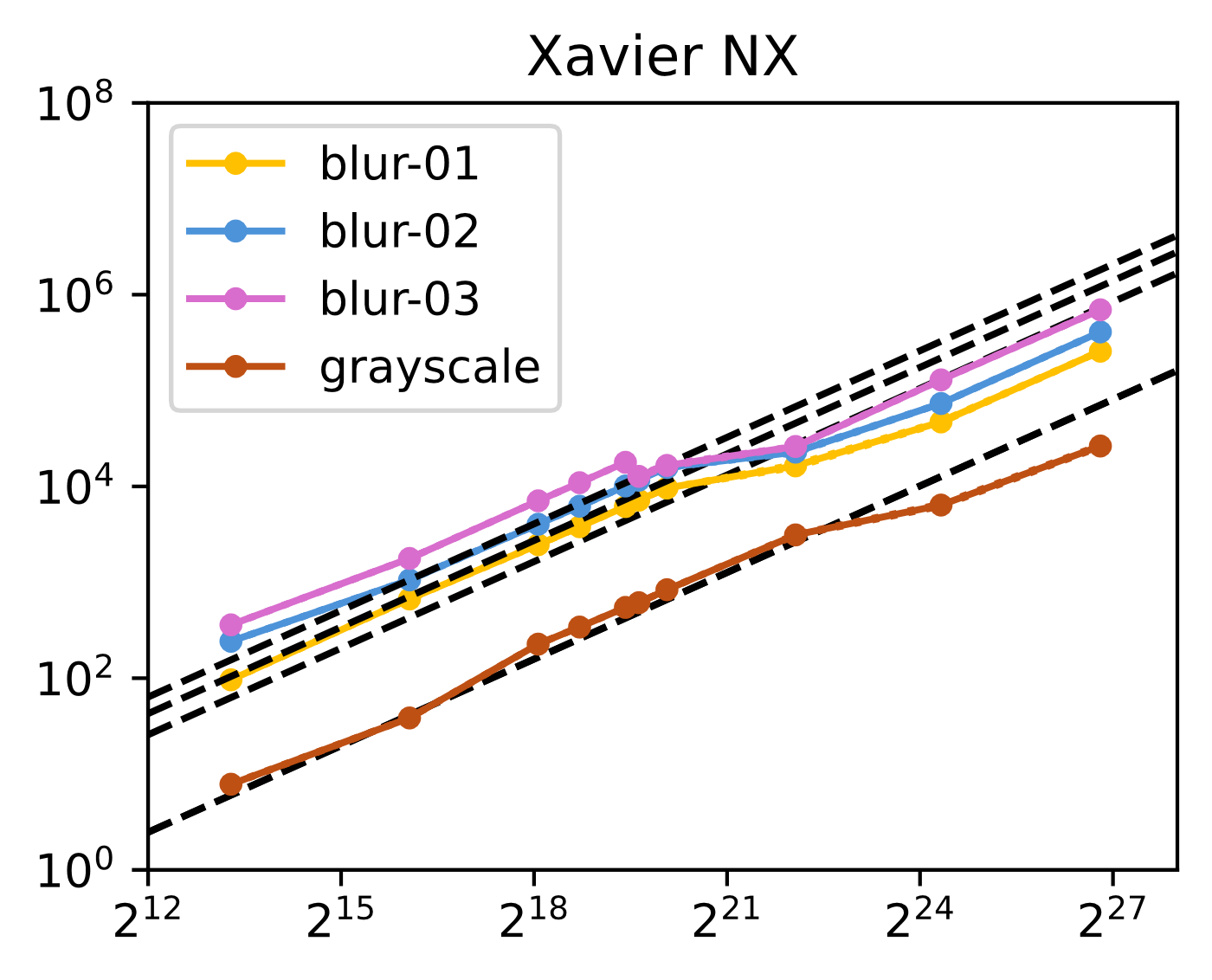
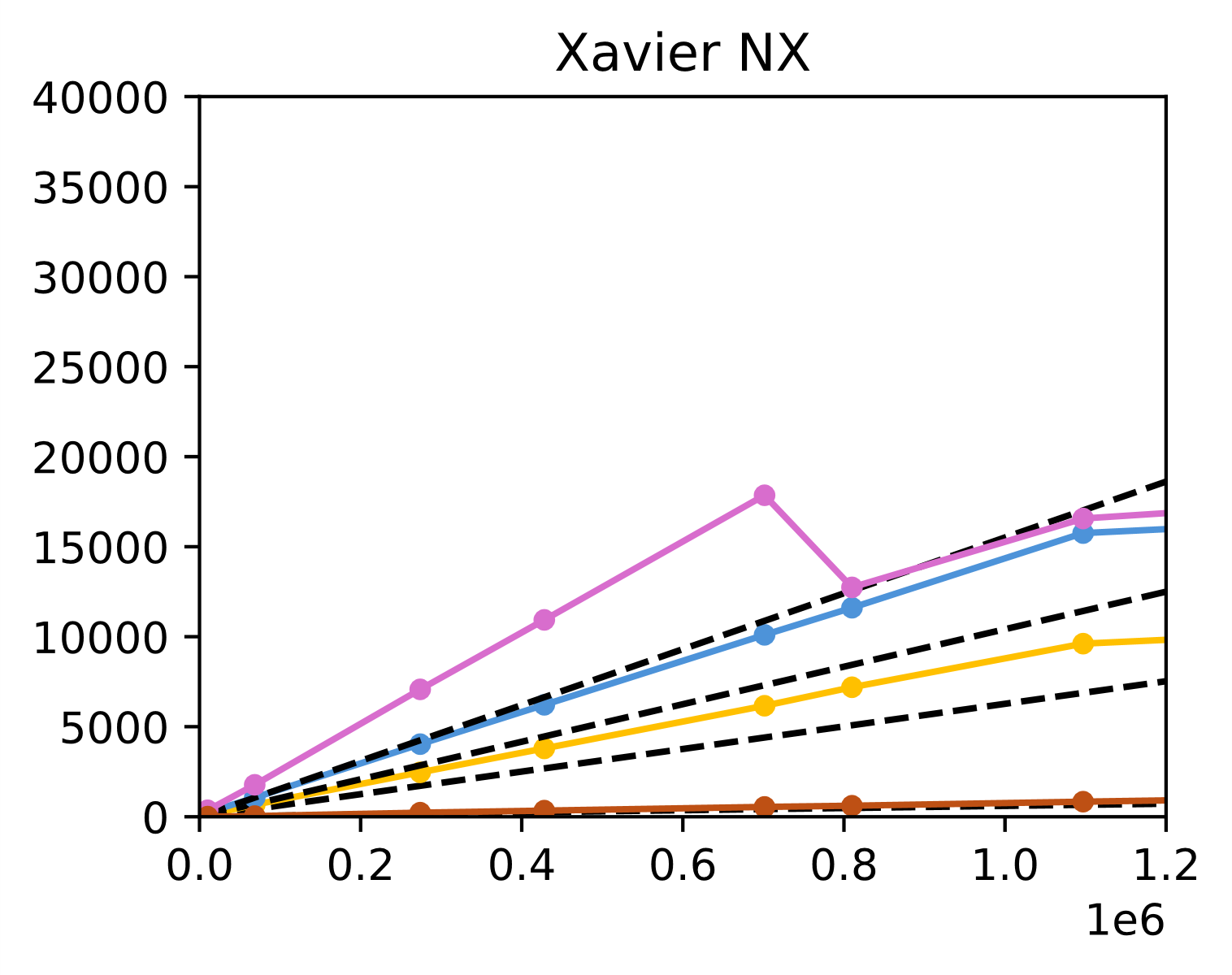


Abbildung 3. Arithmetische Mittel der Ausführungszeiten, in Abhängigkeit von der Bildgröße. Die horizontale Achse stellt die Anzahl Pixel dar, die vertikalen Achse die mittlere Ausführungszeit in Mikrosekunden (µs). Das linke Diagramm zeigt die Werte für die Bilder mit bis zu 1.2 Millionen Pixeln, mit linear skalierten Achsen. Das rechte Diagramm zeigt alle Werte, mit logarithmisch skalierten Achsen. Die gepunkteten Kurven im rechten Diagramm (kaum sichtbar) zeigen das 90%-Konfidenzband. Wegen des unterschiedlichen Aufwands wurde für jede Variante eine separate Gerade mit Achsenabschnitt 0 gefittet.

Anhang A. Ausgabe von deviceQuery für die verwendete Hardware.

###### Xavier NX

[…]

Device 0: "Xavier"

CUDA Driver Version / Runtime Version 10.2 / 10.2

CUDA Capability Major/Minor version number: 7.2

Total amount of global memory: 15827 MBytes (16596041728 bytes)

( 6) Multiprocessors, ( 64) CUDA Cores/MP: 384 CUDA Cores

GPU Max Clock rate: 1109 MHz (1.11 GHz)

Memory Clock rate: 1109 Mhz

Memory Bus Width: 256-bit

L2 Cache Size: 524288 bytes

Maximum Texture Dimension Size (x,y,z) 1D=(131072), 2D=(131072, 65536), 3D=(16384, 16384, 16384)

Maximum Layered 1D Texture Size, (num) layers 1D=(32768), 2048 layers

Maximum Layered 2D Texture Size, (num) layers 2D=(32768, 32768), 2048 layers

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

Max dimension size of a thread block (x,y,z): (1024, 1024, 64)

Max dimension size of a grid size (x,y,z): (2147483647, 65535, 65535)

Maximum memory pitch: 2147483647 bytes

Texture alignment: 512 bytes

Concurrent copy and kernel execution: Yes with 1 copy engine(s)

Run time limit on kernels: No

Integrated GPU sharing Host Memory: Yes

Support host page-locked memory mapping: Yes

Alignment requirement for Surfaces: Yes

Device has ECC support: Disabled

Device supports Unified Addressing (UVA): Yes

Device supports Compute Preemption: Yes

Supports Cooperative Kernel Launch: Yes

Supports MultiDevice Co-op Kernel Launch: Yes

Device PCI Domain ID / Bus ID / location ID: 0 / 0 / 0

Compute Mode:

< Default (multiple host threads can use ::cudaSetDevice() with device simultaneously) >

deviceQuery, CUDA Driver = CUDART, CUDA Driver Version = 10.2, CUDA Runtime Version = 10.2, NumDevs = 1

Result = PASS

###### Tesla V100

[…]

Device 0: "Tesla V100-SXM2-32GB"

CUDA Driver Version / Runtime Version 12.4 / 12.3

CUDA Capability Major/Minor version number: 7.0

Total amount of global memory: 32494 MBytes (34072559616 bytes)

(80) Multiprocessors, ( 64) CUDA Cores/MP: 5120 CUDA Cores

GPU Max Clock rate: 1530 MHz (1.53 GHz)

Memory Clock rate: 877 Mhz

Memory Bus Width: 4096-bit

L2 Cache Size: 6291456 bytes

Maximum Texture Dimension Size (x,y,z) 1D=(131072), 2D=(131072, 65536), 3D=(16384, 16384, 16384)

Maximum Layered 1D Texture Size, (num) layers 1D=(32768), 2048 layers

Maximum Layered 2D Texture Size, (num) layers 2D=(32768, 32768), 2048 layers

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

Max dimension size of a thread block (x,y,z): (1024, 1024, 64)

Max dimension size of a grid size (x,y,z): (2147483647, 65535, 65535)

Maximum memory pitch: 2147483647 bytes

Texture alignment: 512 bytes

Concurrent copy and kernel execution: Yes with 4 copy engine(s)

Run time limit on kernels: No

Integrated GPU sharing Host Memory: No

Support host page-locked memory mapping: Yes

Alignment requirement for Surfaces: Yes

Device has ECC support: Enabled

Device supports Unified Addressing (UVA): Yes

Device supports Compute Preemption: Yes

Supports Cooperative Kernel Launch: Yes

Supports MultiDevice Co-op Kernel Launch: Yes

Device PCI Domain ID / Bus ID / location ID: 4 / 4 / 0

Compute Mode:

< Default (multiple host threads can use ::cudaSetDevice() with device simultaneously) >

[…]

deviceQuery, CUDA Driver = CUDART, CUDA Driver Version = 12.4, CUDA Runtime Version = 12.3, NumDevs = 4

Result = PASS

###### AMD Radeon RX 6800 XT

[…]

Device 0: "AMD Radeon RX 6800 XT"

HIP Driver Version / Runtime Version 50422.0 / 50422.0

HIP Capability Major/Minor version number: 10.3

Total amount of global memory: 16368 MBytes (17163091968 bytes)

MapSMtoCores for SM 10.3 is undefined. Default to use 64 Cores/SM

MapSMtoCores for SM 10.3 is undefined. Default to use 64 Cores/SM

(36) Multiprocessors, ( 64) HIP Cores/MP: 2304 HIP Cores

GPU Max Clock rate: 2575 MHz (2.58 GHz)

Memory Clock rate: 1000 Mhz

Memory Bus Width: 256-bit

L2 Cache Size: 4194304 bytes

Maximum Texture Dimension Size (x,y,z) 1D=(16384), 2D=(16384, 16384), 3D=(16384, 16384, 8192)

Total amount of constant memory: 2147483647 bytes

Total amount of shared memory per block: 65536 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

Max dimension size of a thread block (x,y,z): (1024, 1024, 1024)

Max dimension size of a grid size (x,y,z): (2147483647, 2147483647, 2147483647)

Maximum memory pitch: 2147483647 bytes

Texture alignment: 256 bytes

Run time limit on kernels: No

Integrated GPU sharing Host Memory: No

Support host page-locked memory mapping: Yes

Device has ECC support: Disabled

Supports Cooperative Kernel Launch: No

Supports MultiDevice Co-op Kernel Launch: No

Device PCI Domain ID / Bus ID / location ID: 0 / 3 / 0

Compute Mode:

< Default (multiple host threads can use ::hipSetDevice() with device simultaneously) >

[…]

deviceQuery, HIP Driver = HIPRT, HIP Driver Version = 50422.0, HIP Runtime Version = 50422.0, NumDevs = 2

Result = PASS

Anhang C. Gemessene Zeiten für die Eingabedaten aus der Beispieldatei

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **128 Bins** | | | | | | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Transferzeit Device zu Host (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **Device** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| Xavier NX | global | 1.860 | 1.904 | 2.016 | 2.016 | 2.483 | 9.493 | 9.516 | 9.561 | 9.561 | 9.814 | 0.068 | 0.085 | 0.092 | 0.092 | 0.322 | 11.452 | 11.558 | 11.674 | 11.674 | 12.389 |
| global\_stride | 1.849 | 1.895 | 2.044 | 2.044 | 2.383 | 9.555 | 9.586 | 9.606 | 9.606 | 9.745 | 0.081 | 0.084 | 0.096 | 0.096 | 0.283 | 11.562 | 11.604 | 11.756 | 11.756 | 12.148 |
| private | 1.644 | 1.867 | 1.934 | 1.934 | 2.245 | 2.012 | 2.037 | 2.069 | 2.069 | 2.240 | 0.075 | 0.085 | 0.091 | 0.091 | 0.227 | 3.794 | 4.010 | 4.129 | 4.129 | 4.400 |
| private\_stride | 1.417 | 1.737 | 1.916 | 1.916 | 2.309 | 1.023 | 1.038 | 1.058 | 1.058 | 1.217 | 0.061 | 0.085 | 0.090 | 0.090 | 0.220 | 2.536 | 2.889 | 3.075 | 3.075 | 3.434 |
| Tesla V100 | global | 6.615 | 6.615 | 6.616 | 6.616 | 6.666 | 3.232 | 3.233 | 3.234 | 3.234 | 3.242 | 0.019 | 0.019 | 0.019 | 0.019 | 0.024 | 9.867 | 9.868 | 9.870 | 9.870 | 9.922 |
| global\_stride | 6.615 | 6.616 | 6.617 | 6.617 | 6.641 | 3.232 | 3.234 | 3.234 | 3.234 | 3.239 | 0.018 | 0.019 | 0.020 | 0.020 | 0.029 | 9.868 | 9.869 | 9.871 | 9.871 | 9.894 |
| private | 6.615 | 6.615 | 6.616 | 6.616 | 6.640 | 0.306 | 0.307 | 0.308 | 0.308 | 0.310 | 0.019 | 0.019 | 0.019 | 0.019 | 0.040 | 6.940 | 6.942 | 6.944 | 6.944 | 6.968 |
| private\_stride | 6.615 | 6.616 | 6.616 | 6.616 | 6.620 | 0.065 | 0.066 | 0.068 | 0.068 | 0.075 | 0.018 | 0.019 | 0.019 | 0.019 | 0.021 | 6.701 | 6.702 | 6.703 | 6.703 | 6.710 |
| Radeon RX 6800 XT | global | 1.170 | 1.184 | 1.194 | 1.194 | 11.573 | 1.032 | 1.033 | 1.034 | 1.034 | 1.039 | 0.019 | 0.021 | 0.023 | 0.023 | 0.351 | 2.226 | 2.242 | 2.251 | 2.251 | 12.957 |
| global\_stride | 1.162 | 1.178 | 1.190 | 1.190 | 2.217 | 1.035 | 1.037 | 1.040 | 1.040 | 1.045 | 0.018 | 0.020 | 0.023 | 0.023 | 0.029 | 2.225 | 2.239 | 2.252 | 2.252 | 3.273 |
| private | 1.171 | 1.175 | 1.179 | 1.179 | 2.088 | 0.112 | 0.114 | 0.115 | 0.115 | 0.118 | 0.018 | 0.020 | 0.023 | 0.023 | 0.030 | 1.307 | 1.312 | 1.317 | 1.317 | 2.219 |
| private\_stride | 1.166 | 1.174 | 1.181 | 1.181 | 2.060 | 0.065 | 0.066 | 0.067 | 0.067 | 0.070 | 0.018 | 0.020 | 0.023 | 0.023 | 0.029 | 1.255 | 1.262 | 1.271 | 1.271 | 2.143 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **27 Bins** | | | | | | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Transferzeit Device zu Host (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **Device** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| Xavier NX | global | 1.850 | 1.937 | 2.045 | 2.045 | 2.240 | 11.243 | 11.266 | 11.289 | 11.289 | 11.403 | 0.076 | 0.078 | 0.093 | 0.093 | 0.242 | 13.200 | 13.323 | 13.440 | 13.440 | 13.684 |
| global\_stride | 1.851 | 1.897 | 2.006 | 2.006 | 2.216 | 11.324 | 11.338 | 11.362 | 11.362 | 11.485 | 0.062 | 0.079 | 0.111 | 0.111 | 0.207 | 13.283 | 13.361 | 13.477 | 13.477 | 13.701 |
| private | 1.516 | 1.623 | 1.840 | 1.840 | 2.128 | 2.059 | 2.076 | 2.110 | 2.110 | 2.268 | 0.058 | 0.065 | 0.078 | 0.078 | 0.190 | 3.650 | 3.795 | 4.010 | 4.010 | 4.326 |
| private\_stride | 1.366 | 1.390 | 1.478 | 1.478 | 2.230 | 1.055 | 1.071 | 1.091 | 1.091 | 1.247 | 0.053 | 0.054 | 0.057 | 0.057 | 0.190 | 2.489 | 2.538 | 2.640 | 2.640 | 3.421 |
| Tesla V100 | global | 6.611 | 6.617 | 6.619 | 6.619 | 6.667 | 3.854 | 3.855 | 3.856 | 3.856 | 3.863 | 0.018 | 0.019 | 0.020 | 0.020 | 0.026 | 10.486 | 10.493 | 10.494 | 10.494 | 10.548 |
| global\_stride | 6.616 | 6.617 | 6.619 | 6.619 | 6.648 | 3.855 | 3.857 | 3.858 | 3.858 | 3.866 | 0.018 | 0.019 | 0.020 | 0.020 | 0.028 | 10.493 | 10.494 | 10.497 | 10.497 | 10.525 |
| private | 6.617 | 6.617 | 6.619 | 6.619 | 6.648 | 0.165 | 0.166 | 0.166 | 0.166 | 0.188 | 0.018 | 0.019 | 0.020 | 0.020 | 0.028 | 6.801 | 6.803 | 6.805 | 6.805 | 6.857 |
| private\_stride | 6.616 | 6.617 | 6.619 | 6.619 | 6.632 | 0.066 | 0.067 | 0.068 | 0.068 | 0.078 | 0.018 | 0.019 | 0.020 | 0.020 | 0.024 | 6.703 | 6.705 | 6.706 | 6.706 | 6.722 |
| Radeon RX 6800 XT | global | 1.237 | 1.240 | 1.245 | 1.245 | 2.544 | 1.270 | 1.271 | 1.272 | 1.272 | 1.502 | 0.019 | 0.021 | 0.024 | 0.024 | 0.403 | 2.531 | 2.535 | 2.541 | 2.541 | 4.432 |
| global\_stride | 1.227 | 1.239 | 1.244 | 1.244 | 2.128 | 1.273 | 1.274 | 1.275 | 1.275 | 1.312 | 0.019 | 0.022 | 0.024 | 0.024 | 0.029 | 2.525 | 2.539 | 2.544 | 2.544 | 3.426 |
| private | 1.216 | 1.224 | 1.230 | 1.230 | 2.132 | 0.115 | 0.117 | 0.118 | 0.118 | 0.121 | 0.020 | 0.021 | 0.023 | 0.023 | 0.031 | 1.355 | 1.366 | 1.372 | 1.372 | 2.268 |
| private\_stride | 1.219 | 1.225 | 1.231 | 1.231 | 2.140 | 0.069 | 0.071 | 0.072 | 0.072 | 0.074 | 0.019 | 0.021 | 0.023 | 0.023 | 0.029 | 1.312 | 1.319 | 1.326 | 1.326 | 2.230 |

Anhang D. Gemessene Zeiten für die generierten Eingabedaten

Es ist . Dargestellt sind nur die Messergebnisse für n = 8, 16, 24, 32. Auf die Darstellung der Zeiten für den Transfer vom Device zum Host wurde verzichtet.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  |  | **Xavier NX, pseudozufällige Daten, 128 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.018 | 0.018 | 0.019 | 0.019 | 0.087 | 0.038 | 0.049 | 0.054 | 0.054 | 0.111 | 0.107 | 0.112 | 0.128 | 0.128 | 0.238 |
|  | atomic\_global\_stride | 0.018 | 0.018 | 0.019 | 0.019 | 0.060 | 0.059 | 0.071 | 0.085 | 0.085 | 0.123 | 0.118 | 0.138 | 0.152 | 0.152 | 0.255 |
|  | atomic\_private | 0.018 | 0.018 | 0.019 | 0.019 | 0.056 | 0.048 | 0.051 | 0.054 | 0.054 | 0.182 | 0.105 | 0.112 | 0.132 | 0.132 | 0.267 |
|  | atomic\_private\_stride | 0.018 | 0.018 | 0.019 | 0.019 | 0.111 | 0.075 | 0.088 | 0.103 | 0.103 | 0.174 | 0.133 | 0.156 | 0.174 | 0.174 | 0.357 |
| 16 | atomic\_global | 0.037 | 0.038 | 0.039 | 0.039 | 0.306 | 0.116 | 0.118 | 0.128 | 0.128 | 0.206 | 0.194 | 0.196 | 0.219 | 0.219 | 0.570 |
|  | atomic\_global\_stride | 0.037 | 0.038 | 0.039 | 0.039 | 0.085 | 0.122 | 0.126 | 0.130 | 0.130 | 0.209 | 0.203 | 0.206 | 0.220 | 0.220 | 0.338 |
|  | atomic\_private | 0.037 | 0.038 | 0.040 | 0.040 | 0.079 | 0.051 | 0.051 | 0.056 | 0.056 | 0.140 | 0.128 | 0.129 | 0.152 | 0.152 | 0.253 |
|  | atomic\_private\_stride | 0.037 | 0.038 | 0.039 | 0.039 | 0.080 | 0.077 | 0.104 | 0.107 | 0.107 | 0.199 | 0.155 | 0.184 | 0.204 | 0.204 | 0.333 |
| 24 | atomic\_global | 2.969 | 3.012 | 3.108 | 3.108 | 3.458 | 12.260 | 12.268 | 12.284 | 12.284 | 12.428 | 15.321 | 15.395 | 15.485 | 15.485 | 15.822 |
|  | atomic\_global\_stride | 2.844 | 2.881 | 2.985 | 2.985 | 3.284 | 12.372 | 12.386 | 12.403 | 12.403 | 12.688 | 15.329 | 15.386 | 15.468 | 15.468 | 15.745 |
|  | atomic\_private | 2.765 | 2.849 | 2.938 | 2.938 | 3.219 | 3.207 | 3.216 | 3.231 | 3.231 | 3.297 | 6.092 | 6.161 | 6.254 | 6.254 | 6.520 |
|  | atomic\_private\_stride | 2.287 | 2.453 | 2.797 | 2.797 | 3.062 | 1.889 | 1.894 | 1.909 | 1.909 | 2.018 | 4.279 | 4.474 | 4.769 | 4.769 | 5.045 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 600.253 | 601.015 | 602.647 | 602.647 | 609.545 | 3134.966 | 3139.629 | 3146.011 | 3146.011 | 3172.035 | 3738.008 | 3741.836 | 3749.600 | 3749.600 | 3774.030 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 568.542 | 568.940 | 570.526 | 570.526 | 617.709 | 579.631 | 579.976 | 580.133 | 580.133 | 580.493 | 1148.526 | 1149.107 | 1150.832 | 1150.832 | 1198.083 |

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|  |  | **Xavier NX, konstante Daten, 128 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.017 | 0.019 | 0.020 | 0.020 | 0.089 | 0.039 | 0.050 | 0.057 | 0.057 | 0.119 | 0.108 | 0.112 | 0.131 | 0.131 | 0.287 |
|  | atomic\_global\_stride | 0.017 | 0.018 | 0.019 | 0.019 | 0.061 | 0.059 | 0.071 | 0.085 | 0.085 | 0.123 | 0.116 | 0.133 | 0.151 | 0.151 | 0.231 |
|  | atomic\_private | 0.017 | 0.018 | 0.019 | 0.019 | 0.073 | 0.048 | 0.052 | 0.055 | 0.055 | 0.086 | 0.105 | 0.110 | 0.126 | 0.126 | 0.216 |
|  | atomic\_private\_stride | 0.017 | 0.017 | 0.018 | 0.018 | 0.067 | 0.074 | 0.088 | 0.103 | 0.103 | 0.148 | 0.132 | 0.156 | 0.165 | 0.165 | 0.288 |
| 16 | atomic\_global | 0.038 | 0.039 | 0.045 | 0.045 | 0.365 | 0.199 | 0.204 | 0.222 | 0.222 | 0.336 | 0.278 | 0.291 | 0.318 | 0.318 | 0.739 |
|  | atomic\_global\_stride | 0.038 | 0.040 | 0.048 | 0.048 | 0.107 | 0.206 | 0.211 | 0.225 | 0.225 | 0.290 | 0.287 | 0.297 | 0.334 | 0.334 | 0.445 |
|  | atomic\_private | 0.037 | 0.038 | 0.039 | 0.039 | 0.080 | 0.073 | 0.098 | 0.102 | 0.102 | 0.180 | 0.152 | 0.179 | 0.203 | 0.203 | 0.306 |
|  | atomic\_private\_stride | 0.038 | 0.038 | 0.040 | 0.040 | 0.082 | 0.117 | 0.122 | 0.127 | 0.127 | 0.190 | 0.199 | 0.202 | 0.219 | 0.219 | 0.317 |
| 24 | atomic\_global | 2.830 | 2.875 | 2.984 | 2.984 | 3.557 | 33.876 | 33.883 | 33.895 | 33.895 | 33.981 | 36.813 | 36.847 | 36.968 | 36.968 | 37.635 |
|  | atomic\_global\_stride | 2.857 | 2.936 | 3.031 | 3.031 | 3.320 | 33.638 | 33.648 | 33.667 | 33.667 | 33.757 | 36.590 | 36.679 | 36.782 | 36.782 | 37.075 |
|  | atomic\_private | 2.809 | 2.858 | 2.959 | 2.959 | 3.314 | 7.873 | 7.882 | 7.906 | 7.906 | 8.294 | 10.779 | 10.854 | 10.959 | 10.959 | 11.546 |
|  | atomic\_private\_stride | 2.816 | 2.890 | 2.970 | 2.970 | 3.407 | 6.123 | 6.132 | 6.150 | 6.150 | 6.241 | 9.028 | 9.101 | 9.199 | 9.199 | 9.658 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 579.709 | 595.695 | 600.437 | 600.437 | 608.195 | 8582.007 | 8582.134 | 8582.925 | 8582.925 | 8594.232 | 9162.101 | 9181.184 | 9183.991 | 9183.991 | 9201.661 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 584.012 | 597.749 | 599.504 | 599.504 | 611.621 | 1537.560 | 1558.552 | 1592.471 | 1592.471 | 1670.969 | 2136.375 | 2158.716 | 2191.524 | 2191.524 | 2269.287 |
|  |  | **Tesla V100, pseudozufällige Daten, 128 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.011 | 0.012 | 0.012 | 0.012 | 0.025 | 0.015 | 0.015 | 0.016 | 0.016 | 0.019 | 0.043 | 0.044 | 0.045 | 0.045 | 0.067 |
|  | atomic\_global\_stride | 0.011 | 0.012 | 0.012 | 0.012 | 0.015 | 0.016 | 0.016 | 0.017 | 0.017 | 0.022 | 0.044 | 0.045 | 0.046 | 0.046 | 0.051 |
|  | atomic\_private | 0.011 | 0.012 | 0.012 | 0.012 | 0.014 | 0.015 | 0.015 | 0.016 | 0.016 | 0.019 | 0.043 | 0.044 | 0.045 | 0.045 | 0.049 |
|  | atomic\_private\_stride | 0.011 | 0.012 | 0.012 | 0.012 | 0.015 | 0.022 | 0.023 | 0.023 | 0.023 | 0.025 | 0.050 | 0.051 | 0.052 | 0.052 | 0.055 |
| 16 | atomic\_global | 0.054 | 0.054 | 0.055 | 0.055 | 0.068 | 0.032 | 0.032 | 0.033 | 0.033 | 0.038 | 0.102 | 0.103 | 0.105 | 0.105 | 0.128 |
|  | atomic\_global\_stride | 0.053 | 0.054 | 0.054 | 0.054 | 0.060 | 0.032 | 0.032 | 0.032 | 0.032 | 0.034 | 0.102 | 0.102 | 0.104 | 0.104 | 0.114 |
|  | atomic\_private | 0.054 | 0.054 | 0.054 | 0.054 | 0.056 | 0.017 | 0.017 | 0.017 | 0.017 | 0.022 | 0.087 | 0.088 | 0.089 | 0.089 | 0.093 |
|  | atomic\_private\_stride | 0.053 | 0.054 | 0.054 | 0.054 | 0.056 | 0.023 | 0.023 | 0.024 | 0.024 | 0.025 | 0.092 | 0.093 | 0.095 | 0.095 | 0.098 |
| 24 | atomic\_global | 10.502 | 10.503 | 10.504 | 10.504 | 10.548 | 4.167 | 4.168 | 4.168 | 4.168 | 4.179 | 14.689 | 14.690 | 14.692 | 14.692 | 14.742 |
|  | atomic\_global\_stride | 10.503 | 10.503 | 10.505 | 10.505 | 10.532 | 4.169 | 4.169 | 4.171 | 4.171 | 4.205 | 14.691 | 14.691 | 14.695 | 14.695 | 14.756 |
|  | atomic\_private | 10.502 | 10.503 | 10.504 | 10.504 | 10.524 | 0.480 | 0.480 | 0.481 | 0.481 | 0.488 | 11.001 | 11.002 | 11.004 | 11.004 | 11.025 |
|  | atomic\_private\_stride | 10.503 | 10.503 | 10.504 | 10.504 | 10.516 | 0.089 | 0.090 | 0.092 | 0.092 | 0.107 | 10.611 | 10.613 | 10.615 | 10.615 | 10.642 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 2673.875 | 2673.885 | 2673.893 | 2673.893 | 2675.952 | 1061.546 | 1061.553 | 1061.564 | 1061.564 | 1070.549 | 3735.467 | 3735.475 | 3735.492 | 3735.492 | 3744.480 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 2673.872 | 2673.881 | 2673.892 | 2673.892 | 2676.035 | 18.487 | 18.518 | 18.553 | 18.553 | 18.607 | 2692.397 | 2692.444 | 2692.478 | 2692.478 | 2694.614 |

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|  |  | **Tesla V100, konstante Daten, 128 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.012 | 0.012 | 0.012 | 0.012 | 0.024 | 0.015 | 0.015 | 0.016 | 0.016 | 0.018 | 0.043 | 0.044 | 0.045 | 0.045 | 0.066 |
|  | atomic\_global\_stride | 0.012 | 0.012 | 0.012 | 0.012 | 0.017 | 0.016 | 0.016 | 0.017 | 0.017 | 0.019 | 0.044 | 0.045 | 0.046 | 0.046 | 0.054 |
|  | atomic\_private | 0.012 | 0.012 | 0.012 | 0.012 | 0.015 | 0.015 | 0.015 | 0.016 | 0.016 | 0.019 | 0.043 | 0.044 | 0.045 | 0.045 | 0.052 |
|  | atomic\_private\_stride | 0.012 | 0.012 | 0.012 | 0.012 | 0.014 | 0.023 | 0.023 | 0.023 | 0.023 | 0.025 | 0.051 | 0.051 | 0.052 | 0.052 | 0.056 |
| 16 | atomic\_global | 0.054 | 0.054 | 0.055 | 0.055 | 0.069 | 0.060 | 0.060 | 0.061 | 0.061 | 0.063 | 0.131 | 0.131 | 0.134 | 0.134 | 0.158 |
|  | atomic\_global\_stride | 0.053 | 0.054 | 0.054 | 0.054 | 0.057 | 0.060 | 0.060 | 0.061 | 0.061 | 0.062 | 0.130 | 0.131 | 0.133 | 0.133 | 0.139 |
|  | atomic\_private | 0.053 | 0.054 | 0.054 | 0.054 | 0.055 | 0.017 | 0.017 | 0.018 | 0.018 | 0.018 | 0.087 | 0.088 | 0.089 | 0.089 | 0.091 |
|  | atomic\_private\_stride | 0.053 | 0.054 | 0.054 | 0.054 | 0.056 | 0.023 | 0.023 | 0.024 | 0.024 | 0.025 | 0.092 | 0.094 | 0.095 | 0.095 | 0.097 |
| 24 | atomic\_global | 10.505 | 10.506 | 10.507 | 10.507 | 10.555 | 11.626 | 11.627 | 11.628 | 11.628 | 11.653 | 22.151 | 22.152 | 22.155 | 22.155 | 22.217 |
|  | atomic\_global\_stride | 10.505 | 10.506 | 10.507 | 10.507 | 10.531 | 11.626 | 11.626 | 11.627 | 11.627 | 11.633 | 22.150 | 22.152 | 22.153 | 22.153 | 22.182 |
|  | atomic\_private | 10.505 | 10.506 | 10.506 | 10.506 | 10.521 | 0.480 | 0.481 | 0.482 | 0.482 | 0.487 | 11.005 | 11.006 | 11.007 | 11.007 | 11.022 |
|  | atomic\_private\_stride | 10.505 | 10.506 | 10.506 | 10.506 | 10.517 | 0.174 | 0.175 | 0.185 | 0.185 | 0.190 | 10.698 | 10.700 | 10.710 | 10.710 | 10.722 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 2673.885 | 2673.894 | 2673.903 | 2673.903 | 2676.022 | 2970.182 | 2970.189 | 2970.206 | 2970.206 | 2979.272 | 5644.111 | 5644.129 | 5644.149 | 5644.149 | 5653.215 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 2673.888 | 2673.893 | 2673.903 | 2673.903 | 2676.014 | 45.312 | 45.357 | 45.373 | 45.373 | 45.428 | 2719.243 | 2719.287 | 2719.311 | 2719.311 | 2721.460 |

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|  |  | **Radeon RX 6800 XT, pseudozufällige Daten, 128 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.021 | 0.023 | 0.025 | 0.025 | 0.048 | 0.024 | 0.025 | 0.027 | 0.027 | 0.061 | 0.063 | 0.071 | 0.074 | 0.074 | 0.499 |
|  | atomic\_global\_stride | 0.021 | 0.023 | 0.025 | 0.025 | 0.032 | 0.025 | 0.026 | 0.028 | 0.028 | 0.132 | 0.065 | 0.071 | 0.075 | 0.075 | 0.181 |
|  | atomic\_private | 0.018 | 0.023 | 0.025 | 0.025 | 0.030 | 0.022 | 0.025 | 0.027 | 0.027 | 0.030 | 0.056 | 0.069 | 0.074 | 0.074 | 0.136 |
|  | atomic\_private\_stride | 0.019 | 0.023 | 0.025 | 0.025 | 0.031 | 0.024 | 0.027 | 0.029 | 0.029 | 0.030 | 0.059 | 0.073 | 0.076 | 0.076 | 0.087 |
| 16 | atomic\_global | 0.022 | 0.023 | 0.024 | 0.024 | 0.438 | 0.029 | 0.029 | 0.031 | 0.031 | 0.047 | 0.069 | 0.074 | 0.078 | 0.078 | 0.893 |
|  | atomic\_global\_stride | 0.022 | 0.023 | 0.024 | 0.024 | 0.235 | 0.028 | 0.029 | 0.031 | 0.031 | 0.033 | 0.069 | 0.074 | 0.078 | 0.078 | 0.290 |
|  | atomic\_private | 0.020 | 0.023 | 0.024 | 0.024 | 0.030 | 0.023 | 0.026 | 0.028 | 0.028 | 0.091 | 0.064 | 0.071 | 0.075 | 0.075 | 0.141 |
|  | atomic\_private\_stride | 0.020 | 0.023 | 0.024 | 0.024 | 0.030 | 0.024 | 0.027 | 0.028 | 0.028 | 0.030 | 0.061 | 0.071 | 0.075 | 0.075 | 0.084 |
| 24 | atomic\_global | 1.610 | 1.742 | 3.095 | 3.095 | 3.295 | 1.201 | 1.201 | 1.203 | 1.203 | 1.403 | 2.833 | 2.966 | 4.320 | 4.320 | 4.726 |
|  | atomic\_global\_stride | 1.605 | 2.922 | 3.094 | 3.094 | 3.415 | 1.200 | 1.204 | 1.206 | 1.206 | 1.507 | 2.831 | 4.179 | 4.319 | 4.319 | 4.639 |
|  | atomic\_private | 1.588 | 1.593 | 1.607 | 1.607 | 2.658 | 0.154 | 0.157 | 0.159 | 0.159 | 0.165 | 1.767 | 1.772 | 1.786 | 1.786 | 2.835 |
|  | atomic\_private\_stride | 1.588 | 1.591 | 1.606 | 1.606 | 2.503 | 0.085 | 0.086 | 0.088 | 0.088 | 0.094 | 1.695 | 1.699 | 1.715 | 1.715 | 2.605 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 206.038 | 206.718 | 207.263 | 207.263 | 207.949 | 307.547 | 309.423 | 311.516 | 311.516 | 313.280 | 514.998 | 516.651 | 518.834 | 518.834 | 520.519 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 205.586 | 205.896 | 206.507 | 206.507 | 213.529 | 22.198 | 22.477 | 22.753 | 22.753 | 23.354 | 228.221 | 228.598 | 229.312 | 229.312 | 236.515 |

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|  |  | **Radeon RX 6800 XT, konstante Daten, 128 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.023 | 0.023 | 0.025 | 0.025 | 0.048 | 0.025 | 0.027 | 0.028 | 0.028 | 0.059 | 0.070 | 0.073 | 0.076 | 0.076 | 0.485 |
|  | atomic\_global\_stride | 0.022 | 0.023 | 0.026 | 0.026 | 0.039 | 0.026 | 0.026 | 0.028 | 0.028 | 0.100 | 0.068 | 0.073 | 0.077 | 0.077 | 0.148 |
|  | atomic\_private | 0.019 | 0.023 | 0.025 | 0.025 | 0.030 | 0.022 | 0.026 | 0.027 | 0.027 | 0.029 | 0.059 | 0.073 | 0.075 | 0.075 | 0.144 |
|  | atomic\_private\_stride | 0.018 | 0.024 | 0.025 | 0.025 | 0.030 | 0.024 | 0.027 | 0.029 | 0.029 | 0.030 | 0.059 | 0.074 | 0.077 | 0.077 | 0.092 |
| 16 | atomic\_global | 0.022 | 0.023 | 0.026 | 0.026 | 0.445 | 0.056 | 0.056 | 0.058 | 0.058 | 0.062 | 0.101 | 0.103 | 0.107 | 0.107 | 0.962 |
|  | atomic\_global\_stride | 0.022 | 0.023 | 0.024 | 0.024 | 0.144 | 0.051 | 0.056 | 0.058 | 0.058 | 0.062 | 0.096 | 0.103 | 0.106 | 0.106 | 0.227 |
|  | atomic\_private | 0.020 | 0.023 | 0.025 | 0.025 | 0.029 | 0.026 | 0.028 | 0.030 | 0.030 | 0.078 | 0.063 | 0.074 | 0.077 | 0.077 | 0.125 |
|  | atomic\_private\_stride | 0.020 | 0.023 | 0.025 | 0.025 | 0.031 | 0.025 | 0.028 | 0.030 | 0.030 | 0.063 | 0.063 | 0.074 | 0.077 | 0.077 | 0.111 |
| 24 | atomic\_global | 2.494 | 2.504 | 2.519 | 2.519 | 2.947 | 6.875 | 6.876 | 7.145 | 7.145 | 7.383 | 9.401 | 9.416 | 9.680 | 9.680 | 10.683 |
|  | atomic\_global\_stride | 2.491 | 2.502 | 2.516 | 2.516 | 2.619 | 6.913 | 6.924 | 7.187 | 7.187 | 7.213 | 9.440 | 9.459 | 9.720 | 9.720 | 9.836 |
|  | atomic\_private | 1.620 | 1.625 | 1.641 | 1.641 | 2.533 | 0.396 | 0.398 | 0.399 | 0.399 | 0.402 | 2.042 | 2.048 | 2.063 | 2.063 | 2.950 |
|  | atomic\_private\_stride | 1.621 | 1.629 | 1.660 | 1.660 | 2.633 | 0.261 | 0.263 | 0.264 | 0.264 | 0.272 | 1.904 | 1.916 | 1.947 | 1.947 | 2.916 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 226.236 | 226.475 | 226.892 | 226.892 | 228.848 | 1794.445 | 1796.035 | 1803.207 | 1803.207 | 1816.006 | 2021.211 | 2023.682 | 2030.177 | 2030.177 | 2043.649 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 226.386 | 226.733 | 227.304 | 227.304 | 229.530 | 78.592 | 80.093 | 80.811 | 80.811 | 82.160 | 306.108 | 307.260 | 308.217 | 308.217 | 310.558 |

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|  |  | **Xavier NX, pseudozufällige Daten, 27 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.018 | 0.018 | 0.022 | 0.022 | 0.064 | 0.042 | 0.049 | 0.054 | 0.054 | 0.128 | 0.107 | 0.111 | 0.131 | 0.131 | 0.268 |
|  | atomic\_global\_stride | 0.018 | 0.018 | 0.022 | 0.022 | 0.061 | 0.055 | 0.072 | 0.086 | 0.086 | 0.129 | 0.115 | 0.143 | 0.157 | 0.157 | 0.240 |
|  | atomic\_private | 0.018 | 0.018 | 0.020 | 0.020 | 0.063 | 0.037 | 0.049 | 0.054 | 0.054 | 0.114 | 0.107 | 0.112 | 0.131 | 0.131 | 0.244 |
|  | atomic\_private\_stride | 0.018 | 0.019 | 0.020 | 0.020 | 0.065 | 0.072 | 0.084 | 0.103 | 0.103 | 0.166 | 0.130 | 0.151 | 0.182 | 0.182 | 0.331 |
| 16 | atomic\_global | 0.035 | 0.037 | 0.039 | 0.039 | 0.435 | 0.175 | 0.180 | 0.186 | 0.186 | 0.260 | 0.251 | 0.256 | 0.277 | 0.277 | 0.697 |
|  | atomic\_global\_stride | 0.037 | 0.038 | 0.044 | 0.044 | 0.072 | 0.183 | 0.189 | 0.200 | 0.200 | 0.274 | 0.260 | 0.267 | 0.297 | 0.297 | 0.383 |
|  | atomic\_private | 0.037 | 0.037 | 0.038 | 0.038 | 0.078 | 0.058 | 0.072 | 0.086 | 0.086 | 0.150 | 0.135 | 0.151 | 0.164 | 0.164 | 0.258 |
|  | atomic\_private\_stride | 0.036 | 0.037 | 0.039 | 0.039 | 0.103 | 0.084 | 0.108 | 0.113 | 0.113 | 0.163 | 0.161 | 0.187 | 0.205 | 0.205 | 0.276 |
| 24 | atomic\_global | 2.975 | 3.020 | 3.110 | 3.110 | 3.383 | 27.121 | 27.126 | 27.135 | 27.135 | 27.195 | 30.184 | 30.230 | 30.329 | 30.329 | 30.635 |
|  | atomic\_global\_stride | 2.880 | 2.948 | 3.040 | 3.040 | 3.223 | 26.966 | 26.978 | 27.245 | 27.245 | 27.360 | 29.945 | 30.075 | 30.304 | 30.304 | 30.576 |
|  | atomic\_private | 2.872 | 2.968 | 3.062 | 3.062 | 3.396 | 5.510 | 5.528 | 5.544 | 5.544 | 5.931 | 8.477 | 8.584 | 8.703 | 8.703 | 9.158 |
|  | atomic\_private\_stride | 2.871 | 2.954 | 3.049 | 3.049 | 3.349 | 3.886 | 3.893 | 3.902 | 3.902 | 4.067 | 6.860 | 6.919 | 7.042 | 7.042 | 7.391 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 572.285 | 573.327 | 574.698 | 574.698 | 605.823 | 6874.745 | 6874.786 | 6875.043 | 6875.043 | 6882.925 | 7447.218 | 7448.568 | 7451.293 | 7451.293 | 7480.732 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 565.509 | 566.793 | 572.418 | 572.418 | 610.911 | 897.024 | 897.138 | 897.272 | 897.272 | 897.577 | 1462.915 | 1464.115 | 1469.853 | 1469.853 | 1508.225 |

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|  |  | **Xavier NX, konstante Daten, 27 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.018 | 0.018 | 0.020 | 0.020 | 0.084 | 0.039 | 0.053 | 0.056 | 0.056 | 0.127 | 0.105 | 0.112 | 0.132 | 0.132 | 0.305 |
|  | atomic\_global\_stride | 0.018 | 0.018 | 0.019 | 0.019 | 0.093 | 0.056 | 0.071 | 0.086 | 0.086 | 0.126 | 0.115 | 0.135 | 0.155 | 0.155 | 0.249 |
|  | atomic\_private | 0.017 | 0.018 | 0.022 | 0.022 | 0.075 | 0.044 | 0.050 | 0.055 | 0.055 | 0.121 | 0.108 | 0.112 | 0.135 | 0.135 | 0.242 |
|  | atomic\_private\_stride | 0.018 | 0.018 | 0.020 | 0.020 | 0.078 | 0.074 | 0.098 | 0.105 | 0.105 | 0.194 | 0.135 | 0.160 | 0.184 | 0.184 | 0.291 |
| 16 | atomic\_global | 0.038 | 0.039 | 0.047 | 0.047 | 0.323 | 0.201 | 0.207 | 0.219 | 0.219 | 0.288 | 0.280 | 0.289 | 0.326 | 0.326 | 0.667 |
|  | atomic\_global\_stride | 0.039 | 0.040 | 0.049 | 0.049 | 0.085 | 0.206 | 0.211 | 0.231 | 0.231 | 0.317 | 0.287 | 0.298 | 0.340 | 0.340 | 0.431 |
|  | atomic\_private | 0.037 | 0.038 | 0.039 | 0.039 | 0.097 | 0.073 | 0.094 | 0.101 | 0.101 | 0.192 | 0.150 | 0.173 | 0.188 | 0.188 | 0.302 |
|  | atomic\_private\_stride | 0.037 | 0.037 | 0.039 | 0.039 | 0.091 | 0.109 | 0.118 | 0.122 | 0.122 | 0.194 | 0.186 | 0.198 | 0.210 | 0.210 | 0.316 |
| 24 | atomic\_global | 2.891 | 2.990 | 3.117 | 3.117 | 3.504 | 33.631 | 33.666 | 33.912 | 33.912 | 34.016 | 36.684 | 36.881 | 37.107 | 37.107 | 37.568 |
|  | atomic\_global\_stride | 2.608 | 2.881 | 2.993 | 2.993 | 3.304 | 33.629 | 33.647 | 33.690 | 33.690 | 34.039 | 36.564 | 36.644 | 36.792 | 36.792 | 37.306 |
|  | atomic\_private | 2.817 | 2.860 | 2.967 | 2.967 | 3.246 | 7.905 | 7.917 | 7.931 | 7.931 | 8.236 | 10.820 | 10.882 | 10.978 | 10.978 | 11.320 |
|  | atomic\_private\_stride | 2.805 | 2.844 | 2.948 | 2.948 | 3.251 | 6.118 | 6.128 | 6.143 | 6.143 | 6.249 | 9.027 | 9.077 | 9.172 | 9.172 | 9.588 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 566.573 | 567.751 | 575.397 | 575.397 | 586.327 | 8581.193 | 8581.416 | 8582.334 | 8582.334 | 8594.198 | 9148.009 | 9150.052 | 9158.773 | 9158.773 | 9176.809 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 573.721 | 574.259 | 576.022 | 576.022 | 628.082 | 1458.498 | 1463.966 | 1464.023 | 1464.023 | 1489.438 | 2033.499 | 2038.479 | 2041.332 | 2041.332 | 2092.294 |

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|  |  | **Tesla V100, pseudozufällige Daten, 27 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.012 | 0.012 | 0.012 | 0.012 | 0.024 | 0.015 | 0.015 | 0.016 | 0.016 | 0.018 | 0.043 | 0.044 | 0.045 | 0.045 | 0.067 |
|  | atomic\_global\_stride | 0.012 | 0.012 | 0.012 | 0.012 | 0.015 | 0.016 | 0.016 | 0.017 | 0.017 | 0.018 | 0.044 | 0.045 | 0.046 | 0.046 | 0.051 |
|  | atomic\_private | 0.012 | 0.012 | 0.012 | 0.012 | 0.014 | 0.015 | 0.015 | 0.016 | 0.016 | 0.018 | 0.043 | 0.044 | 0.045 | 0.045 | 0.049 |
|  | atomic\_private\_stride | 0.012 | 0.012 | 0.012 | 0.012 | 0.013 | 0.018 | 0.018 | 0.019 | 0.019 | 0.022 | 0.046 | 0.047 | 0.048 | 0.048 | 0.052 |
| 16 | atomic\_global | 0.054 | 0.055 | 0.056 | 0.056 | 0.068 | 0.051 | 0.052 | 0.052 | 0.052 | 0.054 | 0.122 | 0.124 | 0.125 | 0.125 | 0.147 |
|  | atomic\_global\_stride | 0.053 | 0.054 | 0.054 | 0.054 | 0.060 | 0.051 | 0.052 | 0.052 | 0.052 | 0.056 | 0.122 | 0.123 | 0.124 | 0.124 | 0.129 |
|  | atomic\_private | 0.053 | 0.054 | 0.055 | 0.055 | 0.056 | 0.016 | 0.016 | 0.017 | 0.017 | 0.018 | 0.087 | 0.087 | 0.089 | 0.089 | 0.092 |
|  | atomic\_private\_stride | 0.053 | 0.054 | 0.055 | 0.055 | 0.061 | 0.018 | 0.019 | 0.019 | 0.019 | 0.020 | 0.089 | 0.090 | 0.091 | 0.091 | 0.097 |
| 24 | atomic\_global | 10.504 | 10.504 | 10.505 | 10.505 | 10.549 | 9.315 | 9.316 | 9.317 | 9.317 | 9.326 | 19.839 | 19.840 | 19.841 | 19.841 | 19.890 |
|  | atomic\_global\_stride | 10.504 | 10.505 | 10.505 | 10.505 | 10.528 | 9.315 | 9.316 | 9.317 | 9.317 | 9.324 | 19.839 | 19.840 | 19.842 | 19.842 | 19.863 |
|  | atomic\_private | 10.504 | 10.505 | 10.505 | 10.505 | 10.523 | 0.252 | 0.253 | 0.254 | 0.254 | 0.260 | 10.776 | 10.777 | 10.778 | 10.778 | 10.797 |
|  | atomic\_private\_stride | 10.504 | 10.504 | 10.505 | 10.505 | 10.510 | 0.120 | 0.123 | 0.125 | 0.125 | 0.130 | 10.645 | 10.647 | 10.650 | 10.650 | 10.657 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 2673.937 | 2673.944 | 2673.954 | 2673.954 | 2676.044 | 2379.249 | 2379.255 | 2379.263 | 2379.263 | 2388.235 | 5053.223 | 5053.238 | 5053.256 | 5053.256 | 5062.234 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 2673.934 | 2673.942 | 2673.950 | 2673.950 | 2676.086 | 27.624 | 27.652 | 27.667 | 27.667 | 27.707 | 2701.602 | 2701.629 | 2701.651 | 2701.651 | 2703.804 |

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|  |  | **Tesla V100, konstante Daten, 27 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.012 | 0.012 | 0.012 | 0.012 | 0.026 | 0.015 | 0.015 | 0.016 | 0.016 | 0.018 | 0.043 | 0.044 | 0.045 | 0.045 | 0.068 |
|  | atomic\_global\_stride | 0.011 | 0.012 | 0.012 | 0.012 | 0.015 | 0.016 | 0.016 | 0.017 | 0.017 | 0.018 | 0.045 | 0.045 | 0.046 | 0.046 | 0.050 |
|  | atomic\_private | 0.011 | 0.012 | 0.012 | 0.012 | 0.015 | 0.015 | 0.015 | 0.016 | 0.016 | 0.018 | 0.043 | 0.044 | 0.045 | 0.045 | 0.052 |
|  | atomic\_private\_stride | 0.011 | 0.012 | 0.012 | 0.012 | 0.014 | 0.018 | 0.018 | 0.019 | 0.019 | 0.022 | 0.046 | 0.047 | 0.048 | 0.048 | 0.052 |
| 16 | atomic\_global | 0.054 | 0.054 | 0.055 | 0.055 | 0.069 | 0.060 | 0.060 | 0.061 | 0.061 | 0.065 | 0.131 | 0.132 | 0.133 | 0.133 | 0.155 |
|  | atomic\_global\_stride | 0.053 | 0.054 | 0.054 | 0.054 | 0.057 | 0.060 | 0.060 | 0.061 | 0.061 | 0.063 | 0.130 | 0.131 | 0.132 | 0.132 | 0.137 |
|  | atomic\_private | 0.053 | 0.054 | 0.054 | 0.054 | 0.055 | 0.016 | 0.016 | 0.017 | 0.017 | 0.018 | 0.086 | 0.087 | 0.088 | 0.088 | 0.094 |
|  | atomic\_private\_stride | 0.053 | 0.054 | 0.054 | 0.054 | 0.057 | 0.019 | 0.019 | 0.019 | 0.019 | 0.023 | 0.089 | 0.090 | 0.091 | 0.091 | 0.096 |
| 24 | atomic\_global | 10.507 | 10.508 | 10.516 | 10.516 | 11.364 | 11.626 | 11.627 | 11.630 | 11.630 | 15.949 | 22.153 | 22.155 | 22.166 | 22.166 | 27.340 |
|  | atomic\_global\_stride | 10.507 | 10.507 | 10.508 | 10.508 | 10.573 | 11.625 | 11.626 | 11.627 | 11.627 | 11.662 | 22.152 | 22.153 | 22.155 | 22.155 | 22.267 |
|  | atomic\_private | 10.506 | 10.507 | 10.508 | 10.508 | 10.528 | 0.253 | 0.254 | 0.255 | 0.255 | 0.262 | 10.779 | 10.781 | 10.782 | 10.782 | 10.805 |
|  | atomic\_private\_stride | 10.506 | 10.507 | 10.508 | 10.508 | 10.522 | 0.173 | 0.175 | 0.185 | 0.185 | 0.198 | 10.700 | 10.702 | 10.712 | 10.712 | 10.736 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 2673.560 | 2673.571 | 2673.915 | 2673.915 | 2675.945 | 2970.186 | 2970.192 | 2970.207 | 2970.207 | 2979.209 | 5643.794 | 5643.807 | 5644.156 | 5644.156 | 5653.195 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 2673.897 | 2673.904 | 2673.914 | 2673.914 | 2676.051 | 45.362 | 45.377 | 45.389 | 45.389 | 45.436 | 2719.295 | 2719.319 | 2719.335 | 2719.335 | 2721.519 |

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|  |  | **Radeon RX 6800 XT, pseudozufällige Daten, 27 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.020 | 0.023 | 0.025 | 0.025 | 0.055 | 0.029 | 0.030 | 0.031 | 0.031 | 0.055 | 0.070 | 0.075 | 0.078 | 0.078 | 0.481 |
|  | atomic\_global\_stride | 0.020 | 0.022 | 0.025 | 0.025 | 0.029 | 0.029 | 0.030 | 0.032 | 0.032 | 0.119 | 0.069 | 0.074 | 0.078 | 0.078 | 0.161 |
|  | atomic\_private | 0.019 | 0.022 | 0.025 | 0.025 | 0.030 | 0.026 | 0.029 | 0.031 | 0.031 | 0.033 | 0.061 | 0.074 | 0.078 | 0.078 | 0.140 |
|  | atomic\_private\_stride | 0.018 | 0.022 | 0.025 | 0.025 | 0.028 | 0.027 | 0.031 | 0.033 | 0.033 | 0.035 | 0.064 | 0.074 | 0.078 | 0.078 | 0.087 |
| 16 | atomic\_global | 0.021 | 0.023 | 0.024 | 0.024 | 0.583 | 0.046 | 0.046 | 0.048 | 0.048 | 0.051 | 0.088 | 0.092 | 0.095 | 0.095 | 1.146 |
|  | atomic\_global\_stride | 0.022 | 0.023 | 0.023 | 0.023 | 0.129 | 0.045 | 0.046 | 0.048 | 0.048 | 0.049 | 0.087 | 0.090 | 0.094 | 0.094 | 0.200 |
|  | atomic\_private | 0.020 | 0.023 | 0.023 | 0.023 | 0.028 | 0.028 | 0.031 | 0.033 | 0.033 | 0.075 | 0.065 | 0.075 | 0.079 | 0.079 | 0.124 |
|  | atomic\_private\_stride | 0.018 | 0.022 | 0.023 | 0.023 | 0.029 | 0.027 | 0.031 | 0.033 | 0.033 | 0.035 | 0.061 | 0.076 | 0.079 | 0.079 | 0.087 |
| 24 | atomic\_global | 2.247 | 2.253 | 2.264 | 2.264 | 2.695 | 4.491 | 4.493 | 4.759 | 4.759 | 4.985 | 6.765 | 6.778 | 7.040 | 7.040 | 8.032 |
|  | atomic\_global\_stride | 2.244 | 2.254 | 2.264 | 2.264 | 2.614 | 4.503 | 4.522 | 4.787 | 4.787 | 4.822 | 6.787 | 6.818 | 7.072 | 7.072 | 7.424 |
|  | atomic\_private | 1.379 | 1.381 | 1.386 | 1.386 | 2.272 | 0.259 | 0.263 | 0.264 | 0.264 | 0.265 | 1.663 | 1.667 | 1.674 | 1.674 | 2.552 |
|  | atomic\_private\_stride | 1.376 | 1.379 | 1.385 | 1.385 | 2.353 | 0.173 | 0.175 | 0.177 | 0.177 | 0.180 | 1.574 | 1.578 | 1.585 | 1.585 | 2.548 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 204.174 | 204.395 | 204.741 | 204.741 | 205.473 | 1166.275 | 1174.485 | 1179.170 | 1179.170 | 1189.967 | 1370.550 | 1379.748 | 1383.837 | 1383.837 | 1394.385 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 204.168 | 204.448 | 205.269 | 205.269 | 206.141 | 37.960 | 38.278 | 39.135 | 39.135 | 41.036 | 242.572 | 243.374 | 244.178 | 244.178 | 246.621 |

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|  |  | **Radeon 6800 XT, konstante Daten, 27 Bins** | | | | | | | | | | | | | | |
|  |  | **Transferzeit Host zu Device (ms)** | | | | | **Ausführungszeit (ms)** | | | | | **Gesamtzeit (ms)** | | | | |
| **n** | **Kernel** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** | **Min** | **Q10** | **Med** | **Q90** | **Max** |
| 8 | atomic\_global | 0.020 | 0.023 | 0.025 | 0.025 | 0.047 | 0.029 | 0.031 | 0.031 | 0.031 | 0.060 | 0.070 | 0.077 | 0.080 | 0.080 | 0.540 |
|  | atomic\_global\_stride | 0.023 | 0.024 | 0.026 | 0.026 | 0.035 | 0.029 | 0.032 | 0.032 | 0.032 | 0.121 | 0.074 | 0.079 | 0.082 | 0.082 | 0.171 |
|  | atomic\_private | 0.017 | 0.023 | 0.025 | 0.025 | 0.030 | 0.027 | 0.030 | 0.031 | 0.031 | 0.033 | 0.062 | 0.075 | 0.080 | 0.080 | 0.137 |
|  | atomic\_private\_stride | 0.022 | 0.023 | 0.025 | 0.025 | 0.036 | 0.029 | 0.031 | 0.033 | 0.033 | 0.034 | 0.069 | 0.077 | 0.081 | 0.081 | 0.093 |
| 16 | atomic\_global | 0.022 | 0.023 | 0.024 | 0.024 | 0.444 | 0.058 | 0.060 | 0.062 | 0.062 | 0.066 | 0.103 | 0.106 | 0.109 | 0.109 | 0.958 |
|  | atomic\_global\_stride | 0.022 | 0.023 | 0.024 | 0.024 | 0.139 | 0.058 | 0.060 | 0.062 | 0.062 | 0.066 | 0.103 | 0.106 | 0.110 | 0.110 | 0.224 |
|  | atomic\_private | 0.019 | 0.023 | 0.024 | 0.024 | 0.030 | 0.028 | 0.032 | 0.034 | 0.034 | 0.080 | 0.062 | 0.075 | 0.081 | 0.081 | 0.129 |
|  | atomic\_private\_stride | 0.019 | 0.023 | 0.024 | 0.024 | 0.031 | 0.028 | 0.032 | 0.034 | 0.034 | 0.035 | 0.062 | 0.078 | 0.081 | 0.081 | 0.087 |
| 24 | atomic\_global | 2.489 | 2.504 | 2.523 | 2.523 | 2.914 | 6.877 | 6.878 | 7.147 | 7.147 | 7.318 | 9.394 | 9.413 | 9.684 | 9.684 | 10.574 |
|  | atomic\_global\_stride | 2.493 | 2.498 | 2.515 | 2.515 | 2.624 | 6.911 | 6.917 | 7.186 | 7.186 | 7.202 | 9.438 | 9.450 | 9.717 | 9.717 | 9.815 |
|  | atomic\_private | 1.626 | 1.631 | 1.645 | 1.645 | 2.525 | 0.407 | 0.409 | 0.410 | 0.410 | 0.415 | 2.058 | 2.065 | 2.078 | 2.078 | 2.951 |
|  | atomic\_private\_stride | 1.626 | 1.644 | 1.662 | 1.662 | 2.526 | 0.266 | 0.267 | 0.269 | 0.269 | 0.279 | 1.915 | 1.936 | 1.955 | 1.955 | 2.813 |
| 32 | atomic\_global |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_global\_stride | 225.563 | 225.732 | 226.023 | 226.023 | 226.965 | 1787.229 | 1792.958 | 1798.073 | 1798.073 | 1807.456 | 2013.279 | 2019.195 | 2024.317 | 2024.317 | 2033.143 |
|  | atomic\_private |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | atomic\_private\_stride | 225.372 | 225.749 | 226.134 | 226.134 | 226.802 | 79.102 | 80.256 | 81.032 | 81.032 | 82.052 | 304.886 | 306.422 | 307.093 | 307.093 | 308.878 |