Grøstl

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Florian Mendel, Christian Rechberger,
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www.groestl.info

First SHA-3 Candidate Conference, 2009

MAT, DTU
IAIK, TU Graz

The Grøstl Hash Function

- Grøstl is FAST
- Grøstl is PROVABLY SECURE
- Grøstl is SIDE-CHANNEL RESISTANT
- Grøstl is SIMPLE
- …

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- Grøstl is SIMPLE
- …
- Grøstl TASTES GOOD and is CO_2 NEUTRAL
- Grøstl is THE ANSWER to
  the question on life, the universe and everything.

What sets Grøstl apart:

- The team
  - Hash design experience
  - Hash cryptanalysis experience
- Solid at every level
  - Hash function → compression function → two permutations
- Simplicity of Grøstl
  - Simplicity of design
  - Simplicity of analysis
- Balanced implementation characteristics

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The Grøstl Design Team







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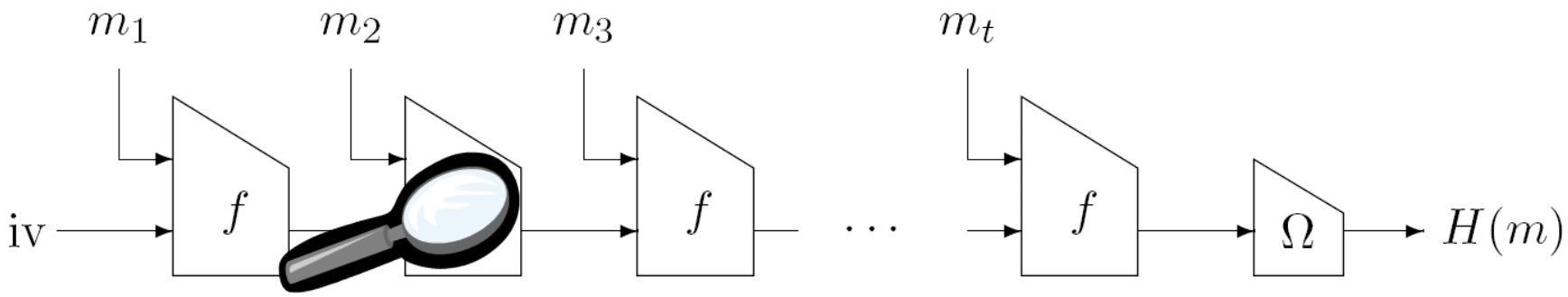
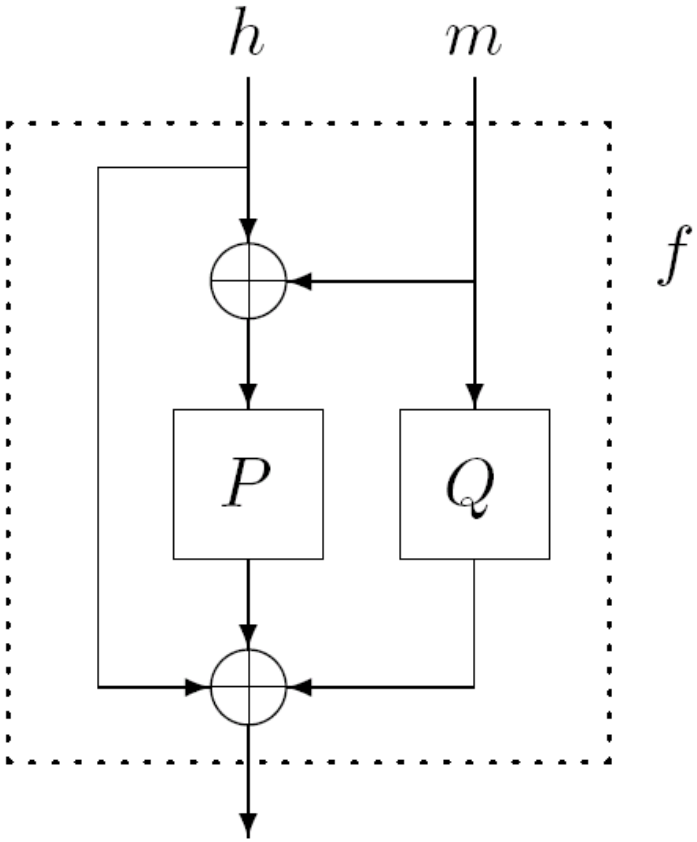
The Grøstl Hash Function



The Grøstl Compression Function

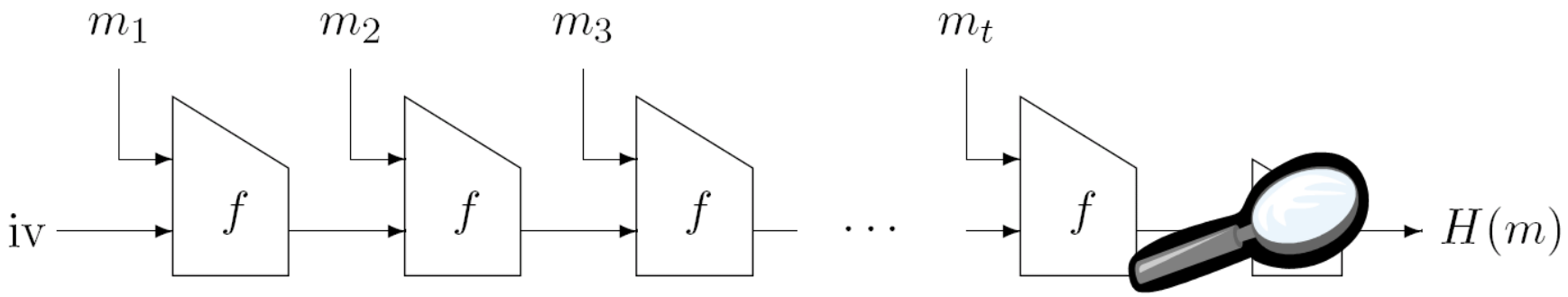


Grøstl-256:
512-bit permutations

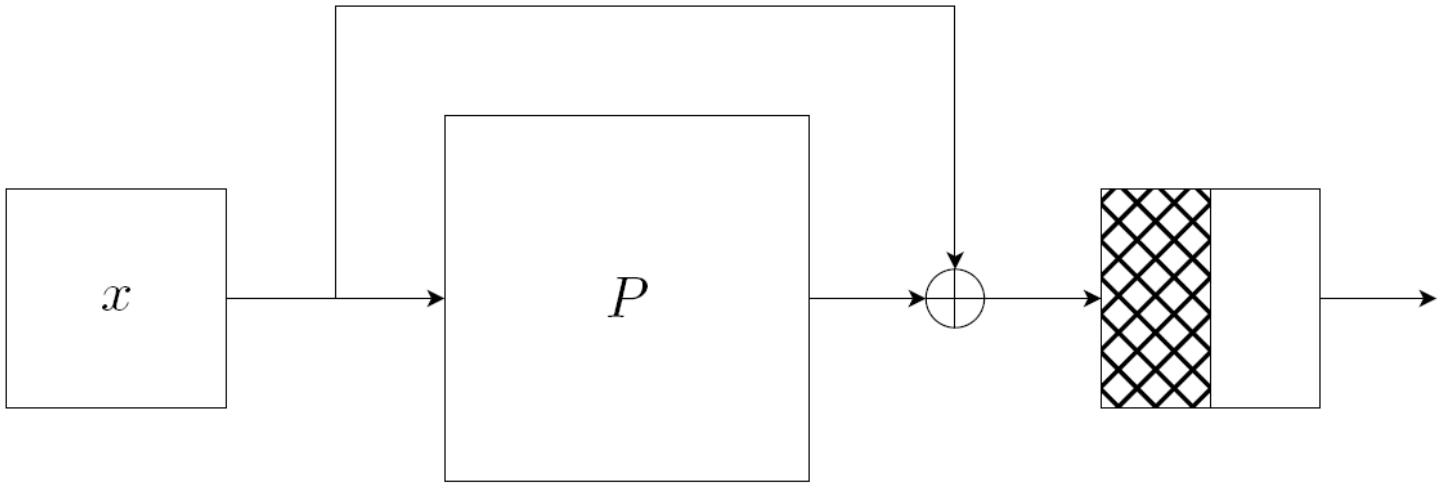
Grøstl-512:
1024-bit permutations

$$f(h, m) = P(h \oplus m) \oplus Q(m) \oplus h$$

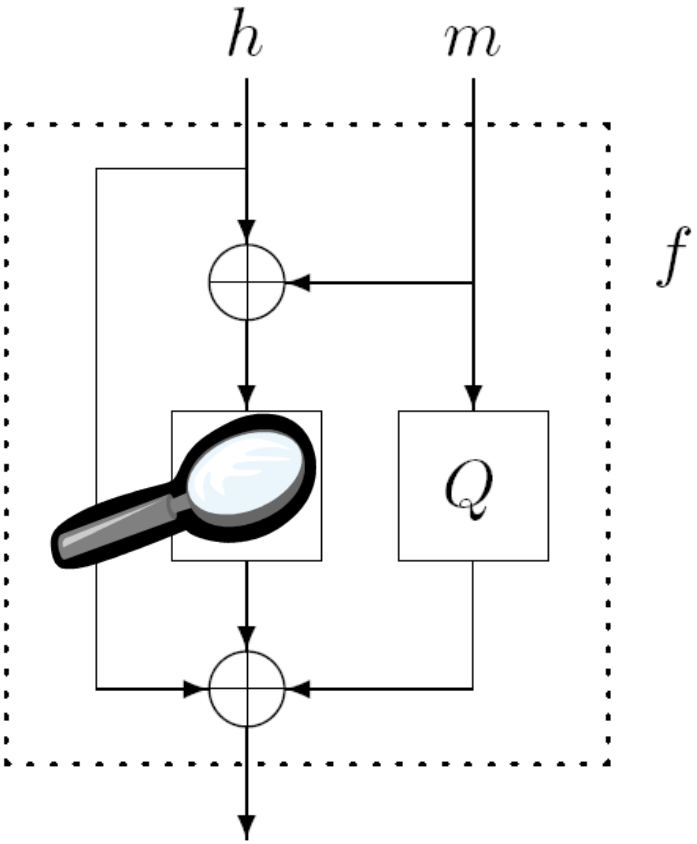
The Grøstl Hash Function



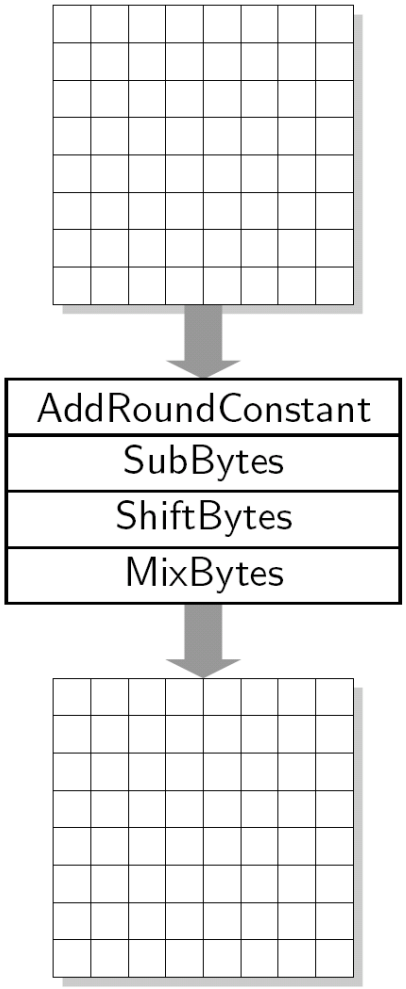
The Output Transformation



The Grøstl Compression Function



The State / Round Transformation



AES-like

Grøstl-256:
8x8 geometry
10 rounds

Grøstl-512:
8x16 geometry
14 rounds

Simple and proven solid

- Iteration
  - wide-pipe + MD + output transform
- Compression function
  - two permutations in well studied construction
- Permutation
  - “wide trail” design strategy → bounds on various attacks
  - undergone serious cryptanalysis

- Reduction proofs for collisions/preimages: done
- Reduction proofs for RO-indifferentiability: to be done

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  - **Simplicity of analysis**
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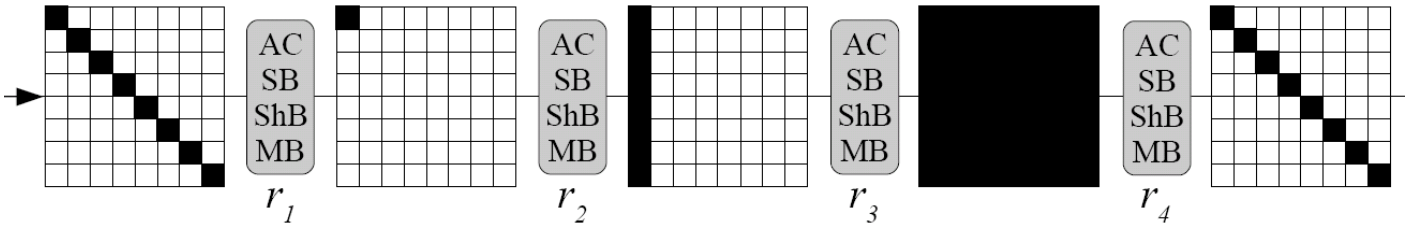
Simplicity of Analysis



- Grøstl allows to construct optimal (truncated) differentials, and prove bounds on them

➔Bounds on “standard” differential attack

Internal Cryptanalysis

- **Rebound-Attacks** on the compression function
  6 rounds out of 10 (FSE 2009)

- Side-effects of this work
  - Practical collision attack on Twister compress
  - Compression function attack on Cheetah-512 (8.5 out of 12)
  - Compression function attack on Maelstrom (8.5 out of 10)
  - Compression function attack on Whirlpool (7.5 out of 10)

- Freedom left for attacks on block ciphers based hashes
  - But not for Grøstl

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Balanced implementation characteristics

- No preference for particular platform
- No preference for particular wordsize

- Allows table based implementations

- Allows implementation techniques without tables
  - Bit-sliced
  - Special instructions (e.g. Intel)

No Cache Attacks

Performance

	Grøstl 256	Grøstl 512
AMD Opteron (64-bit)	19,50	
Intel Core2Duo (64-bit)	21,45	30,45
Intel Core2Duo (32-bit)	23,11	36,70
Intel Pentium M 760 (32-bit)	28,90	67,40
ATMega 163 (8-bit), estimates	415,00	580,00

Numbers are cycles/byte for long messages

Further speed-ups to be expected

Hardware: many trade-offs possible, see Appendix

Summary

Summary of Grøstl

- Solid construction at every level
  - Iteration
    wide-pipe + MD + output transform
  - Compression function
    provable query complexities for collision/preimage
  - Permutation
    - “wide trail” design strategy → bounds on various attacks
    - undergone serious cryptanalysis
- More flexible implementation characteristics than SHA-2
- Easier to get confidence in

Grøstl Q&A

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Supporting slides

The name Grøstl

An open call

What would be the name/pronunciation
of the DISH „hash“
in YOUR language/country?

- Examples:
  - Austrian/Austria: Gröstl
  - Danish/Denmark: Biksemad
  - Swiss-German/Switzerland: Rösti

Security claims / attacks

- The Grøstl hash function:

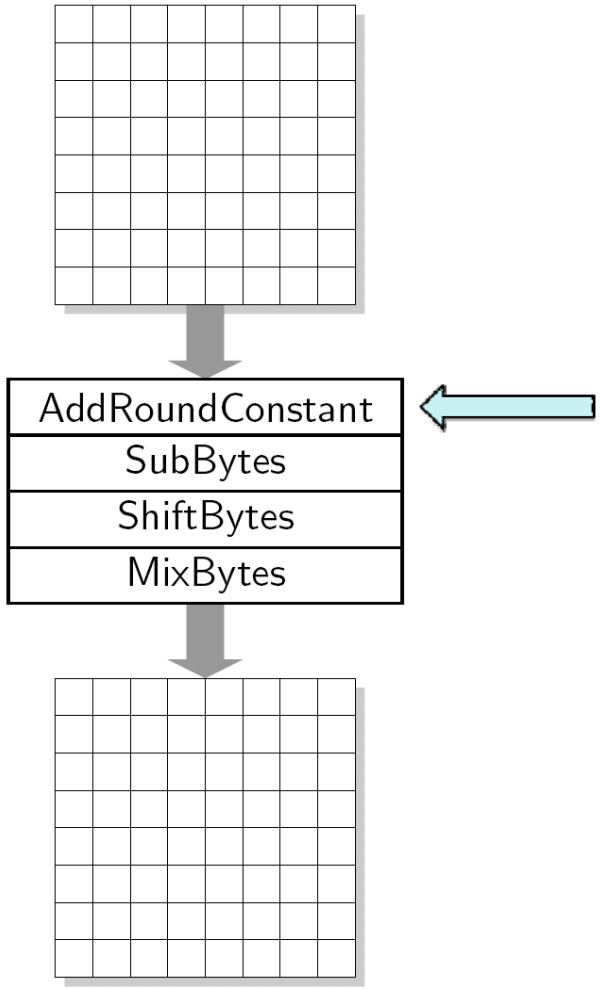
Attack type	Claimed complexity	Best known attack
Collision	$2^{n/2}$	$2^{n/2}$
d-collision	$\lg(d) \cdot 2^{n/2}$	$(d!)^{1/d} \cdot 2^{n(d-1)/d}$
Preimage	2^n	2^n
Second preimage	2^{n-k}	2^n

- The Grøstl compression function:

Attack type	Claimed complexity	Best known attack
Collision	$2^{\ell/4}$	$2^{\ell/3}$
Preimage	$2^{\ell/2}$	$2^{\ell/2}$

Supplementary Illustration for the Permutations P & Q

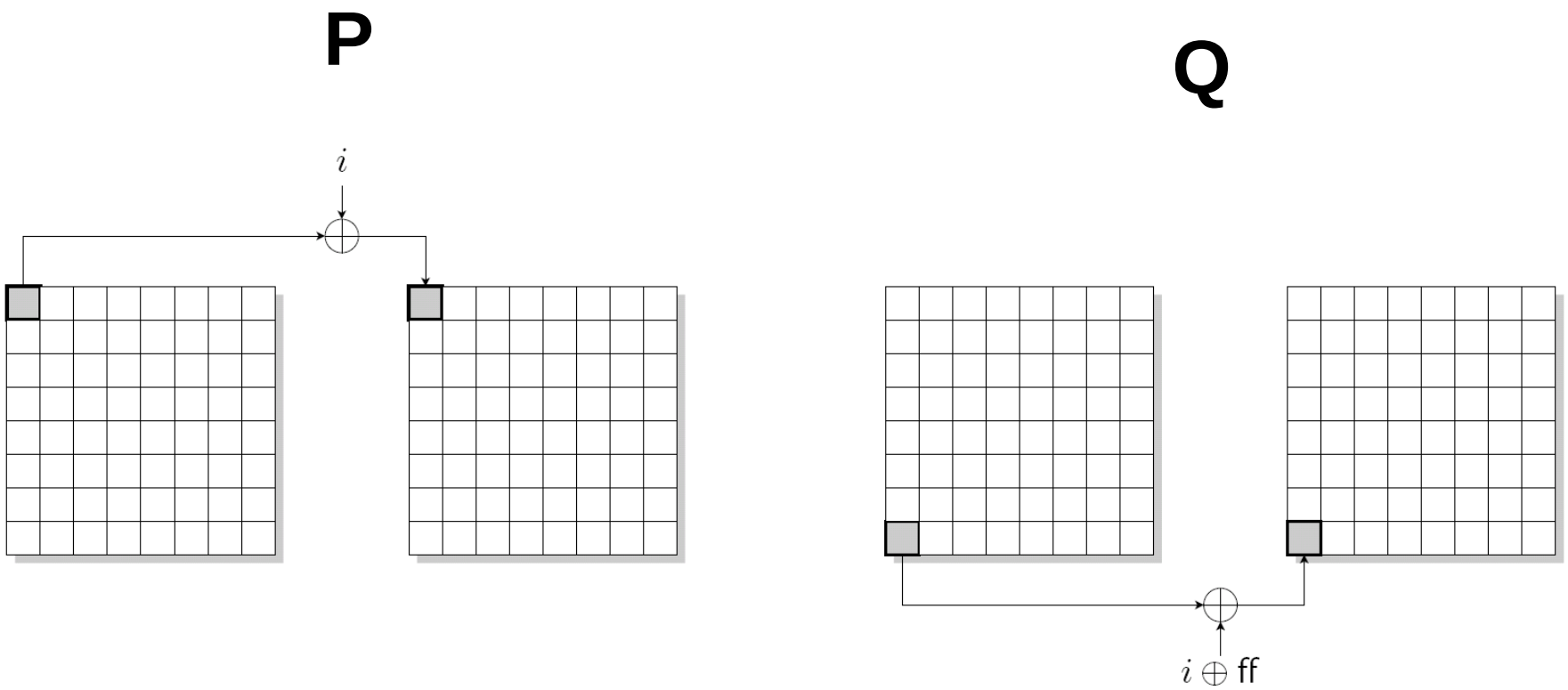
The State / Round Transformation



Grøstl-256:
8x8 geometry

Grøstl-512:
8x16 geometry

AddRoundConstant



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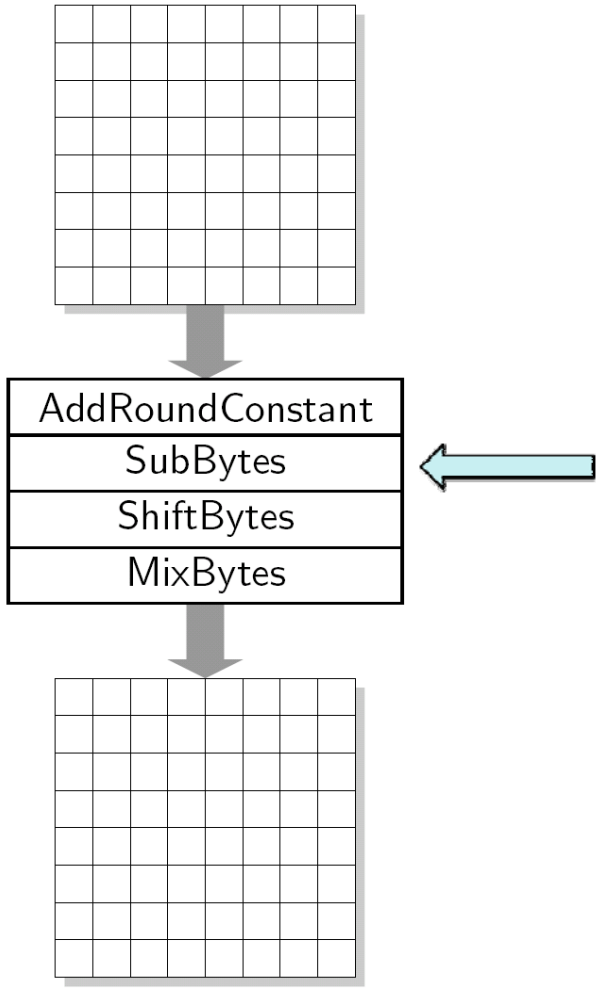

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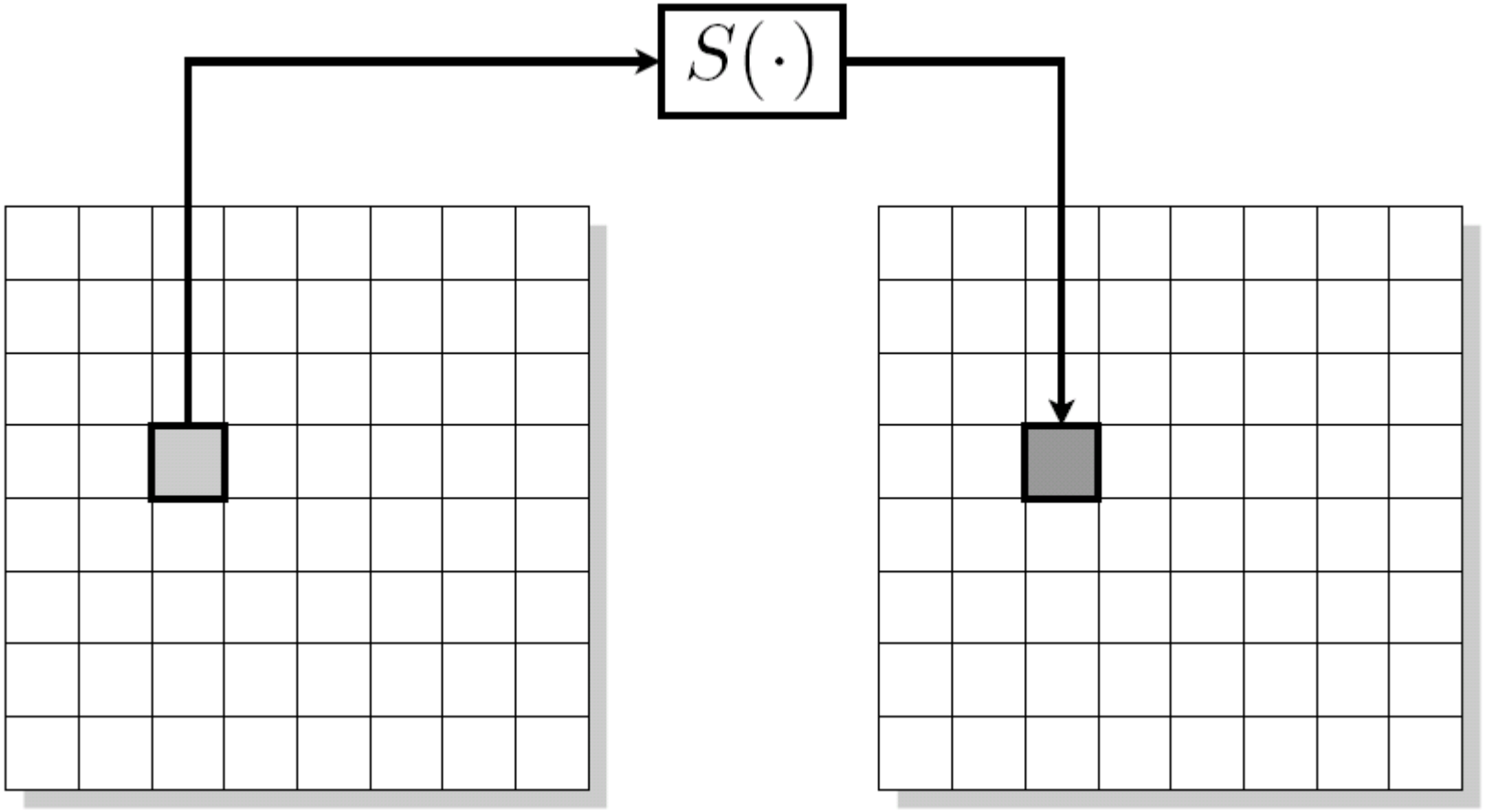
8x8 geometry

Grøstl-512:
8x16 geometry

SubBytes

same as the 8-bit AES Sbox



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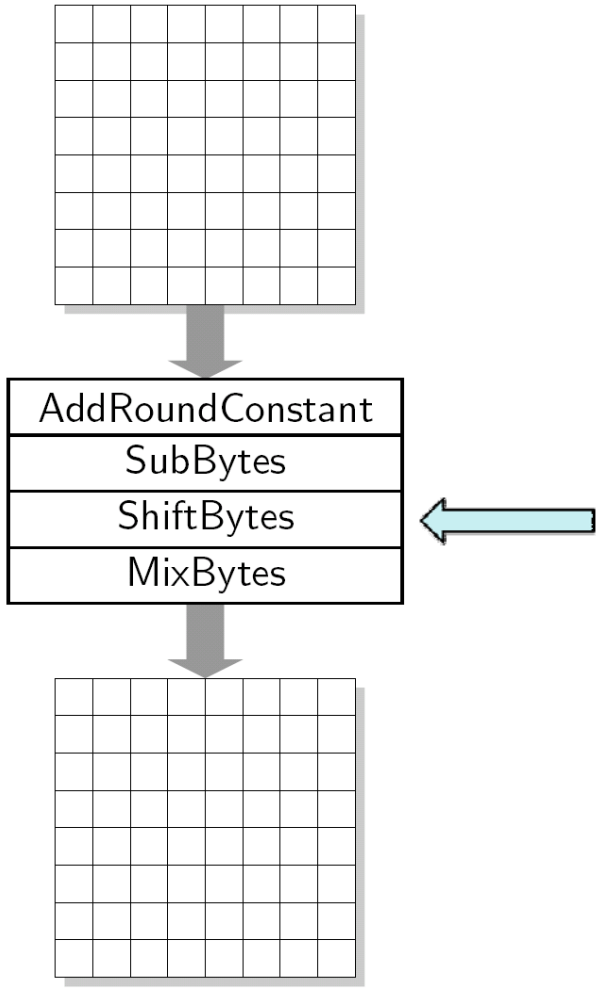

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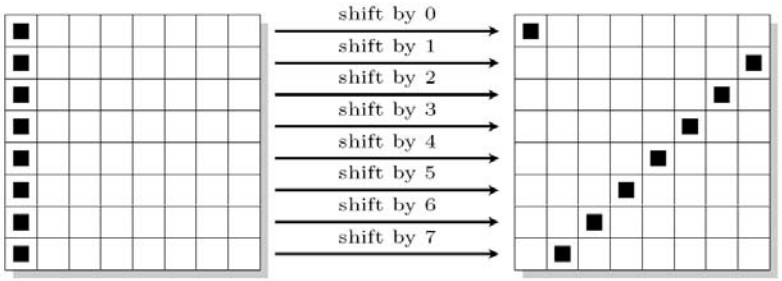
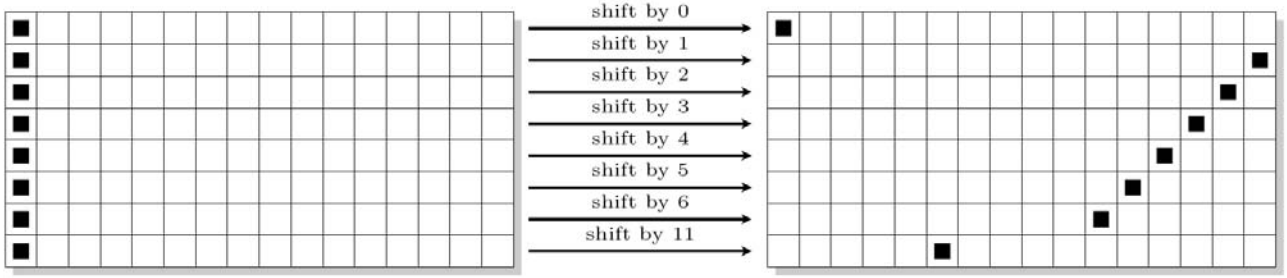
Grøstl-512:
8x16 geometry

ShiftBytes / ShiftBytesWide

Grøstl-256



Grøstl-512



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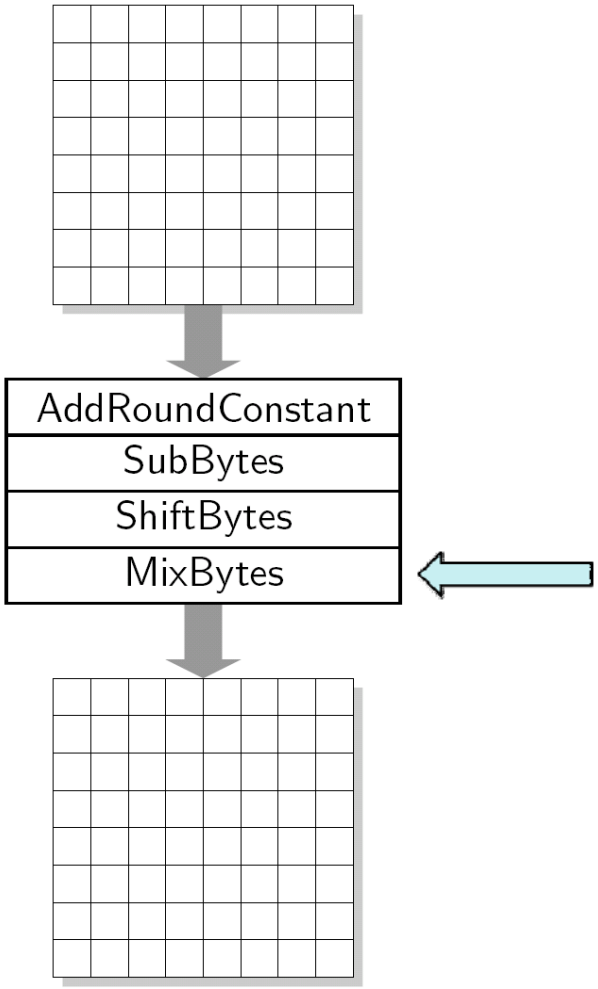
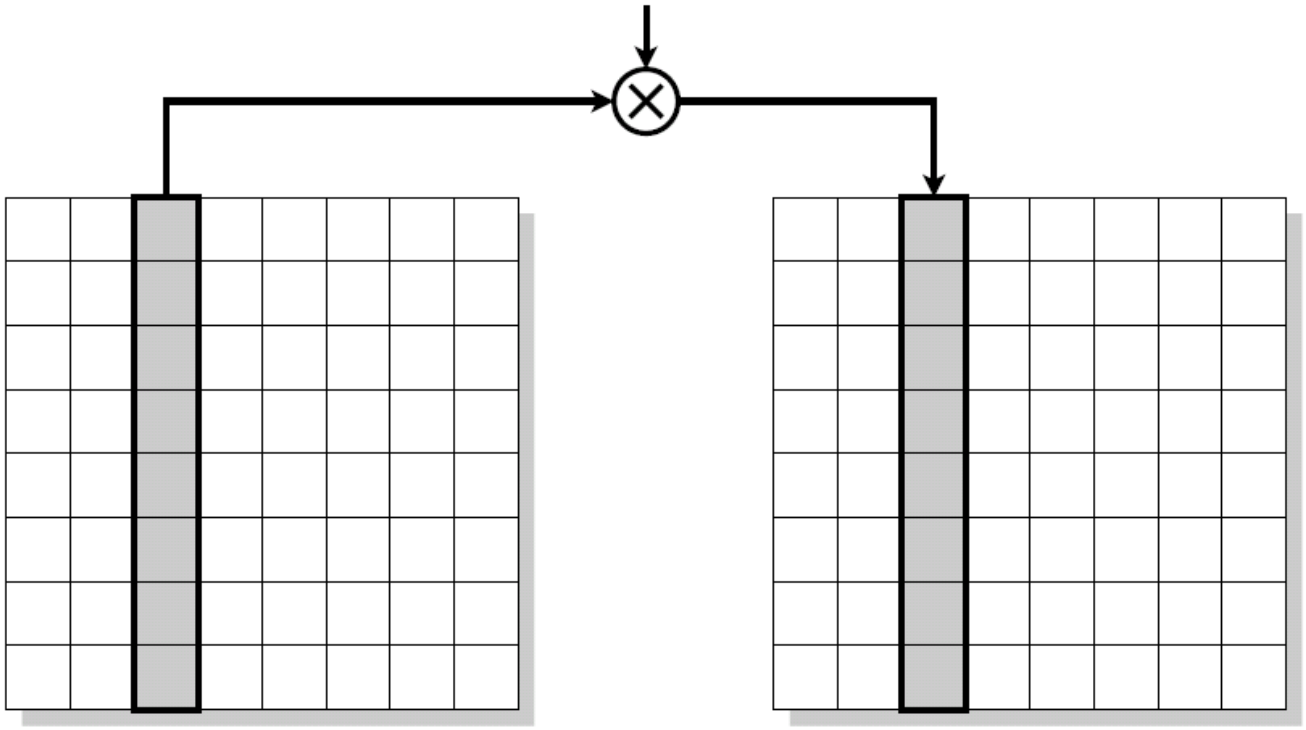


Grøstl-256:
8x8 geometry

Grøstl-512:
8x16 geometry

MixBytes

$$B = \mathrm{circ}(02, 02, 03, 04, 05, 03, 05, 07)$$



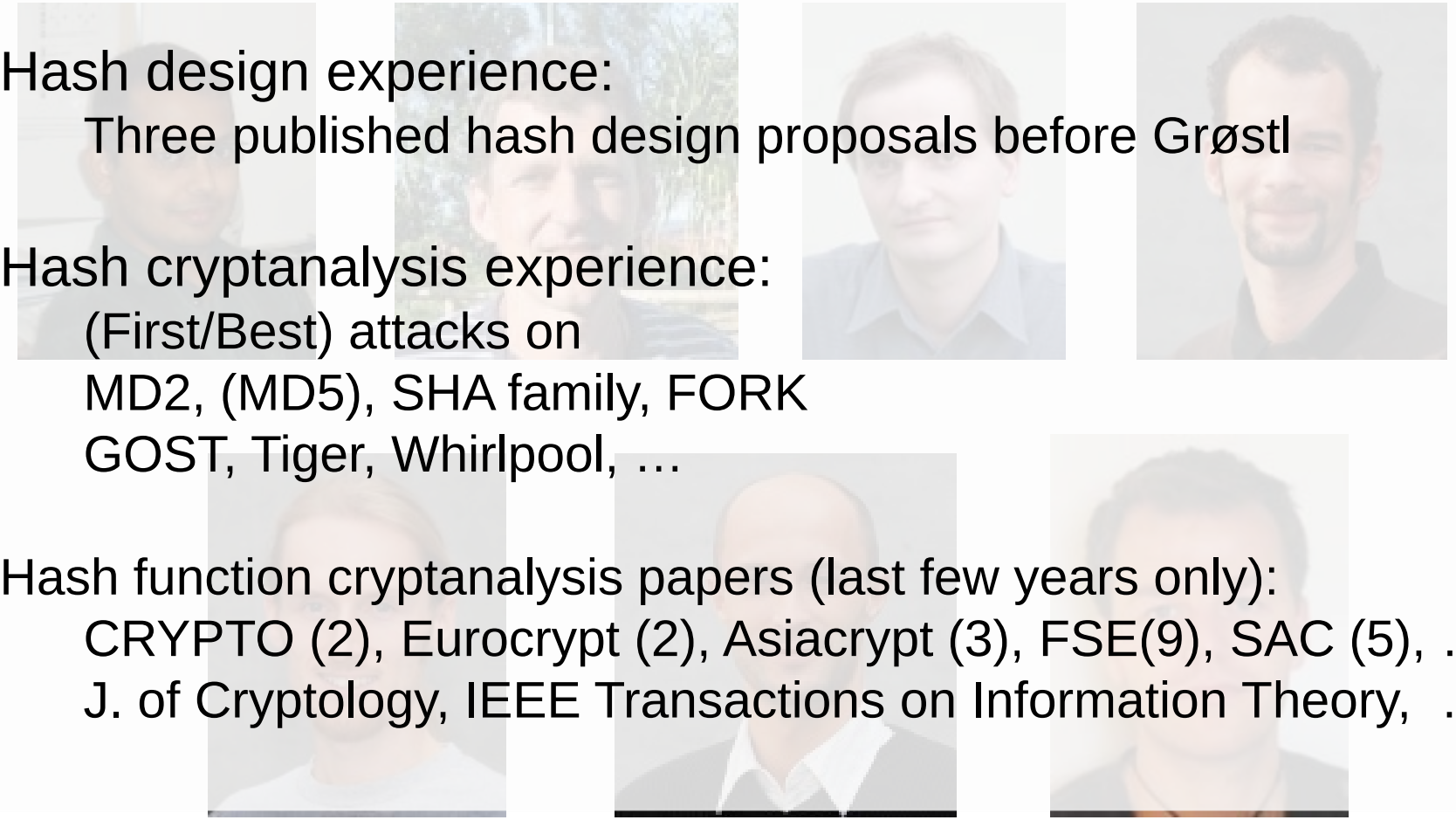
Hardware Performance:

- Grøstl allows extremely flexible implementations
  various memory/gates/throughput/latency/… trade-offs

Some implementation results:

	Area	Throughput(Gbits/s)
High throughput ASIC (0,18µm)	58 kGates	6,30
High throughput ASIC (0,18µm)	50 kGates	2,70
Low cost ASIC (0,18µm)	19 kGates	0,90
Low cost ASIC (0,18µm)	16 kGates	0,33
Spartan 3 FGPA	6.5 kSlices	4,40
Virtex 5 FGPA	1,7 kSlices	10,20

Proven track record:



Hash design experience:

Three published hash design proposals before Grøstl

Hash cryptanalysis experience:

(First/Best) attacks on
MD2, (MD5), SHA family, FORK
GOST, Tiger, Whirlpool, …

Hash function cryptanalysis papers (last few years only):

CRYPTO (2), Eurocrypt (2), Asiacrypt (3), FSE(9), SAC (5), …
J. of Cryptology, IEEE Transactions on Information Theory, …

Grøstl SHA-3 cryptanalysis

Recent SHA-3 related breaks/cryptanalysis of the Grøstl team:

- Blender, JH, Sarmal, TIB3, Twister, Vortex, Boole, DCH, SHAMATA
- BMW, Essence, JH, Vortex, MeshHash, Tangle