



Flash Memory Summit



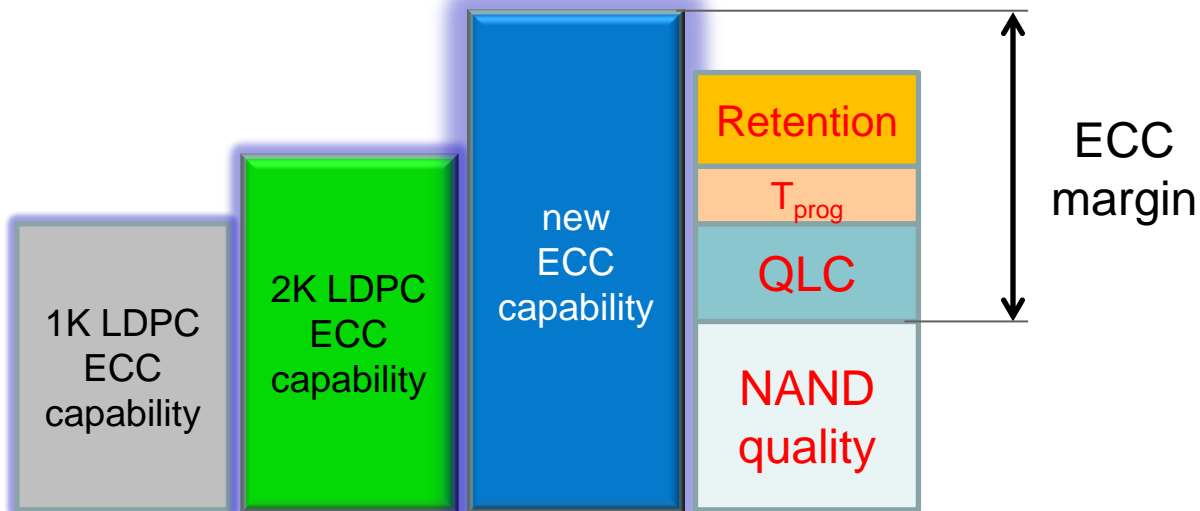
**SiliconMotion**

# Novel 4K Error Correcting Code for QLC NAND

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ECC team, Silicon Motion, Inc.

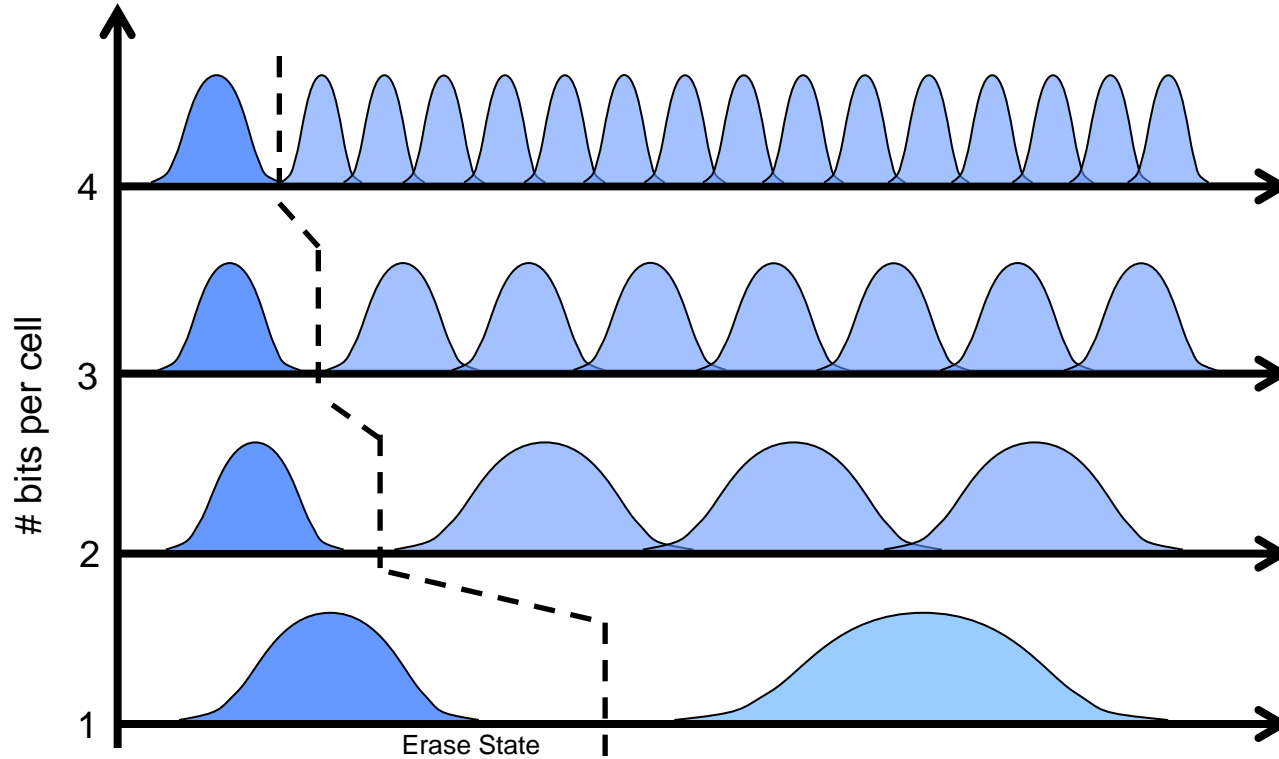


# We always need stronger ECC engine.



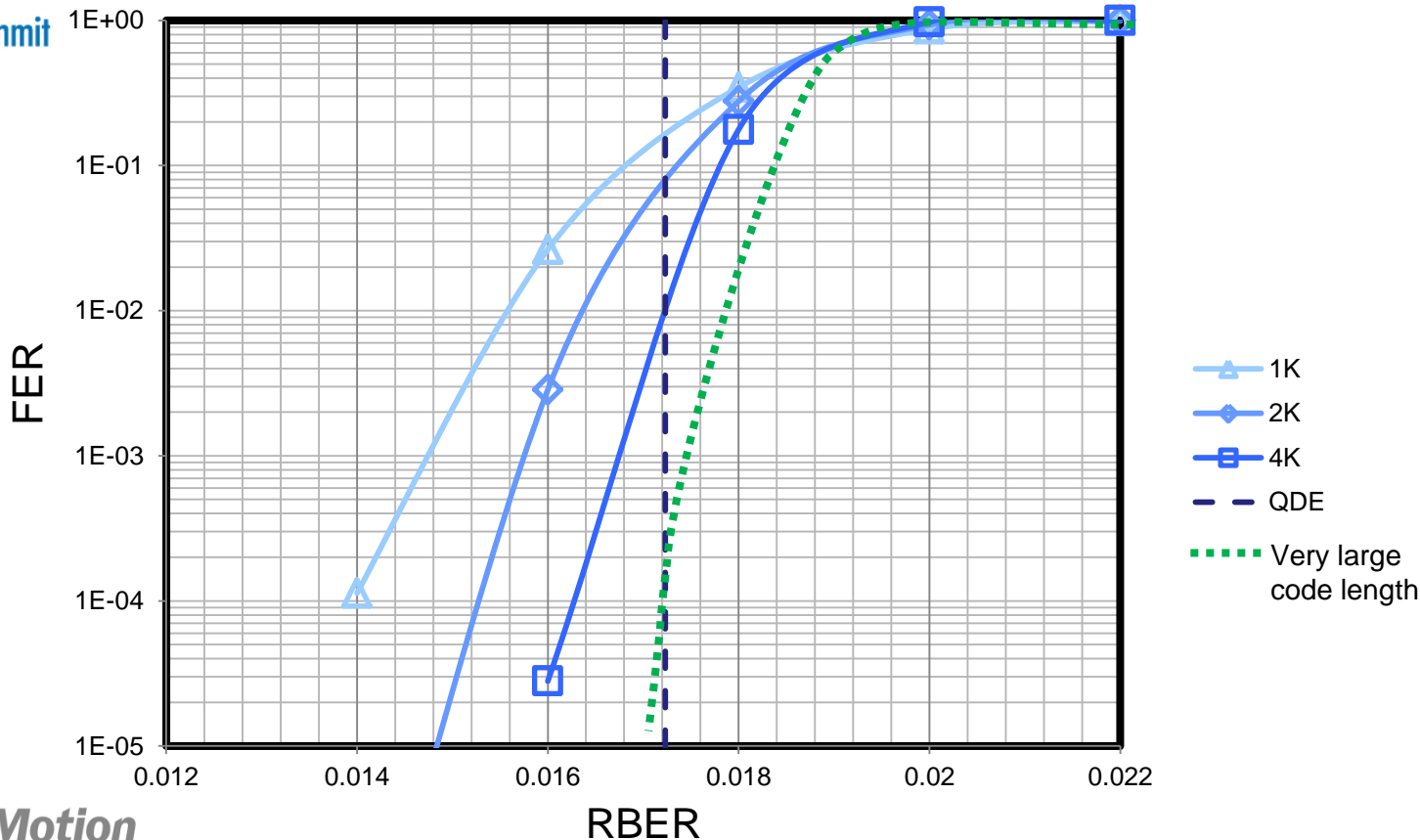


# QLC NAND





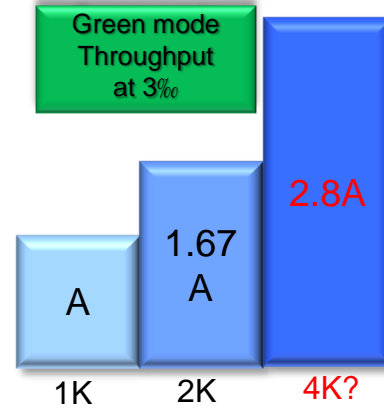
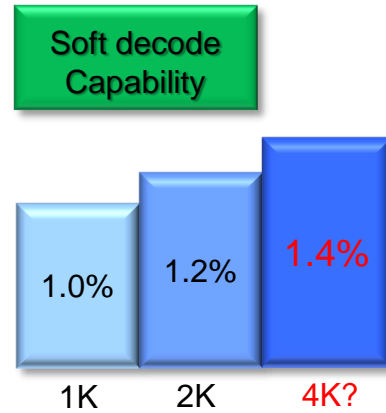
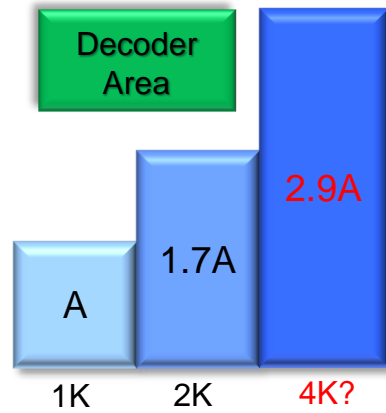
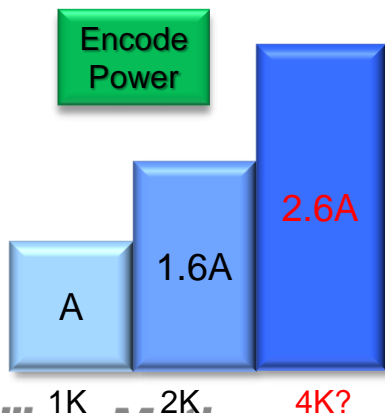
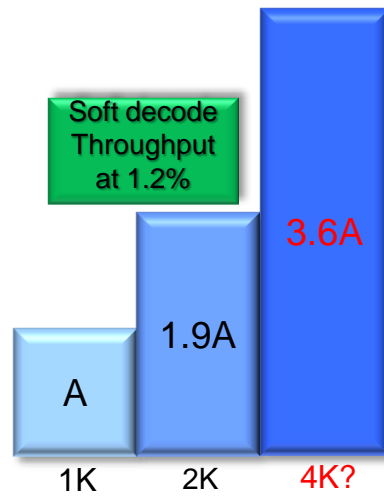
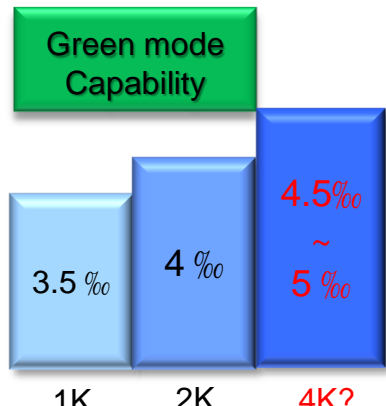
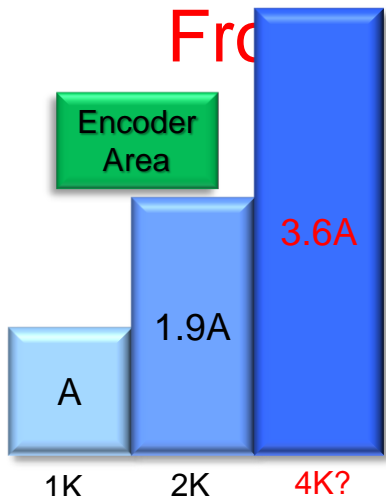
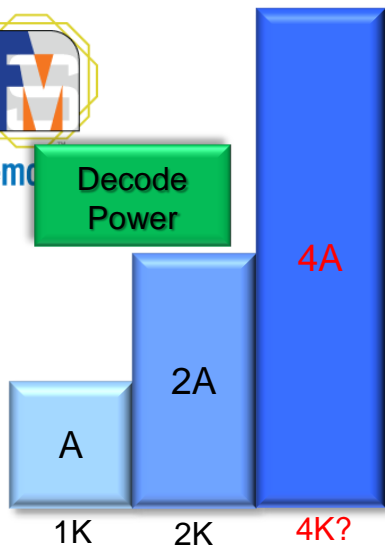
# Larger code length





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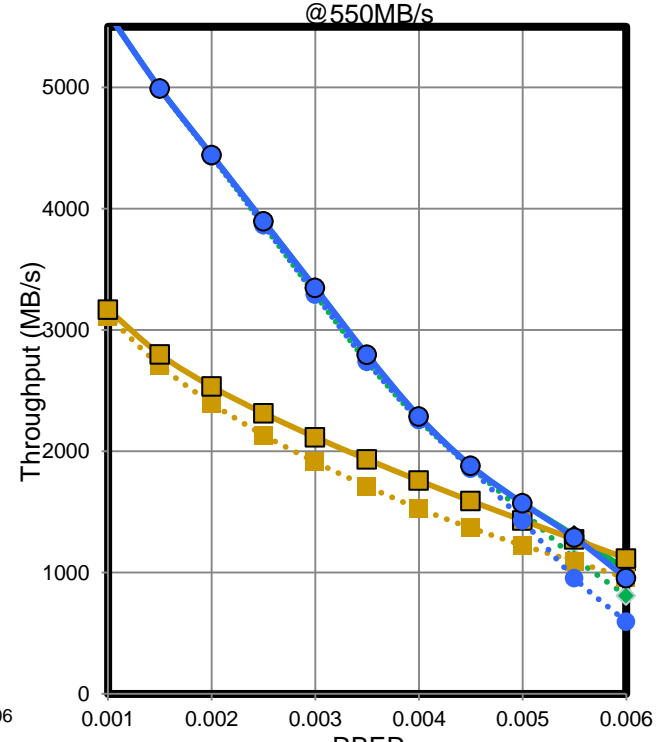
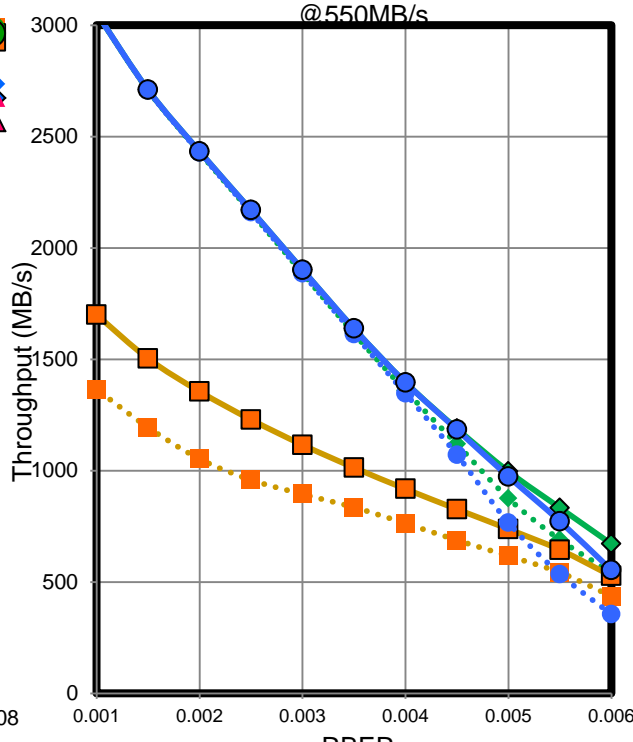
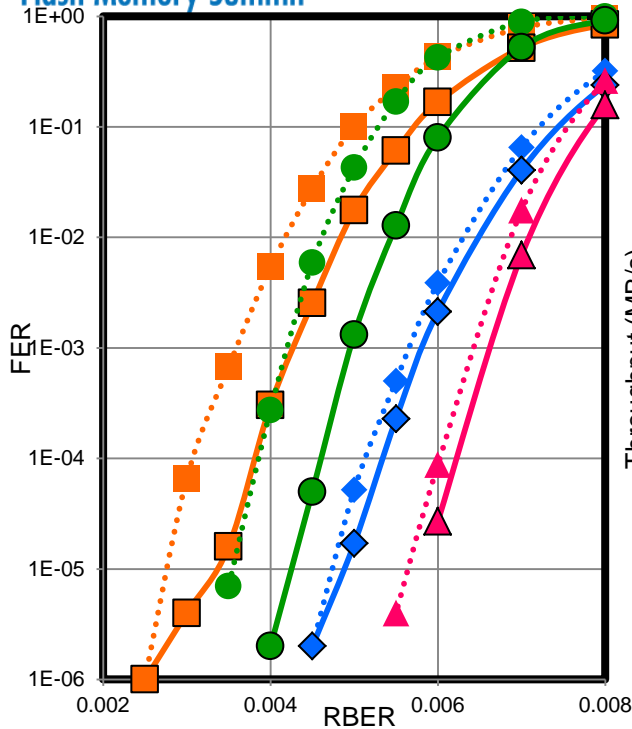
# From 1K to 2K





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# Before 4K



- 1K green
- 1K new green
- 1K hard
- 2K green
- 2K new green
- 2K hard

- 1K green mode
- 1K new green mode
- 1K hard regular
- 1K new hard regular
- 1K hard overall

- 2K green mode
- 2K new green mode
- 2K hard regular
- 2K new hard regular
- 2K hard overall



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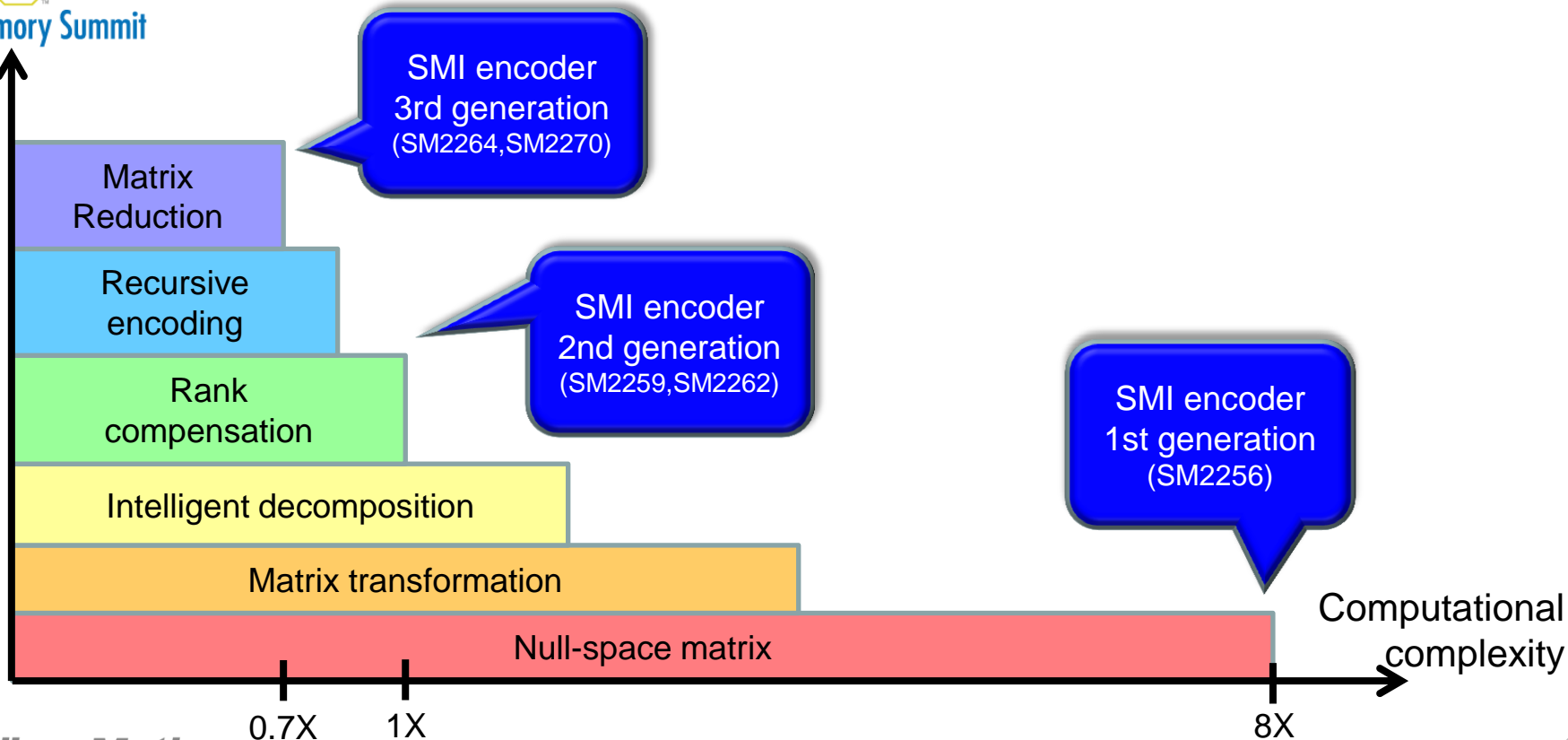
## Evolution of Encoder

- SRAA-based QC-LDPC encoder
  - Full-rank  $H$  – two stage encoder
  - Non-full rank  $H$  – generator matrix
- Regular v.s irregular base matrix



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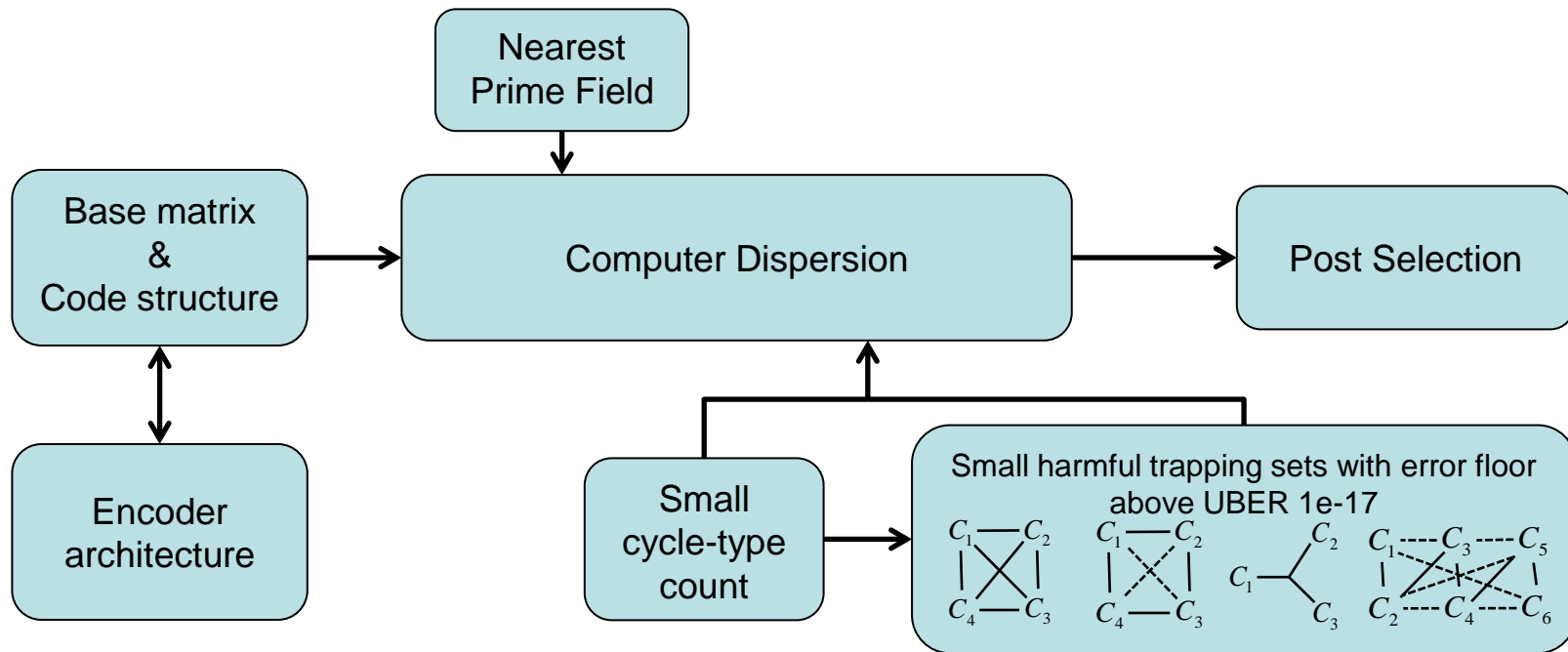
# Encoder Evolution





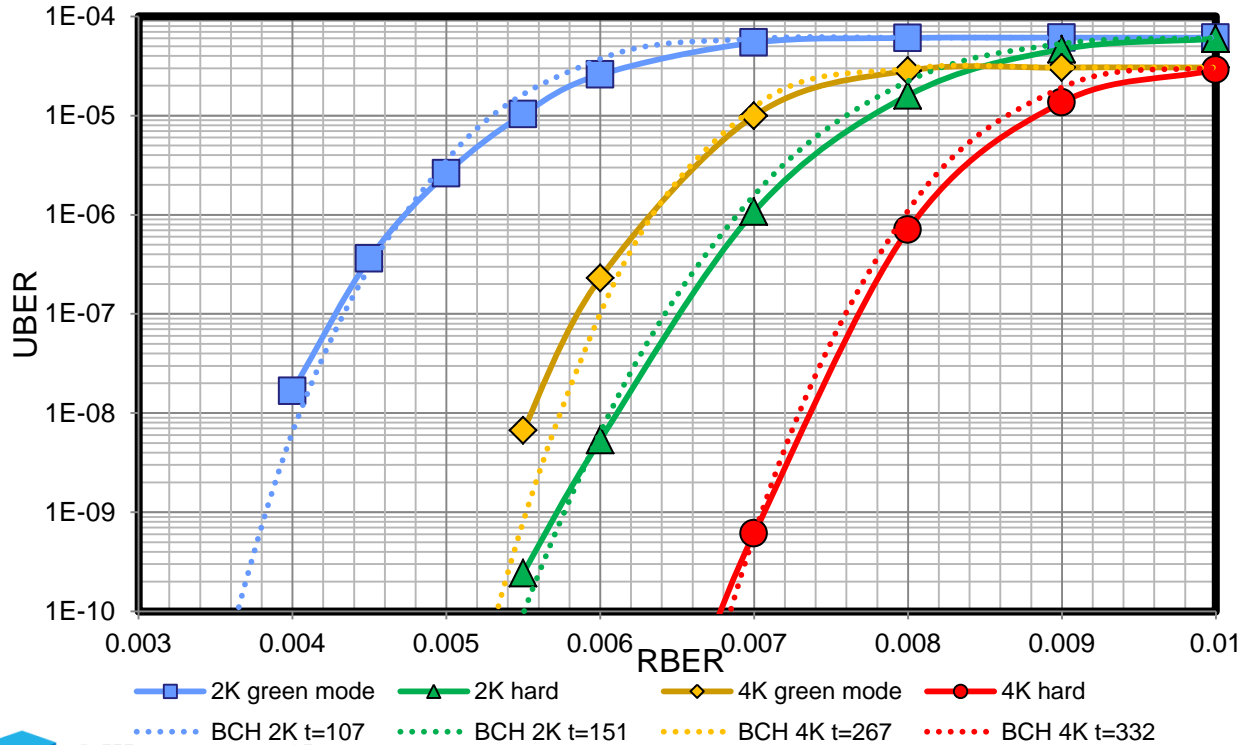


# 4K LDPC construction

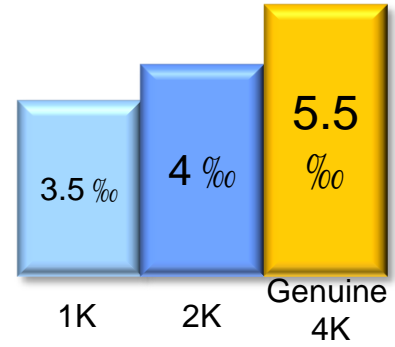




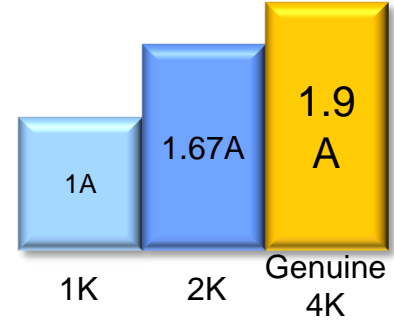
# Genuine 4K LDPC



Green mode Capability

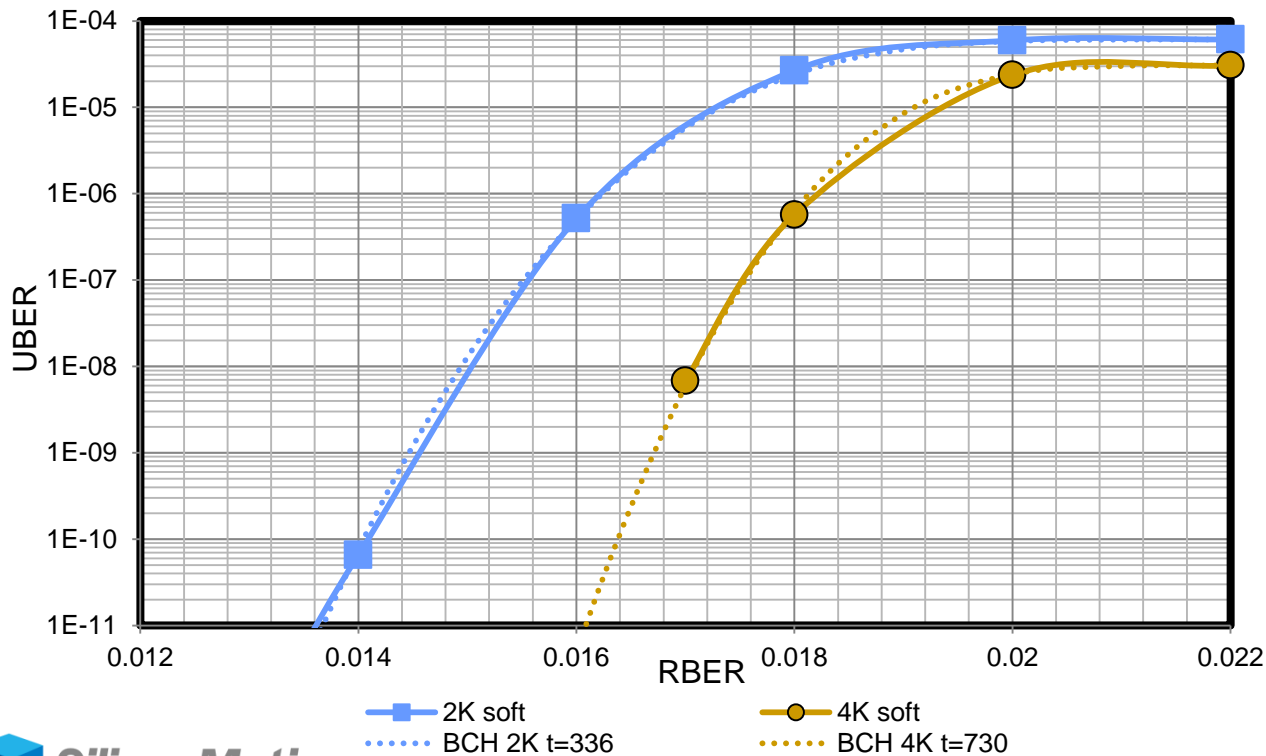


Green mode Throughput at 3%

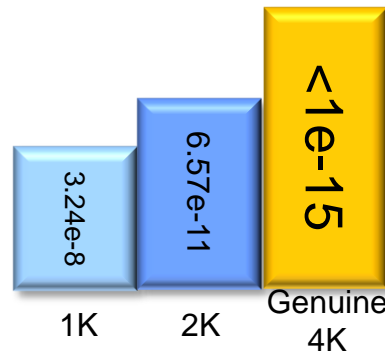




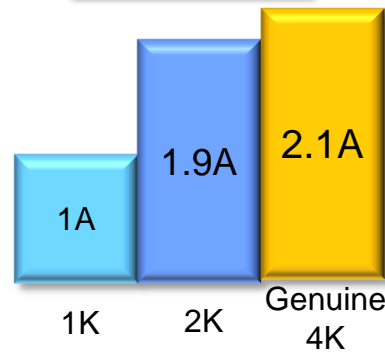
# Genuine 4K LDPC



Soft decode  
UBER at 1.4%

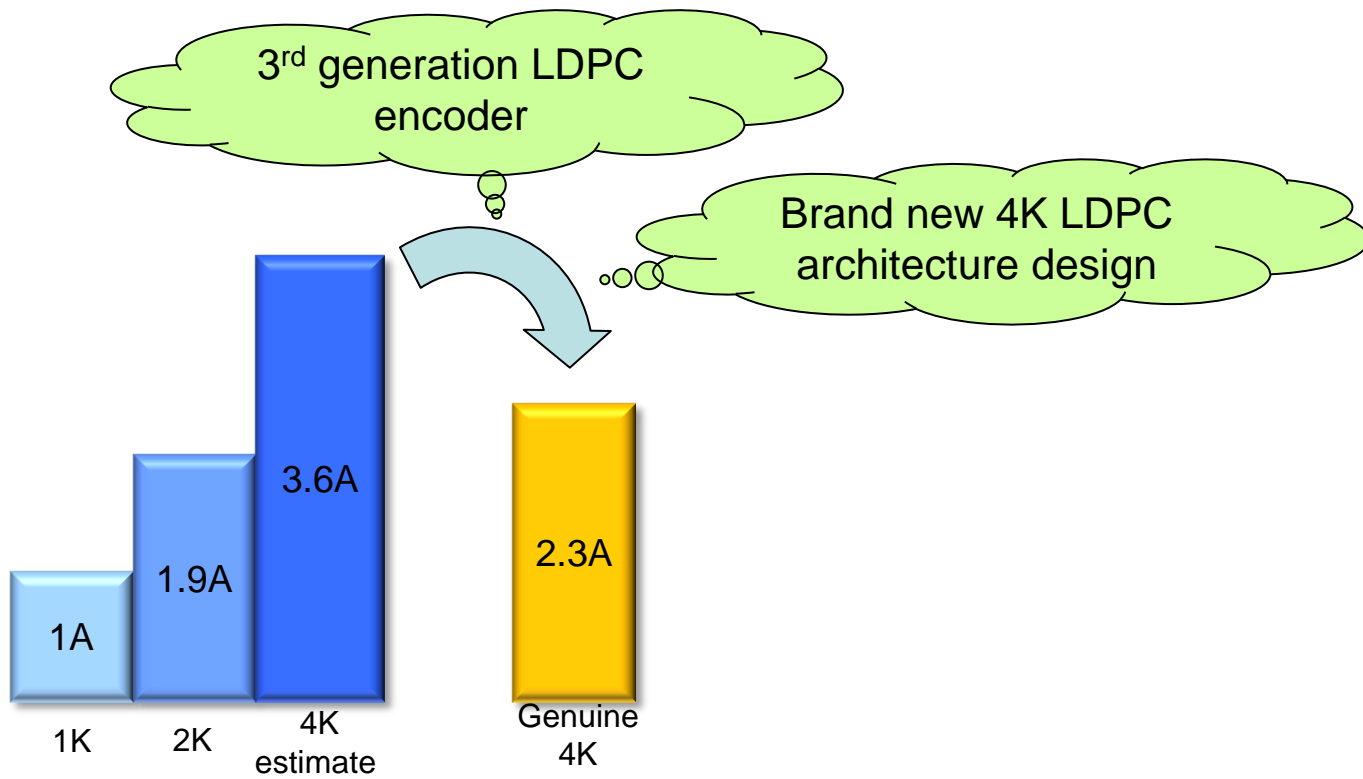


Soft decode  
Throughput  
at 1.2%



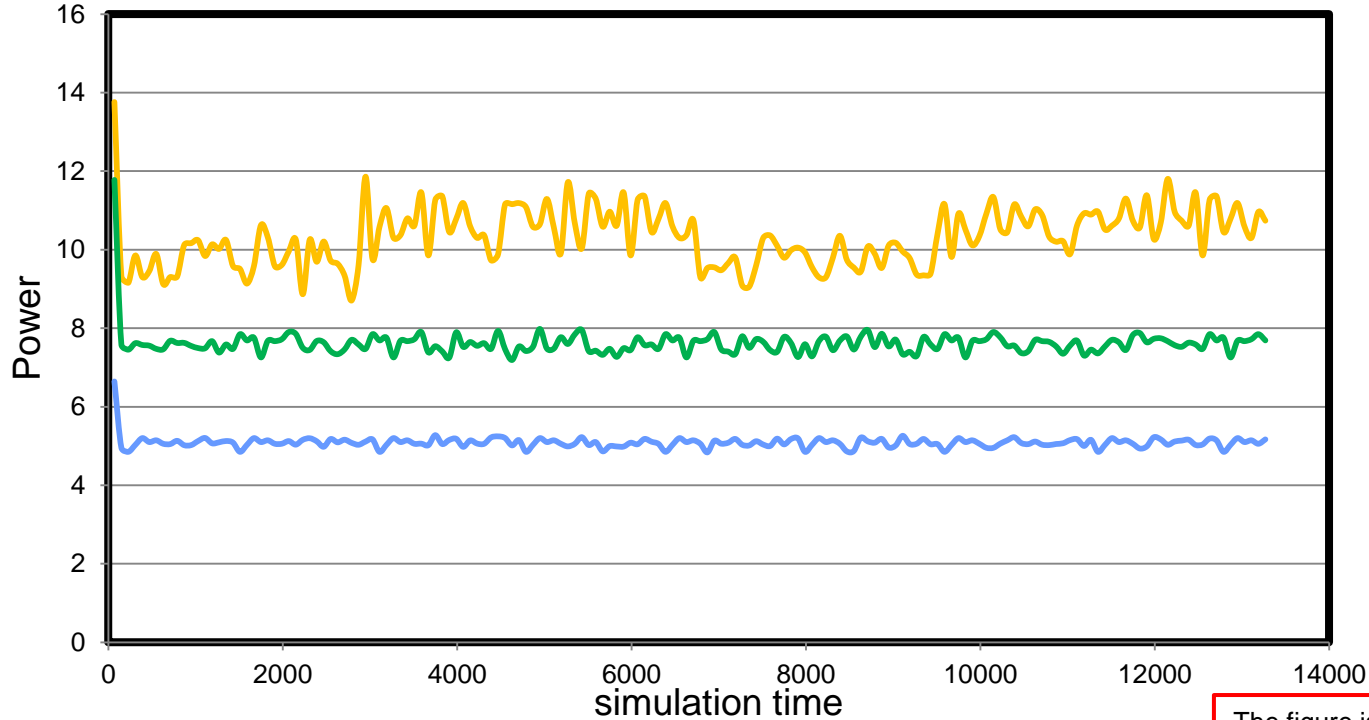


# Encoder Area

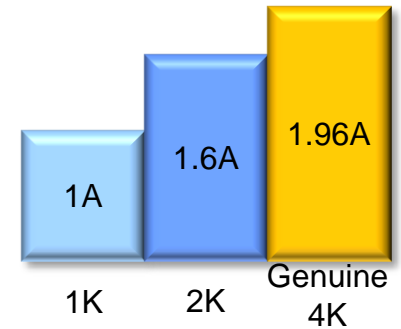




# Encoder Power



Encode  
avg. dynamic  
Power

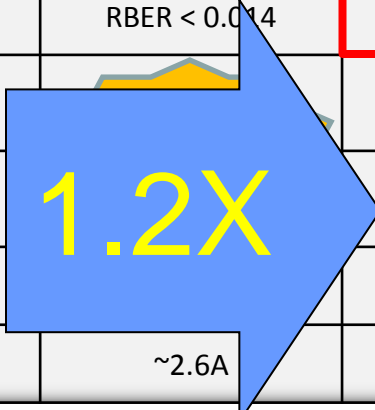


The figure is only an illustration. It does not reflect any actual architecture or algorithm that is used in the product.



# Genuine 4K Code

	1K Full	2K Full	4K Full Estimate	Genuine 4K
Green Mode Capability <sup>+</sup>	RBER < 0.0035	RBER < 0.004	RBER < 0.0045	RBER < 0.0055
Hard Decoding Capability <sup>+</sup>	RBER < 0.0055	RBER < 0.006	RBER < 0.007	RBER < 0.0075
Soft Decoding Capability <sup>#</sup>	RBER < 0.01	RBER < 0.012	RBER < 0.014	RBER < 0.014
Hard Decode Throughput @ RBER = 0.012	4.50 T	7.54 T	8.42 T	8.42 T
Soft Decode Throughput @ RBER = 0.003	1.89 T	3.65 T	4.03 T	4.03 T
Encoder Area	1A	1.91A	2.32A	2.32A
Encode Power	1A	1.6A	~2.6A	1.96A



<sup>+</sup>: Green Mode capability and hard decoding capability are defined as FER < 10<sup>-3</sup>

<sup>#</sup>: Soft decoding capability is defined as UBER < 10<sup>-15</sup>



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Thank you for your attention!



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