ReLU Strikes Back: Exploiting Activation Sparsity in Large Language Models

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Oncel Tuzel, Golnoosh Samei, Mohammad Rastegari, Mehrdad Farajtabar

ICLR'24 | Apple

Motivation

Training vs Inference

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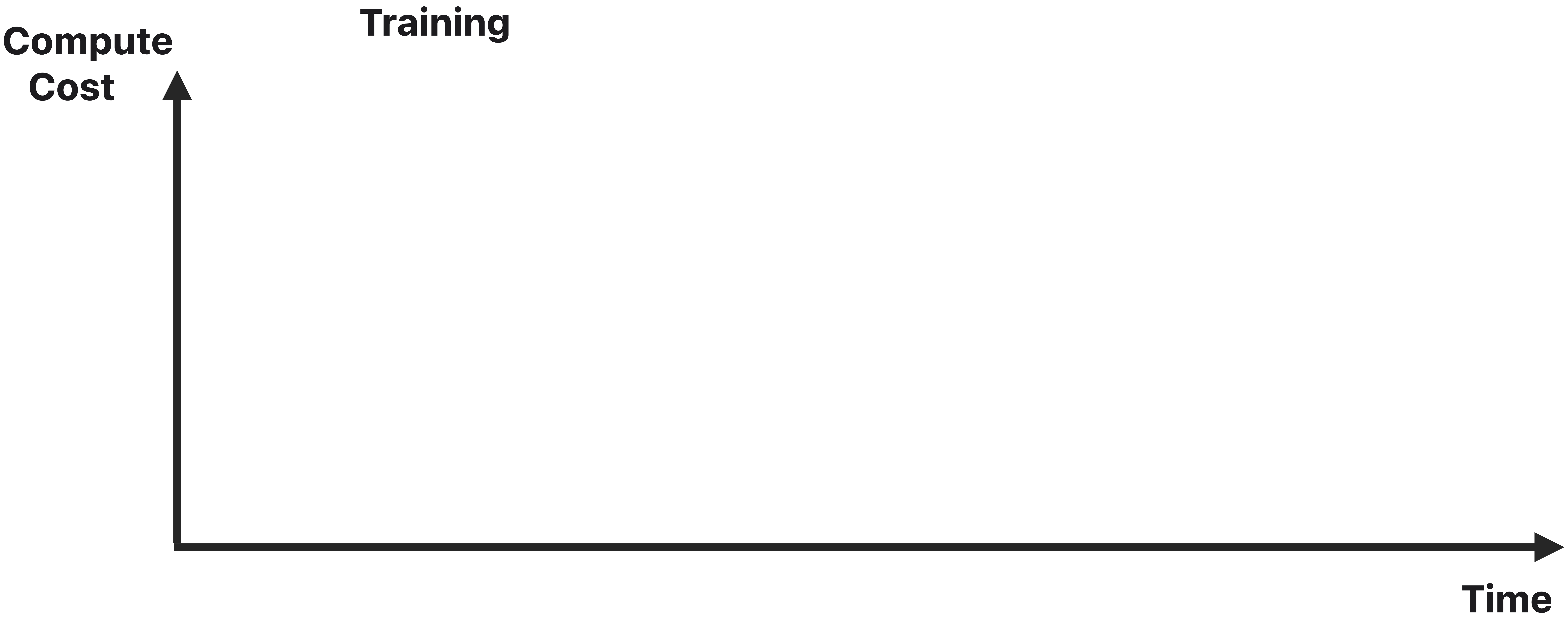

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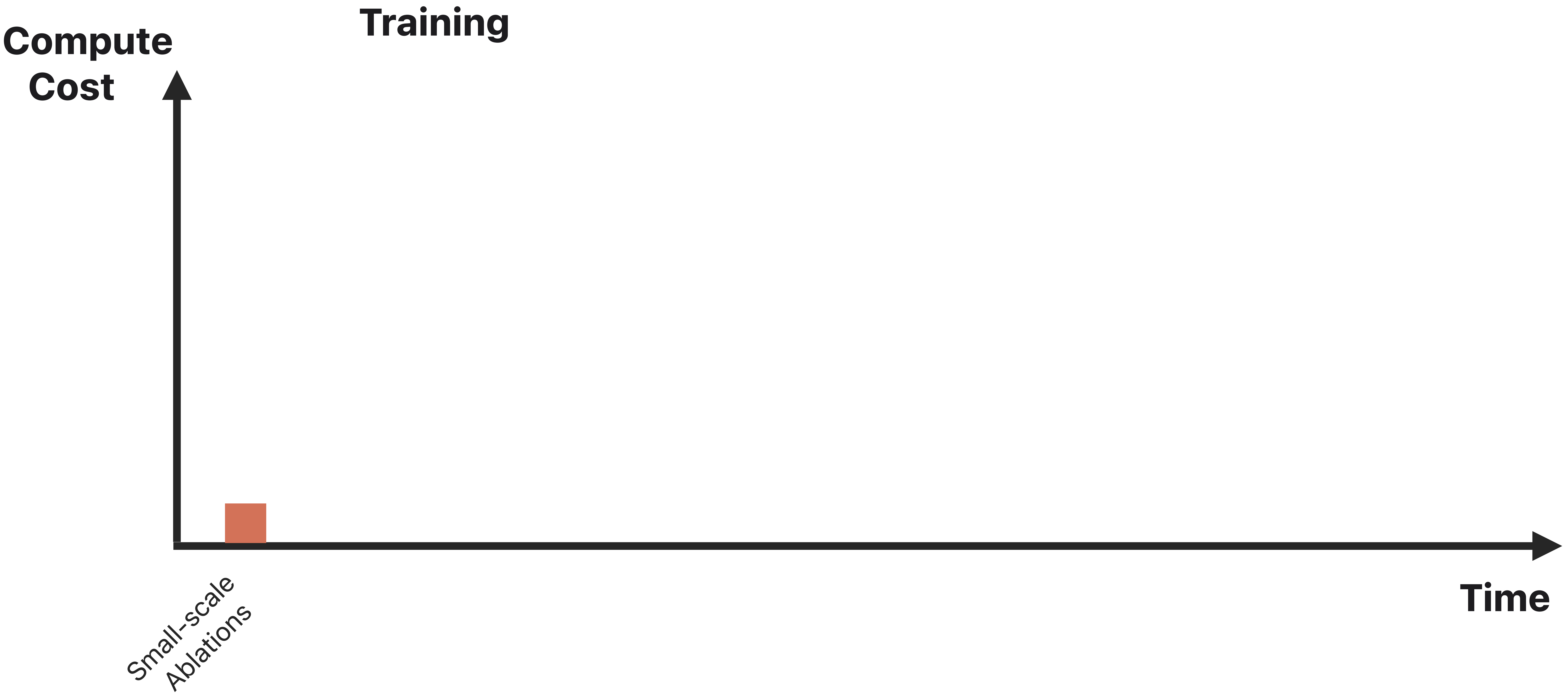

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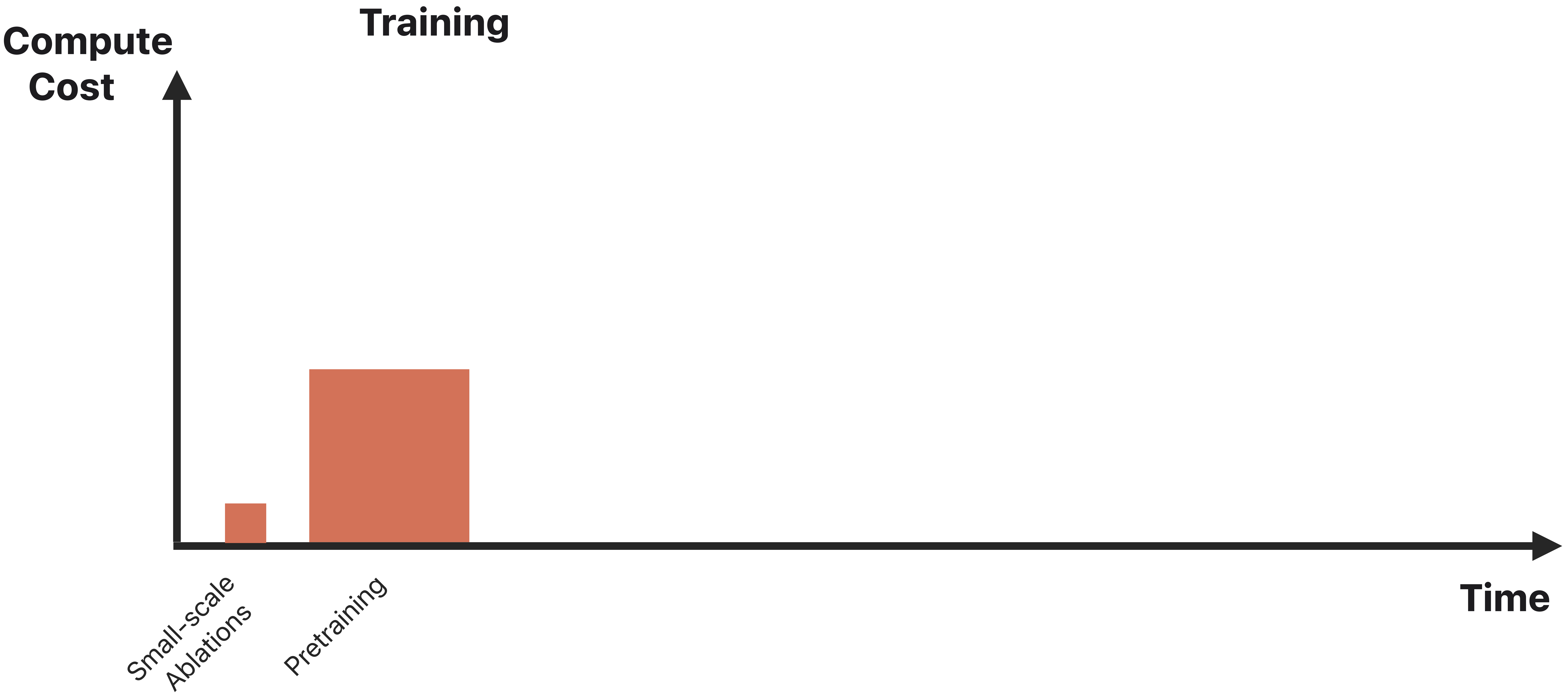

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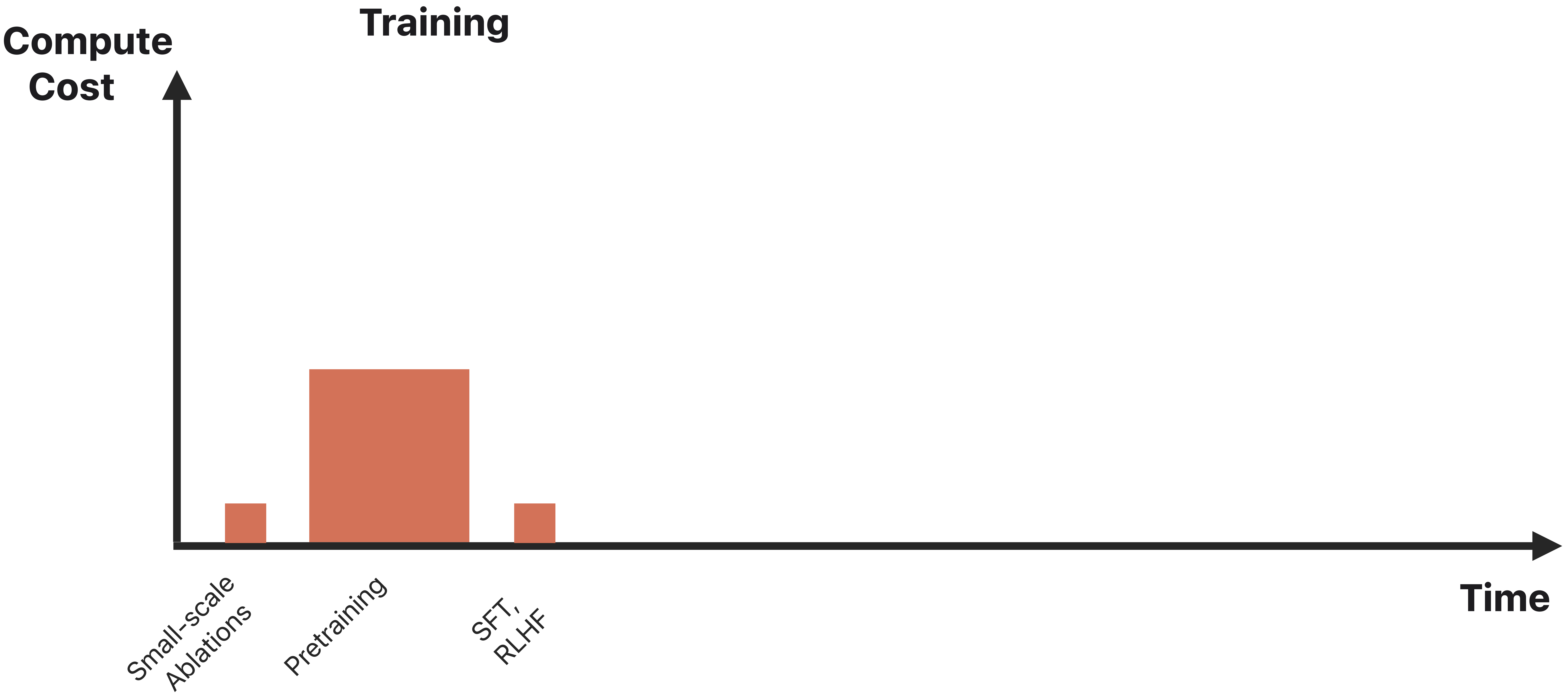

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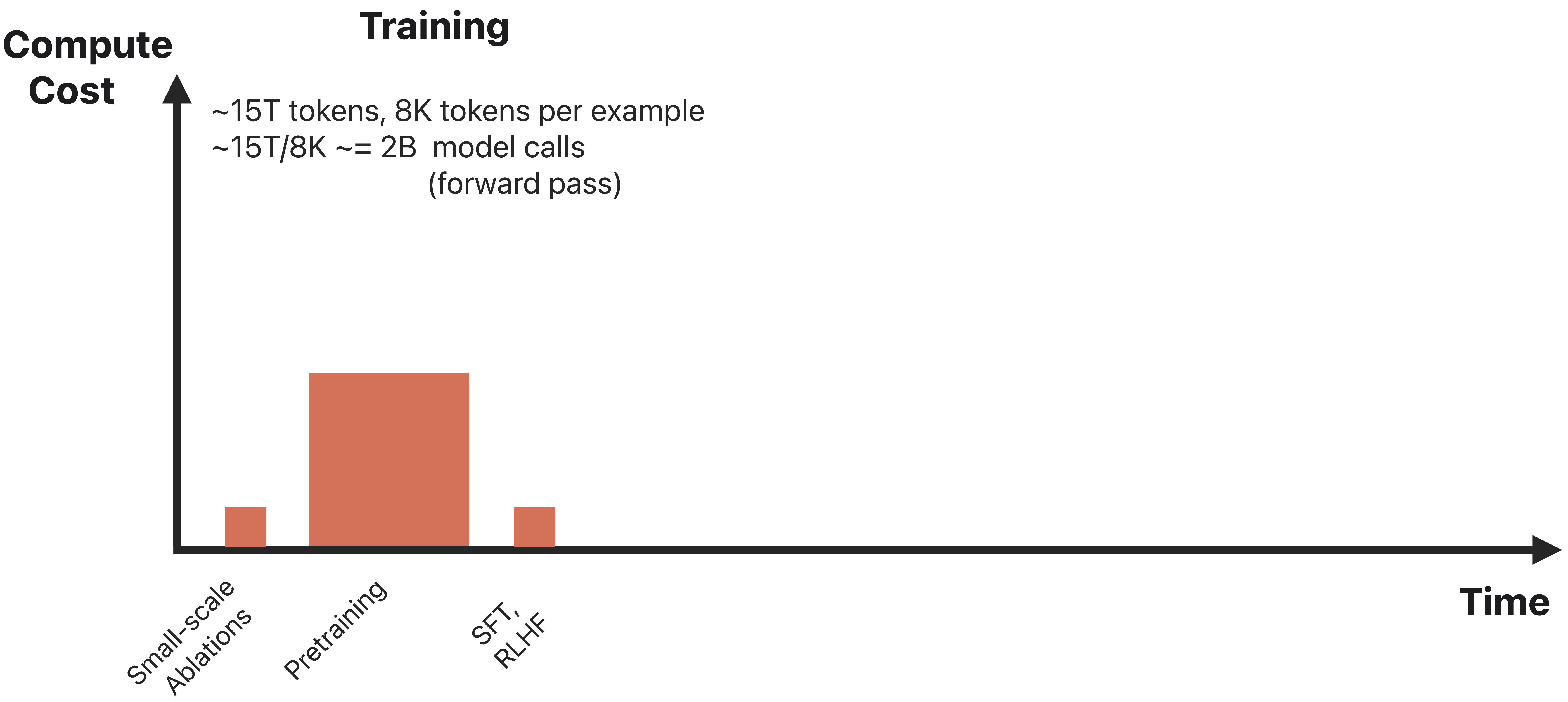

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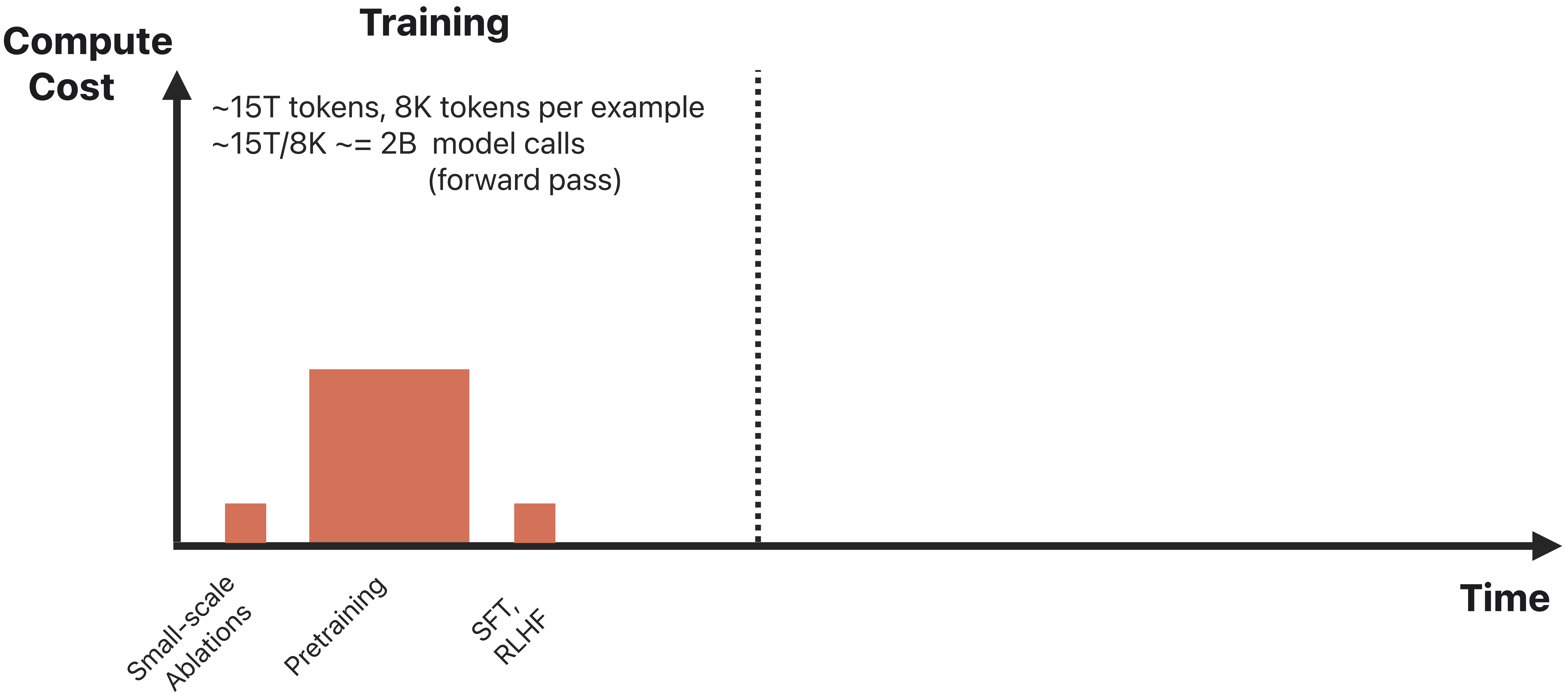

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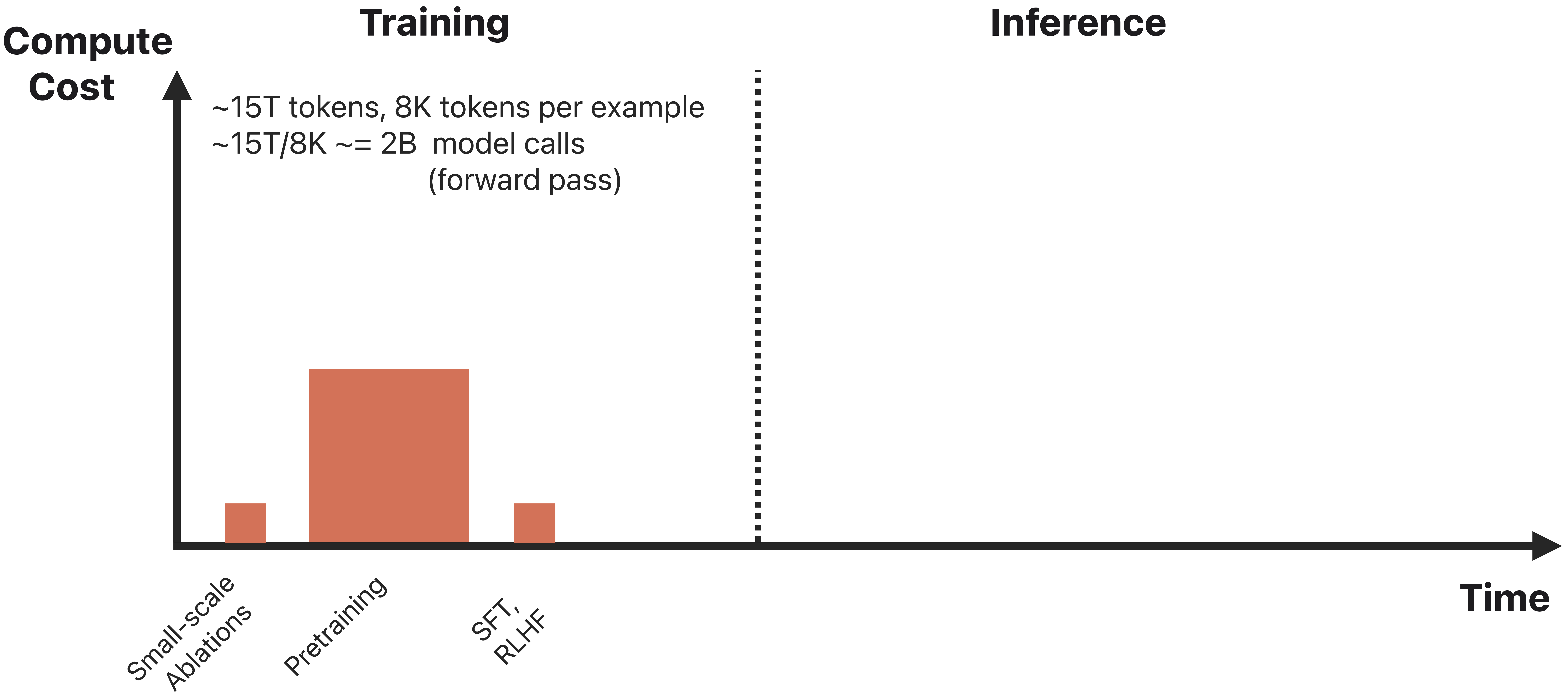

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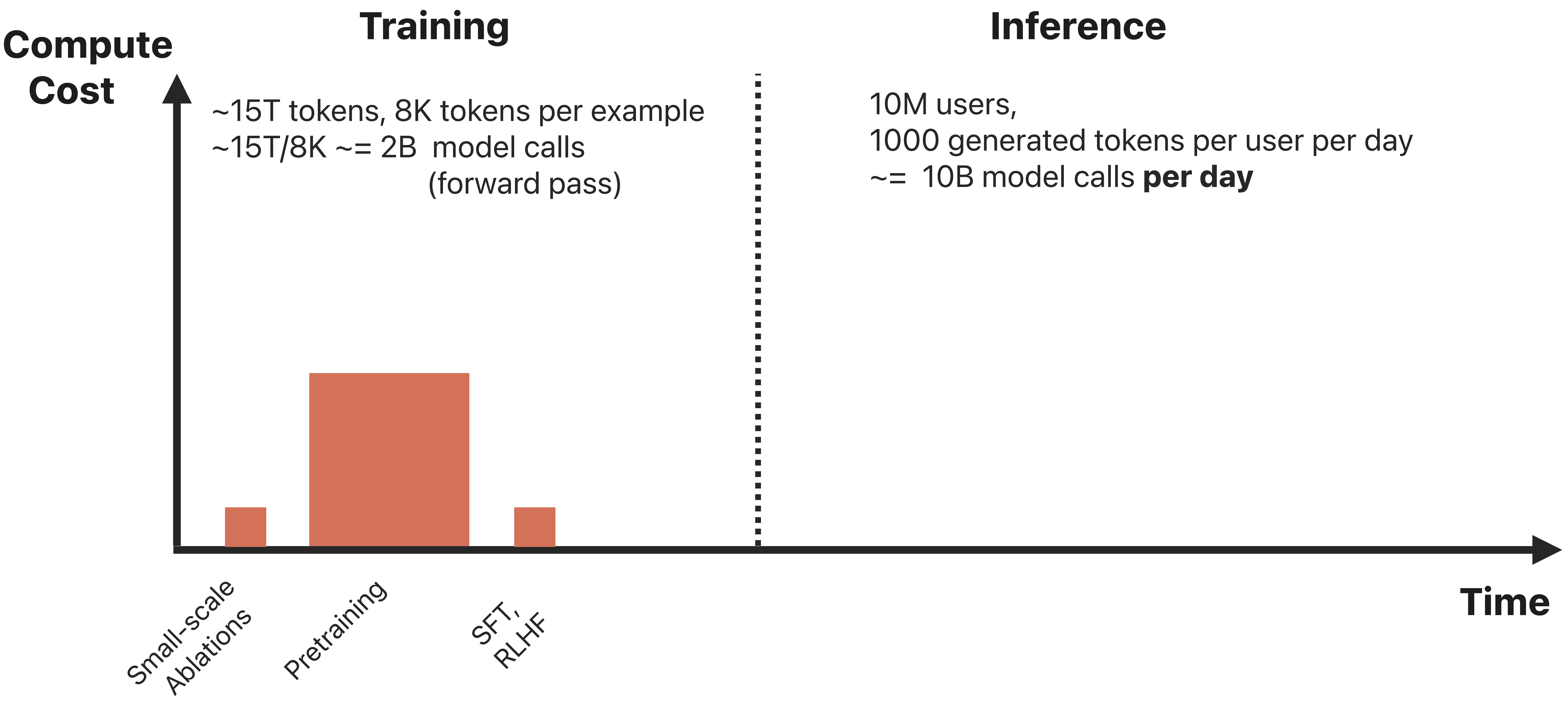

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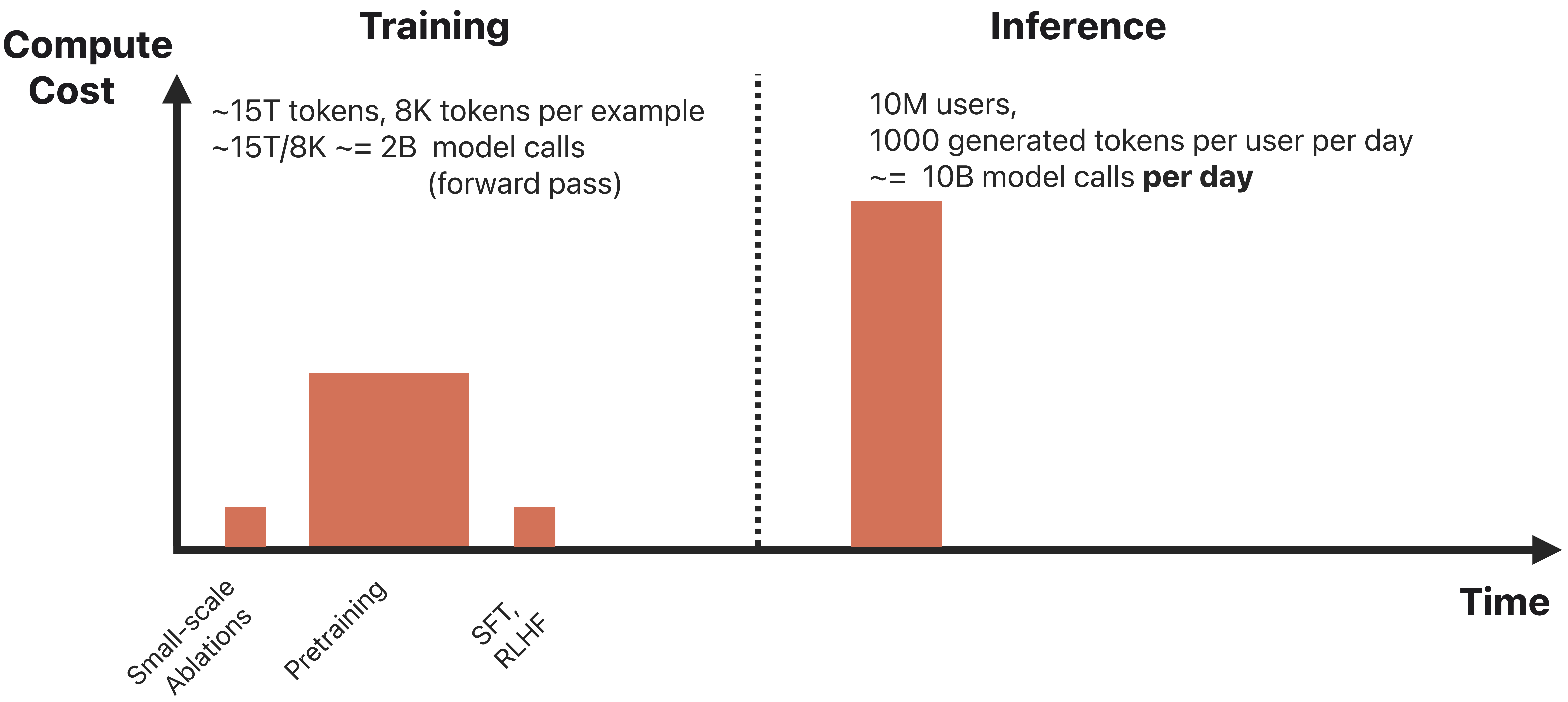

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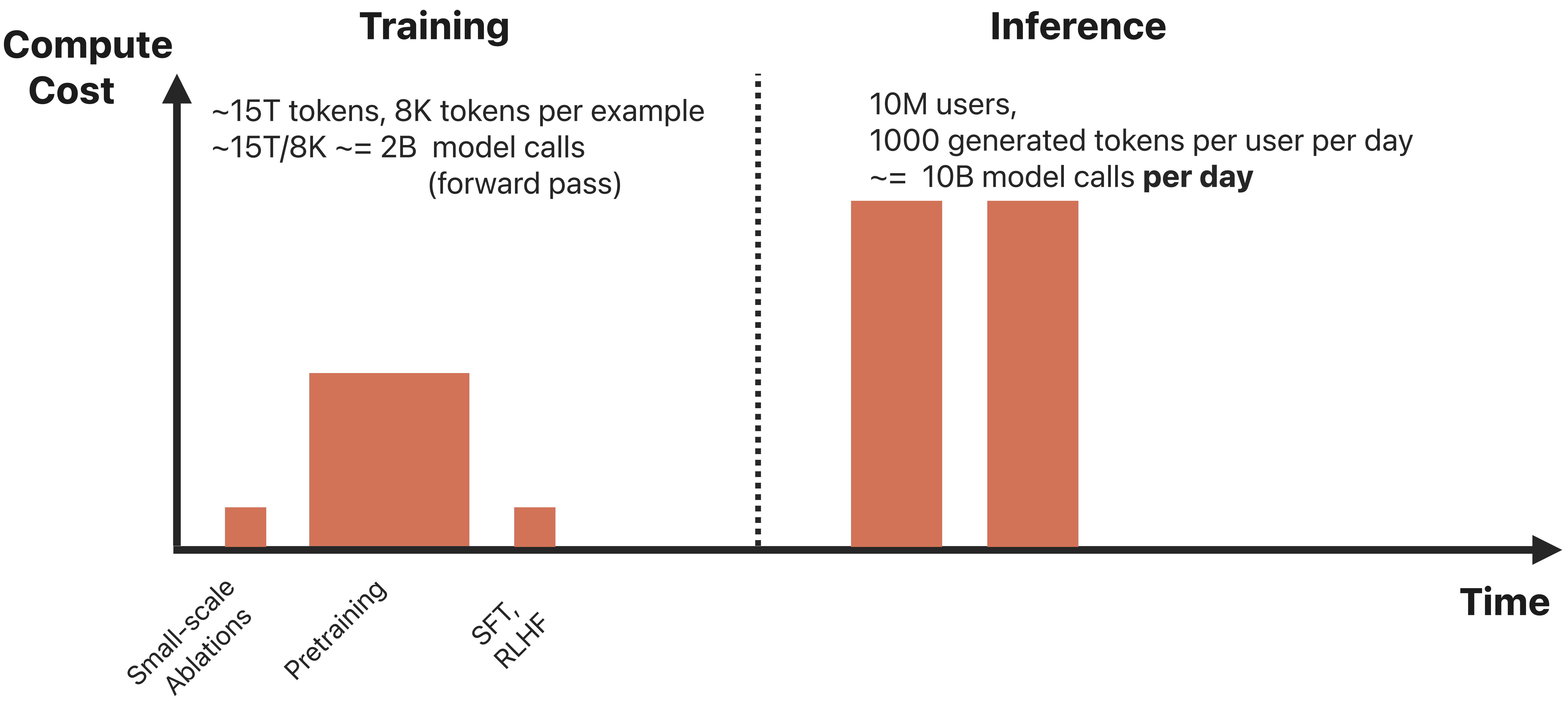

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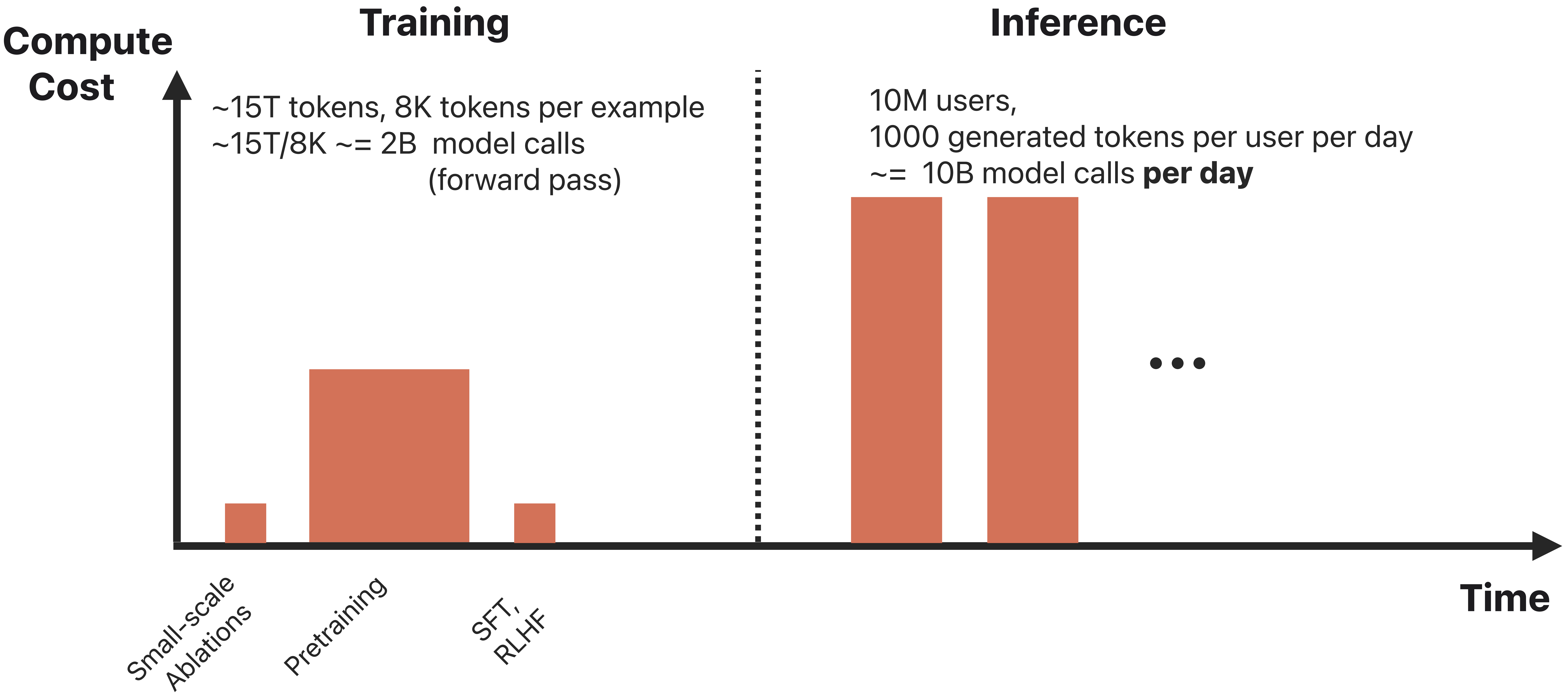

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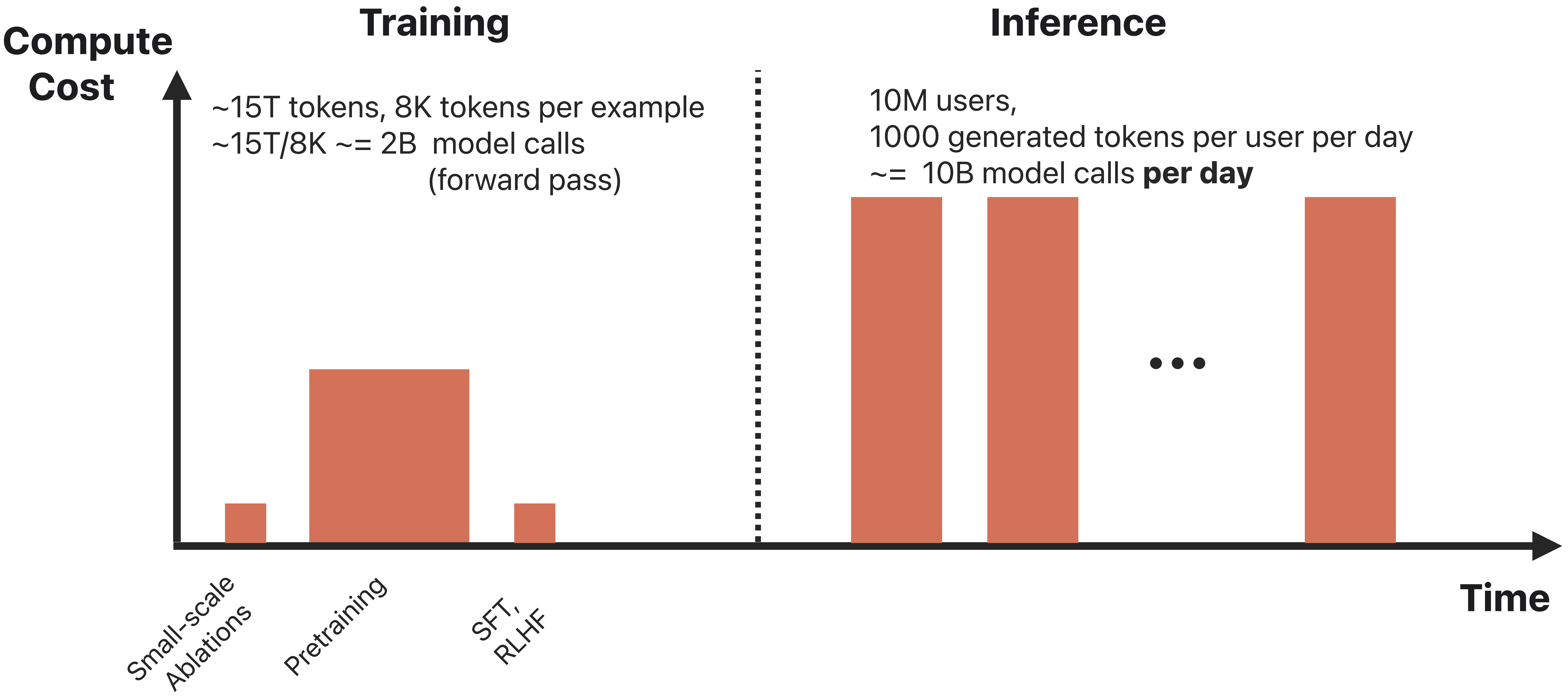

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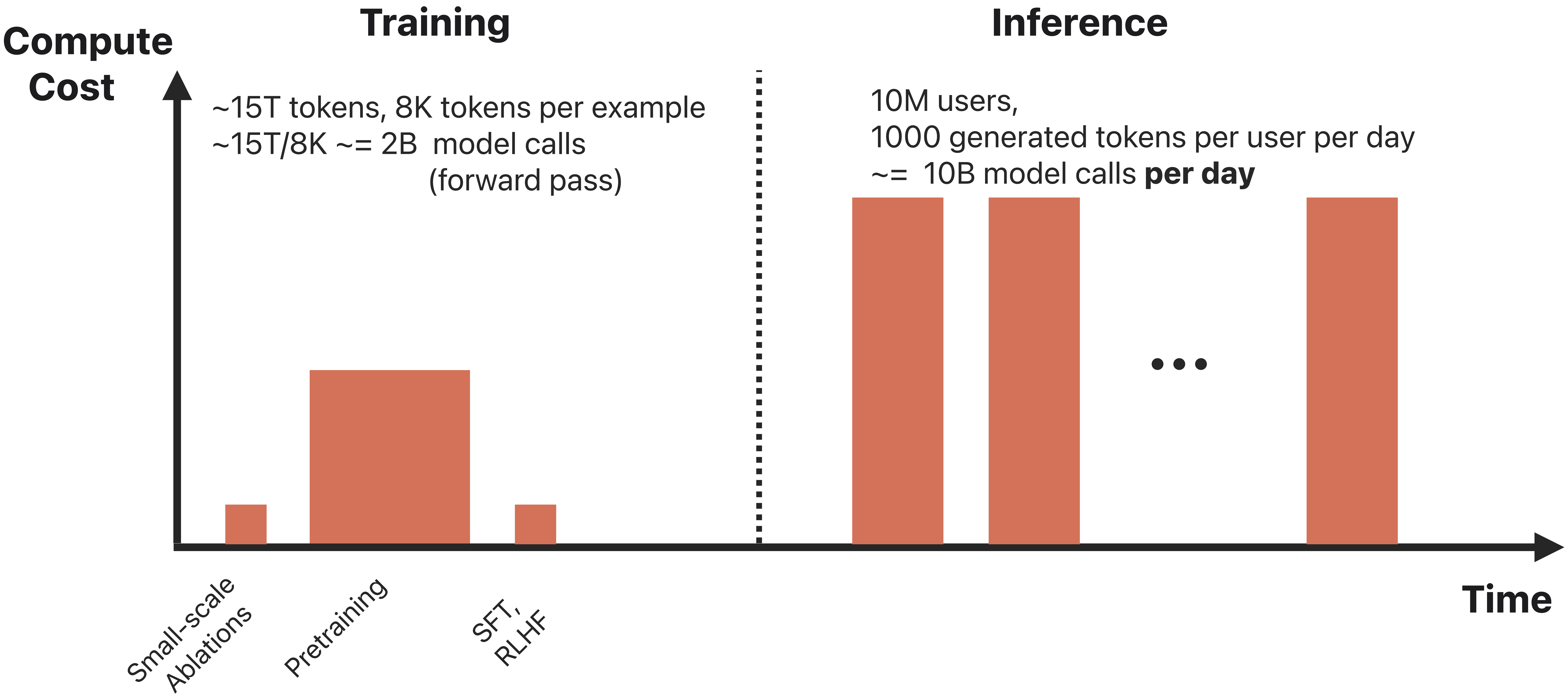
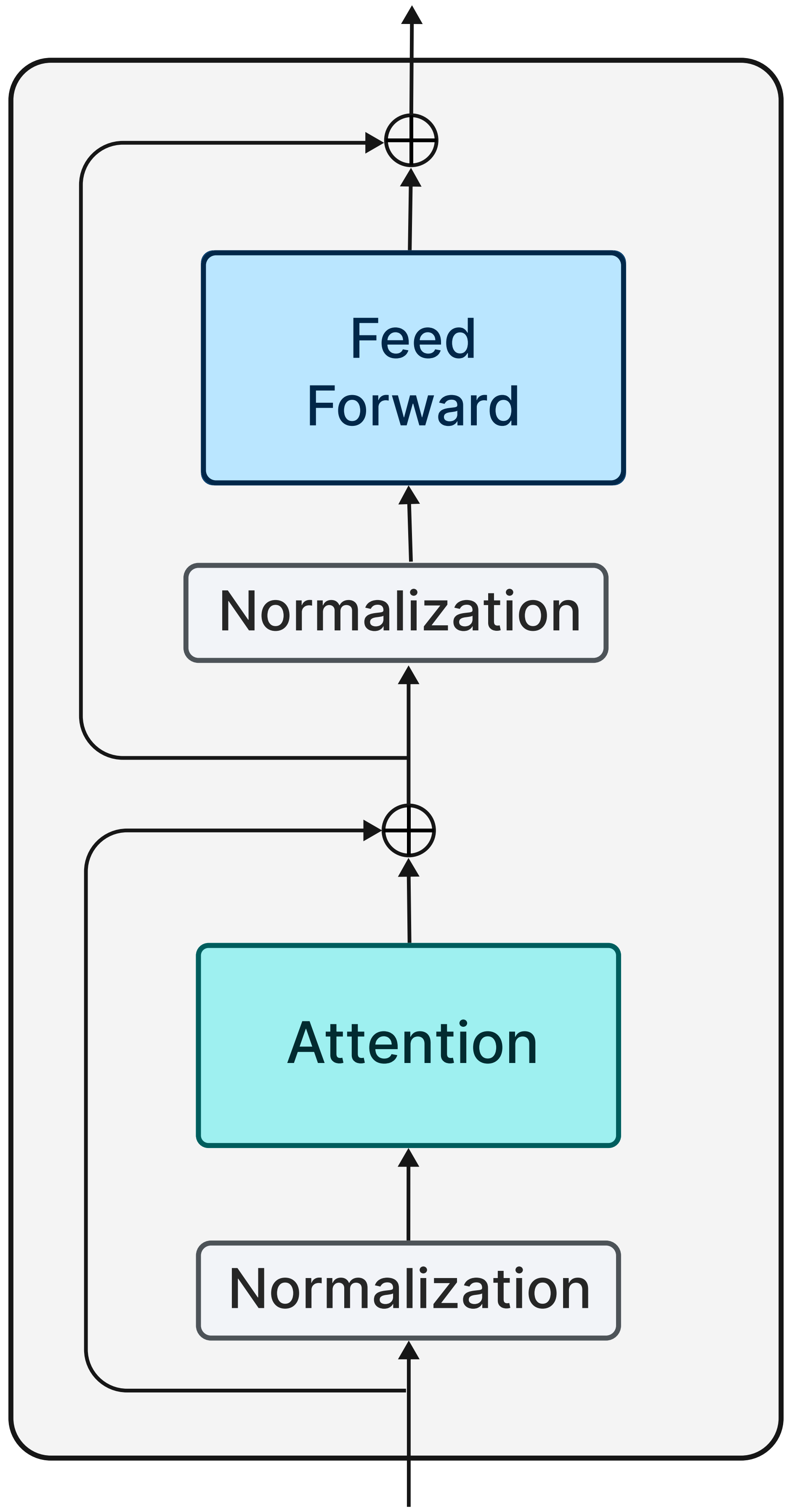


[1] OpenAI's ChatGPT now has 100 million weekly active users
https://techcrunch.com/2023/11/06/openais-chatgpt-now-has-100-million-weekly-active-users/

Inference costs almost always outweigh training costs.

Motivation: Where are we spending our compute?



Transformer Block

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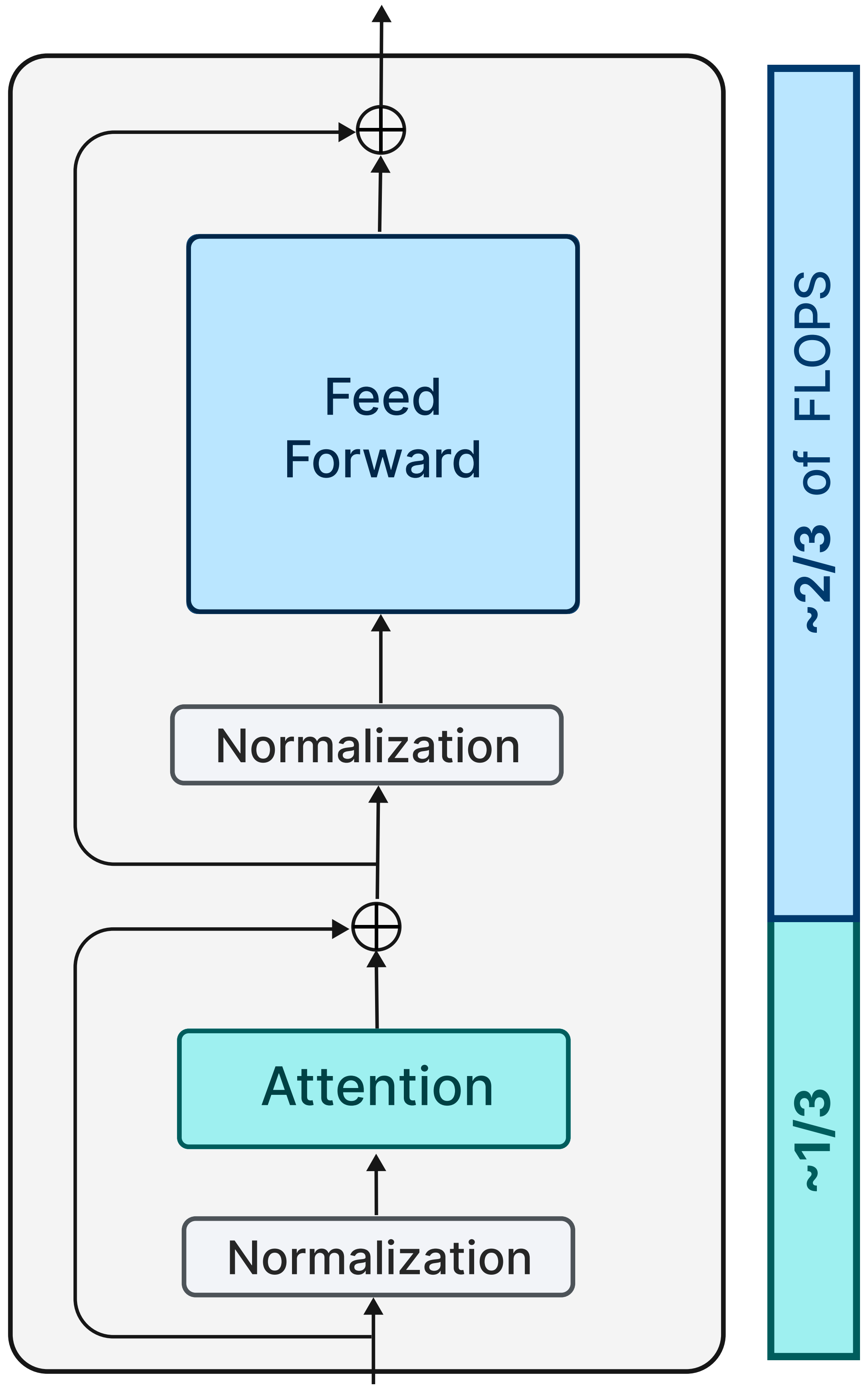

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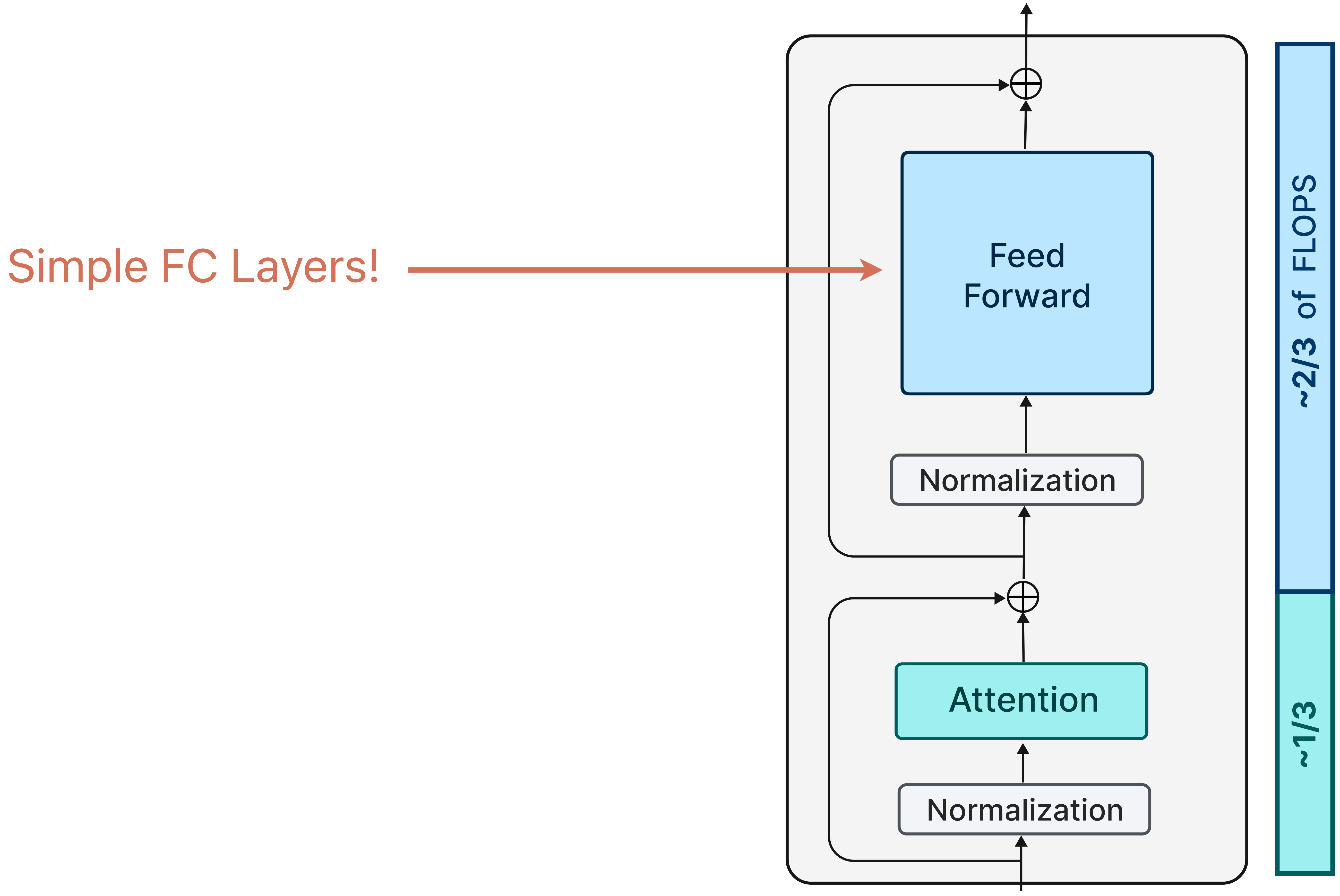

Transformer Block

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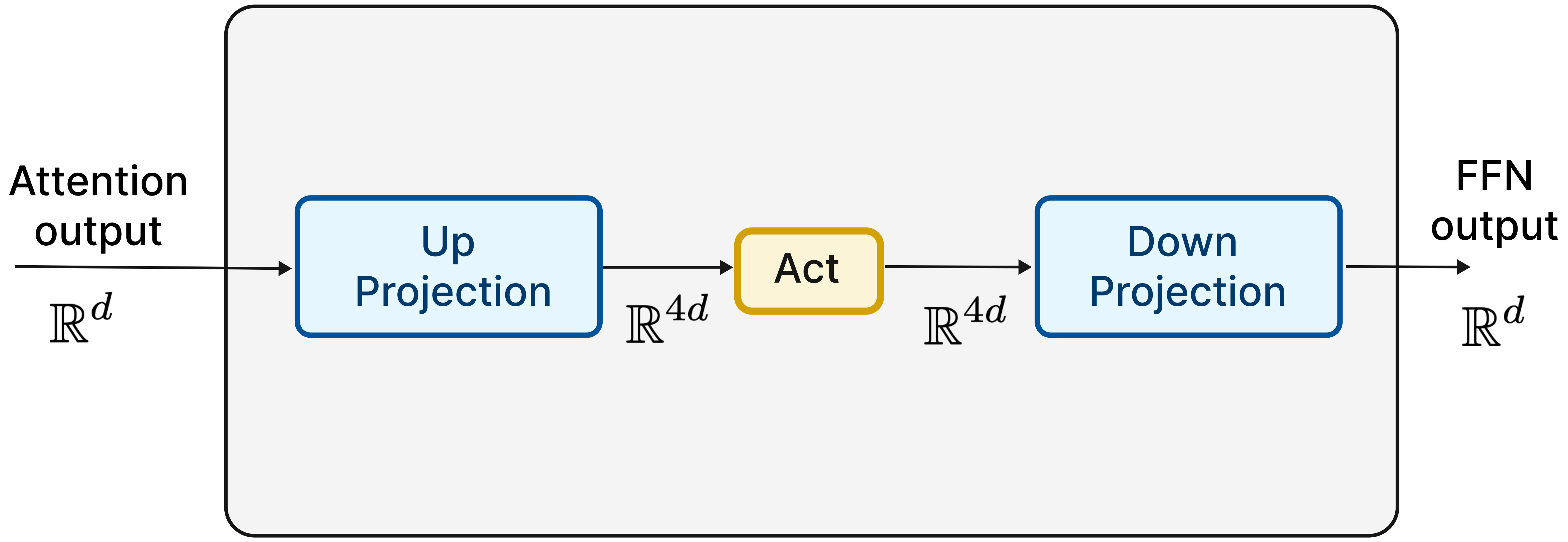

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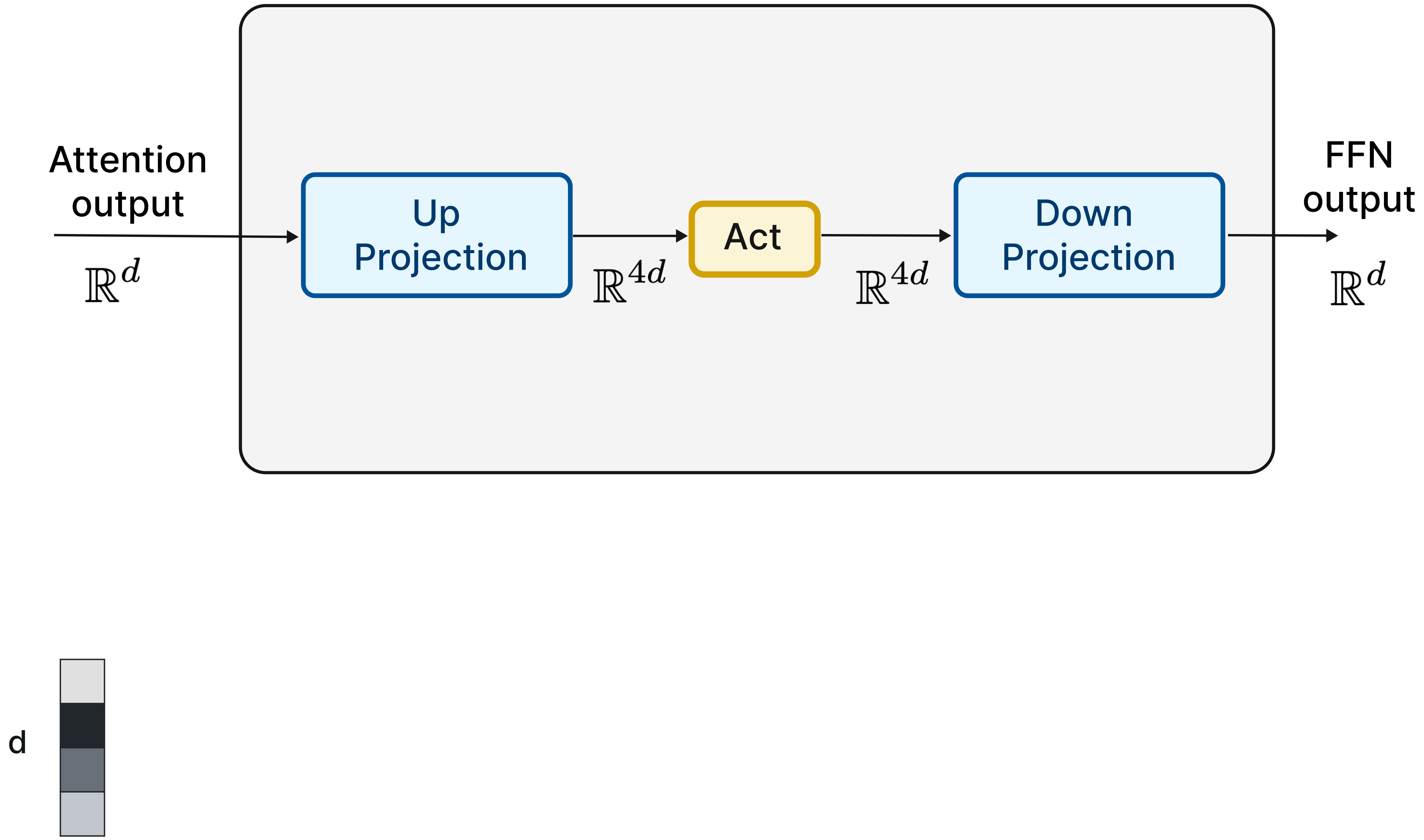

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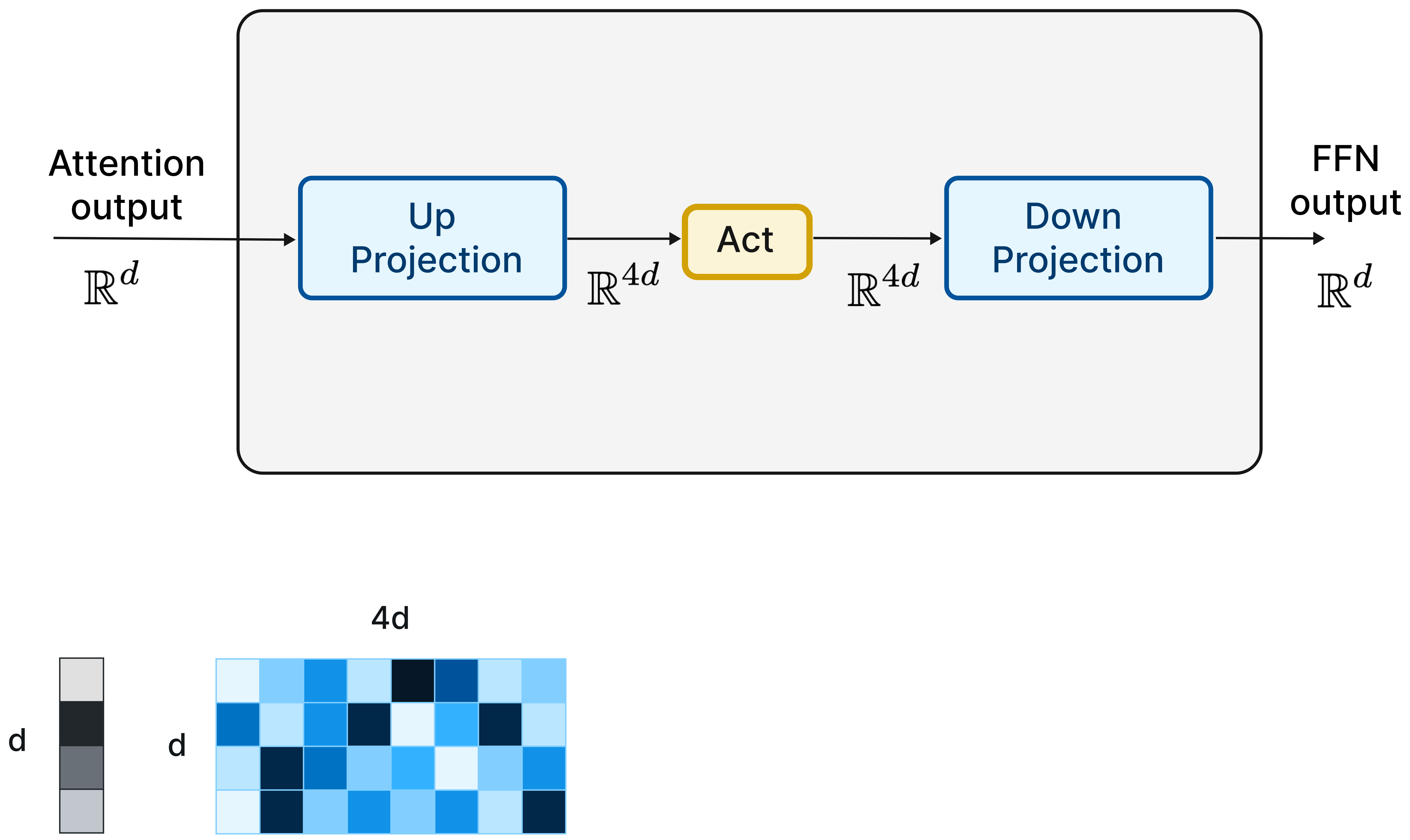

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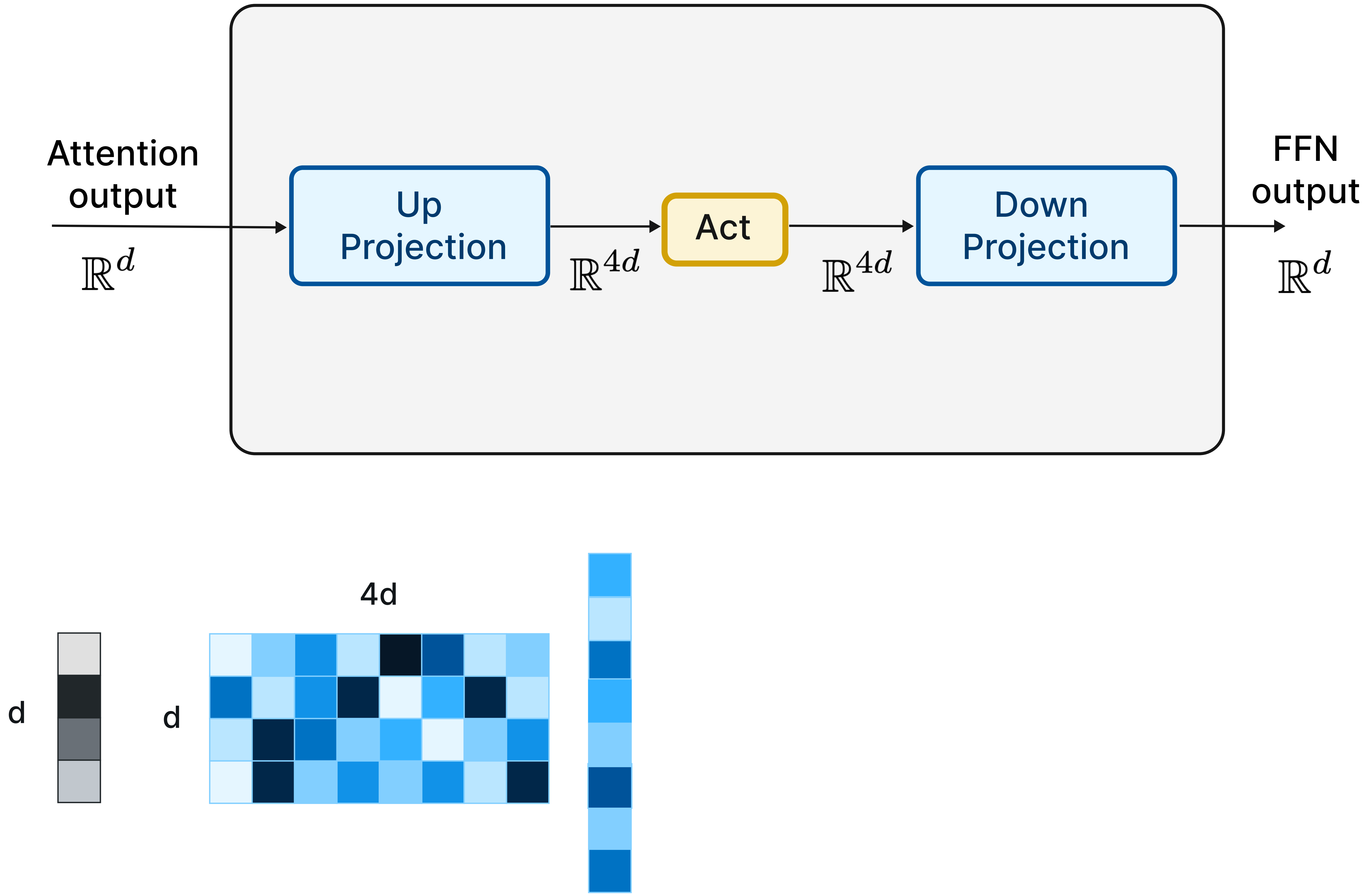

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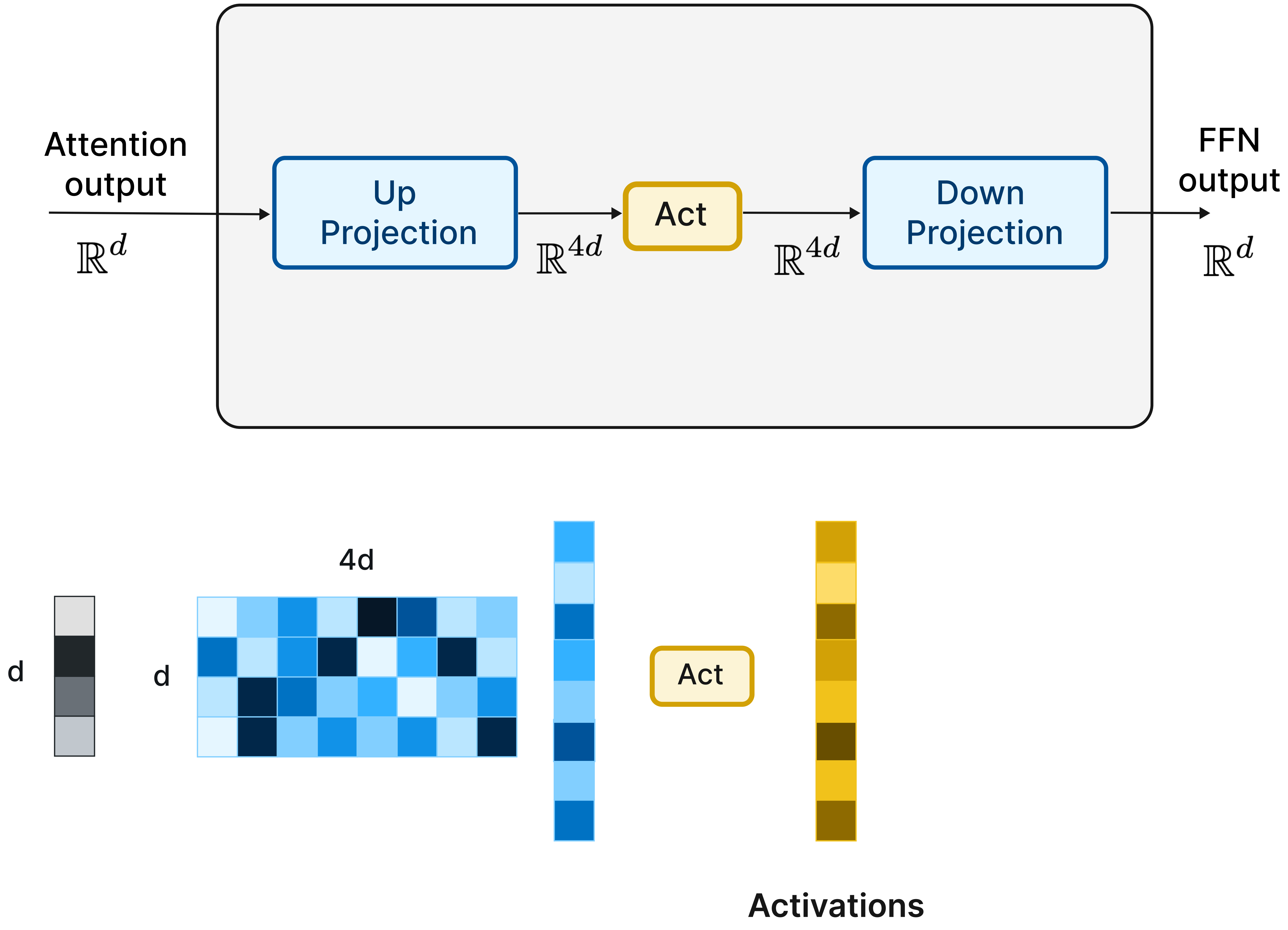

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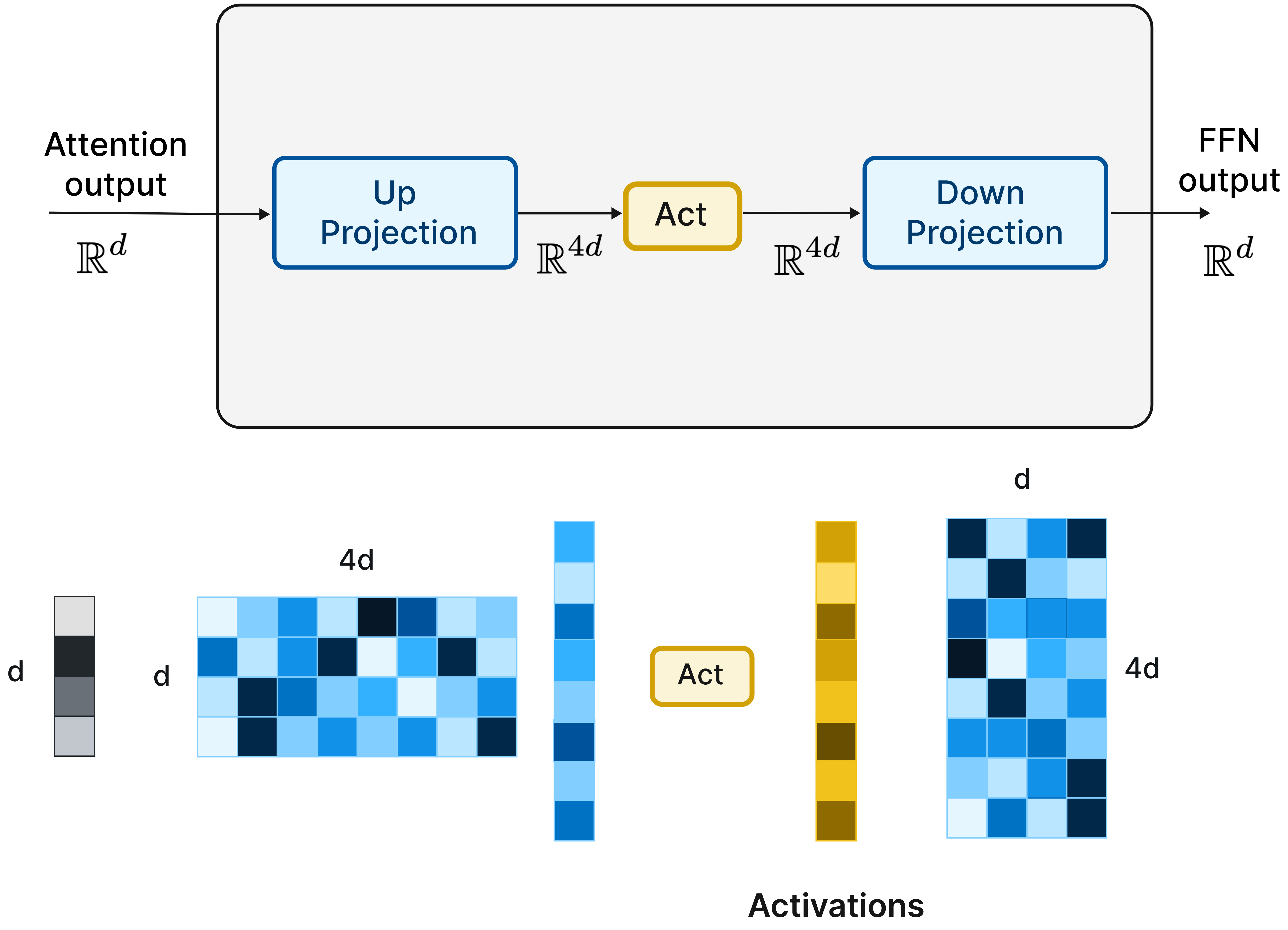

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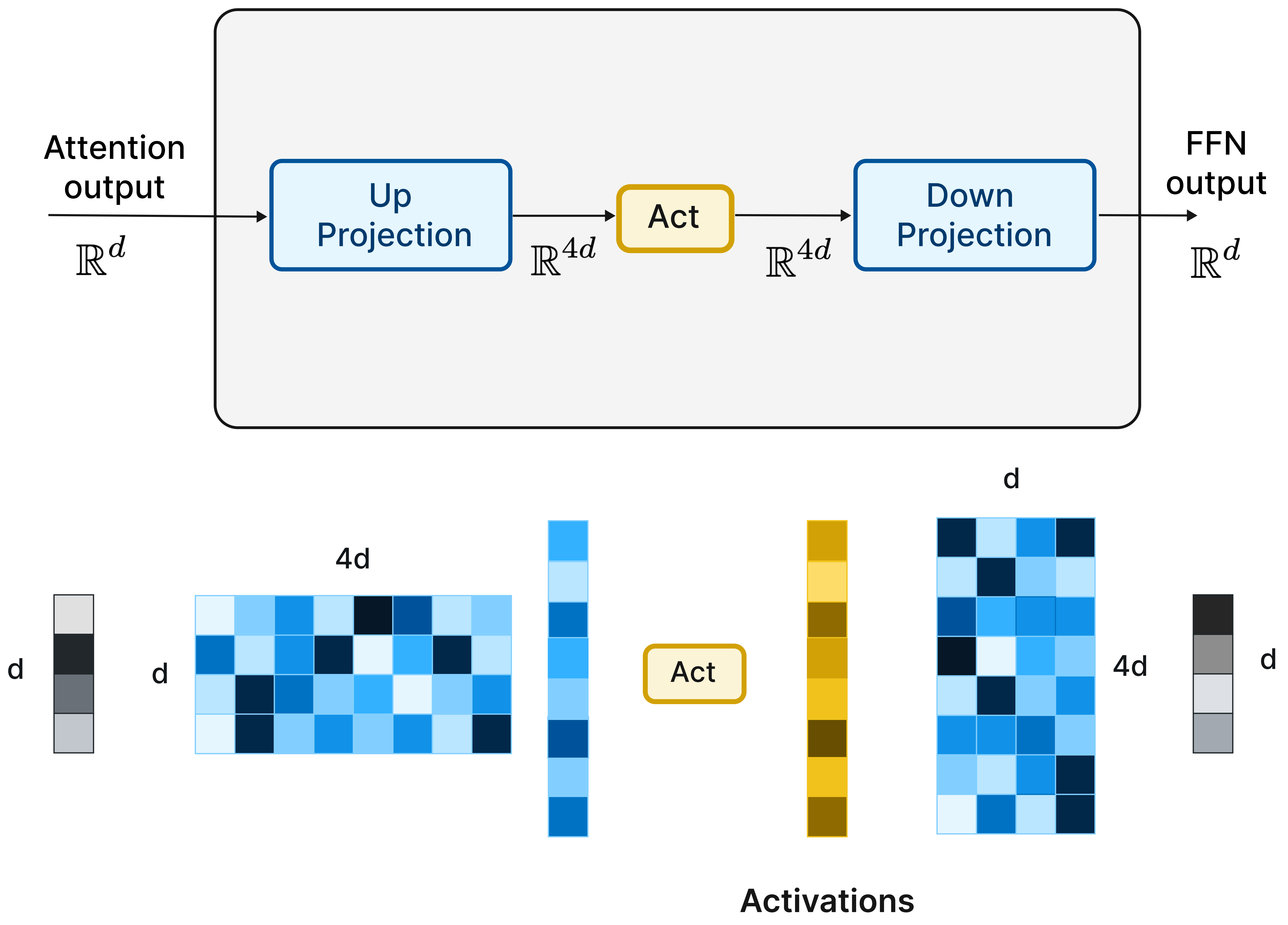

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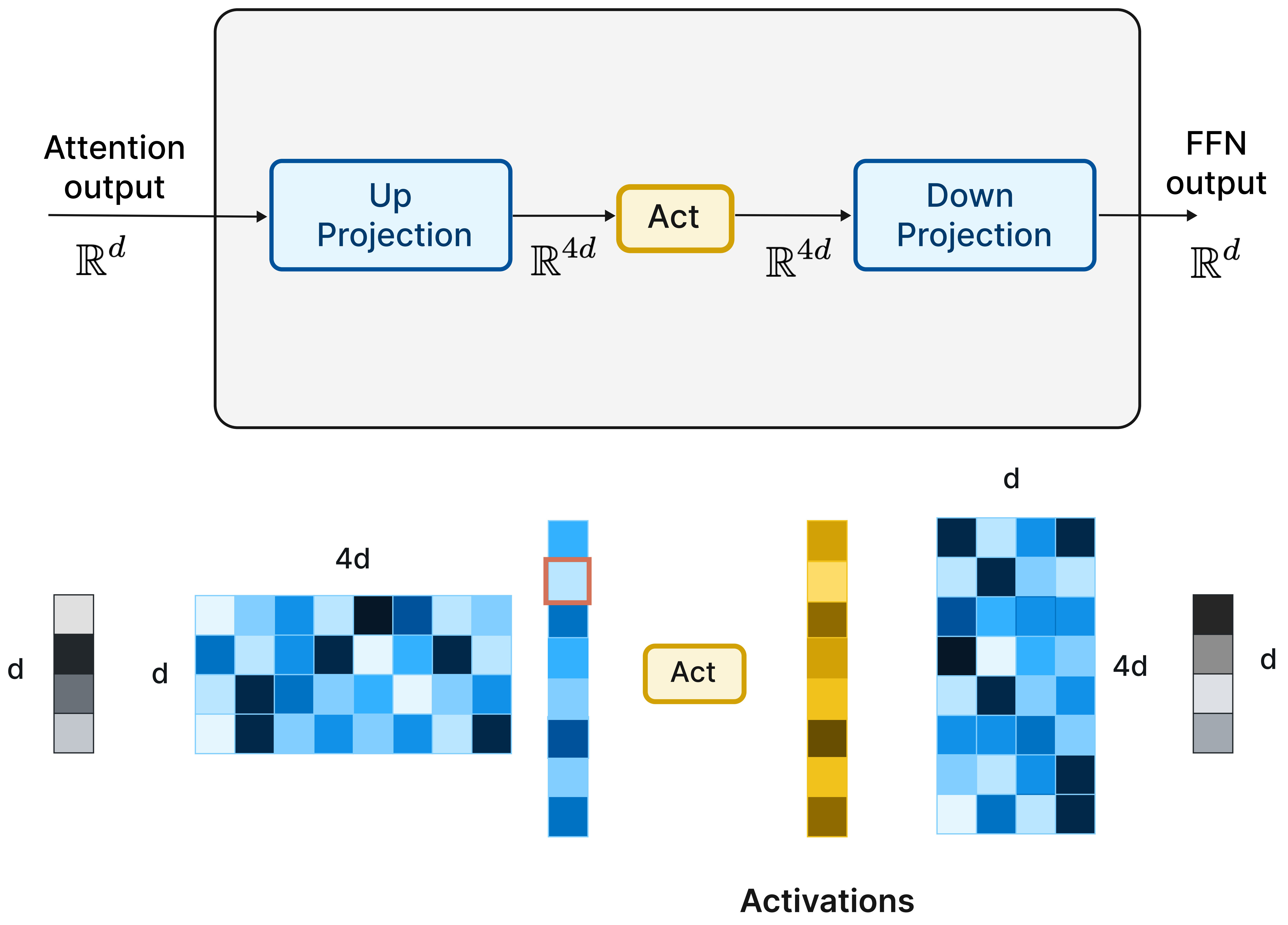

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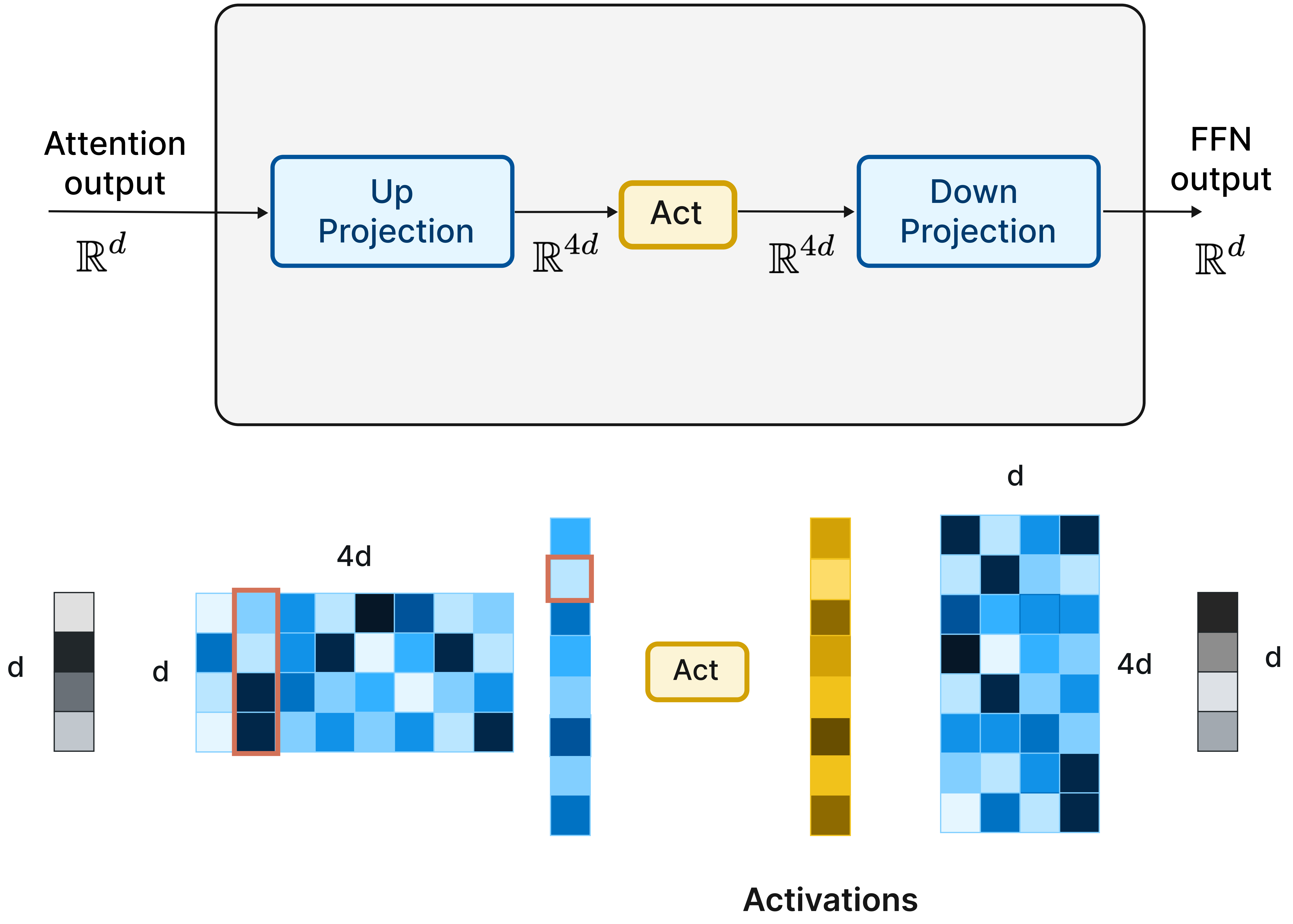

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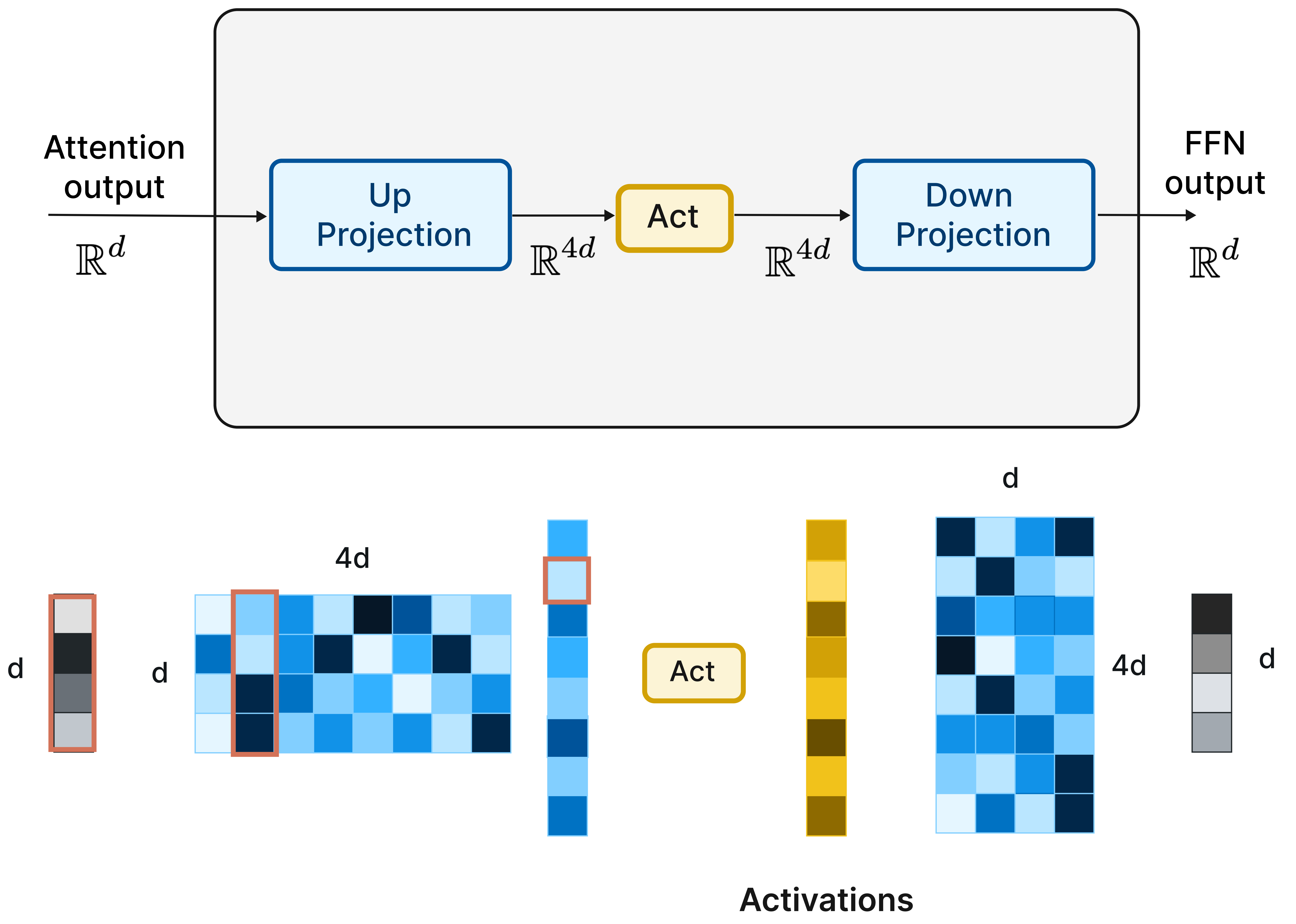

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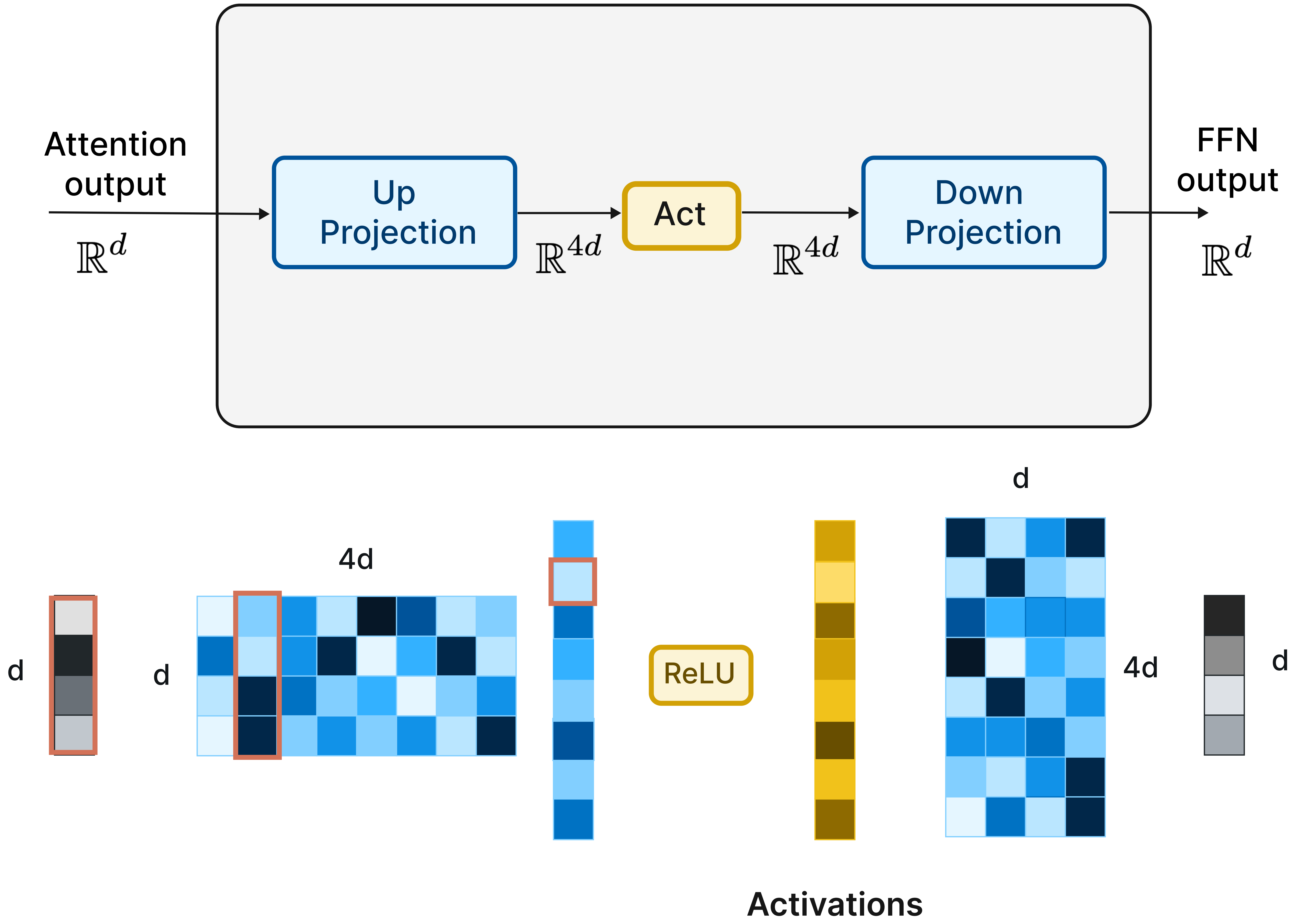

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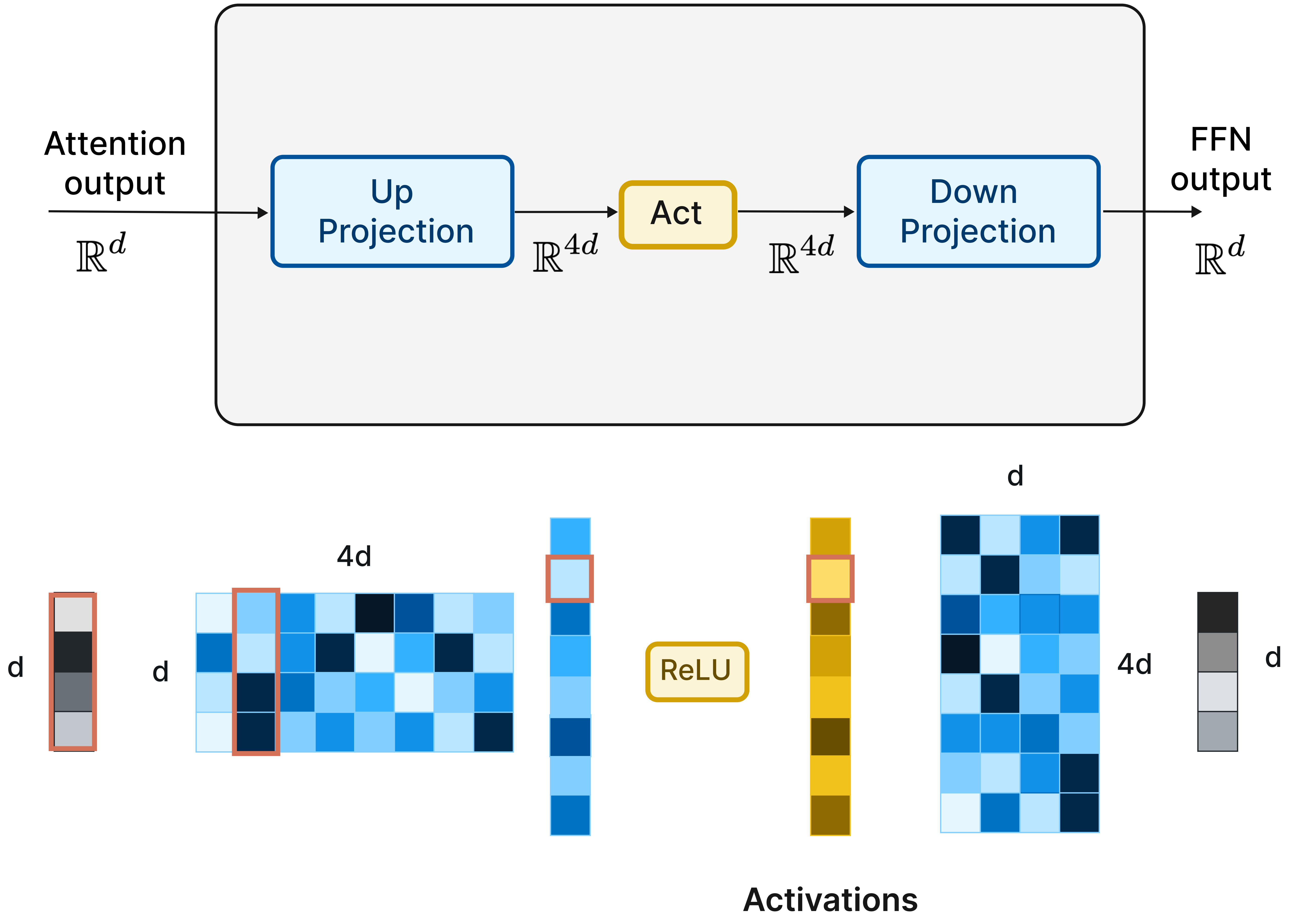

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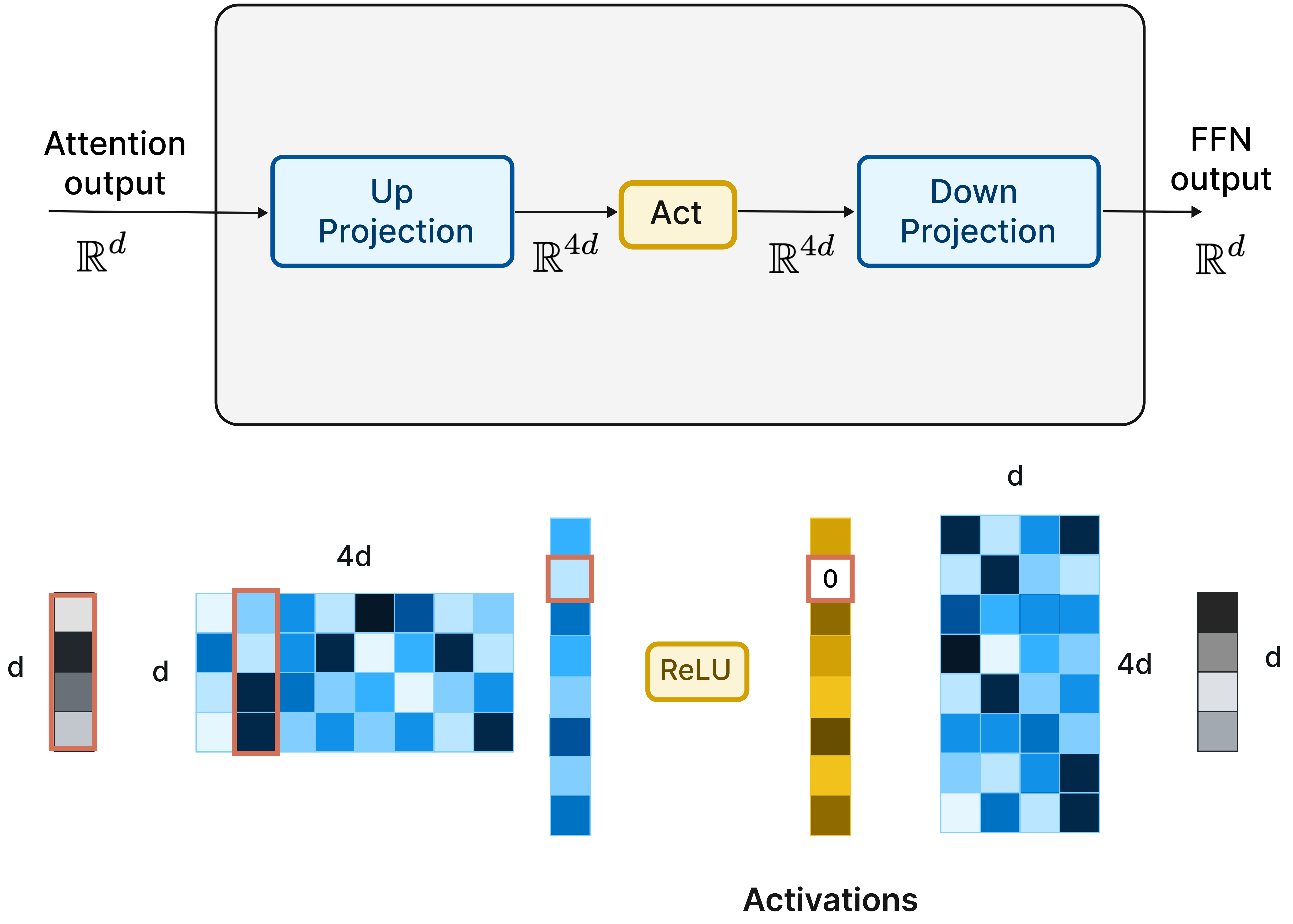

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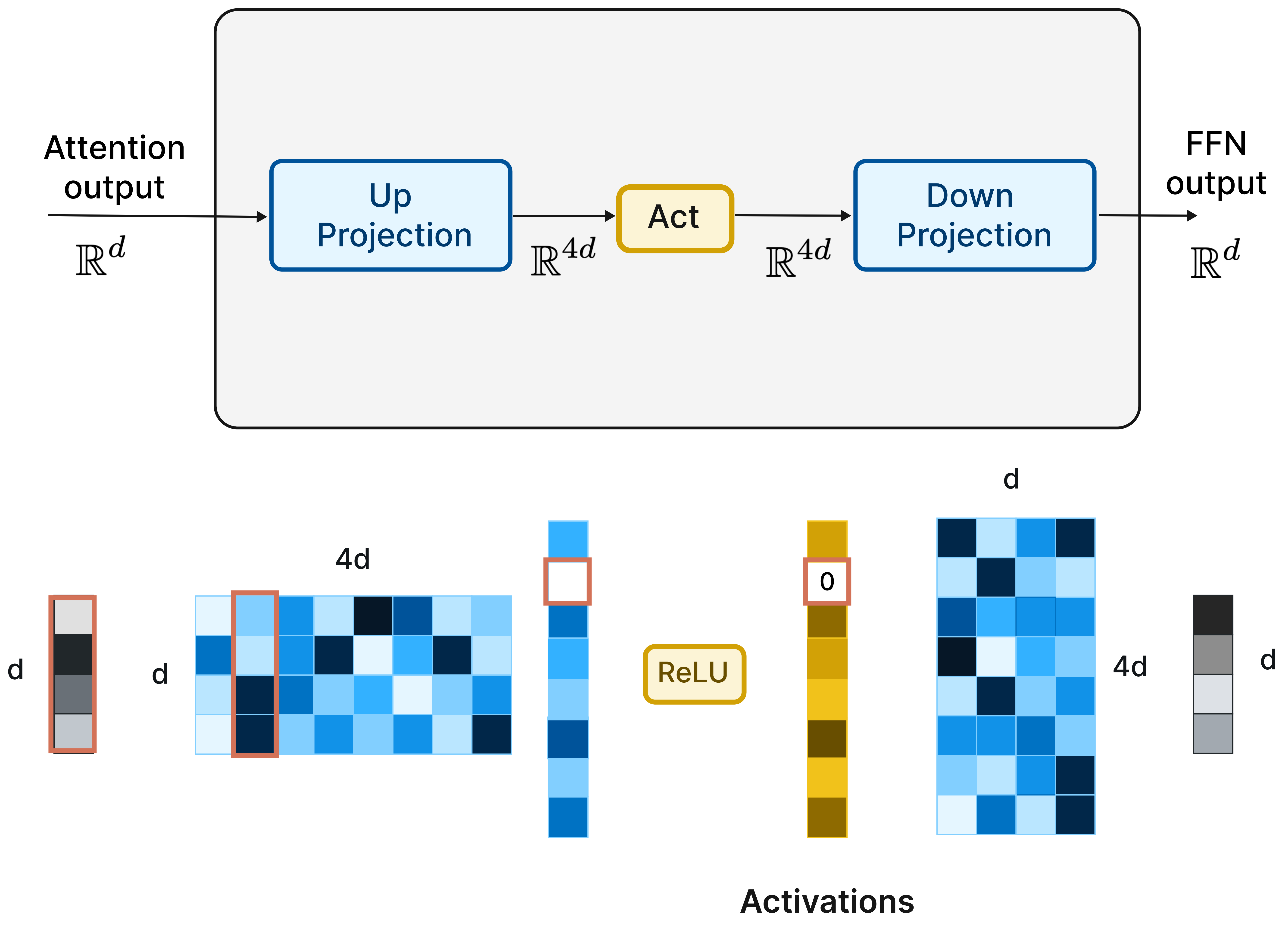

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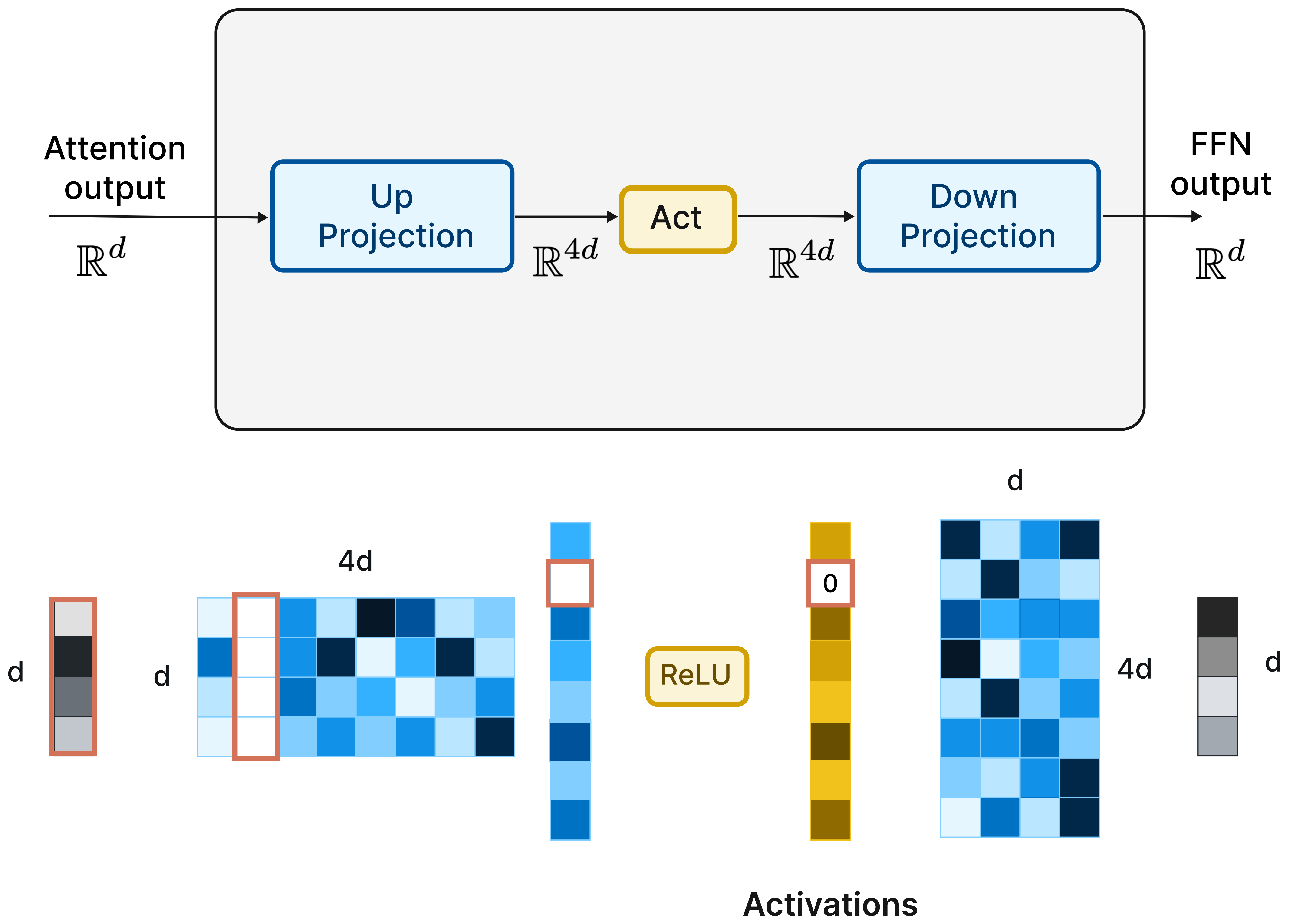

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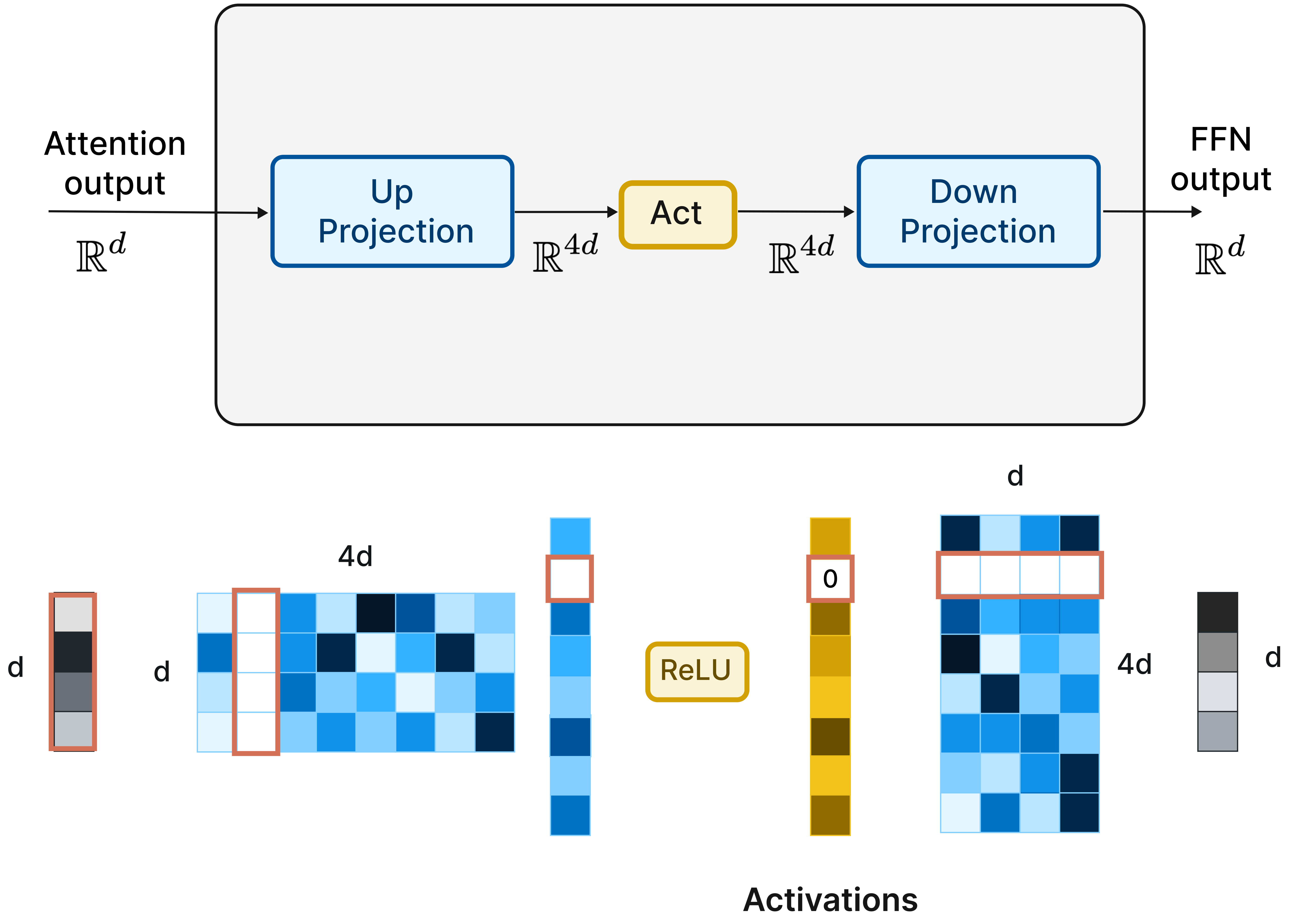

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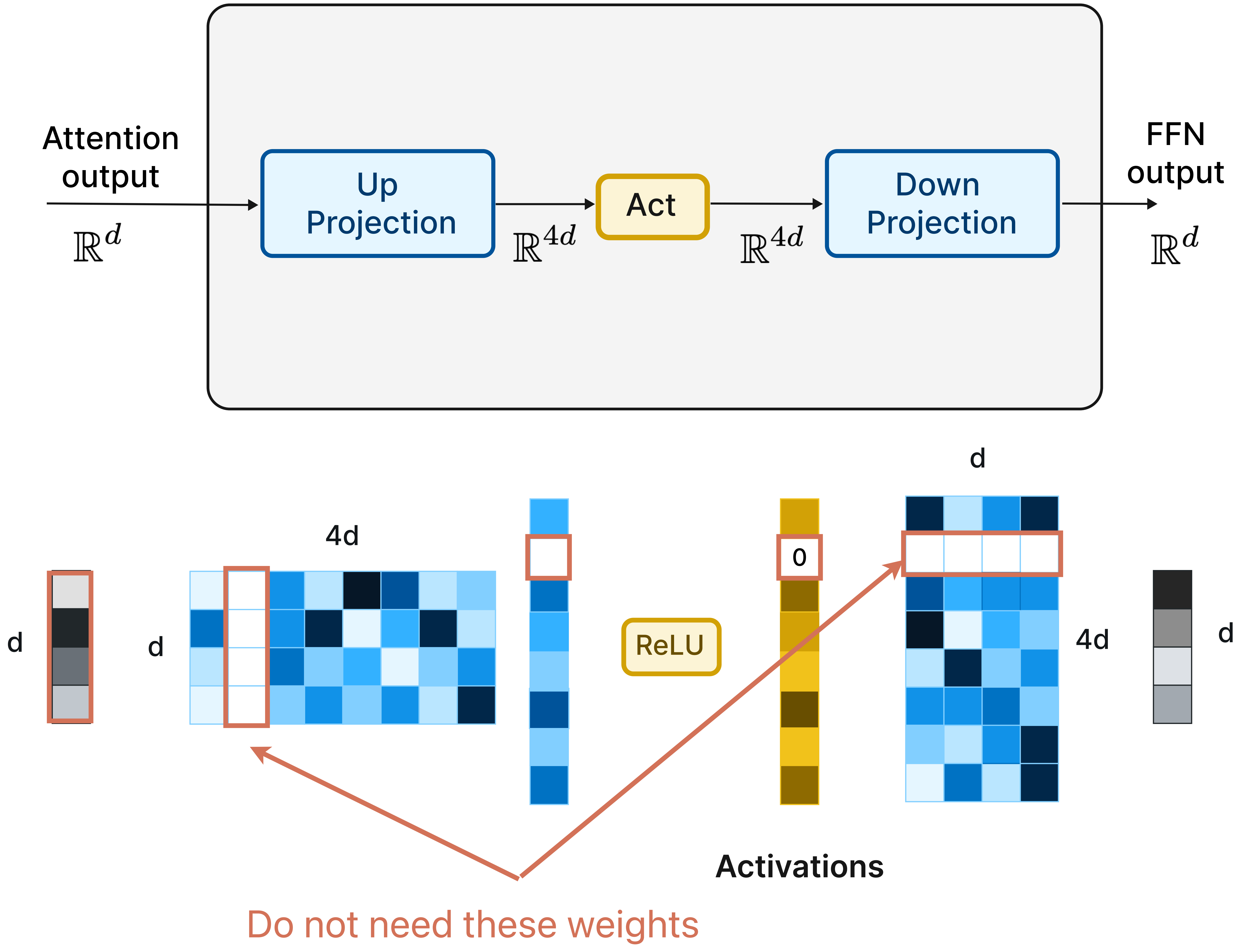

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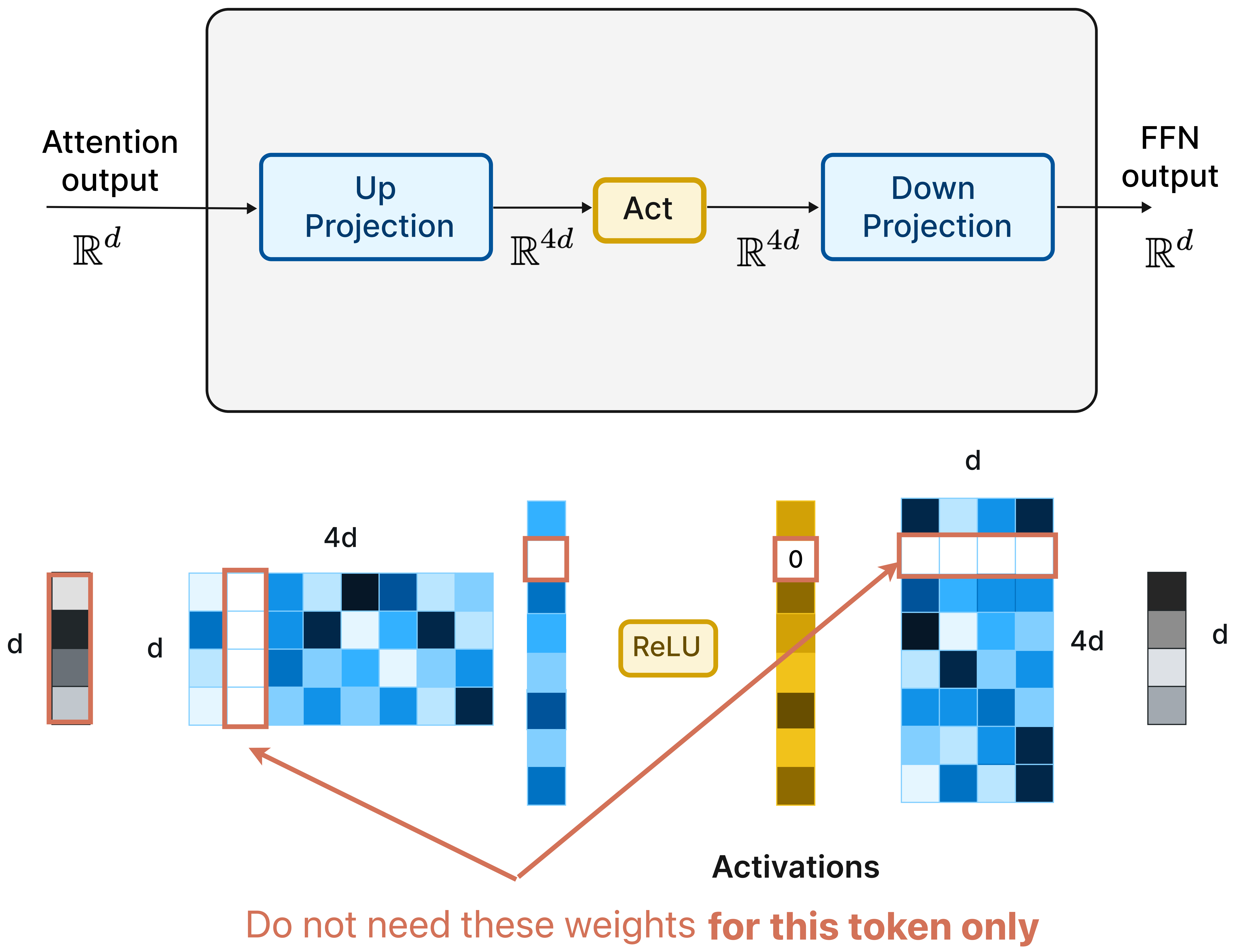
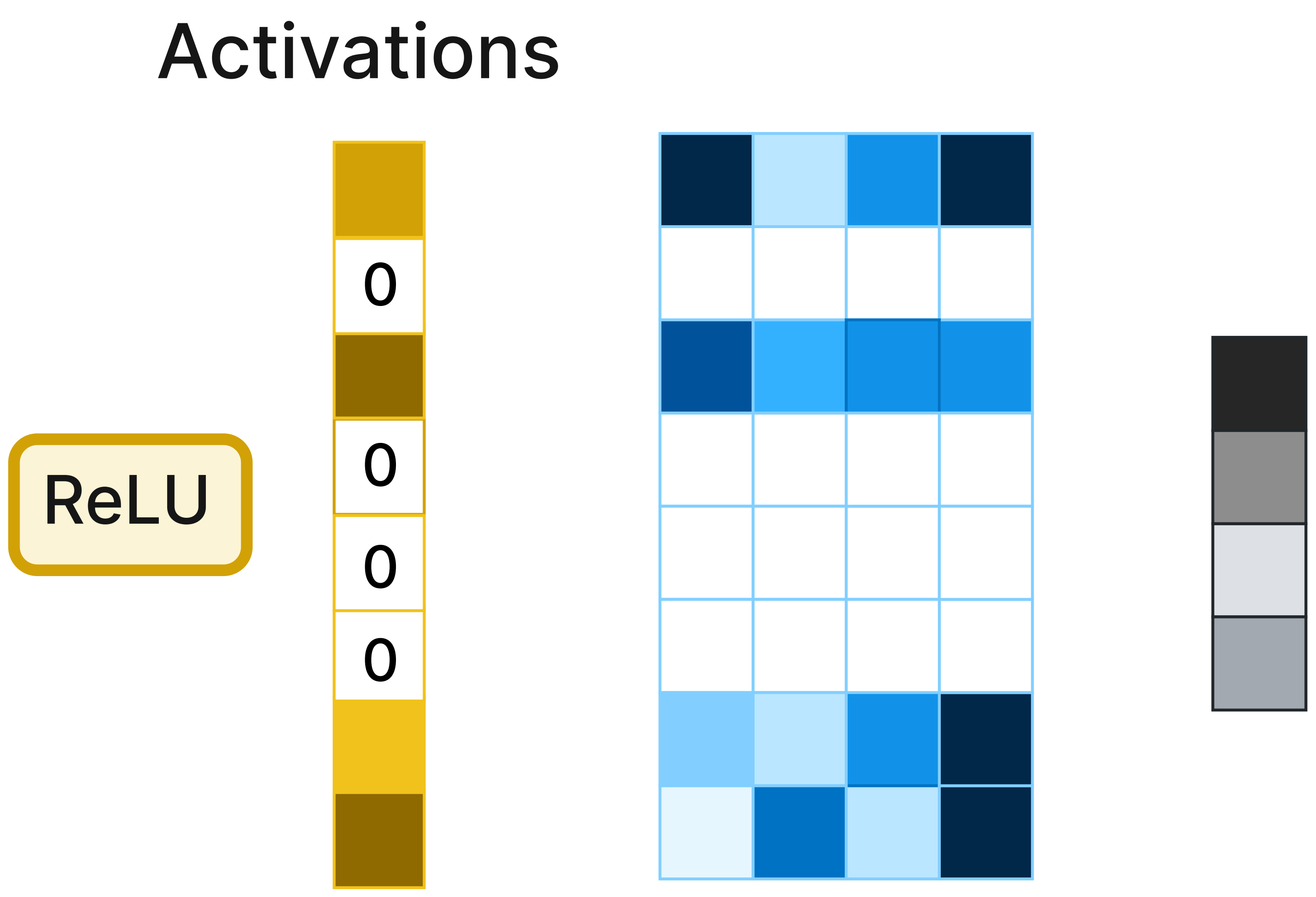


Activation Sparsity: The Benefits of ReLU



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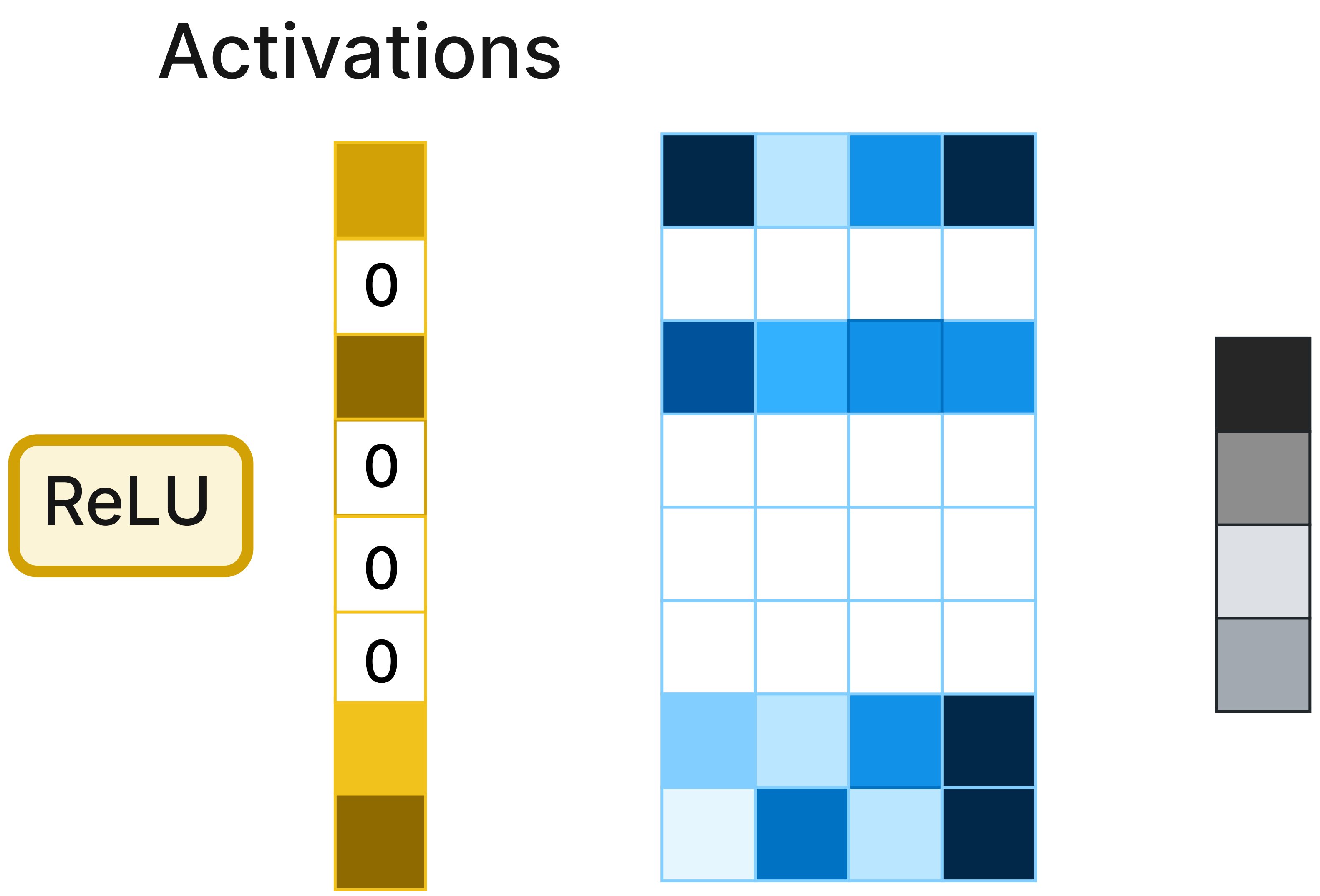

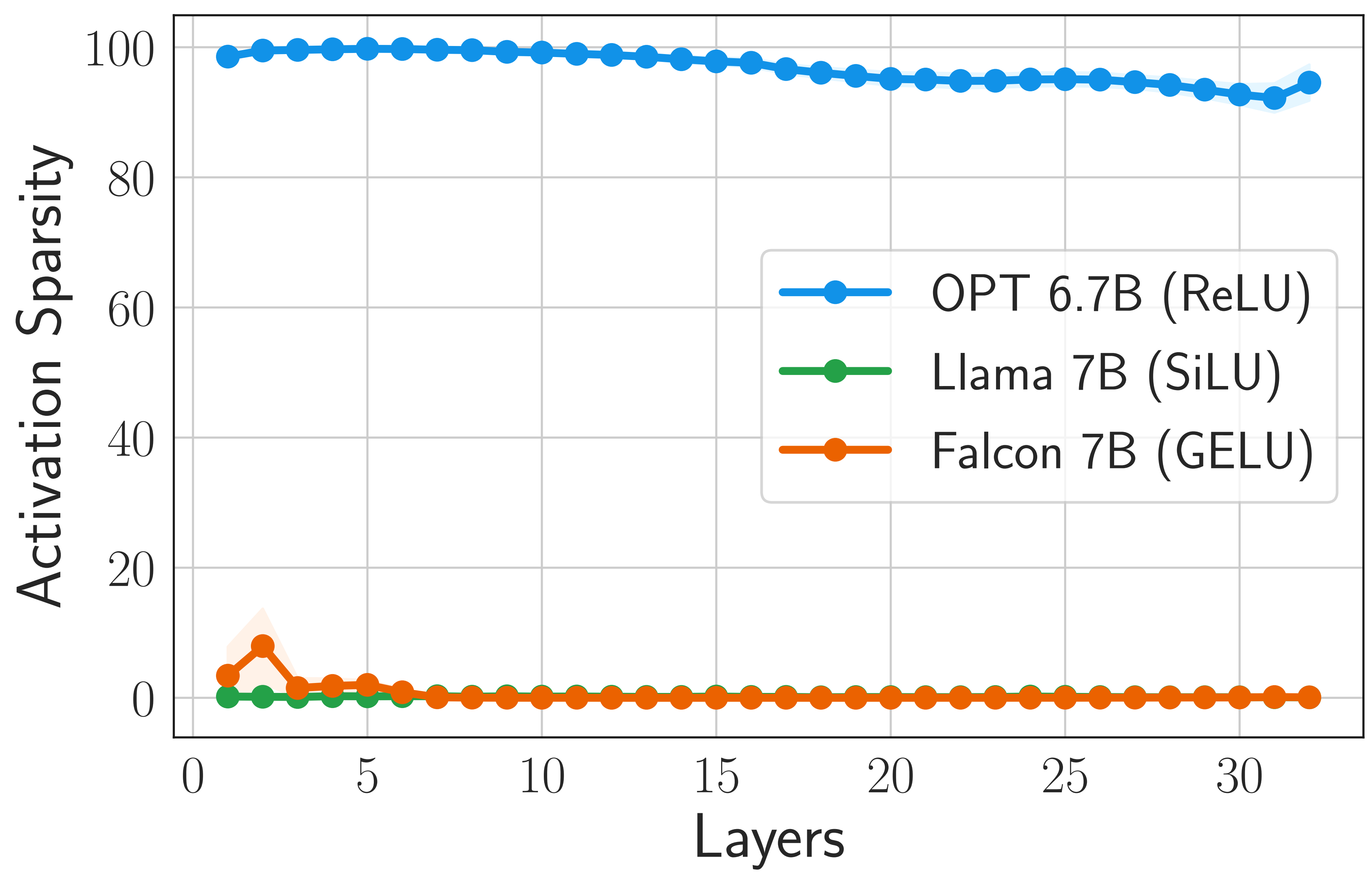

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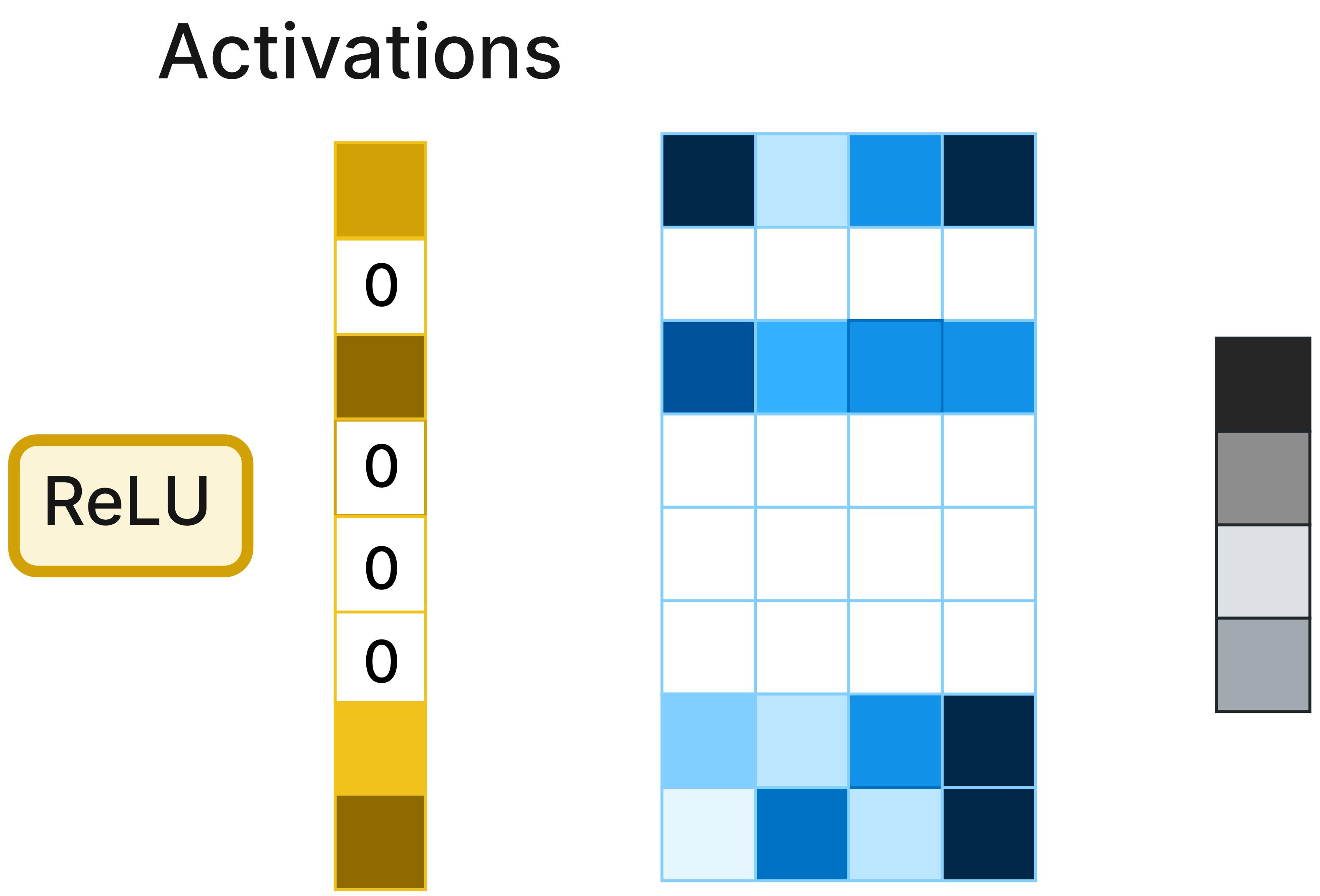
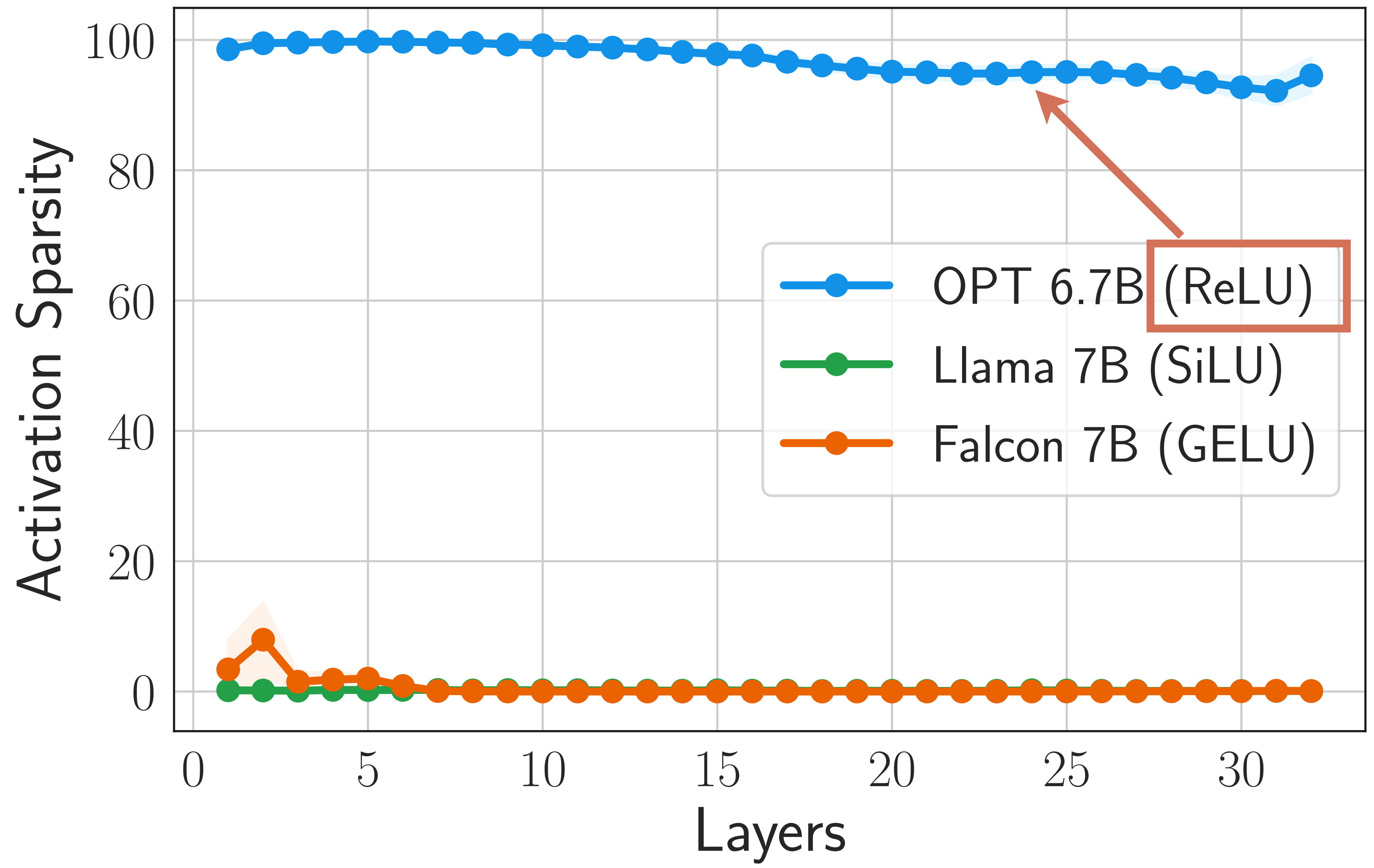
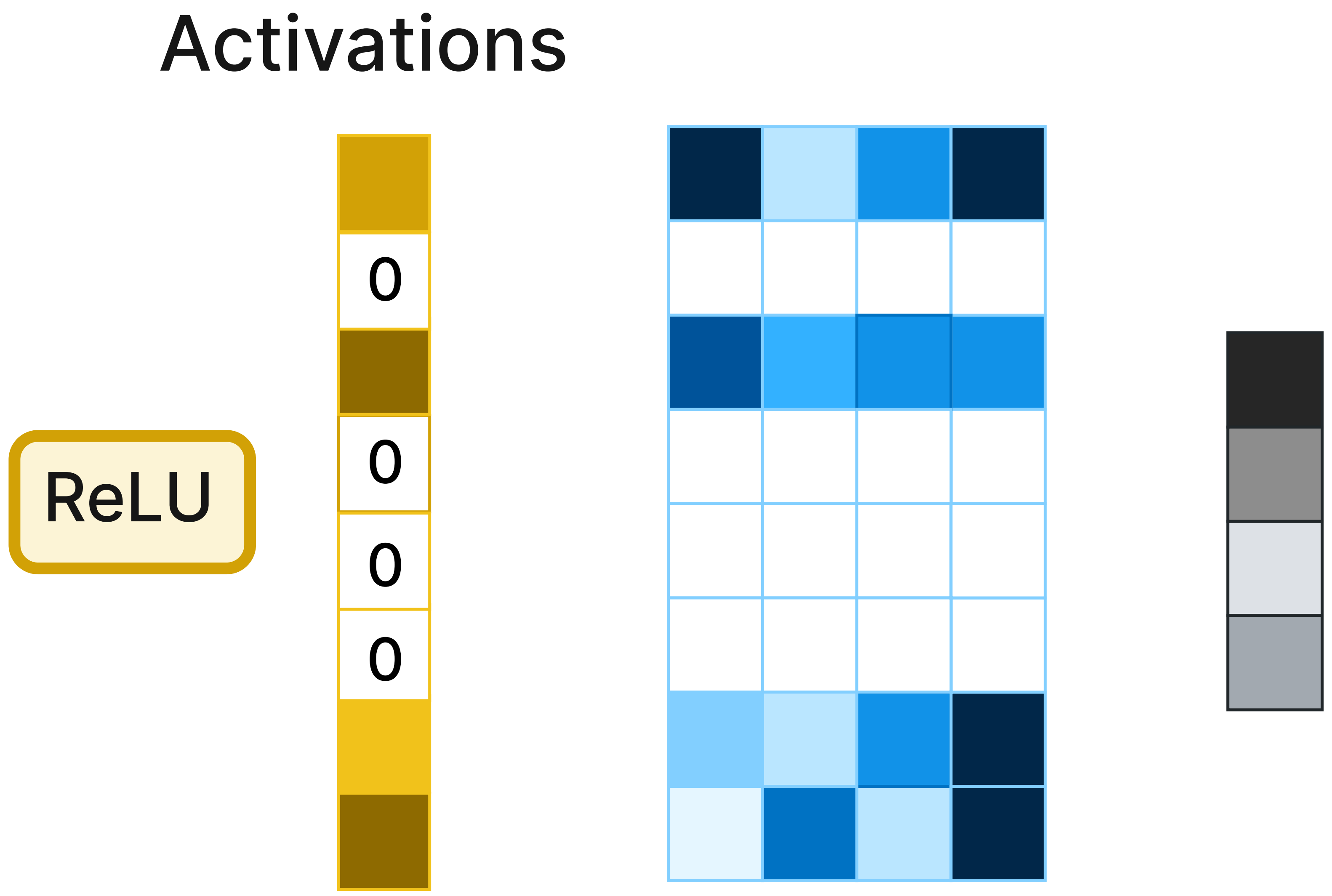




Activation Sparsity: Efficient Implementation



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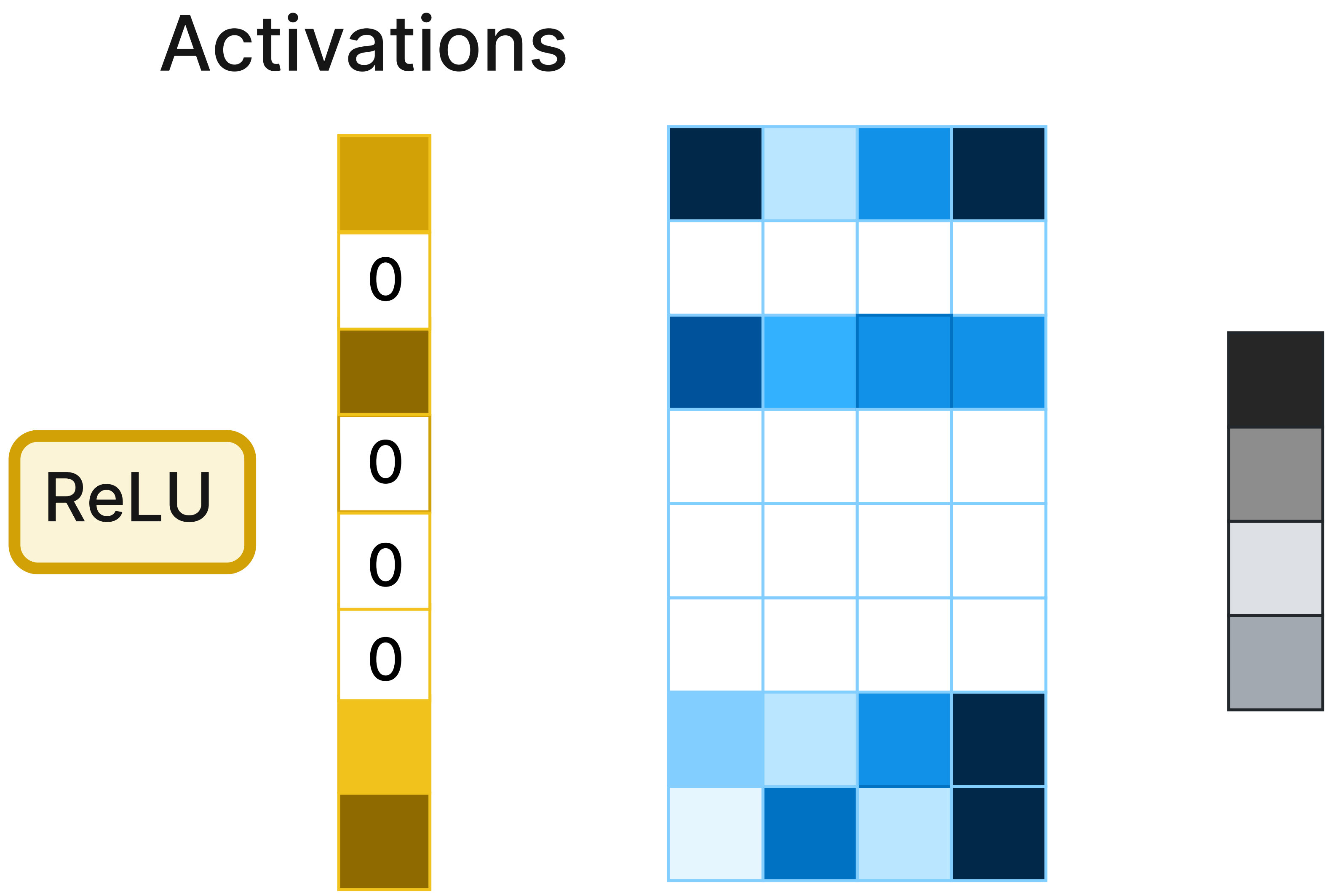

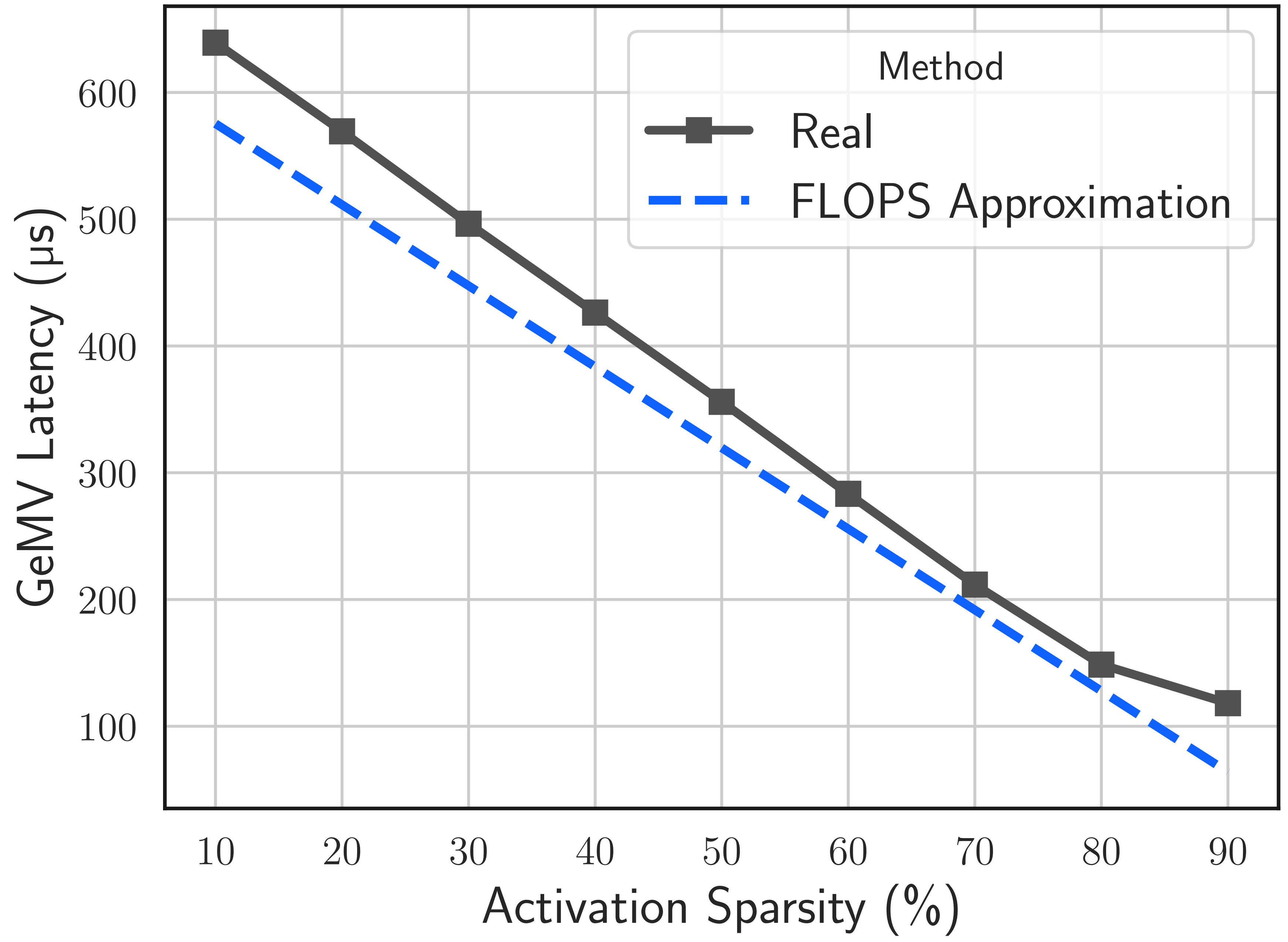

Efficient Matrix-Vector product Metal Kernel on M2-Macbook Pro

But most of the LLMs are already pre-trained without ReLU

ReLUfication: Bringing ReLU Back to non-ReLU Pre-Trained Models

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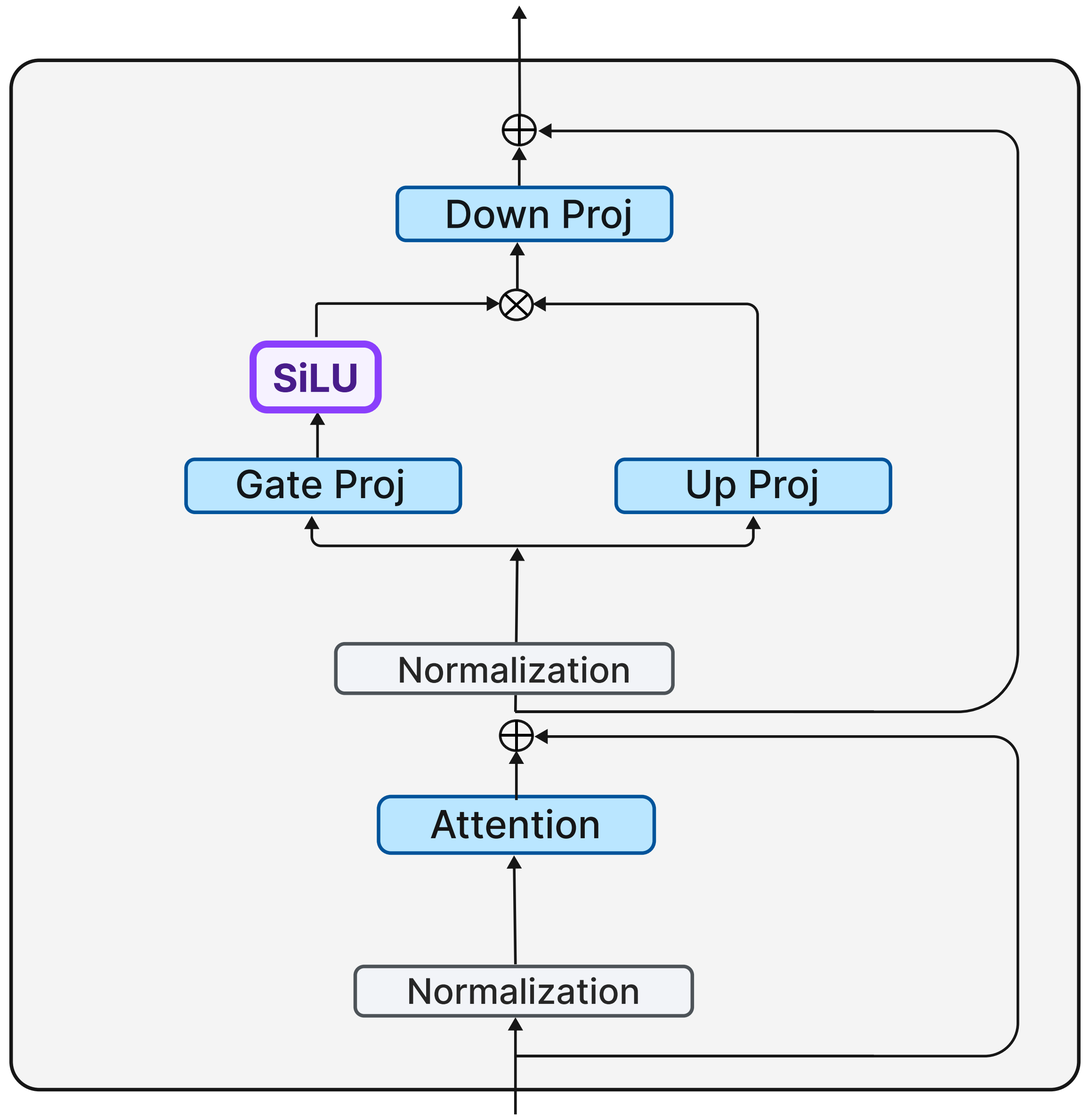

LLaMA Layer

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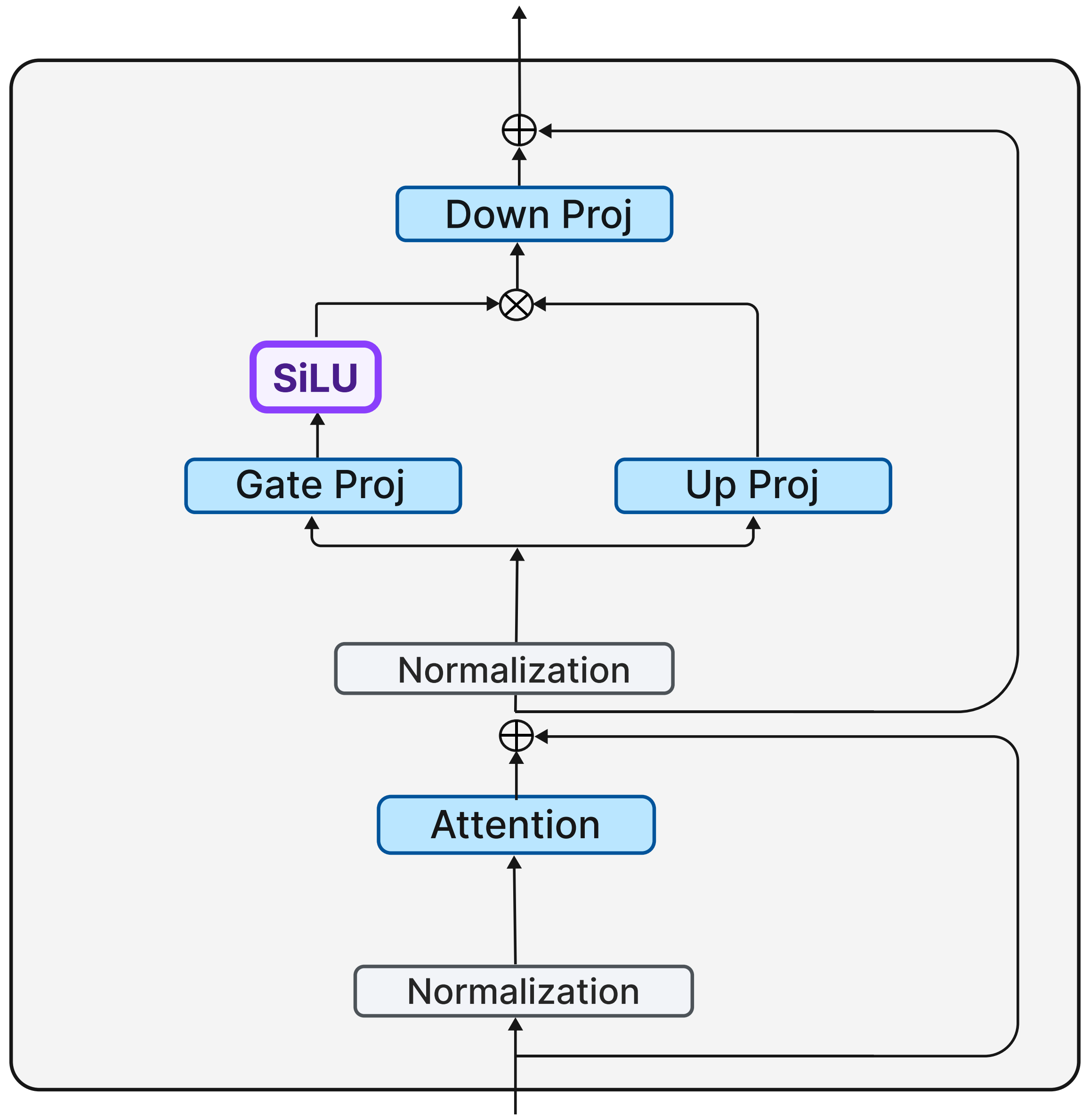

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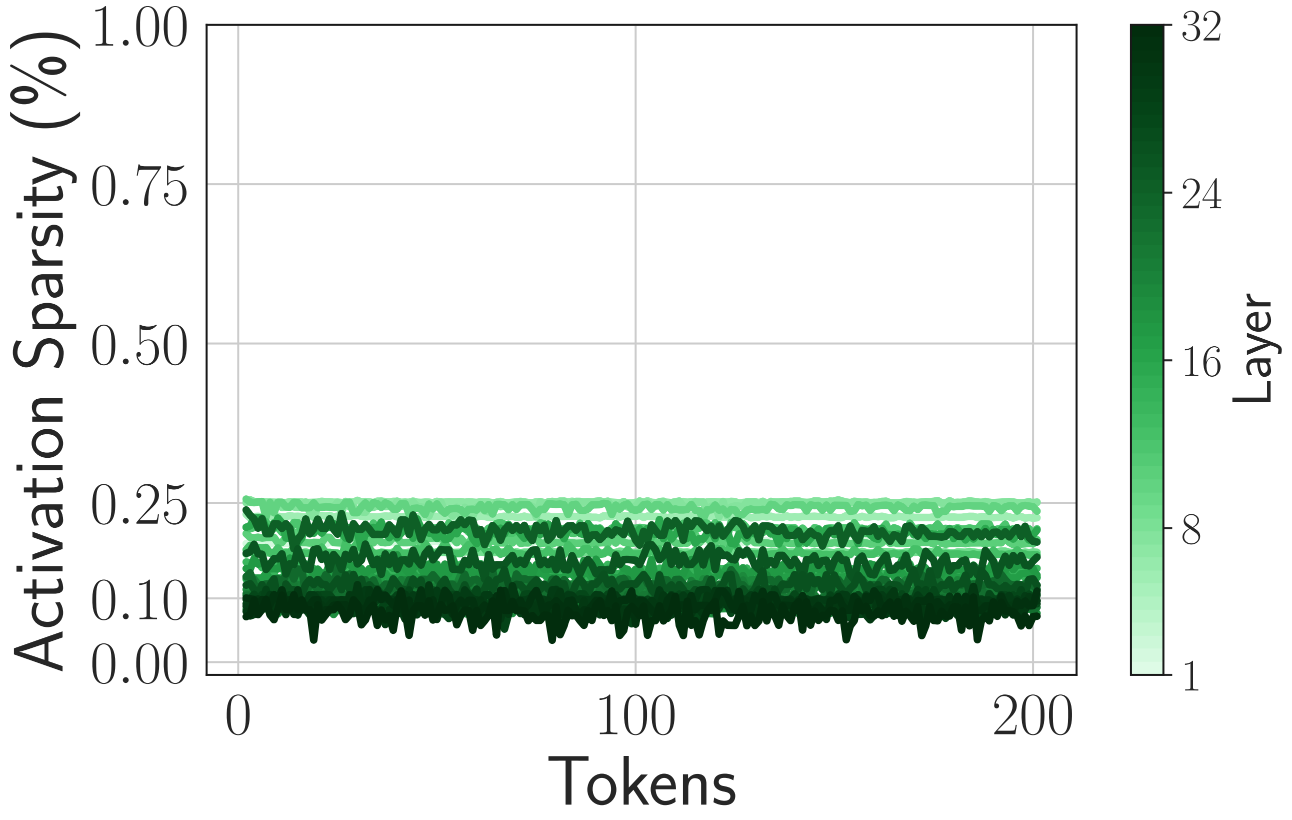

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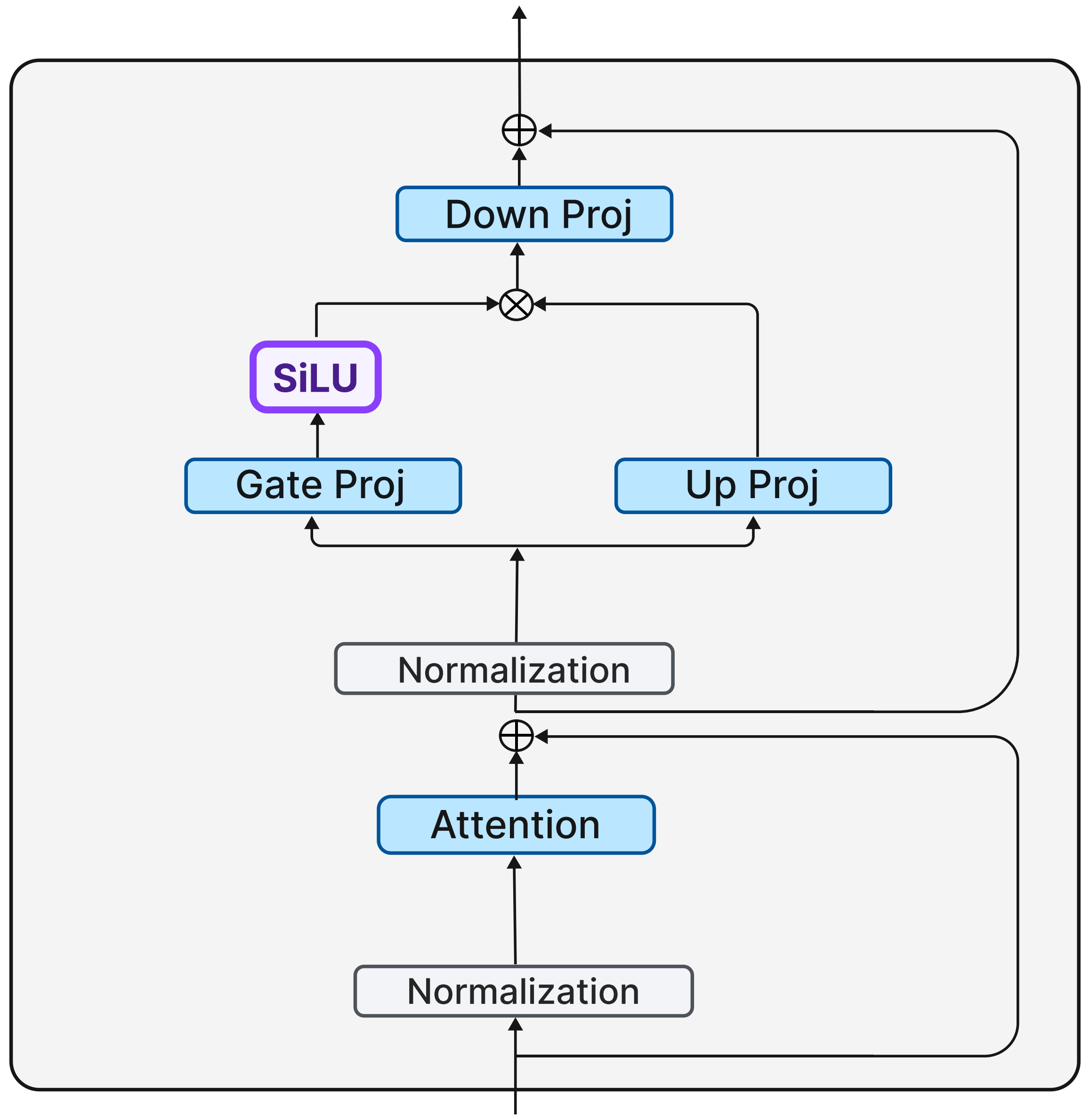

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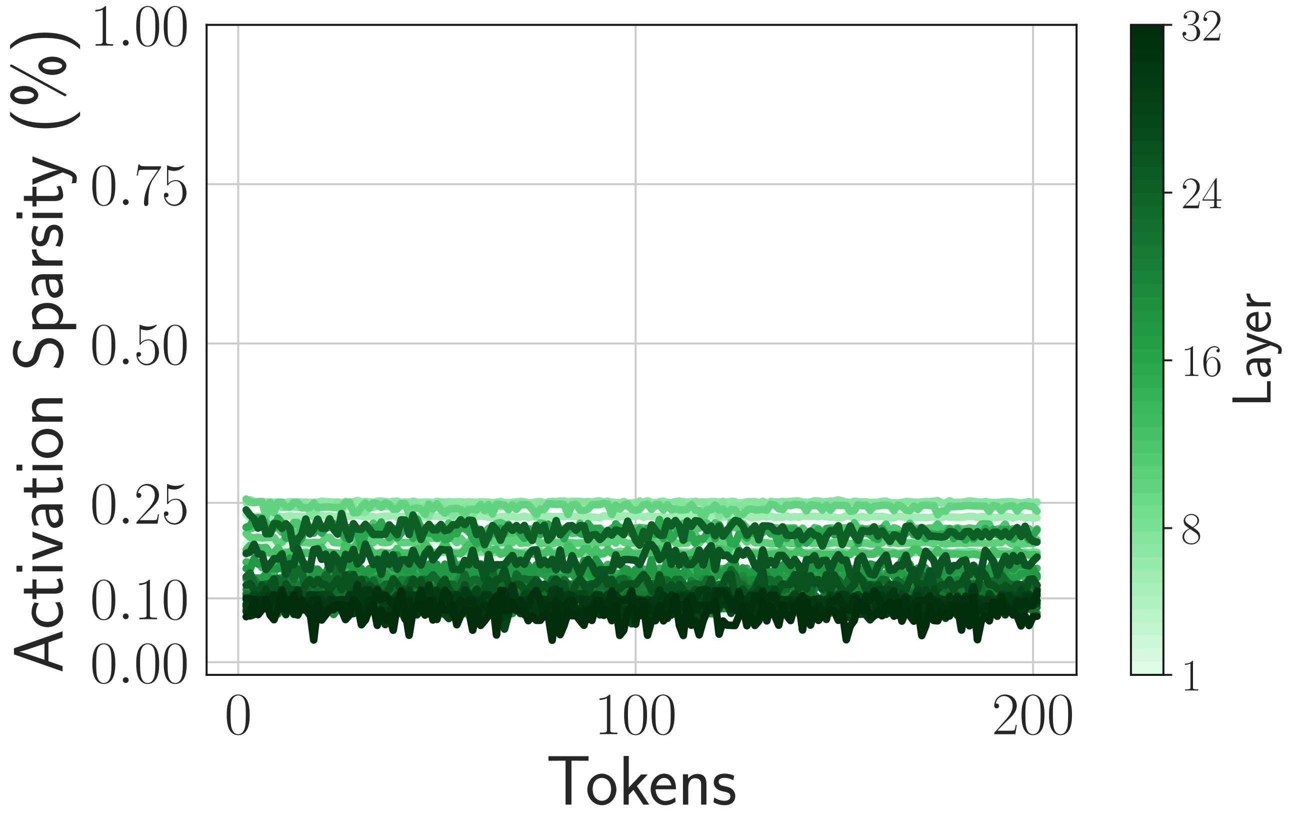

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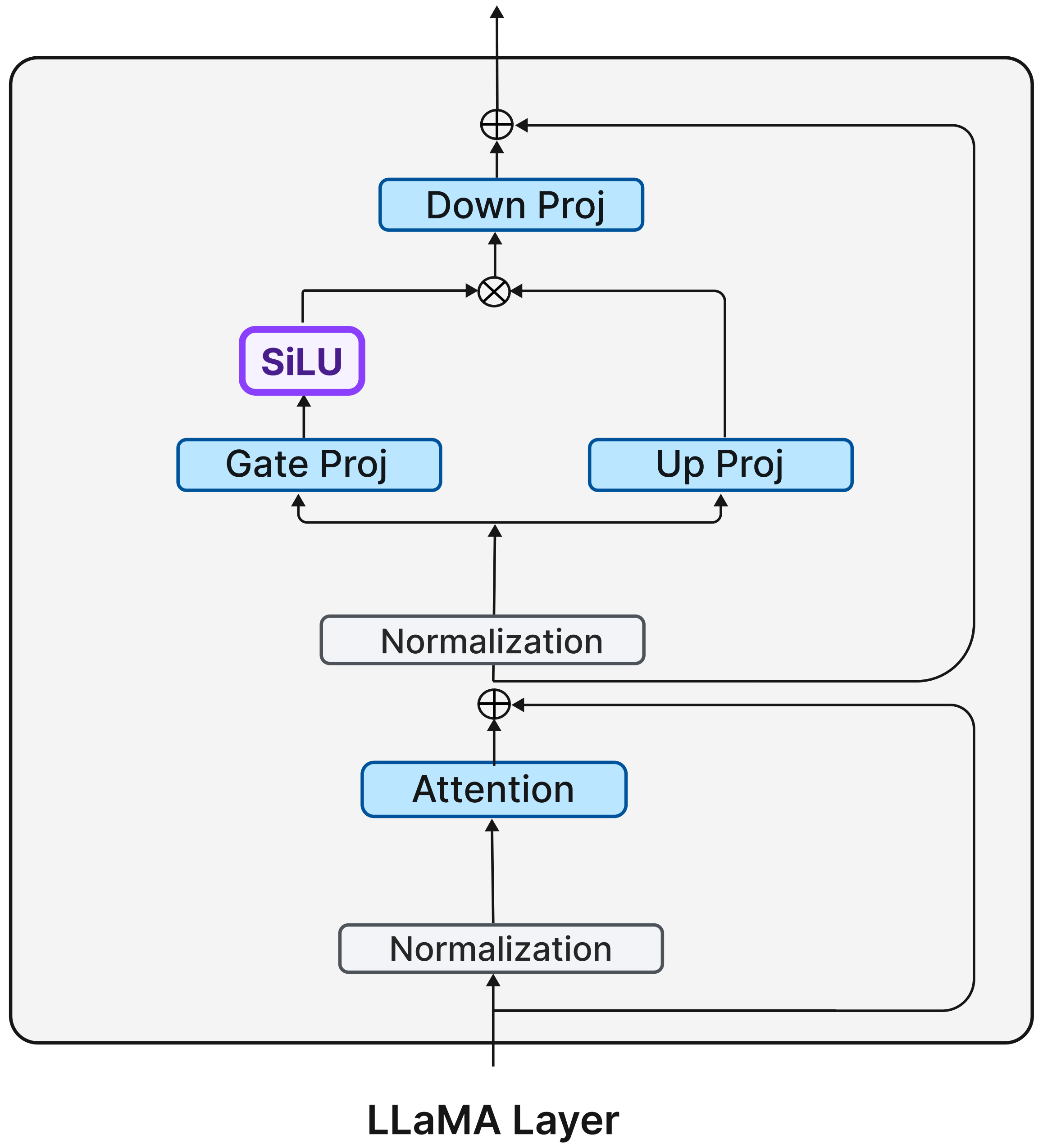

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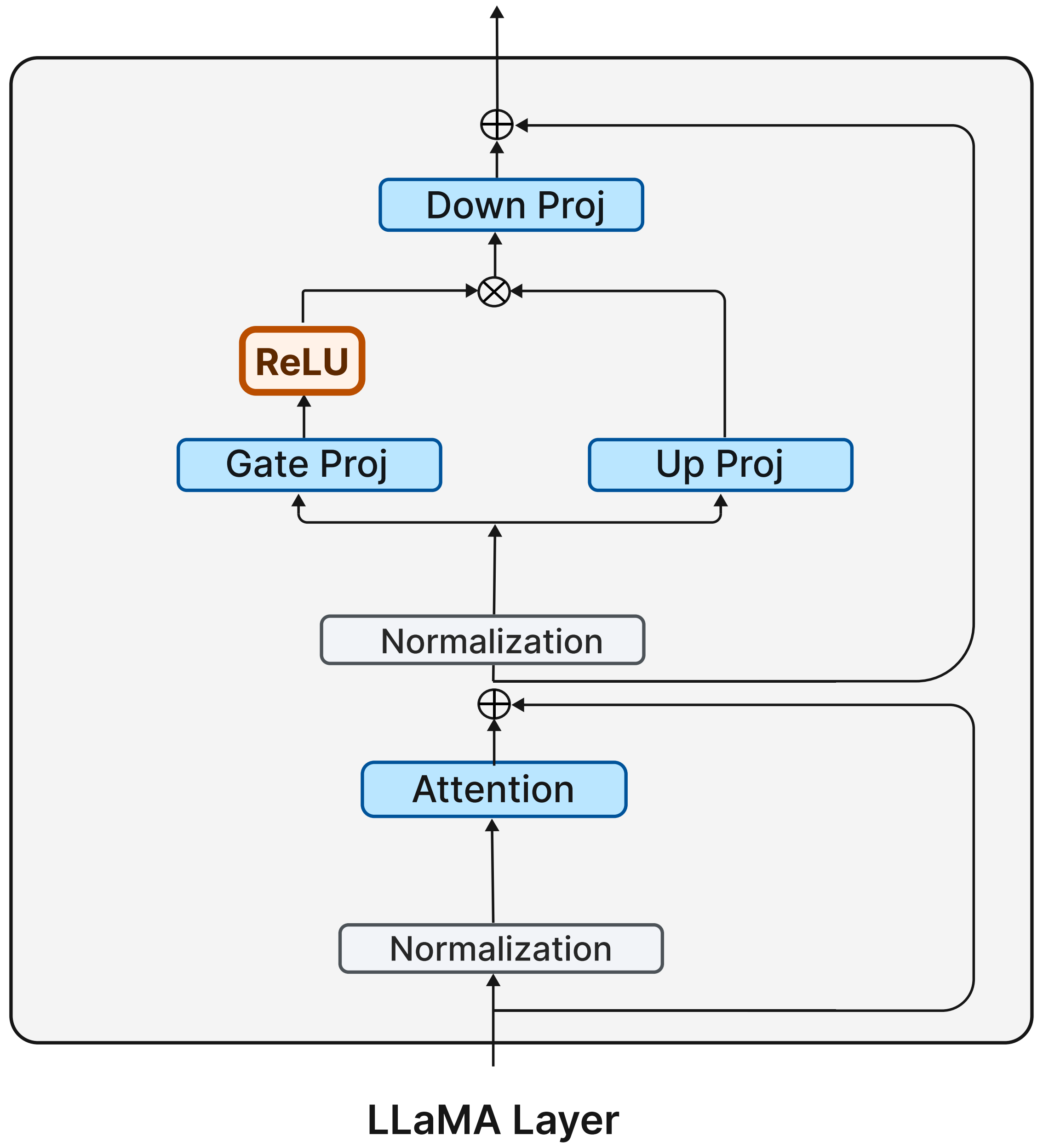

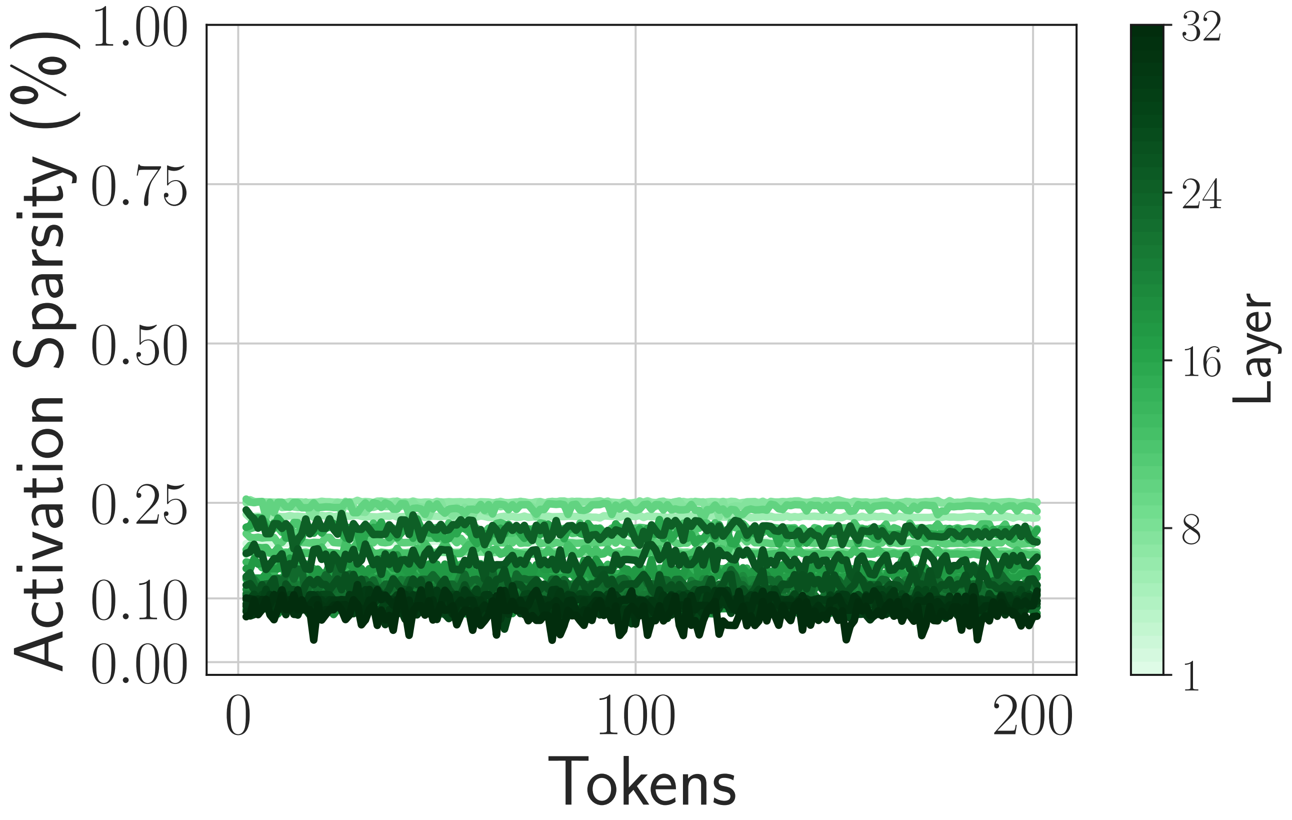

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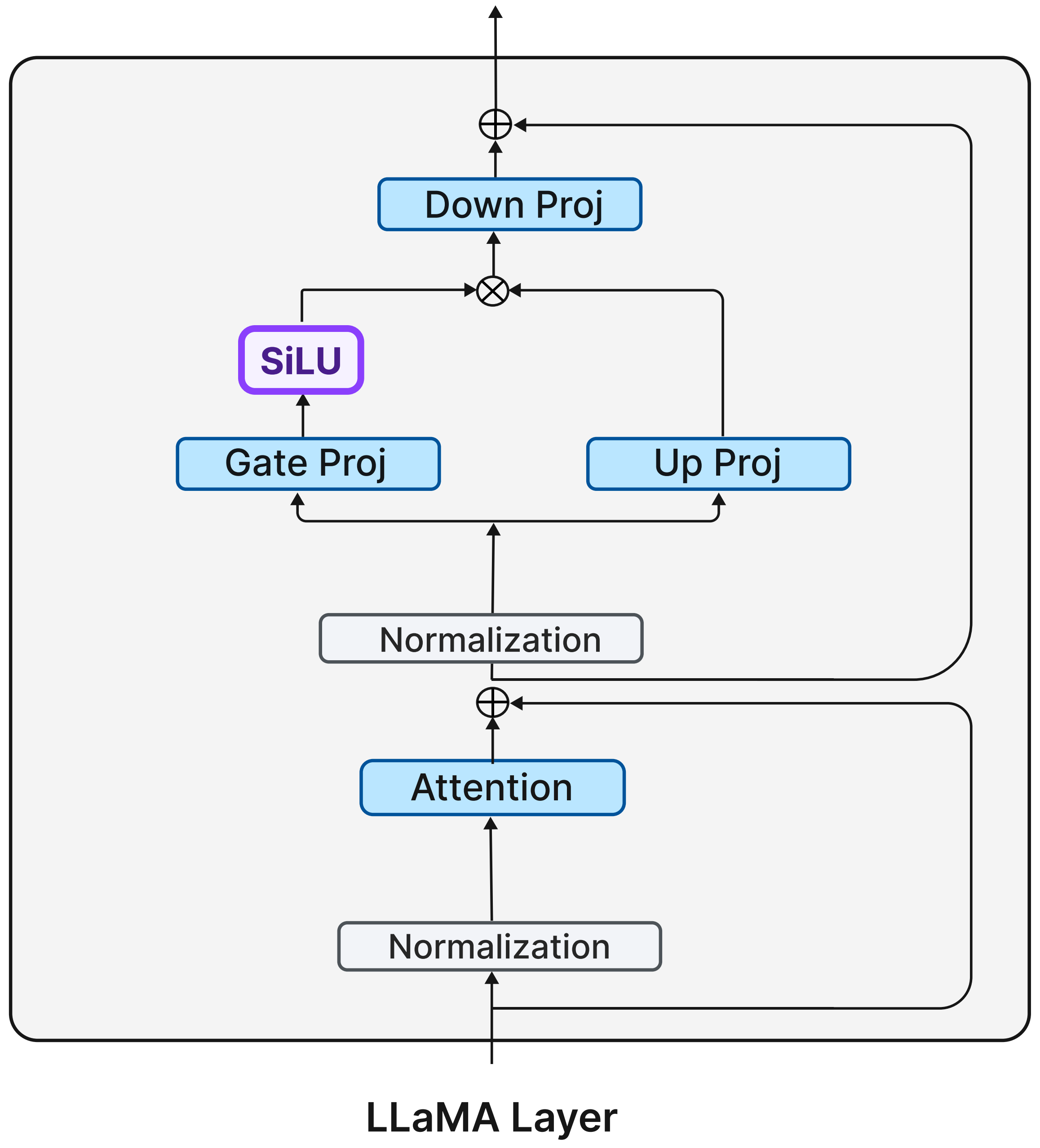

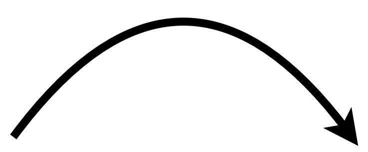

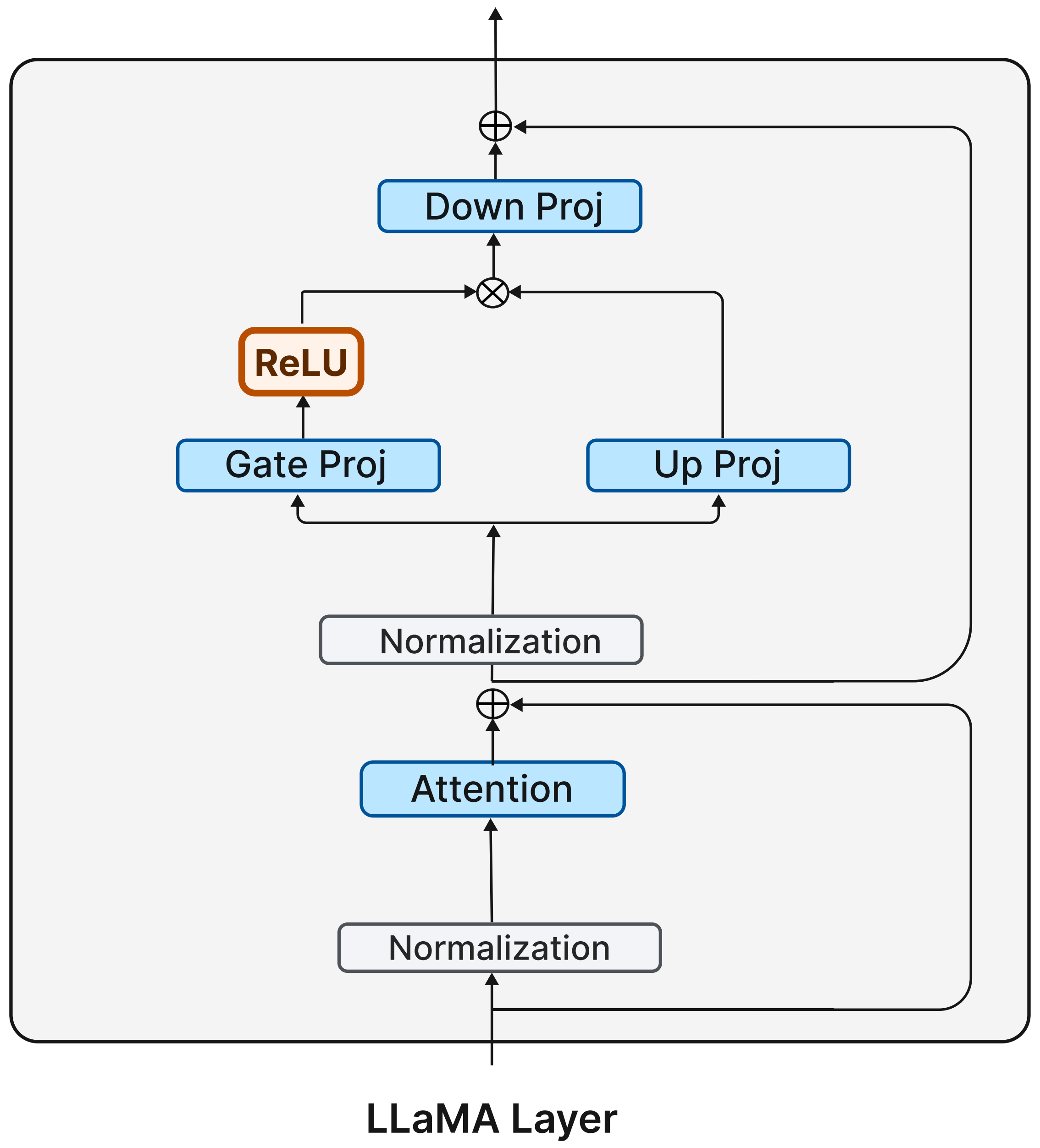

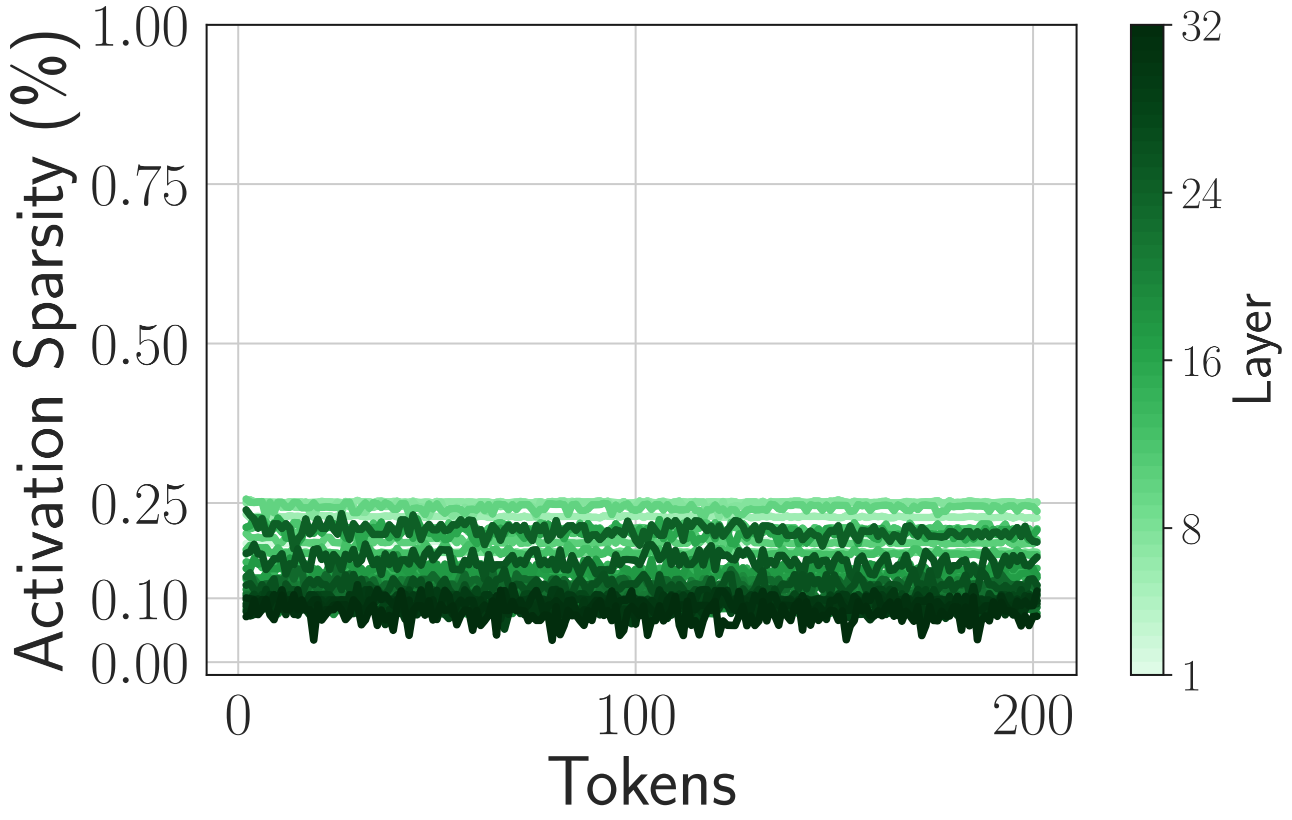

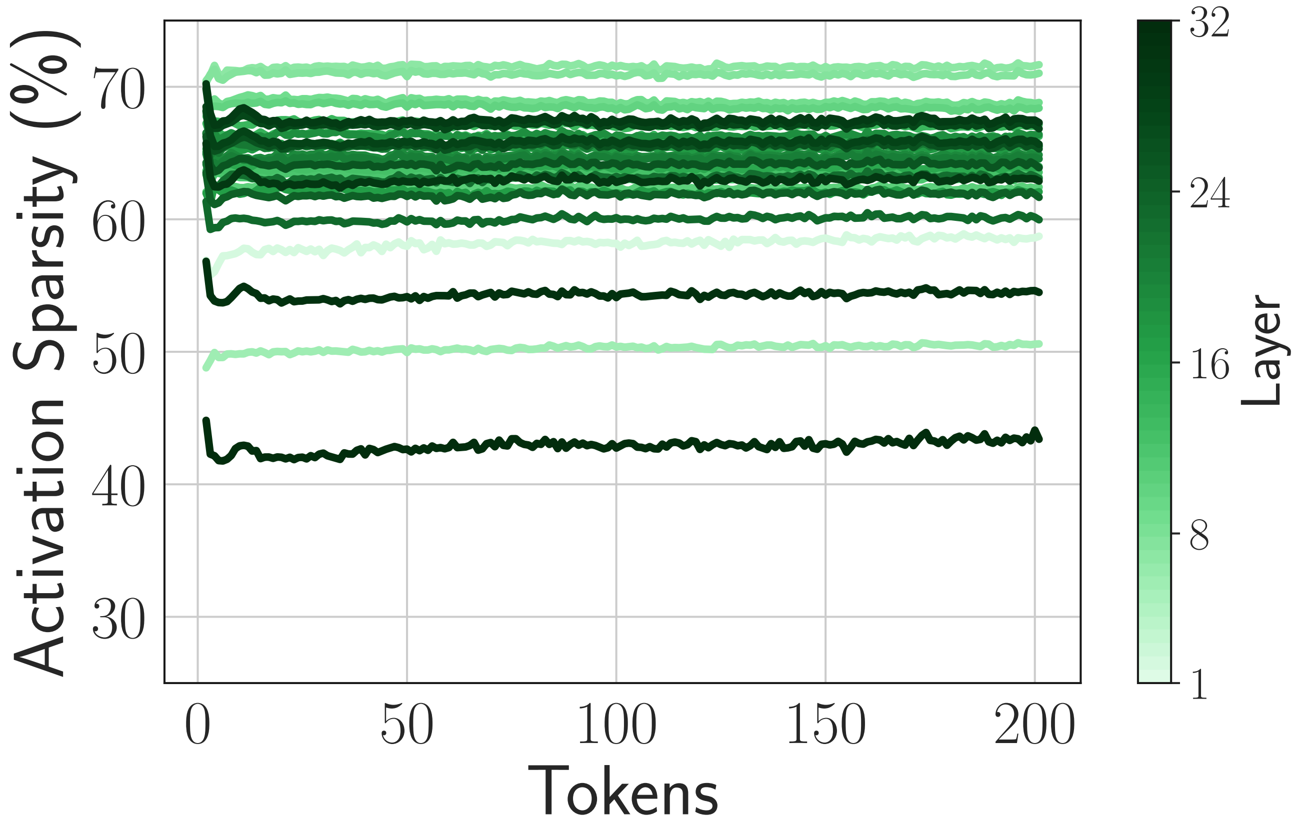

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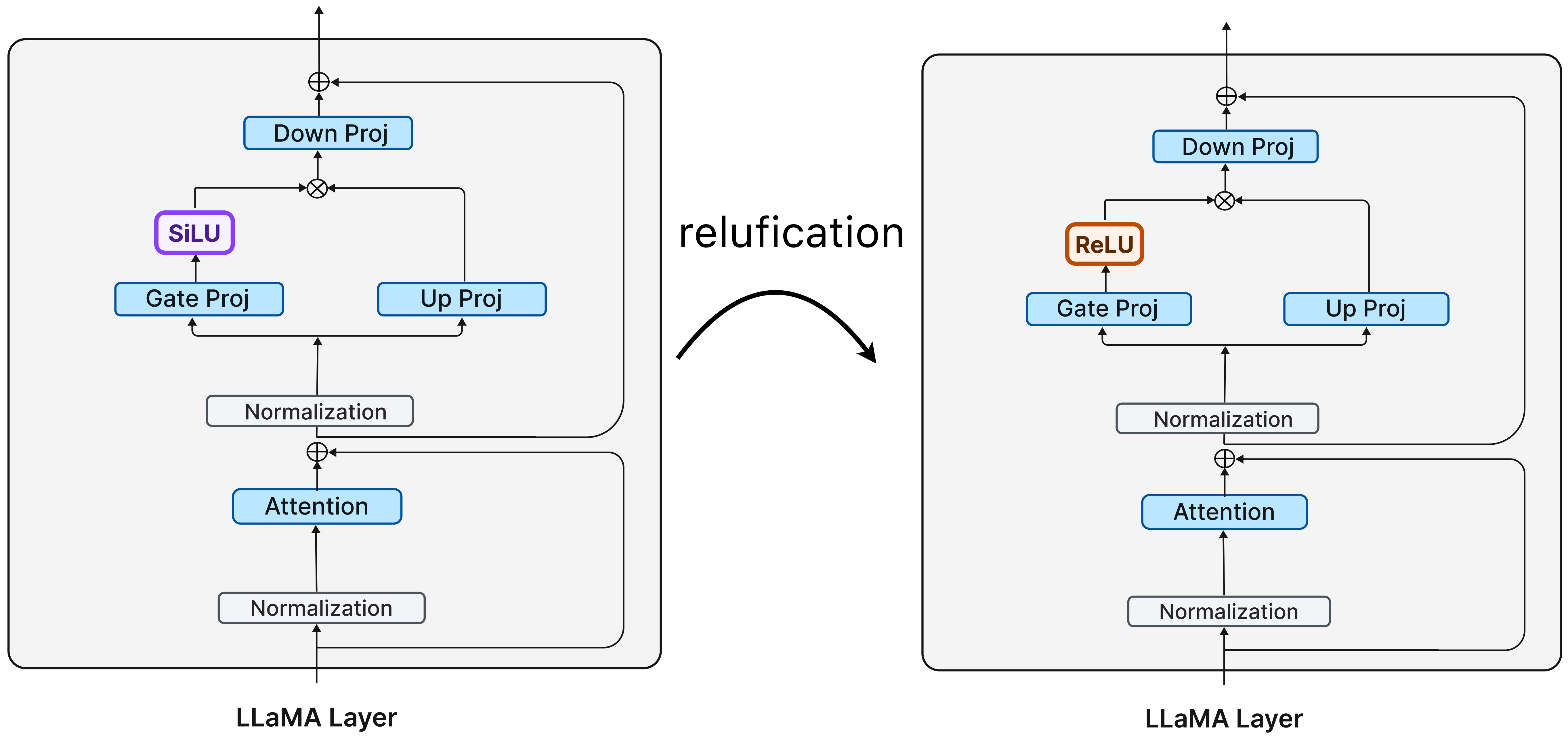
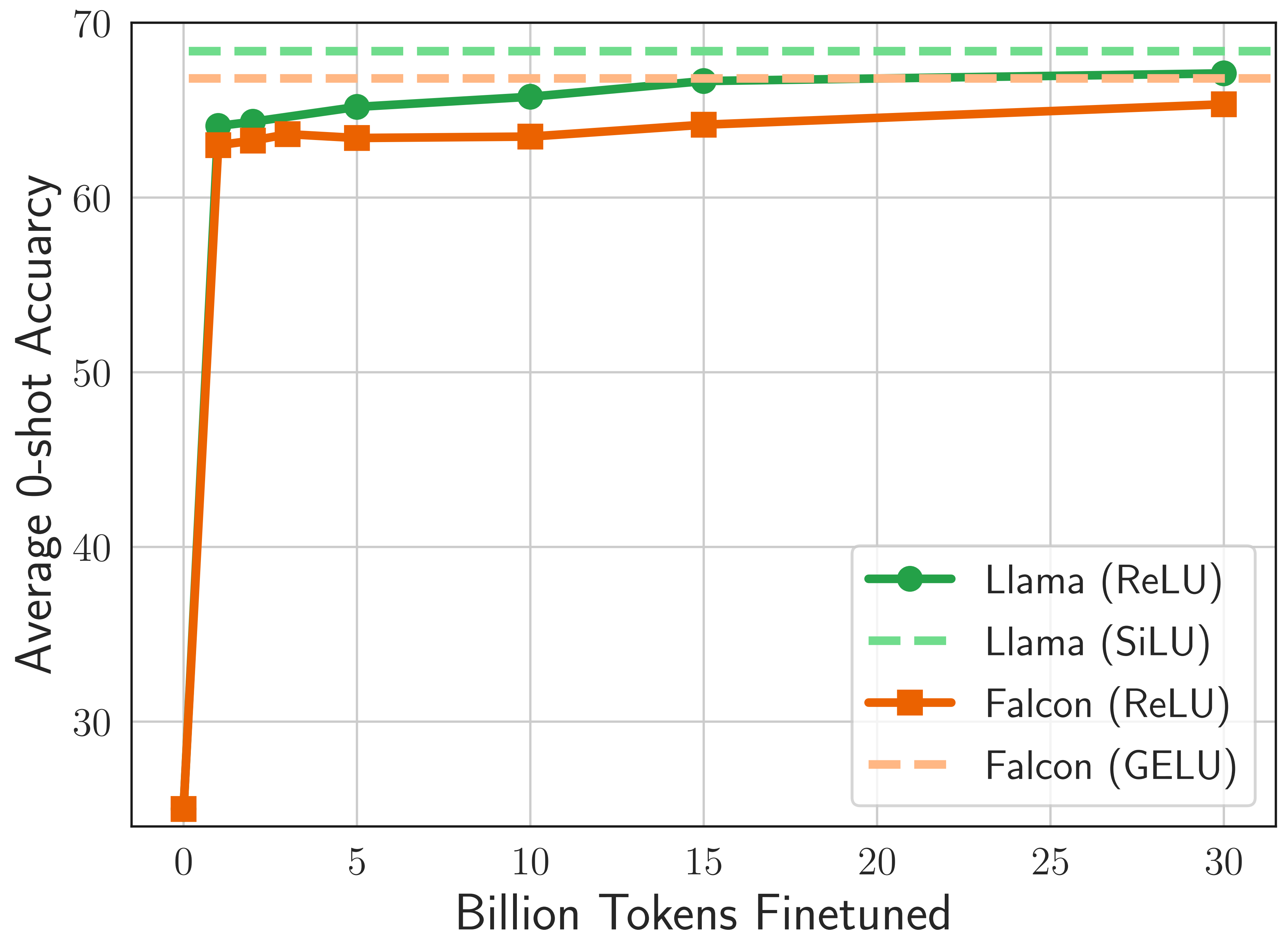
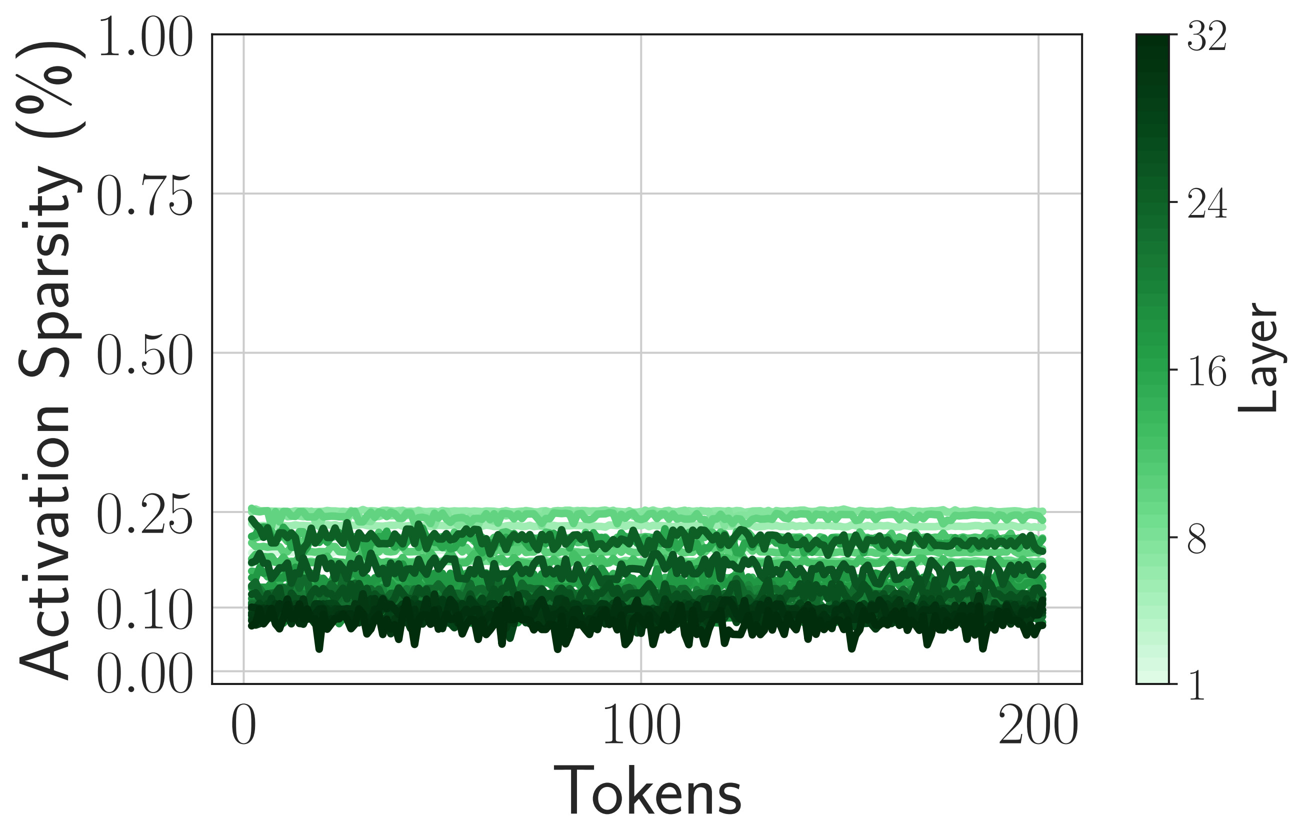
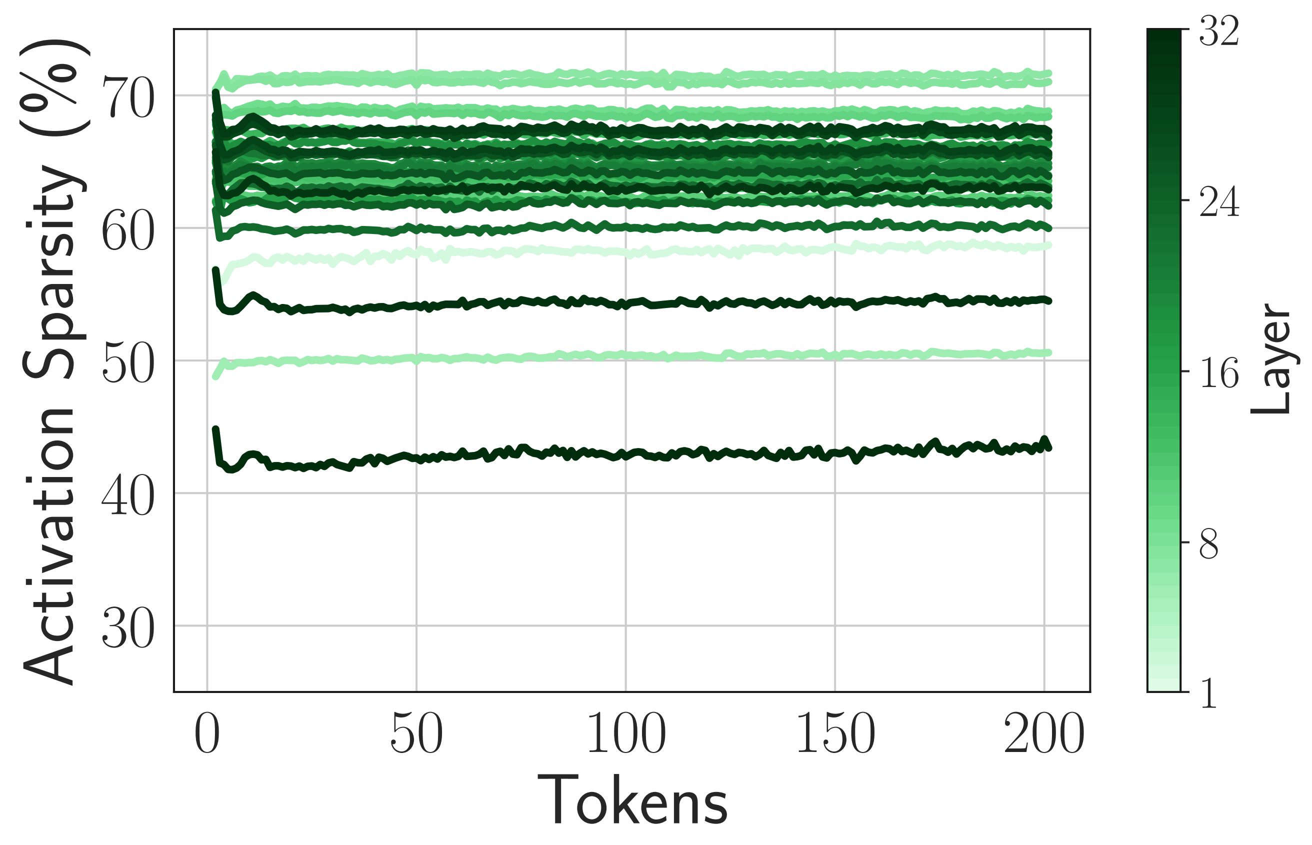
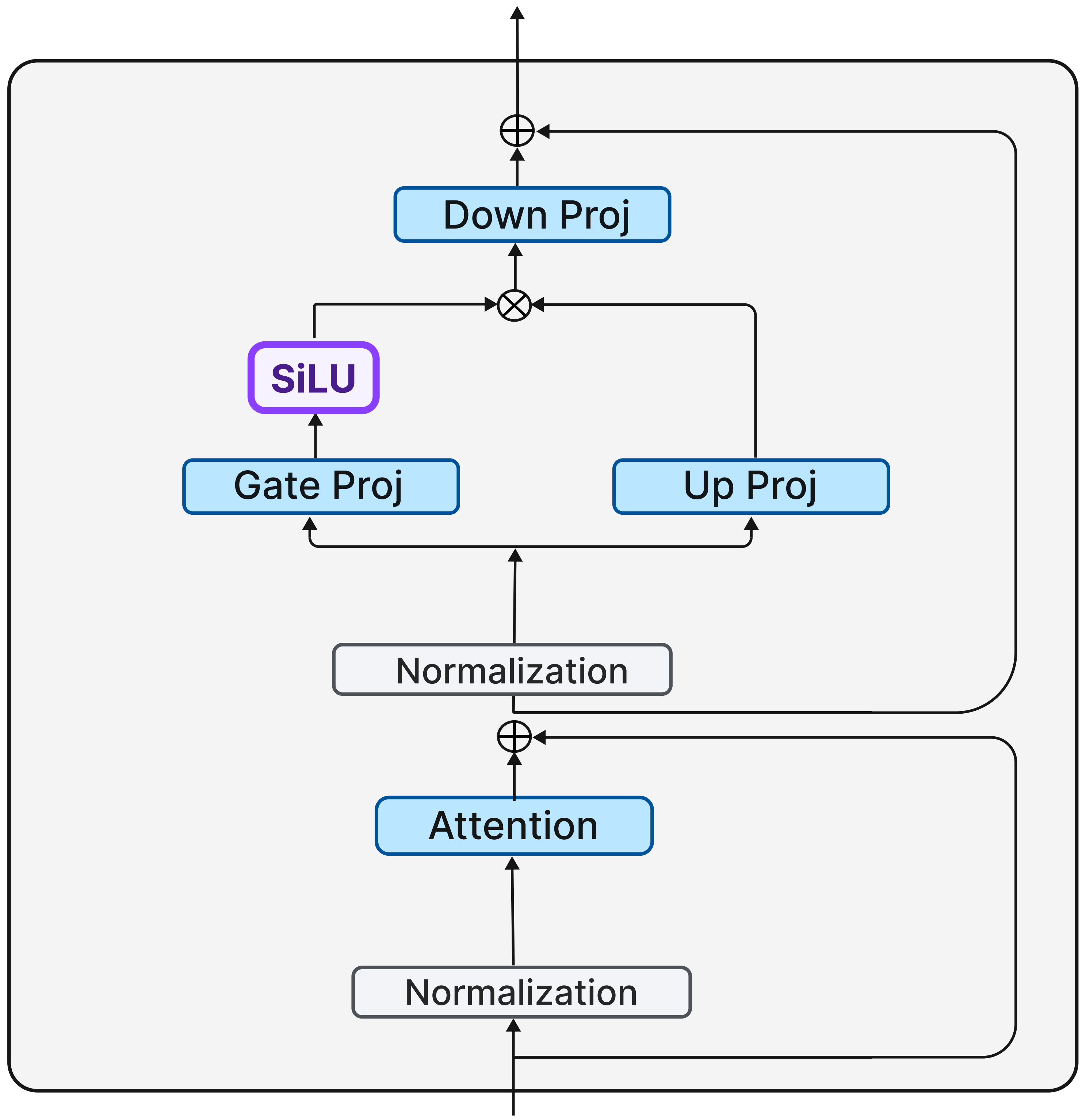




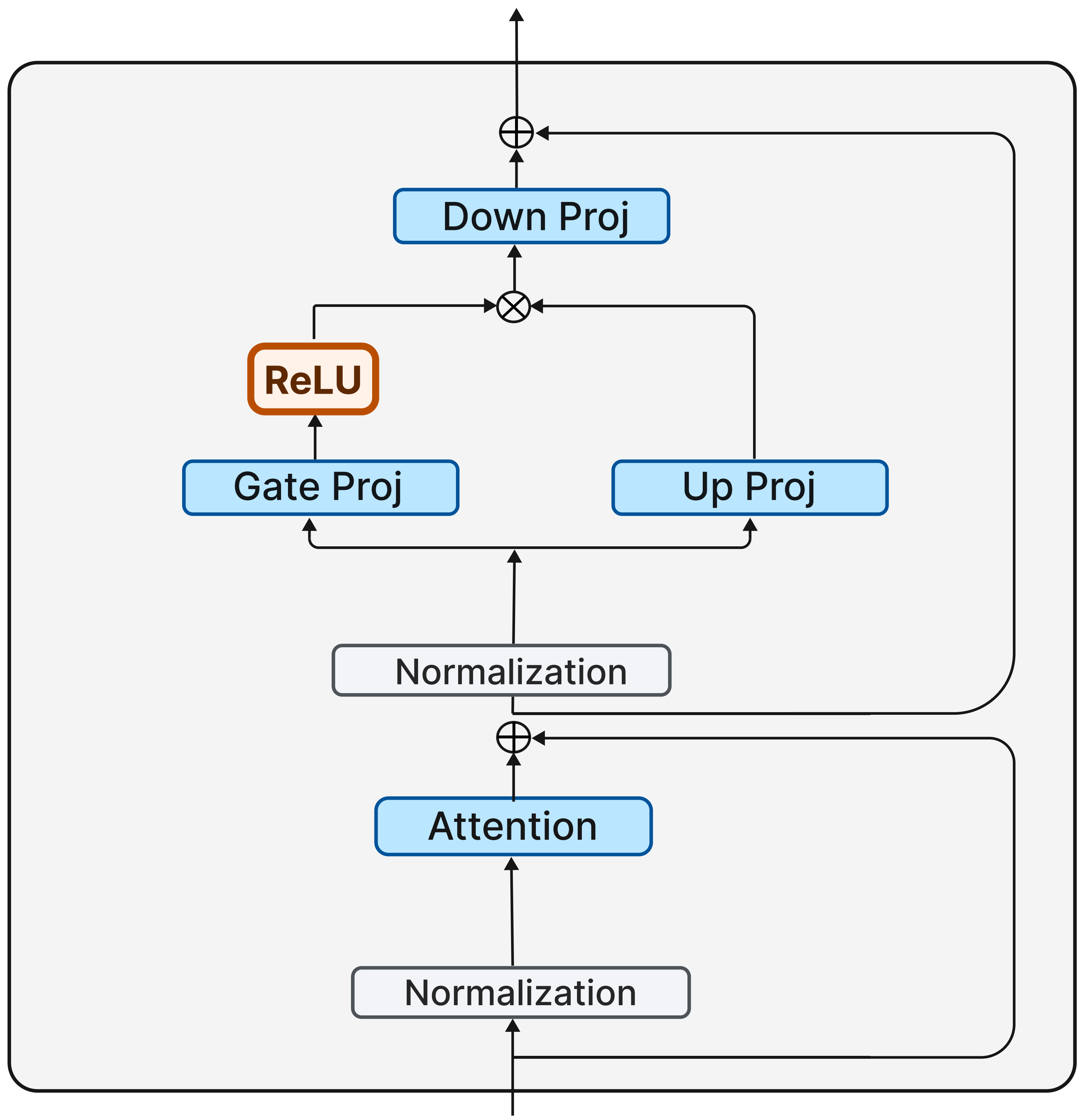




ReLUfication Stages

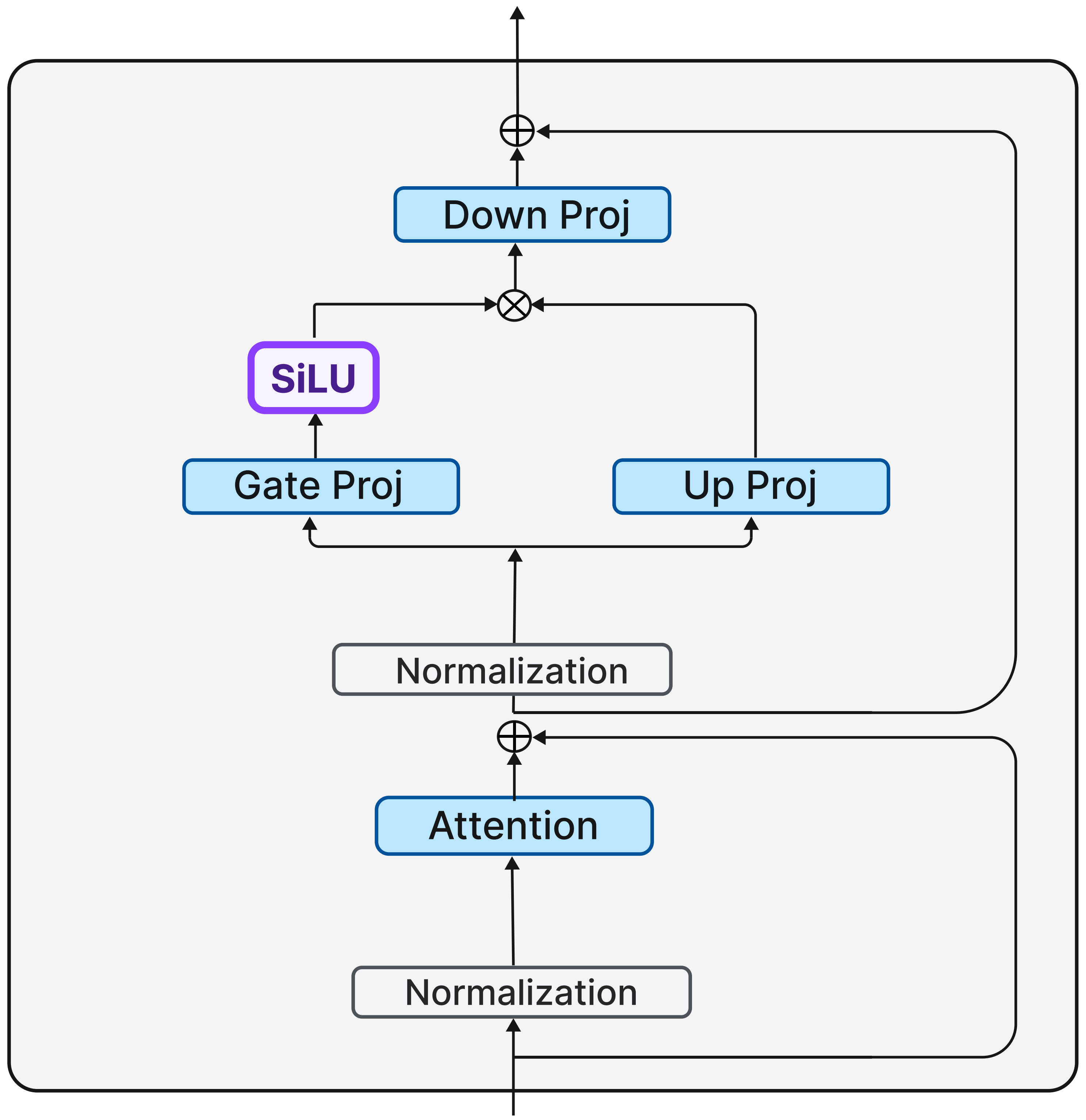


no relufication



relufication - stage 1

ReLUfication Stages



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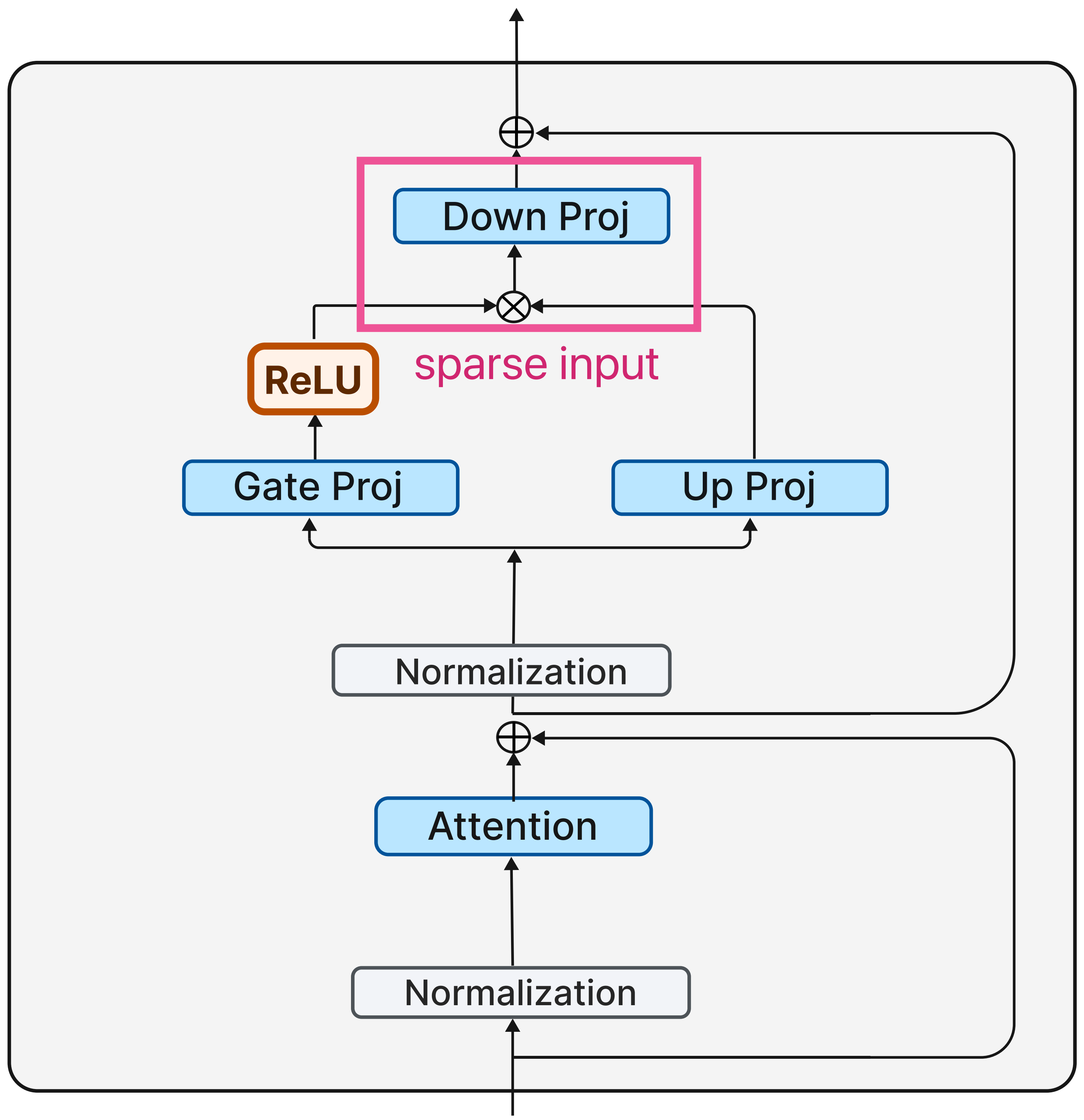

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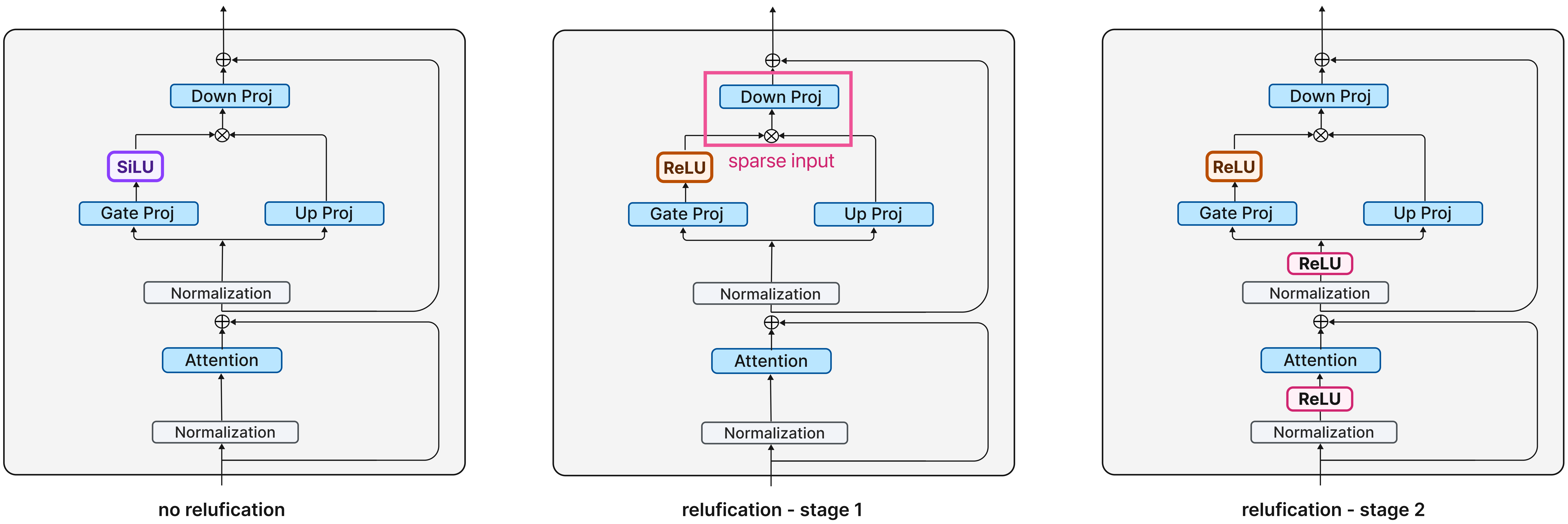

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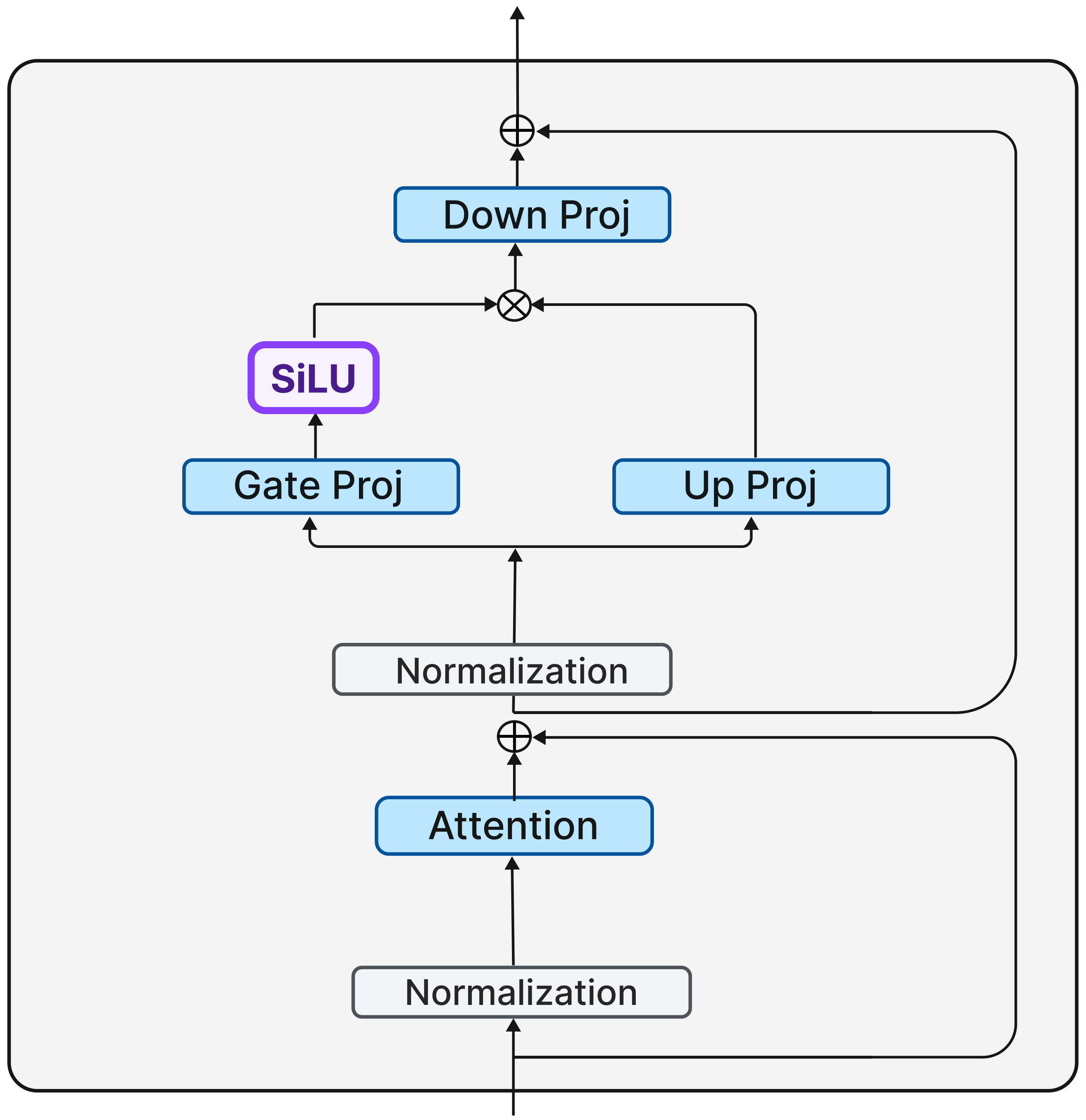

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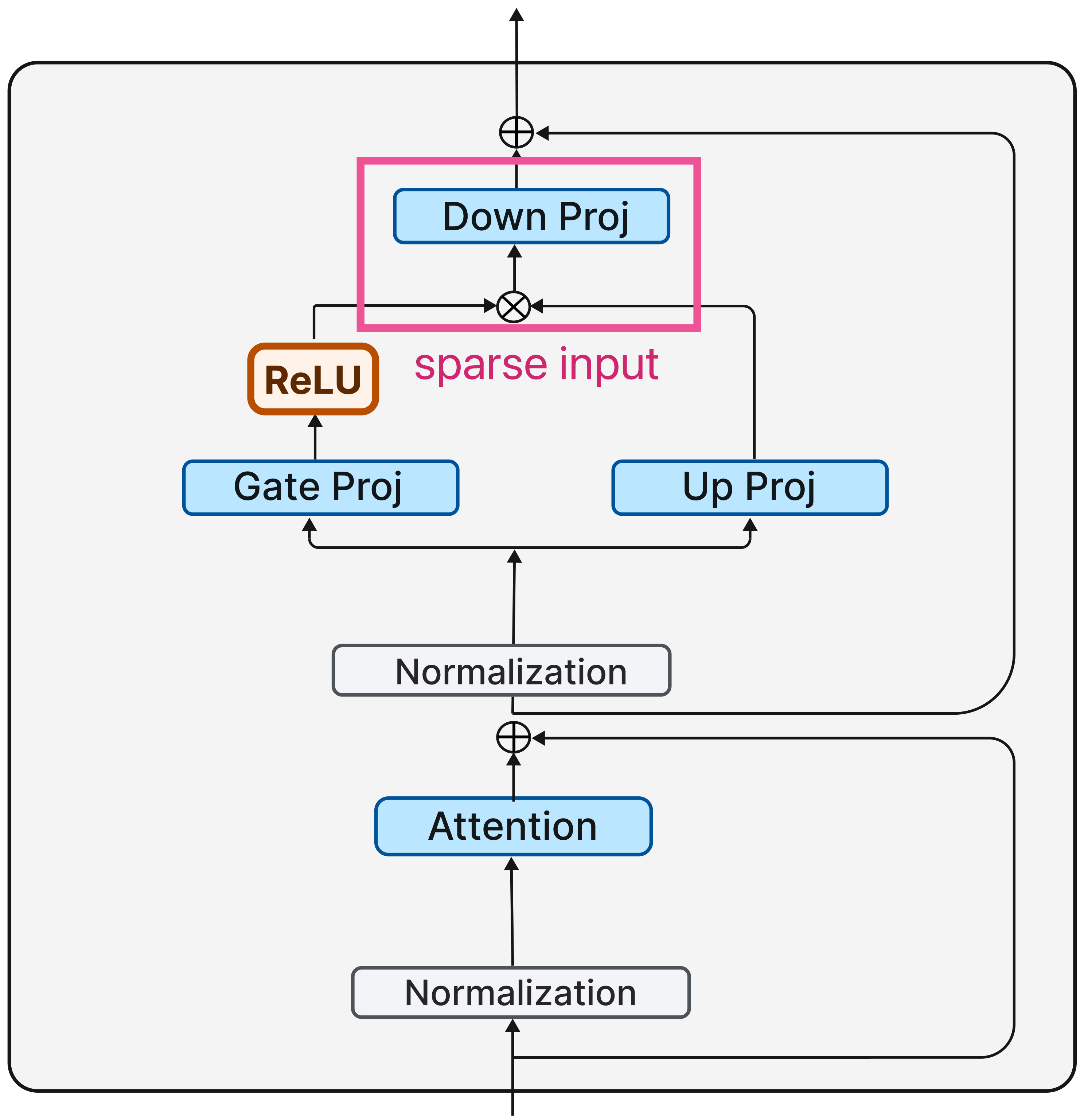

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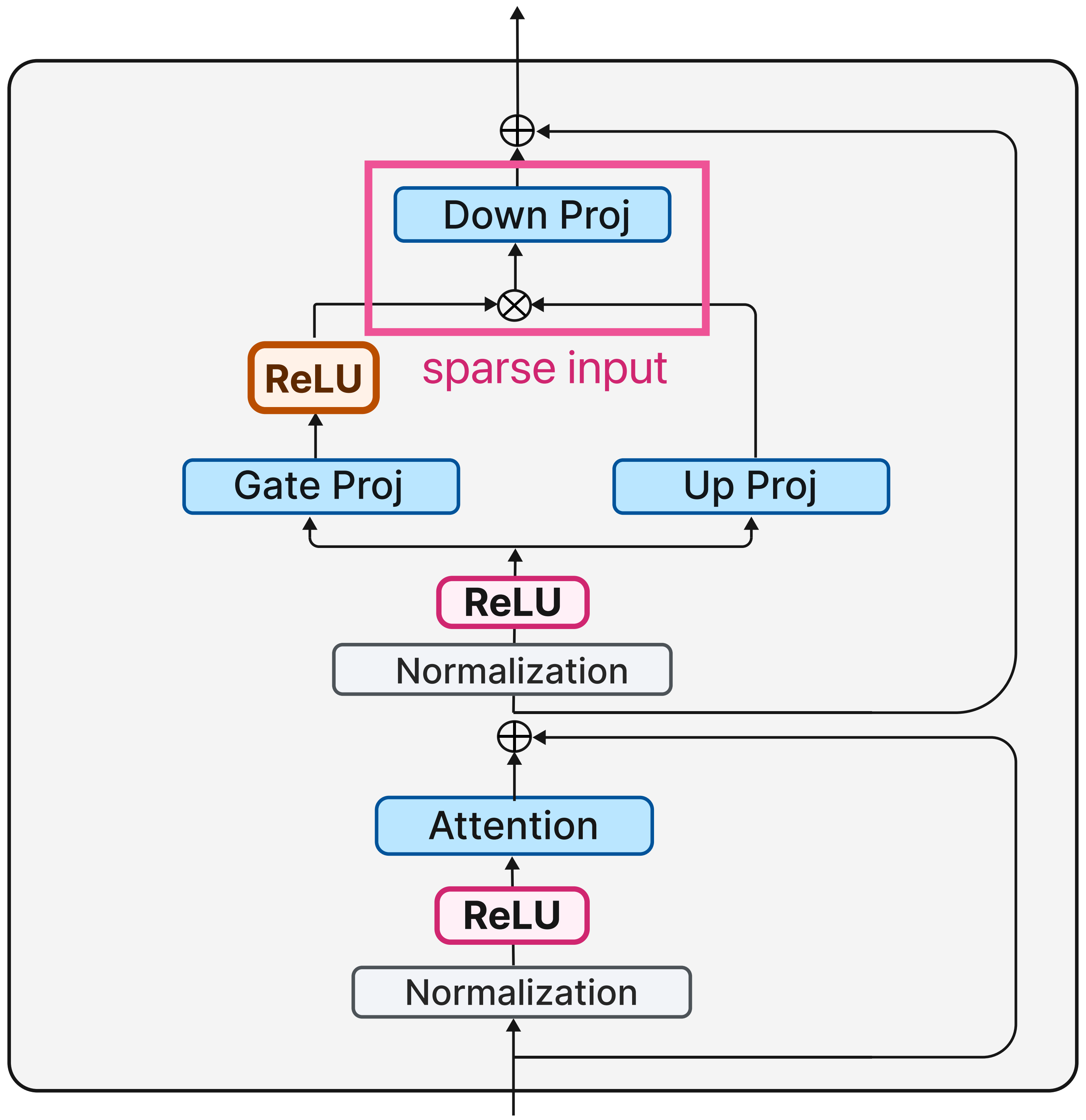
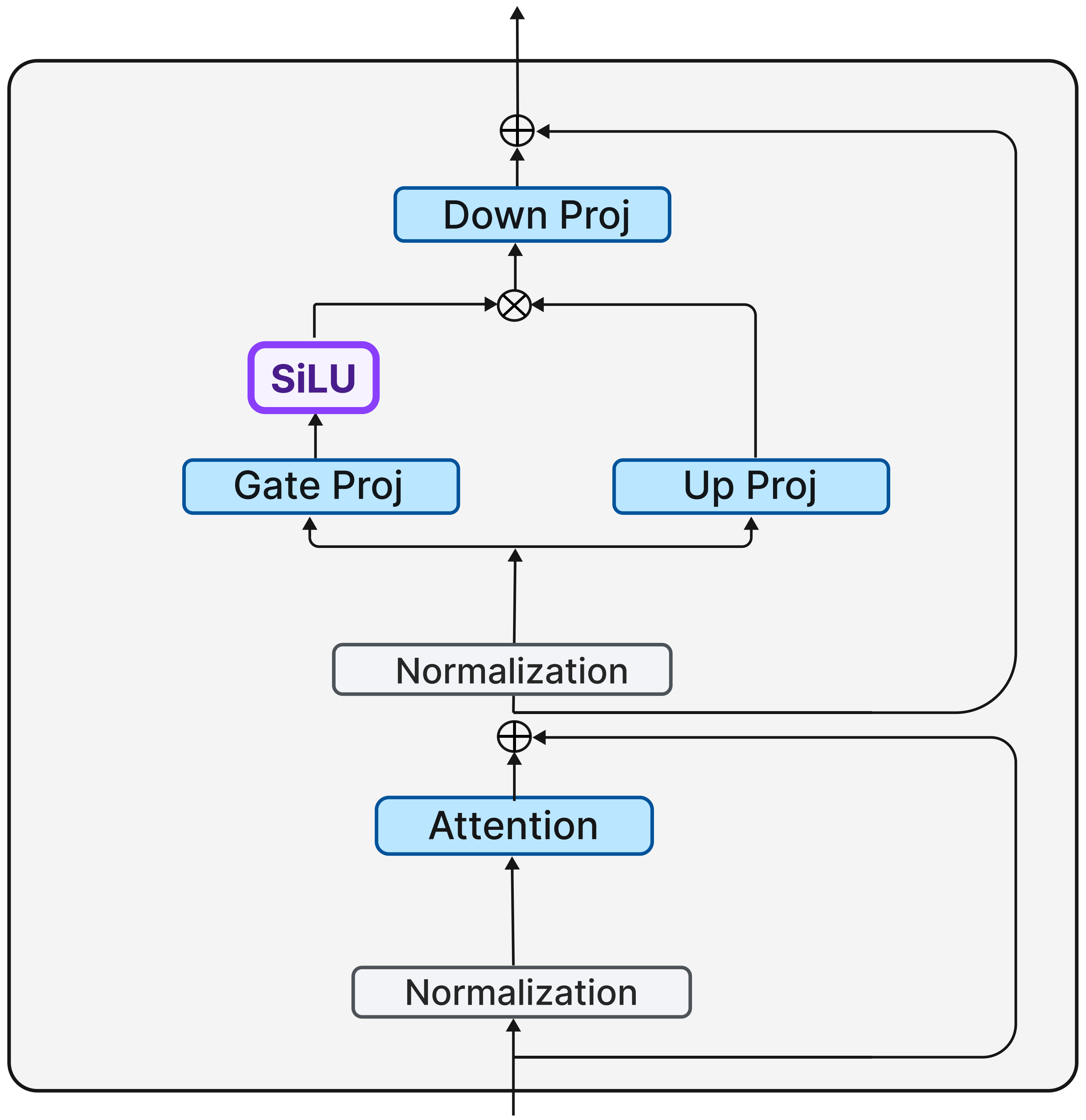


relufication - stage 2

ReLUfication Stages



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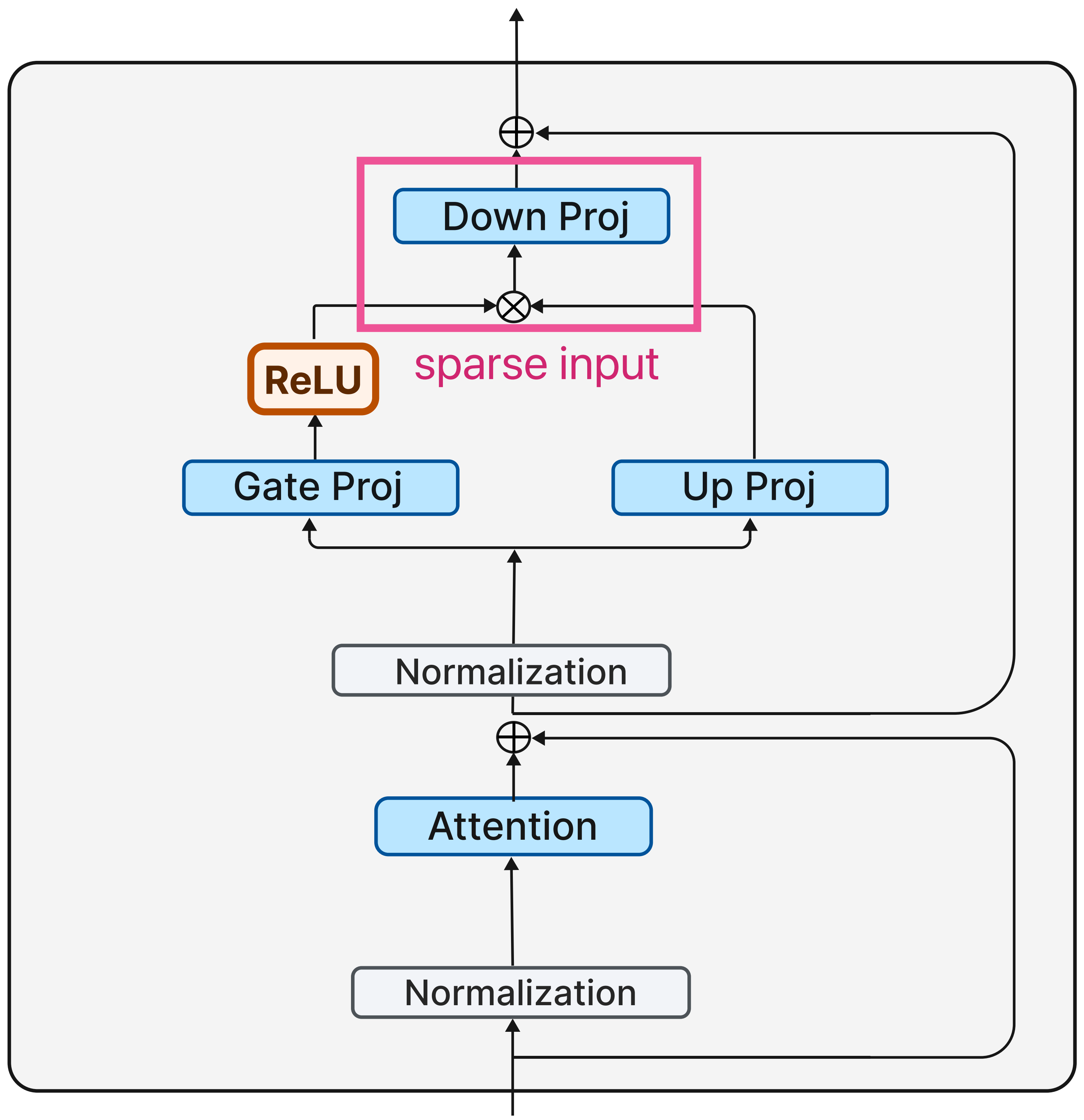
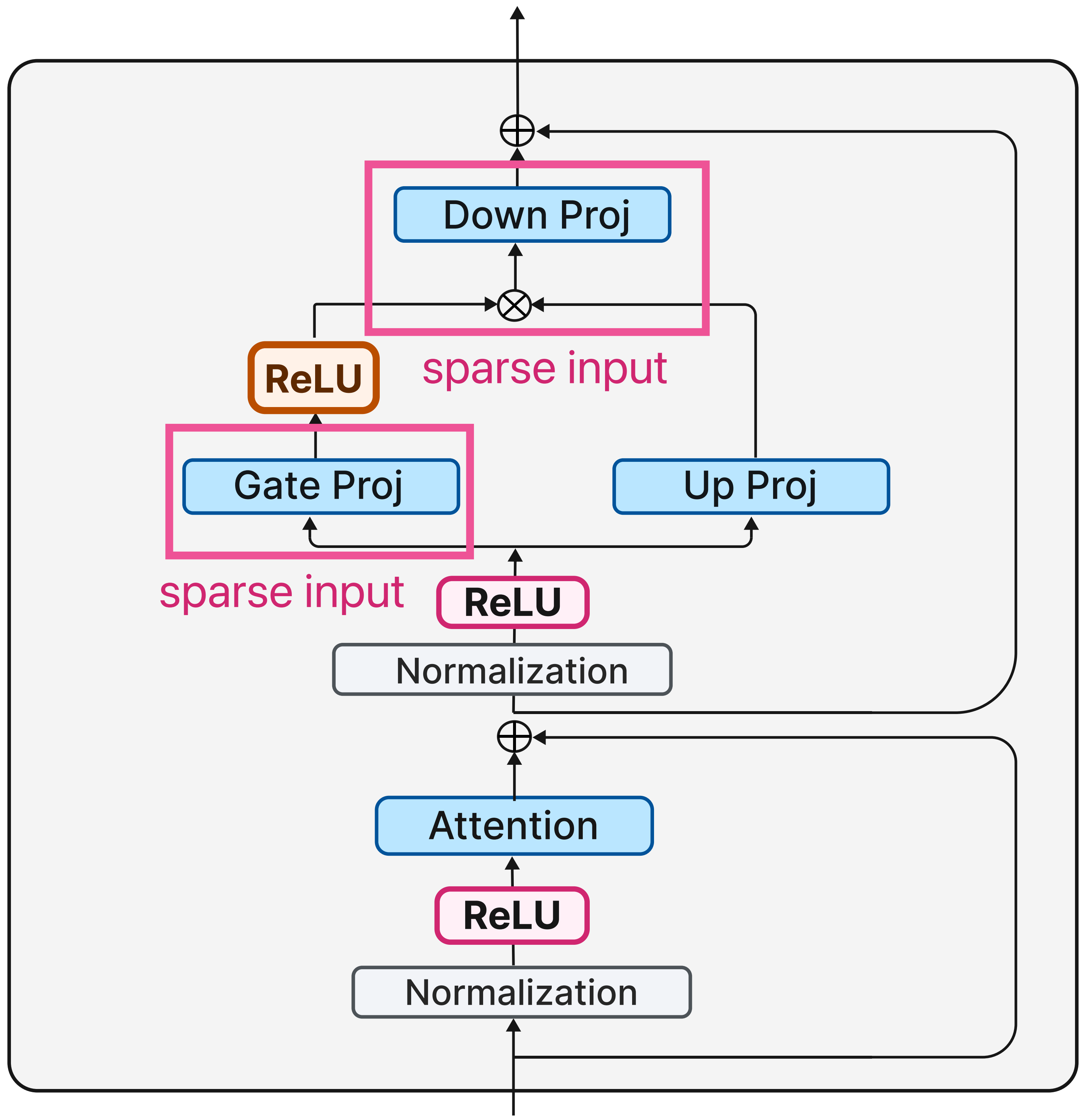
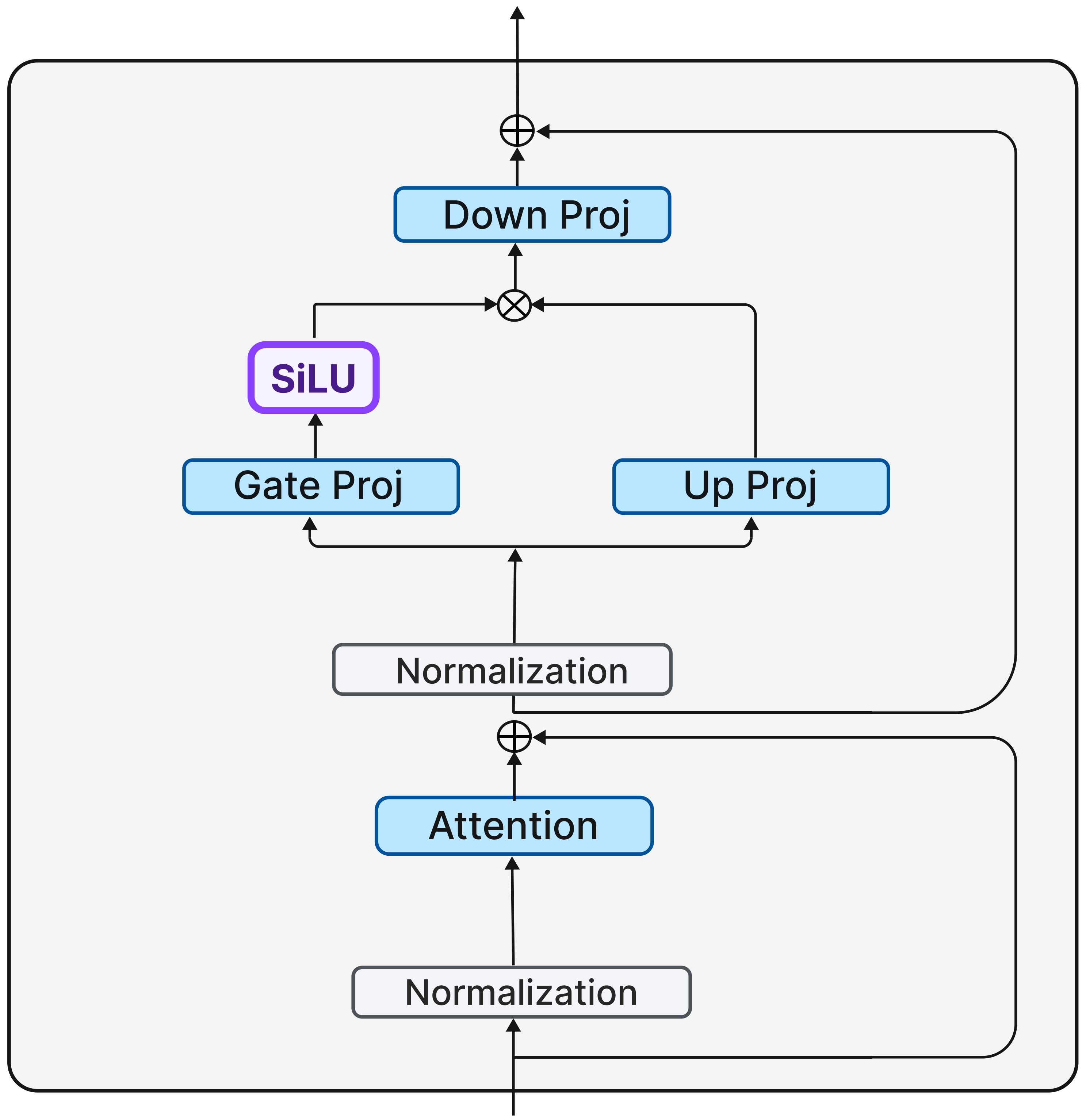


relufication - stage 1

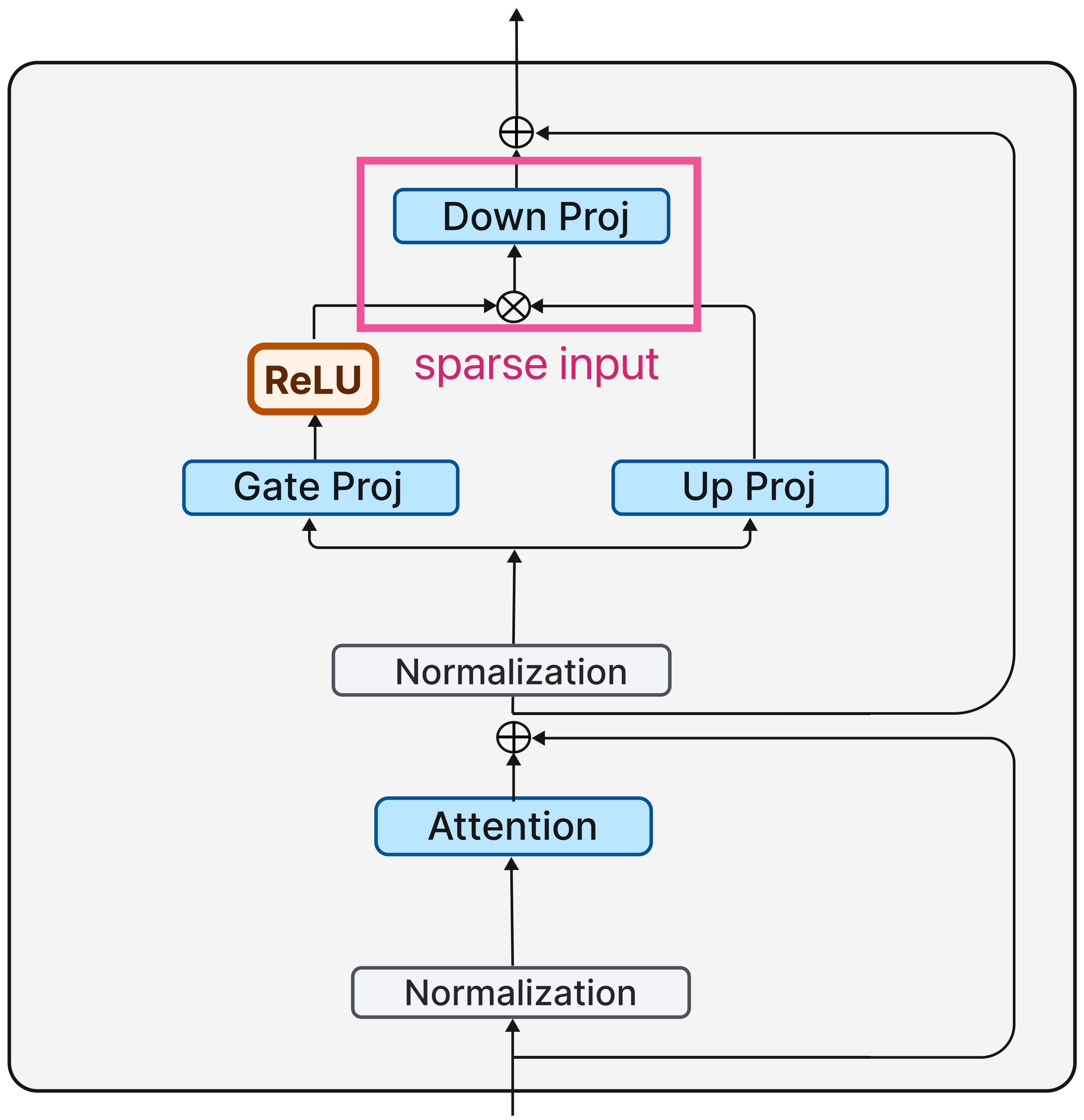


relufication - stage 2

ReLUfication Stages



no relufication



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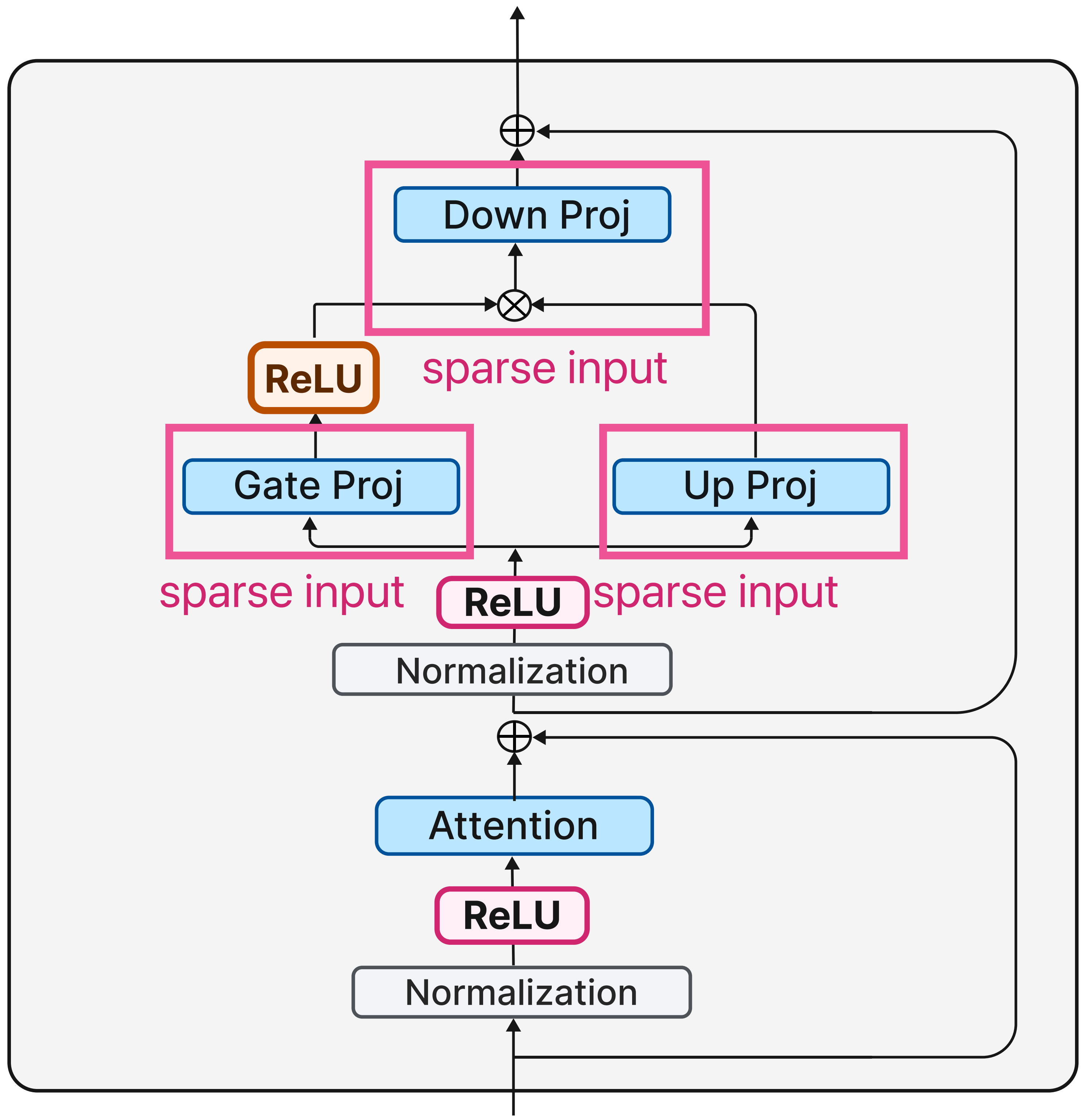
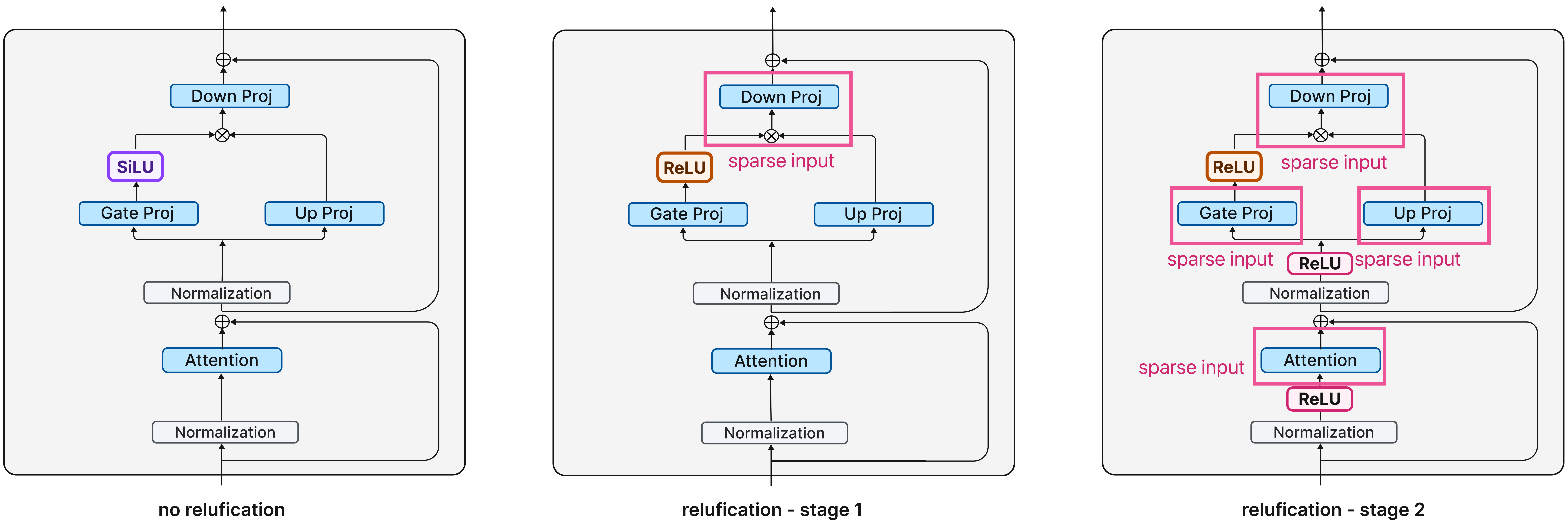


relufication - stage 2

ReLUfication Stages



ReLUfication: Results

Model	Input Sparsity (%)			FLOPS (G)	Avg 0-shot Acc %
	QKV	UpProj	DownProj		
Llama 7B	0	0	0	6.6	68.4
Llama 7B (relufied-s1)	0	0	62	4.8	67.1
Llama 7B (relufied-s2)	51	67	65	2.9	66.4
Falcon 7B	0	1	0	6.6	66.8
Falcon 7B (relufied-s1)	0	0	94	4.1	65.2
Falcon 7B (relufied-s2)	56	56	95	2.2	64.8
OPT 6.7B	0	0	97	4.5	59.8
OPT 6.7B (relufied-s2)	50	40	97	2.8	58.6

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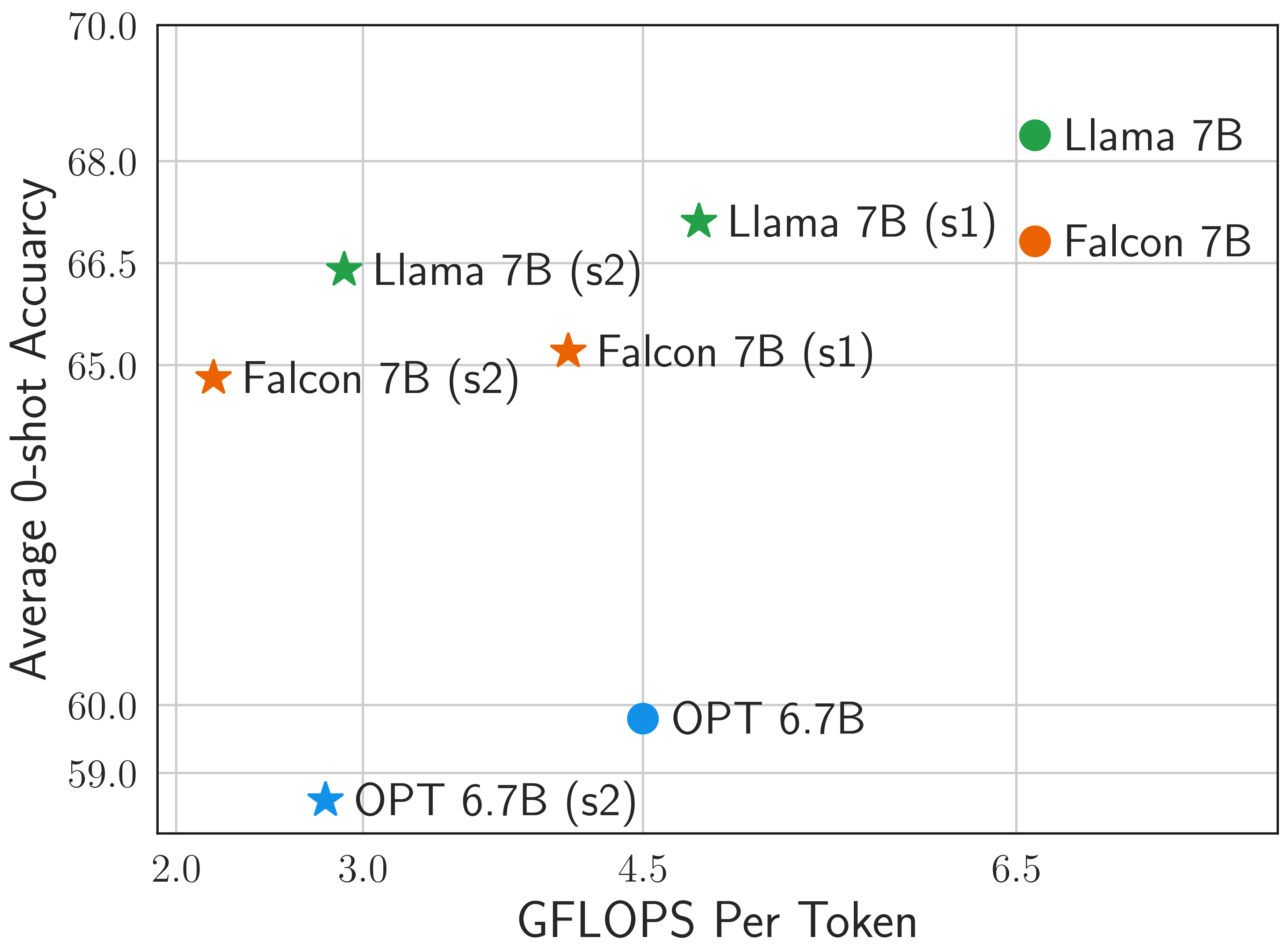

Why aren’t we training our LLMs with ReLU?

The Impact of Activation Function on Performance

When trained from scratch...

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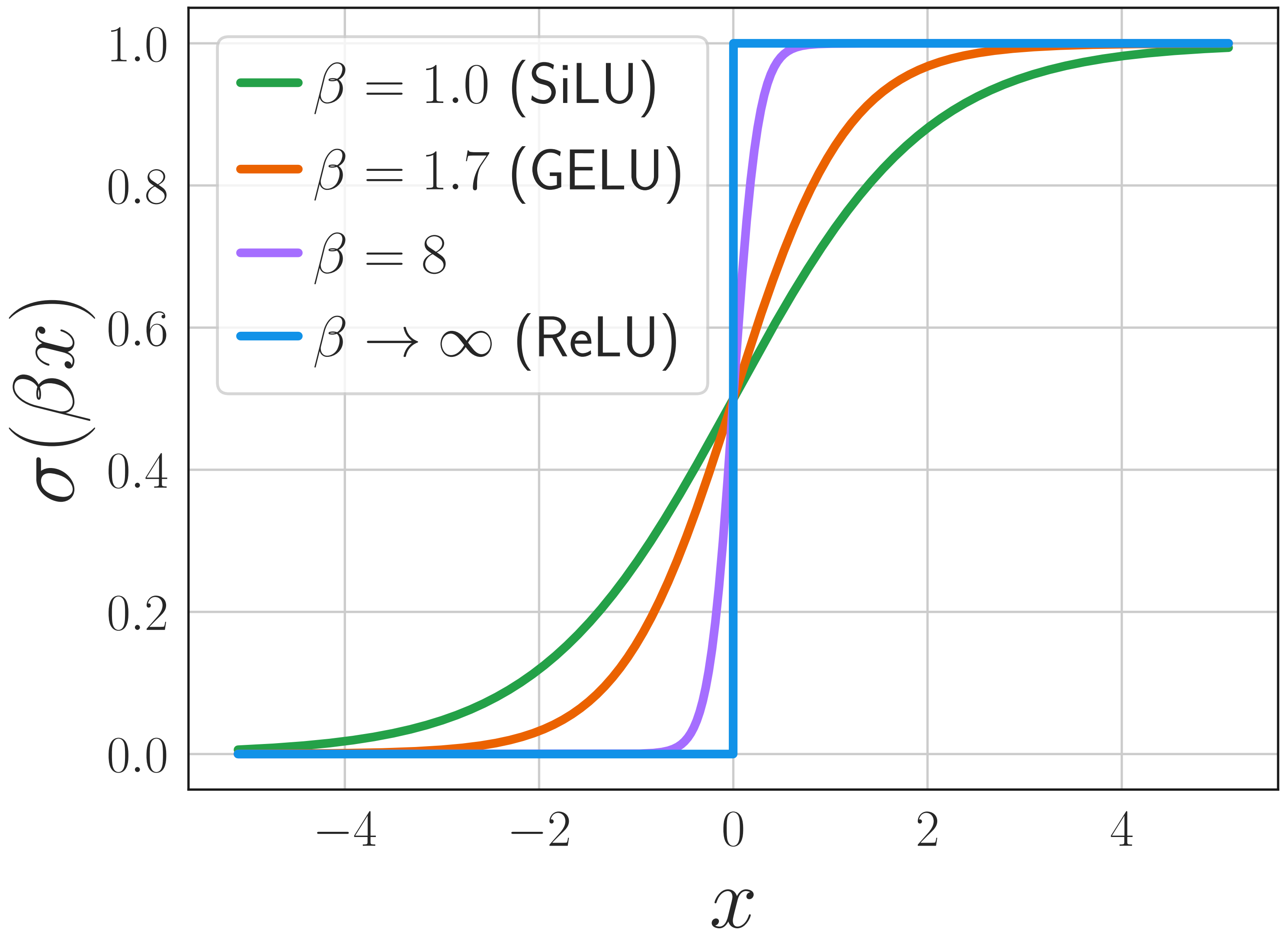

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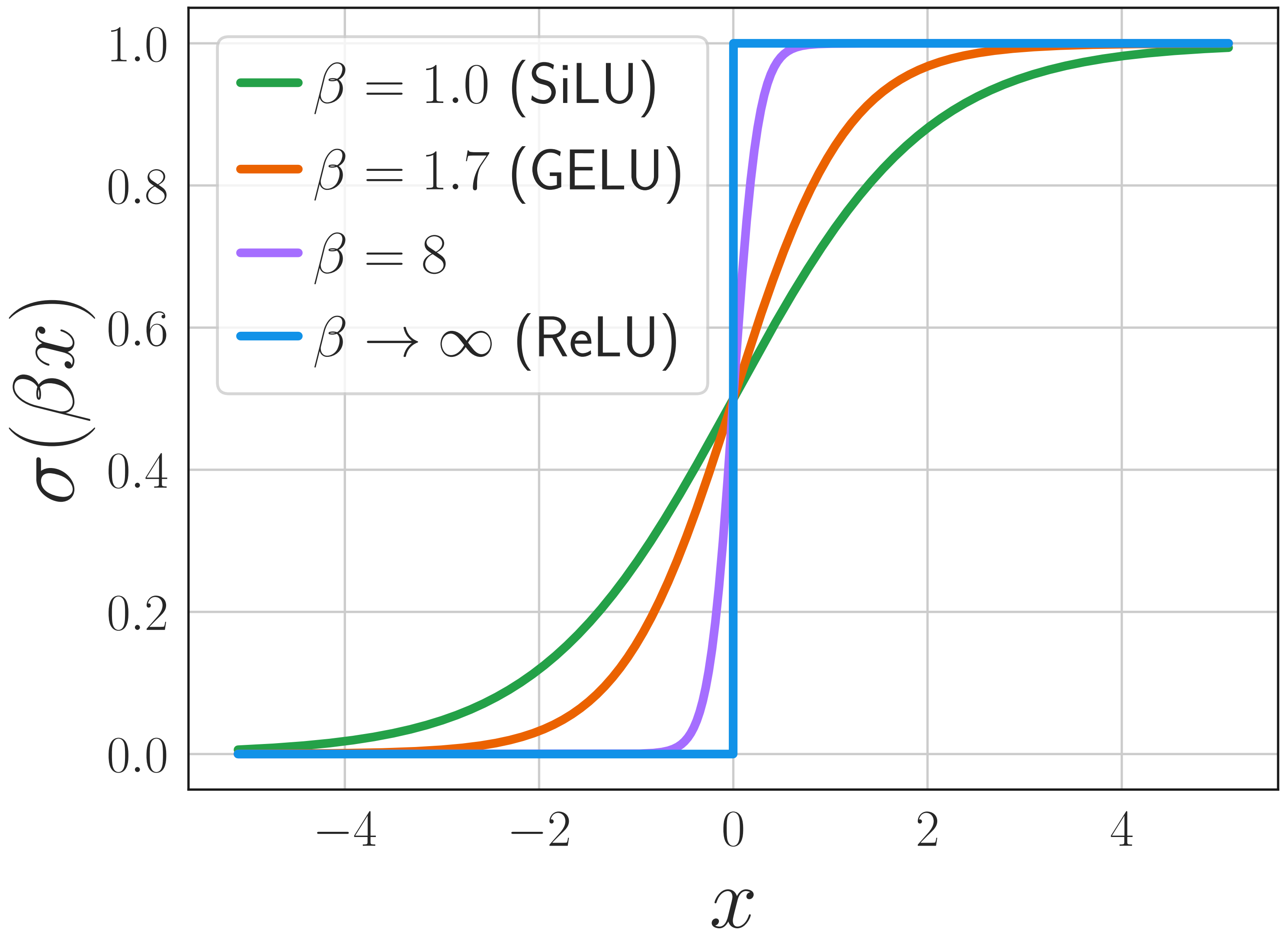

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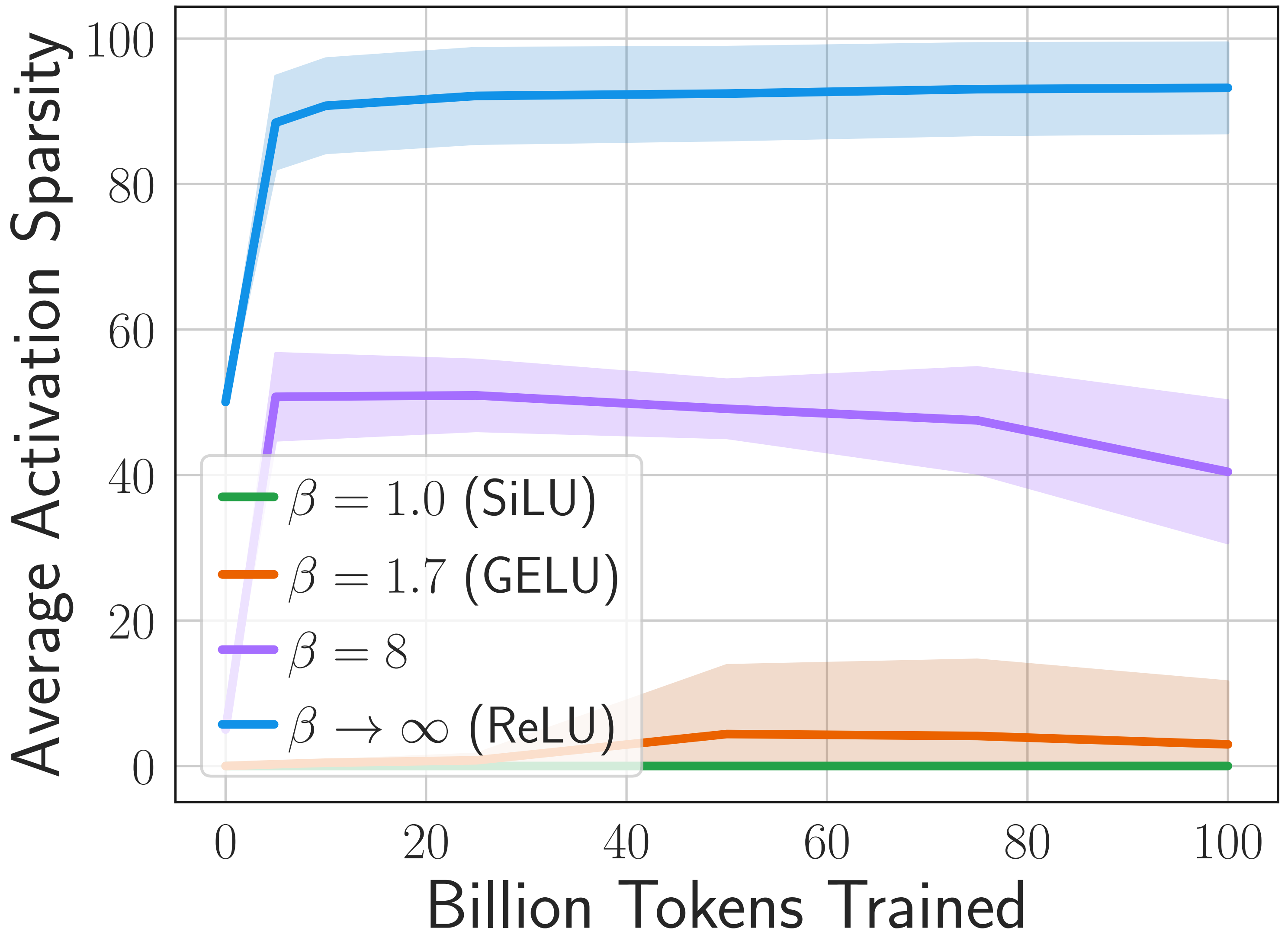

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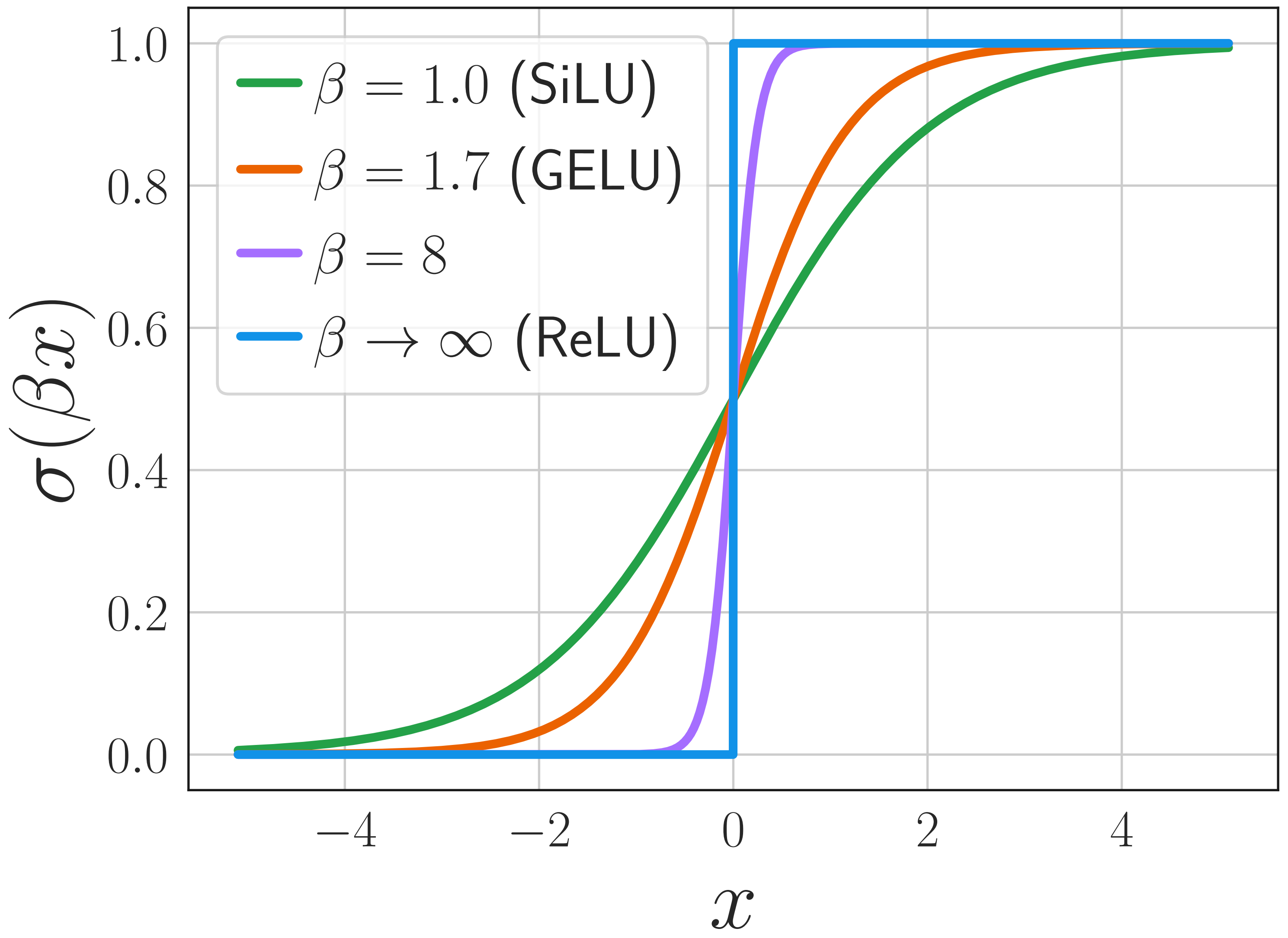

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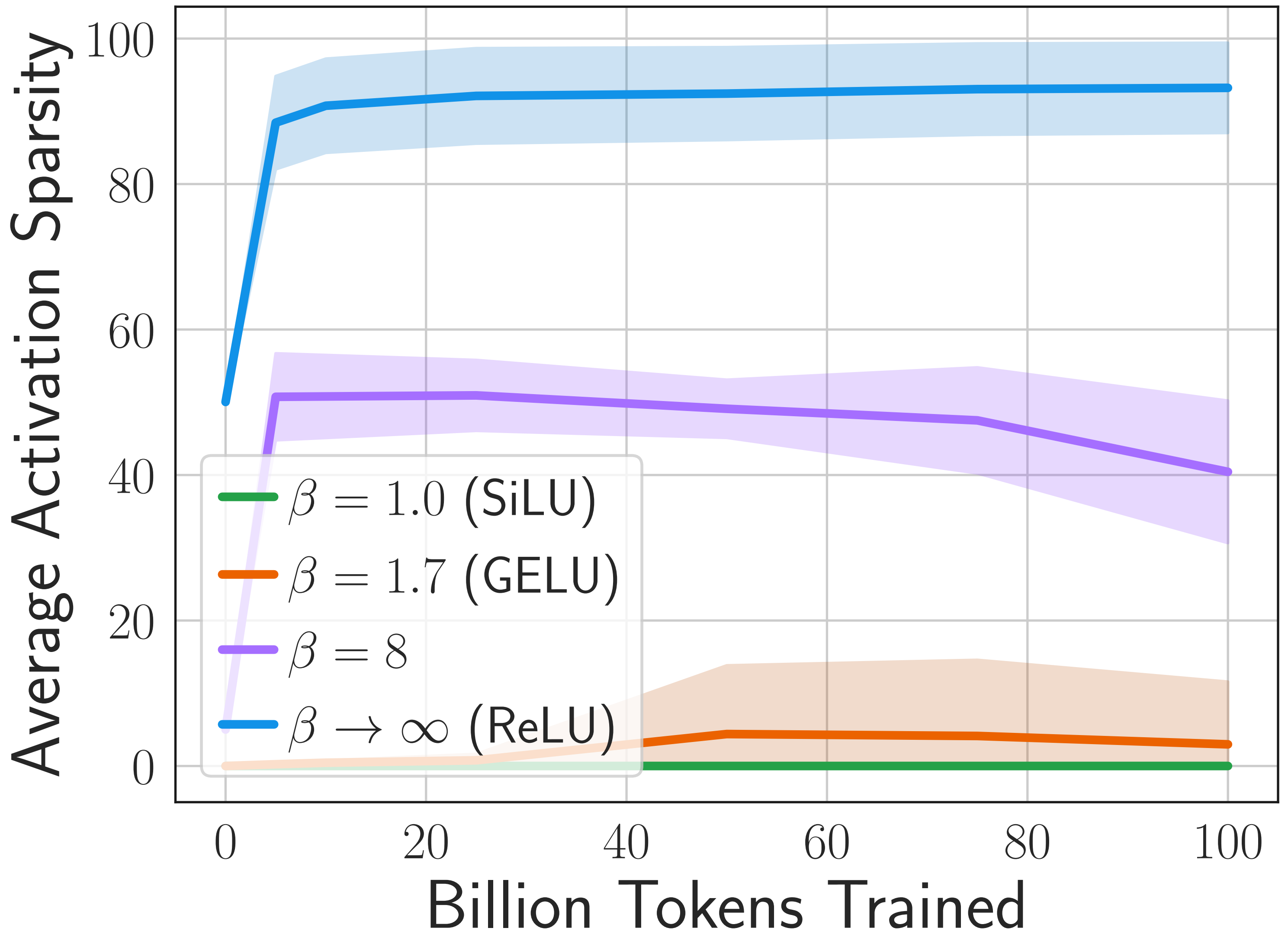

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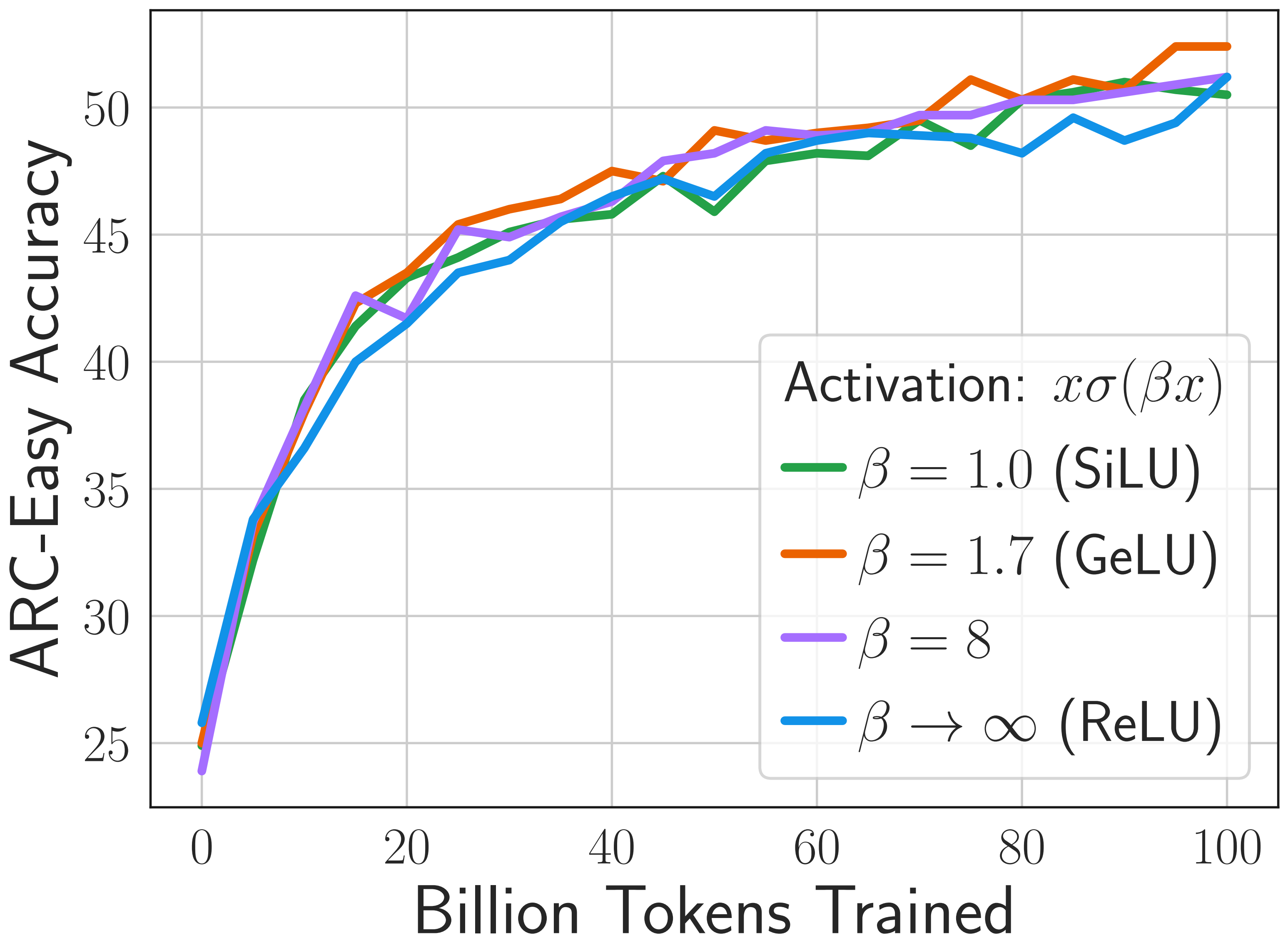

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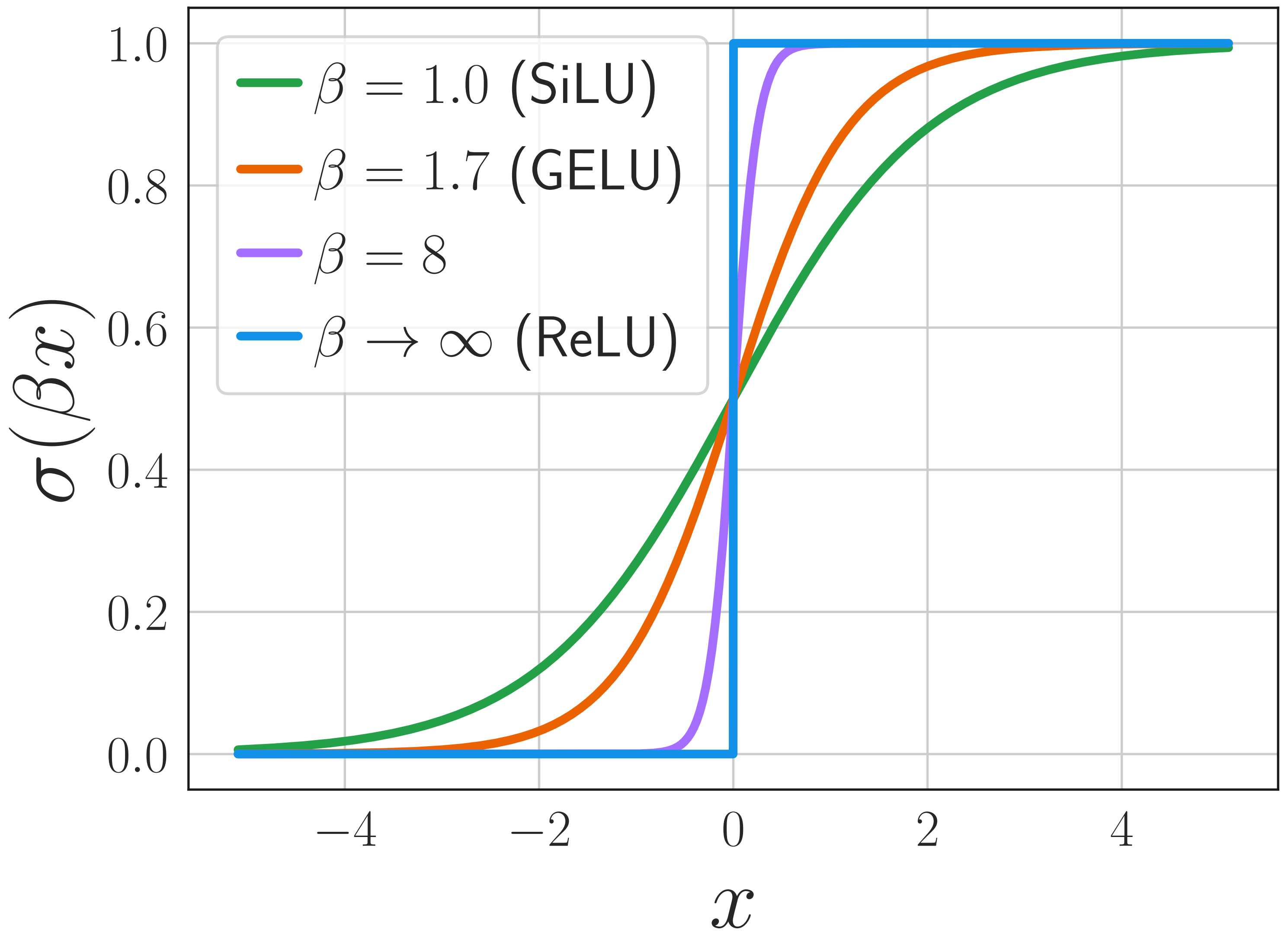

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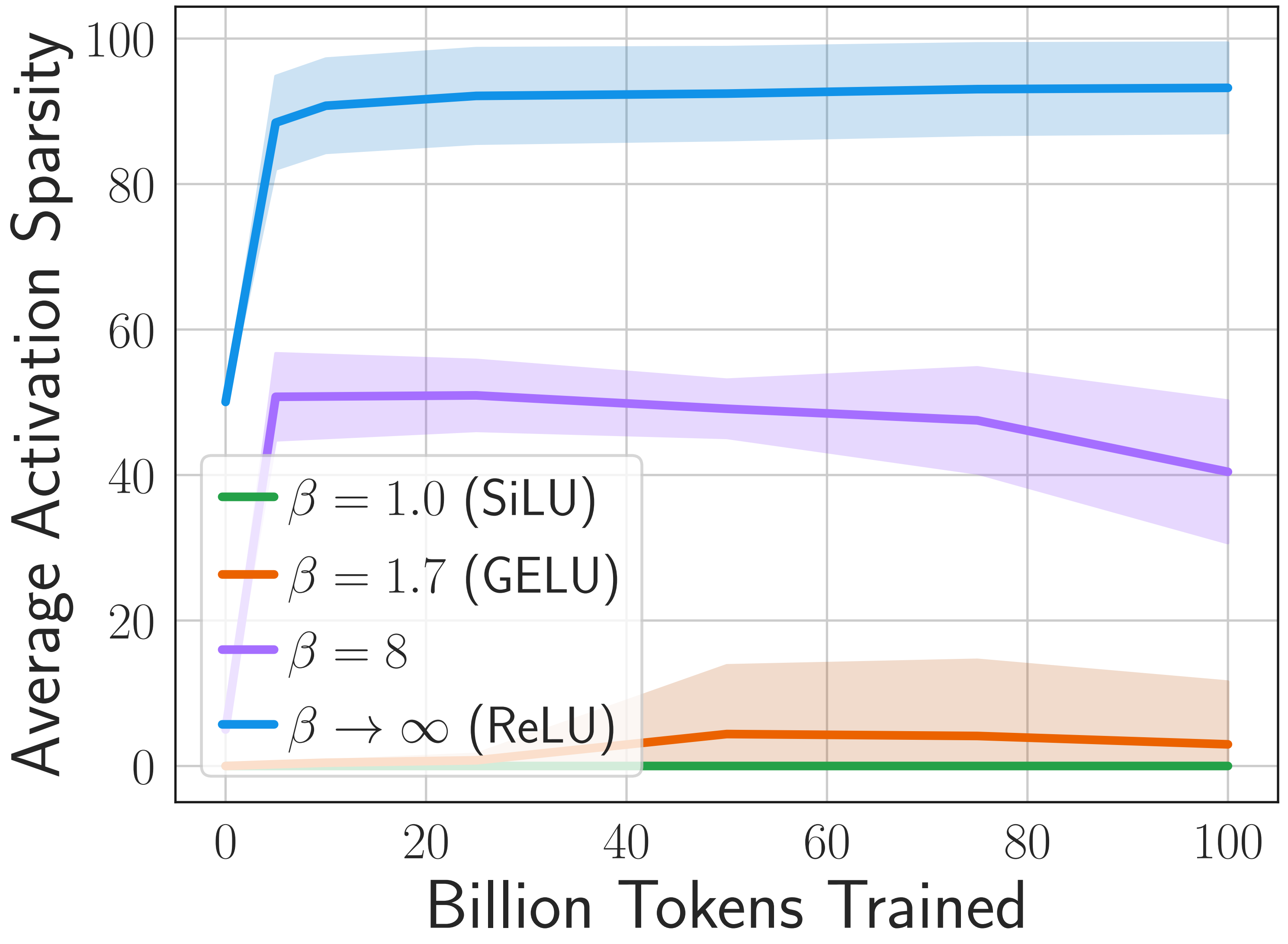

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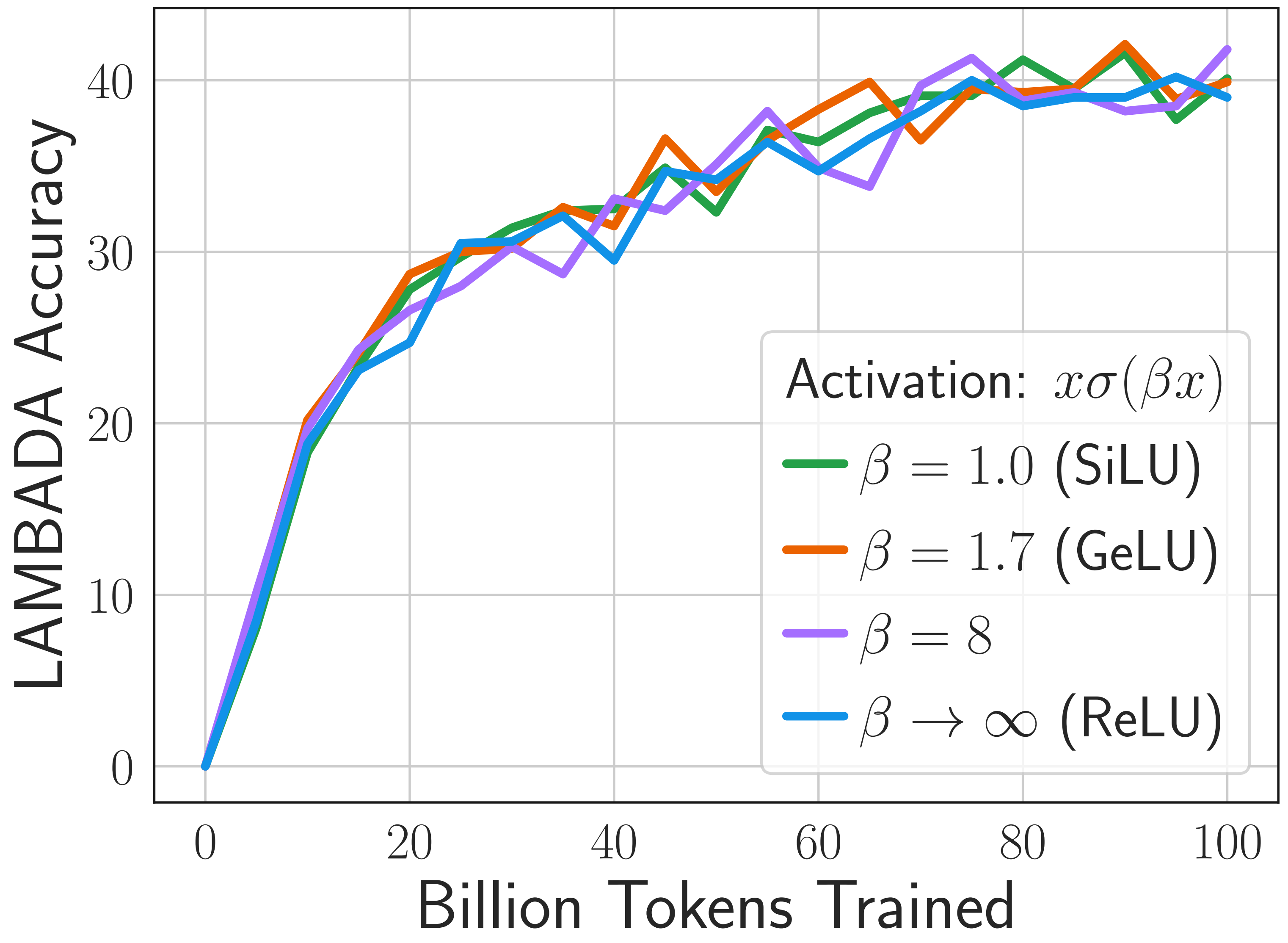

Concluding Remarks

Recap

- ReLU activations are sparse. We can use this property for faster inference.
- The majority of LLMs are trained without ReLU.
- We can change their activation function to ReLU, and fine-tune them for a short time (ReLUfication).
- But do these alternative activation functions (e.g., GELU, SwiGLU) really improve performance?
  Maybe we should reconsider the choice of activation function.

Future Directions: Multiple Tokens

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Limitation of our work:
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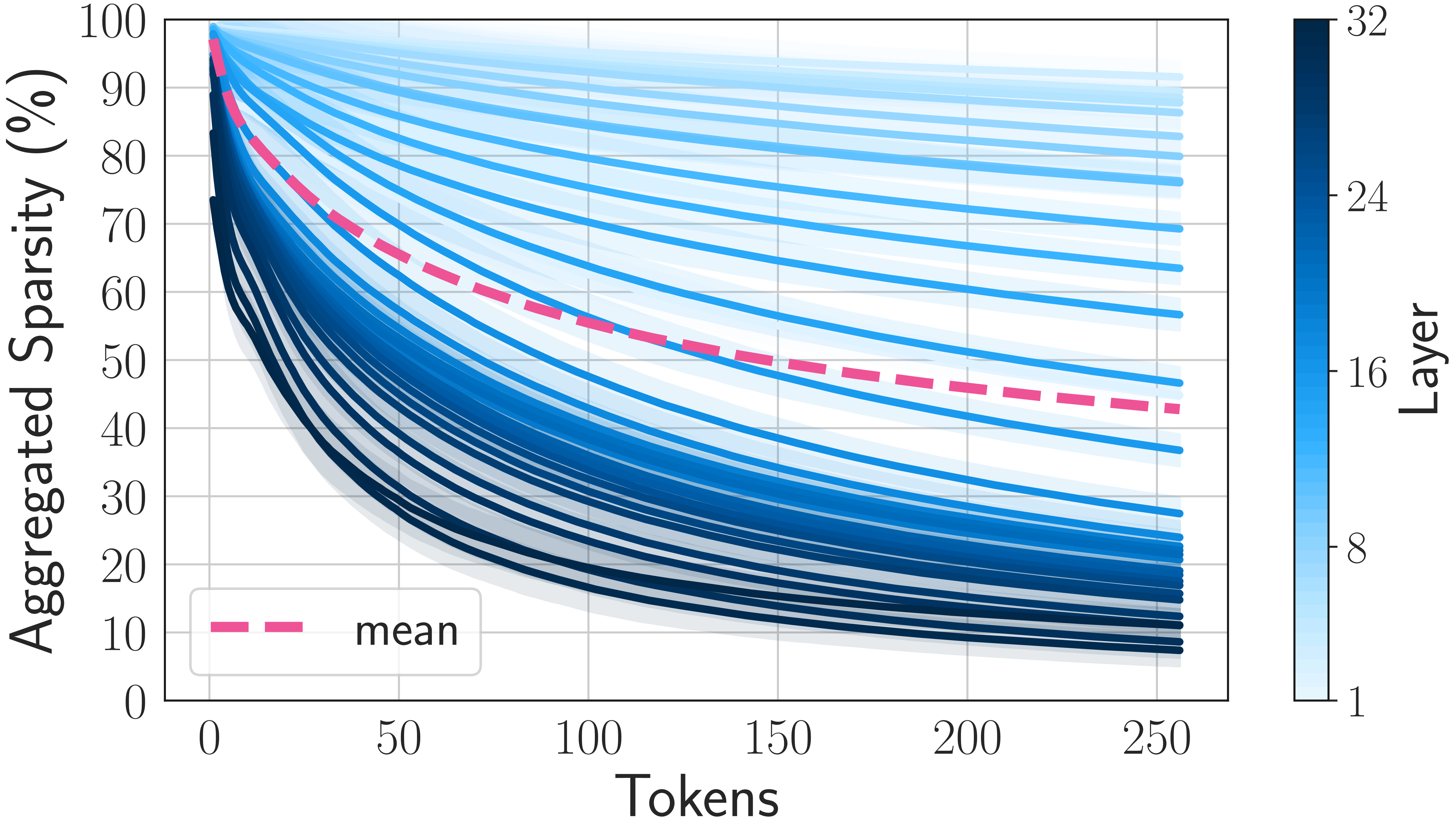

Future Directions: Improved Sparsity

For the GLU-based activation functions (e.g., SwiGLU), we notice lower activation sparsity (~60%) even after ReLUfication.

Tackling this issue:

[1] Song, Chenyang, et al. "ProSparse: Introducing and Enhancing Intrinsic Activation Sparsity within Large Language Models." arXiv preprint arXiv:2402.13516.

[2] Lee, Je-Yong, et al. "CATS: Contextually-Aware Thresholding for Sparsity in Large Language Models." arXiv:2404.08763.

Poster Session: Halle B #89