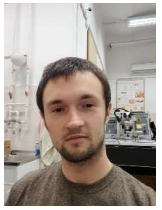
Neuromorfic Electronics @ BME








+ 11 STUDENTS

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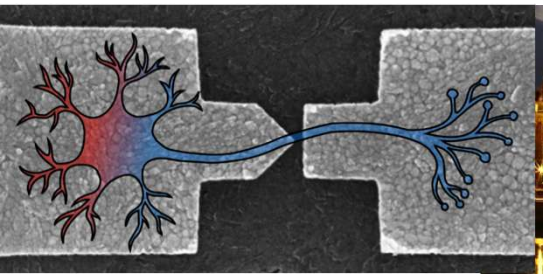
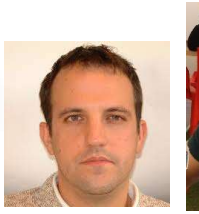
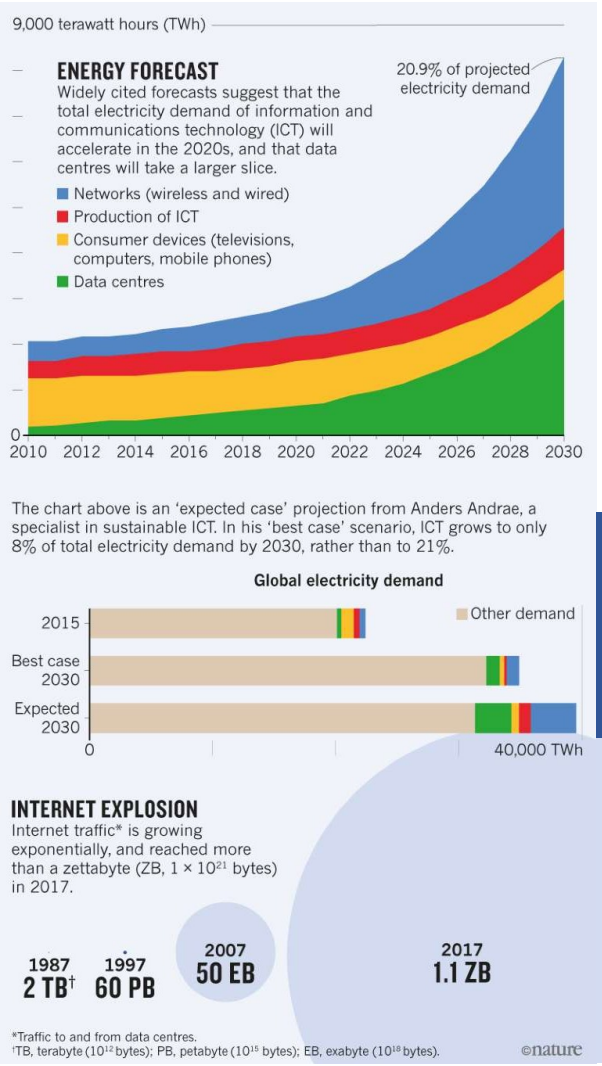
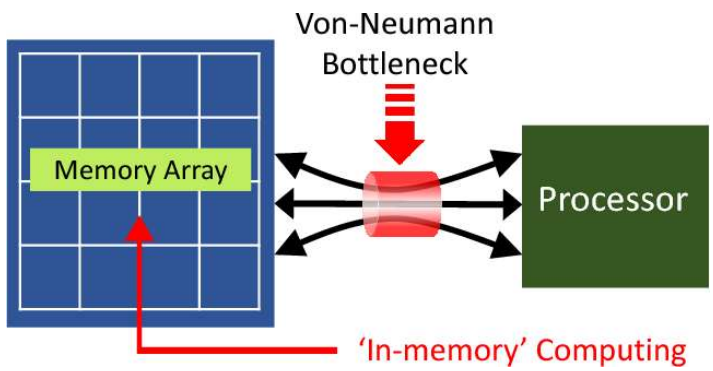
Key collaborators:

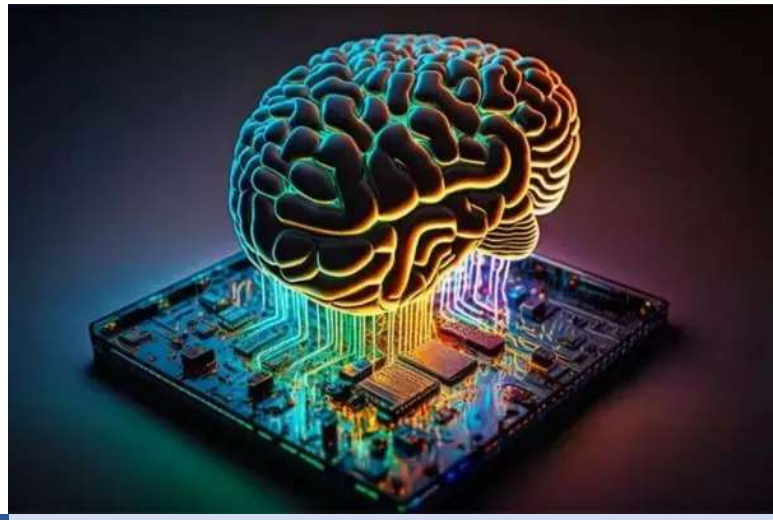


Energy efficient computing?







von Neumann computer

Digital (0,1)

Separate memory and processor

General hardware + software

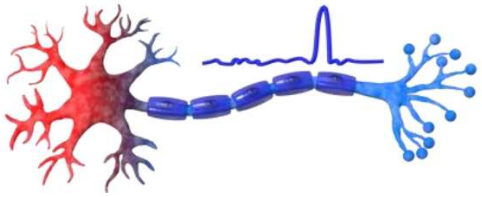
Neuromorphic computing

Analalog

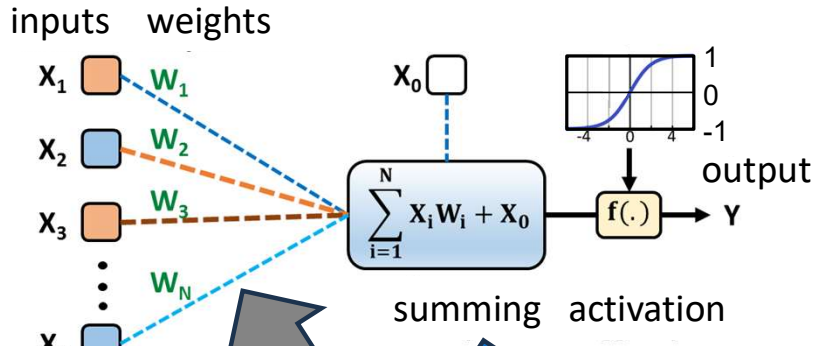
In memory computing

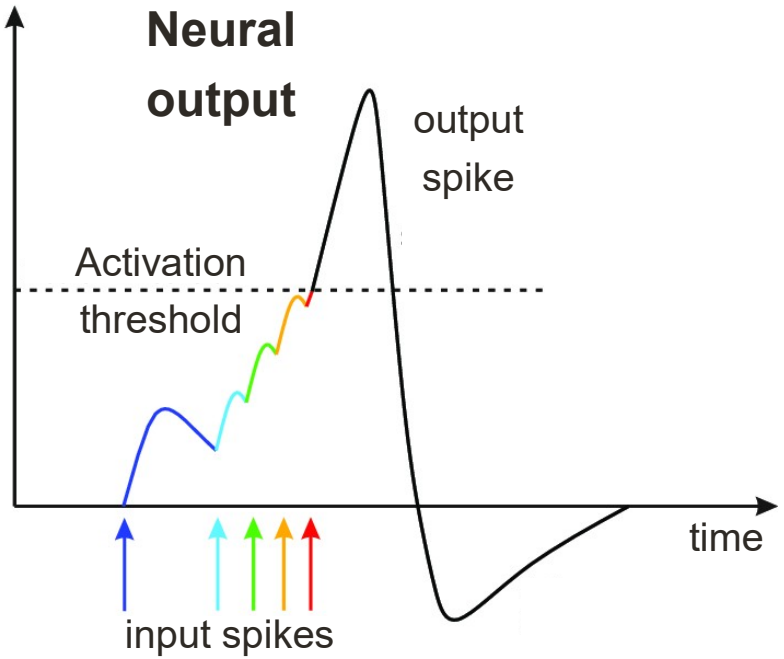
"Edge computing" with targeted hardware

Biological and artificial neurons



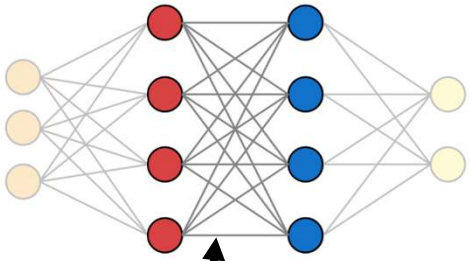
Artificial neuron



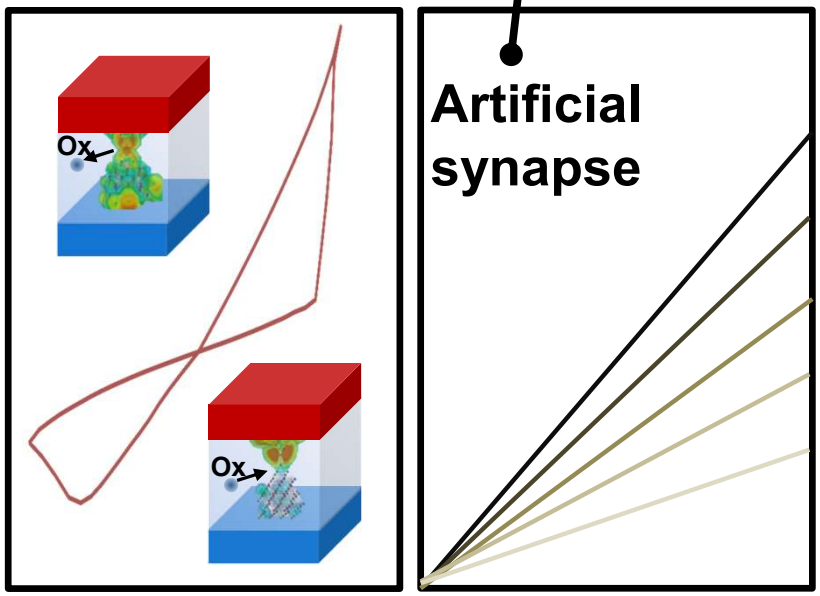


Learning: variation of synaptic weights

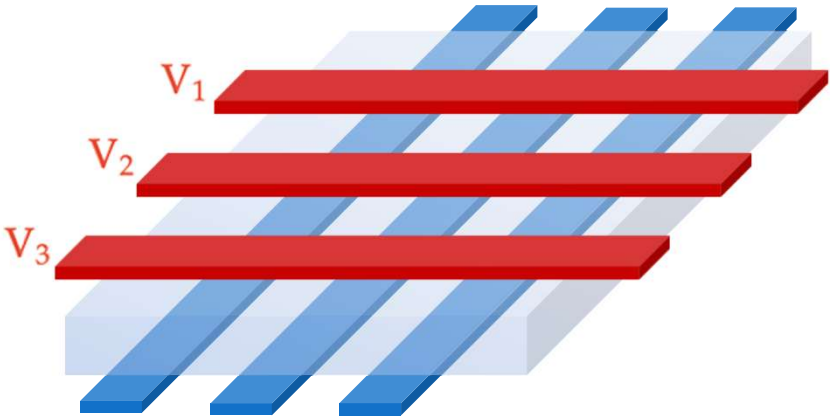
Memristors as artificial synapses



MEMRISTOR



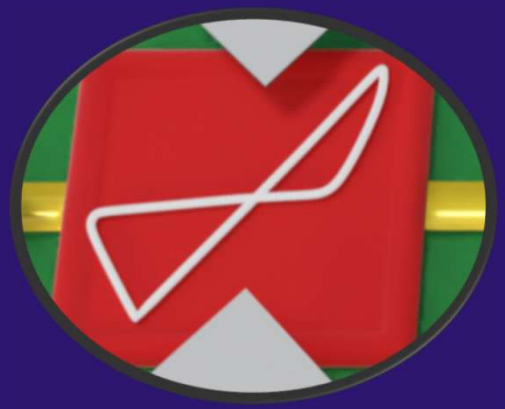
Artificial synapse



$$I_2 = V_1 \cdot G_{12} + V_2 \cdot G_{22} + V_3 \cdot G_{32}$$

N^2 hardware multiplications in a single step

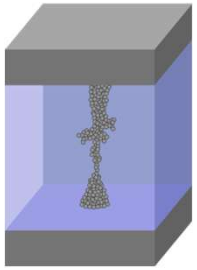
Memristive artificial synapses



How small?

Down to single atom!

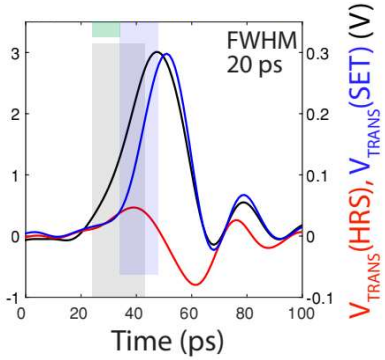
NANO LETTERS 20, 1192 (2020)
ACS APPL. NANO MAT. 6, 21340 (2023)



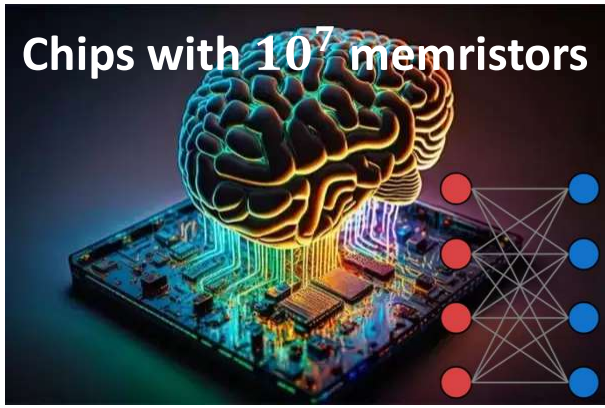
How fast?

Down to 15ps switching!

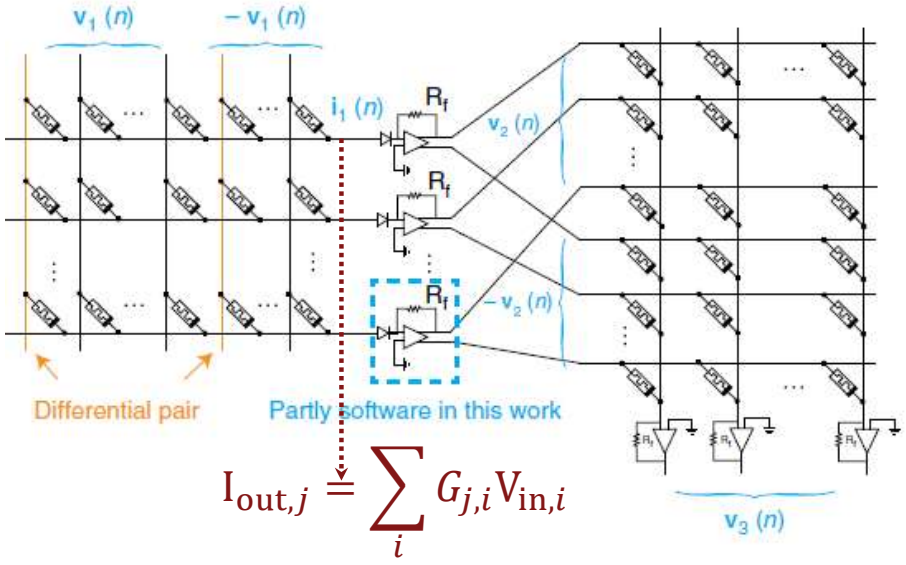
ADV. ELEC. MATERIALS 9 2201104 (2023



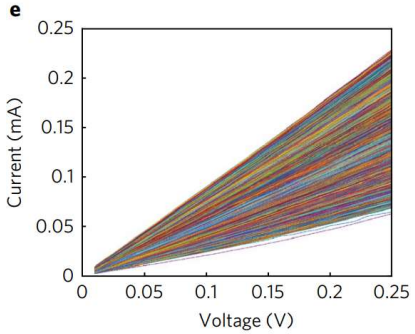
How many?

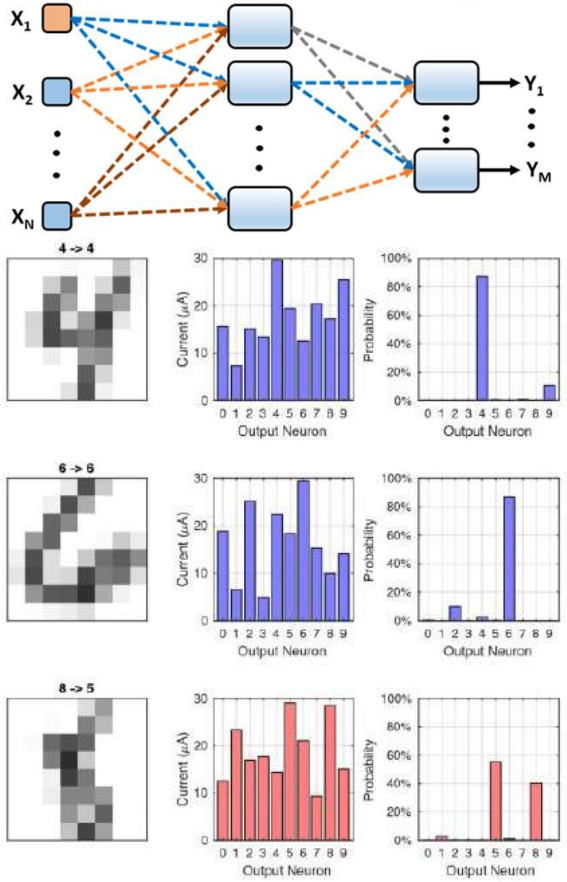


Memristive neural networks



Efficient and self-adaptive in-situ learning in multilayer memristor neural networks **NATURE COMM. 9**:2385 (2018)





High accuracy handwritten digit recognition (8200 memristors)

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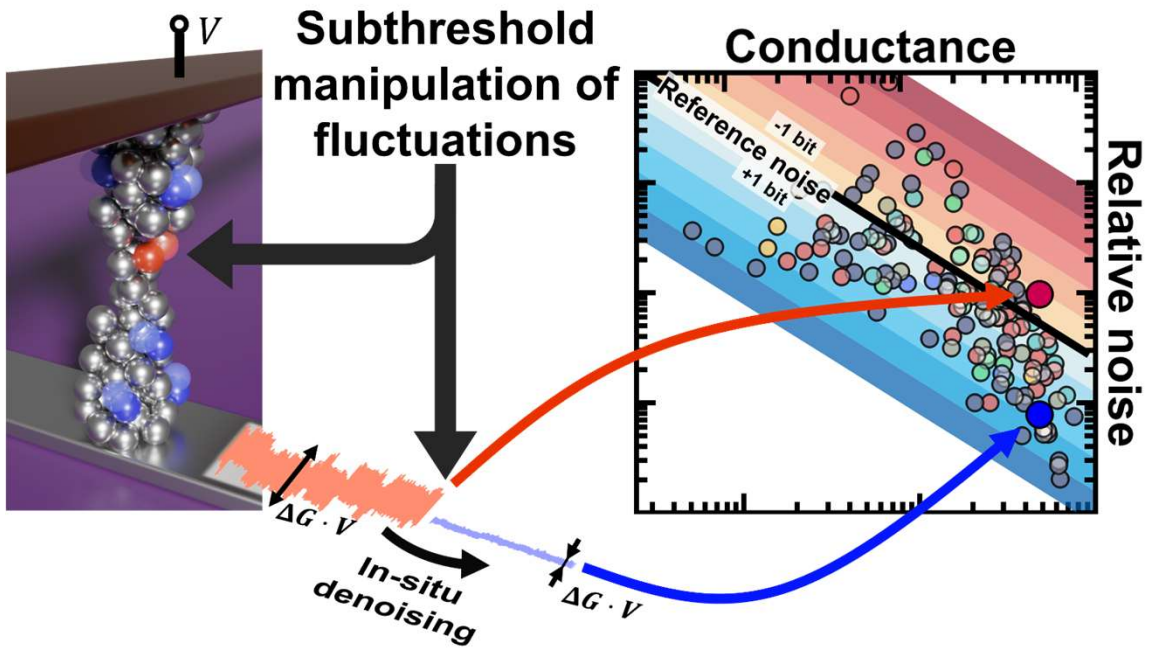
Benchmarking Stochasticity Behind Reproducibility: Denoising Strategies In Memristive Filaments



ACS APPL MATERIALS & INTERFACES 17, 25654 (2025)

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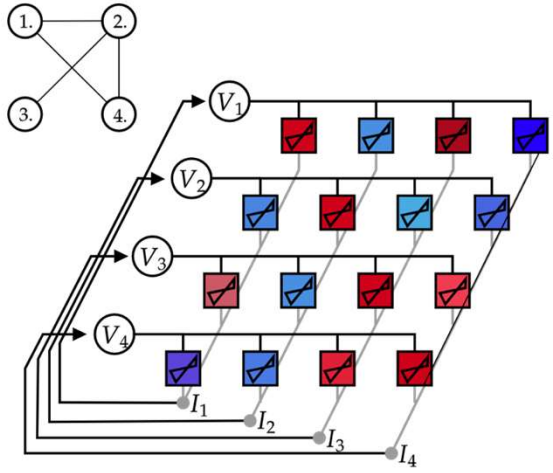
Noise tailoring, noise annealing and external perturbation injection strategies in memristive Hopfield neural networks



J.G. Fehérvári et al., *Noise tailoring, noise annealing and external perturbation injection strategies in memristive Hopfield neural networks,* **APL MACHINE LEARNING 2** 016107 (2024)

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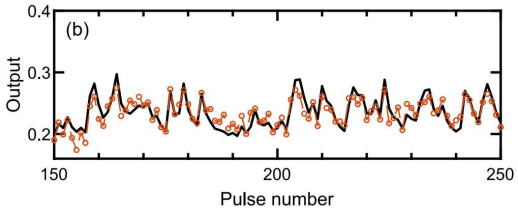
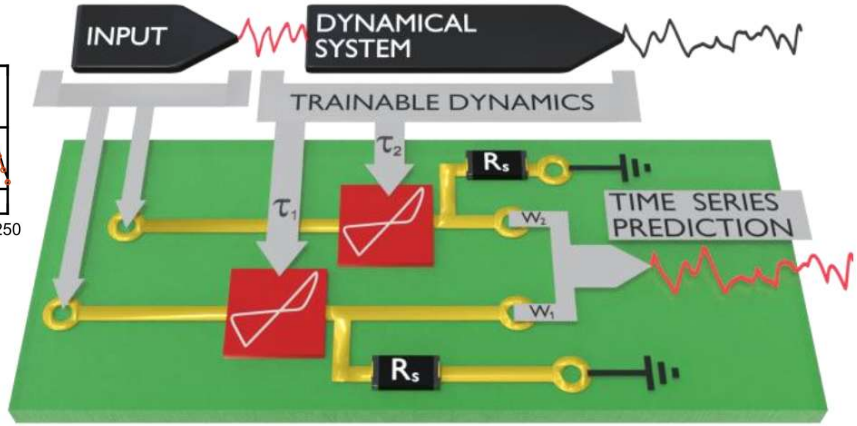
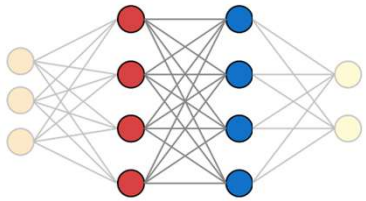
Temporal Signal Recognition and Time Series Prediction with Dynamical Memristors





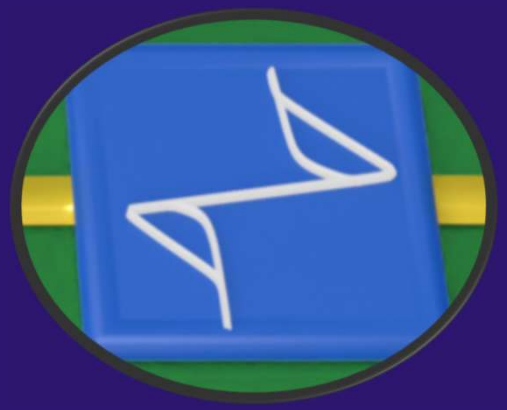
network complexity → dynamical complexity

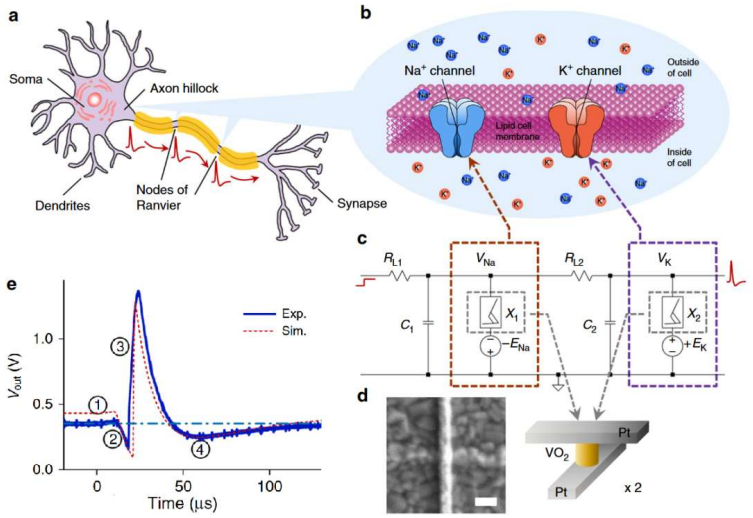


D. Molnár et al., *Neural information processing and time-series prediction with only two dynamical memristors,* ***Adv. Electron. Mater. 2025, e00353***

VO_2 memristor – artificial neuron

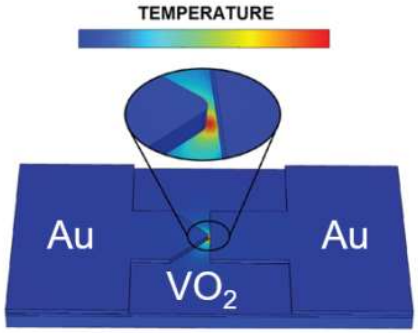
VO_2 Mott memristor



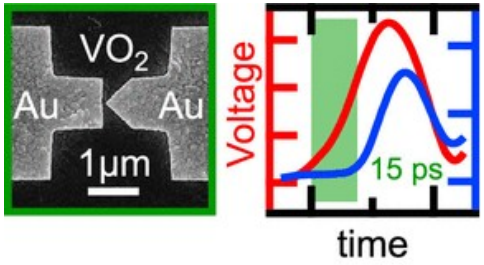


"23 biological neuron spiking behaviors experimentally demonstrated in VO_2 active memristor neurons"
Yi et al. **NATURE COMM 9**, 4661 (2018)

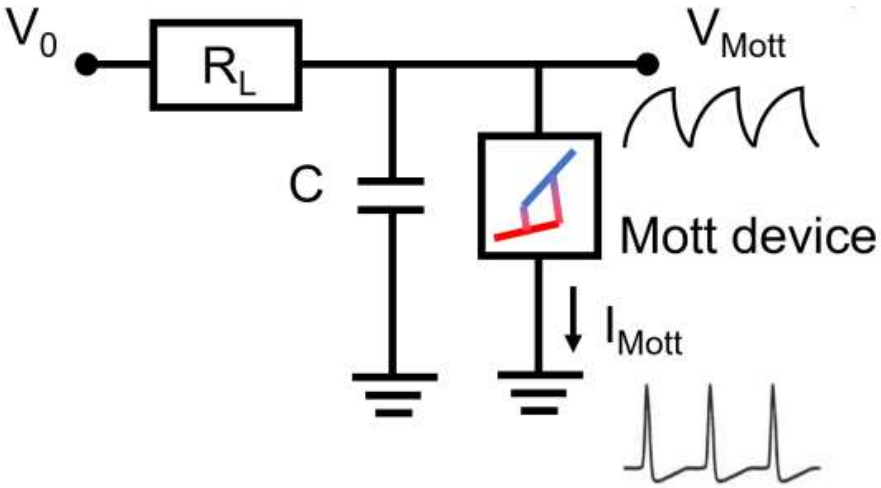
Size: **Switching focused to 30nm active region**
ACS APPLIED NANO MATERIALS 6, 9137 (2023)

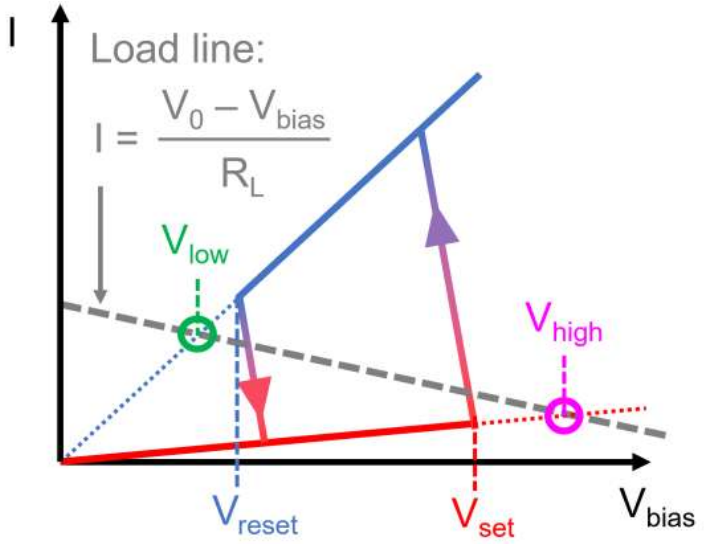


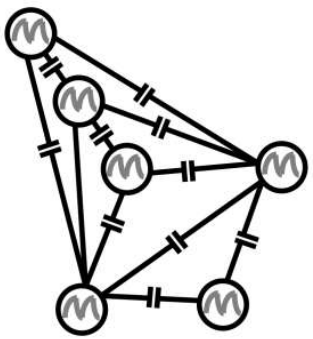
Speed: **Down to 15ps switching!**
ACS NANO 18 21966 (2024)

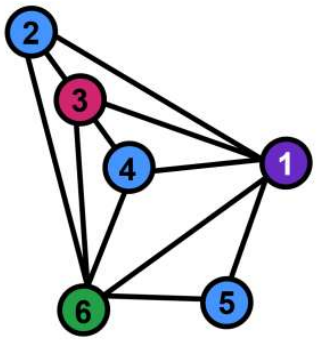


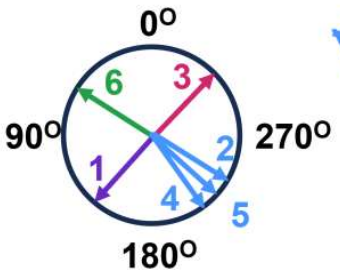
Oscillating neural networks from VO_2 memristors











Maher et al., *CMOS-compatible oscillation-based VO_2 Ising machine solver,* **NATURE COMMUNICATIONS 15**, 3334 (2024)

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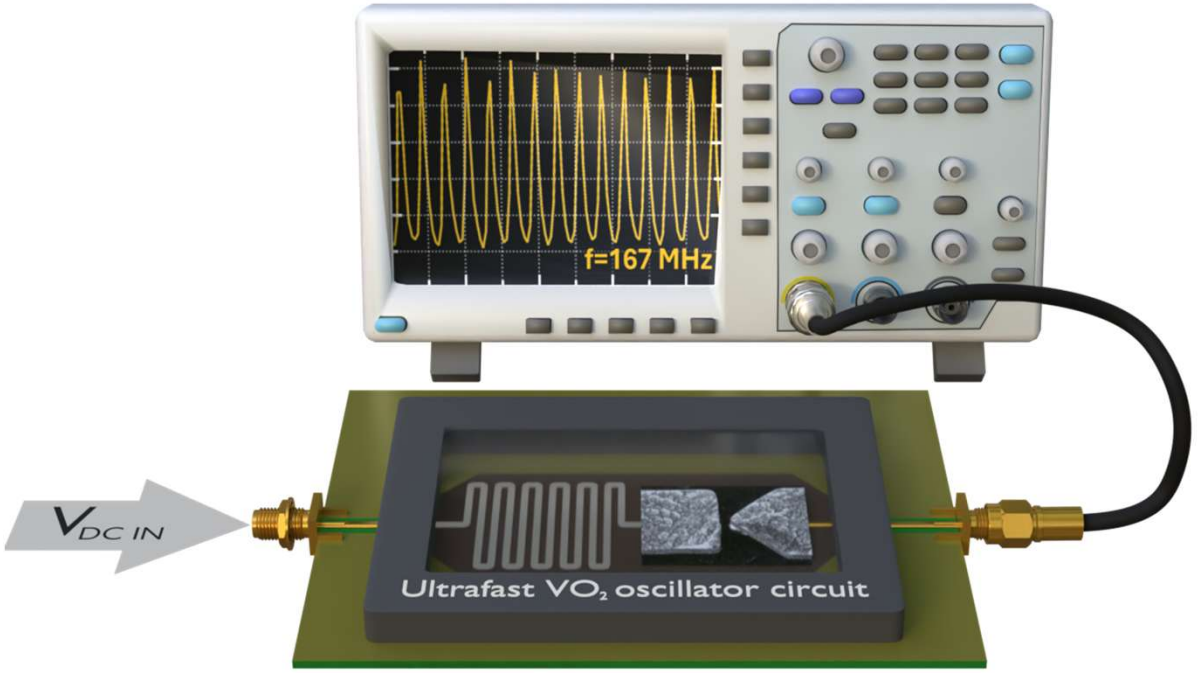
Development of ultrafast VO_2 oscillator circuits



Pollner et el., *VO2 oscillator circuits optimized for ultrafast, 100 MHz-range operation,* ***Adv. Electron. Mater. 2025, e00433***

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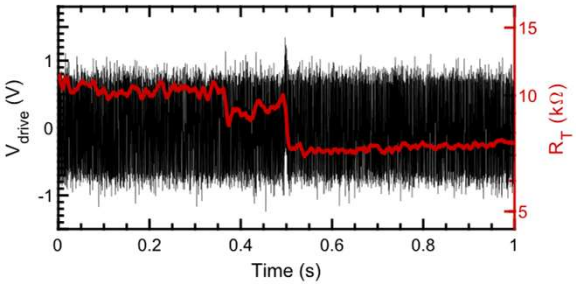
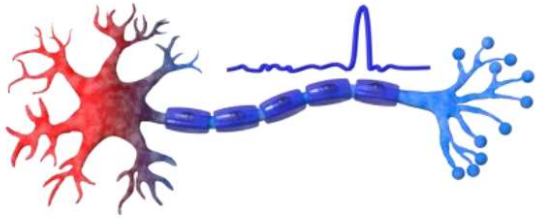
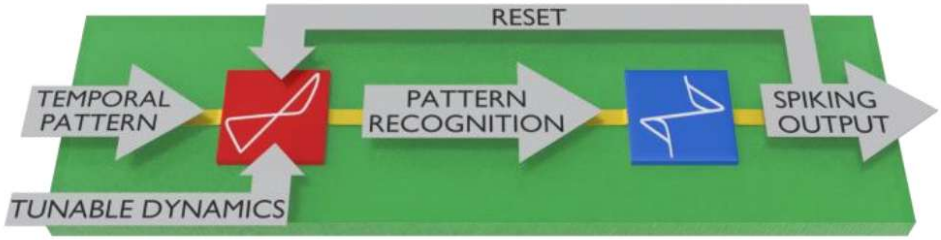
Neural circuit with a synapse an a neuron type memristor







D. Molnár et al., *Neural information processing and time-series prediction with only two dynamical memristors,* ***Adv. Electron. Mater. 2025, e00353***

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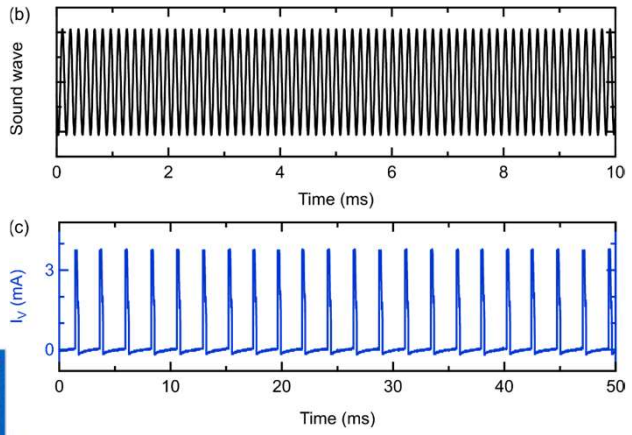
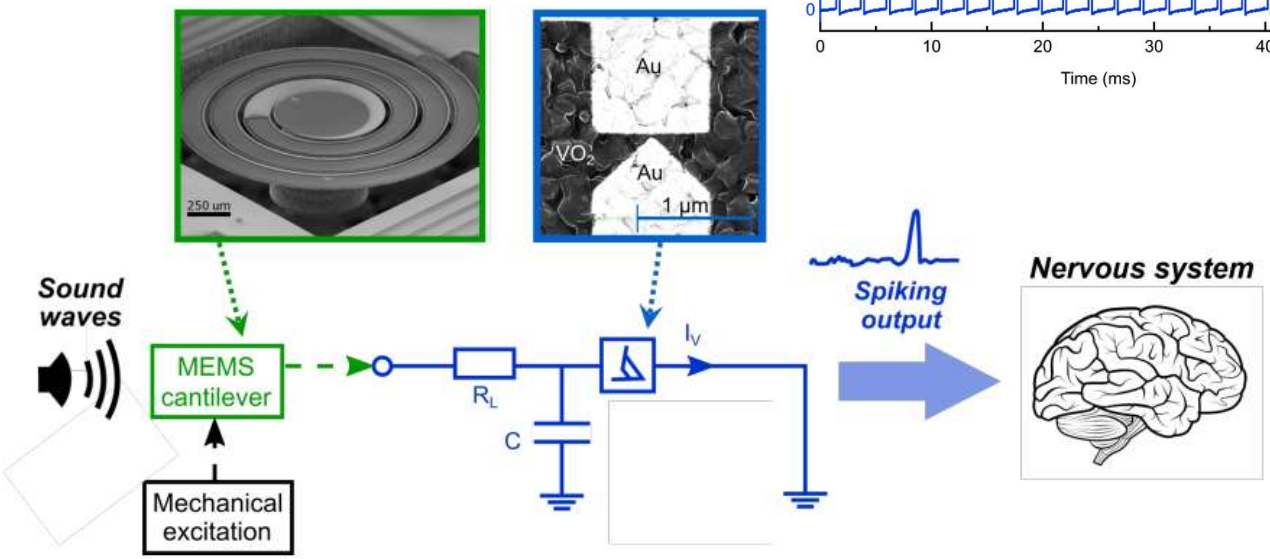
Artificial hearing with a memristive neural circuit





T. N. Török et al., *Memristor-Driven Spike Encoding for Fully Implantable Cochlear Implants*, ***arXiv:2509.26582***

Neuromorphic electronics @ BME

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Budapest University of Technology and Economics

- **26 TDK works, 8 BME TDK 1st prize, 8 OTDK 1st prize**
- **OTKA, KDP, UNKP, HUN-REN-BME, QNL research grants**
- **Join us!**

https://nanoelectronics.physics.bme.hu/neuromorphic_electronics

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