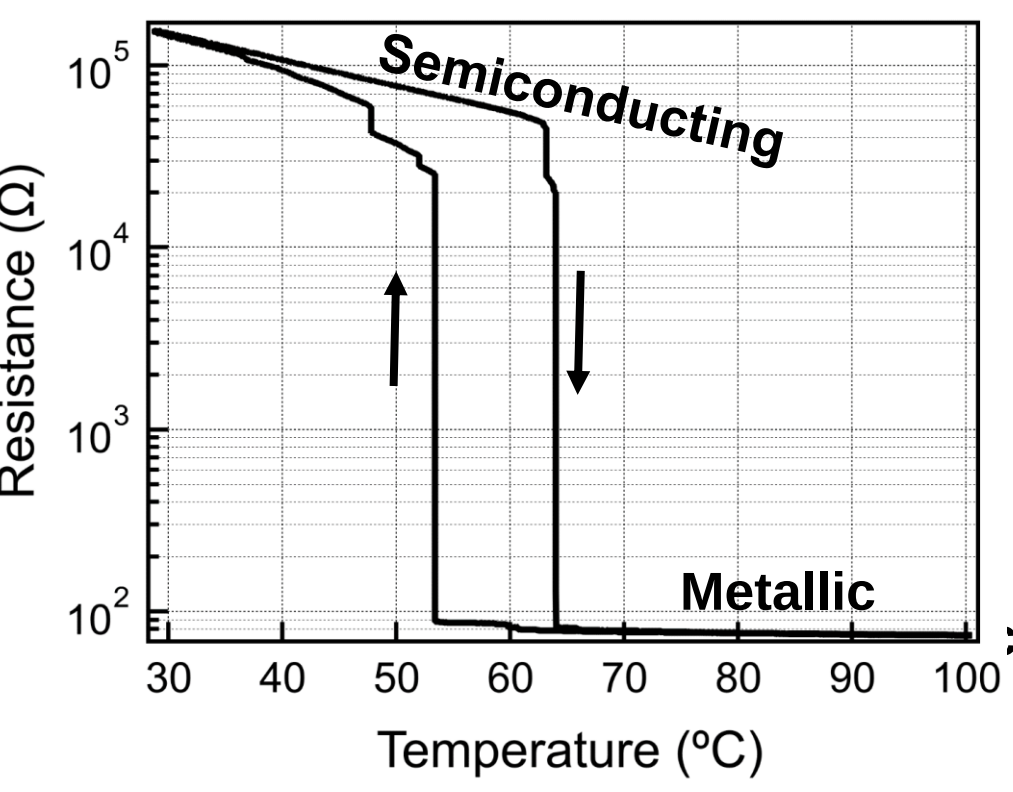


Volatile Mott memristors are key components of neuromorphic circuits alongside conventional non-volatile resistive switches. While the latter essentially play the role of artificial synapses in neural network applications, the former act as artificial neurons implementing several neural spiking patterns[1]. In addition, Mott memristors are well applied to oscillating neural networks, where information processing occurs in the dynamic domain and the computation is encoded by the phase of the oscillators. All these applications require fast operation, but until today, only oscillation frequencies in the 10 MHz regime have been achieved with the most common, VO₂-based Mott memristors [2]. Here we investigate the dynamic operation of nanoscale VO₂ Mott memristors, where the functionality is concentrated in the ultrasmall, ~30 nm wide region between the contacting electrodes[3]. By analyzing and comparing the results of time-resolved pulsed experiments and the evolution of the device states along the constant bias oscillatory operation, we explore the physical and geometrical speed limitation of VO₂ oscillators.

1. Phase change property of VO₂

Thermally-induced phase transition

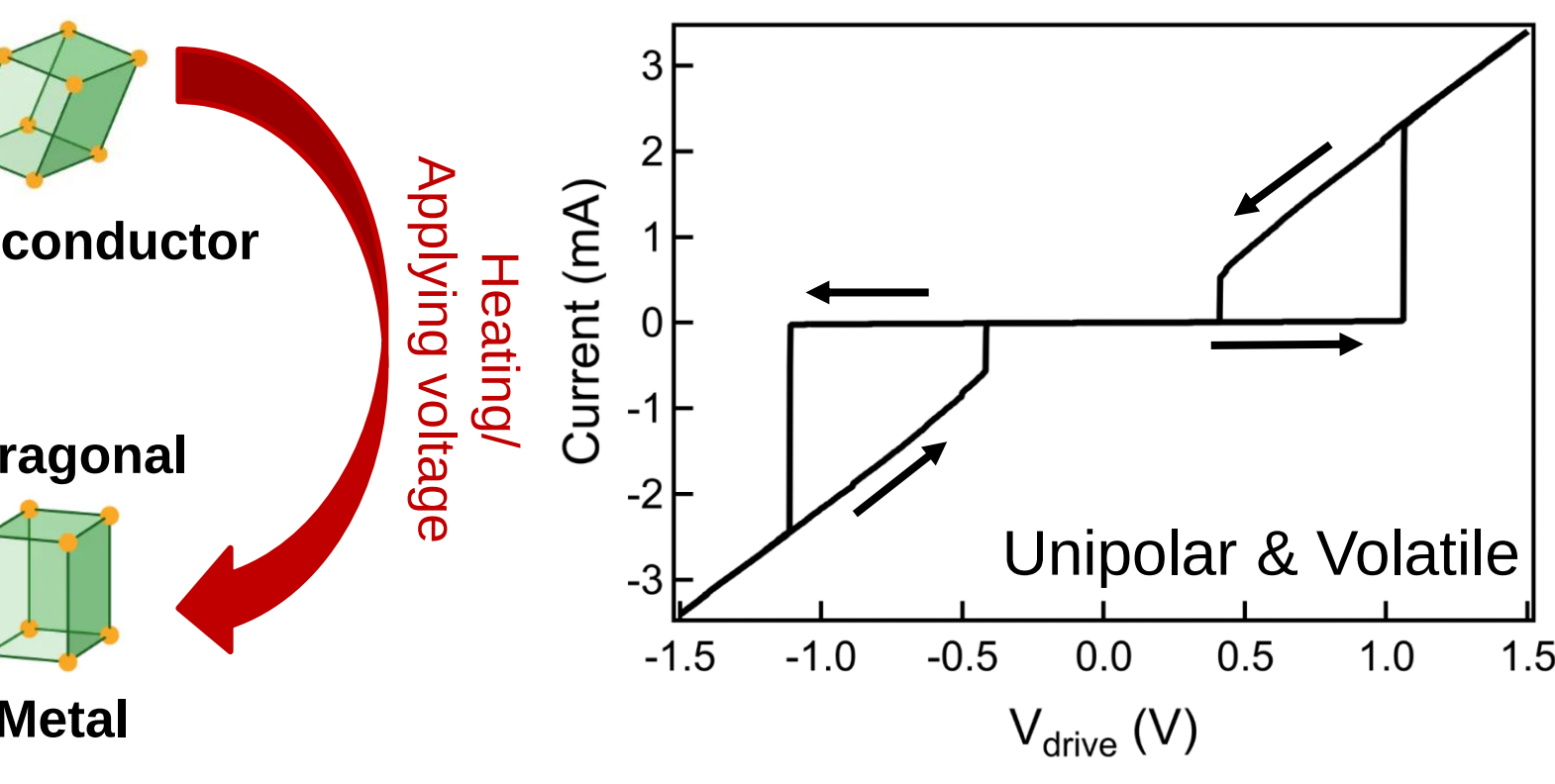


Physical mechanism behind the phase change: **Mott transition**

Phase transition can be triggered:

- Thermally
- Electrically
- Applying mechanical stress, pressure
- Optically

Electrically induced phase transition



Property changes during the phase transition:

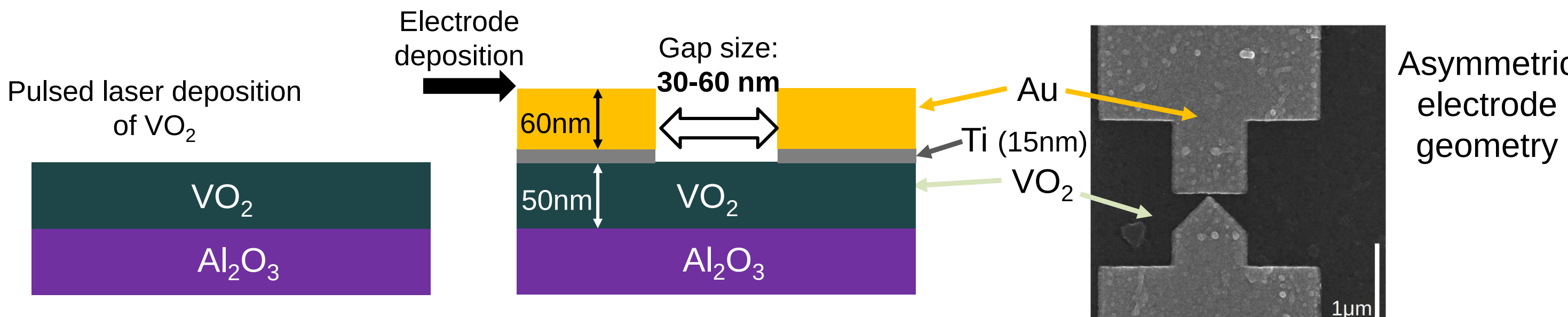
- Electrical conductivity
- Optical transmission
- Thermal conductivity

Possible applications of VO₂

- Resistive switches
- Optical switches

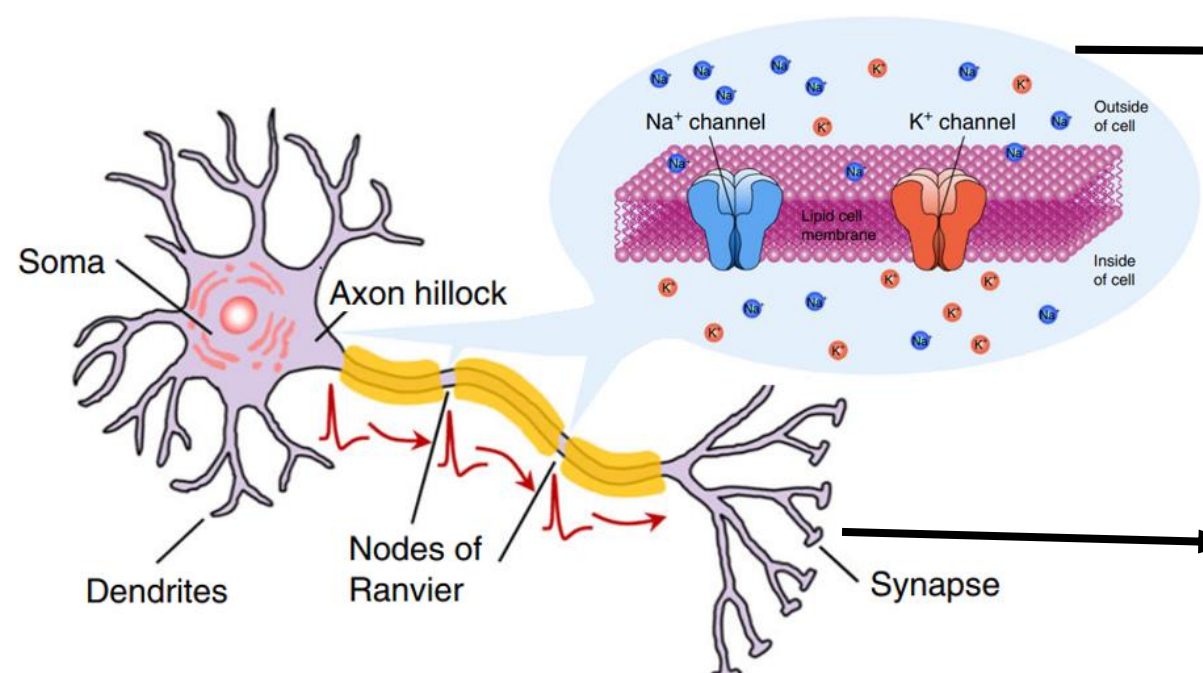
2. VO₂ based resistive switching memories

Sample fabrication:

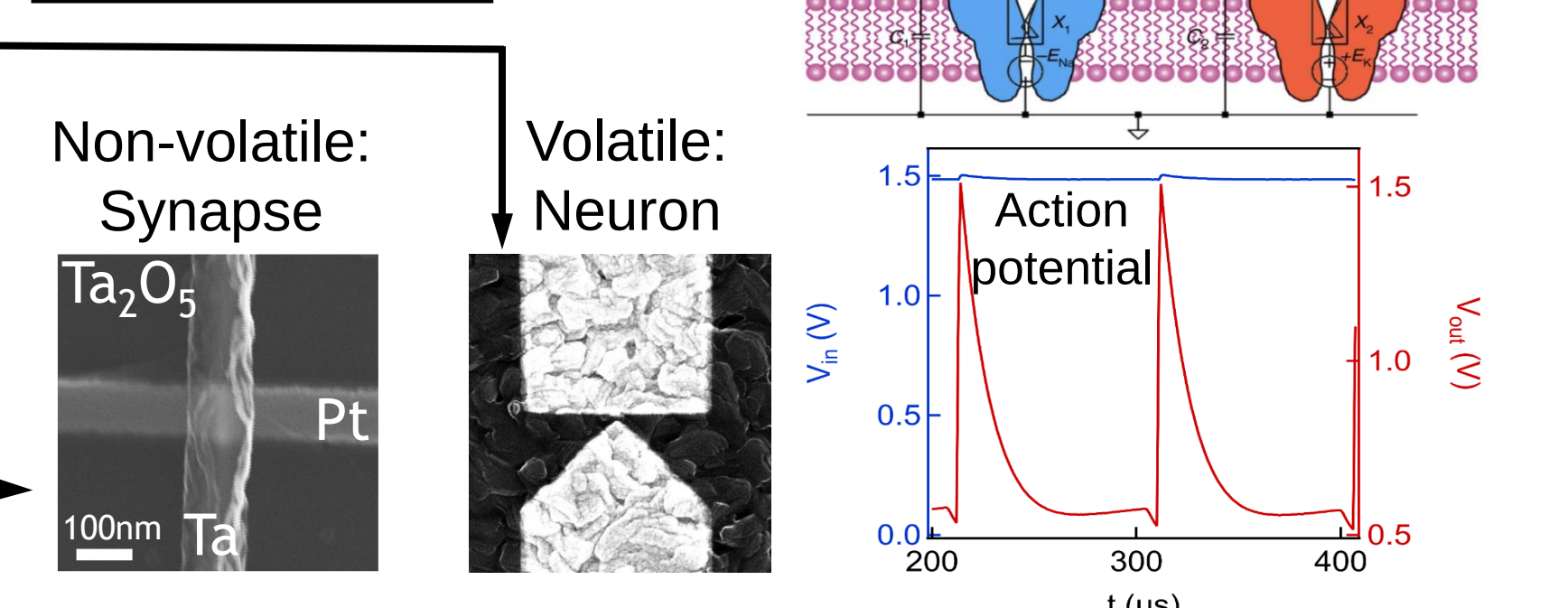


3. Application of VO₂ based resistive switches

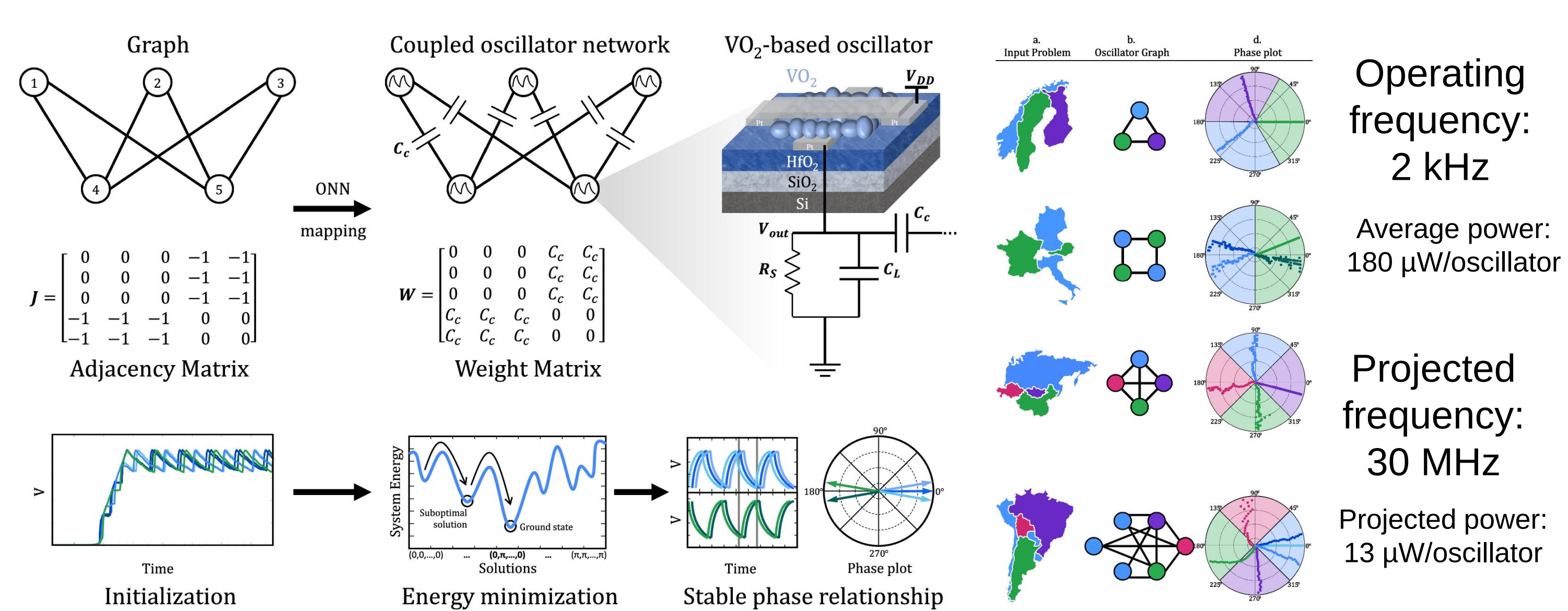
Biological neuron [1]:



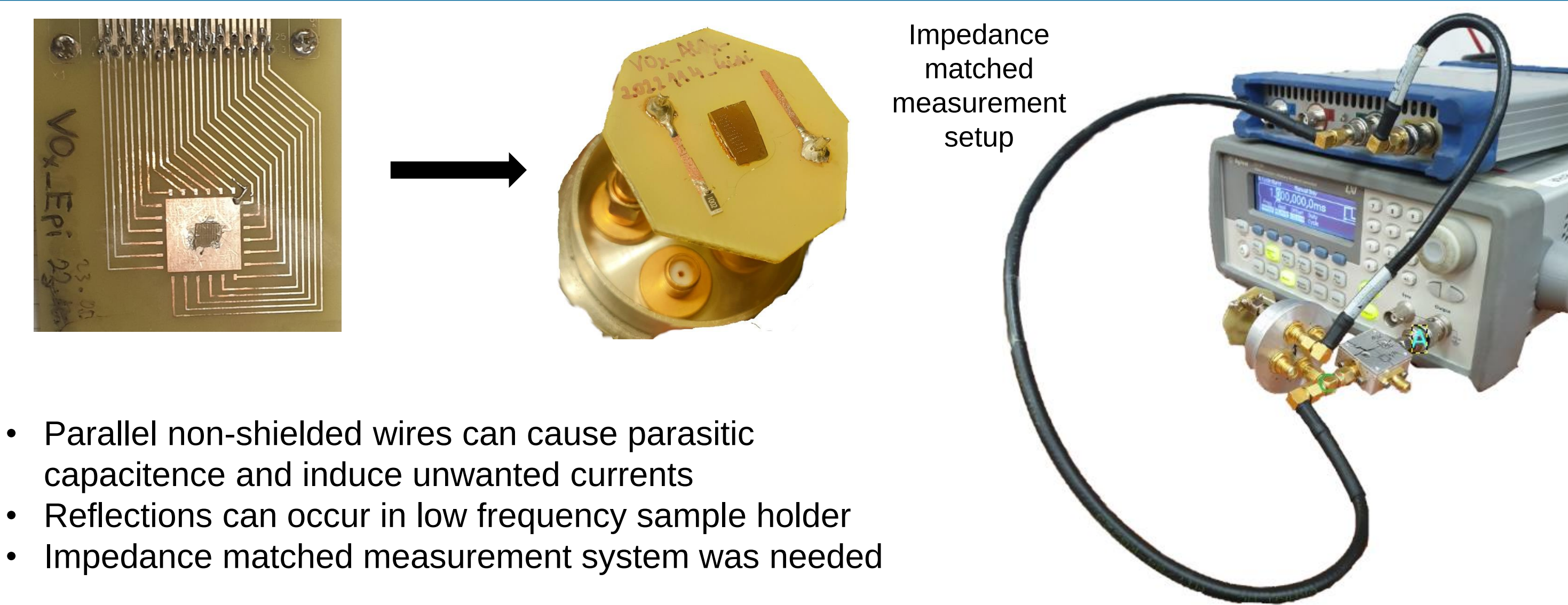
Artificial neuron:



Oscillator-based neural network [4]:



4. Sample holder optimisation

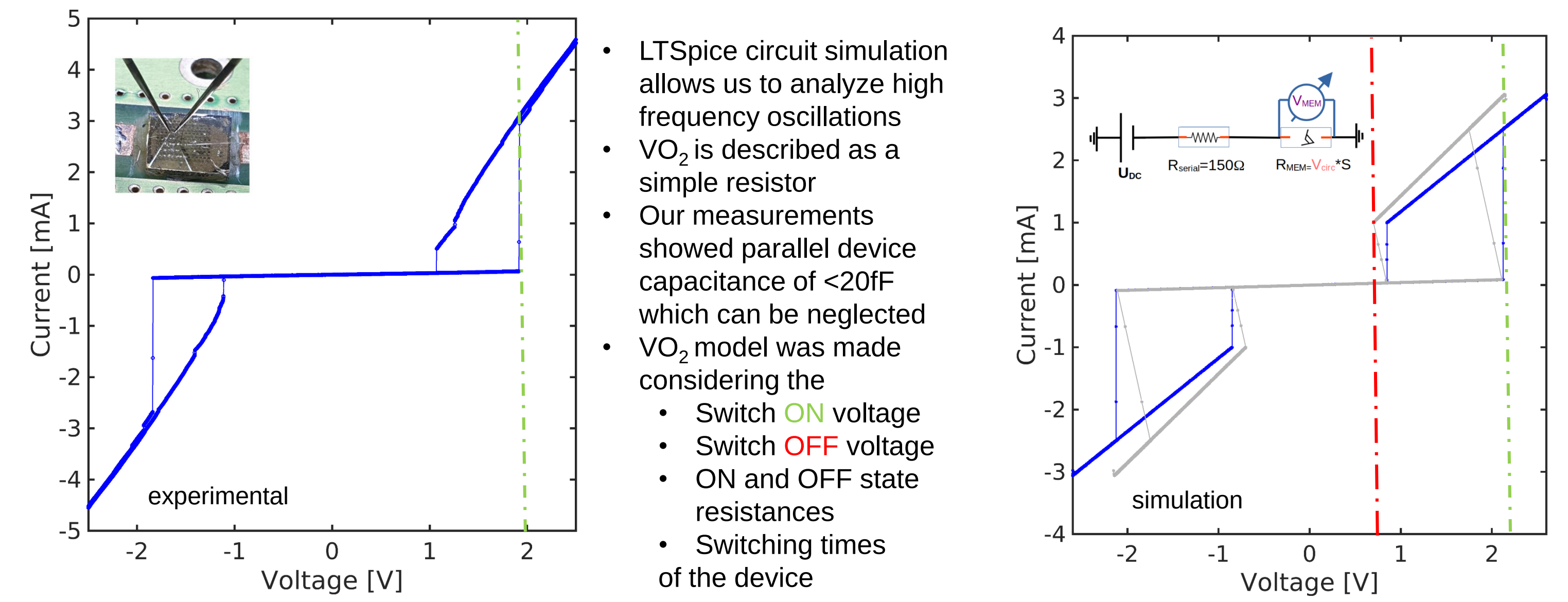


- Parallel non-shielded wires can cause parasitic capacitance and induce unwanted currents
- Reflections can occur in low frequency sample holder
- Impedance matched measurement system was needed

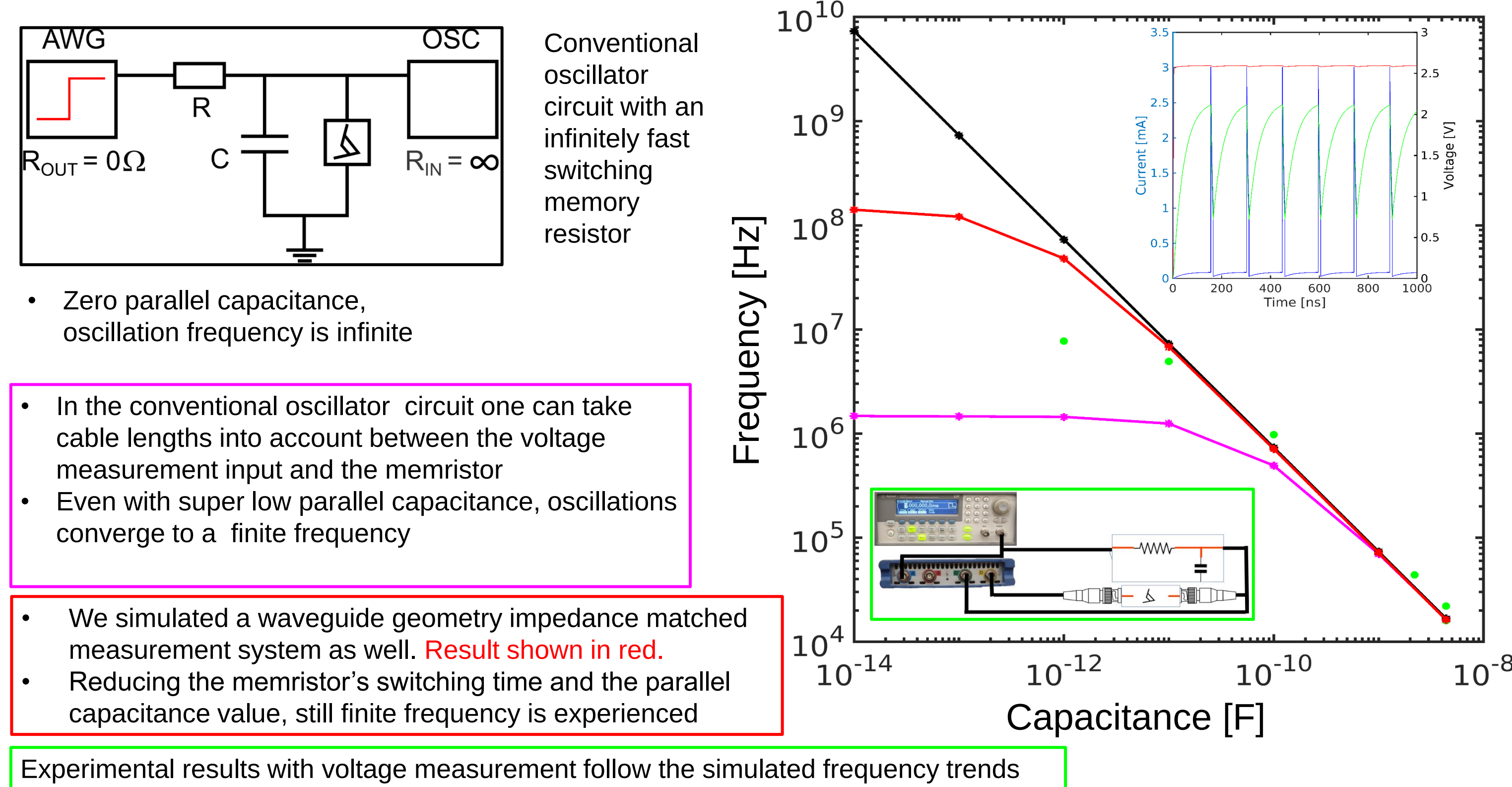
References

- [1] Yi, W. et al. Biological plausibility and stochasticity in scalable VO₂ active memristor neurons. Nature Communications 9, 4661925 (2018)
- [2] Mian, M.S. et al., Self-oscillation up to 9 MHz based on voltage triggered switching in VO₂/TiN point contact junctions, Journal of Applied Physics, 117, 215305 (2015)
- [3] Pósa, L. et al, Interplay of Thermal and Electronic Effects in the Mott Transition of Nanosized VO₂ Phase Change Memory Devices. ACS Applied Nano Materials, 6, 9137 (2023)
- [4] Olivier, M. et al, A CMOS/compatible oscillation/based VO₂ Ising machine solver. Nature Communications 15, 3334 (2024)

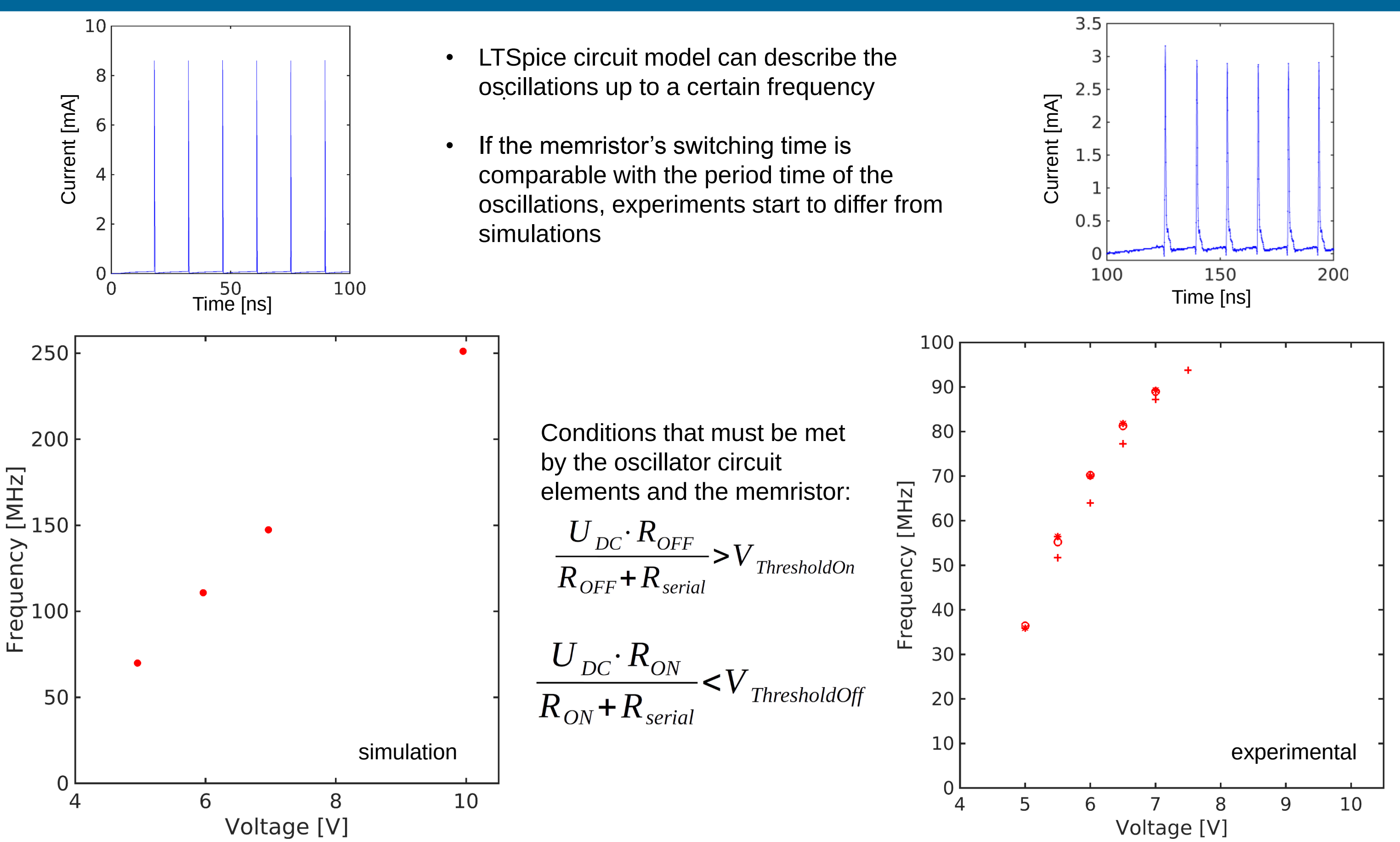
5. LTSpice VO₂ model



6. Oscillator circuit models



7. Ultrafast oscillations



8. Nanosecond observation

