Workshop "Bridging Memory Phenomena: DON'T FORGET IT – A Dive into Memory Devices"

Würzburg, 3rd – 7th August 2026

Workshops Organization

Chairs: Fabian Hartmann (JMU), Sven Höfling (JMU), Victor Lopez-Richard (UFSCAR)
Local Organization: Fabian Hartmann (JMU)

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Complexity, Topology and Dynamics in Quantum Matter

Overview and Scope of the Workshop

The “Bridging Memory Phenomena: DON’T FORGET IT: A Dive into Memory Devices” workshop is the 4th edition of the Paulista–Bavarian Workshop on Nano-Tailored Semiconductor Devices (NTSD). Its scope encompasses nonlinear dynamical systems and memory-related phenomena in advanced materials and devices, adopting a cross-disciplinary perspective that bridges physics, biophysics, materials science, device engineering, and modeling. Particular emphasis is placed on memristors, memcapacitors, memtransistors, and emerging mem-emissive systems, as well as memory effects in solids and optical systems—both functional and parasitic—and their implications for device performance, reliability, and functionality. The workshop further addresses the integration of memory devices with neuromorphic and neuronal circuits, focusing on adaptive, reconfigurable, and bio-inspired technologies. It aims to strengthen scientific dialogue, promote the exchange of ideas, and identify converging and diverging perspectives on memory effects, while outlining concrete directions for future collaborative research. The program will feature invited talks by leading experts in the field, alongside contributed oral and poster presentations. A dedicated social and networking program will provide an informal and stimulating environment that fosters discussion, interaction, and the development of new collaborations.

In its three previous editions, the Paulista–Bavarian Workshop on Nano-Tailored Semiconductor Devices (NTSD) has brought together early-career researchers, established scientists, and technology developers to exchange ideas on advances in nanotechnology, quantum materials, and solid-state physics. The workshop tradition is to foster dialogue across complementary experimental, theoretical, and simulation approaches in nanofabrication, advanced characterization, nanoscale electronics and optoelectronics, and nano-enabled applications.

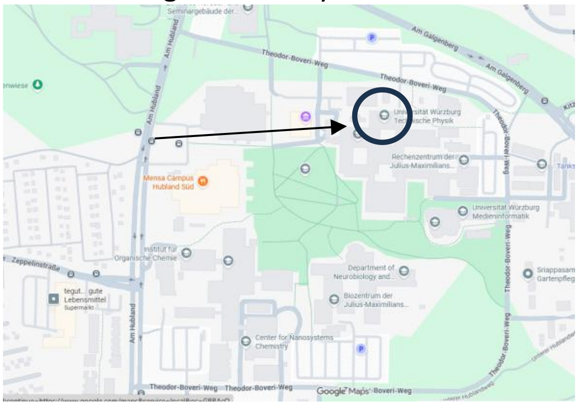
In this year’s edition, **“Bridging Memory Phenomena: DON’T FORGET IT: A Dive into Memory Devices,”** the focus expands toward memory phenomena in materials and devices and their technological relevance. The workshop promotes cross-disciplinary discussions integrating nanoscale processing and synthesis, advanced characterization, theoretical modeling, and novel device concepts relevant to adaptive, neuromorphic, and reconfigurable technologies. By explicitly encouraging young researchers to present and discuss their work in an international environment, NTSD aims to catalyze new research directions, strengthen the interplay between theory and experiment, and further consolidate long-term academic and scientific cooperation.

We welcome all participants to Würzburg University!!

Fabian Hartmann, Sven Höfling and Victor Lopez-Richard

Workshop Venue Würzburg

The Workshop will be held at the Faculty for Physics and Astronomy of the University of Würzburg, Theodor Boveri Weg, 97074 Würzburg. The faculty is located at the Hubland Campus, on a hill at the eastern edge of the city.



The **[Röntgen Lecture Hall](#)** is located in ground floor of the Block A. You can also find the **[Venue on Google Maps](#)**.

How to get there

By car:

From the A3 take the exit "Rottendorf" and follow the B8 to Würzburg. At the traffic light in Würzburg take the left-hand lane onto Stadtring Süd in the direction of Ansbach / Schwäbisch Hall. Leave the Stadtring Süd at the the Frauenland / Stadtmitte exit and head for the Stadtmitte (city centre).

From the A7 take the exit "Estenfeld" and follow the B19 to Würzburg (ca. 7 km). Get in the left-hand lane before the Würzburg place name sign and continue straight on (Stadtring Süd) in the direction of Ansbach / Schwäbisch Hall. Leave the Stadtring Süd at the Frauenland / Stadtmitte exit and head for the Stadtmitte (city centre).

By plane:

Frankfurt Airport: Take the ICE train from Frankfurt Airport long distance train station to Würzburg central station (Hbf) (1.5h)

Nürnberg Airport: Take the U2 to Nürnberg central station (Hbf). From there take the ICE train to Würzburg central station (Hbf) (1.5h)

Munich Airport: Take the Metro (S1 or S8) to Munich central central station (Hbf). From there take the ICE train to Würzburg central station (Hbf) (3h)

By train:

Please see the travel service of Deutsche Bahn on how to get to Würzburg central station.

Public transportation:

From the city center, use bus lines 10, 14, 114 or 214 (exits Campusbrücke, Universitätsbibliothek).

Social Events

The social program will complement the scientific sessions by providing informal settings that promote dialogue and community building. Poster-session gatherings will serve as interactive meeting points, while additional social activities will offer opportunities to experience the city of Würzburg and its rich wine culture. These events are designed to strengthen professional connections in a relaxed and inspiring atmosphere.

Lunches and Coffee breaks

Coffee breaks will be organized in front of the Röntgen lecture hall. Lunches will be provided in the main dinning hall of the University of Würzburg, Campus South (Mensa Campus Hubland Süd Würzburg). The dining hall is 2 min away from the workshop venue.

Wine tasting – Monday 3rd August

As part of the workshop program, participants will have the opportunity to attend a wine tasting at Juliusspital Würzburg. This special event offers an introduction to the renowned Franconian wine culture in a unique historical setting. You will be able to sample a selection of regional wines and foods while learning more about the traditions of one of Germany's oldest wine estates. The evening will provide an excellent opportunity for networking and cultural exchange in a relaxed atmosphere. Meeting point is on Monday 3rd at 18:45 at Juliusspital Weingut Würzburg - Google Maps.

Poster session – Tuesday 4th August

A dedicated poster session will be held during the workshop, although the posters will remain displayed throughout the entire duration of the event. The session will take place in front of the workshop room and will provide participants with the opportunity to discuss their research in an informal and interactive setting. To encourage networking and scientific exchange, snacks and drinks will be provided during the poster session. This format allows attendees to engage with the presented work at their own pace over the course of the workshop.

Workshop dinner – Wednesday 5th August

The conference dinner will take place at Alter Kranen, a traditional restaurant located directly on the banks of the Main River. Participants will enjoy typical Franconian cuisine in a warm and welcoming atmosphere. The restaurant offers a beautiful view over the Main, creating the perfect setting for an enjoyable evening with colleagues and friends. Main River close to the city center and the old bridge. Meeting point is on Wednesday, 5th at 19:00 at Brauerei-Gasthof Alter Kranen - Google Maps.

Excursion – Thursday 6th August

Franconia is one of Germany's most renowned wine-producing regions, famous for its picturesque vineyards, historic villages, and distinctive wines such as Silvaner, often bottled in the traditional "Bocksbeutel" bottle. The excursion will offer participants the opportunity to experience the unique cultural landscape of the region and learn more about its long-standing wine-making traditions.

We will meet at the workshop venue (**9:30 am**) again for a short walk (5 km) through the vineyards along the **Rosen- und Weinweg** (*Rose and Wine Trail*). Along the way, we will complement the panoramic views with some local wine as we make our way to the Maria-Schmerz-Kapelle (*Chapel of Our Lady of Sorrows*). We will then descend to **Randersacker** and enjoy some afternoon in the wine village close to the Main river.

We will stay for lunch in Vinothek Steigerwald from 12:00 located Würzburger Straße 13, 97236 Randersacker https://maps.app.goo.gl/eiCYcacA3gRMWKdu7

Meeting at the Old Main Bridge in the evening ca. 16:30

From there one can either walk along the Main river to reach the old bridge, or come by bus from station Randersacker Maingasse, most convenient is to take bus 555 at 15:03, 16:03 or 17:03 in direction Hauptbahnhof ZOB, Würzburg. Other connections are also possible. Exit bus at Mainfranken Theater to reach the Old Main Bridge.

Workshop Programm:

Time	Day 1	Day 2	Day 3	Day 4	Day 5
	03 Aug	04 Aug	05 Aug	06 Aug	07 Aug
9:00-9:40		Jose Pedro Rino	Carlos César Bof Bufon	Excursion to Randersacker	Fabian Hartmann
9:40-10:20		Leonardo Castelano	Jitendra Kumar		Manuel Meyer
10:20-11:00		Coffee	Coffee		Coffee
11:00-11:40		Soumen Pradhan	Ivan G. Scheblykin		Selena Barragan
11:40-12:10		Rafael Schio Wengenroth Silva	Diego Radillo		Closing Remarks
12:10-14:00	Registration and Welcome	Lunch	Lunch	Tapas in Randersacker	
14:00-14:40	Victor Lopez Richard	Marcio Peron Franco de Godoy	Carlos Silva		Networking
14:40-15:20	Juan Bisquert	Ana Luiza Costa Silva	Matthias Jung		
15:20-16:00	Coffee	Coffee	Coffee		
16:00-16:40	Alisson Cadore	Lab Visits	Fran Kurnia	Old Main Bridge	
16:40-17:20	Bavarian Academic Center for Latin America		Andreas Pfenning		
17:20-19:00	Free	Poster Session	Free	Free	
19:00-End	Wine Tasting	Free	Workshop Dinner		

Invited speakers:

- Marcio Peron Franco de Godoy: Departamento de Física, Universidade Federal de Sao Carlos, Brazil
- Ana Luiza Costa Silva: Departamento de Física, Universidade Federal de Sao Carlos, Brazil
- Ovidiu Lipan: Department of Physics, University of Richmond, USA
- Leonardo Castelano: Departamento de Física, Universidade Federal de Sao Carlos, Brazil
- Jose Pedro Rino: Departamento de Física, Universidade Federal de Sao Carlos, Brazil
- Victor Lopez-Richard: Departamento de Física, Universidade Federal de Sao Carlos, Brazil
- Soumen Pradhan: Physikalisches Institut, Julius-Maximilians-Universität Würzburg, Germany
- Fabian Hartmann: Physikalisches Institut, Julius-Maximilians-Universität Würzburg, Germany
- Carlos Silva: Universidade Nova de Lisboa Faculdade de Ciências e Tecnologia, Portugal
- Alisson R. Cadore: Brazilian Nanotechnology National Laboratory (LNNano), Brazilian Center for Research in Energy and Materials, Brazil
- Carlos César Bof Bufon: Instituto de Geociências e Ciências Exatas, Universidade Estadual Paulista, Brazil
- Juan Bisquert: Instituto de Tecnología Química, Valencia, Spain
- Fran Kurnia: Electrochemical Materials Laboratory, Department of Chemistry, Technical University of Munich, Germany
- Ivan Scheblykin: Chemical Physics, Lund University, Sweden

List of abstracts

MEMORY RESPONSES AS FINGERPRINTS OF NANOSCALE TRANSPORT MECHANISMS

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Memory effects are commonly regarded as functional properties of emerging electronic devices; however, they can also serve as powerful characterization tools for probing transport and relaxation phenomena at the nanoscale. In this talk, I present a unified framework in which memory responses emerge from the interplay between drift transport, described by a perturbed Drude model, polarization dynamics governed by Debye relaxation, and carrier diffusion following Fick's law. These nonequilibrium processes generate characteristic signatures in cyclic voltammetry, hysteresis loops, current gaps at zero applied voltage, and impedance spectra. By establishing direct connections between such memory patterns and the underlying physical mechanisms, it becomes possible to extract information on carrier trapping, polarization, diffusion, and characteristic relaxation times from purely electrical measurements. Several examples involving nanoscale electronic and optoelectronic devices are presented to demonstrate how memory responses can act as fingerprints of internal dynamics, providing a versatile spectroscopic approach for identifying dominant transport mechanisms and guiding the development of advanced functional materials and devices.

FROM CHARGE DYNAMICS TO MEMORY: HYSTERESIS IN GRAPHENE-BASED 2D DEVICES

Gabriel Labes Rodrigues[1], Victor Lopez-Richard[2], Alisson R Cadore[1,3*]

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Two-dimensional (2D) materials and their van der Waals heterostructures provide an exceptional platform for engineering memory effects through interface design and electrostatic coupling. In this talk, we present graphene-based memory systems built from hBN/graphene-based heterostructures and use them as a model platform to elucidate the physical origins of hysteresis and memory behavior in graphene field-effect transistors (GFETs) [1-3]. External parameters, such as gate-voltage amplitude, sweep rate, and operating temperature, can tune the volatile or nonvolatile response of these memory devices. By modeling nonequilibrium carrier dynamics as a competition between charge injection and reabsorption processes, we identify two distinct regimes: one governed by intrinsic, frequency-independent relaxation and another exhibiting frequency-locked behavior, in which the device response is dictated by the external drive [2]. These results establish layered 2D heterostructures as tunable materials platforms for memory functionalities, with implications for multilevel storage, neuromorphic materials, and cryogenic electronics.

Keywords: 2D transistors; electrical hysteresis; volatile and non-volatile response.

References

[1] A.R. Cadore et al. *Appl. Phys. Lett*. 108, 233101, 2016.
[2] G. Labes Rodrigues et al. *ACS Appl. Electron. Mater.* 7, 22, 10081–10089, 2025.
[3] V. Lopez-Richard et al. *J. Phys. Chem. C* 130, 3, 1347–1356, 2026.

Acknowledgments: This study was financed in part by CAPES, CNPq (311536/2022-0 and 301145/2025-3), INCT-DQ (408783/2024-9), and FAPESP (CEMol-CEPID 2024/00989-7).

OVERVIEW OF FUNDING OPPORTUNITIES IN BAVARIA AND GERMANY

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This presentation provides an overview of funding opportunities available for researchers, academics, and institutions in Bavaria and Germany, with a focus on programmes supporting research collaboration, international exchange, and innovation.

The talk will introduce selected funding schemes, including BayIntAn, LATinBAY, and the Hightech Agenda Bavaria. BayIntAn (Bavarian International Academic Cooperation) supports the establishment and strengthening of international academic collaborations by funding joint activities between Bavarian and international research institutions, such as workshops, networking events, and preparatory activities for future projects. LATinBAY promotes cooperation between Bavaria and Latin America by supporting scientific exchange, mobility, and the development of sustainable research partnerships between institutions in both regions. The Hightech Agenda Bavaria is a major investment initiative of the Bavarian government aimed at strengthening cutting-edge research and innovation, supporting strategic fields such as artificial intelligence, quantum technologies, life sciences, and future-oriented technologies.

MEMORY EFFECT ON ZINC SELENIDE

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ZnSe is a direct wide-band- gap II-VI semiconductor, displaying low absorptivity at infrared wavelengths. It is a preferred material for lenses, windows output couplers, and beam expanders. It is also used in laser-diodes and green-blue LEDs. Recently, an effective interatomic potential comprising of two- and three-body interactions was developed to describe this zinc selenide semiconductor in molecular dynamics simulations. Several physical properties, such as elastic constants, dispersion relation, specific heat, Debye temperature, and melting were described very well. Cycles of heating/cooling the system from low temperature to temperatures well above the melting point were performed at several rates. Depending on the cooling/heating rate, the system partially or fully crystallizes/melts or freezes into a glass, exhibiting hysteresis in the volume-temperature curve during the glass transition. Relaxation time (strongly temperature-dependent) in glass and supercooled liquids measures how quickly the material approaches a more stable structural configuration, typically showing slow *a*-relaxation (structural/viscosity-related), which freezes below the glass transition and faster *b*-relaxation (local motions) that persists at lower temperatures. A simple model based on this assumption is provided and could describe the hysteretic volume-versus-temperature characteristic observed on ZnSe. The connection between these relaxation times and ZnSe properties is under investigation.

Keywords: zinc selenide, molecular dynamics simulations, memory effect

A SINGLE-ELECTRON MEMRISTOR

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In this work, we characterize a system consisting of two coupled quantum dots containing a single electron transport under the Coulomb blockade regime. We examine how voltage biases applied to each dot can serve as logic inputs and how the electrical response can serve as the logic output. Using a Markov master equation approach, we model the transport dynamics in terms of the occupancy probabilities of the charge states and characterize the electrical current across the upper dot as a function of the voltage biases, as well as the appearance of memory effects for a set of chosen parameters. Then, we demonstrate how the system's behavior can generate AND, NOR, and XOR gates by restricting the voltage inputs to specific regions and identifying the conditions necessary for successful performance. We emphasize the role of memory effects as a practical resource for applications.

TRI-FUNCTIONAL OXIDE INTERFACE-BASED DEVICES FOR NEXT GENERATION COMPUTATIONS

Soumen Pradhan[1*], Kirill Miller[1], Fabian Hartmann[1*], Merit Spring[1], Silke Kuhn[1], Victor Lopez-Richard[2], Michael Sing[1], Ralph Claessen[1], Sven Höfling[1]

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The continuous miniaturization of electronic devices is rapidly approaching the atomic scale, challenging the continuation of Moore's law and motivating the exploration of alternative computing paradigms [1]. Moreover, the conventional von Neumann architecture suffers from speed and energy inefficiencies due to data transfer between separate processing and memory units, especially under increasing data demands. Reconfigurable device technologies that enable on-demand functionalities within a single element offer a promising route toward reducing circuit complexity, area, and energy consumption [2]. In this work, we demonstrate a tri-functional oxide interface nanostructure capable of reconfigurable logic-in-memory and reservoir computing operations. The device exploits the quasi-two-dimensional electron gas formed at the $LaAlO_3/SrTiO_3$ interface [3], incorporating laterally defined side gates. By tuning biasing conditions, the device can be dynamically switched among transistor (T), memristive (M), and memcapacitive (MC) states. A 1T1MC configuration exhibits nonlinear and short-term memory characteristics suitable for pattern recognition in physical reservoir computing architecture using a 4-bit pulse scheme. A 1T1M setup supports synaptic plasticity, transitioning from short- to long-term memory behavior, while 2T1M structures enable reconfigurable OR/AND logic operations with in-situ output storage [4]. The ability to integrate and reconfigure multiple functionalities within a single oxide interface device highlights a versatile platform for adaptive, energy-efficient, and beyond-von Neumann computing architectures.

Keywords: Reconfigurability, Memristor, Memcapacitor, Logic-in-memeory, Reservoir Computing

References:

1. Shalf, J.M., *et al*., Computing beyond moore's law. Computer 48(12), 14–23 (2015).
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3. Ohtomo, A., *et al.*, A high-mobility electron gas at the $LaAlO_3$/ $SrTiO_3$ heterointerface. Nature 427(6973), 423–426 (2004).
4. Pradhan, S., Miller, K., Hartmann, F. *et al.* Oxide interface-based polymorphic electronic devices for neuromorphic computing. *Nat. Commun.* **17**, 3406 (2026).

ANALYTICAL RESERVOIR COMPUTING WITH MEMRISTIVE DEVICES

Rafael Schio Wengenroth Silva[1*], Soumen Pradhan[2], Fabian Hartmann[2], Victor Lopez-Richard[1]

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Reservoir computing (RC) exploits physical dynamical systems as untrainable nonlinear feature extractors, training only a linear readout. While reservoir adaptation has been investigated mainly in software-based recurrent reservoirs through universal heuristics, intrinsic plasticity, and local learning rules [1], analytical input design for physical memristive-device (memdevice) reservoirs based on first-principles modeling of internal memory variables remains largely unexplored.

We model the internal carrier density $\delta n(t)$ of memdevices within the relaxation time approximation. From this structure we derive a closed-form expression for the resolution of the device response between two protocols differing in active bits (a quantitative measure of feature separability in the reservoir state space). The framework integrates with a standard RC pipeline (polynomial augmentation followed by a ridge-regression readout), grounded in Cover's theorem on linear separability [2], Bishop's basis-function formalism [3], and the one-vs-all justification for multiclass classification of Rifkin and Klautau [4].

The closed-form resolution depends explicitly on the device characteristic time τ, the pulse duration t_p, the inter-pulse waiting time t'_p, and the sequence structure, providing a tractable analytical landscape for joint optimization of input protocols and intrinsic device parameters. The linear superposition structure further reveals that discriminating two protocols depends only on the contributions of the bits in which they differ, with all other contributions canceling exactly—an analytical reduction with no empirical analogue. The framework applies to memdevices whose internal dynamics are well-described by the linear memory equation; its predictive power for measured device responses is conditional on a sufficient correlation between the modeled internal variable and the experimentally accessible output of the device circuit. This analytical framework opens a path to rigorous co-optimization of input protocols and intrinsic device parameters in memdevice-based RC, complementing predominantly empirical approaches in the literature. Experimental validation by our collaborators on memcapacitive device platforms is the natural next step, building on recent demonstrations of pulse-driven reservoir computing in 1T1MC architectures [5].

Keywords: reservoir computing; memristive devices; analytical optimization

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IMPROVING THE STORAGE OF LIGHT-ASSISTED INFORMATION BY ATMOSPHERE

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New insights into understanding synaptic phenomena that emulate cognitive operations as learning can be obtained by photonic-based neuromorphic systems. One way to mimic some of the synaptic functions is employing the inherent persistent photoconductivity of oxide semiconductor devices. In this approach, the learning process is stimulated by light, and its efficacy can be modeled by considering the short-term memory (STM) and long-term memory (LTM) after the light is switched off. These two states can be accessed depending on the frequency of the photonic stimuli, exhibiting a “forgetting” mechanism over time. Here we add some ingredients to the experiment considering the surface influence under the main gases that compose a free atmosphere: oxygen, nitrogen, and carbon dioxide, as well as in vacuum, synthetic air, and free atmosphere. Na-doped ZnO thin films were grown in a sustainable and versatile synthesis process using the spray-pyrolysis technique, providing transparent polycrystalline films with wurtzite c-axis orientation. The two-terminal Na-doped ZnO showed exciting results concerning STM and LTM mechanisms depending on the surface oxi-reduction, which is predominantly STM in oxygen presence due to inhibition of superficial oxygen vacancy influence. Essays with continuum and pulsed illumination exhibit different profiles with reasonable contrast in the photoresponse, allowing the recording of different signals using Morse code. Under vacuum conditions, the LTM is achieved with retention of information higher than hours. Our results enlighten an interesting approach to surface-activated neuromorphic devices.

Keywords: oxides, photoconductivity, polycrystalline, ZnO

LIGHT-INDUCED MEMCAPACITIVE BEHAVIOR IN PLANAR HFO_{2-X} DEVICES

Ana Luiza Costa Silva[1*], Soumen Pradhan[2], Igor Ricardo Filgueira e Silva[1], Leonardo Kleber Castelano[1], Sabrina Estevam[2], Sven Höfling[2], Marcio Peron Franco de Godoy[1], Victor Lopez-Richard[1], Fabian Hartmann[2]

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Memcapacitive systems have emerged as promising energy-efficient building blocks for neuromorphic computing, as their intrinsic memory-dependent capacitance enables information processing with minimal static power consumption. Yet, realizing memcapacitive functionality in scalable, CMOS-compatible thinfilm platforms and modulating it with light remains an open challenge. In this work, we investigate the electrical and memcapacitive behavior of a lateral planar device based on a non-stoichiometric hafnium oxide (HfO2-x) thin film deposited on an undoped gallium arsenide (GaAs) substrate. This geometry avoids the fabrication complexity of vertical stacks while retaining the dielectric memory of the oxide layer. Cyclic current-voltage (I-V) sweeps and capacitance measurements were carried out at room temperature under dark and illuminated conditions, using optical excitation as an external, non-electrical stimulus to modulate the device memory state. The results reveal a pronounced charge accumulation effect even at zero applied voltage, indicating capacitive contributions likely associated with charge trapping within the HfO2-x layer or at the oxide/GaAs interface. Lock-in measurements allowed the extraction of the real and imaginary components of the current, from which the equivalent capacitance and apparent resistance were determined. Under illumination, the device exhibits a characteristic butterfly-shaped response, demonstrating that memcapacitive behavior is achievable in a planar electrode configuration. Frequency-dependent analysis under illumination indicates a fast dielectric relaxation process, with a characteristic timescale on the order of tens of microseconds. The experimental observations are supported by theoretical modeling, suggesting that the memory effect arises from dielectric polarization dynamics within the material. These results highlight the potential of HfO2-x-based planar devices for low-power, light-responsive memcapacitive applications.

Keywords: Memcapacitor; Hafnium Oxide; Dielectric Polarization; Optical Modulation

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DEFECTS AS ACTIVE ELEMENTS IN NEUROMORPHIC MOF DEVICES

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Metal-organic framework thin films (SURMOFs) are gaining traction as active layers in emerging electronic devices, yet their potential for neuromorphic computing remains largely unexplored due to intrinsically low conductivity and susceptibility to environmental degradation. Rather than circumventing these limitations, we adopt a defect-engineering strategy that transforms both pre-existing and environmentally induced defects into functional elements for neuromorphic device operation.

Using HKUST-1 SURMOF as a model system, we demonstrate that native structural defects — specifically mixed-valent Cu^{2+}/Cu^{+} sites and missing linker vacancies — can be controllably modulated by relative humidity. While aggressive hydrolysis at high RH leads to catastrophic collapse, moderate humidity establishes a reversible regime: water molecules physisorb on unsaturated metal centres, thereby tuning the electronic structure without compromising framework integrity. This reversible defect–guest interaction creates a dynamic medium for modulating charge transport.

We exploit this regime to create key neuromorphic device functionalities within monolithic SURMOF heterojunctions. The controlled interplay of native and humidity-mediated defects yields pronounced resistive switching with ambipolar character, negative differential resistance, and conductivity states that emulate synaptic weight modulation. These phenomena — demonstrated in ultrathin vertical junctions at room temperature[1–3] — establish SURMOFs not merely as porous frameworks but as active memristive elements capable of supporting the signature behaviours required for neuromorphic hardware.

Our results position defect-engineered SURMOFs as a materials platform for beyond-von-Neumann architectures, where environmental sensitivity, rather than being a weakness, becomes a design degree of freedom for adaptive and reconfigurable electronic devices.

Keywords: SURMOFs; Defect engineering; Neuromorphic devices

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DYNAMICAL SYMBIOSIS OF SOLAR CELL AND MEMRISTOR

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When combined with energy-harvesting components, memristors offer an opportunity to realize self-powered physical AI systems. We demonstrate a solar cell-driven memristor architecture as a physical AI platform for light-driven computation. In this system, incident light is directly converted into electrical stimuli by integrated solar cells, which modulate the conductance states of memristors. These conductance changes can encode computational states and learning behaviors, enabling direct processing of optical information without intermediate digital conversion. Such a light-driven memristive system enables simultaneous sensing, energy harvesting, memory storage, and computation within a unified physical structure. This approach reduces external power requirements, simplifies system architecture, and supports adaptive, event-driven computation, making it ideal for intelligent processing directly on devices, continuous environmental sensing, and distributed smart sensor systems.

In the second part of the talk, I will discuss how neuron-like bursting behavior can be generated using the negative differential resistance regime of a thyristor. The ability to produce pulse bursts or oscillatory signals is particularly useful for emulating asynchronous systems, which often exhibit dynamically varying levels of activity.

Keywords: self-powered physical AI; light-driven computation; neuron-like bursting.

MEMLUMORS: STATE-DEPENDENT PHOTOLUMINESCENCE AND OPTICAL MEMORY

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Photoluminescence (PL) is traditionally viewed as a direct response of a material to optical excitation. In this talk, I will present a different perspective in which optical excitation not only generates emission, but also writes hidden internal states that persist in time and space. This perspective forms the basis of the *memlumor* (memory + luminophore), introduced in 2024,[1] describing a luminescent material whose PL response depends on excitation history through photophysical and photochemical processes. The key feature of a memlumor is that its photoluminescence quantum yield (PLQY) becomes excitation-history dependent: excitation light modifies the internal state of the material, and this modified state subsequently alters the efficiency and dynamics of PL. Thus, the same optical input can produce different PL outputs depending on the previous illumination history enabling fully optical neuromorphic data processing.

I will focus on PL-readable charge-trapping memory in semiconductors, particularly in metal-halide perovskites.[2] In these systems, selective trapping of one carrier type produces a transient free-carrier imbalance (photodoping), which modifies radiative and nonradiative recombination pathways and therefore changes the PLQY. Because trap populations persist after excitation, this mechanism naturally produces volatile optical memory on microsecond-to-millisecond timescales. Our recent experimental results demonstrated memlumor behavior in perovskites, including hysteresis, paired-pulse facilitation, leak-and-integrate response, and retention times spanning from microseconds to hours, with operation energies in the femtojoule range. We also demonstrated classification of binary 5-bit optical pulse sequences using the PL response of metal-halide perovskites, which can be viewed as a form of reservoir computing.[3] Other possible mechanisms of luminescent memory, including efficient singlet–triplet annihilation or triplet–triplet up-conversion leading to delayed singlet exciton emission in organic systems, will also be discussed.

Keywords: photoluminescence; memory, charge trapping

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TWO DIMENSIONAL METAL-ORGANIC FERRIMAGNETS

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In this work, we study the unprecedented diversity and high degree of tunability of the of magnetic properties in a family of cyanocarbon-based 2D metal–organic networks. These networks are synthesized by the coordination of tetracyanoethylene (TCNE) and metal atoms [1]. Their magnetic properties are measured using synchrotron x-ray spectroscopy. An Ising-like model describing these systems is proposed in order to rationalize its behavior, not only aiding the understanding of the experimental observations, but defining a theoretical framework through which explore the properties of such materials. Experimental data reveals that coordination networks of TCNE with Fe, Ni and Eu present ferromagnetic ordering, as observed in **Fig. 1 a-c**. Given that these systems are isostructural, the synthesis of mixed networks is possible. Ni+Fe and Ni+Eu networks are subsequently investigated. It is found that, while same species coupling is parallel, different species coupling is antiparallel, resulting on ferrimagnetic behavior, **Fig. 1 d-f**. Aided by Monte Carlo simulations we show that it is possible to use the metal-to-metal stoichiometry of the materials as a straightforward control parameter for their magnetic properties; opening the potential for the emergence of exotic phenomena such as exchange bias and magnetization compensation on atom-thin 2D systems, which to date have eluded experimental observation.

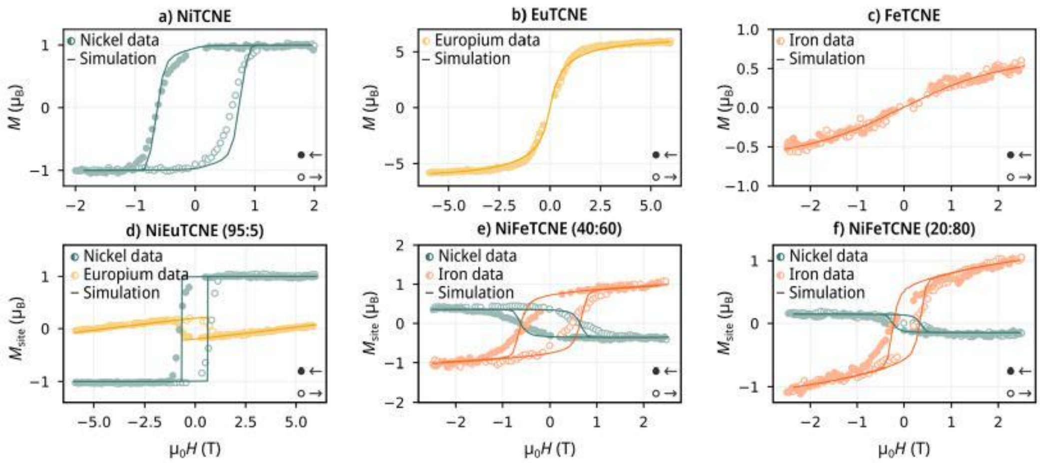

Fig 1. Magnetization curves of single-element (top row) and mixed (bottom row) xTCNE coordination networks measured at T=4 K. The name of the sample is shown on top of each data set. For the mixed samples, the metal-to-metal ratio is indicated in parenthesis.

Keywords: Ferrimagnetism; Low-dimension; Metal-organics

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ZINC-TIN OXIDE DEVICES FOR SUSTAINABLE ELECTRONIC SYSTEMS

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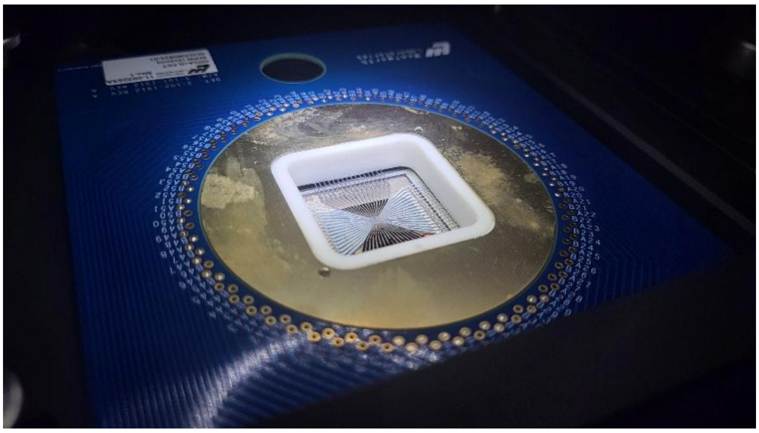
Sustainable, earth-abundant materials offer a promising route toward addressing the economic, environmental, and energy challenges of modern computing. In this work, we explore zinc-tin oxide (ZTO), an amorphous semiconductor, as a versatile platform for energy-efficient and scalable neuromorphic computing systems.

Initially, ZTO memristors were designed to demonstrate the necessary qualities for use as in-memory computing units in neural network accelerating applications. However, with the aim of more faithfully emulating biological neuronal structures, the study of physical reservoir computing systems (PRC) was pursued. By exploiting the inherent non-linear mechanisms of tailor-designed memristors, the resulting PRC implementations achieve considerable improvements in both network size and accuracy in a practical digit recognition task.

ZTO-based diodes were also developed in tandem with the previously mentioned systems. With potential use as sneak-path-preventing selective devices in active crossbars for neuromorphic applications or other high-frequency tasks, the Schottky diodes show record-breaking metrics when compared with vertically stacked solution-based oxide structures currently reported in the literature.

Overall, this work highlights ZTO as a promising material platform for advancing efficient, scalable, and biologically inspired computing technologies.



Keywords: Zinc-tin oxide; memristor; neuromorphic computing; reservoir computing; diode; high-frequency

THE DRAM MEMORY WALL IN THE AGE OF AI

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DRAM remains the dominant main-memory technology in computers, smartphones, and wearable devices. However, the rapid growth of artificial intelligence is placing unprecedented pressure on the DRAM market. Rising demand from AI data centres has contributed to substantial price increases and has shifted manufacturers' priorities towards high-margin AI products rather than conventional consumer markets. At the same time, memory access has become a major energy and performance bottleneck: a significant proportion of the energy consumed by modern AI systems is spent transferring large volumes of data between DRAM and AI accelerators. This talk provides an overview of current DRAM technologies, methods for modelling and simulating DRAM subsystems and architectures, and emerging approaches to computing within or near DRAM. By moving selected computations closer to where the data is stored, these approaches can reduce communication with the host system and improve both performance and energy efficiency.

Keywords: DRAM, AI, in-memory computing

BIAS-CONTROLLED CONDUCTANCE IN A LITHIONIC MEMRISTOR FOR IN-MEMORY COMPUTING

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In-memory computing based on memristors has emerged as a promising strategy to overcome the data-transfer bottleneck of conventional von Neumann architectures, although regulating the conductance modulation remains a key challenge. Here, we demonstrate a lithionic memristor comprising a spinel $Li_4Ti_5O_{12}$ (LTO) thin film between Pt electrodes, exhibiting controllable conductance for in-memory computing applications. As the voltage sweep range increases, the minimum current shifts from 0 V to approximately ±0.2 V, whereas under lower sweeping biases the device displays conventional bipolar switching with the minimum current centered at 0 V. These observations suggest that the intrinsic charge transport characteristics of LTO determine the switching behavior, endurance, retention, and analog conductance modulation. Nanoscale electrical characterization further reveals a reversible current percolation network driven by localized electric fields, providing insight into the resistive switching mechanism. The resulting tunable conductance states enable efficient on-chip data classification through optimization of computational parameters such as the learning rate. These findings establish lithionic memristors as promising energy-efficient platforms that integrate memory and computation within a single nanoscale device for future artificial intelligence and edge computing systems.

SPIN-BASED QUANTUM MEMORIES IN SEMICONDUCTOR QUANTUM DOTS FOR DETERMINISTIC PHOTONIC QUANTUM TECHNOLOGIES

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Semiconductor quantum dots provide a solid-state platform for generating single and entangled photons with high efficiency and high optical quality. In our work, the confined electron and hole spins act as quantum memories that link stationary and flying qubits. These spin states retain coherence long enough to control photonic emission and to mediate entanglement through radiative cascades and spin-selective optical transitions. Advances in device engineering, including optimized nanophotonic structures and low-density quantum dot growth, now enable deterministic operation. This contribution connects spin physics in quantum dots with memory-device concepts and highlights how spin-based quantum memories can support future photonic quantum technologies and networked quantum architectures.

MEMFLASH CELLS: FROM FUNDAMENTALS TO LIGHT-SENSITIVE QUANTUM DOT MEMRISTORS WITH BI-DIRECTIONAL AND WAVELENGTH-DEPENDENT CONDUCTANCE CONTROL

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Passive circuit elements with inherent memory functionality, such as memristors (or more general memristive devices), have opened new perspectives in hardware implementations of brain inspired computing architectures. The memristor theory based on symmetry arguments was first outlined in 1971 by the nonlinear circuit theorist Leon Chua [1]. With their time- and state-dependent resistance, [2] memristive devices are suitable to emulate synaptic functionalities [3,4] and more complex computing tasks as object detection and classification that have been reported with memristor networks. [5] We discuss a specific realization of memristive devices, namley MemFlash cells in which the internal state variable are charges localized on a capacitive coupled floating gate. We discuss various realizations of MemFlash cells and focus later on the realization of a memristive device based on the mature III-V-semiconductor platform in which the memristance of the device is controlled by charge localized on site-controlled InAs quantum dots. Interband absorption processes in the quantum dot barrier matrix lead to photo-generated electron-hole-pairs that, depending on the applied bias voltage, charge or discharge the quantum dots and hence decrease or increase the memristance. Wavelength-dependent conductance control is observed by illumination with red and infrared light, which leads to charging via interband and discharging via intraband absorption, respectively. The presented memristor enables optical conductance control and may thus be considered for sensory applications in artificial neural networks as light-sensitive synapses or optically tunable memories.

Keywords: MemFlash, flash, charge trapping, floating-gate, quantum dot

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A TOPOLOGICAL INSULATOR FIELD EFFECT MEMRISTOR

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Overcoming the limitations of conventional computing and the von Neumann architecture requires new computational paradigms capable of solving complex problems efficiently and within realistic time scales**.** Quantum and neuromorphic computing rely on unconventional materials and device functionalities, yet achieving resilience to imperfections and reliable operation remains a major challenge[1,2]. This has motivated growing interest in topological materials[3] that provide robust and low-power operation while preserving coherence. However, integrating topological transport with memory functionality into a reconfigurable device has remained elusive. Here, we present a topological field-effect memristor in which topological protection preserves edge state coherence, enabling the coexistence of coherent transport and non-volatile memory functionality. Utilizing inverted InAs/GaInSb/InAs trilayer quantum wells[4,5], we realize a quantum spin Hall insulator that can be reconfigured between the conventional field-effect transistor operation into memristive functionality. Unlike other memristor implementations, one resistance state is entirely governed by dissipationless, coherent transport through topologically protected helical edge channels. Our results establish a prototypical topological electronic device that merges coherent transport and neuromorphic principles within a single platform, paving the way for hybrid quantum-neuromorphic architectures and expanding the functional landscape of topological electronics.

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Keywords: Topological Insulator, Memristor, InAs/GaSb quantum wells, III-V semiconductor

MULTILEVEL TOPOLOGICAL MEMRISTOR BASED ON INAS/GAINSB/INAS TRIPLE QUANTUM WELLS

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The development of computing technologies beyond the limitations of conventional von Neumann architectures electronic devices that intrinsically combine memory and functionality while operating with high energy efficiency, as envisioned in emerging paradigms of unconventional computing [1]. In this context, semiconductor quantum heterostructures hosting low-dimensional electronic states offer a versatile platform for realizing novel memory concepts that can interface with quantum and neuromorphic information-processing schemes [1].

In the present work, we investigate memristive transport on a 2D topological insulator based on InAs/GaInSb/InAs triple quantum well Hall bar device with an HfO_2 gate dielectric. Gate-voltage sweeps reveal pronounced hysteretic conductance behavior and robust multilevel resistance states, while retention measurements demonstrate non-volatile memory operation over more than 10,000 read pulses. The ON/OFF ratio can be continuously tuned through the applied gate-voltage sweep range, enabling reconfigurable programming of resistance states and adjustment of the memory window. Moreover, the memristive behavior persists in edge-dominated transport regimes, consistent with transport in InAs/GaInSb quantum spin Hall systems [2], indicating compatibility between non-volatile memory functionality and low-dimensional electronic transport. The observed hysteresis is consistent with intrinsic floating-gate-like charge storage, potentially arising from dielectric charge trapping and carrier redistribution within the quantum well system. These gate-tunable, multilevel, and non-volatile memory characteristics establish the InAs/GaInSb/InAs triple quantum well as a promising platform for topological memristive devices and future hybrid quantum-neuromorphic architectures [1,3].

Keywords: Memristor, Topological electronics, Non-volatile memory, Quantum Spin Hall effect

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