

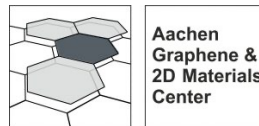


Neuromorphic Computing for Autonomous AI Systems – the NeuroSys Cluster4Excellence in the Aachen Region

Max C. Lemme

RWTH Aachen University – Chair of Electronic Devices

AMO GmbH, Aachen



RWTH Aachen University

- Large European Technical Univ.
- Ca. 50.000 students
- Triangle:
Germany / Belgium / Netherlands
- Chair of Electronic Devices



AMO GmbH

- High-Tech SME / Institute (non-profit) / Research Foundry
- 400 m² clean room
- 80 staff members in 40 funded R&D projects
- > 100 R&D partners across Europe and beyond
- Silicon technology, Nanofabrication & New Materials
- Targeted applications
 - Nanoelectronics, Sensors, Flexible Electronics
 - Nanophotonics
 - Quantum Technologies
 - Neuromorphic Computing
 - Environmental Nanotechnology
- Mission: Technology Transfer
 - R&D Partners & Start Ups (Black Semiconductor, Protemics, AMOtronics)

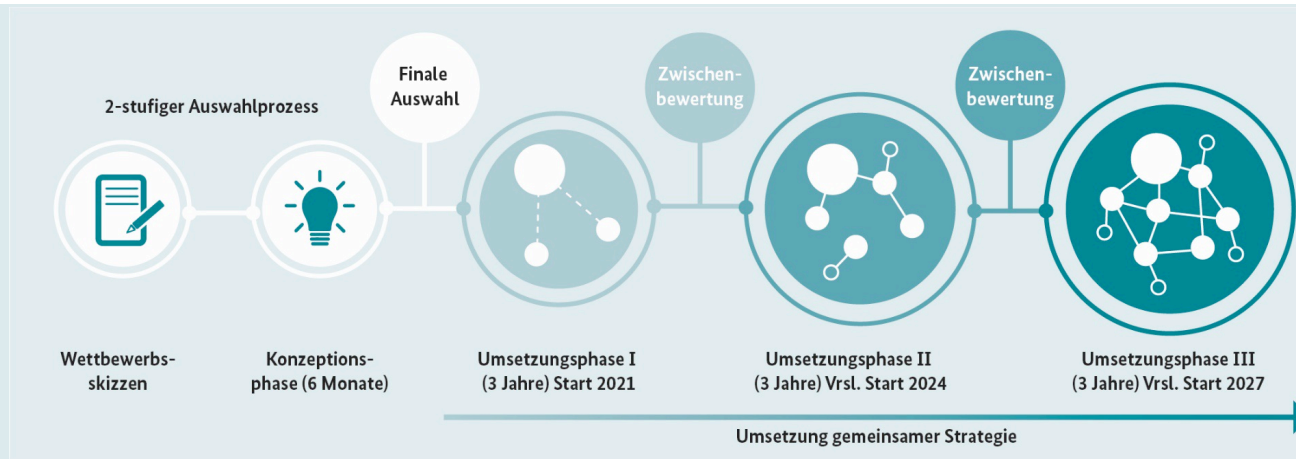
From Knowledge to Impact

- Flagship of the German Hightech-Strategy 2025
- Regional Clusters
- Create Innovations of the Future from Excellent Research

Criteria for Clusters4Future

1. Critical mass of different innovation drivers and actors from Science, Industry and Society within a region
2. Recent research results with high potential for breakthroughs
3. Dynamic competition, for a positive start-up and entrepreneurial climate





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Competition phase

- 137 submissions (Nov. 2019)
- 16 Ideas selected for Concept Phase (Feb. 2020)
- 6-month Concept Phase (01.05.2020 – 31.10.2020)
- 7 Clusters selectrd (Jan 2021)

Realization Phases

- Private/Public Co-Financing
- Funding: up tp 5 Mio. € /year and Cluster
- Increasing financial committment by actors over time
 - Realization Phase I: 80% funding rate
 - Realization Phase II: 65% funding rate
 - Realization Phase III: 50% funding rate

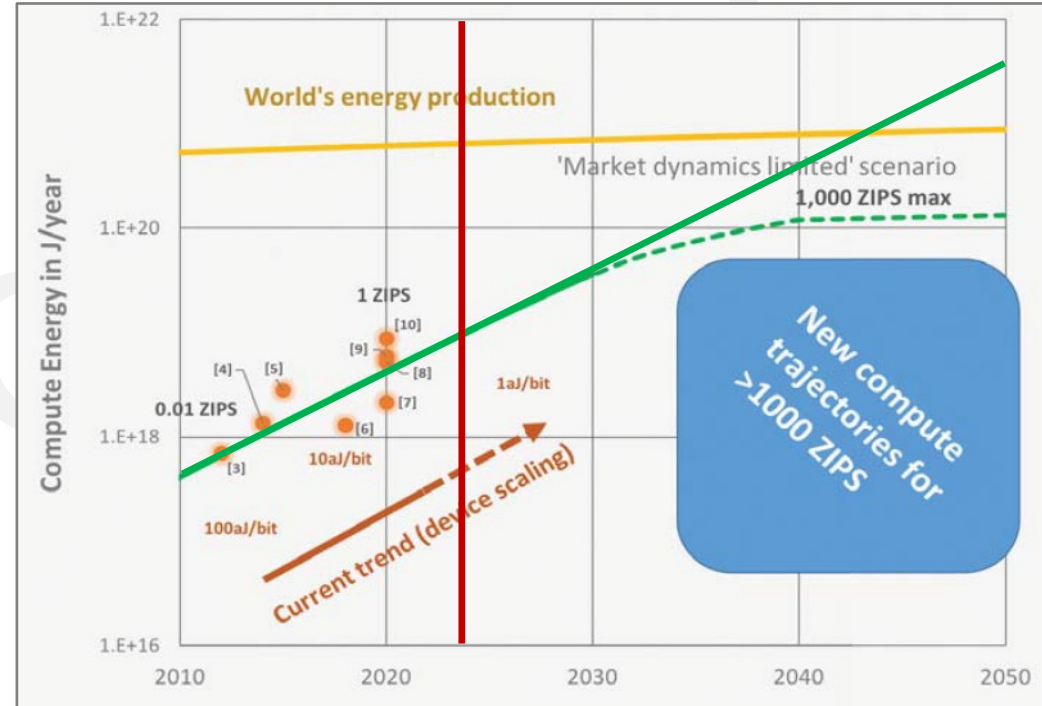
NeuroSys Setting

Machine Learning and Artificial Intelligence: The need for new hardware!

Estimated CO₂ emissions from training common natural language processing (NLP) models and familiar consumption ⁽¹⁾

Consumption	CO ₂ e (t)
Human life, avg, 1 year	5
American life, avg, 1 year	16.4
Car, avg incl. fuel, 1 lifetime	57.152
Training one model (GPU)	
NLP pipeline, full tuning	35.592
Transformer (big), full tuning	284.019

(1) E. Strubell et al., in Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics Italy, 2019 pp. 3645–3650.



Source: SRC Decadal Plan, 2020

NeuroSys Setting

A better AI-chip makes a better product

AI hardware as strategic technology

- Edge computing (Billion Sensor Networks)
- Energy efficiency is mandatory (Green Deal)
- Reliable supply chains
- Technology Sovereignty
- Cyber Security
- Data security and privacy
- Ethics in AI



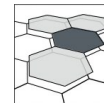
Deutscher Bundestag

Enquete-Kommission

„Künstliche Intelligenz –
Gesellschaftliche Verantwortung
und wirtschaftliche, soziale und
ökologische Potenziale“



Bytes statt Blech



Aachen
Graphene &
2D Materials
Center



„Cyber-attacks are moving...
from software to hardware,
threatening devices in
homes, cars, businesses,
networks, and cloud.“

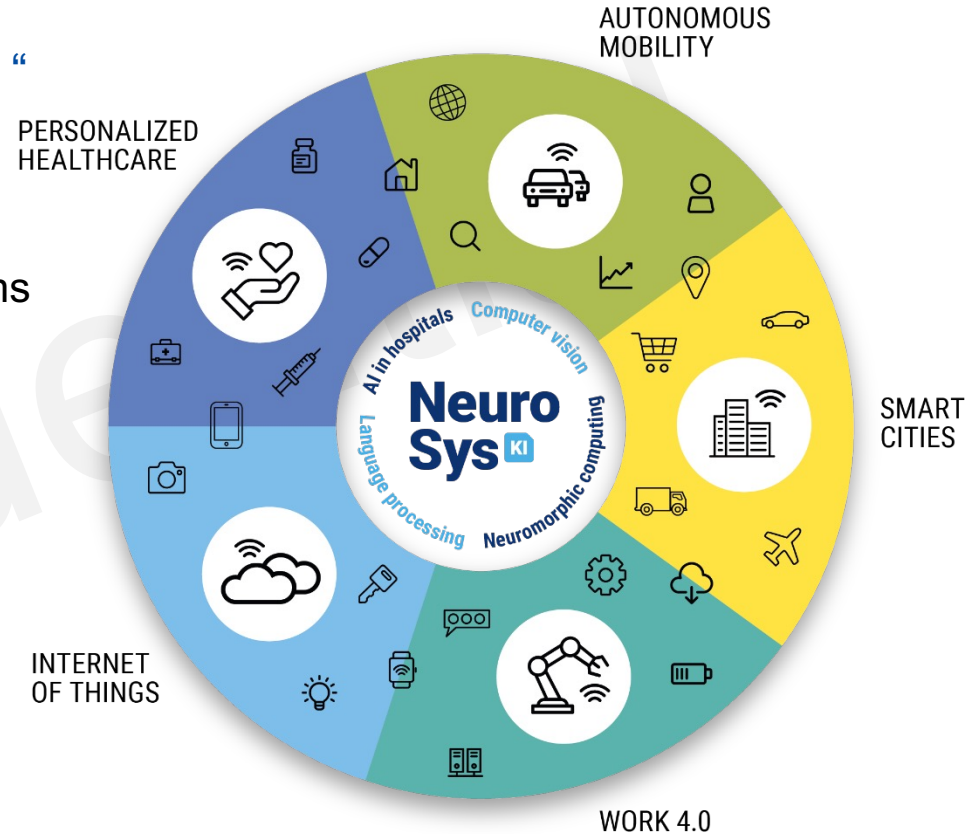


„AI systems will influence all areas of life “

AI-committee of the German Parliament

Neuromorphic hardware has no alternative

- Energy efficiency for autonomous systems
- Technology sovereignty
- Patient sovereignty
- Enormous economical potential
- European values in AI
- NeuroSys as a disruptive AI technology
- Beyond the limits of classical microelectronics: an opportunity



NeuroSys Basis: Excellent Research

Cluster4Future NeuroSys

Cluster of Excellence

ML⁴Q

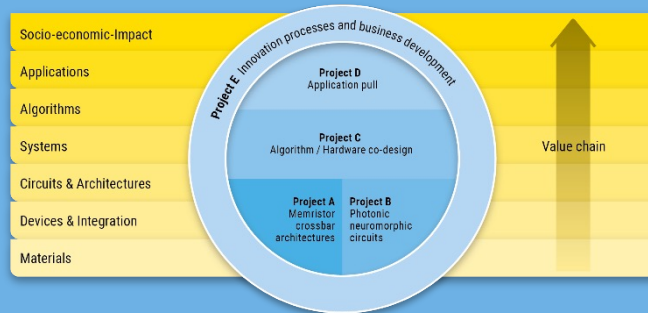
INTERNET OF
PRODUCTION | **RWTHAACHEN
UNIVERSITY**

NEUROTEC

ZUKUNFTSAGENTUR
**RHEINISCHES
REVIER**

Digital
Hardware
Hub Aachen

NeuroSys core projects



**RWTH Human
Technology Center**

**Aachen Graphene
& 2D Materials
Center**

**RWTH
AI Center**

**JARA-
FIT**

**Helmholtz Institute for
Biomedical Engineering**

**MISEL
FET-
Open**

EU Flagships
Graphene, HBP, QT

DFG SFB
NanoSwitches

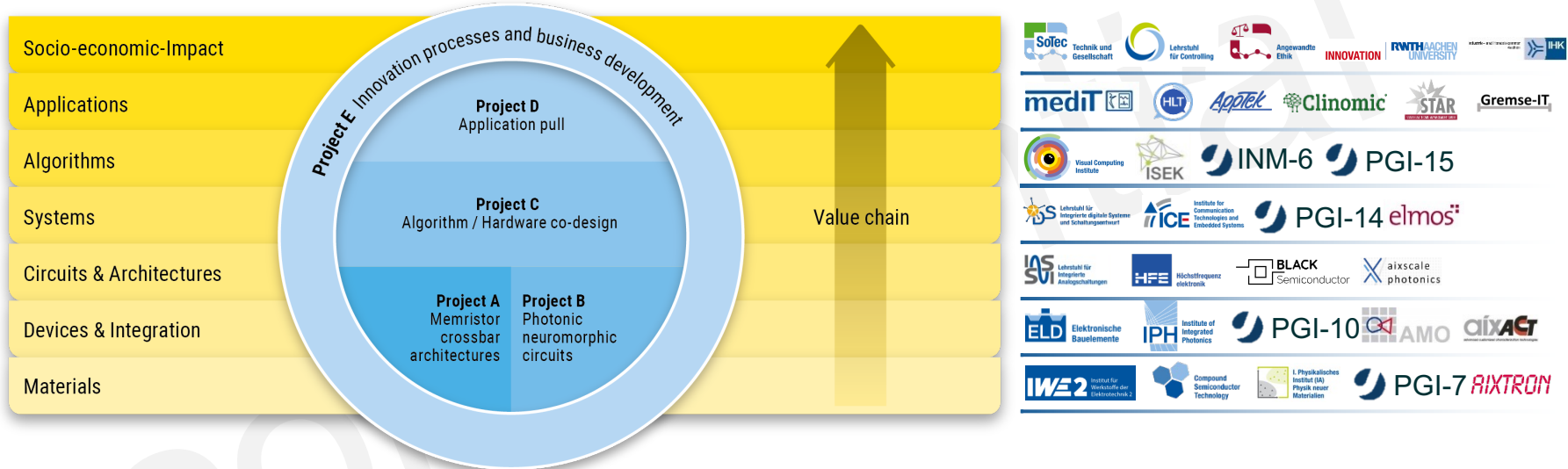
BMBF
NeuroTec

BMBF
ForLab

DFG SPP
2262 & 1796

**7 ERC
Grants**

Excellence along the entire value chain



- Cluster defined through transdisciplinarity
- Long timeline and funding format allow growth in-tune with the technology readiness level
- Structure allows orchestration of the topic in the region – integration of different formats



NEUROMORPHIC HARDWARE FOR AUTONOMOUS ARTIFICIAL INTELLIGENCE SYSTEMS



Project Partners

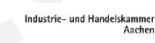
Science



Business



Society



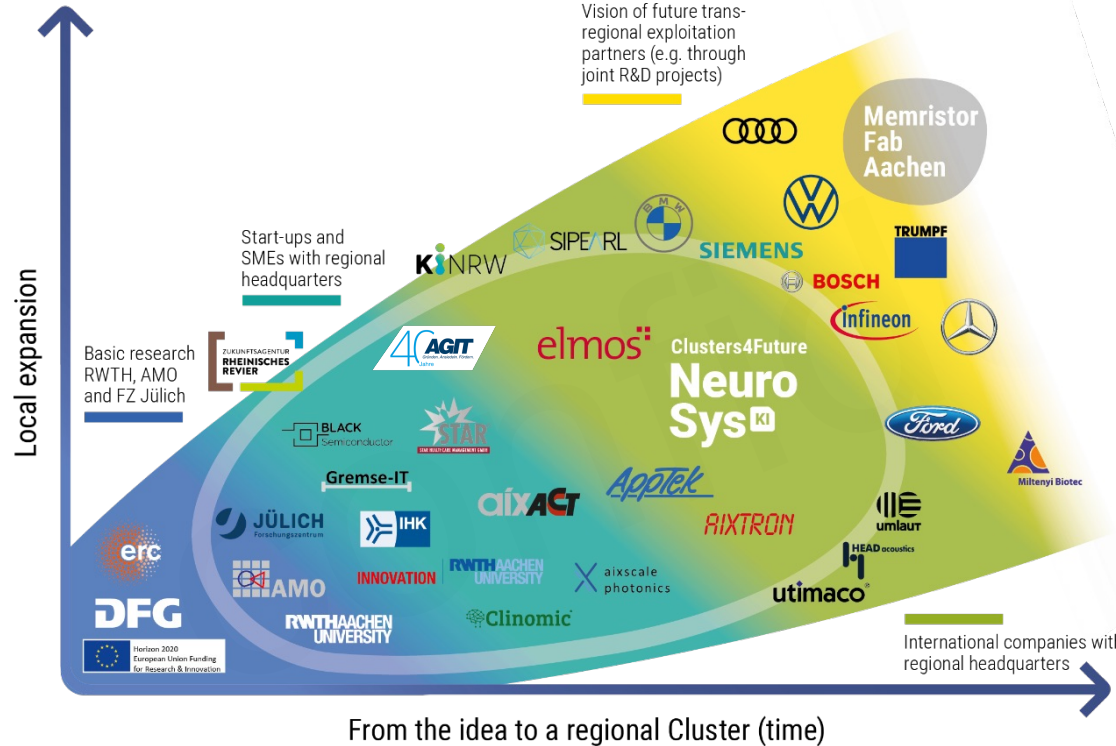
Advisory Board



Prof. Klaus Mainzer
Prof. Thomas Mikolajick



NeuroSys Strenght: a Techno-Socio-Economic Cluster



Critical Mass and Dynamic Network

Transdisciplinary consortium: physics, materials science, neuroscience, engineering, computer science, economics, ethics, sociology

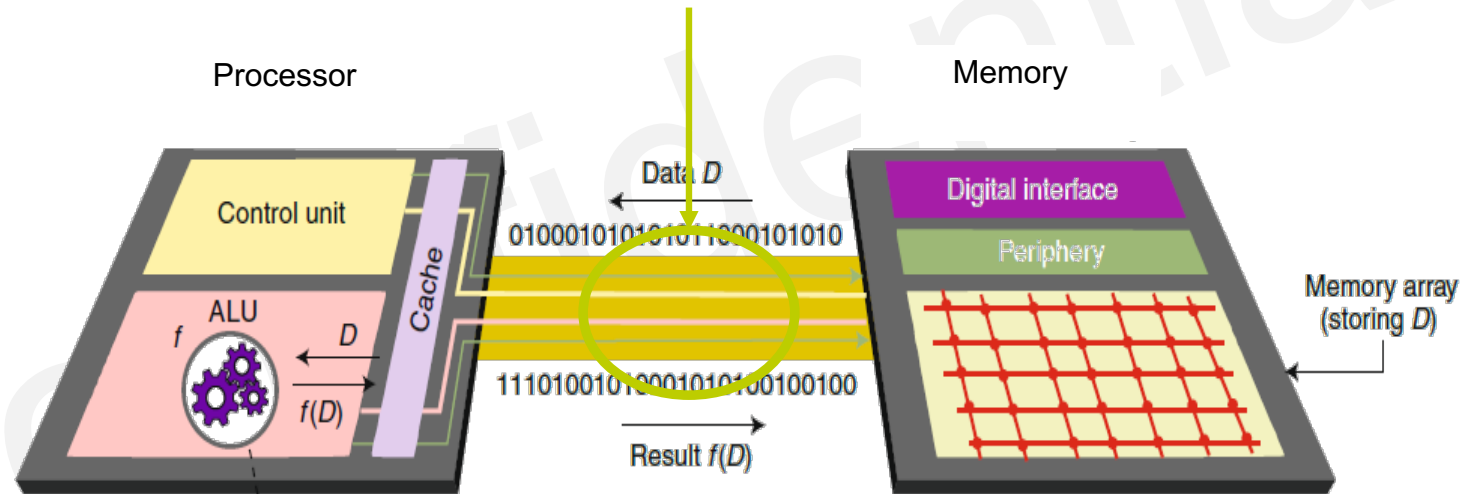
Regional start-ups and companies

Corporations and internationally renowned scientists make up the **Advisory Board** → **partners of tomorrow**

Innovation drivers: IHK Aachen, RWTH Innovation GmbH, REVIERa, Zukunftsagentur Rheinisches Revier (ZRR), KI.NRW (FhG) → **enhancing regional impact**

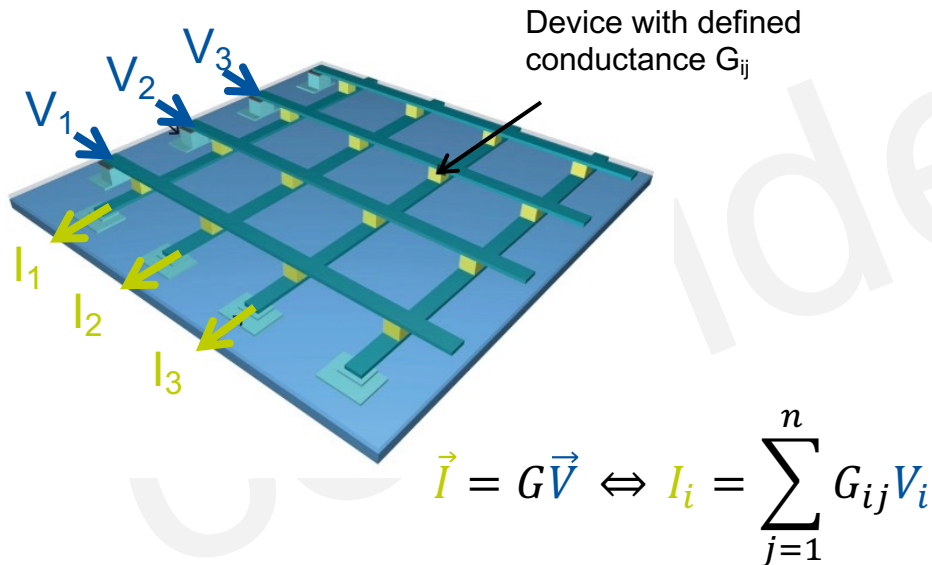
Machine Learning and Artificial Intelligence: The need for new hardware!

Von-Neumann bottleneck



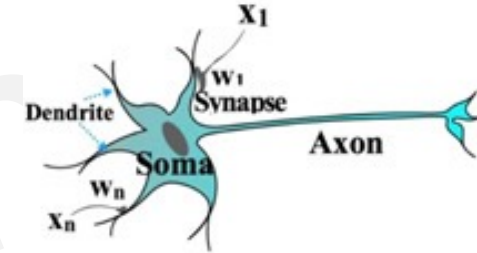
(2) A. Sebastian et al., Nat. Nanotechnol., 1–16, 2020

Computing in memory

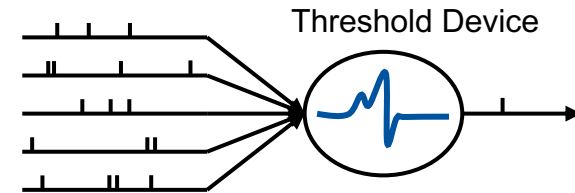


Adapted from: (3) A. Mehonic *et al.*, Advanced Intelligent Systems. 2, 2000085 (2020).

Biological Neural Network

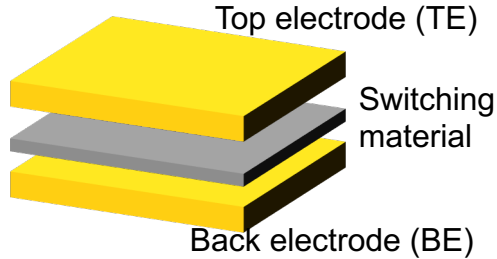


Spiking Neural Network



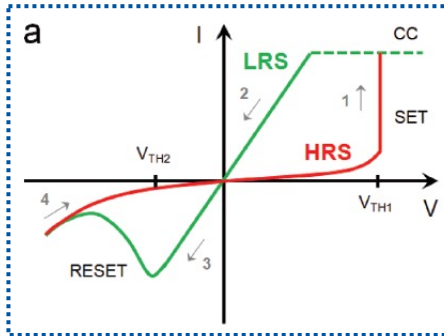
Adapted from: (4) X. Zhang *et al.*, physica status solidi (a). 215, 1700875 (2018).

Memristors → „memory transistor“ (Leon Chua, 1971)

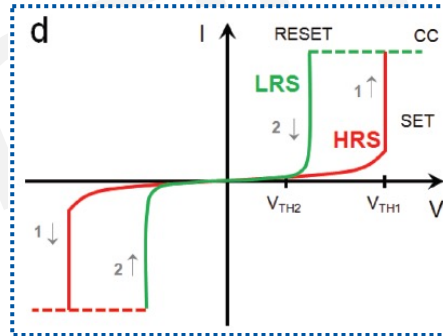


- Debate ongoing: Resistive switching $\neq$ Memristor
 - "memristive devices"
 - "resistive switching"

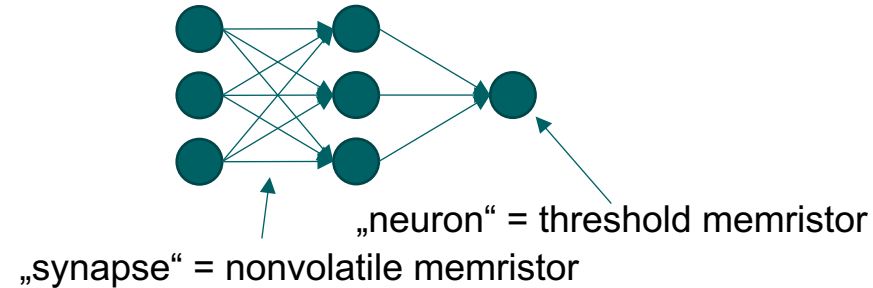
Bipolar (non-volatile)



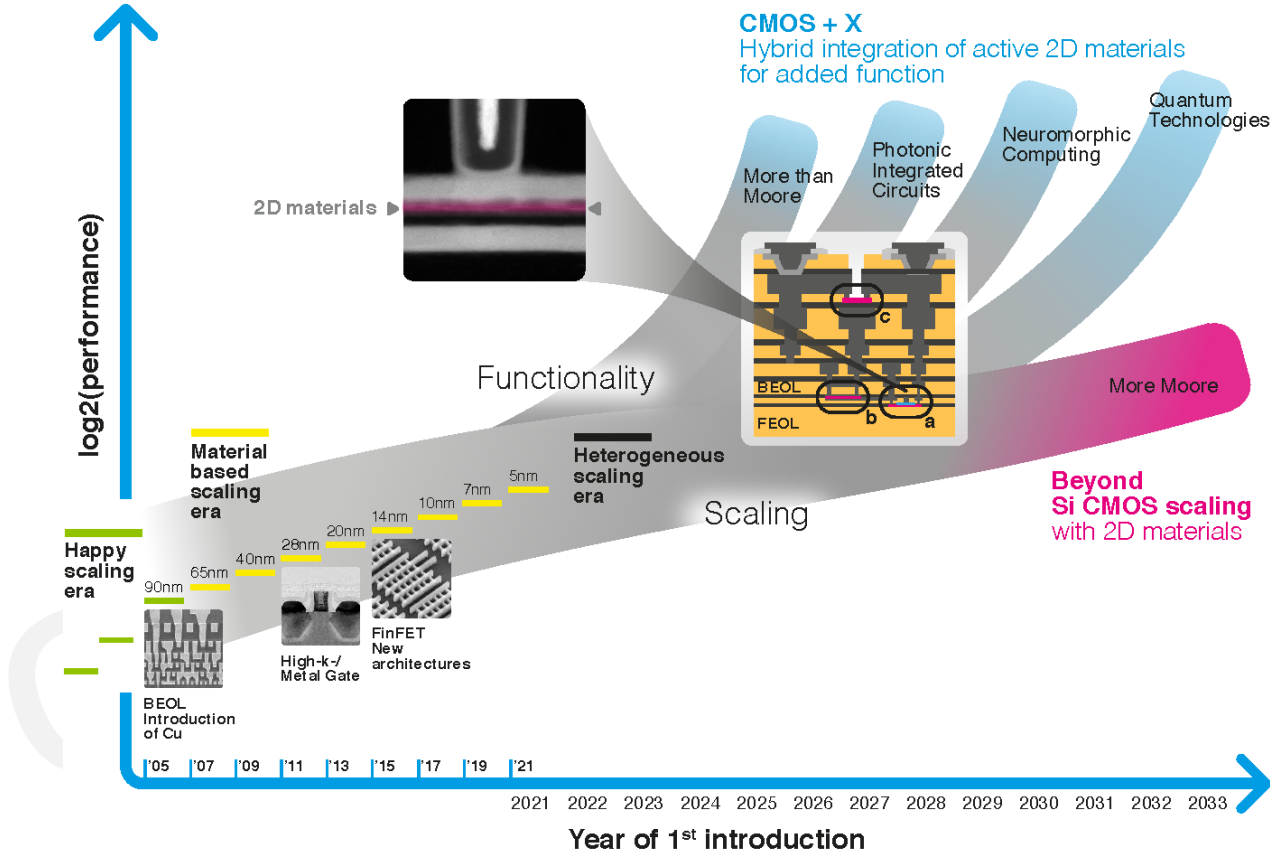
Threshold (volatile)



Adapted from (5) M. Lanza et al., Advanced Electronic Materials. 5, 1800143 (2019).



Highlights: New Materials



Lemme *et al.*, Nat. Comm., 2022

Highlights: Artificial Neural Networks vs. Brain-Inspired Neural Networks

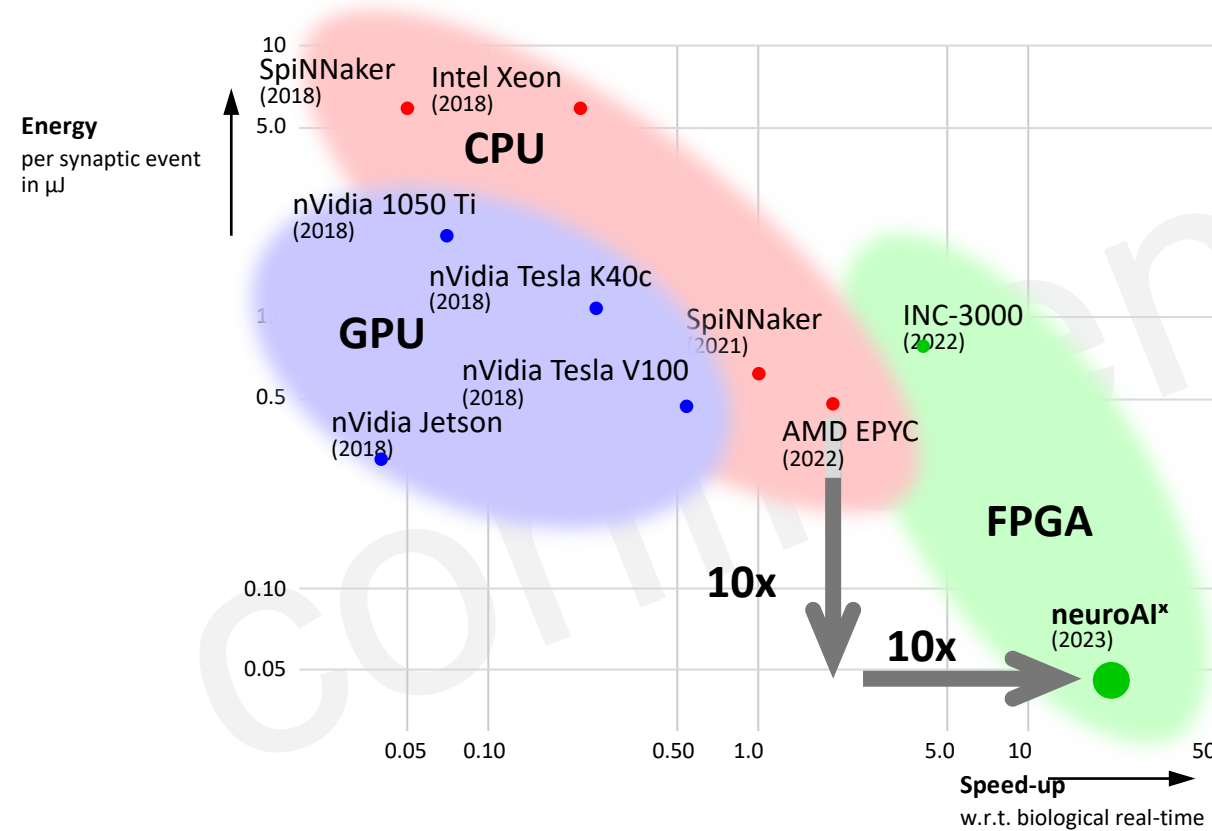


**CLUSTERS
4 FUTURE**
Innovationsnetzwerke
für unsere Zukunft



GEFÖRDEBT VOM

Bundesministerium
für Bildung
und Forschung

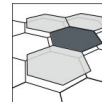
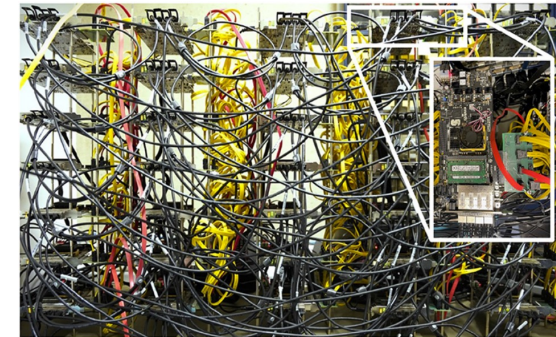


Frontiers in Computational Neuroscience

TYPE Original Research
PUBLISHED 20 April 2023
DOI 10.3389/fncom.2023.1144143

neuroAIx-Framework: design of future neuroscience simulation systems exhibiting execution of the cortical microcircuit model 20x faster than biological real-time

Kevin Kauth*, Tim Stadtmann, Vida Sobhani and Tobias Gemmeke
Chair of Integrated Digital Systems and Circuit Design, RWTH Aachen University, Aachen, Germany



STARTSEITE / PRESSE / PRESSEMELDUNGEN

16. MAI 2023 |

AIXTRON plant Investition von bis zu 100 Millionen Euro / Neues Innovationszentrum in Herzogenrath soll dem Spezialanlagenbauer noch mehr Platz für Forschung und Entwicklung bieten.

EQS-Media / 16.05.2023 / 15:14 CET/CEST

AIXTRON plant Investition von bis zu 100 Millionen Euro

Neues Innovationszentrum am Standort in Herzogenrath soll dem Spezialanlagenbauer noch mehr Platz für Forschung und Entwicklung bieten.

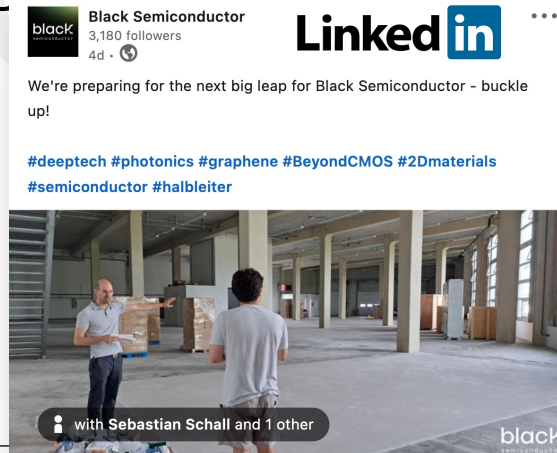
Herzogenrath, 16. Mai 2023 – AIXTRON SE (FSE: AIXA, ISIN DE000A0WMPJ6) plant, bis zu 100 Millionen Euro am Standort in Herzogenrath zu investieren. Entstehen soll dabei ein neues Innovationszentrum, das dem Spezialanlagenbauer künftig noch mehr Kapazität für Forschung und Entwicklung bietet. Grünes Licht für das Projekt bekam AIXTRON an diesem Dienstag vom Aufsichtsrat des Unternehmens.



15.08.2023



- Founded: November 2019
- December 2021: VC Seed round of 6M€
- Januar 2022: Kickoff BMBF Cluster4Excellence NeuroSys
- June 2023: Black Semiconductor selected by the European Commission as one of the "Important F...



25.08.2023



Clinomic Group successfully closes a EUR 16 million financing round

- The medtech company and NeuroSys-member Clinomic successfully closed a financing round in July 2023
- In addition to the existing shareholders, Sana Kliniken AG and a family office participated in the funding. The capital will be used for further growth strategy and product development.
- Clinomic has been revolutionizing acute and critical care medicine since 2019. Clinomic Group creates innovative solutions for critically ill patients by combining translational medical research, with modern technologies and data science. With 75 employees, Clinomic is actively shaping the evolution of healthcare towards a smart, efficient and resource-driven digital transformation.
- The financing will support Clinomic in accelerating the digitalization of the healthcare system and the optimization of processes in intensive and acute care medicine.



Thank you for your attention!



GRAPHENE FLAGSHIP



**Bundesministerium
für Bildung
und Forschung**

DFG
Deutsche
Forschungsgemeinschaft



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- European Union Horizon 2020: 829035 (QUEFORMAL), 881603 (Graphene Flagship), 952792 (2D-EPL), 971398 (ULTRAPHO)