

Proposal title

Neuromorphic Optomemristor Chips for Robust Cryogenic Artificial Intelligence Systems

Project summary

This project will explore neuromorphic computing using pre-fabricated optomemristor chips operated at cryogenic temperatures, relevant to quantum, space, and secure AI electronics. The student will experimentally characterise how optically addressable memristive synapses behave under deep cooling, evaluate robustness against cryogenic-induced noise, and implement simple neuromorphic tasks (e.g. pattern recognition) using measured device characteristics. By combining device-level measurements with circuit-level modelling and basic learning algorithms, the student will help assess whether optomemristor-based neuromorphic hardware can provide reliable, low-power AI functionality in extreme environments where conventional CMOS processors struggle.

Host institution and supervisors

University of Southampton, UK (School of Electronics and Computer Science)

Supervisor: Dr Firman Simanjuntak (expertise in nanofabrication, neuromorphic devices, and space electronics)

Mentors: PhD students with complementary expertise in neuromorphic devices and AI algorithms. Industrial (informal support): Von Ardenne GmbH (VA), Germany, providing background on thin-film optomemristor technology used to fabricate the chips.

The project will be hosted in Southampton's device characterisation laboratories and SET group offices, providing daily interaction with PhD students working on the related memristor-based AI accelerators programme.

Research quality

Cryogenic processors are increasingly important for quantum computing interfaces, deep-space missions, and secure AI systems that must operate reliably at very low temperatures. Yet current CMOS-based hardware shows degraded performance, vulnerability to "freeze attacks", and susceptibility to magnetic interference, motivating alternative device concepts for robust neuromorphic computing in these regimes. Memristors provide non-volatile, analogue, synapse-like behaviour and can implement energy-efficient neuromorphic computing; when combined with optical stimulation, optomemristors enable high-bandwidth, photonic-neuromorphic integration.

The host group has already fabricated memristor chips using advanced thin-film and nanofabrication processes in collaboration with Von Ardenne GmbH. This undergraduate project will not involve fabrication; instead, the student will focus on:

- (Week 1-4) Optically-controlled electrical response of the memristor arrays (e.g., I–V curves, switching statistics, and synaptic behaviours) under cryogenic and magnetic conditions.
- (Week 3-6) Assessing how cryogenic operation and magnetic-field-inspired noise affect synaptic metrics such as weight update linearity and variability.
- (Week 7-8) Extracting compact, data-driven device models and mapping them into neuromorphic simulations (e.g. pattern recognition or associative memory tasks).

Opportunity to learn across the stack

The project is designed to expose the student to multiple tiers of the neuromorphic stack, while keeping the workload realistic for an 8-week placement.

Device / materials

Hands-on training in using probe stations and cryogenic setups to measure memristive devices, including compliance-current control and automated I–V sweeps. Interpretation of device physics concepts (filamentary switching, retention, variability) in the context of optomemristor technology and its thin-film origins.

Circuit / architecture

Construction of simple crossbar-style or synapse-array models using measured device parameters, including non-idealities such as variability and limited dynamic range. Exploration of how these non-idealities impact circuit-level metrics like signal-to-noise ratio and effective weight precision at cryogenic temperatures.

Algorithm / software

Implementation (in Python) of small neuromorphic tasks such as classification on toy datasets or associative recall, constrained by the experimentally obtained device models. Investigation of basic error-mitigation strategies (e.g. redundancy, simple re-training, or noise-aware thresholding) to compensate for cryogenic-induced noise.

By the end of the project, the student will understand how device-level characteristics measured in the lab propagate upward to affect neuromorphic algorithm performance in realistic extreme environments.

Research environment

The student will join an active research team at Southampton working on optoelectronic AI processors for cryogenic and space electronics, ensuring immersion in a vibrant neuromorphic materials and computing environment. Day-to-day supervision will be provided by the primary supervisor and a senior PhD student or postdoc who is directly involved in the ongoing optomemristor project, guaranteeing close guidance and rapid feedback. The experimental work will take place in fully equipped device characterisation laboratories with access to cryogenic probe stations, semiconductor analysers, laser sources (for optical programming demonstrations where appropriate), and data-acquisition computers. For modelling and algorithmic work, the student will use established neuromorphic simulation workflows, including version-controlled code repositories to encourage good research practices.

The group maintains strong links with industrial partner Von Ardenne GmbH, whose thin-film deposition technology underpins the pre-fabricated optomemristor chips used in this project, giving industrial relevance and potential for informal interaction (e.g. remote seminar or Q&A) during the placement. The broader NeuMat community and local seminars on neuromorphic hardware and sustainable AI will provide further exposure to the UK's neuromorphic talent pipeline and future PhD opportunities.