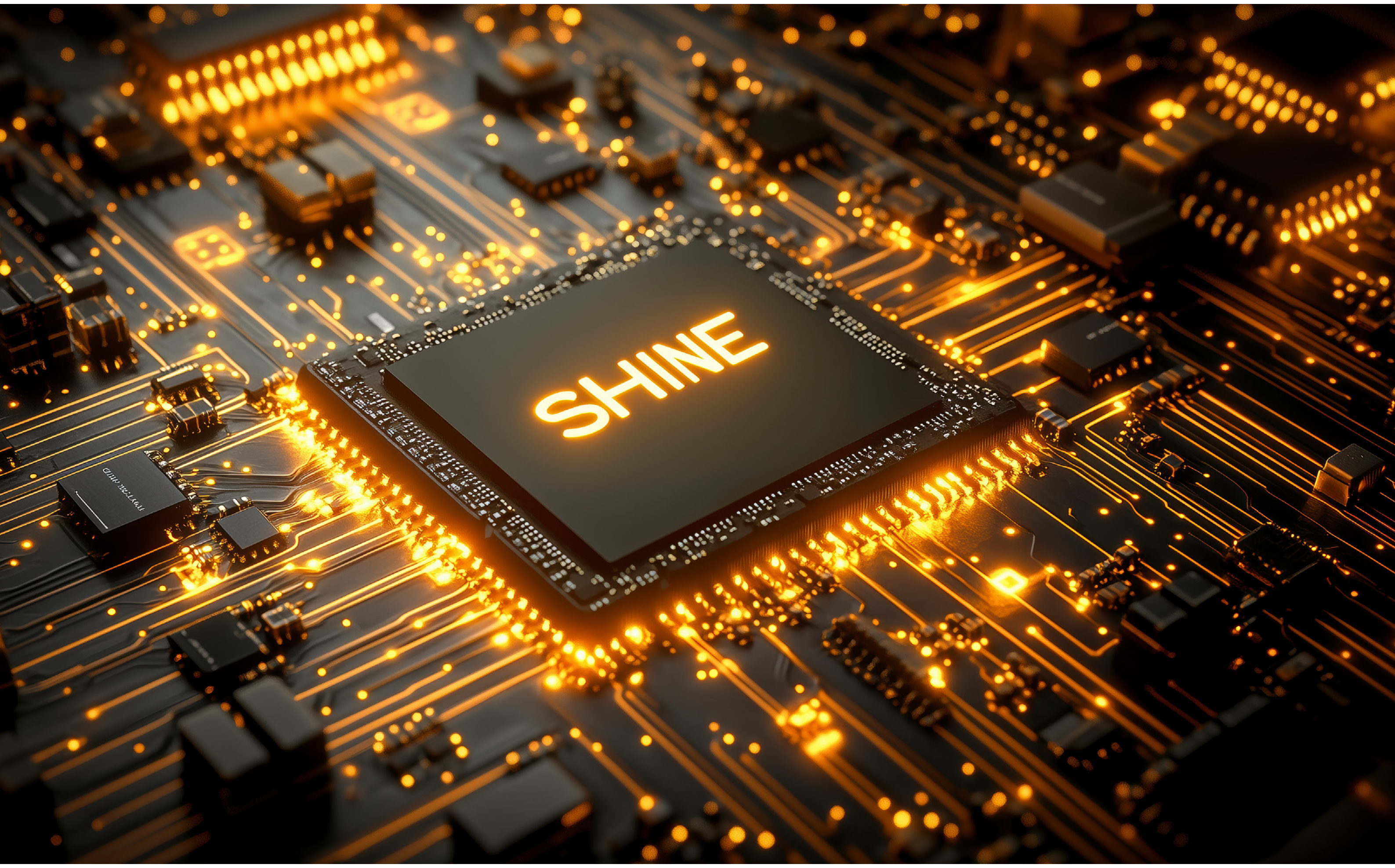
Research Centre

Shining a light on chip chatter



From lab concept to real-world integration, a multi-institutional collaboration produces a compact photonic modulator-memory device that turbocharges how data moves between computer chips — more efficiently, with far less energy.

As the world's voracious appetite for data grows ever larger, so too does the need for microelectronic systems to keep up. From data centres to AI processors to edge computing to next-generation communications, tomorrow's technologies will need faster, more efficient ways for chips to talk to each other.

Image above was created with the assistance of DALL·E 2

Hosted at the College of Design and Engineering, the Singapore Hybrid-Integrated Next-Generation μ-Electronics (SHINE) Centre is leading efforts to meet this challenge. At the intersection of materials science, electronics and photonics, the Centre brings together researchers across disciplines to develop advanced microelectronics with an emphasis on real-world impact. As a platform for academic-industry collaboration, SHINE also offers opportunities for partners across the semiconductor value chain to co-develop and translate emerging technologies into practical applications.

Professor Aaron Thean directs the SHINE Centre, which brings together researchers across disciplines to develop advanced microelectronics with an emphasis on real-world impact.

Researchers at SHINE recently demonstrated, for the first time, a compact device that unifies optical modulation and memory. This paves the way for a faster, more energy-efficient and adaptable way for microchips to communicate, one that could bring data-processing to new frontiers.

The collaborative project brought together a multidisciplinary team from SHINE; the Integrative Sciences and Engineering Program, NUS Graduate School; the School of Electronics and Information Technology, Sun Yat-Sen University, China; the Centre for Quantum Technologies, NUS; and industry partner POET Technologies.

The team's paper was selected for the IEEE *International Electron Devices Meeting* that took place from 9–13 December 2023 in San Francisco.

Untangling the gridlock

To speed up chip-to-chip communication, researchers are increasingly turning away from traditional electrical connections and turning to photonics, where beams of light ferry information instead of electrons. Because photons don't face electrical resistance, they move swiftly and cleanly. This means faster data flows, using less energy, without generating excessive heat.

But translating this potential into real-world applications hasn't been an easy cruise. One major roadblock has been the lack of devices capable of modulating and storing optical signals concurrently. Existing modulators, which convert electrical signals to optical ones, tend to be power-hungry and lack built-

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(Top) Keynote speaker Professor Aaron Thean, Deputy President (Academic Affairs) and Provost of NUS, outlined ways CDE and SHINE Centre have been expanding the talent pool in the semiconductor industry.

(Bottom) The panel from left to right: Dr Radha Nagarajan (Marvell Technology), Dr Arvind Sundarrajan (Applied Materials), Dr Siah Soh Yun (GlobalFoundries), Dr Patrick Lo (Advance Micro Foundry), Dr Alfred Yeo (STATS ChipPAC), Ms Chen Lan (AMD) and Mr Noam Mizarhi (Marvell Technology).

in memory. Without memory, these systems must constantly refresh their settings, which undermine efficiency and flexibility.

Tackling this challenge head-on, the collaborative team designed a compact electro-optic modulator with integrated memory — a device they dubbed Electro-Optic Modulator and Memory (EOMM). They achieved this by combining lithium niobate on insulator (LNOI), a material known for its ability to alter how light behaves under an electric field, with hafnium zirconium oxide (HZO), a ferroelectric material that retains memory states without the need for continuous power.

"The ferroelectric properties of HZO create stable electric fields that influence the optical properties of LNOI. This imprints memory states onto the device," explains Professor Aaron Thean, Director of the SHINE Centre. "Unlike conventional modulators, this design doesn't need constant electrical input to remember its configuration, significantly cutting down energy usage and enhancing operational efficiency."

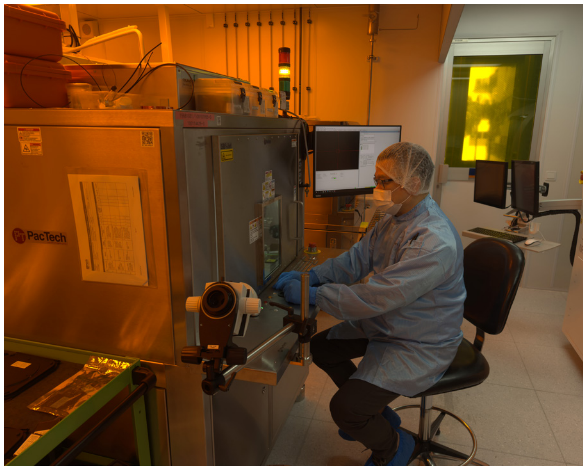
To further enhance the performance of the EOMM, the team incorporated indium-tin oxide electrodes, which allow light to be controlled electrically without blocking it, keeping signals clean and sharp. They also integrated tiny resistive heaters to provide an additional way to fine-tune the light when needed. Together, these features give the device both speed and flexibility.

Real-world potential

Working with industry partner POET Technologies, a developer of advanced photonic integration platforms, the researchers took their innovation one step closer to real-world deployment. They integrated the EOMM device into POET Technologies' high-speed optical interposer chip (400G Tx/Rx) to test how the technology could perform in a commercial-grade photonic system.

In simulated models of chiplet-to-chiplet communication networks, where multiple chips communicate through a shared photonic interconnect, the EOMM-enabled system achieved up to 70% power savings compared to conventional electrical links, and 30–50% lower energy consumption compared to optical systems that still rely on electronic routing.

"Through cross-disciplinary collaboration and close partnerships with industry, research like this highlights the real-world potential for commercial reconfigurable photonic systems that can adapt on the fly," adds Prof Thean. "Enabling memory and modulation in a single device is a holy grail for faster, smarter and more efficient chip communication in high-performance environments like data centres, AI processors and photonic neural networks." ◆



(Top) POET Technologies and SHINE have embarked on projects together to develop advanced processes and manufacturing techniques for hybrid integration of photonics devices.

(Bottom) POET researchers work on their photonics project with SHINE in the cleanroom.