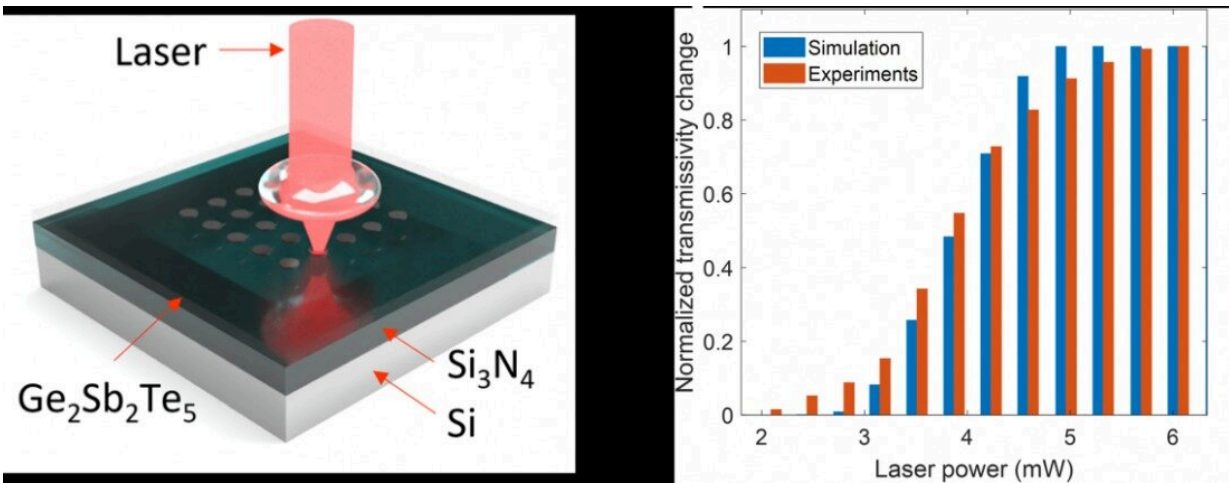


Advancing photonics materials with cellular automation

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(Left) Schematic diagram of the $\text{Ge}_2\text{Sb}_2\text{Te}_5$ programmable optical stack. (Right) Simulated and measured normalised transmissivity change at 300 ns laser pulses width different laser powers. Credit: SUTD

Inspired by the "Game of Life" SUTD researchers are applying cellular automation to efficiently model phase change materials with multiple optical phases for next-generation photonics devices.

Researchers from the Singapore University of Technology and Design (SUTD) have designed a novel [computational model](#) that accurately predicts the properties of photonics materials, paving the way for next-generation photonics devices. Their findings, published in *npj*

Computational Materials, could lead to futuristic holographic displays, enhanced LiDAR sensors for reliable self-driving cars and better machine learning capabilities via all-optical neural networks.

Pioneered in the 1960s, photonics refers to the ability to harness, generate, detect and transmit fundamental light particles called photons and light waves. Since then, photonics has revolutionized fields like telecommunications, with fiber [optic cables](#) enabling the high-speed, high-bandwidth transfer of data even across great distances.

Typically, photonics materials have fixed properties and cannot be tuned. However, phase change materials, which were originally developed for optical data storage purposes, can be programmed to have different optical properties, for example reflecting or absorbing.

For new photonics applications, more than two optical states are needed. However, achieving such conditions can be easier said than done.

"Optimizing the programming conditions to create different phases is challenging, time-consuming and tedious," said study leader Associate Professor Robert Simpson from SUTD's Engineering Product Development pillar.

Before the onset of COVID-19, Assoc Prof Simpson shared that his team had been leveraging experimental techniques to design and develop photonics computational materials (PCM) with two or more optical states. Taking inspiration from the late mathematician John Conway, who devised The Game of Life in the 1970s, the team sought to explore instead how cellular automation could help design PCMs with multiple optical phases.

"Cellular automation is a way to model interacting cells," explained Assoc Prof Simpson. "When thousands of cells interact, the collective behavior of a simple system becomes complex and interesting patterns

emerge."

Accordingly, Assoc Prof Simpson and his colleagues used cellular automation to simulate the crystallization of the PCM $\text{Ge}_2\text{Sb}_2\text{Te}_5$ under certain conditions. "We showed that the model accurately predicts the laser pulses required to partially switch PCMs and produce a wide range of optical states," he added. To the team's surprise, they found that $\text{Ge}_2\text{Sb}_2\text{Te}_5$ exhibited growth-dominated crystallization instead of being governed by nucleation, and this effect is important because the optical response of photonics devices can be tuned to multiple optical levels via crystal growth.

As the first model of its kind to simulate multi-level phase change switching, the research team has made its code [open source](#) to encourage other researchers to develop and optimize other programmable photonics materials.

"Moving forward, we are also developing new PCMs that are transparent in the visible spectrum, instead of those that are non-transparent, such as $\text{Ge}_2\text{Sb}_2\text{Te}_5$," concluded Assoc Prof Simpson. "Transparency is key in enabling futuristic applications like holographic displays."

More information: Yunzheng Wang et al, A scheme for simulating multi-level phase change photonics materials, *npj Computational Materials* (2021). [DOI: 10.1038/s41524-021-00655-w](https://doi.org/10.1038/s41524-021-00655-w)

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