OUT THINKING THE BRAIN

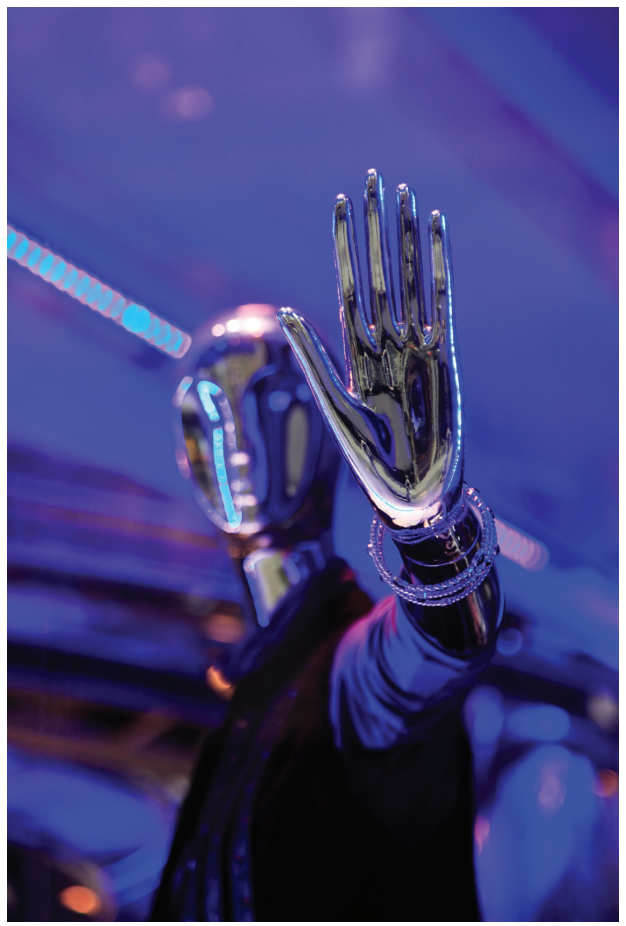
UA PHYSICS PROFESSOR PUSHING NEUROMORPHIC COMPUTING TO NEXT LEVEL


Dr. Laurent Bellaiche

Imagine the office of a theoretical physicist. Most might conjure an image of a charmingly cluttered workspace, a desk littered in a moonscape of manilla folders and unfiled paperwork, walls festooned with pinned-up snapshots, Post-It notes and assorted posters, and yes, a chalkboard bearing the scribbles of mysterious formulas and equations.

Stepping into the office of Dr. Laurent Bellaiche, an Arkansas Research Alliance Fellow and Distinguished Professor of Physics at the University of Arkansas, is almost like stepping inside his mind, which is ironic because he has devoted part of his research to duplicating the awesome power of the human brain.

"In the last five years, artificial intelligence has made a giant leap from a topic of solely academic interest to an industry-shaping IT sector," Bellaiche said.



"This change has been driven not only by the progress in the AI algorithms, but by the development of specialized hardware for AI. Today, new energy-efficient hardware solutions, such as neuromorphic devices, are required to ensure the growing computational needs of the AI market."

IBM says that neuromorphic computing "will have an even greater impact on our way of life than the invention of the internet." Neuromorphic devices are of particular interest to Bellaiche. His work centers on the advancement of ultrafast terahertz (THz) neuromorphic computing, which physically implements neural networks in brain-inspired hardware to speed up their computation.

A terahertz wave has 1 trillion cycles per second allowing for extremely rapid computation. Or, more simply put, a computer that processes information as quickly as the human brain. This could enable systems that complement or enhance efforts that typically require a human's input.

"A quantum neuromorphic device also might be a solution of the artificial brain puzzle as it would unlock a vast space of states with only a few elementary computing elements — qubits," he said. "For example, a quantum computer with 53 qubits, realized in 2019, allows AI to sample a computational state-space of dimension 253 (about 1016). Because of it, quantum AI is thought to be one of the next breakthroughs in neuromorphic computing."

To appreciate neuromorphic computing is to appreciate the capability of the brain, which can process certain types of information within as little as 13 milliseconds. It understands different languages, identifies shapes and can determine the difference between purple and pink. Meanwhile, today's best AI still lacks the computational abilities to perform almost routine determinations, such as understanding who a pedestrian is and what is a stop sign.

Now, large companies like IBM and Intel are rushing to create efficient neuromorphic computers, but there are roadblocks.

"The two main problems are slow response times of transistor-based neuromorphic circuits and the high energy consumption per spike," explained Bellaiche. "Having ultrafast response times will be a breakthrough for neuromorphic circuits."

To achieve THz-speed neuromorphic computing, Bellaiche computationally simulates properties of unique combinations of diverse materials. Specially, he seeks materials possessing multiple states that


Bellaiche said the two main problems are slow response times and high energy consumption. (Photos provided)

emulate synaptic and neuronic behaviors — memristors. The ideal memristor has yet to be discovered, but Bellaiche and his team — with support from an ARA Impact Grant — have identified two promising candidates.

This early research resulted in a recent Vannevar Bush Faculty Fellowship that is the U.S. Department of Defense's most prestigious single-investigator award. But there's still work to do.

"We must perform more simulations to predict the different systems that can be used for THz neuromorphic computing," Bellaiche said. "We must conduct experiments to confirm these predictions. Finally, we must design prototypes, circuits and devices using these materials for THz neuromorphic computing."

As companies such as IBM, Hewlett Packard, Samsung and many other research labs compete for solutions, Bellaiche and his team create and piece together the computational building blocks for industries of the future.

Until then, we're just going to have to rely on our own brain power to do the heavy thinking.

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