Optical switching at record speeds opens door for ultrafast, light-based electronics and computers

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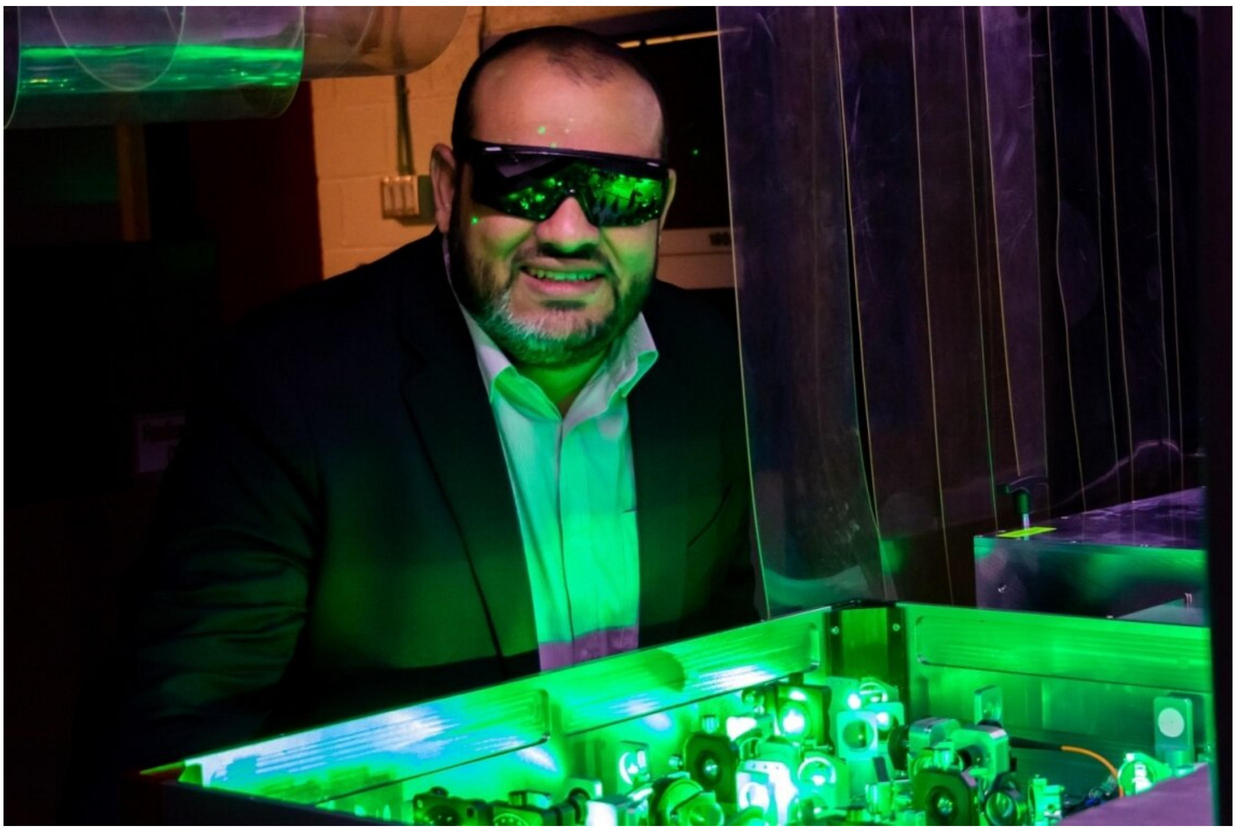

University of Arizona Assistant Professor of Physics and Optical Sciences Mohammed Hassan. Credit: Mohammed Hassan

Imagine a home computer operating 1 million times faster than the most expensive hardware on the market. Now imagine that level of computing power as the industry standard. University of Arizona researchers hope to pave the way for that reality using light-based optical computing, a marked improvement from the semiconductor-based transistors that currently run the world.

"Semiconductor-based transistors are in all of the electronics that we use today," said Mohammed Hassan, assistant professor of physics and optical sciences. "They're part of every industry—from kids' toys to rockets—and are the main building blocks of electronics."

Hassan lad an international team of researchers that published the research article "Ultrafast optical switching and data encoding on synthesized light fields" in *Science Advances* in February. UArizona physics postdoctoral research associate Dandan Hui and physics graduate student Husain Alqattan also contributed to the article, in addition to researchers from Ohio State University and the Ludwig Maximilian University of Munich.

Semiconductors in electronics rely on electrical signals transmitted via microwaves to switch—either allow or prevent—the flow of electricity and data, represented as either "on" or "off." Hassan said the future of electronics will be based instead on using laser light to control electrical signals, opening the door for the establishment of "optical transistors" and the development of ultrafast optical electronics.

Since the invention of semiconductor transistors in the 1940s, technological advancement has centered on increasing the speed at which electric signals can be generated—measured in hertz. According to Hassan, the fastest semiconductor transistors in the world can operate at a speed of more than 800 gigahertz. Data transfer at that frequency is measured at a scale of picoseconds, or one trillionth of a second.

Computer processing power has increased steadily since the introduction of the semiconductor transistor, though Hassan said one of the primary concerns in developing faster technology is that the heat generated by continuing to add transistors to a microchip would eventually require more energy to cool than can pass through the chip.

In their article, Hassan and his collaborators discuss using all-optical switching of a light signal on and off to reach data transfer speeds exceeding a petahertz, measured at the attosecond time scale. An attosecond is one quintillionth of a second, meaning the transfer of data 1 million times faster than the fastest semiconductor transistors.

While optical switches were already shown to achieve information processing speeds faster than that of semiconductor transistor-based technology, Hassan and his co-authors were able to register the on and off signals from a light source happening at the scale of billionths of a second. This was accomplished by taking advantage of a characteristic of fused silica, a glass often used in optics. Fused silica can instantaneously change its reflectivity, and by using ultrafast lasers, Hassan and his team were able to register changes in a light's signal at the attosecond time scale. The work also demonstrated the possibility of sending data in the form of "1" and "0" representing on and off via light at previously impossible speeds.

"This new advancement would also allow the encoding of data on ultrafast laser pulses, which would increase the data transfer speed and could be used in long-distance communications from Earth into deep space," Hassan said. "This promises to increase the limiting speed of data processing and information encoding and open a new realm of information technology."

More information: Dandan Hui et al, Ultrafast optical switching and data encoding on synthesized light fields, *Science Advances* (2023). DOI:

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