Real-Time Brain Activity is Captured by a Two-Photon Microscope

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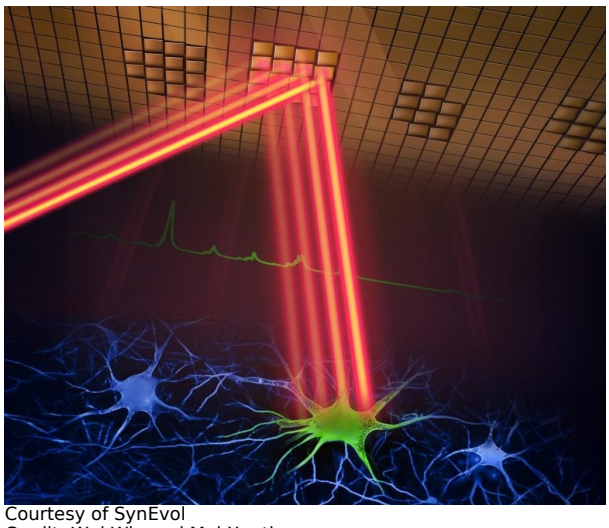
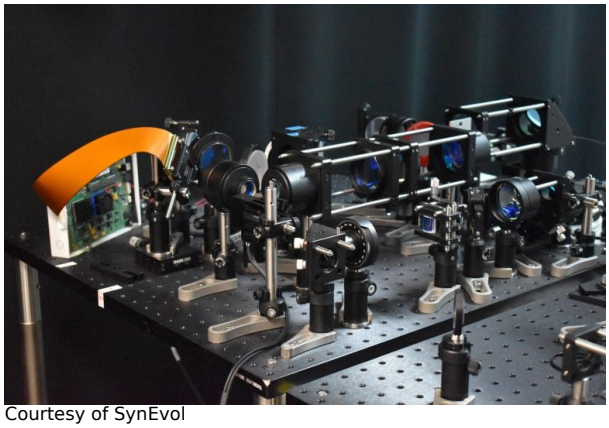


Courtesy of SynEvol
Credit: Wei Wie and Mei Xueting

A new two-photon fluorescence microscope that can record fast images of brain activity at the cellular level has been created by researchers. With a significantly faster imaging speed and less damage to brain tissue than conventional two-photon microscopy, this new method may help us understand neurological disorders and brain function by giving us a better understanding of how neurons communicate in real time.

Weijian Yang, the head of the University of California, Davis research team, said, "Our new microscope is ideally suited for studying the dynamics of neural networks in real-time, which is crucial for understanding fundamental brain functions such as learning, memory, and decision-making." "For instance, it could be used by researchers to watch neural activity during learning to gain a better understanding of how different neurons communicate and interact with one another during this process."

The researchers disclose the novel two-photon fluorescence microscope in Optica, the high-impact academic magazine published by Optica Publishing Group. It uses line illumination instead of point illumination and features a unique adaptive sampling system. They demonstrate how the novel technique reduces the laser power on the brain by more than ten times and allows for in vivo imaging of neuronal activity in a mouse cortex, all at ten times the speed of conventional two-photon microscopy.



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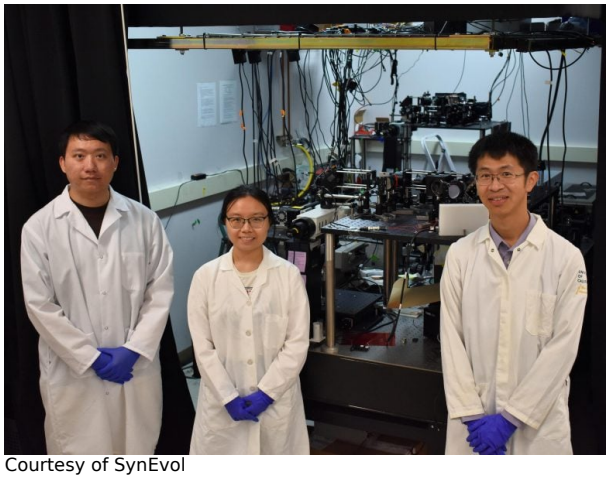
Yunyang Li, the paper's first author, stated, "Our technology could be used to study the pathology of diseases at their earliest stages by providing a tool that can observe neuronal activity in real-time." "This could aid in the better understanding and treatment of neurological disorders like epilepsy, Parkinson's disease, and Alzheimer's disease by researchers."

By sweeping a small point of light across the entire sample region to stimulate fluorescence and then collecting the resulting signal point by point, two-photon microscopy can examine deeply into scattering tissue, such as a mouse brain. After that, each image frame is captured by repeating this process. Two-photon microscopy can cause harm to brain tissue and is slow, despite providing precise images.

Using a novel sampling technique, the researchers hope to get beyond these constraints in the latest study. Instead of employing a point of light, they highlight particular regions of the brain where neurons are firing with a brief line of light. This greatly accelerates the imaging process by allowing a greater region to be stimulated and photographed simultaneously. Additionally, the overall amount of light energy imparted to the brain tissue is decreased, minimizing the possibility of potential injury, because it only pictures neurons of interest, not the background or inactive areas. This plan was dubbed adaptive sampling.



Courtesy of SynEvol

Credit: Molly M. Bechtel, University of California, Davis

In order to precisely target activated neurons, the researchers used a digital micromirror device (DMD), a chip with thousands of individually controllable small mirrors, to dynamically shape and steer the light beam. By adjusting the on and off states of individual DMD pixels to the neuronal structure of the brain tissue being imaged, they were able to achieve adaptive sampling.

Additionally, the researchers devised a method for simulating high-resolution point scanning using the DMD. This facilitates the reconstruction of a high-resolution image from rapid scans, offering a rapid method for locating neuronal regions of interest. This is essential for the high-speed imaging that follows, which uses an adaptive sampling system and short-line excitation.

The ability to examine dynamic neurological processes in real-time, with less risk to living tissue, is greatly advanced by this strong imaging tool that is the result of several discoveries, each of which is noteworthy on its own, according to Yang. Crucially, our method can be used in conjunction with other methods such as remote focusing and beam multiplexing to accomplish volumetric 3D imaging or to speed up imaging even further.

In order to showcase the novel microscope, the researchers imaged calcium signals in real mouse brain tissue, which are markers of neuronal activity. The system's 198 Hz signal capture rate is noticeably faster than that of conventional two-photon microscopes, indicating its capacity to track quick neuronal events that slower imaging techniques would overlook.

Additionally, they demonstrated how individual neuron activity may be isolated using sophisticated computer techniques in conjunction with the adaptive line-excitation methodology. This is crucial for comprehending the functional architecture of the brain and correctly interpreting intricate neuronal interactions.

Subsequently, the scientists are striving to incorporate voltage imaging functionalities into the microscope to obtain an immediate and highly accurate readout of neuronal activity. In addition, they intend to apply the novel approach to practical neuroscience applications, like monitoring neural activity during learning and investigating brain activity in illness conditions. In order to increase the microscope's usefulness for neurological research, they also want to make it more user-friendly and smaller.
