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World's fastest camera relies on new type of imaging, takes 6 million frames per second

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Ultrafast, light-sensitive video cameras are needed for observing high-speed events such as shockwaves, communication between living cells, neural activity, laser surgery and elements of blood analysis. To catch such elusive moments, a camera must be able to capture millions or billions of images continuously with a very high frame rate. Conventional cameras are simply not up to the task.

Now, researchers at the UCLA Henry Samueli School of Engineering and Applied Science have developed a novel, continuously running camera that captures images roughly a thousand times faster than any existing conventional camera.

In a paper in the April 30 issue of *Nature*, UCLA Engineering researchers Keisuke Goda, Kevin Tsia and team leader Bahram Jalali describe an entirely new approach to imaging that does not require a traditional CCD (charge-coupled device) or CMOS (complementary metal-oxide semiconductor) video camera. Building on more than a decade of research on photonic time stretch, a technique for capturing elusive events, the team has demonstrated a camera that captures images at some 6 million frames per second.

"The most demanding application for high-speed imaging involves fast events that are very rare, rogue events or the proverbial needle in the haystack — in other words, unusual events that carry important information," said Jalali, a professor of electrical engineering and principal investigator of the project.

One of the applications he envisions for the camera is flow cytometry, a technique used for blood analysis. Traditional blood analyzers can count cells and extract information about their size, but they cannot take pictures of every cell because no camera is fast and sensitive enough for the job. At the same time, images of cells are needed to distinguish diseased cells from healthy ones. Today, pictures are taken manually under a microscope from a very small sample of blood.

But what if you needed to detect the presence of very rare cells that, although few in number, signify the early stages of a disease? Circulating tumor cells are a perfect example. Typically, there are only a handful of them among a billion healthy cells; yet these cells are precursors to metastasis, the spread of cancer that causes about 90 percent of cancer mortalities.

"The chance that one of these cells will happen to be on the small sample of blood viewed under a microscope is negligible," Jalali said. "To find these rogue cells — needles in the haystack — you need to analyze billions of cells, the entire haystack. Ultra-high-speed imaging of cells in flow is a potential solution for detection of rare abnormal cells."

The new imager operates by capturing each picture with an ultrashort laser pulse — a flash of light only a billionth of a second long. It then converts each pulse to a serial data stream that resembles the data in a fiber optic network rather than the signal coming out of a camera. Using a technique known as amplified dispersive Fourier transform, these laser pulses, each containing an entire picture, are amplified and simultaneously stretched in time to the point that they are slow enough to be captured with an electronic digitizer.

The fundamental problem in performing high-speed imaging, Jalali says, is that the camera becomes less and less sensitive at higher and higher speeds. It is simple to see why: At high frame rates, there is less time to collect photons in each frame before the signal becomes weaker and more prone to noise. The new imager overcomes this because it is the first to feature optical image amplification.

"Our serial time-encoded amplified microscopy (STEAM) technology enables continuous real-time imaging at a frame rate of more than 6 MHz, a shutter speed of less than 450 ps and an optical image gain of more than 300 — the world's fastest continuously running camera, useful for studying rapid phenomena in physics, chemistry and biology," said research co-author Goda, a postdoctoral researcher in the group.

One such phenomenon the group has studied with the new camera is laser ablation, an important technology that is the basis of laser medicine. The camera can capture laser ablation happening in real time, providing important clues for understanding the process and optimizing its effectiveness.

"Unlike other high-speed imaging methods, our approach does not require cooling of the camera or high-intensity illumination — problems that plague conventional CCD and CMOS cameras," said Kevin Tsia, a graduate student in the group and a co-author of the research.

Source: University of California - Los Angeles

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