Debut for world's fastest camera

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The fastest imaging system ever devised has been demonstrated by researchers reporting in the journal Nature.

Their camera's "shutter speed" is just a half a billionth of a second, and it can capture over six million images in a second continuously.

Its "flashbulb" is a fast laser pulse dispersed in space and then stretched in time and detected electronically.

The approach will be instrumental in imaging fast-moving or random events, such as communication between neurons.

What is more, the camera works with just one detector, rather than the millions in a typical digital camera.

Gathering steam

Dubbed Serial Time-Encoded Amplified imaging, or Steam, the technique depends on carefully manipulating so-called "supercontinuum" laser pulses.

These pulses, less than a millionth of a millionth of a second long, contain an enormously broad range of colours.

Two optical elements spread the pinprick laser pulses into an ordered two-dimensional array of colours.

It is this "2-D rainbow" that illuminates a sample. Part of the rainbow is reflected by the sample - depending on light and dark areas of the illuminated spot - and the reflections travel back along their initial path.

Because the spreading of the pulse's various colours is so regular and ordered, the range of colours reflected contains detailed spatial information about the sample.

"Bright spots reflect their assigned wavelength but dark ones don't," explained Bahram Jalali, the University of California, Los Angeles.
professor who led the research.

"When the 2-D rainbow reflects from the object, the image is copied onto the colour spectrum of the pulse."

The pulse then passes back through the dispersive optics and again becomes a pinprick of light, with the image tucked away within as a series of distributed colours.

However, that colour spectrum is mixed up in an exceptionally short pulse of light that would be impossible to unpick in traditional electronics.

The team then routes the pulse into a so-called dispersive fibre - a fibre-optic cable that has a different speed limit for different colours of light.

As a result, the red part of the spectrum races ahead of the blue part as the pulse travels along the fibre.

Eventually, the red part and blue part separate in the fibre, arriving at very different times at the fibre's end.

All that remains is to detect the light as it pops out of the fibre with a standard photodiode and digitise it, assigning the parts of the pulse that arrive at different times to different points in two-dimensional space.

The result of all this optical trickery: an image that represents a snapshot just 440 trillionths of a second long.

The researchers used a laser that fired more than six million pulses in a second, resulting in as many images. However, they say that the system can be improved to acquire more than 10 million images per second - more than 200,000 times faster than a standard video camera.

'Rogue cells'

Another imaging system known as a streak camera can capture images with an even shorter shutter speed, but they can only capture a fixed number of images and must be triggered to do so for a given event.

The Stream camera, by contrast, can capture images continuously, making it ideal for random events that cannot be triggered.

Some applications that may benefit from the approach include observing the communication between cells, or the activity of neurons.

But the perfect example of an application for the Stream camera's specifications is analysing flowing blood samples in an approach known as flow cytometry.

The imaging of individual cells in a fast-flowing volume of blood is impossible for current cameras, a small random sample is taken and those few cells are imaged manually with a microscope.

"But, what if you needed to detect the presence of very rare cells that, although few in number, signify early stages of a disease?,” asks Keisuke Goda, lead author of the study.

Dr Goda cites circulating tumour cells as a perfect example of such a target. Precursors to metastasis, they may exist as only a few among a billion healthy cells.

"The chance that one of these cells will happen to be on the small
sample of blood viewed under a microscope is virtually negligible."

But with the Steam camera, fast-flowing cells can be individually imaged.

The team is working to extend the technique to 3-D imaging with the same time resolution, and to increase the effective number of "pixels" in a given image to 100,000.

"Our next step is to improve the spatial resolution so we can take crystal clear pictures of the inner structure of cells," Professor Jalali told BBC News.

"We are not there yet, but if we are able to accomplish this, then there is no shortage of applications in biology."