# Popular Science

Events in the world can occur at rates incomprehensible to humans. From explosions to photosynthesis, the chemical and physical processes occurring happen too fast to observe with the naked eye. Cameras can be tinkered with to increase the frame rate to 25,600 frames per second [1], fast enough to see how popcorn kernels pop. But what if we want to go faster? Traditional methods achieve this frame rate by advancing the technology inside of a camera. To obtain even higher frame rates, new methods consider how the images are captured and stored. Some of these methods rely on the event being reproducible and capturing the frames by probing the sample multiple times[2] to obtain each frame. However, its nearly impossible to create an explosion in reproducible conditions. Thus, a new technique FRAME offers another approach, capturing all the frames in one single image [3].

Technically, a long exposure on a camera is capturing all of the image frames at once. The problem therefore isn't with capturing the light, but organising the frames. The technique FRAME, which stands for Frequency Recognition Algorithm for Multiple Exposures, utilises a tagging technique to label and recognise the frames (that's the Recognition part of the acronym). Imagine a camera capturing a rapidly spinning fan illuminated by a laser beam. By tagging the laser beam at different times, the images corresponding to the tag can be identified in the final image. It is similar to handing out different T-shirts to people in a queue, it doesn't matter if the people in the queue get rearranged, the T-shirts (tags) identify who was first in the queue, second, third and so on. The queue is then organised and the T-shirts (tags) removed in post-processing. This is how the Recognition algorithm identifies the order of the frames. If the T-shirts are handed out in a distinct time interval, the exact timing of the person or the frame can be identified.

To get more technical these T-shirts (tags) are analogous to a particular spatial frequency in relation to an image. These tags don't change anything about the image, but work as a label to help identify each frame. To fully appreciate how it works we must first understand spatial frequencies. Images, in a simple sense, are made up of thousands of lines combined to make anything you like. The closer the lines are to each other the higher the spatial frequency in that region. Think of spatial frequency like the amount of stuff in an area. The different tags are then just a particular spatial frequencies added to the image. To continue with our analogy, imagine the T-shirts being striped and the number of stripes on the T-shirt correspond to the frequency of the T-shirt.

In the current use of FRAME, these tags are identified after the camera has taken all the images. However, there is another way to access these tags. Identifying the tags by using the tags behaviour means you could separate the images without the need of the Frequency Recognition algorithm. Similar to a striped T-shirt detector inside of the queue. The people in the queue can then be organised by their stripes without the need for any post processing. This could potentially increase the flexibility and speed at which FRAME is performed. This striped T-shirt detector technique is thoroughly examined in this thesis.

# References

[1] Moynihan T. A Slo-Mo Camera With an Insanely High Frame Rate (And Price Tag); 2014. Available from: `https://www.wired.com/2014/07/phantom-v2511-camera/`.

[2] Alexeev I, Heberle J, Cvecek K, Nagulin K, Schmidt M. High Speed Pump-Probe Apparatus for Observation of Transitional Effects in Ultrafast Laser Micromachining Processes. Micromachines. 2015 12;6:1914–1922.

[3] Ehn A, Bood J, Li Z, Berrocal E, Aldén M, Kristensson E. FRAME: femtosecond videography for atomic and molecular dynamics. Light: Science Applications. 2017;6(9).