Programmable array microscopy and its application to neurobiology

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A conventional microscope forms an image of a whole plane instantaneously, with limited depth-resolution. By contrast the laser scanning microscope images a single point at a time, resulting in confocal images with optical sectioning. The recently developed programmable array microscope (PAM) is functionally a hybrid of the two; it can simulate a widefield microscope, a confocal laser scanning microscope, or any intermediate device.

We have developed a novel PAM in collaboration with Cairn Research Limited. It uses a liquid on silicon (LCoS) array placed in the primary image plane to spatially filter the emission and excitation light. The LCoS is fully programmable and can be dynamically controlled at high resolution (1280x1024 pixels) with high refresh rate (1.44 kHz); the illumination and detection light beams can thus be patterned in a controlled manner with total versatility. Furthermore, our PAM allows simultaneous detection of both the conjugate and non-conjugate images.

We implemented the PAM in a configuration suited for biological experiments. We characterised its performance under different operating conditions and analysed how they can be optimised. We rigorously investigated various imaging strategies, with emphasis on fast confocal microscopy (60 fps) and depth-resolved imaging. We also investigated the possibility to realise selective illumination experiments. Finally, we realised *in vivo* combined Ca^{2+} imaging and electrophysiological experiments with the PAM, using the flight motoneurones of the locust (*Schistocerca gregaria*), a well-established model of motor pattern generation and sensory processing.