AN OPTICAL SYSTEM FOR RECORDING NEURAL POTENTIALS AT OVER 1KHZ

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1. THE NEED FOR HIGH-SPEED VOLTAGE IMAGING

Neural activity occurs with bandwidths of up to ~1kHz, and while electrophysiological methods can record at this speed, they cannot record from large numbers of individually-targetable neurons simultaneously. Genetically-Encoded Voltage Indicators (GEVIs) offer a path towards this goal [1], but modern microscopes lack the speed to truly image dozens of neurons located over a large field of view at speeds in excess of 1kHz [2].

2. PATTERNED RECORDING AND ILLUMINATION OF NEURONS WITH THROUGHPUT-EFFICIENT READOUT (PRINTER)

To solve this problem, we present a system that streamlines the imaging process, recording only one datapoint per neuron, rather than one datapoint for each of the millions of pixels covering the field of view. This is done by using a laser and Digital Multimirror Device (DMD) to pattern each neuron in turn, either holographically (see Figure 1) or with ordinary patterned illumination, and record the fluorescence from the whole neuron onto a single high-speed silicon photomultiplier (SiPM). Using holographic illumination allows the focal plane to be changed dynamically but requires averaging to overcome the speckled nature of a single hologram; direct projection is faster, but can only pattern a single plane.

The 23kHz frame rate of the DMD allows data to potentially be recorded from 23 neurons with a bandwidth of 1kHz; methods for scaling the system to record from thousands of neurons simultaneously using SiPM arrays will be discussed.

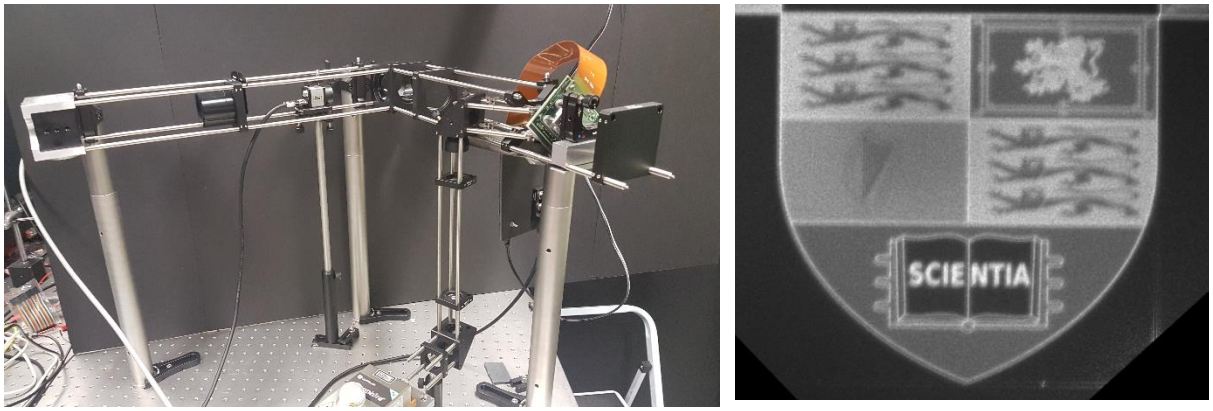

Figure 1 (left): Pattern projection system before it was integrated into the microscope. (Right): Imperial College London crest, created by projecting 100 holograms on the DMD in rapid sequence, and reconstructing the speckle-averaged image using a lens.

3. REFERENCES

1. T Knöpfel and C Song, Nature Reviews Neuroscience 20:719–727 **2019**
2. Kazemipour *et al.*, Nature Methods 16:778–786 **2019**