

High-speed, Large-FOV Ca^{2+} Imaging Reveals Functional Cortical Network Architecture

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Abstract

Functional brain-wide Ca^{2+} imaging at single-cell resolution could transform neuroscience but is constrained by trade-offs among field of view (FOV), speed, spatial resolution, and signal-to-noise ratio (SNR). We overcome these limits by combining a standard resonant-galvo scanner with novel large optical components—a previously untested approach that enables fast, wide, contiguous-FOV imaging with single-cell resolution, high SNR, and minimal aberration. This system monitored activity from ~16,000 cortical neurons across a $3 \times 3 \text{ mm}^2$ FOV at 15 Hz during behavior, exceeding prior reports in both sampling rate and neuron count. Using these data, we constructed single-cell functional networks and found weak scale-free, yet significant small-world, topology, which can promote economical communication via fast, efficient propagation of activity. We then examined how networks are integrated versus segregated across brain states using modularity and their cortical spatial distribution. Modularity during non-rapid eye movement (NREM) sleep was higher than during wakefulness, indicating a more segregated network; however, modules were spatially intermixed across regions in both states. These results provide new insights into cellular-scale organization of functional networks across altered states of consciousness.

Short biography

Masanori Murayama received his Ph.D. from Tokyo University of Pharmacy and Life Science. In 2006, he joined Dr. Larkum's lab at the University of Bern, studying in vivo dendritic physiology of layer-5 pyramidal neurons in rats (Murayama et al., JNP 2007; Nature 2009; PNAS 2009). In 2010, he became a principal investigator at the RIKEN Center for Brain Science, investigating cortico-cortical interactions in sensory perception. Using multidisciplinary approaches in mice, his team showed that cortical top-down input is essential for accurate perception (Manita et al., Neuron 2015), that top-down signals during NREM sleep support perceptual memory consolidation (Miyamoto et al., Science 2016), and that memory is further strengthened when the amygdala engages the top-down circuit (Saito et al., Neuron 2025). They recently developed a fast-scanning, wide-FOV two-photon microscope to probe large-scale network architectures (Ota et al., Neuron 2021).

