Computationally enhanced microscopy

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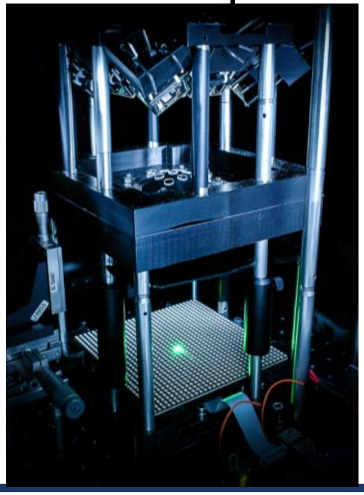
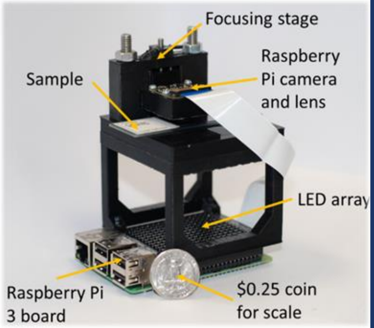
Abstract

Microscopes can zoom either capture high-resolution, narrow field-of-view images or vice versa due to fundamental physical limitations. To capture both (high-resolution wide-field images) one can use high-resolution optics and scan the sample, but this is time consuming and requires expensive components. Instead we are using computational imaging techniques to create low-cost microscopes with performance unrivalled by the commercial alternatives.

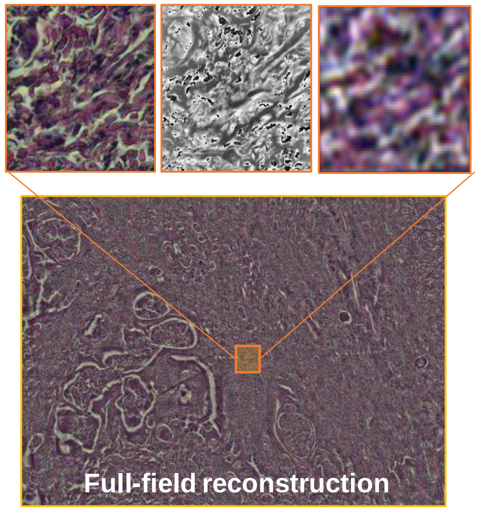
Multi-camera computational microscope



£100 computational microscope



Reconstruction (amplitude and phase) **Raw image**



Project Description

We are using a computational imaging technique called Fourier ptychography to increase the resolution by combining multiple images captured from multiple angles in time sequence. Such image stack is then transformed to the Fourier domain and all images are combined to increase the synthetic aperture of the microscope. However, time-sequential illumination is time consuming and we are developing multiple camera devices to parallelized the process and increase the speed for moving sample imaging. We are also developing low-cost devices and novel reconstruction algorithms to improve the robustness and commercialization potential of the technique.

Project outcomes

- Reconstructed 100-megapixel images with sub-micron resolution.
- Recover optical aberrations and complex phase of the diffracted wavefront.
- Demonstrated technique validity on a 3D printed £100 microscope [1]
- Applied the technique to quantum correlated imaging [2]
- Currently validating applicability for high-speed imaging and implementing novel reconstruction optimization strategies.

[1] Aidukas, T., Eckert, R., Harvey, A.R. *et al.* Low-cost, sub-micron resolution, wide-field computational microscopy using opensource hardware. *Sci Rep* **9,** 7457 (2019). https://doi.org/10.1038/s41598-019-43845-9
[2] Aidukas, T., Konda, P.C., Harvey, A.R. *et al.* Phase and amplitude imaging with quantum correlations through Fourier Ptychography. *Sci Rep* **9**, 10445 (2019). https://doi.org/10.1038/s41598-019-46273-x