Deep Learning Assisted Microsphere Nanoscopy

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ABSTRACT

Introduction

Microsphere nanoscopy is an innovative, label-free super-resolution imaging technique that transforms conventional optical microscopes into nanoscopes, achieving resolutions of 45–100 nm[1]. Despite its transformative potential for fields like biology, material science, and engineering, the technique faces challenges of low imaging contrast, slow speed, and sample-dependent quality. Deep learning (DL) has emerged as a powerful tool for image analysis and enhancement, demonstrating success in addressing similar issues in microscopy. By leveraging DL, this project aims to develop one of the fastest, most reliable, and widely applicable label-free super-resolution imaging systems. Key advances in microsphere nanoscopy include the Bangor-built unibody integrated objective nanoscope and the use of scanning superlenses. However, limitations in current methods underscore the need for DL to optimize image quality and speed.

Methods

Using convolutional neural network (CNN) deep learning algorithms [2], we successfully trained a neural network capable of upscaling imaging objects in the 100–300 nm range of microsphere nanoscopy obtained images, as shown in Fig.1. The model also effectively removes vignetting effects associated with images and enhances image quality and contrast. These advancements significantly improve the performance of microsphere nanoscopy, making the technique more reliable for various applications. However, challenges persist when imaging smaller objects in the 50–60 nm range. Current neural networks face difficulties in achieving similar levels of enhancement for these scales. This issue may be addressed through the integration of attention mechanisms, which could provide improved feature extraction and scaling for finer structures in future iterations of the model.

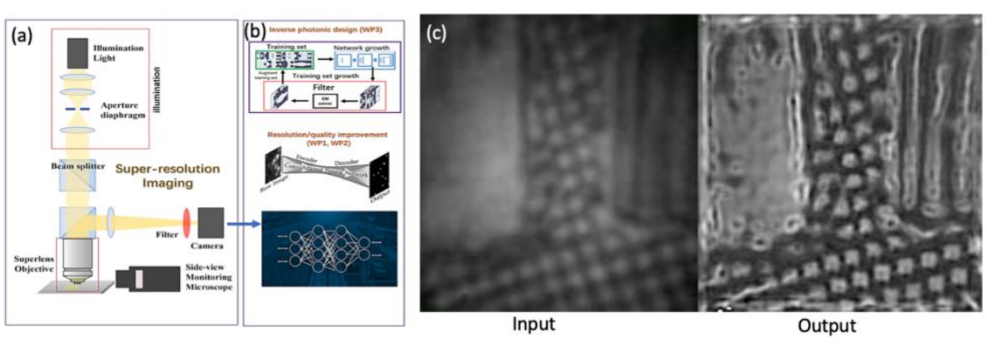

Fig. 1 (a) nanoscopy setup (b) Deep learning model (c) Example input and output of the model for 100-300 nm nano-objects

References

[1] Wang, Z. B., et al. *Nat. Commun.*, 2011, 2:218.
[2] Dong, C., et al. "Learning a deep convolutional network for image super-resolution." *ECCV*, 2014.