MULTIVIEW SCANNING MICROSCOPY THROUGH A MULTIMODE FIBER ENDOSCOPE

Sakshi Singh[1], Simon Labouesse[1], Rafael Piestun[1]
[1]Department of Electrical, Computer, and Energy Engineering, University of Colorado Boulder, CO, 80309, USA
E-mail: sakshi.singh@colorado.edu

KEY WORDS: Confocal microscopy, multimode fibers, endoscopy, multiview scanning

Multimode fibers (MMFs) are attractive for endoscopic applications due to their thin cross-section, a large number of degrees of freedom and flexibility. However modal dispersion and intermodal coupling prohibit direct image transmission through MMFs. Notwithstanding, imaging through MMFs is possible by measuring its transmission matrix (TM) [1,2] and using it to generate controlled illuminations on the far end of the MMF such as focal spots. The focal spots can be used to scan the object while the back-reflected signal enables the reconstruction of the object.

Confocal laser scanning microscopy (CLSM) is a useful technique for improving optical resolution and image contrast when imaging inside scattering tissue volumes. Remarkably, CLSM can be performed through an MMF when its TM is known [3] using a virtual pinhole to reject the out-of-focus light. However, the method compromises the signal-to-noise ratio (SNR) and allows limited control over the pinhole size.

We present a digital multiview scanning method to improve resolution and image contrast while retaining a high SNR in MMF imaging. The method is based on extracting multiview perspectives of the scanned object, re-shifting them appropriately and combining them together to achieve a high-SNR reconstruction using multiple sub-airy unit pinholes. This approach is reminiscent of multiview image scanning techniques [4-6].

In this presentation, we describe the experimental imaging system, which is comprised of a spatial light modulator to generate focal spots at the MMF's distal (far) end, a distal camera for TM calibration, a proximal (near) camera to measure the reflected speckle fields and other ancillary optics. We discuss the reconstruction method, compare our method with single-view digital confocal microscopy, and experimentally demonstrate MMF imaging with improved SNR and optical sectioning.

REFERENCES

[1] S. Popoff, G. Lerosey, R. Carminati, M. Fink, A. Boccara, and S. Gigan. "Measuring the transmission matrix in optics: an approach to the study and control of light propagation in disordered media". *Physical review letters*, *104*(10), 100601 (2010).

[2] A.M. Caravaca-Aguirre and R. Piestun. "Single multimode fiber endoscope". *Optics express*, 25(3), 1656-1665 (2017).

[3] D. Loterie, S. Farahi, I. Papadopoulos, A. Goy, D. Psaltis, & C. Moser. "Digital confocal microscopy through a multimode fiber". *Optics express*, 23.18, 23845-23858 (2015).

[4] C.R. Sheppard. "Super-resolution in confocal imaging". *Optik (Stuttgart),* 80(2), 53-54 (1988).

[5] C. B. Müller and J. Enderlein. "Image scanning microscopy." *Physical review letters* 104.19, 198101 (2010).

[6] C. Roider, R. Heintzmann, R. Piestun, and A. Jesacher, "Deconvolution approach for 3D scanning microscopy with helical phase engineering," *Optics Express,* 24, 15456-15467 (2016).