

Adaptive multiphoton endomicroscopy through a dynamically deformed multicore optical fiber using proximal detection

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The development of ultra-compact optical endomicroscopes that propagate spatially coherent radiation through a multicore or multimode optical fibre to achieve laser scanning microscopy with no distal optical elements is a rapidly growing field. These approaches essentially measure and manipulate the phase variations across the cores or modes of the optical fibre, typically using a spatial light modulator^{1,2}. However, most of these approaches rely on the optical fibre being near stationary during imaging in order that the relative optical path lengths of each fibre core or mode do not change as the strain across the fibre changes.

We demonstrate multiphoton excited fluorescence imaging through a polarisation maintaining multicore fibre (PM-MCF) using all-proximal detection, including while the optical fibre is physically manipulated. Single-shot proximal measurement of the relative optical path lengths of all the cores of the PM-MCF in double pass is achieved using a Mach-Zehnder interferometer read out by a scientific CMOS camera operating at 416 Hz. A non-linear least squares fitting procedure is then employed to determine the fibre motion-induced lateral shift of the excitation spot at the distal tip of the PM-MCF. An experimental validation of this approach is presented that compares the proximally measured motion-induced lateral shift in focal spot position to an independent, distally measured, ground truth. The proximal measurement of fibre motion-induced shift in focal spot position can be applied to correct for such shifts during raster-scanned multiphoton excited fluorescence imaging through a moving PM-MCF, see figure 1. The result is an MCF endomicroscopy approach that enables multiphoton fluorescence imaging with all-proximal detection through moving optical fibres³.

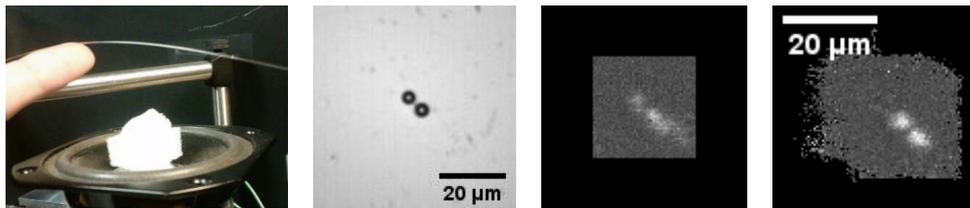


Fig. 1. Image correction while the multicore optical fiber is perturbed by hand. From left to right: photo of the multicore fibre being deformed; transmitted light image of fluorescent beads; endoscope image without correction and corrected fluorescence endomicroscope image. Adapted from³.

¹ Paul French, Chris Dunsby, Mark Neil, Carl Paterson, “Scannerless microconfocal endoscope”, patent US 8,585,587 B2 (priority 10/07/2008)

² A. J. Thompson, et al, “Adaptive phase compensation for ultracompact laser scanning endomicroscopy,” *Opt. Lett.* 36, 1707 (2011)

³ S. C. Warren, et al, “Adaptive multiphoton endomicroscopy through a dynamically deformed multicore optical fiber using proximal detection,” *Opt. Express*, 24 (19), pp. 21474-21484 (2016)