

LENSELESS VIBRATIONAL MICROSCOPY WITH A MULTIMODE FIBRE

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Raman spectroscopy is a powerful method of recording the vibrational spectra of constituent molecules within a sample in a label-free manner. Its applications span materials science, biomedical analysis and clinical studies. The need to access deep tissues and organs *in vivo* has triggered major advances in fibre Raman probes that are compatible with endoscopic applications [1]. However, imaging still remains out of reach for the current state of art fibre Raman systems without compromising the compactness and flexibility. At the same time over the last years, wavefront correction methods through complex media have enabled a number of microscopy modalities to be applied through a multimode fibre [2]. However, to the best of our knowledge, Raman endoscopy through a single multimode fibre has not been demonstrated.

Here we present the first demonstration of Raman imaging through a single multimode fibre (MMF), which is the smallest footprint Raman imaging fibre probe to date. We use a spatial light modulator to acquire the transmission matrix of the fibre [2]. We then apply the obtained correction to digitally scan a diffraction-limited spot beyond the proximal end of a step-index multimode fibre (50 μm core diameter), collecting the Raman signal through the very same fibre. Focusing light at a distance from the facet, we achieve a field of view of 200 μm diameter which is 4 times wider than the core. We record Raman images of polystyrene beads, as well as four-channel Raman images of a pharmaceutical mixture. To further demonstrate the capability of our method, we image clusters of *M. smegmatis* bacteria, and finally, operate the fibre as an optical trap, immobilising a polystyrene bead and simultaneously acquiring its vibrational spectra. This ultra-thin probe offers numerous new directions for vibrational spectroscopy due to a combination of its small footprint, imaging modality and ability to record wide field of view data.

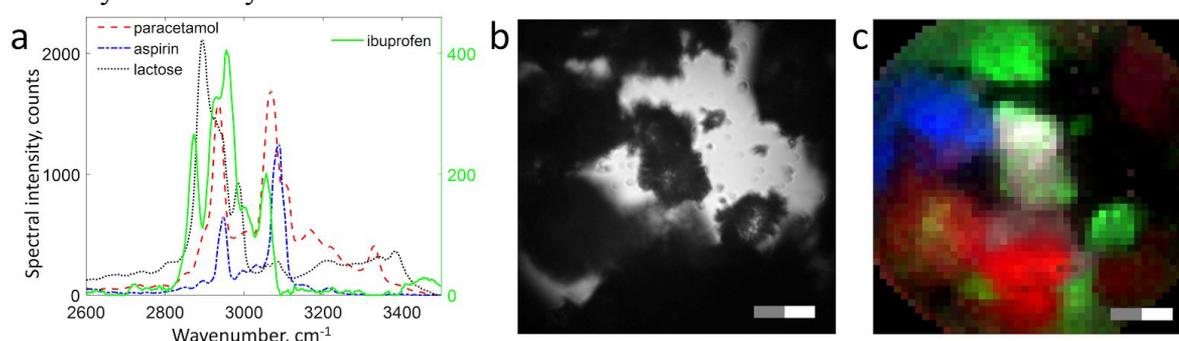


Figure 1. Raman imaging of pharmaceutical compounds within a mixture: a) Raman spectra; b) bright field image of drug clusters; c) Raman image of 4 compounds with a \varnothing 200 μm FOV. Scale bars are 40 μm , with the white part being 20 μm .

[1] Stevens O, Iping Petterson IE, Day JCC, Stone N. Developing fibre optic Raman probes for applications in clinical spectroscopy. *Chem Soc Rev.* 2016;45:1919–34.

[2] Čižmár T, Dholakia K. Exploiting multimode waveguides for pure fibre-based imaging. *Nat Commun.* 2012;3(May):1027.