Light-sheet microscopy beam path miniaturisation using optical MEMS

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Light-sheet microscopy (LSM) as 3D fluorescence imaging tool has shown impressive growth over the last decade, specifically with open-source and application tailored systems in mind. By structuring the fluorescence excitation light to only illuminate a thin sheet of the sample in the active focal plane of an orthogonal imaging path, low light doses and fast 3D imaging can be achieved. In this work, we present digital control of the light-sheet creation, positioning and imaging using Microelectromechanical Systems (MEMS) micromirrors and the use of their inherent miniaturisation potential.

The micromirrors used for active control were fabricated using a commercial silicon-on-insulator process with device layer thicknesses of 10µm or 25µm and apertures between 0.7mm and 1.7mm. Multiple actuation mechanisms were employed for control of different excitation and imaging beam parameters. Electrostatic actuation allowed for >25kHz scan speeds to create the light-sheet, electrothermal control of a 2D tilt mirror allowed for its positioning in 3D space, and bimorph electrothermal control of a mirror surface curvature allowed for positioning of the focal plane of the imaging path. The MEMS were controlled using an Arduino microcontroller and a custom amplifier circuit to create the drive signals. The optical design of the LSM beam paths use off-the-shelf singlet and doublet lenses to allow flexibility and low-cost, with an overall foot-print of 130x60mm for the excitation path and 160x50mm for the imaging path, including fibre-coupled delivery of the fluorescence excitation lasers.

Our latest results showcasing the 3D positioning accuracy, light-sheet characteristics and imaging performance will be presented. This includes both the miniaturisation of larger field-of-view and higher resolution systems, allowing their tailoring for varying imaging applications. A further focus will be on the integration and characterisation of full 3D imaging, using the synchronisation of all MEMS devices and the inclusion of flexible auto-focus and -positioning potentials.