A cost-effective, modular, research-grade optical microscope

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Optical microscopy is a ubiquitous tool in the physical and life sciences and in histopathology, where visible light microscopy is used to analyse clinical tissue sections at the micron scale to help diagnose diseases. In recent years, microscope technologies have dramatically evolved, but these have generally come with increased cost and complexity. To widen access to advanced microscopy capabilities, we have developed a cost-effective modular platform for optical microscopy (www.openscopes.com). Many of these instruments can be based around a new low-cost and flexible microscope stand, 'openFrame', for which the core components are open source. openFrame can support implementations of a wide range of microscope modalities for diverse applications, including research, pathology and training. Unlike many commercial microscopes that are often designed for specific applications and cannot be easily upgraded or adapted for different imaging modalities, openFrame-based instruments can be relatively easily maintained, upgraded or adapted to another modality without requiring manufacturer support. To this end, openFrame-based instruments are envisaged to operate with open-source software, enabling researchers to assemble and modify their microscopes with minimal challenges presented by proprietary (closed) hardware or software. Here, we describe the implementation of a low-cost, research-grade modular optical microscope applicable to research and pathology.

Keywords: Clinical diagnosis, imaging modalities, modular optical microscope, open-source software, research and pathology.

nology[7,8], and also in the examination of histopathology tissue sections for clinical diagnosis[9–11]. In recent decades, advances in technology have dramatically expanded the capabilities of optical microscopy, driven in part by the progress in computational techniques, as well as in light sources and detectors. There is wide interest in implementing advanced microscopy techniques, as well as in exploiting standard instruments for biology and medicine. Most workhorse optical microscopes provide a trans-illumination mode for brightfield imaging. Many offer wide-field epi-fluorescence imaging using LED, lamp or laser sources for fluorescence excitation, and scientific cameras (with sufficient sensitivity for single photon detection) are used for detection. A commercial research-grade microscope integrating these modalities typically costs over 5,000,000 Indian rupees (INR), which can limit access for scientists in many situations. The capabilities of such a microscope can, however, be realized at a significantly reduced cost by assembling a modular instrument from off-the-shelf optical, mechanical and electronic components, and using open-source software. For example, high-power solid-state lasers can be replaced with industrial-grade diode lasers, and scientific cameras such as EMCCD or sCMOS cameras can be replaced with CMOS machine vision cameras – and the newly available, lower cost-cooled CMOS cameras (www.cellcam.co.uk/cameras/). Objective lenses with high numerical apertures (e.g. 100× oil immersion, 1.30 NA (Numerical Aperture)) lenses are available at a reasonable cost (<60,000 INR), and personal computers specified for gaming applications are sufficient for most microscopy image processing. However, the main microscope stand can still be expensive, and proprietary hardware