Frugal Science

- innovations from an innovator

Prof Manu Prakash

Inventor and Innovations

Profile by Mr CR Chandrasekar

There are over seven billion human beings in the world. However, the number of other living mobile organisms far exceeds and can be measured in trillions. Some of these organisms are visible to the naked eye but most remain invisible due to their size, including parasites and bacteria which are constant source of human strife. Conventional microscopes with their power of magnification enable 'invisible' organisms and parasites to be seen and microscopy is hence a crucial medical technique. However, the cost of a microscope can be prohibitive.

Another problem is posed by centrifuges, which are important in laboratory medicine to separate biological fluids but can also be costly for most rural/field settings. The current Covid19 pandemic has highlighted the need for rapid diagnostics.

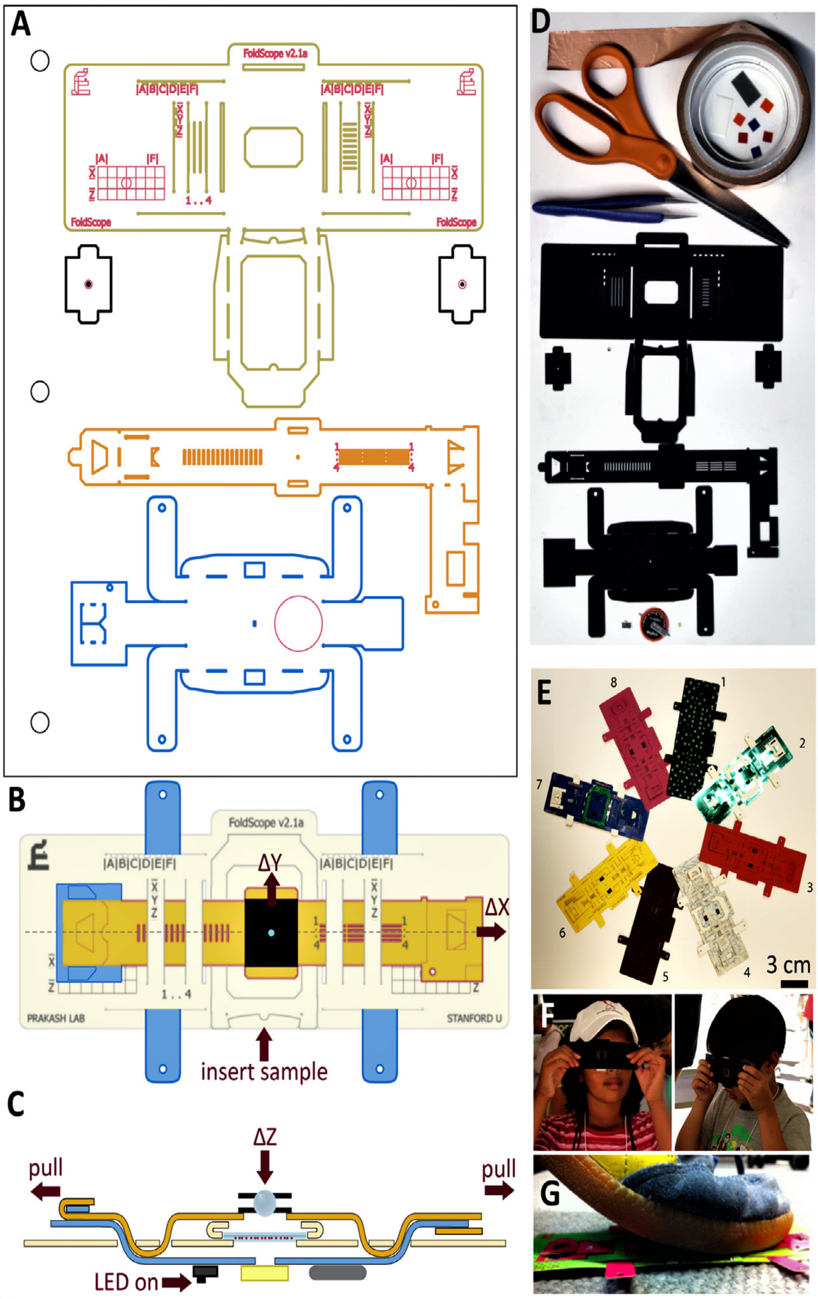
Five of Manu Prakash' inventions taken from available open-source references are listed below (1-4)

1. Foldscope (1)– a field microscope useful in fight against malaria -One million in use

'An ultra-low-cost origami-based approach for large-scale manufacturing of microscopes, specifically demonstrating brightfield, darkfield, and fluorescence microscopes. Merging principles of optical design with origami enables high-volume fabrication of microscopes from 2D media. Flexure mechanisms created via folding enable a flat compact design. Structural loops in folded paper provide kinematic constraints as a means for passive self-alignment. This light, rugged instrument can survive harsh field conditions while providing a diversity of imaging capabilities, thus serving wide-ranging applications for cost-effective, portable microscopes in science and education.'

Figure -Foldscope design, components, and usage. (1)
(A) CAD layout of Foldscope paper components on an A4 sheet. (B) Schematic of an assembled Foldscope illustrating panning, and (C) cross-sectional view illustrating flexure-based focusing. (D) Foldscope components and tools used in the assembly, including Foldscope paper components, ball lens, button-cell battery, surface-mounted LED, switch, copper tape and polymeric filters. (E) Different modalities

Manu Prakash is a 39-year-old Indian born scientist and he is a Professor of Bioengineering at Stanford University, USA. He is a well-known innovator and has produced inventive ways of addressing the above problems –low-cost field microscope, low-cost centrifuge, open-source high throughput imaging platform etc.



assembled from coloured paper stock. (F) Novice users demonstrating the technique for using the Foldscope. (G) Demonstration of the field-rugged design, such as stomping under foot.

2. Paperfuge -Hand-powered ultralow-cost paper centrifuge [2]

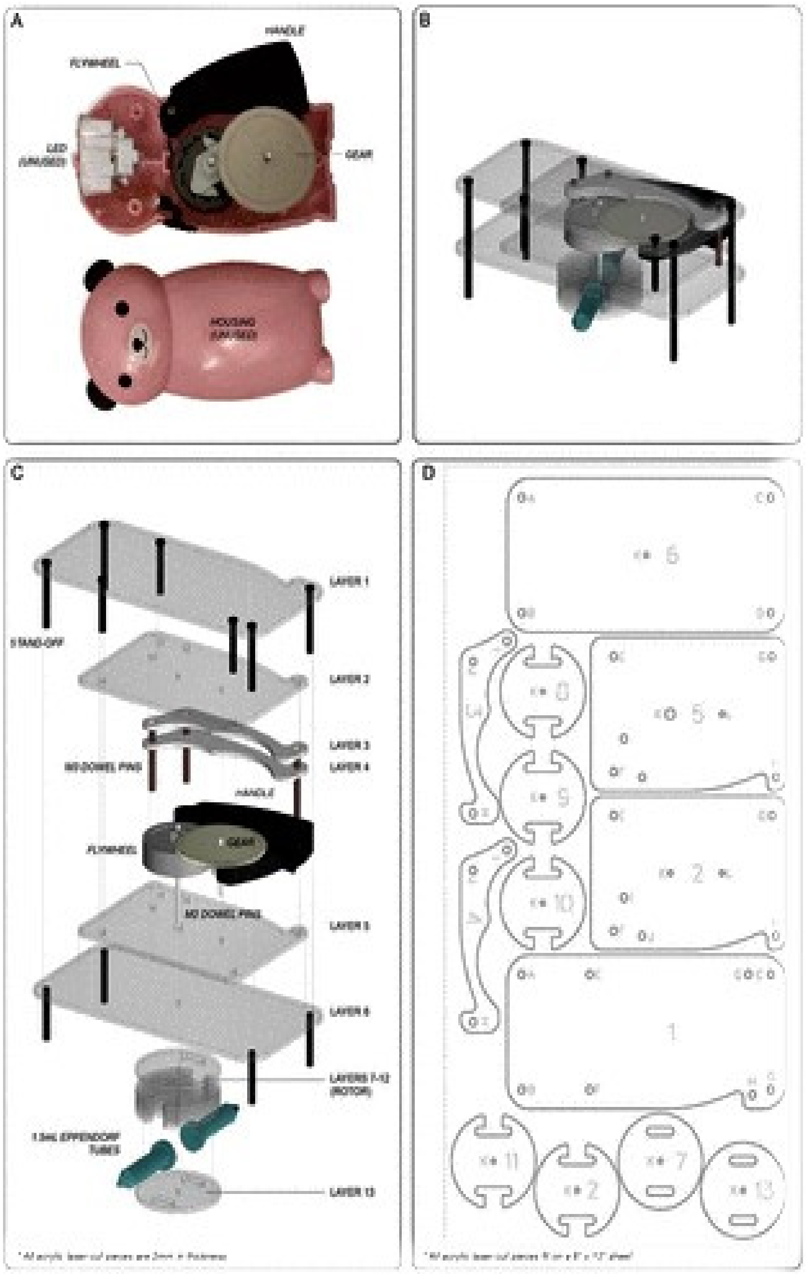
'a lightweight, ultralow-cost centrifuge based on an ancient toy. The "paperfuge" can separate blood components in less than 2 minutes. The hand-powered device highlights how creative design can be used to make diagnostic tools for use in global settings with limited resources'[2]

The team designed a whirligig, which they call a "paperfuge," made with a paper disk and braided fishing line for the string. They analyzed the mechanics of the device, which consists of successive winding and unwinding phases. Based on their modelling, they optimized the components, including the disk radius and width, and the string radius and length. Using a high-speed camera, they showed that the paperfuge could reach speeds of 125,000 revolutions per minute (rpm) using only human power.

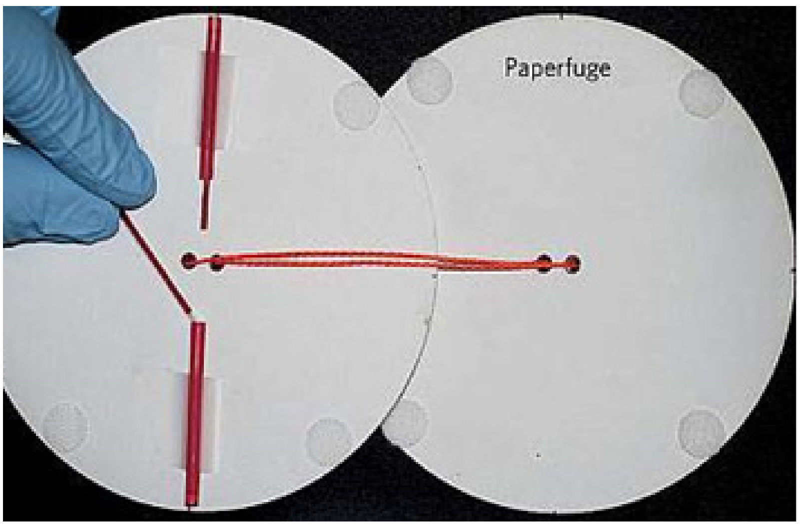
The researchers used drinking straws to hold tubes containing blood samples and found that the paperfuge could separate pure plasma from whole blood in less than 1.5 minutes of spinning. This separation provides a reading of hematocrit, which is used to diagnose anemia. With 15 minutes of spinning, they could separate out a layer known as the buffy coat. This layer is used for diagnosing conditions where a parasite is in the blood—such as malaria and African trypanosomiasis (sleeping sickness). The device weighed 2 grams and could be made for 20 cents.

3. Handyfuge-LAMP: low-cost and electricity-free centrifugation for isothermal SARS -CoV-2 detection in saliva [3]

'An open hardware solution- Handyfuge - that can be assembled with readily available components for the cost of <5 dollars a unit and could be used together with the LAMP assay for point of care detection of COVID-19 RNA from saliva'[3]



'Components of Handyfuge. (A) Dismantled hand-crank flashlight similar to a Dyno-torch flash light providing a one-way ratchet mechanism for converting hand-crank input into uni-directional rotation of the associated gears. (B) Three-dimensional Schematic of a Handyfuge. (C) Assembly and blow-out of of Handyfuge components including borrowed fly-wheel from flash-light and associated acrylic cut pieces. (D) Two-dimensional laser-cut pattern for fabricating a handyfuge.' [3]



4. Octopi-Open configurable high-throughput imaging platform for infectious disease diagnosis in the field [4]

'a low-cost ($250-$500) automated imaging platform that can quantify malaria parasitemia by scanning 1.5 million red blood cells per minute'.

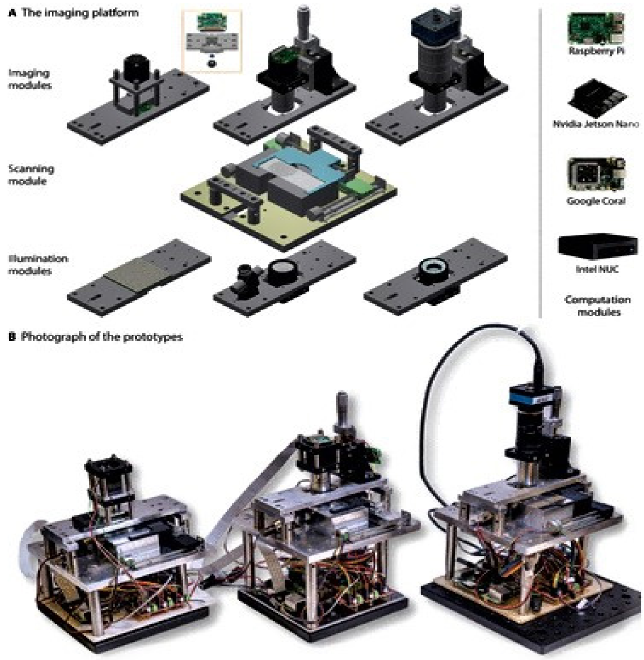


Figure -Reconfigurable high-throughput imaging platform.

'(A) Construction of the modular imaging platform. The left column shows three different imaging modules (top row), a motorized scanning module, and three different illumination modules (bottom row). In the low mag imaging module (top left), a captive linear actuator is used for focus actuation. In the high mag imaging module (top middle and top right), piezoelectric stacks combined with micrometers are used for focus actuation, where the micrometer can be replaced with a captive linear actuator to motorize coarse adjustment. Inset shows the construction of the low-mag imaging module sub-assembly, which consists of a pi-camera, a long pass interference filter and another cellphone lens. For different applications, sub-assemblies with different configurations should be switched as a whole, in contrast to the high mag imaging module, where objectives, filters, tube lens and cameras can be individually switched. The right column shows some examples of currently available portable computing devices that can be used as the computation module. (B) A photograph showing three Octopi prototypes with different imaging modules optimized for different applications.' [(4)]

5. SQUID -Simplifying Quantitative Imaging Platform Development and Deployment [(5)]

'With rapid developments in microscopy methods, highly versatile, robust and affordable implementations are needed to enable rapid and wide adoption by the biological sciences community. Here we report Squid, a quantitative imaging platform with a full suite of hardware and software components and configurations for deploying facility-grade widefield microscopes with advanced features like flat field fluorescence excitation, patterned illumination and tracking microscopy, at a fraction of the cost of commercial solutions. The open and modular nature (both in hardware and in software) lowers the barrier for deployment, and importantly, simplifies development, making the system highly configurable and experiments that can run on the system easily programmable. Developed with the goal of helping translate the rapid advances in the field of microscopy and microscopy-enabled methods, including those powered by deep learning, we envision Squid will simplify roll-out of microscopy-based applications - including at point of care and in low resource settings, make adoption of new or otherwise advanced techniques easier, and significantly increase the available microscope-hours to labs.'[(5)]

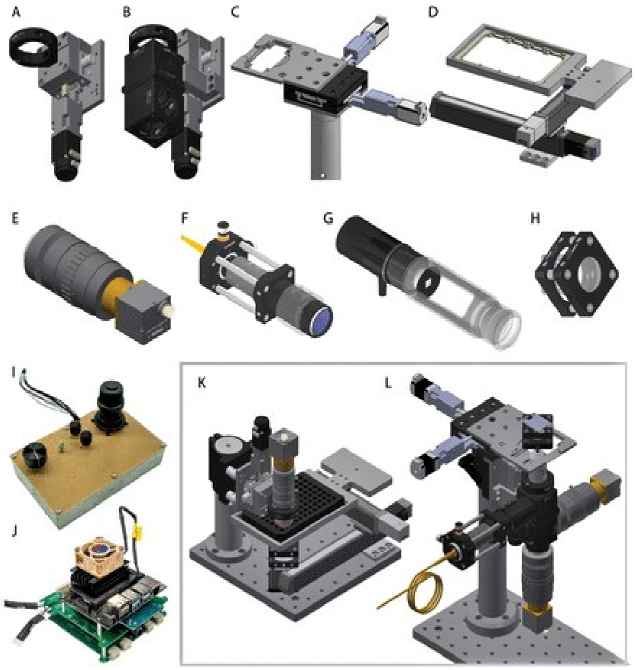


Figure -Squid hardware. (A) Motorized focus block (B) Motorized focus block with two cage cubes mounted (C) 28 mm × 28 mm motorized XY stage (D) 140 mm × 80 mm travel motorized XY stage with a well plate adapter (E) A typical image formation assembly with an industrial camera and a machine vision imaging lens (F) Flat field laser epi-illumination module (G) Flat field LED epi-illumination module (H) LED matrix trans-illuminator (I) Control panel with an analog joystick, a focusing knob, a toggle switch and two rotary potentiometers. Currently the toggle switch is used for enable tracking (when implementing tracking microscopy) and one of the potentiometers is used to adjust the XY stage max speed. (J) Driver stack (shown also a Jetson Nano for running the microscopes in place of a laptop or desktop computer) (K) One example configuration: upright microscope for reading a 96-well plate (termed Nautilus from here on-wards](L) Second example configuration: multi-color flat field epifluorescence microscope with simultaneous transmitted light channel (e.g. for tracking microscopy). [(5)]

More information about the innovator Manu Prakash is available from his latest Medscape interview [(6)] and Wikipedia [(7)].
His scientific publications can be accessed through his Orcid id https://orcid.org/0000-0002-8046-8388

References

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7. Manu Prakash https://en.wikipedia.org/wiki/Manu_Prakash

Improve patient safety by eliminating adverse events in health care settings

It is estimated that every year more than 300,000 patients acquire a healthcare associated infection (HCAI, HAI or nosocominal infection)as a result of care with in the NHS.