Microfluidic Turntable for molecular diagnostic testing

Team contact:
Faith K. Mangwanya, Cambridge Graphene Centre, Department of Engineering (fkm26@cam.ac.uk)
Contribution: Centrifugal microfluidics and instrumentation

Team
Tiong Sun Chia, Protein and Nucleic Acids (PNAC) Division, MRC-Laboratory of Molecular Biology (tiong@mrc-lmb.cam.ac.uk)
Contribution: Biology and Biochemistry

Daniel Popa, Department of Engineering, (dp387@cam.ac.uk)
Contribution: Optoelectronics and electronics

Summary

Lab-on-chip platform facilitates the miniaturisation, and integration of chemical assays facilitating the development of point-of-care devices for resource-limited settings. Centrifugal microfluidics enables seamless implementation and parallelisation of biochemical assays. The objective of the project is to develop a low-cost modular microfluidic turntable to enable the rapid prototyping of molecular diagnostic lab-on-chip discs with minimal engineering expertise. To demonstrate the efficacy of our system, we will develop a lab-on-chip disc for the detection of a pathogen.

Project Proposal

The problem:

Public health is a measure of sustainable development as it contributes to economic growth through productivity and lower expenditure on disease control. In low-income countries, access to healthcare facilities is limited due to a lack of adequate infrastructure and trained personnel. Furthermore, in remote areas, the distance that people have to travel, sometimes by foot, can deter people from seeking medical attention. While rapid tests kits for highly infectious diseases such as HIV or malaria are readily available for early screening, quantitative diagnosis for effective treatment planning still requires centralised laboratory testing. And, when quantitative point-care-devices are in existence they are expensive, bulky and consume a lot of energy. This has driven a research effort to find novel approaches, not only capable of providing quantitative diagnosis, but also simple to use, and inexpensive, which would make diagnostics more accessible.

The biology:

The common pathogen detection assays, implemented in molecular diagnostics, are: immunoassay, polymerase chain reaction (PCR) and hybridization, and each has its advantages and disadvantages. Immunoassay detects the presence of pathogenic antigen and is relatively sensitive. However, it may require multiple expansive antibodies for detection. PCR is a highly sensitive assay based on amplification of the pathogenic genome but it requires additional thermal cycling and cell lysis components within the chip and expensive polymerase enzyme. Assay by hybridization may be relatively simpler in terms of the design and cost but the sensitivity might be low for un-amplified samples. Therefore, the initial prototypes will consider each of these methods and carefully weigh the trade-off among sensitivity, design complexity and cost.

The hardware:

Microfluidics is an enabling lab-on-chip technology that has facilitated the development of highly specialised cartridges for a particular molecular diagnostic assay, and can have a sensitivity that rivals that of bench-top testing. However, while manufacturing the cartridges can be lower than £1, current microfluidic devices require expensive and bulky pumping and valve systems. Centrifugal microfluidics drastically simplifies the system by making use of the centrifugal and Coriolis forces of a rotating disc to pump the fluids, allowing for sample handling, preparation and analyte detection to be integrated on e.g. a turntable.

Our design goals for the microfluidics turntable are: sampling, extraction, filtration, dilution, mixing and centrifugation. The instrument should be able to actuate fluids with reliable flow rates and good fluid control. Furthermore it should be low-cost, and easy to operate.

The Plan:

The objective is to develop an Arduino controlled turntable with a stroboscope for disk visualisation on screen and optical detection for absorbance and fluorescence measurements, as shown in Fig.1. The disc will be fabricated using a laser cutter and paper plotter. The disc will then be rotated on an Arduino controlled motor. Controlling the rotation of the disc will actuate the fluids, i.e., changing the rotation direction and revolutions per second will control fluid actuation, pumping, mixing and centrifugation.

The disc will be fitted with an optical excitation and detection setup. Depending on the detection assay, mentioned above, a suitable light source in conjunction with a photodetector will be used, see Fig.1. The Arduino or an embedded microcontroller will be used for data acquisition, which will be displayed on the touch screen panel provided in the Arduino kit. The absorbance and fluorescence data, will give us information on the presence of the target analyte.

We aim to develop a fully automated instrument that requires no engineering knowledge or expertise to use. We will then demonstrate the efficacy of our system by developing a microfluidic cartridge for the detection of *E. coli*.

The Benefit:

A low-cost open-source centrifugal microfluidic turntable for rapid prototyping of discs targeted for molecular diagnostic testing in resource-limited settings. This will greatly benefit the communities in rural area where access to laboratories is limited. Moreover, rapid diagnosis will facilitate accurate and timely treatment and potentially save lives.

Estimated Cost

Item	Source	Price
PMMA, 500x400x1.5mm	http://uk.rs-online.com/web/p/solid-plastic-sheets/0824480/	£20.40
LED/laser Photodetector	Dependent on assay selected	

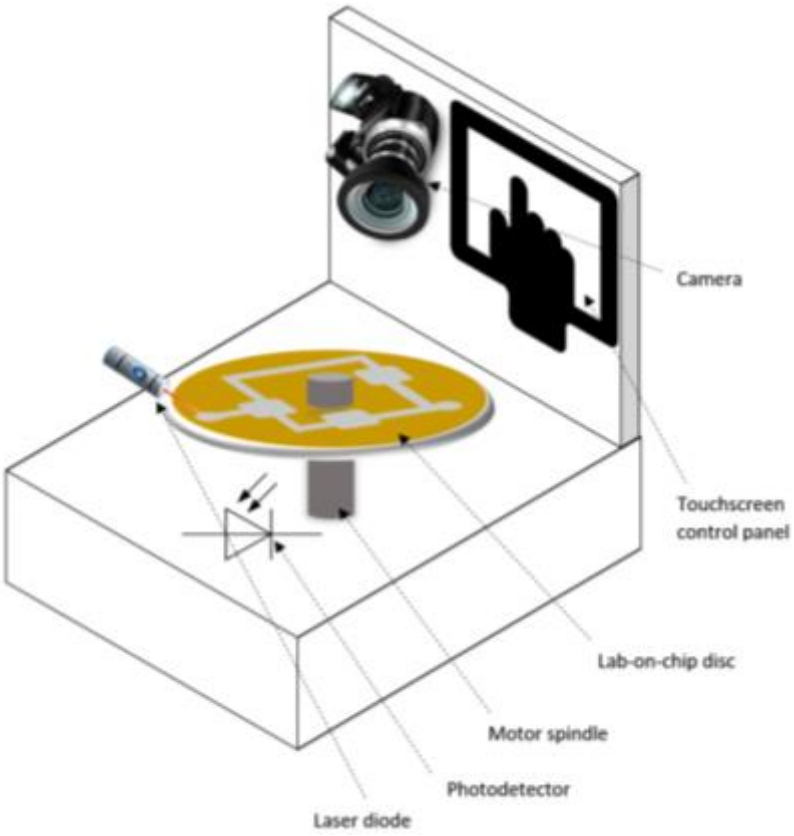

Figure 1: Proposed Microfluidic turntable for molecular diagnostic assay.