SUSTAINABLE COST HARDWARE FOR APPLICATIONS IN SCIENCE RESEARCH AND EDUCATION

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AFFORDABLE SCIENTIFIC EQUIPMENT
ICTP August 23

1. **INTRODUCTION** : we will present news and examples about frugal science and consequently scientific instruments and laboratory equipment, review some of the going on projects in this domain and finally present alternative actions proposals and how tentatively get funding for these actions. The open source paradigm and open hardware initiaves (GOSH) will be taken into account.
2. New version of the "**WATERSCOPE MICROSCOPE**" from **Cambridge** and **Bath** universities (malaria detection in blood and bacteria detection in water). The **funding of a Fab Lab in Tanzania** by both universities to manufacture this microscope is a very good initiative. The new microscope given by the inventors will be shown during our meeting.
3. **GLIA** project between Palestine and Tunisia, the leader is Tarek Loubani doctor from Gaza. 3D printing of stethoscope is very important. https://youtu.be/mX3qH2n-Sco (South South cooperation).
4. **ELECTROPEN** project : after the **Foldscope** and the **Paperfuge** now the group (Manu Prakash post doc Bhamla) turned to the use of piezo elements (taken from gas lighters) to manipulate cells through **electroporation**. https://www.bhamla.gatech.edu/electropen
5. EU **UBORA** project (Italy, Netherlands,Finland, Kenya, Uganda) in the field of instruments for biology and medecine).
6. **LABHAKATON** in Zimbabwe https://labhackathon.wordpress.com/report-and-materials-from-labhackzim-2018/ New kind of approach.ETHIOPIA Challenge, Cameroon Challenge.
7. Presentation of some instruments and laboratory equipment based on **sustainable development** approach (3D printing, Arduino, Raspsberry Pi, Linux, …).
8. **Instrumentation in the domain of sustainable development goals with frugal science**: water purification in india https://www.thebetterindia.com/110376/innovative-technology-for-waste-water-treatment-bengaluru-dr-rajah-vijay-kumar-fpstar/
9. Discussion, projects definition: how to get funding for this domain? Initiating a repository of the scientific instruments and laboratory equipment manufactured through this approach?

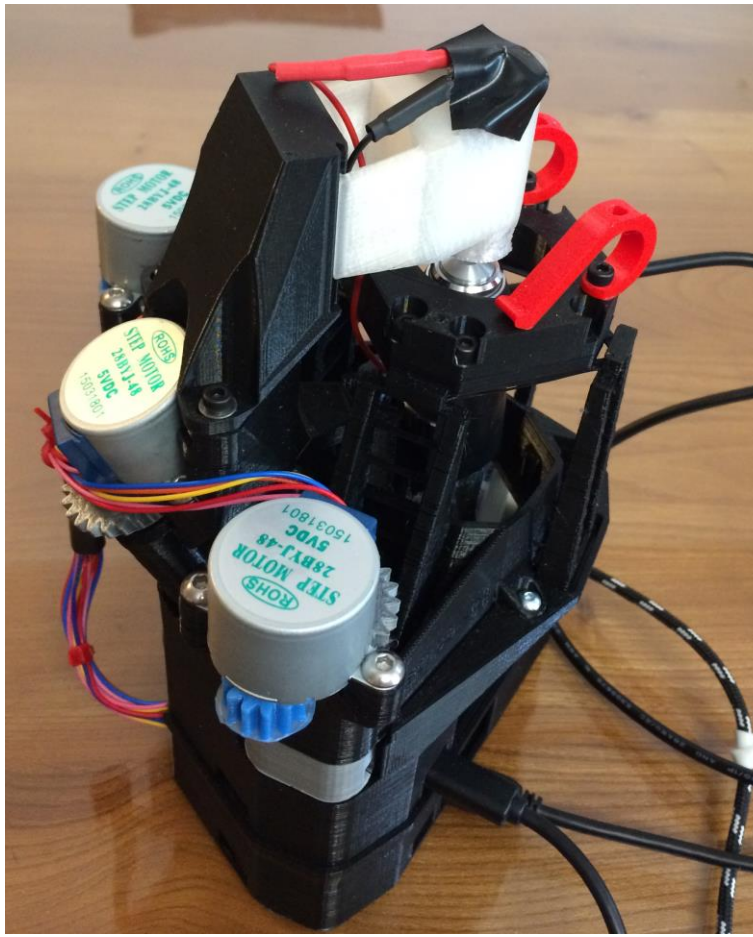
NEW VERSION OF THE WATERSCOPE MICROSCOPE

- The « Open Flexure microscope « developed at Cambridge university (department of Physics) and now bath university has now a new version with Arduino board and Raspberry Pi micro-computer included in the housing.
- Among the new features is the motorized x,y,z settings enabling an automatic focus.

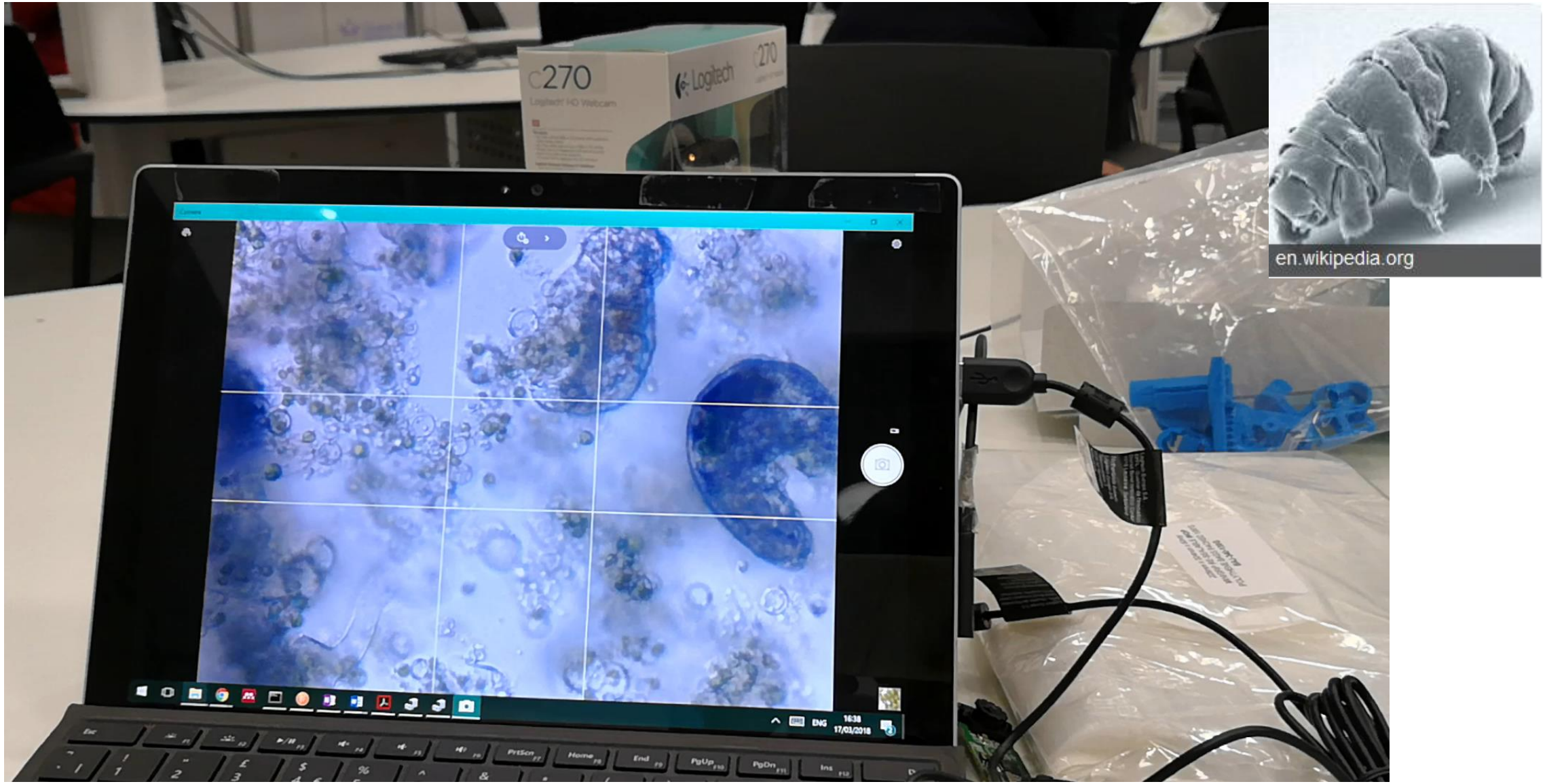
✓ Two main application have been developed: malaria detection in blood and bacteria detection in water.

✓ Very important : the **funding of a Fab Lab in Tanzania** by both universities to manufacture this microscope is a very good initiative.

Richard Bowman, Tianheng Zhao and al.

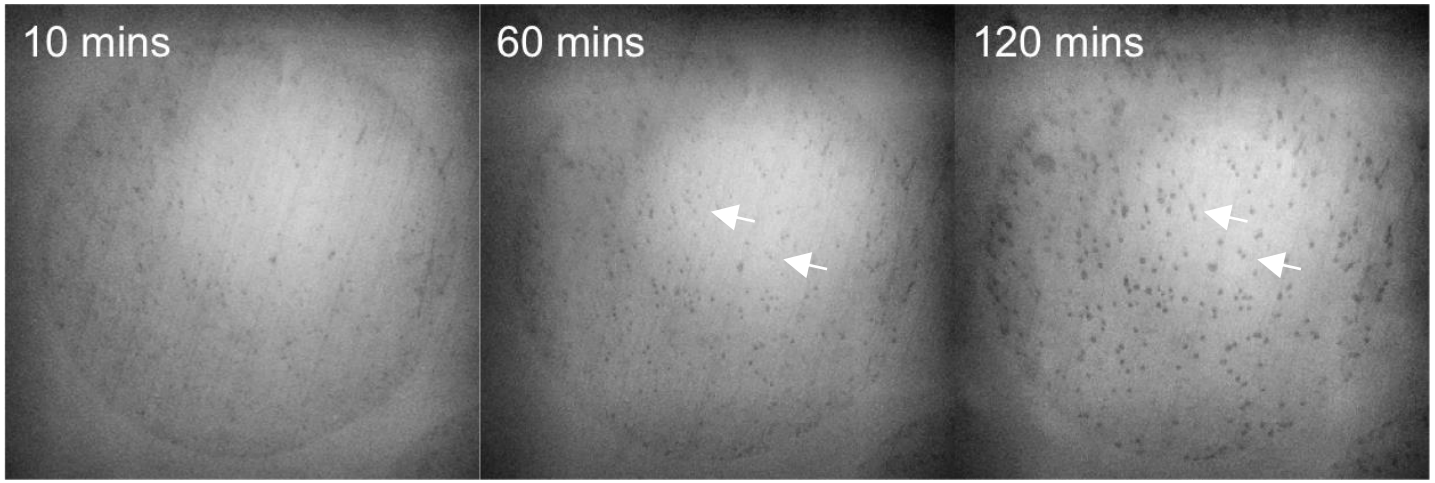


SHOWING TARDIGRADES LIFE FOR ASSESING MICROSCOPE QUALITY

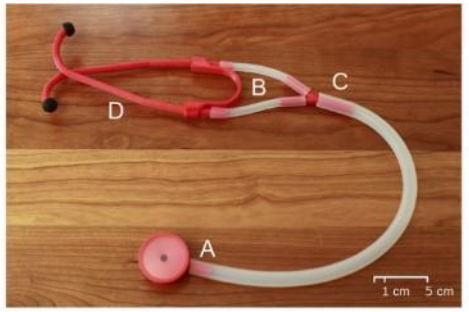


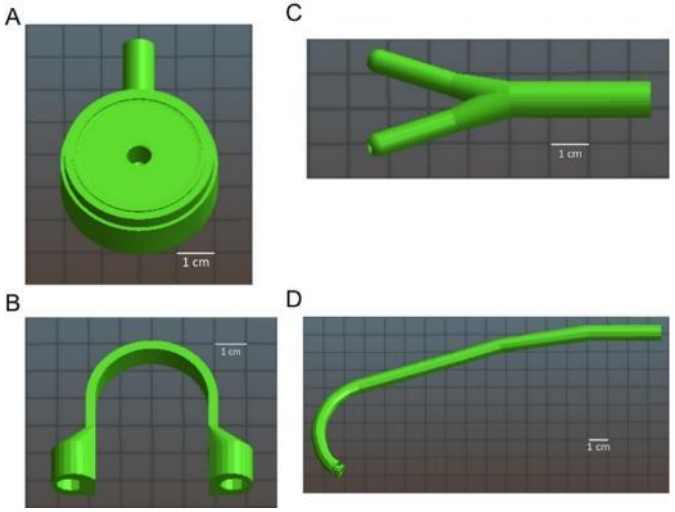
Our solutions

Disposable Cartridge



THE GLIA PROJECT by TAREK LOUBANI : an example of south south cooperation





One of the achievements will be to provide a stethoscope to each one of the medecine students of Tunisia (ap. 1000).
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0193087
https://youtu.be/mX3qH2n-Sco

UBORA: Euro-African Open Biomedical Engineering e-Platform for Innovation through Education

Consortium partners

- Ubora : World wide communauty for open source medical devices

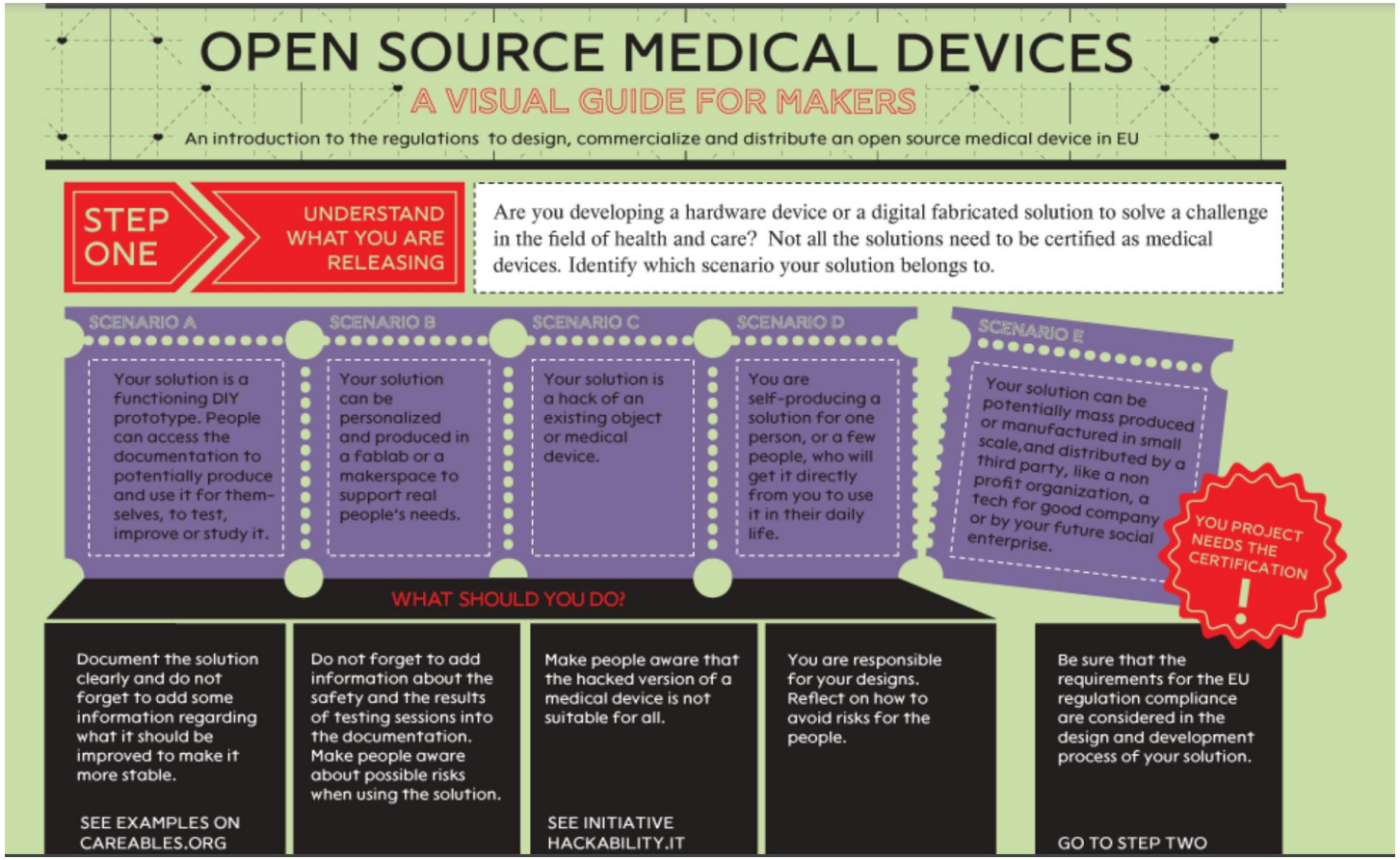
: http://ubora-biomedical.org/

UBORA ("excellence" in Swahili) brings together European and African Universities and their associated technological hubs (supporting biomedical prototyping laboratories and incubators), national and international policymakers and committed and credible stakeholders propelled by a series of Design Schools and Competitions.

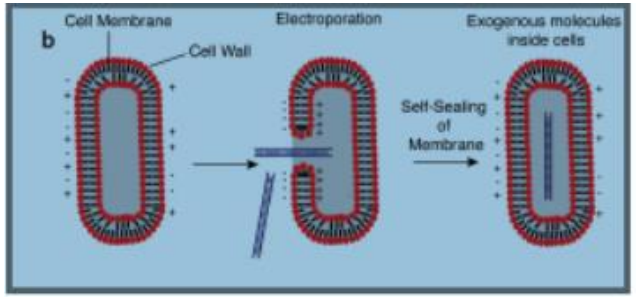
- Partners :Italy, Netherlands,Finland, Spain, Kenya, Uganda
- Technology plays a fundamental role in improving the quality of health, being the fulcrum of an effective healthcare system. The 2030 Agenda for Sustainable Development Goals, adopted by all United Nations Member States, clearly emphasizes the impact of the lack of appropriate medical devices on health conditions.
- The paper "***Co-design open-source medical devices: how to minimize the human error using UBORA e-infrastructure***" was presented by Licia Di Pietro during the session of "Point of care – Global challenges". The presentation is available at the following link: EMBC presentation.

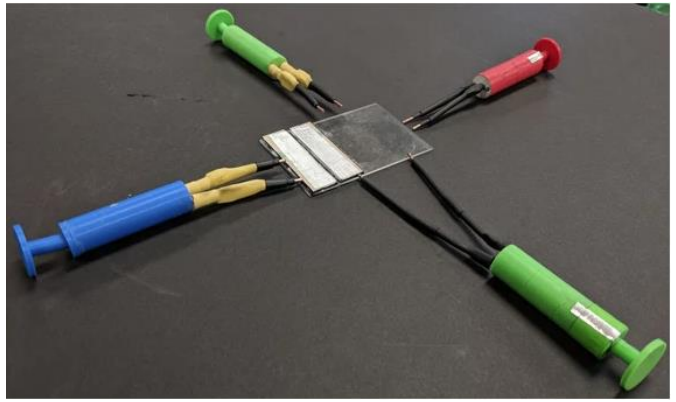
- A similar initiative from a European project for the french speaking countries should be encouraged

[“Open Source Medical Devices — a visual guide for makers” document released by Ubora http://wemake.cc/digitalsocial/osmd-a-visual-guide-for-makers/](http://wemake.cc/digitalsocial/osmd-a-visual-guide-for-makers/)



ELECTRO PORATION BY USING AN ALTERNATIVE LOW COST WAY TO PRODUCE HV IMPULSIONS





https://www.bhamla.gatech.edu/electropen

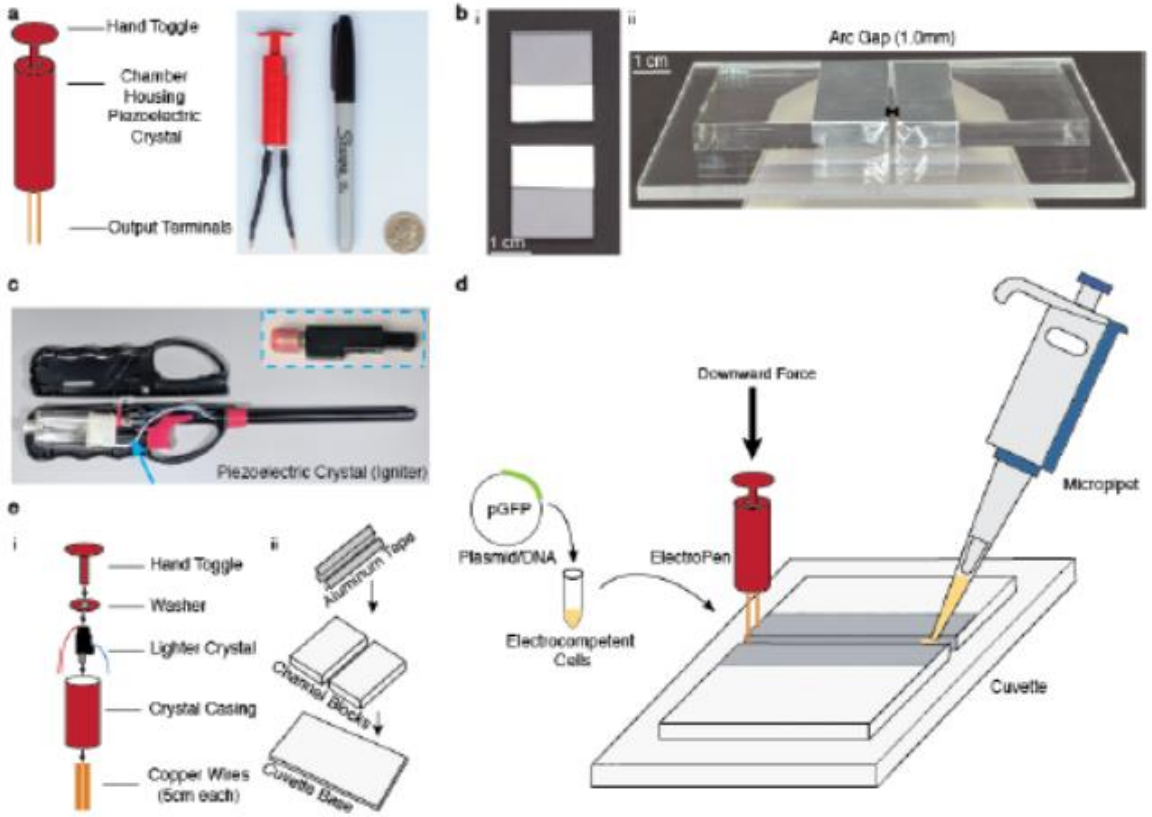


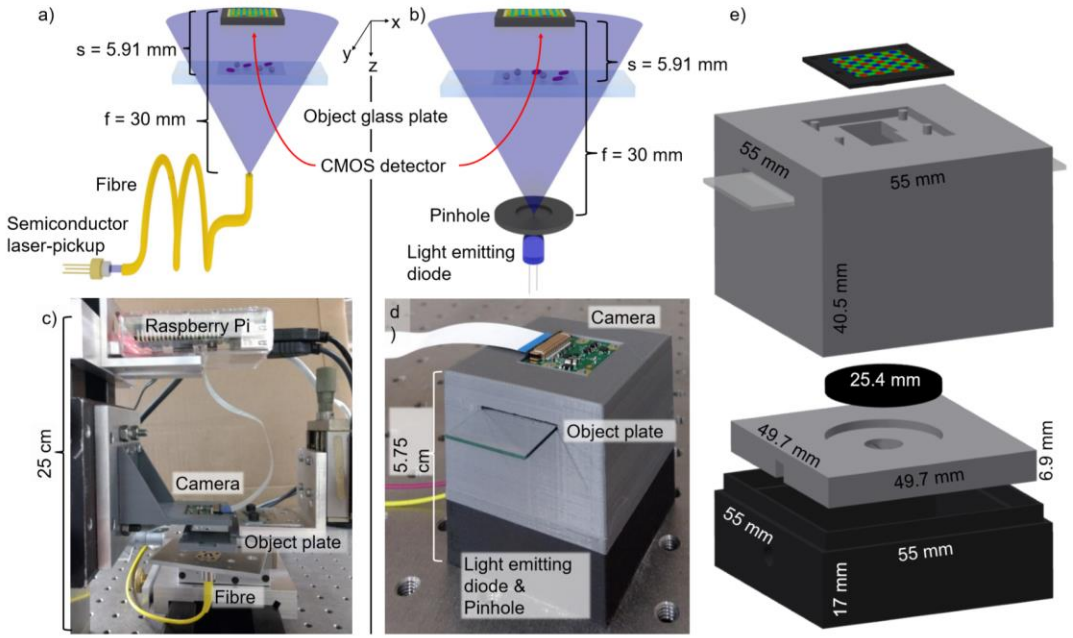
FIG. 1. **ElectroPen Platform** a Design of the 3D-printed low-cost electroporation device along with a depiction of its size scale, demonstrating portability. Device incorporates a simple operation by pressing down to trigger the piezoelectric mechanism, resulting in electrical discharge. b Design of the alternative electroporation cuvette. Cuvette design consists of two blocks (shown here in acrylic) covered with aluminum tape to act as electrodes, and placed on a base with a gap distance of 1.0 mm. The cuvette can be built out of other materials (Supplementary Fig. S9) as an alternative for industrial equivalents. c Depiction of the origin of the piezoelectric ignition mechanism found within the common stove lighter. It is located next to the butane tank, and the toggle on a lighter directly exerts a force on this mechanism to produce a spark. d Illustration of the general protocol for using the ElectroPen system. The cellular suspension is added to the gap in the cuvette, after which the ElectroPen is connected and pressed to trigger a voltage potential. The cell suspension is then recovered in Luria Bertani broth and plated. See Supplementary Movie S4 for a detailed demonstration. e Illustration of the individual components of the 3D-printed ElectroPen platform and custom cuvette.

REVIEW OF NEW INSTRUMENTS AND THEIR APPLICATIONS (MAINLY OPEN SOURCE)

- LOW-COST LENS-LESS HOLOGRAPHIC CELLULAR IMAGING
- SINGLE CELL ISOLATION USING AN OPTICAP PICK UP
- HACKING A MOUSE FOR DETECTION PURPOSES IN MICROFLUIDICS
- LOW-COST MOBILE PHONE MICROSCOPY WITH A REVERSED MOBILE PHONE CAMERA LENS

3D-PRINTABLE PORTABLE OPEN-SOURCE PLATFORM FOR LOW-COST LENS-LESS HOLOGRAPHIC CELLULAR IMAGING

- Stephan Amann, Max von Witzleben, Stefan Breuer, Physics Optics April 2019 arXiv:1904.04497 [physics.optics]
- Methods DIHM construction, light sources, opto-electronics, electrical circuits and 3D print The Blu-ray LD-pickup (SF-AW210) has been dismounted from a commercially available standard computer Blu-ray optical head and its emits a maximum optical output power of 300mW at a wavelength of 405nm for an injection current of 150mW. (hardware and software open source)



1,55µm resolution 3,91µm resolution

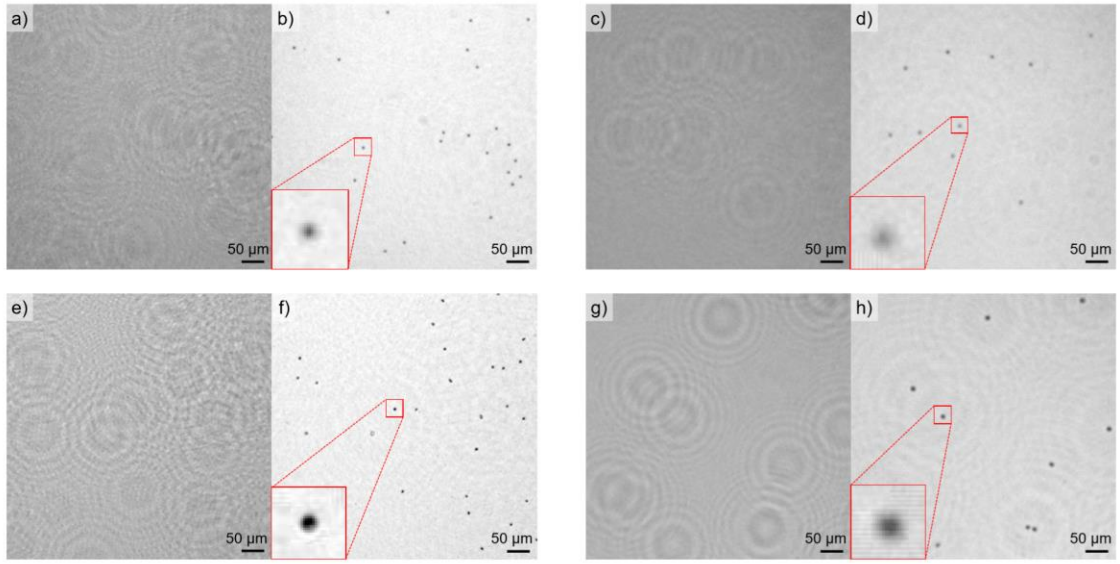
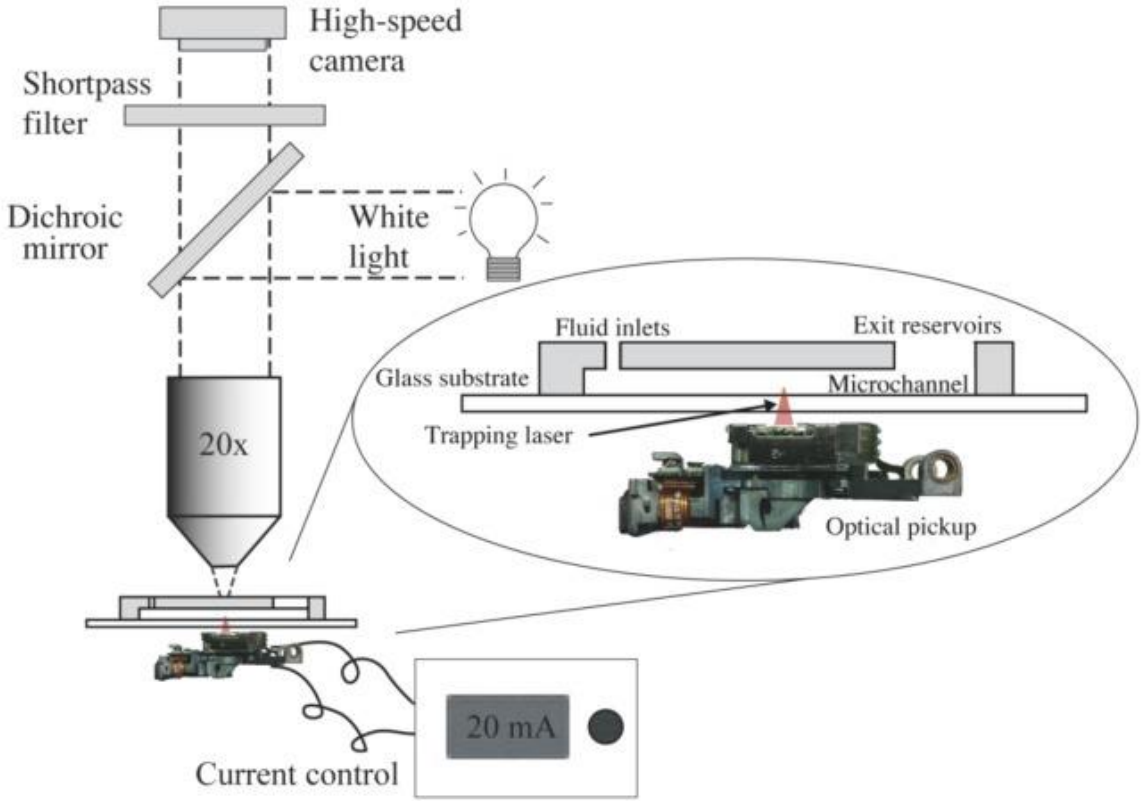


Figure 2: Holograms and according reconstructions of PMSs and human RBCs. Each inset shows a single sphere or RBC enlarged to five times its original size. a) Hologram of PMSs captured with LD setup. b) Reconstruction of (a). c) Hologram of PMSs captured with LED setup. d) Reconstruction of (c). e) Hologram of RBCs captured with laser setup. f) Reconstruction of (e). g) Hologram of RBCs captured with LED setup. h) Reconstruction of (g).

A commercial instrument is already available : IPRASENS

SINGLE-CELL ISOLATION USING A DVD OPTICAL PICKUP.

- Opt Express. 2011 May 23;19(11):10377-86. doi: 10.1364/OE.19.010377.
- Kasukurti A[1], Potcoava M, Desai SA, Eggleton C, Marr DW.
- OLD BUT CREATIVE!!



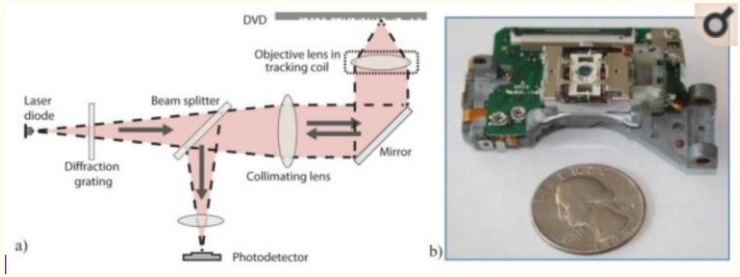
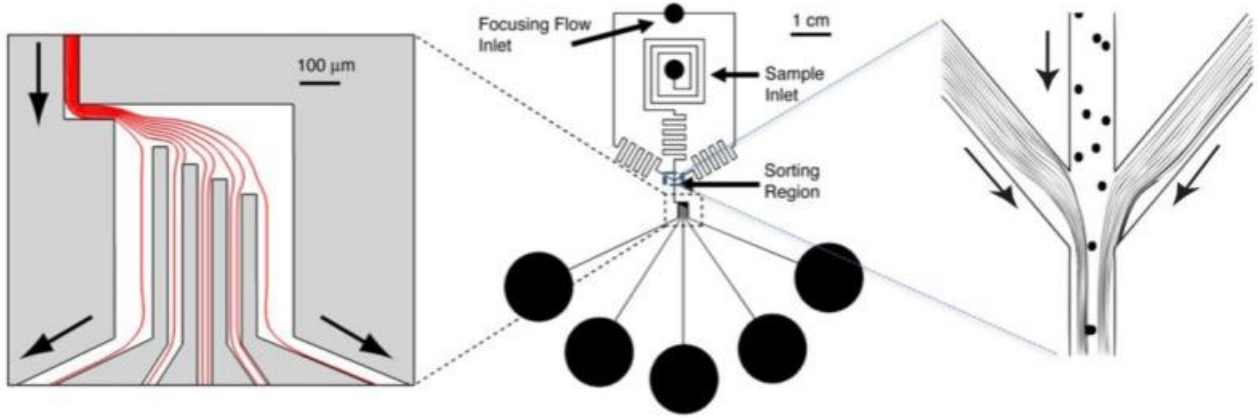


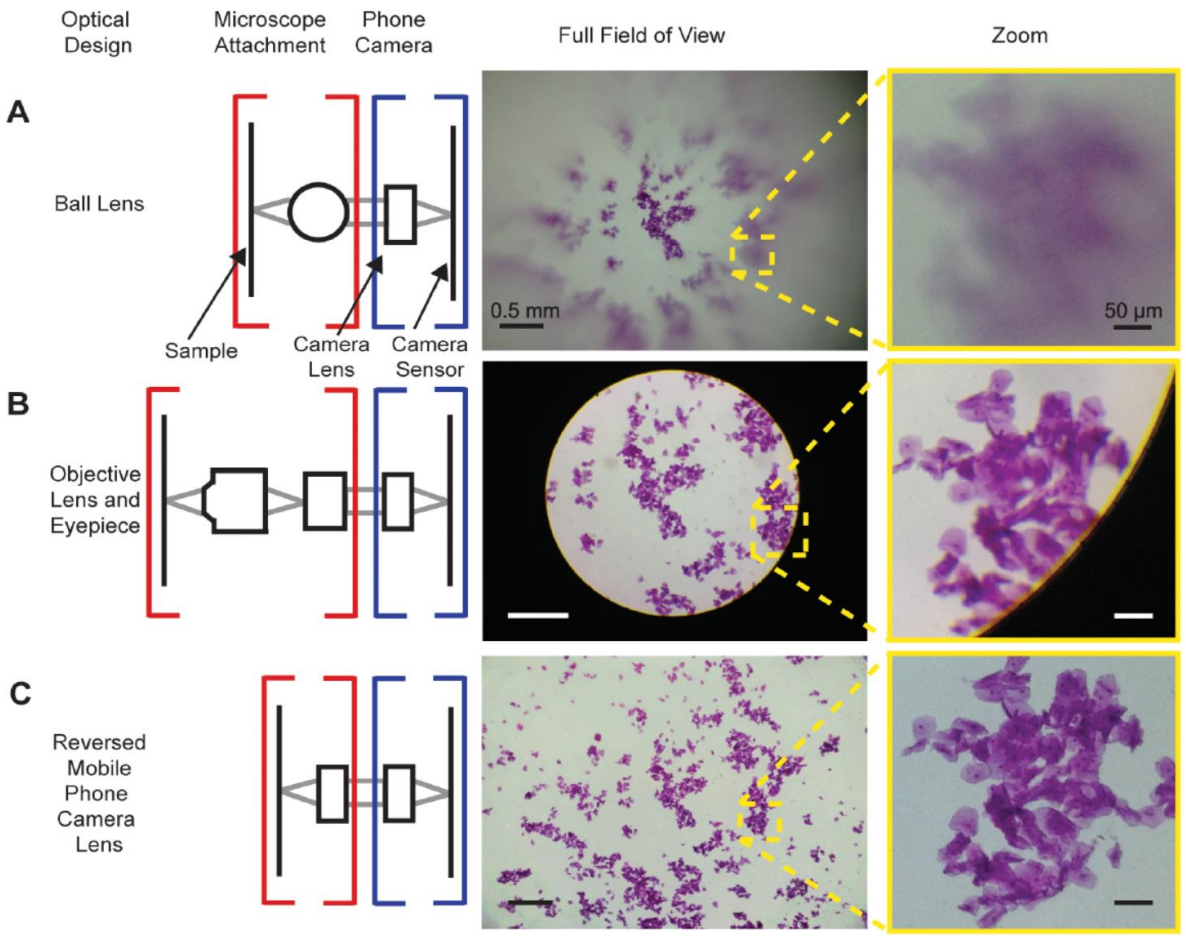
Fig. 1

a) Schematic of an optical pickup displaying the laser diode, the tracking coil, the diffraction grating (subsequently removed for optical trapping experiments) and the photodetector along with other associated optics. b) Top view of the LPC-815 optical pickup employed in these studies.



LOW-COST MOBILE PHONE MICROSCOPY WITH A REVERSED MOBILE PHONE CAMERA LENS

Neil A. Switz, Michael V. D'Ambrosio, Daniel A. Fletcher



Rouge : dispositif ajouté
Bleu : objectif associé au capteur CMOS

Image d'une cellule épithéliale prise avec une lentille sphérique de 6 mm de diamètre

Objectif 4X/0.10 NA et un oculaire de 20X

La meilleure solution: Association de deux objectifs identiques inversés (tête bèche).

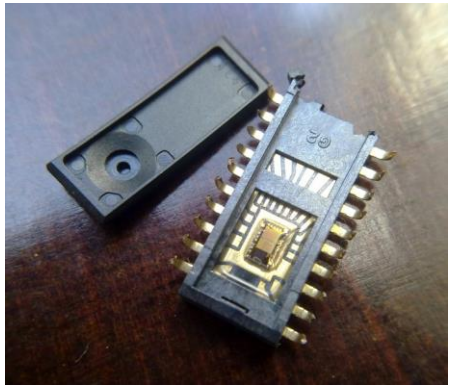
PLOS ONE | www.plosone.org May 2014 | Volume 9 | Issue 5 | e95330

INCLUDING SMARTPHONES IN SCIENTIFIC INSTRUMENTS

AYDOGAN OZCAN

Cellphone microscope : https://www.youtube.com/watch?v=VH5H6uSQUFE

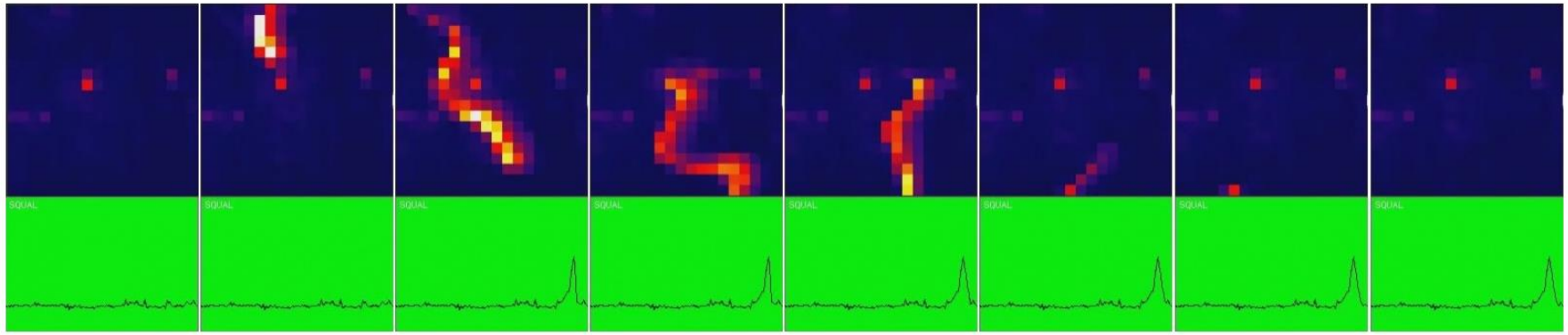
HACKING A MOUSE FOR DETECTION PURPOSES IN MICROFLUIDICS EXPERIMENTS



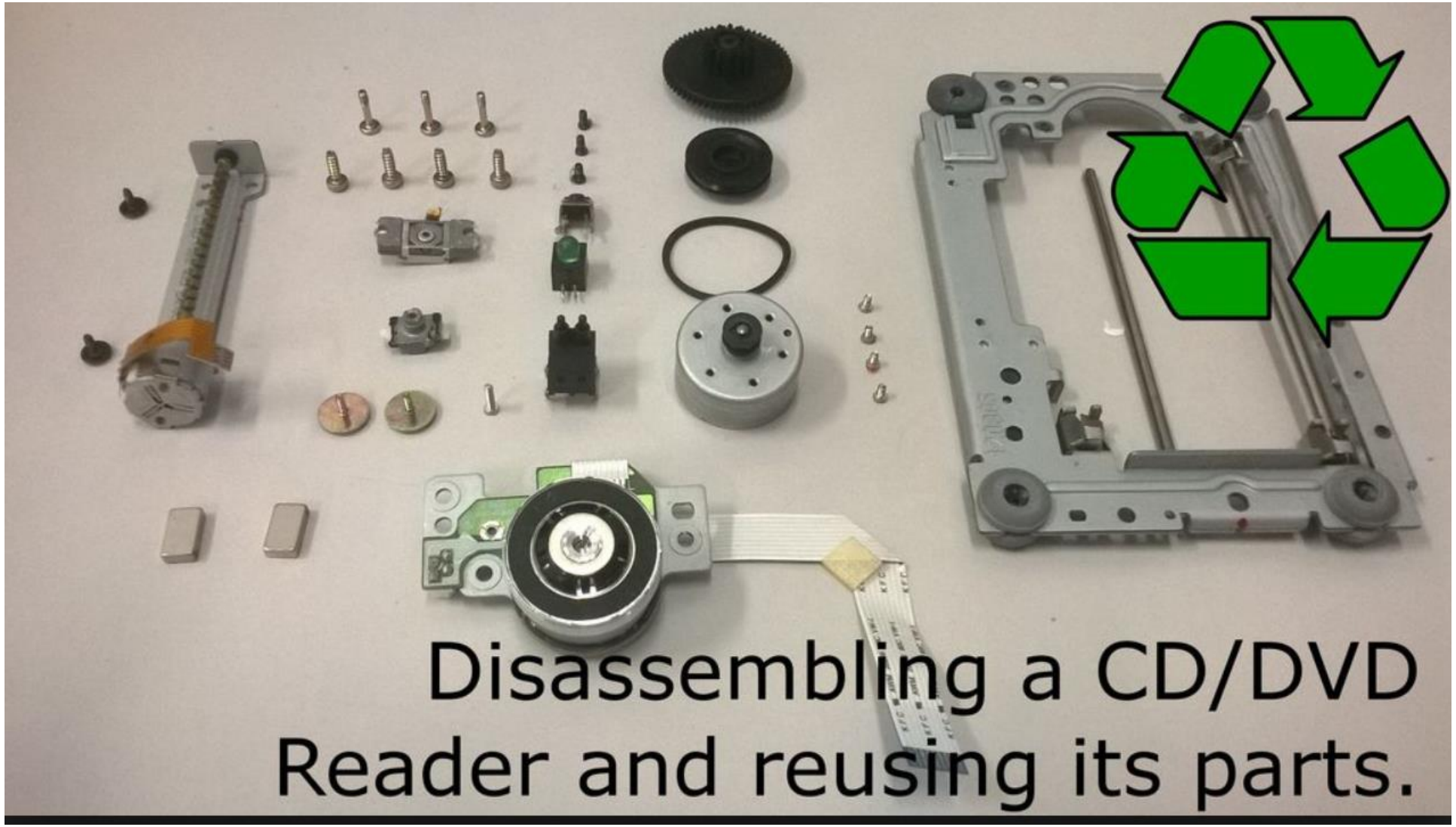
http://hackteria.org/wp-content/uploads/2010/12/MouseHackTest.zip
Video here:
http://www.youtube.com/watch?v=CAqWehKD_z0&feature=youtube_gdata_player

https://www.hackteria.org/wiki/Hacked_Optical_Mouse

Mouse detector connected to Arduino

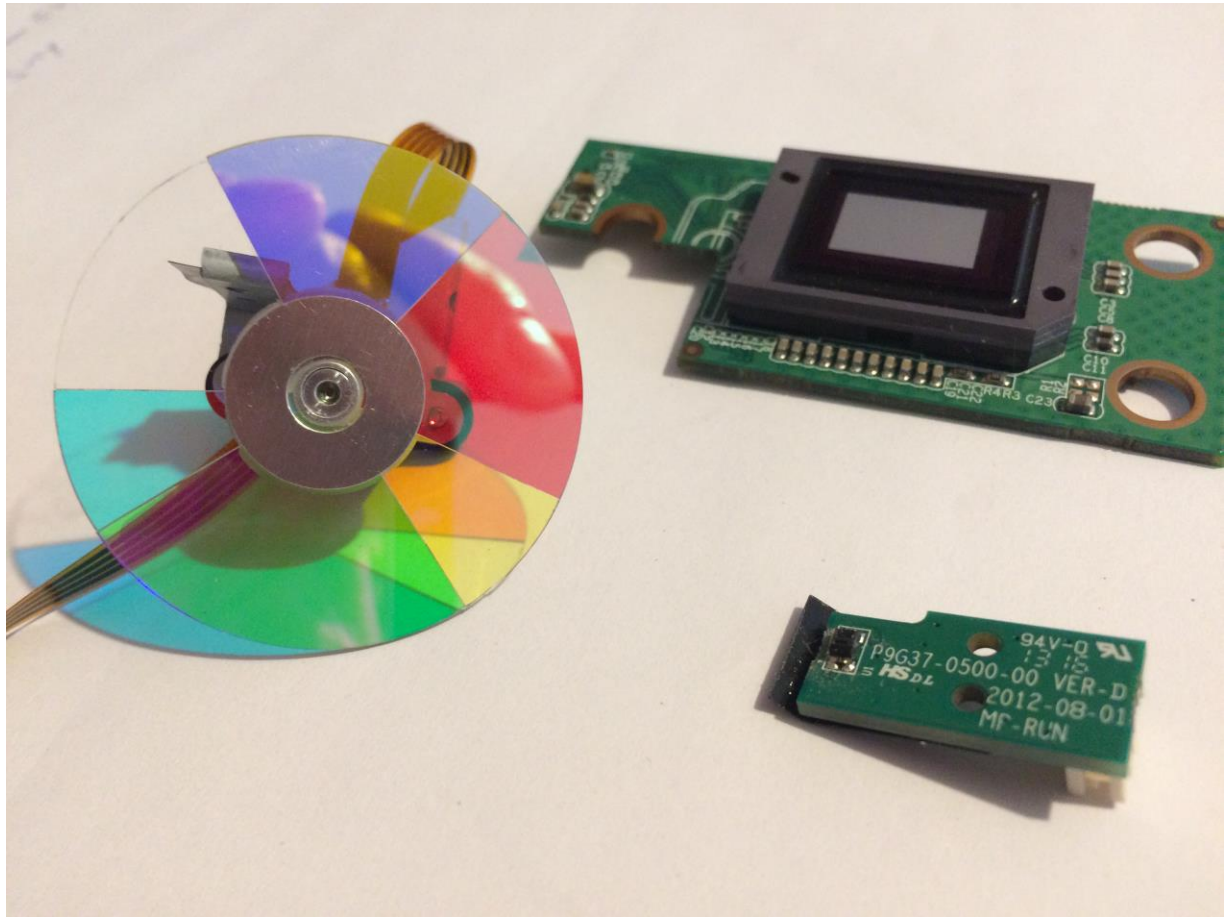


REUSING COMPONENTS FROM SCRAP



Fills in the ODD objectives (insérer image)

COMPONENTS FOUND IN VIDEO PROJECTOR



NEW LOW COST VERSION OF OPTICS PRACTICALS

Low cost Michelson interferometer ($50)
Article from *Physics Education* · September 2016
Shirish Pathare Vikrant Kurmude - Tata Institute of Fundamental Research - (INDE)

https://www.researchgate.net/publication/308136871

Figure 2 shows the schematic diagram and the photograph of the modified apparatus of Michelson-Morley interferometer.

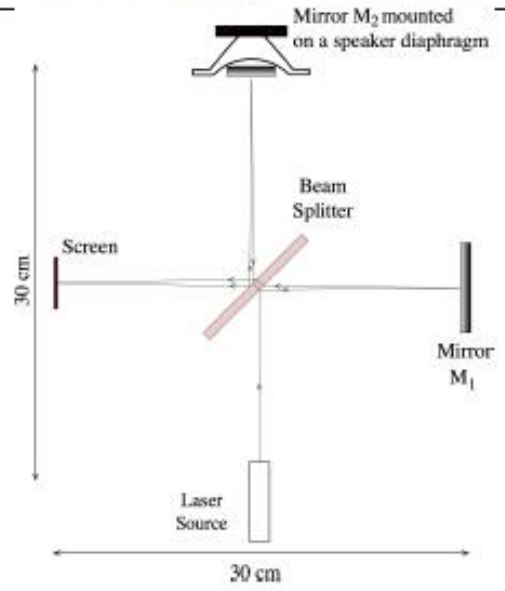


Figure 2a: Schematic of modified apparatus

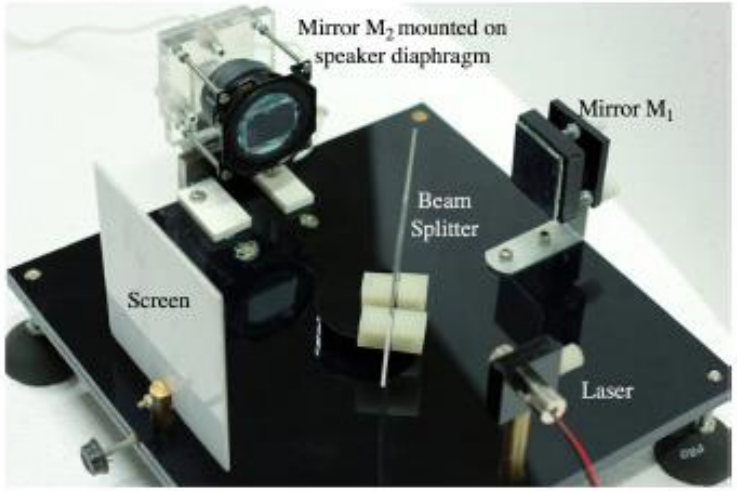
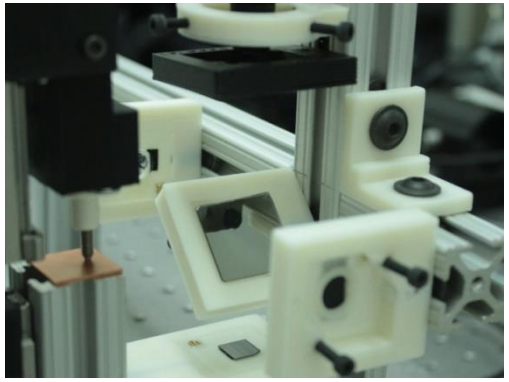
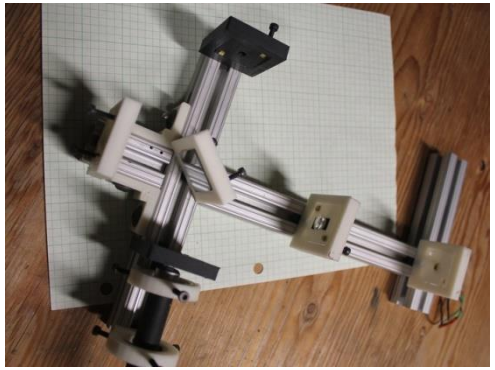


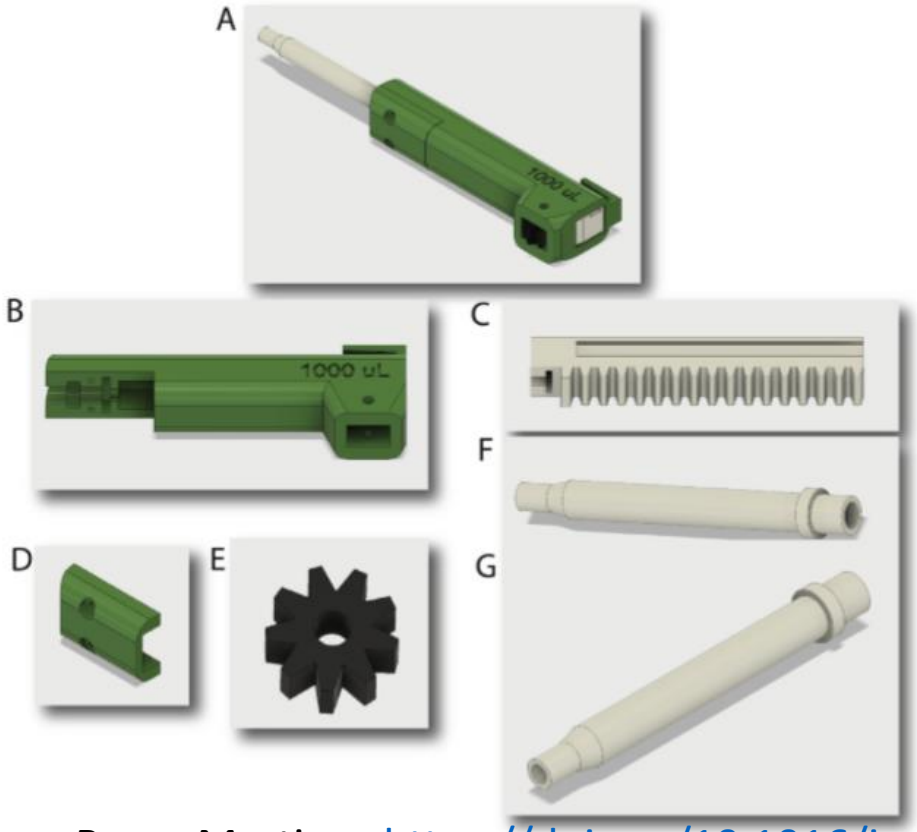
Figure 2b: Photograph of the modified apparatus

3D printing could also bring improvements
http://www.thingiverse.com/thing:3320





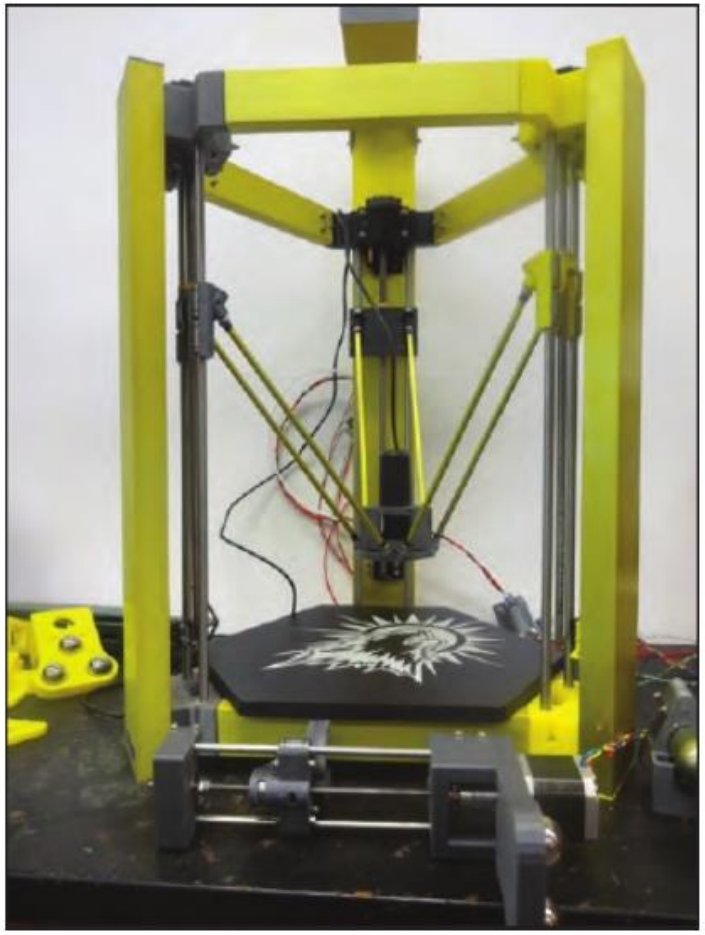
3D PRINTING FOR CHEMISTRY LABORATORY EQUIPMENT



Jorge Bravo Martinez https://doi.org/10.1016/j.ohx.2017.08.002
Under a Creative Commons license

https://www.thingiverse.com/thing:2765367
See also articles from Josuah Pearce Michigan Technology University

JOSUAH PEARCE WORK ON LOW COST LABORATORY EQUIPMENT



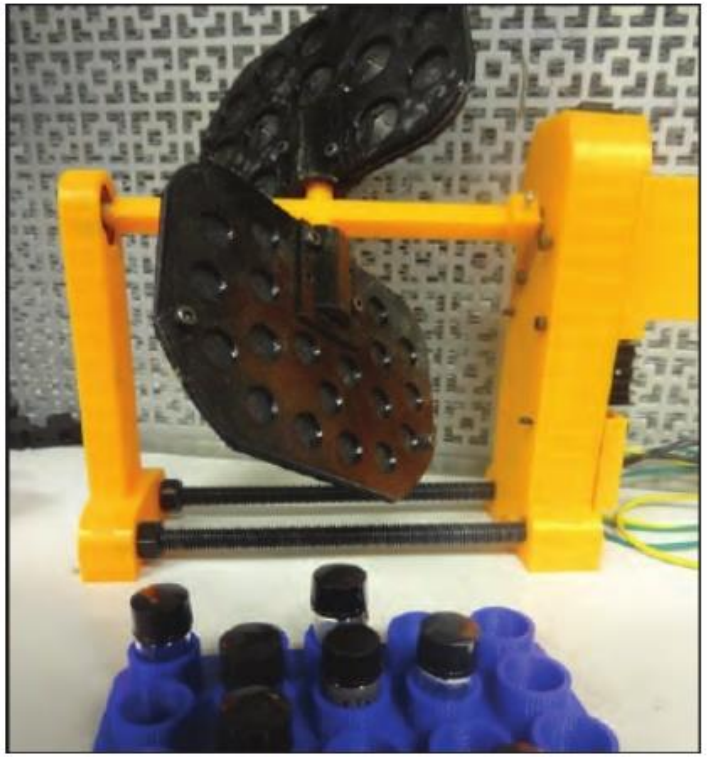


FIGURE 3 An open source 3D-printed sample holder and laboratory sample rotator mixer and shaker controlled with an open source Adafruit pro trinket microcontroller (Dhankani and Pearce 2017).

WATER PURIFICATION

- https://www.thebetterindia.com/110376/innovative-technology-for-waste-water-treatment-bengaluru-dr-rajah-vijay-kumar-fpstar/
- http://scaleneenergywater.com/index.html
- An automatic computer-controlled multi-stage system that uses a resonance of short waves to get rid of impurities, the revolutionary technology doesn't implement any chemicals in its treatment process and depends only on electricity.

The Aquatron Boomtube Resonator(left) and Dr Kumar drinking the water processed from sewage water.

Using the company's Aquatron Boomtube Resonator, the facility will have two units – each with a capacity of treating 1.2 lakh litres per day.

LAB HACKATON ZAMBIA

- The LabHack model combines insights and approaches from the Open Hardware and RRI movements in order to apply creative engineering and computing solutions to address equipment scarcity.
- https://labhackathon.wordpress.com/about/ https://labhackathon.wordpress.com/report-and-materials-from-labhackzim-2018/
- Responsible Research and Innovation (RRI) initiatives have successfully demonstrated the value of conducting research and innovation with and for society.
- « *Science, Technology, Engineering and Mathematics (STEM) education in Africa is challenged by shortages of laboratory equipment in teaching institutions. Large numbers of students often have to share single items of equipment, making it difficult for them to gain the hands-on experience necessary for effective STEM education. Moreover, the dominance of laboratory equipment designed by and for the Global North means that equipment is often difficult to use, maintain and repair within an African context. Thus, many African learning laboratories remain critically under-resourced. While concerted effort has gone into increasing access to STEM education on the African continent, the equipping of learning laboratory spaces remains a challenge. Currently, these efforts are not well-coordinated on institutional, national or regional levels and often rely on the effort of key champions to access inter/national funds for equipment purchase.* "
- LabHack events are a variation on the traditional computer science hackathon. In particular they draw on the 'ethical hackathon' model as developed by the Human Centred Computing theme at the University of Oxford using RRI principles.
- In ethical hackathons interdisciplinary groups work together on tasks that require them to address ethical and societal challenges in addition to technical ones. Drawing on the ethical hackathon, the LabHack encourage teams to consider equipment design on engineering, computing, social, ethical and economic levels. Furthermore, it opens up opportunities for equipping labs in novel and sustainable fashions, by facilitating the open design of key laboratory equipment in, for and by Africans. LabHack offers a platform for students and educators to take matters into their own hands and to design and build the equipment they need to learn. It encourages participants to use the Open Hardware resources available online to design equipment using hardware available in a local context. In this way, it opens up channels for innovation, problem solving and future entrepreneurship within the African STEM community.

NEW WAYS TO SHINE INTEREST FOR INSTRUMENTS : CHALLENGES

- **Cameroon:** after the creation of the challenge in 2017 a second edition is currently underway (APSA, Physics w Borders). As for 2017 a training is organized for the ten better candidates and three of the activities are organized with instruments awarded in 2017!

  http://www.concoursphysiqueafrique.org/resultats.php

- **Ethiopia:** the first edition of a pan african challenge has been organized in 2018 by APSA (French NGO) and Next Einstein Forum. The winner was the projet «AIMD», made by a team of 5 female ethiopian students. It is a frugal sensor for monitoring in real time provoqued birth under medical control.

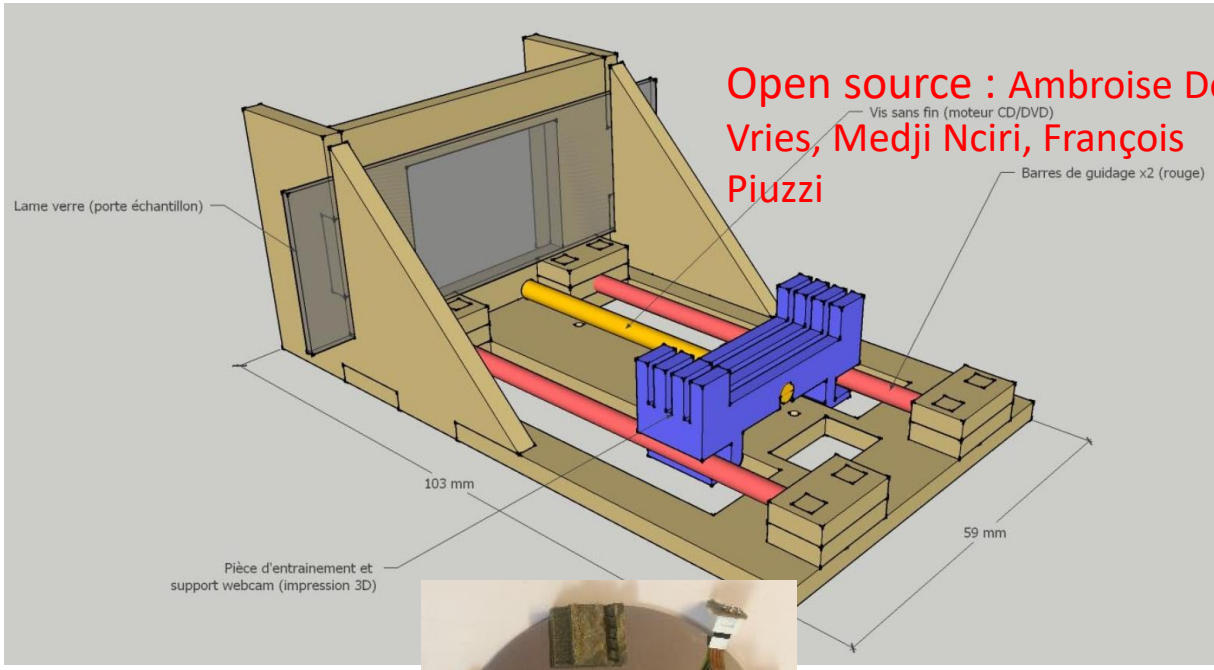
  •The first and second laureates in addition to their prizes will also beneficiate from a training in a Fab Lab in order to improve their instrument through increase of their skills.

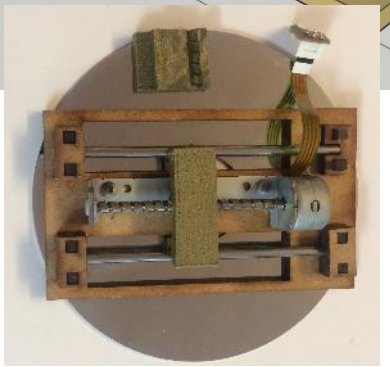
« EXPERIMENT-ACTION » A TENTATIVE TO TRAIN YOUNG SCIENTISTS FROM DEVELOPPING COUNTRIES TO GET SKILLS FOR EXPERIMENTS

- ✓ Mathematical learning societies have launched an initiative called "**Animath**" to develop maths in low resource countries. So at "Physics and optics without border commission" we have in mind to organize trainings for experimental sciences.
- ✓ We will first organize trainings in Paris and then tentatively try to organize trainings in Burkina Faso.
- ✓ The first training in Paris will be devoted to "frugal microscopy".
- ✓ We also want to test funding through "crowdfunding" for making it in Burkina coop. Prof. Arouna Darga.
- ✓ The project is to develop simple but efficient instruments that ideally could be manufactured locally in association to local Fab Labs.

  "this is illustrated here: it involves laser cutting, 3D printing, reusing components from DVD drive and needs to buy a web-cam"

This will be a difficult task so it is open to every one wanting to collaborate.





FUNDING PROSPECTS AND INITIATIVES?

NGO, Institutions, Enterprises, Foundations, Crowdfunding?

FAB LABS IN AFRICA

- Fab lab number is increasing rapidly in Africa. At the beginning there was a reluctancy from the academic world to cooperate with this somehow informal structures.
- Little by little the importance of fab Lab is growing and some universities have their fab lab or a similar structures.
- Now in Europe most of the prototyping is made through 3D printing and Arduino like electronics.

- Source : https://www.fablabs.io/labs/map

INVOLVING YOUNG PROFESSIONALS IN EXPERIMENTAL SCIENCES

- Two interesting young female PhDs from Senegal:

✓ **Maîmouna Diouf:** she has done a PhD in Aix Marseille University in the domain of atomic layer deposition. She developped a low cost instrument for making atomic layer deposition.

✓ She is now a professor in Dakar american university of science and technology american university (http://daust.org/faculty), and she has in mind to organize training on a low cost atomic layer deposition at Dakar university.

- **Marie Pasqualine Sarr** works in the domain of solar energy, she works on the control of mini heliostat (solar collector) and is also a profesor at Université Alioune DIOP of Bambey She wants help to introduce better practicals.

WHERE TO FIND INFORMATION ON OPEN OR LOW COST HARDWARE?

JOURNALS:

« **HardwareX** » (Elsevier, editor Joshua Pearce) https://www.journals.elsevier.com/hardwarex

Plos one : open acces papers on instrumentation mainly oriented in biology https://journals.plos.org/plosone/

Many thematic journals have open access papers like **Sensors**, or **Physics Education**.

INTERNET SITES :

Site « **Instructable** »: includes many projects but not so easy for finding specific projects https://www.instructables.com/

Site « **Thingiverse** » for 3D printing projects https://www.thingiverse.com/

Site « **Hackteria** » it is the site for technology diversion projects https://www.hackteria.org/

Site « **Gaudi Lab** » very good site for for technology diversion (Marc Dusselier). www.gaudi.ch

Site « **Trend in Africa** » interesting developments tested in the field– from Tubingen university in Germany

Site « **Public lab** » site for citizen science founded in USA to pour develop scientific instruments to mainly make measurements for environmental purposes https://publiclab.org/ (low cost spectrometers à bas coût, fluorescence measurements, detection of small particules in air) one of their last development is the Dustuino

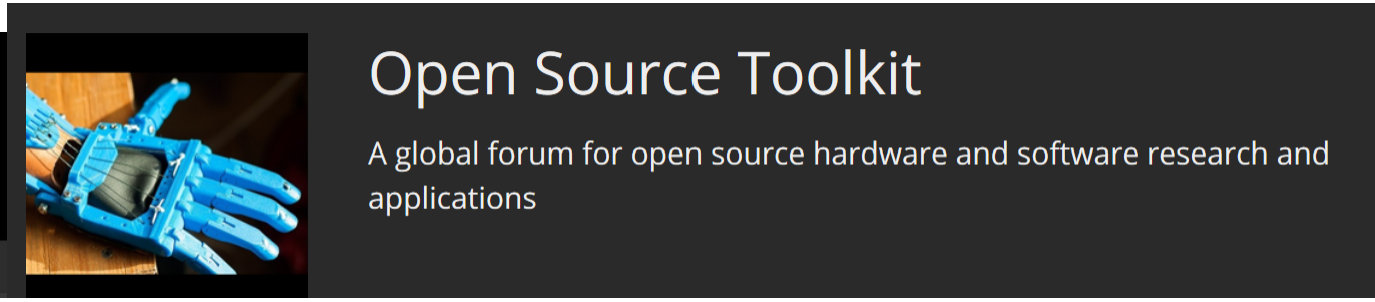
Site **GOSH** (Global Open Source Hardware) developped by young scientists to provide training on open source hardware and to give access to sustainable cost scientific instruments to low resource countries. http://openhardware.science/

Site **Physics open lab** http://physicsopenlab.org/ site from Italy (with an English version) includes different domains of physics and also sustainable cost practicals

Site **Open source toolkit** https://channels.plos.org/open-source-toolkit

Site **ExpEyes** (stads for experimental Eyes) : indian site which provides basic education tools for electronics through a microcontroller and signal generator (http://expeyes.in/) It is caracterized by an open access software and open source structure and is available for diverse environment (for Windows 10 : Expeyes17Setup.exe) It uses Python language.

Site **Physics Toolbox Suite** (*https://physics-toolbox-suite.fr.aptoide.com/)* or Phyphox (http://phyphox.org/



A touch of humor?

A new way to equip Africa's science labs: get students to build their own

5 août 2018, 11:47 CEST

Water urns become bioreactors with this clever design. Jeffrey Barbee, Alliance

Auteur

Louise Bezuidenhout

Research fellow in science and technology studies/bioethics, University of Oxford

How does one train science students without equipment? As a sociologist of science specialising in African countries, this is a question I get asked with sad regularity.

Source: The Conversation

Thank you for your attention

LabHack

LabHack aims bring the ideas and ideology of the Open Hardware movement to the African educational community. LabHack events are a variation on the traditional computer science hackathon. In particular they draw on the 'ethical hackathon' model as developed by the Human Centred Computing theme at the University of Oxford using RRI principles. In ethical hackathons interdisciplinary groups work together on tasks that require them to address ethical and societal challenges in addition to technical ones. Drawing on the ethical hackathon, the LabHack encourage teams to consider equipment design on engineering, computing, social, ethical and economic levels. Furthermore, it opens up opportunities for equipping labs in novel and sustainable fashions, by facilitating the open design of key laboratory equipment in, for and by Africans. LabHack offers a platform for students and educators to take matters
into their own hands and to design and build the equipment they need to learn. It encourages participants to use the Open Hardware resources available online to design equipment using hardware available in a local context. In this way, it opens up channels for innovation, problem solving and future entrepreneurship within the African STEM community.

Teams participating in the LabHack challenge are required to have at least three different disciplines represented in their teams. The design challenges they work on are specifically chosen as basic laboratory equipment used daily in STEM learning laboratories – for instance polymerase chain reaction (PCR) machines, centrifuges and magnetic stirrers. Prior to the event, the teams are required to submit a range of different documents, including design plans, budget and any software code. It is expected that these documents will be shared with other teams and judges. Challenge winners are assessed by criteria including excellence of design, completeness of documentation, frugalness of hardware usage, and ease of equipment use by downstream user.

During LabHacks, participants also have the opportunity to attend a variety of technical, entrepreneurial, Open Hardware and ethics workshops on themes linking to equipment design. There are also social events where teams and other attendees can get to know each and foster long term connections.

The first LabHack was held in Harare in June 2018. Funding was provided by the Global Challenges Research Fund impact award from the Engineering and Physical Sciences Council (EPSRC). The award was presented to Professor Marina Jirotka, Dr

3D-printable portable open-source platform for low-cost lens-less holographic cellular imaging

Stephan Amann, Max von Witzleben, and Stefan Breuer

(Submitted on 9 Apr 2019)

Digital holographic microscopy is an emerging potentially low-cost alternative to conventional light microscopy for micro-object imaging on earth, underwater and in space. Immediate access to micron-scale objects however requires a well-balanced system design and sophisticated reconstruction algorithms, that are commercially available, however not accessible cost-efficiently. Here, we present an open-source implementation of a lens-less digital inline holographic microscope platform, based on off-the-shelf optical, electronic and mechanical components, costing less than $ 190. It employs a Blu-Ray semiconductor-laser-pickup or a light-emitting-diode, a pinhole, a 3D-printed housing consisting of 3 parts and a single-board portable computer and camera with an open-source implementation of the Fresnel-Kirchhoff routine. We demonstrate 1.55 {\mu}m spatial resolution by laser-pickup and 3.91 {\mu}m by the light-emitting-diode source. The housing and mechanical components are 3D printed. Both printer and reconstruction software source codes are open. The light-weight microscope allows to image label-free micro-spheres of 6.5 {\mu}m diameter, human red-blood-cells of about 8 {\mu}m diameter as well as fast-growing plant Nicotiana-tabacum-BY-2 suspension cells with 50 {\mu}m sizes. The imaging capability is validated by imaging-contrast quantification involving a standardized test target. The presented 3D-printable portable open-source platform represents a fully-open design, low-cost modular and versatile imaging-solution for use in high- and low-resource areas of the world.