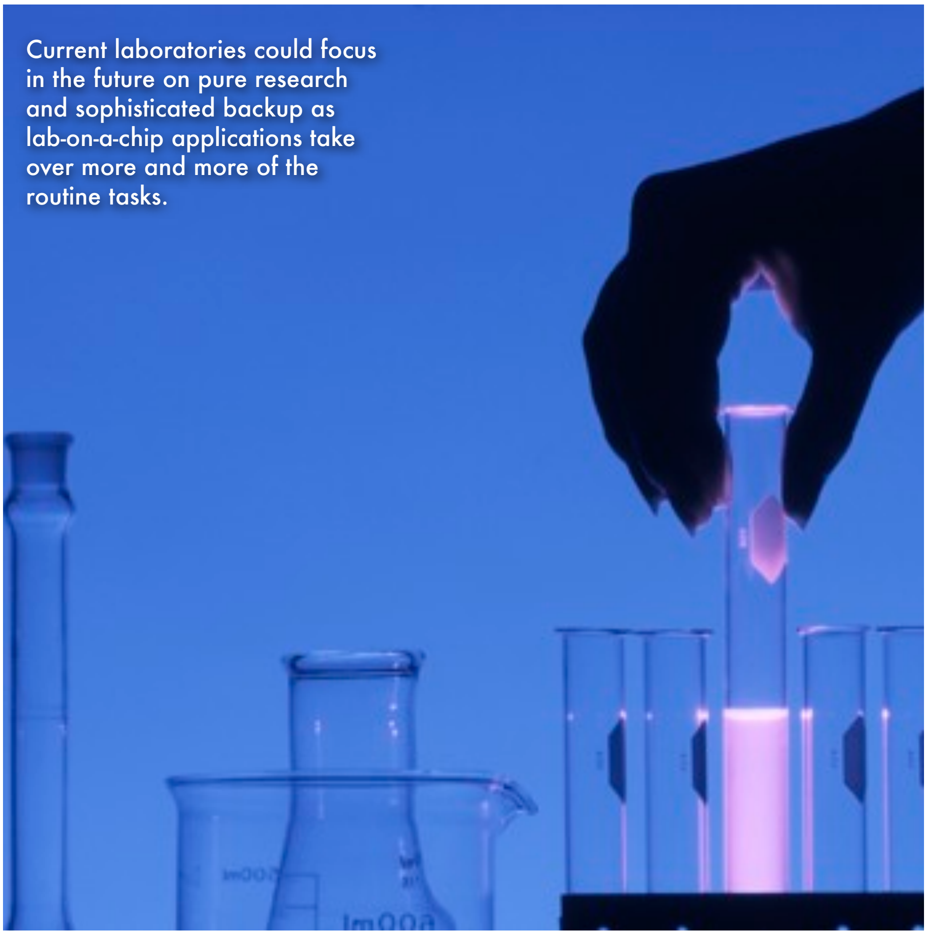
Design

LABORATORY



Current laboratories could focus in the future on pure research and sophisticated backup as lab-on-a-chip applications take over more and more of the routine tasks.

Modular lab-on-a-chip platform for low cost microfluidic applications

The design task

During the Winter semester 2009-2010, you will work in a team of five persons to conceive of, dimension and manufacture a reconfigurable **lab-on-a-chip** platform.

Your goal will be to create a kind of microfluidic "Lego", a building block system of parts that fit together seamlessly. Your system will enable users thereof to piece together a number of parts in order to implement a specific application.

You and your team are encouraged to form your own **corporate identity**, so that the team spirit forms. Imagine that you are bidding on a very big contract with some global player company who will evaluate your project and will give the **best entry** the go-ahead to work on phase 2 of the project. In this sense you are in competition with the other groups, and will have to protect yourself against **industrial espionage**.

Our client company issuing the bid has specified a number of things about the system that have to be met. These **specifications** are provided further on in this document.

The following qualities in your solution will make your design attractive to the client:

- Intelligent modularity
- Simplicity
- Elegance
- Low cost
- Flexibility
- Compatibility
- Interfacibility
- Wide range of devices
- Wide range of applications

It will be important for you to analyse the field of microfluidic applications to discover the kinds of devices that exist in the field. Also, you should review the application areas (chemical analytics, biology, environmental monitoring, medical diagnostics, etc.) so as to discover the range of needs that may exist for the laboratory. Also, do not forget your lecture notes and the textbook literature for inspiration.

All fabrication will be done at IMTEK in the Design Laboratory workshop, or by one of our qualified suppliers. For you, no personal expenses will arise. If special hardware is needed for your project, you will have to submit your needs plus a cost estimate soon, so that we can evaluate whether the expense can be carried by IMTEK.

My team and I wish you and your team much success with your project.

Contents:

Special feature edition of Lab on a Chip

2010

With the kind support of Prof. Dr. Andreas Manz, currently a fellow of FRIAS, a special edition of the journal Lab on a Chip is targeted for 2010. The best student papers will qualify for inclusion into the journal as a special research paper.

In order to qualify, reports must be delivered to the paper specifications of LoaC. The papers will undergo an internal review process, and only the best papers will be submitted to the journal for a professional review process. More details of the procedure will be provided during the class.

Fab

- > CNC Laser. The IR laser system cuts through plastics and provides depth control as well as welding capabilities
- > Lamination
- > CNC milling
- > Styrofoam cutting
- > Drilling
- > Turning (watch and clockmaking lathes are available)
- > Rapid prototyping through an order service
- > PCB exposure and bath
- > Soldering station with multimeter and oscilloscope

Substrates

1

1.5 mm transparent and coloured Plexiglass substrates form the basis of our work.

2

75μm thick transparent poly foil provides intermediate see-through wall and functional membrane.

3

50 μm and 130 μm thick 3M 467MP clear double-sided sticky foil as inter-layer adhesive.

Liquids

4

Water. Most biological processes take place in water. Water can be coloured to demonstrate functionality of devices.

5

Oil. Oils have higher viscosity than water and demonstrate variability of fluid. Also, oil/water mixes povide encapsulation opportunities.

6

Solvents. Solvents need to be tested w.r.t. plastics.

Electronics

7

PCB substrate. Printed circuit boards may be co-integrated (layer or insert) to provide electrodes and circuits.

8

Passives. PCB metallization can be used to provide electrodes for sensors, actuators or heaters.

9

Sensors and actuators. Discrete chips may be used to implement electronic/optical interface.

Fluidic devices

You will be creating microfluidic devices on flat substrates. The materials provided will create opportunities for a reasonable amount of design freedom. In order to make best use of this freedom, it is essential that you have a clear idea of the set of devices you want to create. Here we provide you with a partial minimal list you should implement, but nothing stops you from extending the list into more sophisticated regions of microfluidics, as long as they can be manufactured by the equipment provided.

Open channel. The open channel is used to guide the flow of liquid. It is closed by a substrate stacked above it.

Splitter and joiner. A channel point that splits into two or more channels, or that joins two or more channels.

Via. A channel that extends through the entire substrate, allowing liquid to flow vertically to a device placed above the substrate.

Tank. A place to store liquid.

Seal. A method to form a seal between two joined substrates so that an open channel becomes closed.

Fluidic connector. A device to couple liquid into the fluidic substrate.

Valve. A device to stop flow in a channel by constricting it.

Pump. A device to put pressure on a fluid, causing it to flow.

Fluid Sensor. A measuring device.

Design specifications

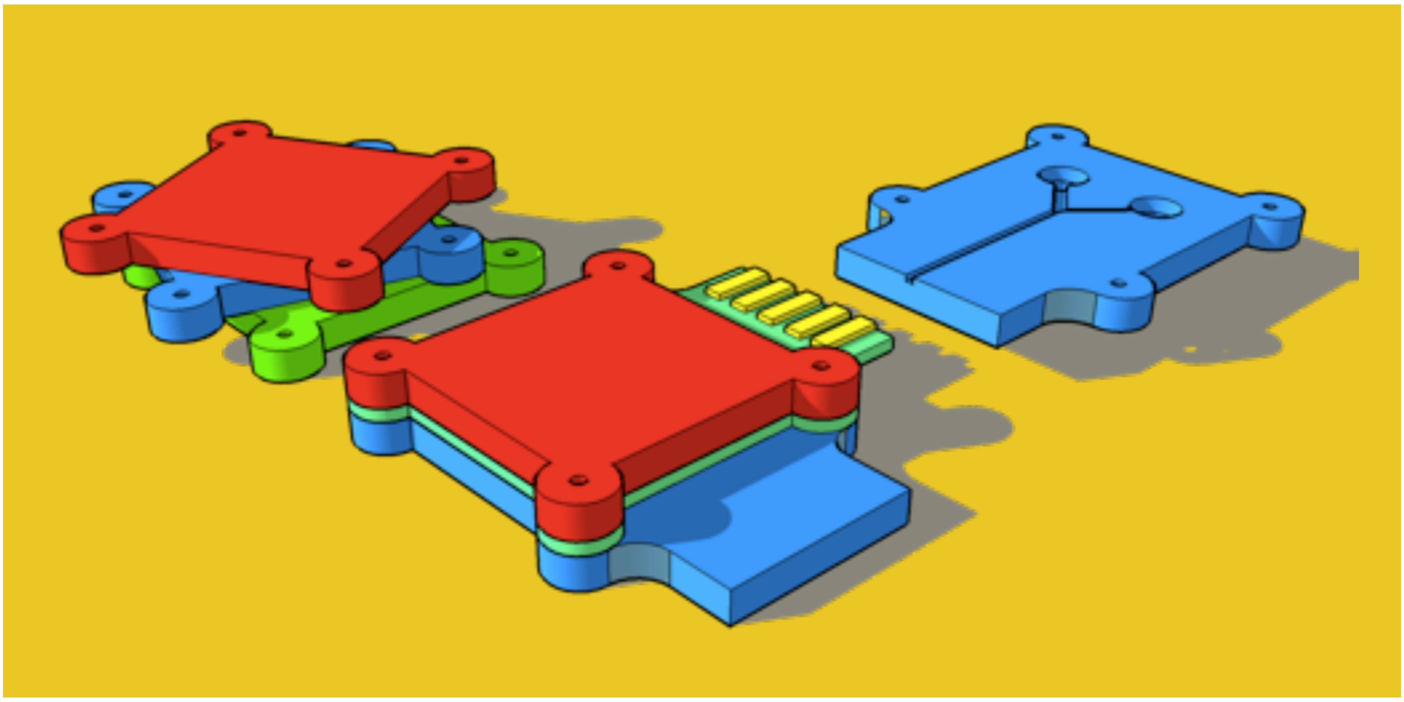
Modularity will be our key principle for interoperability and flexibility of our designs. This will give us a huge advantage, because it will mean that all team designs will be able to be joined together, thereby vastly extending our capabilities. To achieve this goal, we will require **standards** and **norms**, an implicit agreement to which we have to conform.

Your modular units will be 20 x 20 mm, with specified holes in each corned for inserting clamping screws, so that a tightly-sealed stack can be formed. A unit may have one or more protruding "arms", for the purpose of connecting external equipment to the platform. You will be provided with a DXF file of the basic layout variants, within which you can freely vary your design ideas.

In addition, you will be provided with a laser micromachining test chip design DXF file. This design file contains lines of different type. Each type corresponds to a particular setting of the infrared laser's parameters. It allows us to vary dosage, and hence perform cuts of various strengths (and hence depths).

We provide you with a range of acceptable materials for the fabrication. If you wish to try out something else, it is essential to discuss the material with my team. **Some materials emit gases that can damage yourself or the laser equipment**!

Chip laboratories, often called micro total analysis systems (μTAS), are found in environmental monitoring, medical fluid analysis, DNA analysis, drug screening, chemical synthesis, and a range of other application areas where rapid, low cost yet highly accurate analysis is required.
By making the components smaller and tamper-free, sophisticated analysis can be provided to crisis areas, or regions of the world without complex infrastructure.



Standardization

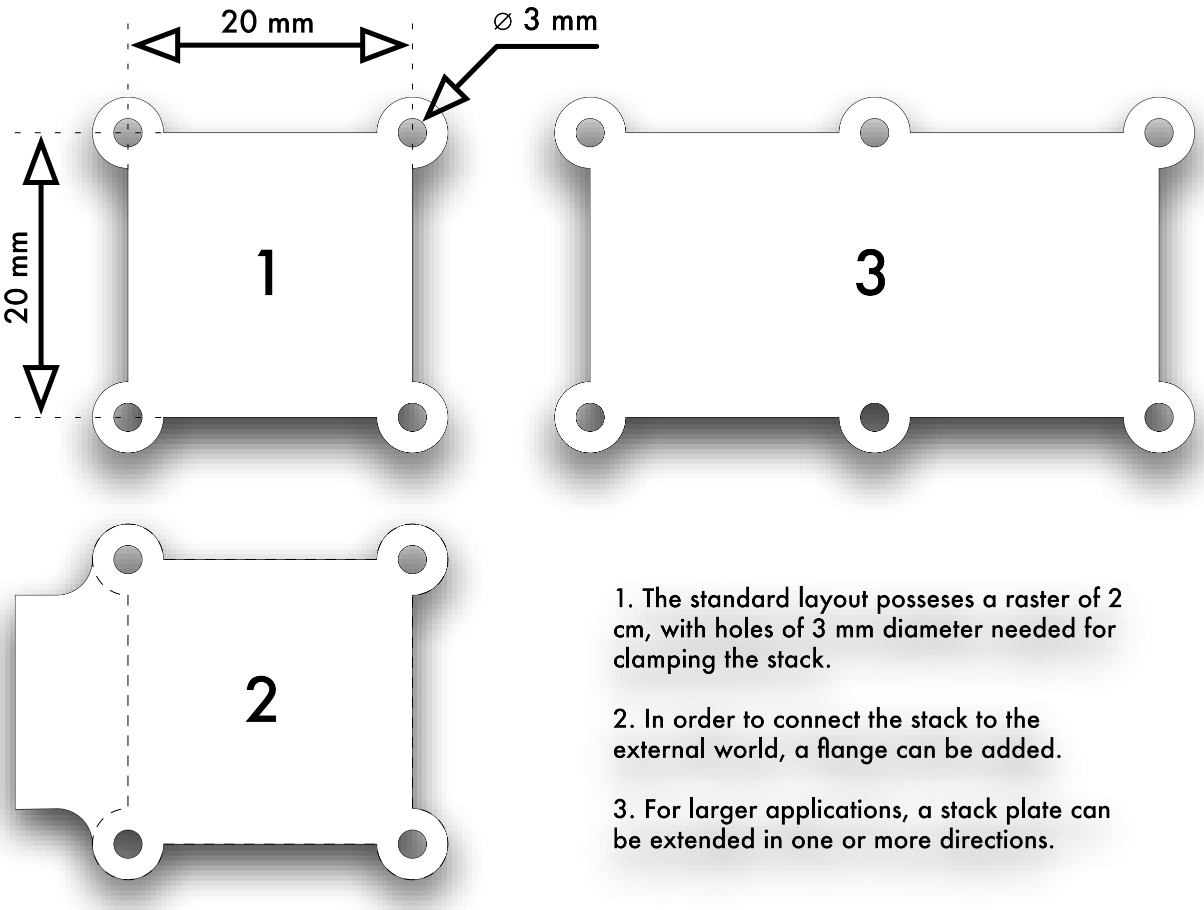
Your design should follow a standard layout, specified at the very least by the size and position of the four fixation holes as shown in the figure below. Then, at least in principle, the microfluidic platelets of all groups will potentially join together.

Further opportunities for standardization are:

1. The fluidic connection between layers.
2. The fluidic connection to the outside world
3. Possible electrical connections, voltages.
4. Components specifications that cover a complete range (of pressure, flow, etc).
5. User interface with display of information and functionality.
6. Holder for a stack of platelets.
7. Colour coding of parts for easy assemby.

Norms

Whenever norms are established, great economic advantages can arise, despite initial fears. Typtical examples are the power plugs of appliances, USB data communication, metric screws, internet, batteries.



1. The standard layout posseses a raster of 2 cm, with holes of 3 mm diameter needed for clamping the stack.

2. In order to connect the stack to the external world, a flange can be added.

3. For larger applications, a stack plate can be extended in one or more directions.

Design procedure

What is your key application?

1. Follow the FRDPARRC technique

Make extensive use of a technique to structure the creative work of your team. The described method is highly effective if applied consistently.

2. Analyze the needs of a laboratory

Laboratories have unit operations, such as measuring, dispensing, mixing, heating, incubating, reacting, etc. See how many you can find, then determine how they can be split into even smaller, simpler parts.

3. Find the counterpart in miniature

Once you know your parts (e.g., reactor, channel, valve, etc.) then see how it can be made smaller given a 2.5 D technology.

4. Understand your design freedom

In order to translate a design requirement into a technology, you need to understand the possibilities and limitations of your manufacturing technology.

5. KISS

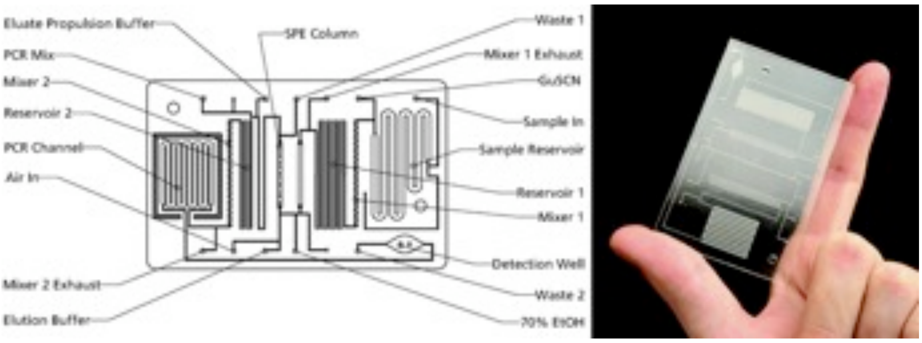
Keep it simple and straightforward. Do not get too deep into developing new manufacturing processes. This can quickly become a trap. Concentrate on achieving a unique microfluidic concept based on the technology provided.

6. Teamwork

A team is more than 5 capable members. Use the team advantage to get leverage on the problem. Try the impossible! And reach for the stars!

Keep in mind ...

... that every successful product is a merging of application, manufacture, functionality and user preferences in one embodiment. The iPhone is essentially a mobile telephone, but only the re-engineering of conventions made it into a unique product.



Laboratories on chip

A laboratory on a chip (LOC) attempts to replace all components of a conventional wet bench laboratory with miniaturized components. Since the human operator is not miniaturized, this usually implies that such a laboratory is designed with a specific task at hand, for example as a chemical synthesis tool, of for bio-chemical analysis. In order to be able to miniaturize laboratory "unit operations", such as mixing, pumping, measuring, etc, we need to have a good idea of what is generally needed in a laboratory, and then, for a specific application, what the specifications of each "unit operation" should be so that we can dimension the miniaturized component accordingly.

In the literature, such laboratories are often referred to as μTAS, or micro total analysis systems.

The copyrighted illustration on this page of a μTAS was taken from the paper: **Alexis F. Sauer-Budge , Paul Mirer, Anirban Chatterjee, Catherine M. Klapperich , David Chargin and Andre Sharon,** *Low cost and manufacturable complete microTAS for detecting bacteria*, **Lab Chip, 2009, DOI: 10.1039/b904854e**. It shows a low cost laboratory on a chip with a wide range of laboratory components, including reservoirs for buffer, analyte, waste material, and sample, a polymerase chain reaction (PCR) channel, a solid phase extraction (SPE) column, and an optical detector (sensor). In this case a pump is not needed.

In general, laboratories are called passive if they are able to operate without the addition of electrical power (and a pump). Since reliable micropumps are really hard to make, many LOCs will rely on capillary forces to drive the flow of liquid, or on an external agents such as a syringe.

Often, LOCs are made of transparent material. This fascilitates checking procedures, and allows the combination of fluidics with optical detection. Also, combinations with microscopy are then possible.

A key aspect of LOCs is cost. It only makes sense to offer an LOC product if it vastly saves cost and time. Thus, low cost manufacturing is also an important issue. Ideally, volume production must be possible, and here injection moulding and embossing is preferred if the substrate material is plastic.

Sources of information

Your should liberally scan the available information sources (web, library, lecture notes, scientific literature) and record interesting ideas and inspiration in your notebook. A noteable journal to look at is the Royal Society of Chemistry's *Lab on a Chip* journal. Here you will find reports on interesting applications, but also on new manufacturing technologies. It will also help you to asses whether your ideas are cutting-edge.

Other sources pertain to material suppliers, periferal equipment, and possible competition (companies that already offer modular solutions).

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