NAPES

NEXT GENERATION ANALYTICAL PLATFORMS
FOR ENVIRONMENTAL SENSING

Bridging Worlds:

From macro- and micro-scale to prototype and product

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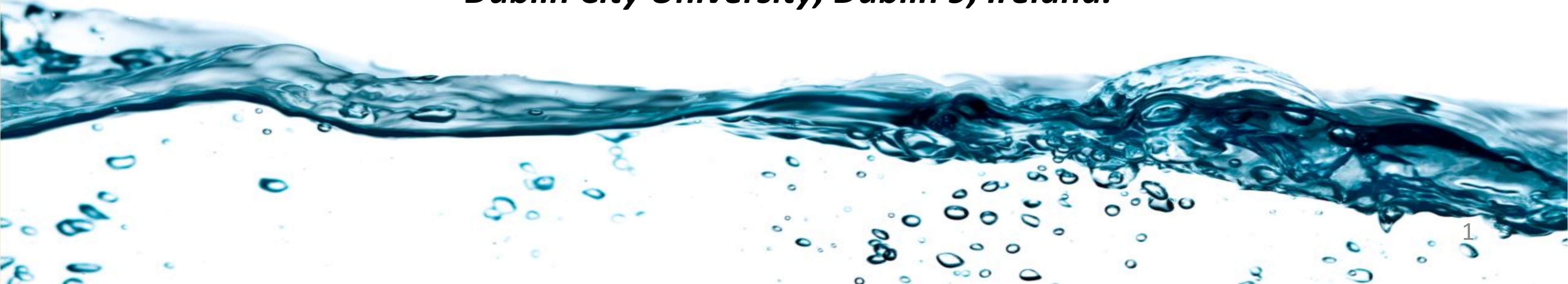
Dublin City University, Dublin 9, Ireland.



Lab to Life

Bench top breakthrough to real-life application

Functional lab-based development of materials/platforms

Parallel project activities

otype development and scaled up production

Incorporation of **Productisation** and **Manufacturability** strategies during lab-based development

Materials development with potential commercial application!!

Product Sales

Bulb image: http://gtnetwork.ie/index.php/gifted-adults/lightbulb/ <accessed 12/11/14>
Production line: http://en.wikipedia.org/wiki/Production_line ,accessed 12/11/14>
Money: http://www.dreamstime.com/stock-photo-business-man-pile-money-vector-illustration-cartoon-image35110170 <accessed 12/11/14>
Drawing board: http://disney.wikia.com/wiki/File:Rocket_design_drawing_board.jpg <accessed 13/11/14>

Our Challenge

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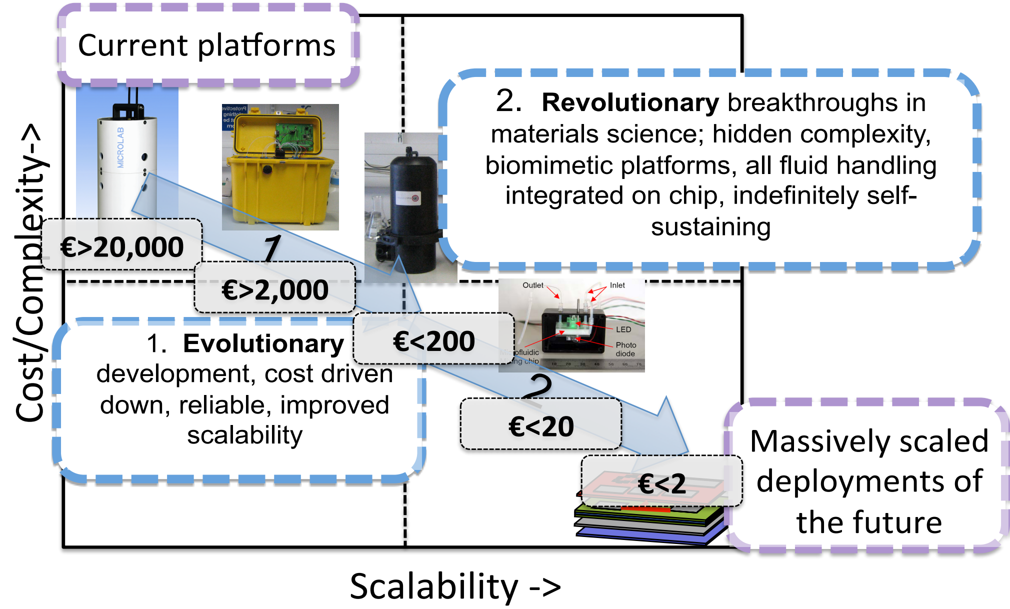
- Development of **low cost, autonomous, deployable environmental sensor platforms**.
- **Innovative sampling and target pre-concentration strategies** for more comprehensive analysis.
- Merging **novel materials** and **microfluidic platforms**



- **Highly specific target detection methods** for determination of bacterial and chemical contaminants.
- **Commercialisation of platform** in parallel to research activities.

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NAPES Research and productisation

MAM-14 Topics

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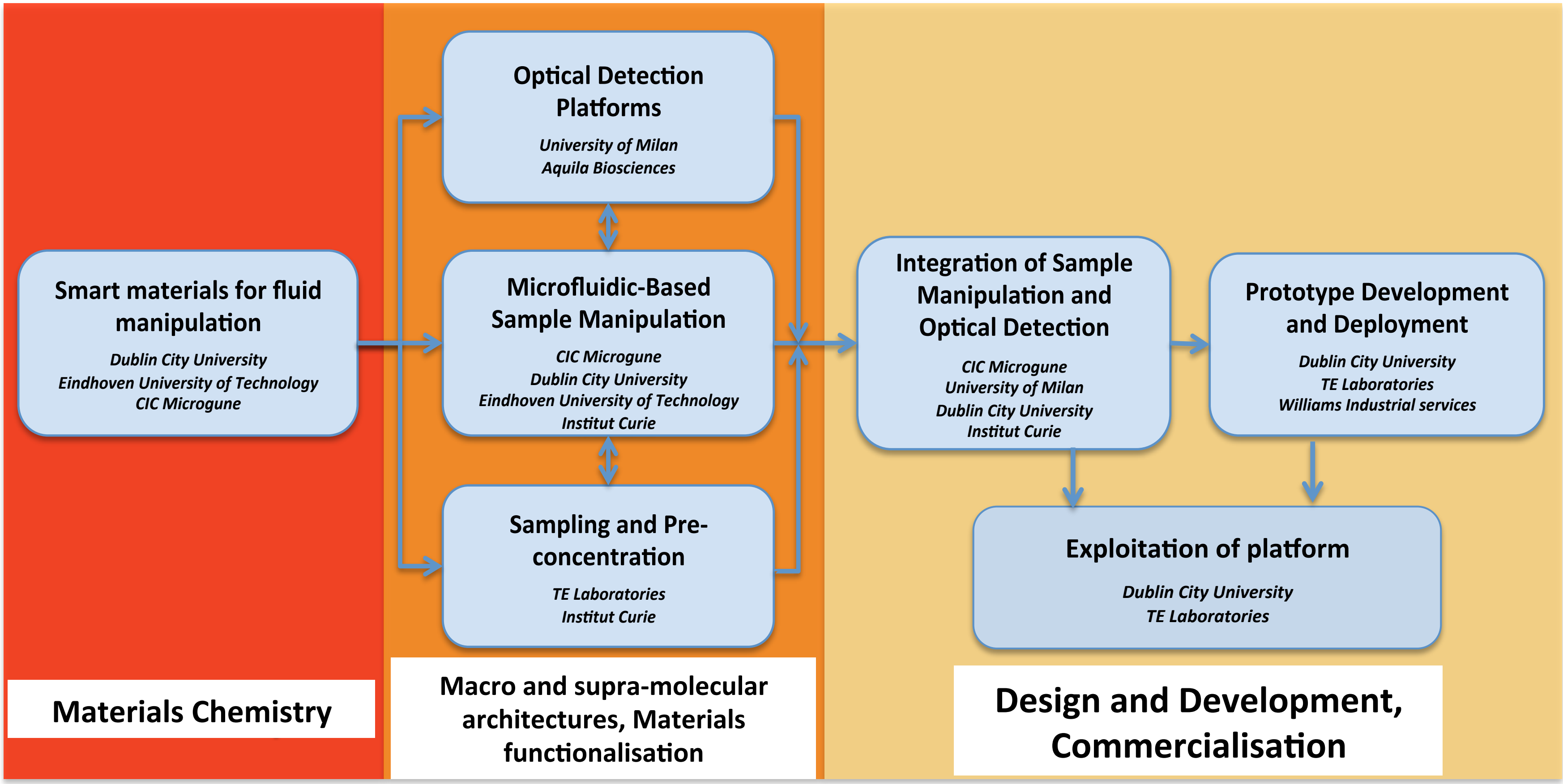

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NAPES Research strategy

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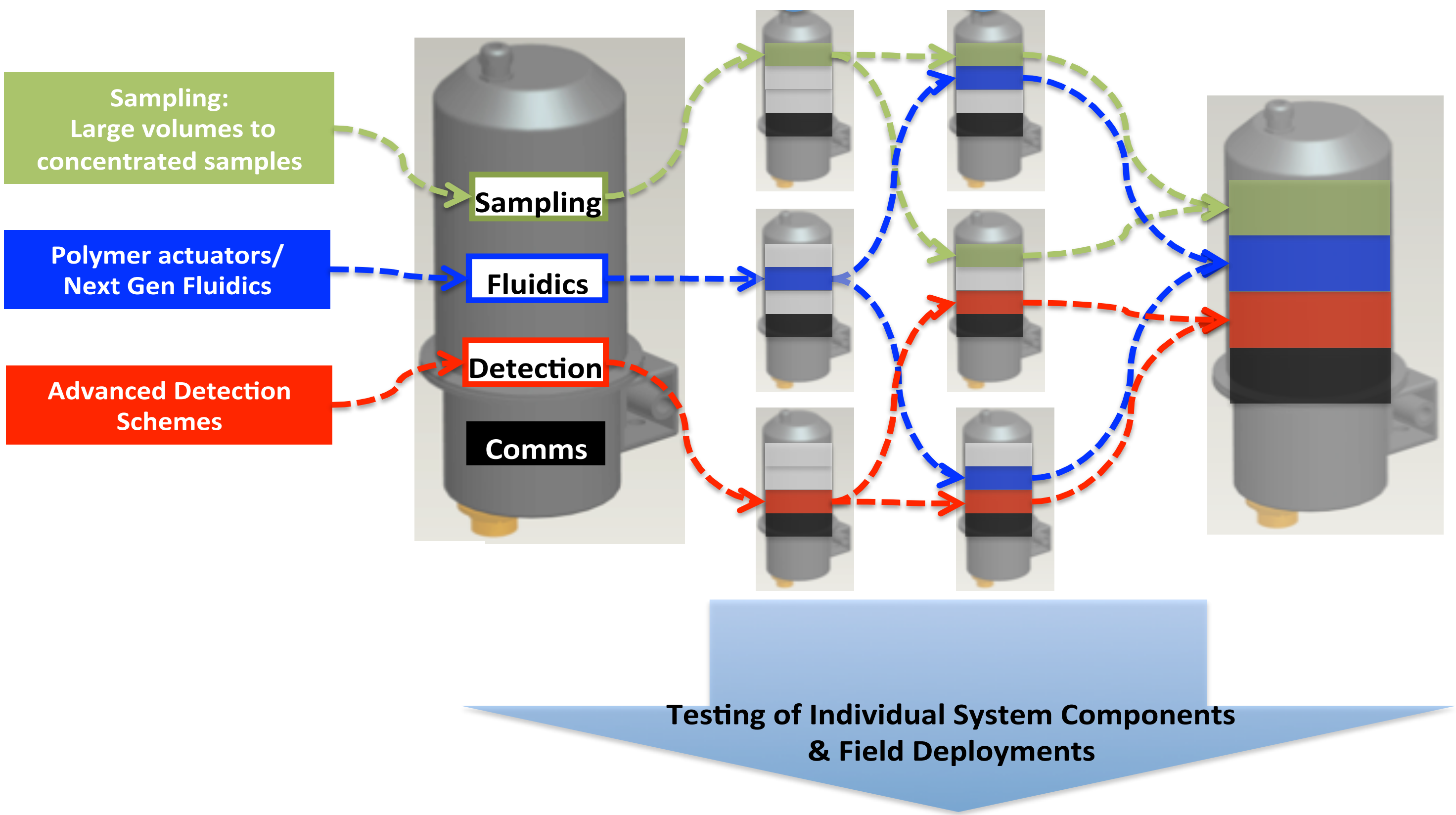
TAL SENSING

"Plug and Play" use of existing systems to test novel platforms



Development of novel detection platform building on existing know-how

Sampling and Pre-Concentration

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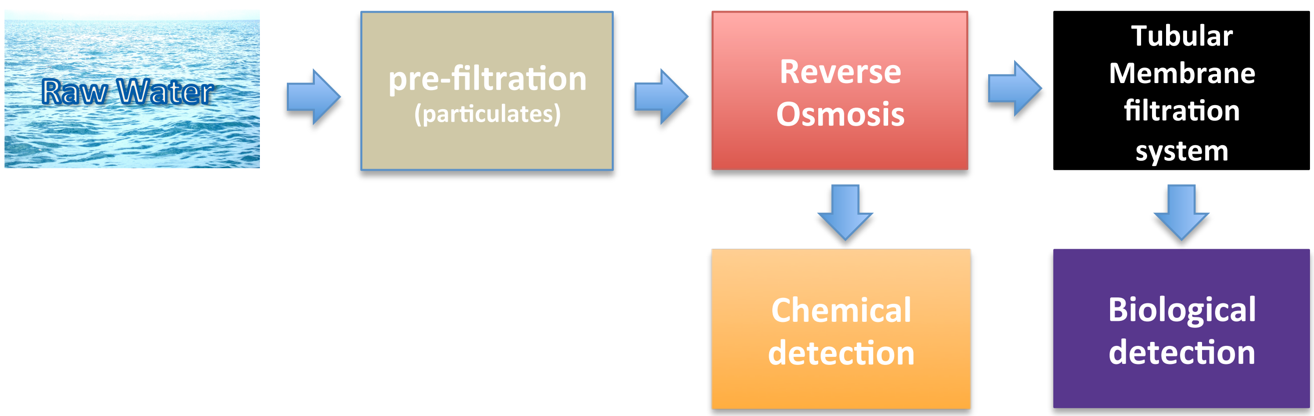
- Portable deployable platforms commonly take **small, mL scale volumes** for analysis
- Milli- and micro-litre samples **may not truly represent large water bodies**
- NAPES sampling systems will facilitate **intake of much larger volumes with sample reduction** and significant pre-concentration using:
  - **Chemical concentration will employ Reverse Osmosis (RO).**
  - **Bacterial concentration will use a tubular membrane based filtration unit (TF).**



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Water image: http://creativity103.com/collections/Water/water_surface.JPG <accessed 11/04/14>

Sampling and Pre-Concentration

Reverse Osmosis (RO) chemical preconcentration

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	Contaminants (ppm)					
	Nitrate	Nitrite	Phosphate	Ammonia	Iron	Manganese
Initial Sample	23.38	0.75	1.79	0.11	0.076	0.024
Run 1	191.86	7.51	3.11	0.21	0.103	0.08
Run 2	74.59	2.42	2.88	0.12	0.039	0.03
Run 3	90.13	2.94	3.07	0.12	0.094	0.028
Run 4	102.08	3.33	2.9	0.12	0.085	0.041
RO Processed water	5.13	0.24	<1	0	0.034	0.013
Conc. factor	**4.4**	**4.4**	**1.6**	**1.09**	**1.1**	**1.7**

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Sampling and Pre-Concentration

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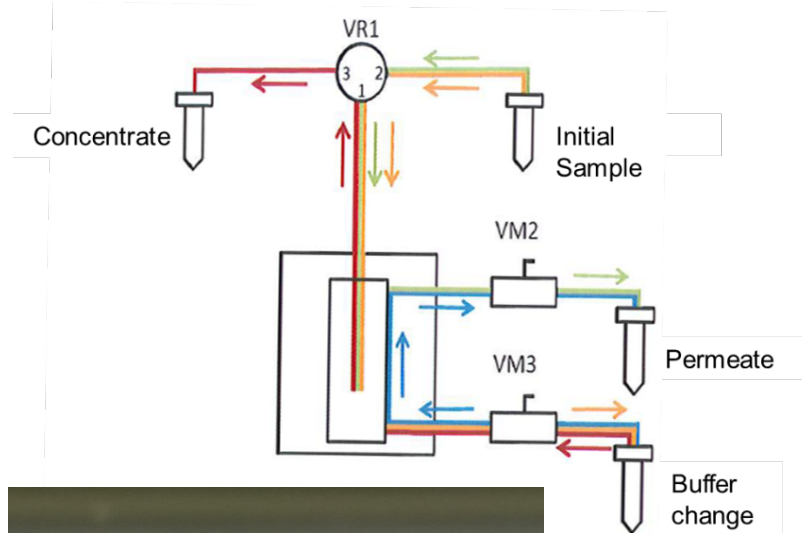
Tubular Membrane Filtration (TF)

- Institut Curie developing a TF system will employ a ceramic membrane system.
- Bacterial concentration **up to 30X**
- Volume throughput of system **1mL/minute**
- **10 mL initial volume** reduced to approx. **100-500 µL**
- Up to **100 fold reduction** in volume in 10 minutes (related sample volume, pressure and pore size).
- Potential for chemical concentration.



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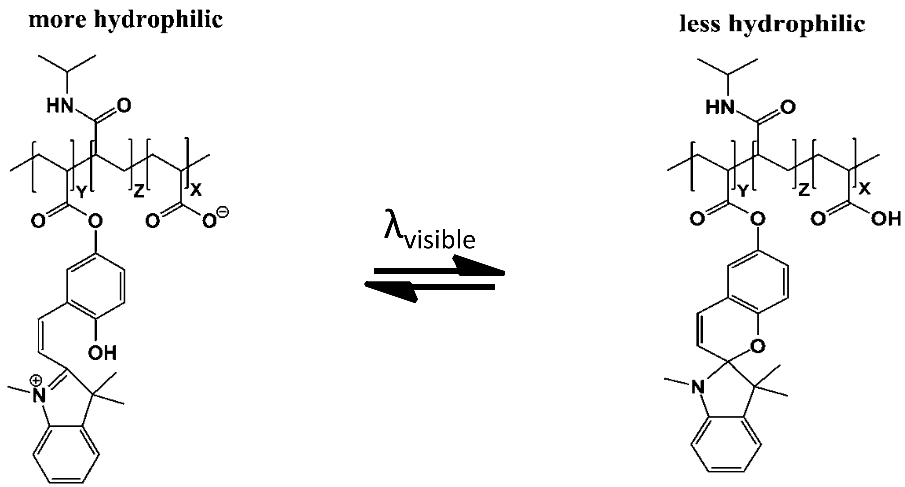
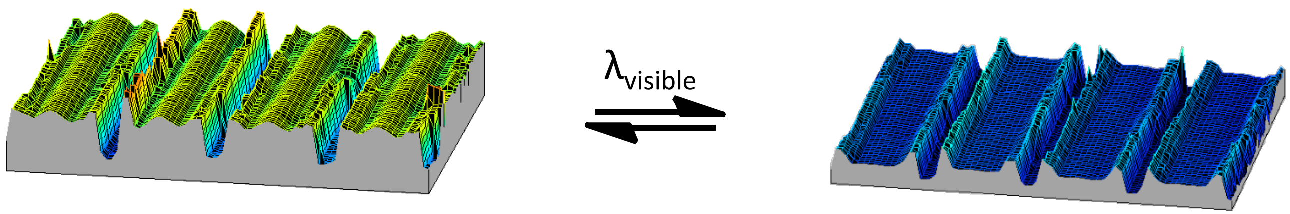
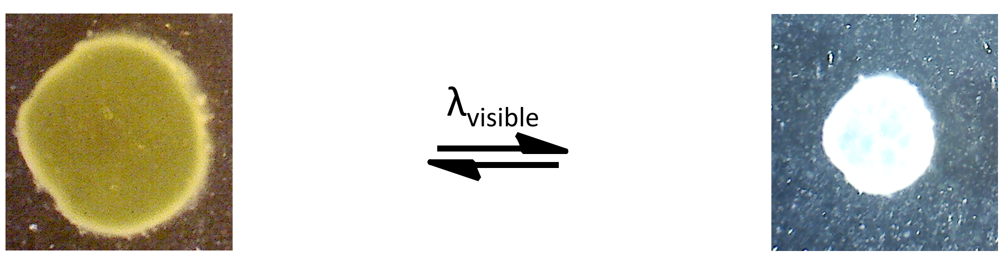
Smart Materials for fluid control

Photoresponsive polymer hydrogels



Molecular switching





Macro-scale change

- Ziolkowski *et al.*, Soft Matter, 2013, 9, 8754–8760.

Smart Materials for fluid control

Microfluidic platforms incorporating smart materials

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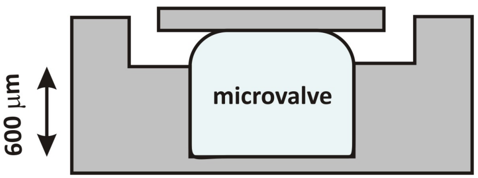

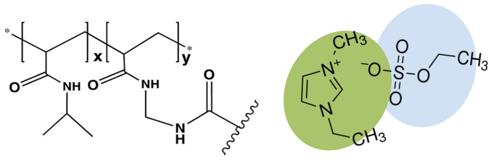

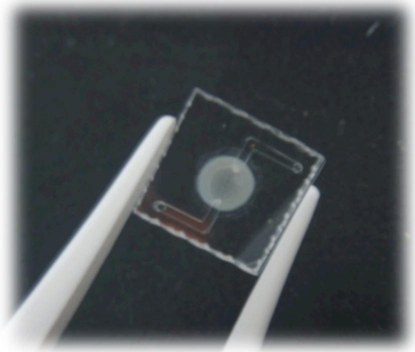

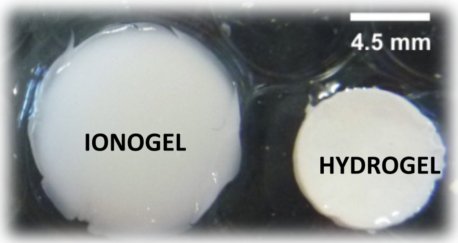

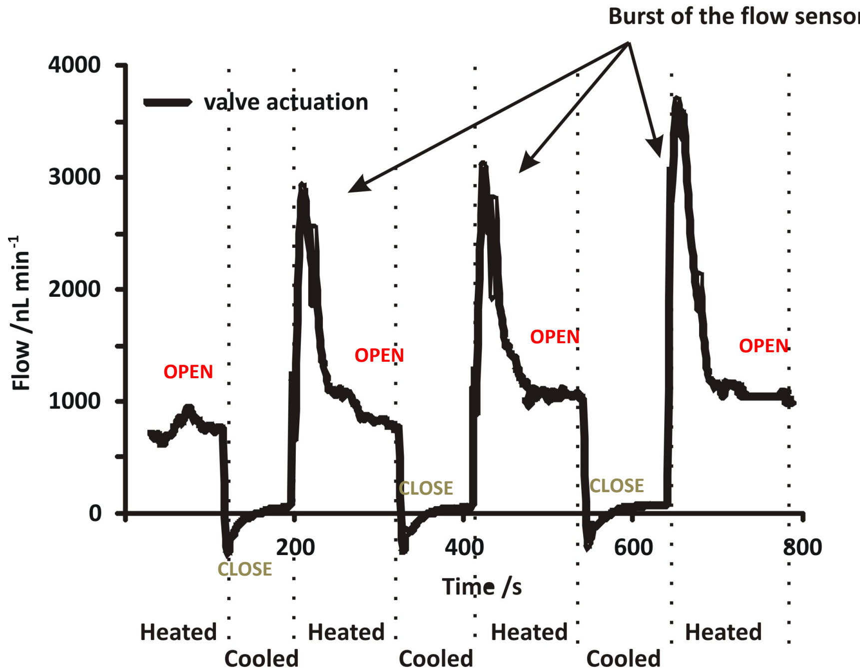

- Actuation in 4s ± 2s
- Recovery in 32s ± 2s
- > 8 cycles
- 33.5 % volume change compared to hydrogels
- Low evaporation process
- Less brittle, Soft (plasticizer)

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Microtechnologies Cooperative Research Center

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Smart Materials for fluid control

Light actuated polymer valves

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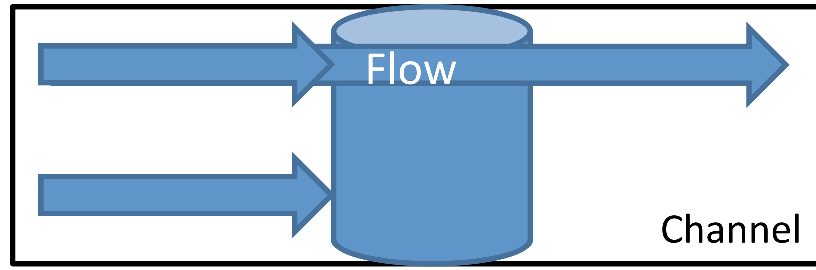
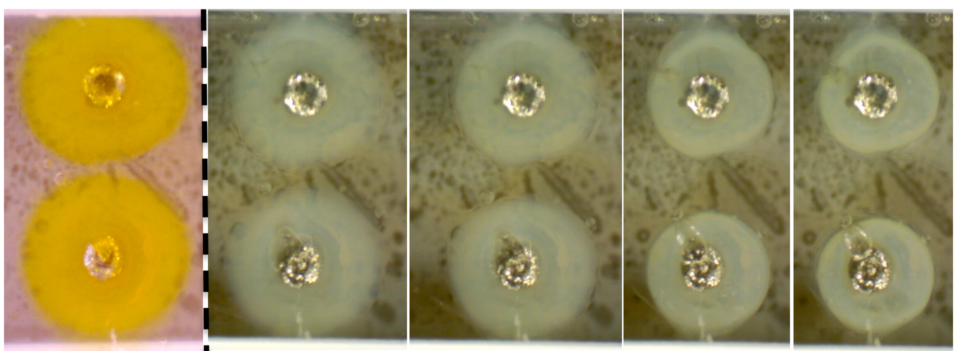
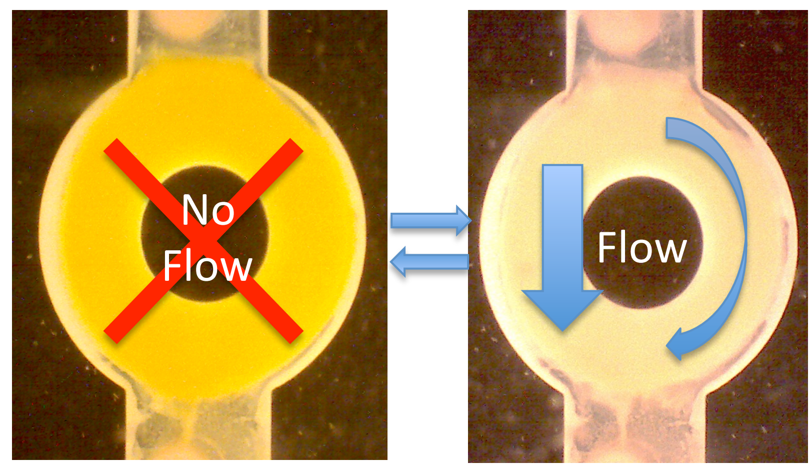
- DCU developed polymer valve systems using light actuated materials.
- **Reproducible** actuation effects over several cycles
- Approx. **10- 40% shrinking** (depending on gel size and light).
- **In-situ polymerisation** of valves





Valve closed/ gel swollen

Valve open/ gel shrunk



DCU

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Smart Materials for fluid control

Polymer valve integrated within microfluidic chips

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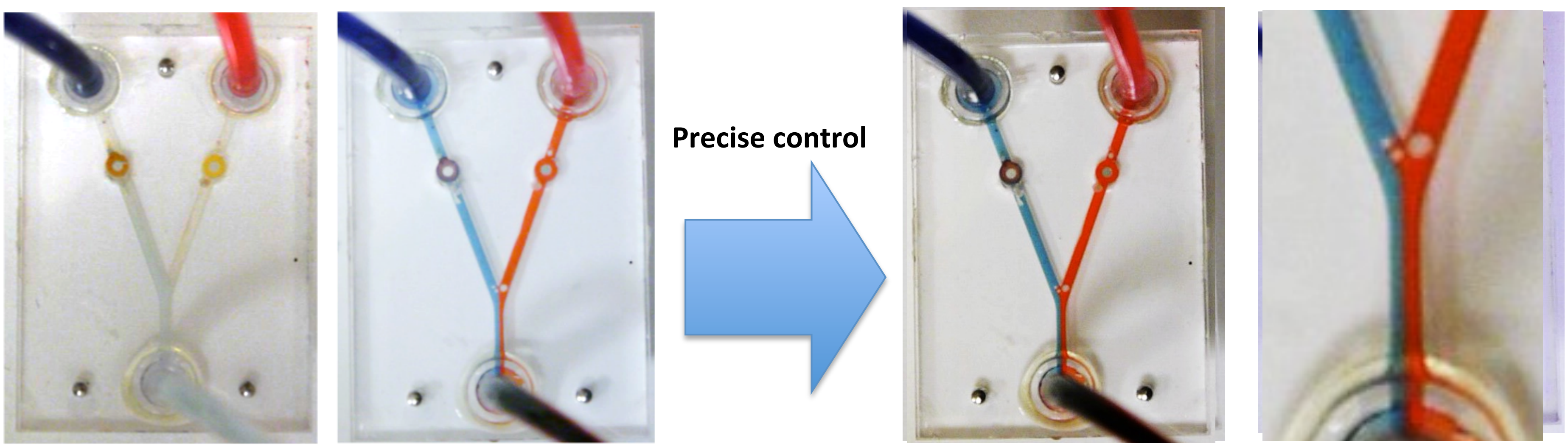
- Integration of valves within microfluidic chips allows for **non-contact** control of valving system
- Surface mount, **low power LED light source** allows for precise illumination of valves with no mechanical components on chip
- **Modular nature of fluidic platform** allows for ease of replacement of fluidic components when replacement required



Valves closed | Valves open | Single channel flow

Smart Materials for fluid control

Photoresponsive ratchets

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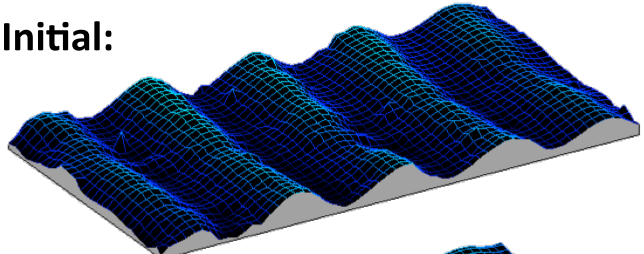
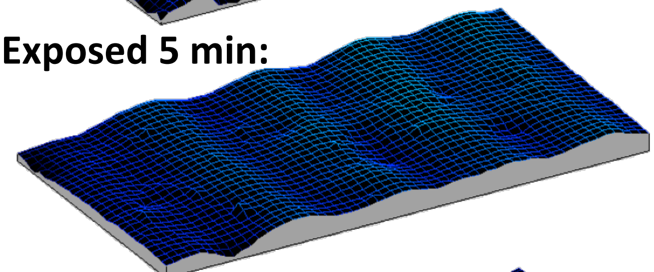
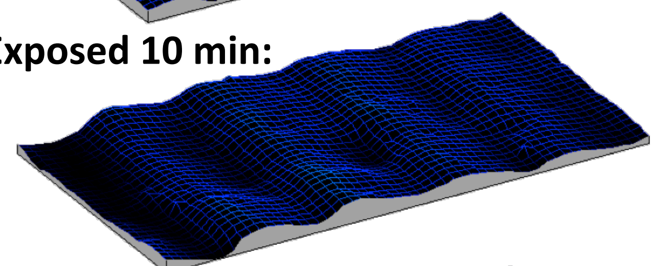
Initial:



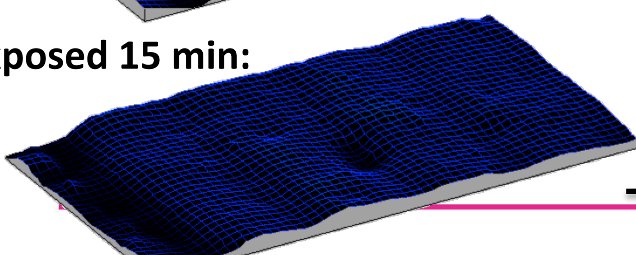
Exposed 5 min:

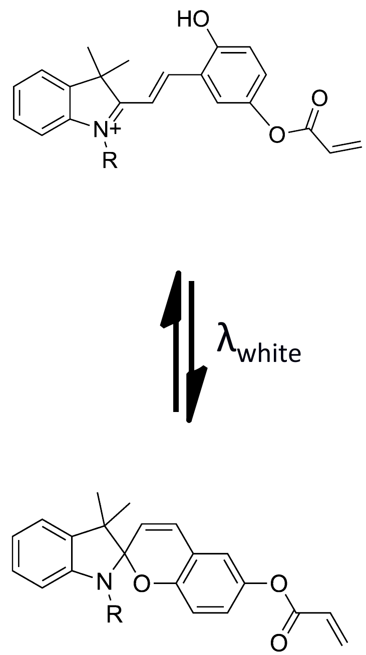


Exposed 10 min:

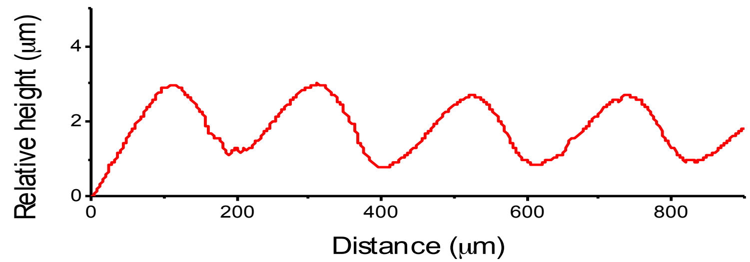


Exposed 15 min:

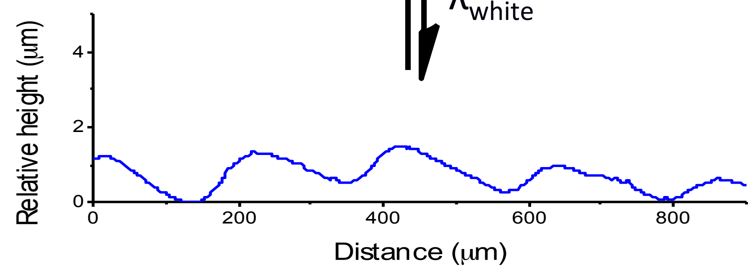




Switchable Mixing



λwhite



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Challenge: Increasing actuation speeds

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Innovative Detection Platforms

Lectin microarray analysis of two strains of C. Jejuni

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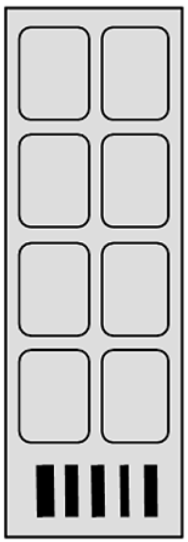
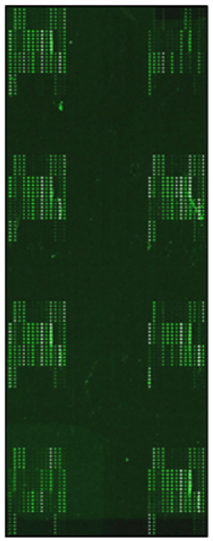
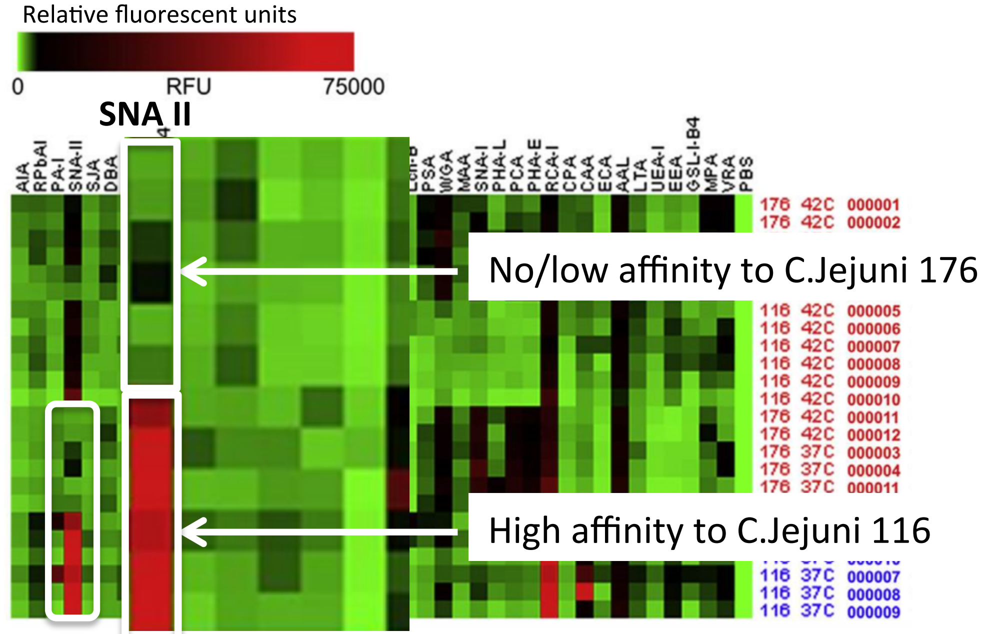


Glass slide:
8 lectin arrays
Per slide.

42 lectins in 6x replications;
256 spots per array



Stained bacteria incubated on lectin array resulting in a specific glycosignature



Fluorescent intensities generate the above heat map based on RFU.

At 37 degree celsius C.Jejuni strain 116 binds to lectin SNA-II with high affinity (red) however strain 176 is not binding to this lectin at all (green/black).

Each pixel is the RFU from one lectin. Each column is a lectin that can detect a specific Glycan.

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Innovative Detection Platforms

On-chip bacterial detection using magnetic bead system

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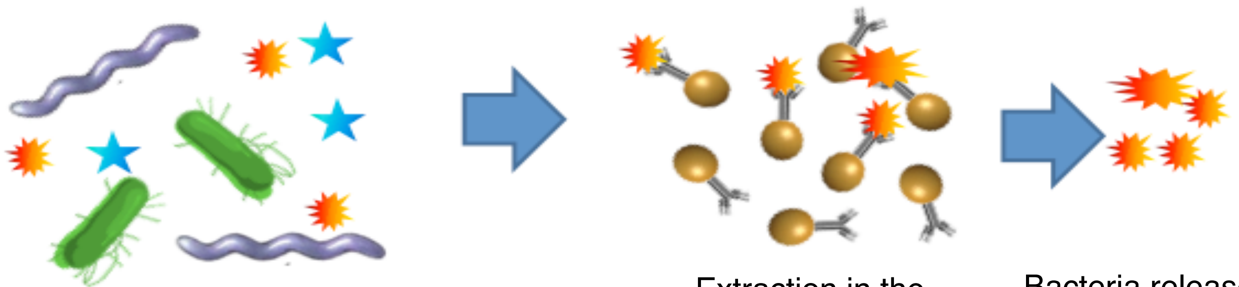

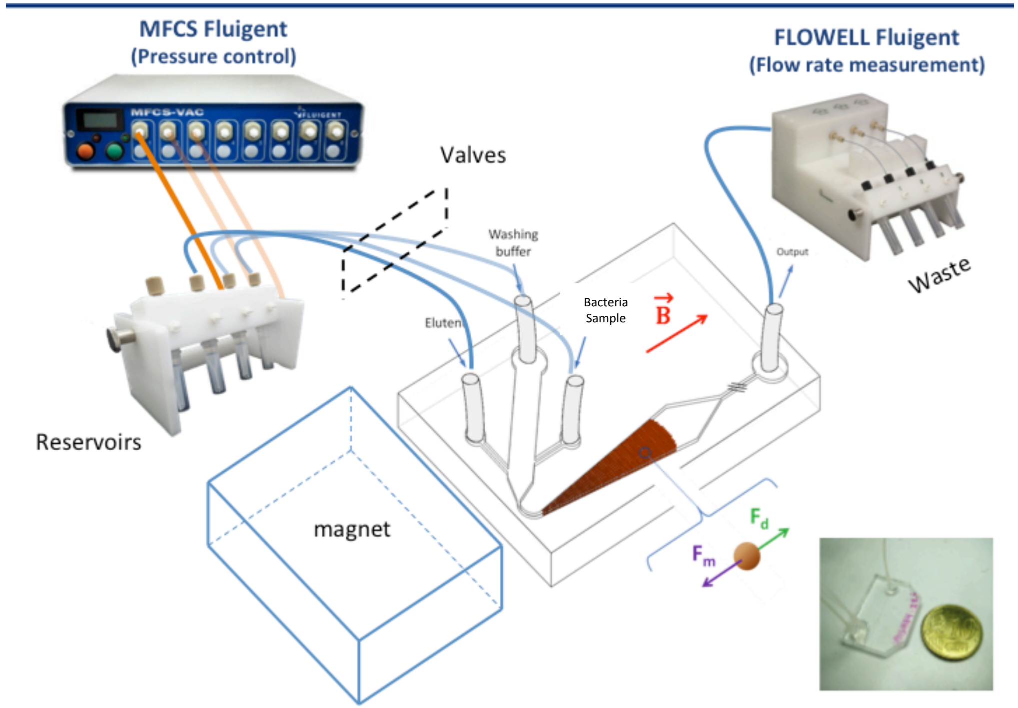

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Innovative Detection Platforms

Microfluidic Magnetic fluidized bed

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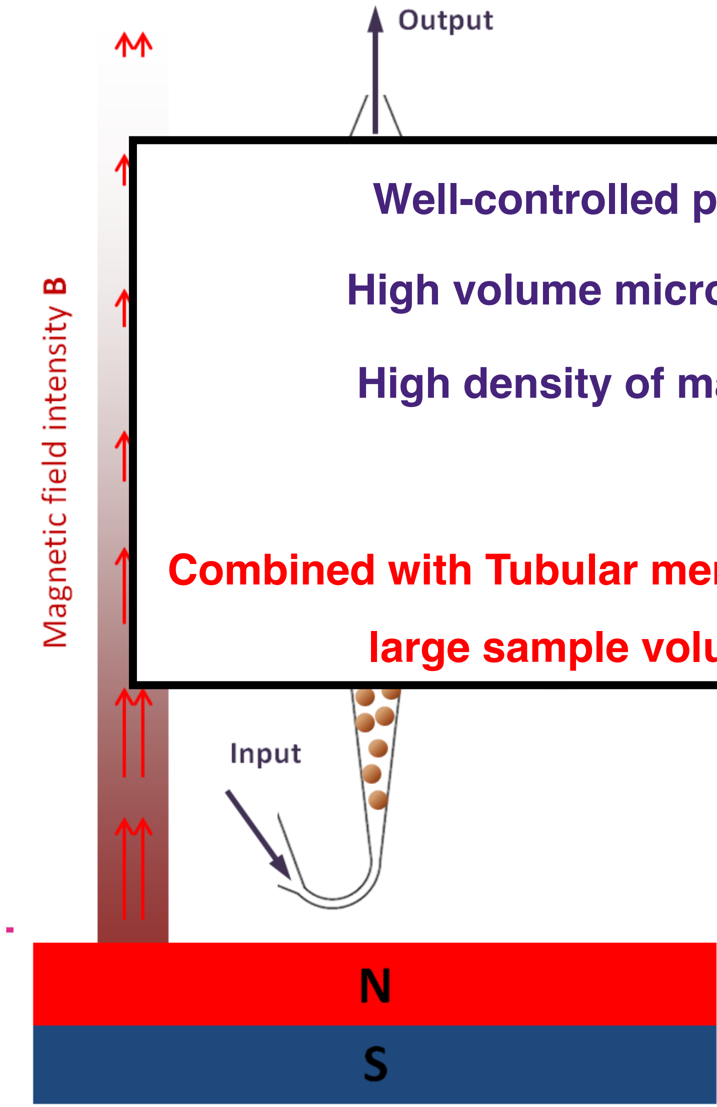
Flow rate : 2 µL/min

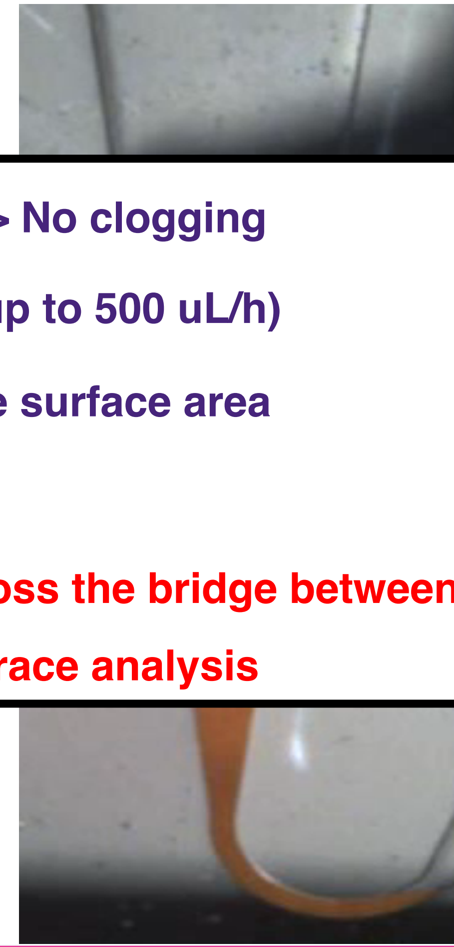


Well-controlled particle re-circulation=> No clogging

High volume microfluidic processsing (up to 500 uL/h)

High density of magnetic beads => large surface area

Combined with Tubular membrane filtration to cross the bridge between large sample volume and microfluidic trace analysis



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Innovative Detection Platforms

Reflective Phantom Interface (RPI) Method

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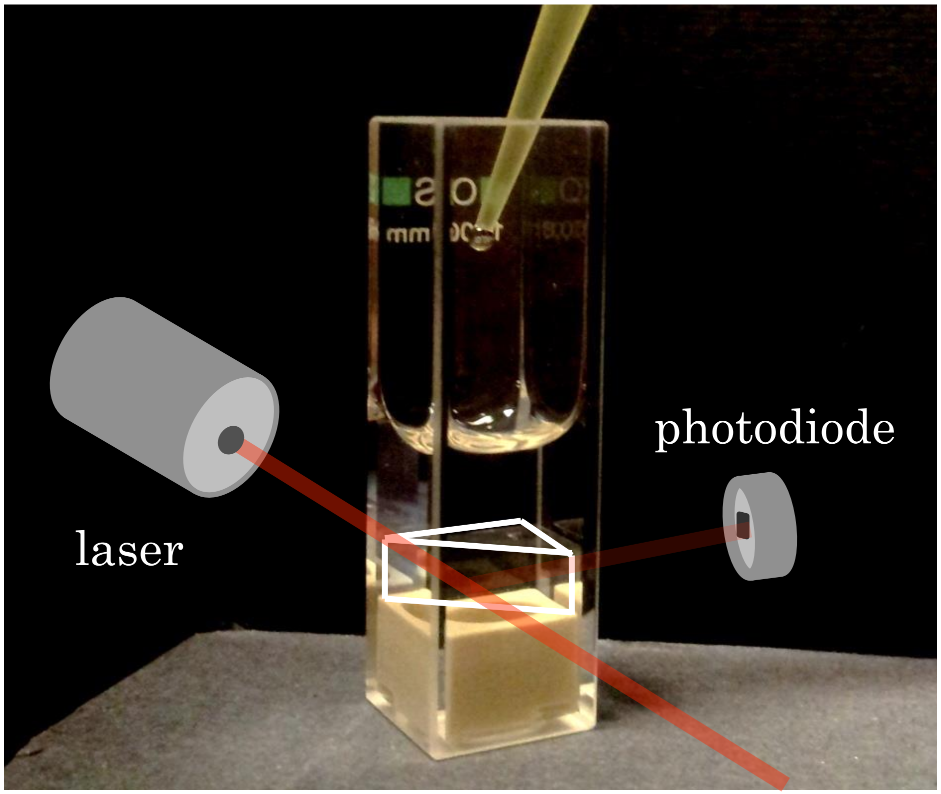

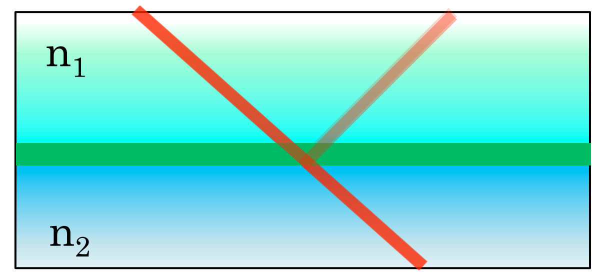

Surface reflectivity is initially very low due to refractive index matching of polymer to water

Binding to surface significantly alters refractive index and increases reflectivity

- F. Giavazzi et al., Proc Natl Acad Sci USA, 110 (2013) 9350-9355
- F. Giavazzi et al., Biosensors and Bioelectronics, in press (2014), DOI: 10.1016/j.bios.2014.02.077

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Innovative Detection Platforms

Bacterial detection by RPI surface

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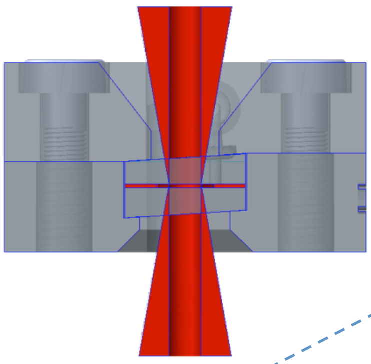
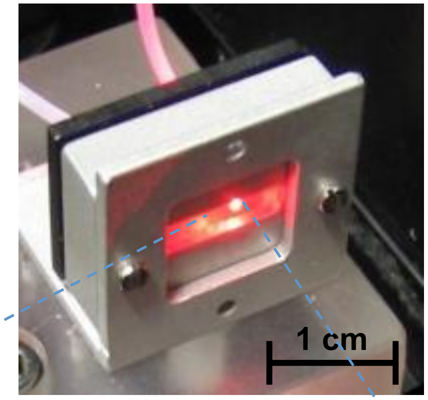
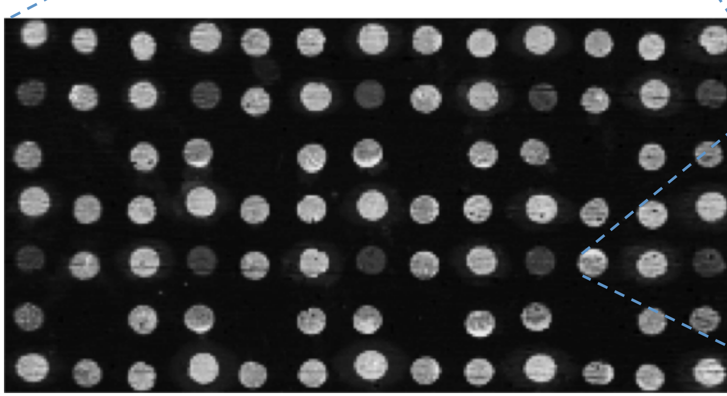
Design and construction of fluidic module



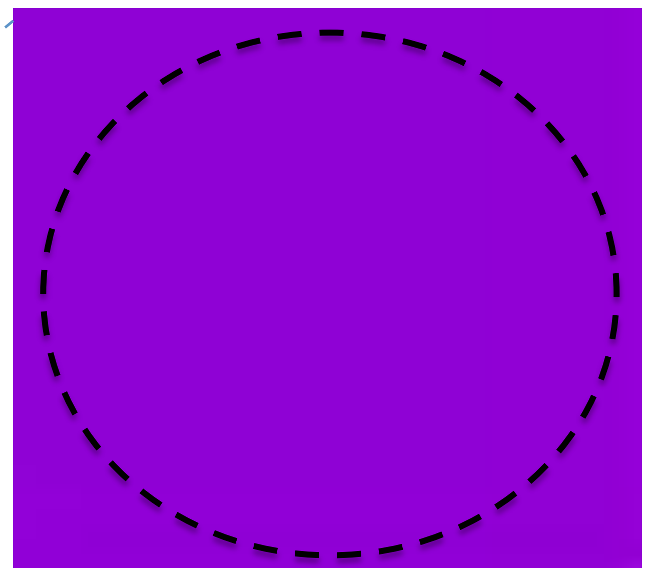


- Aquila Bioscience and University of Milan producing RPI surfaces with strain specific bonding based upon lectin coatings.



Evaluation of the optical platform

Preliminary trial on bacteria detection



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Aquila Bioscience

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Prototype Development

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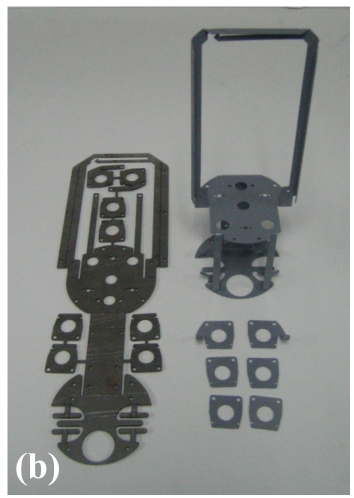
- Dublin City University(DCU) will lead the production of prototype platforms
- Design and engineering of platform for scalable production
- Commercialisation activities in parallel with TEL to carry out market research and influence final system construction.

Design (CAD, Solidworks)



Manufacture of system (3d printing, laser cut frames, components)

Small scale Prototype production line (test scalability)

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Prototype Field deployment

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- Industry-Academic Collaborative activity
- TE Laboratories and Williams Industrial Services and DCU will lead Prototype testing and deployment.

➢ **Phase 1:** Real water samples will be collected for lab based testing of prototypes

➢ **Phase 2:** Field trials at Waste water treatment plants and water supply reservoirs

- Potential for deployments outside of Ireland with partners (e.g Italy, Spain)

Example of DCU coordinated deployment of autonomous phosphate system in Irish river.

DCU TelLab WIS Williams Industrial Services SEVENTH FRAMEWORK PROGRAMME

DCU Led Commercialisation: A Case Study

AMBISENSE
AUTONOMOUS GAS MONITORING

Funding history

2011-2013: Concept & validation

2013-2014: Commercialisation

2014: Incorporation and seed capital

epa Environmental Protection Agency

ENTERPRISE IRELAND where innovation means business

A globally deployed technology: Ireland, UK, Australia, Brazil… more to come…

Concluding remarks

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NEXT GENERATION ANALYTICAL PLATFORMS FOR ENVIRONMENTAL SENSING

- NAPES aims to develop novel materials science and microfluidic platforms while developing a **commercial strategy** in parallel
- Use of **readily sourced electronics and raw materials** to ensure **Scalability** of modules and economic design of final device.
- Combination of **new materials technologies, biochemistry and microfluidics** to produce **low cost sensing platforms** allowing greater accessability to technology.

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NAPES Consortium

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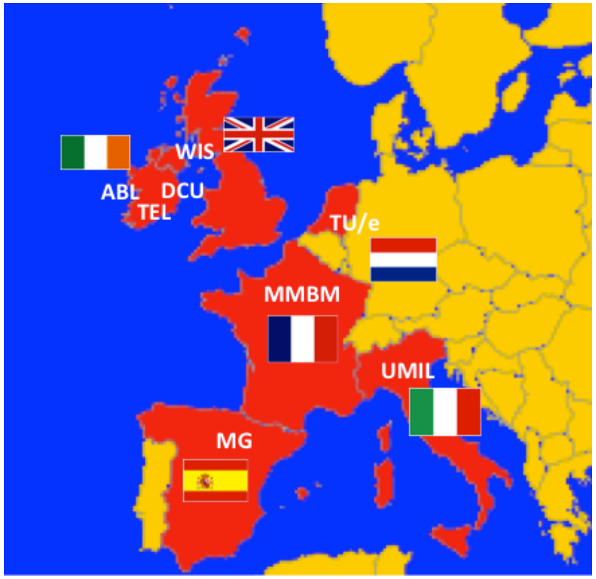

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Acknowledgements

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Project partners:

Eindhoven University of Technology (NL)
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TE Laboratories (IE)
Williams Industrial Systems (UK)
University of Milan (IT)
Aquila Biosciences (IE)

Project Technical Officer; Sergey Gordeyev

Project Officer; Hans-Hartmann Perersen

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MAM-14 Organising Committee

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