NAPES

NEXT GENERATION ANALYTICAL PLATFORMS FOR ENVIRONMENTAL SENSING

Next generation Analytical Platforms for Environmental Sensing

New technologies for old challenges

Simon Coleman

Dublin City University

Overview of Talk

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NEXT GENERATION ANALYTICAL PLATFORMS FOR ENVIRONMENTAL SENSING

1. NAPES Consortium
2. Our Challenge
3. NAPES Platform
4. NAPES Research Strategy
    - Sampling and Pre-concentration
    - Smart Materials for Fluid Handling
    - Innovative Detection Platforms
    - Prototype Development and Deployment
5. Concluding Remarks

NAPES Consortium

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Williams Industrial Services

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Microtechnologies Cooperative Research Center

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Our Challenge

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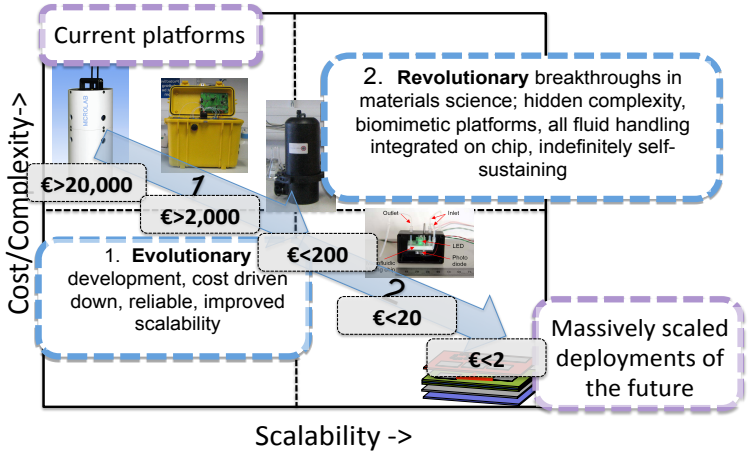
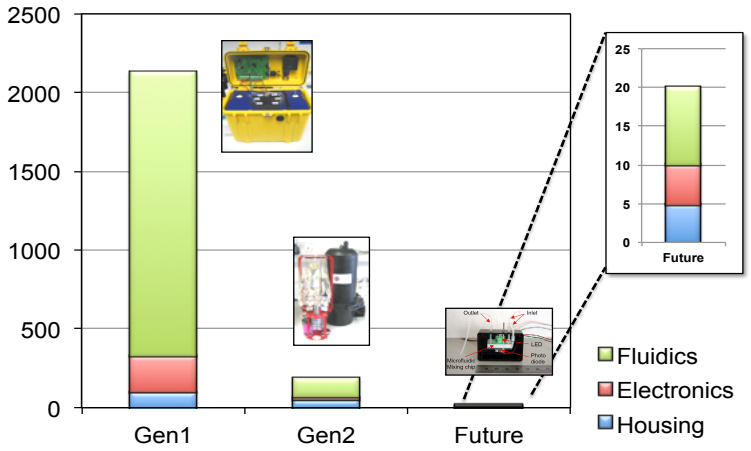
1. **Low-cost, autonomous, deployable platforms**.

2. Enhancing current platforms through:

- **Innovative sampling and target pre-concentration strategies** for more comprehensive analysis of Water supplies.
- Bringing together **novel smart materials technologies** for fluid manipulation and flow control within microfluidic platforms.
- Target detection using **highly specific detection methods** for determination of bacterial (e.g *E.coli*) and chemical (e.g phosphate, surfactants) contaminants.





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NAPES Platform

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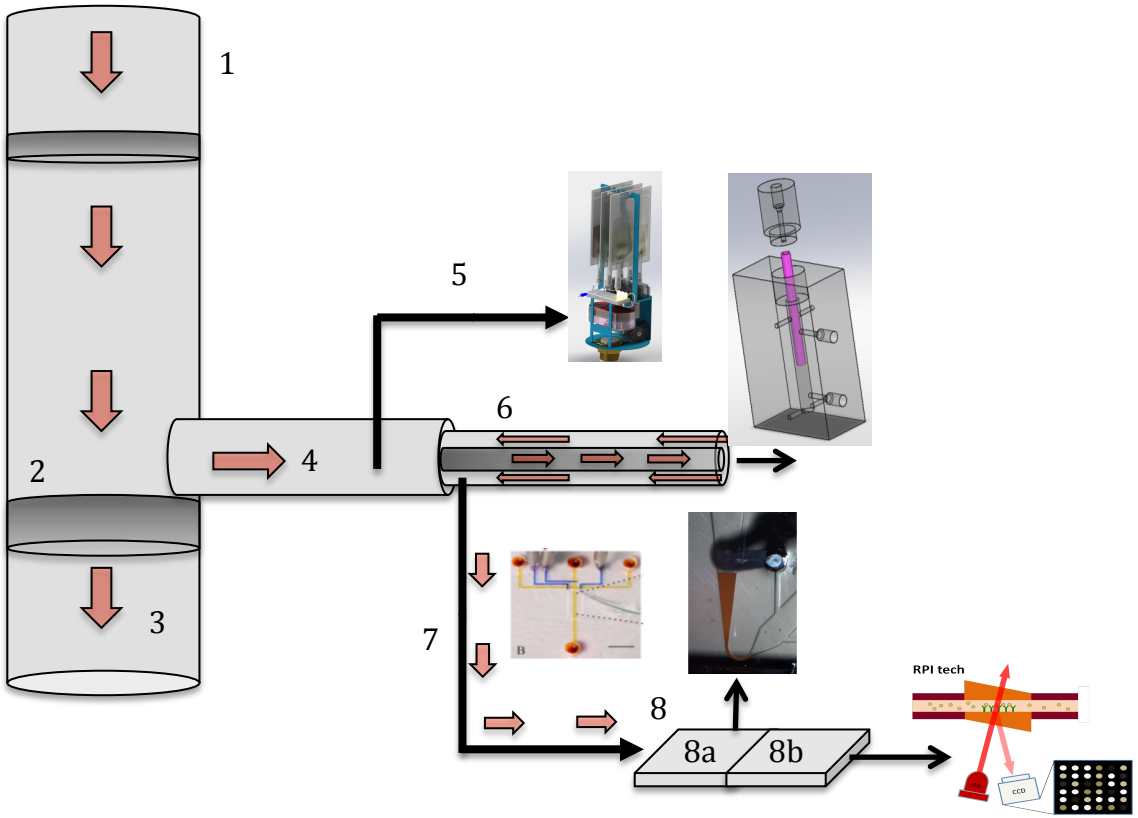

1. Raw sample pre-filtration
2. Reverse osmosis (bacterial/chemical concentration)
3. Purified water stream (water source)
4. Concentrated sample stream
5. Chemical analysis of sample (phosphate, nitrate, nitrite, pH)
6. Tubular membrane filtration (bacterial concentration)
7. Microfluidic sample extract
8. Detection platforms;
   8a: Bead based bacterial capture
   8b: Refractive index based detection

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NAPES Research strategy

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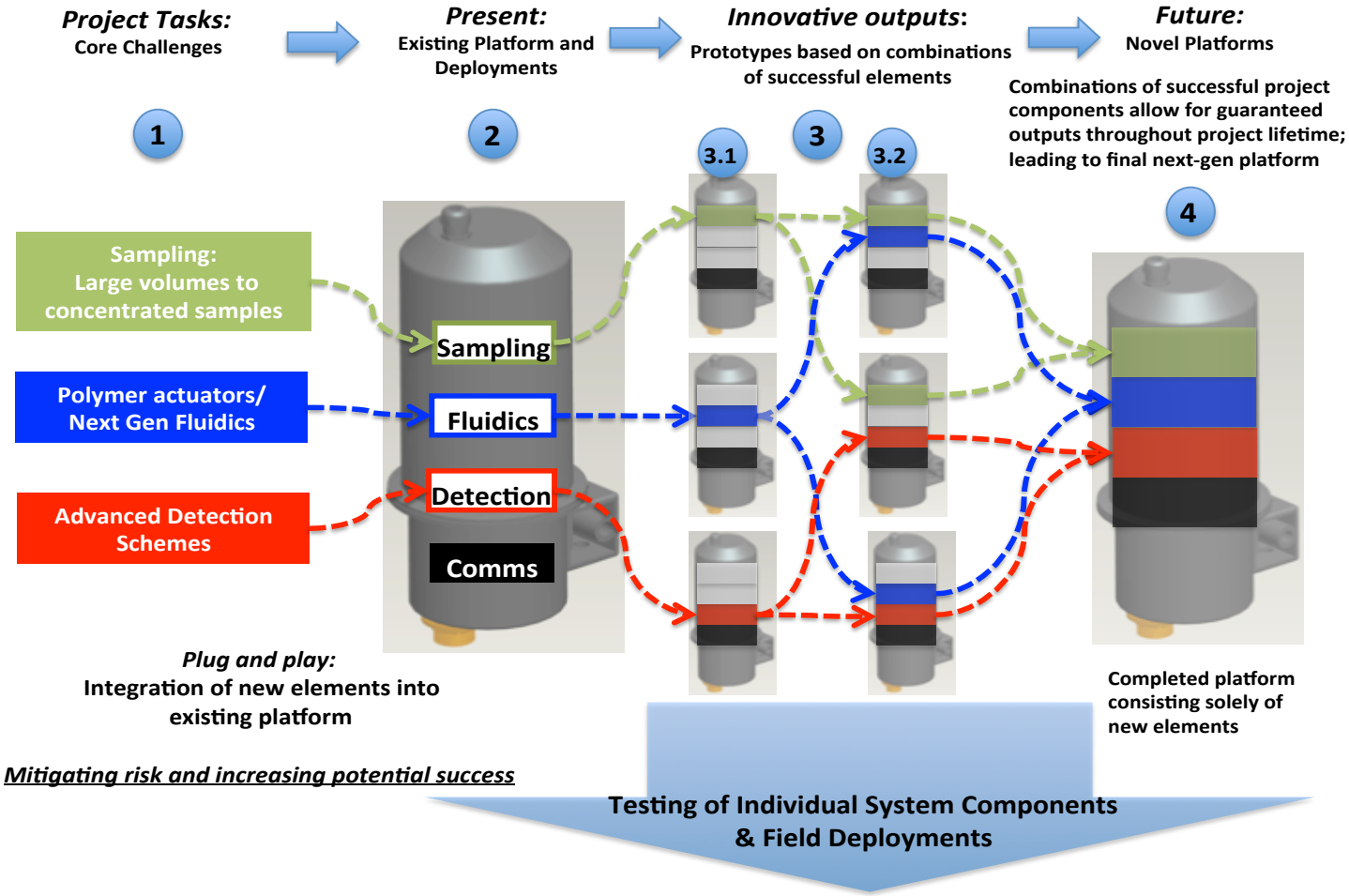

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Sampling and Pre-Concentration

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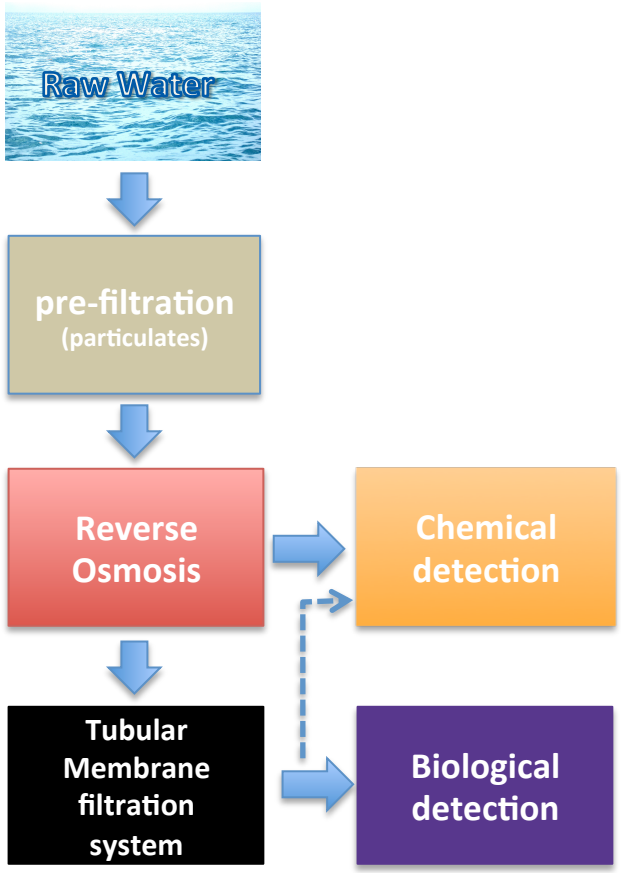
- Commonly, portable deployable platforms take small (millilitre scale) volumes for analysis
- Test protocols often call for detection of **ONE CFU/SPORE** in 100ml – 10L. Microlitre and millilitre sampling is redundant for these specifications.
- Sampling system will process larger volumes (5-10 litres) with sample reduction to 100 milliliter scale and significant concentration in analytes.
- Reverse Osmosis (RO) and a tubular membrane based filtration unit (TF) will be employed for concentration of chemical and bacterial targets.



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

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Sampling and Pre-Concentration

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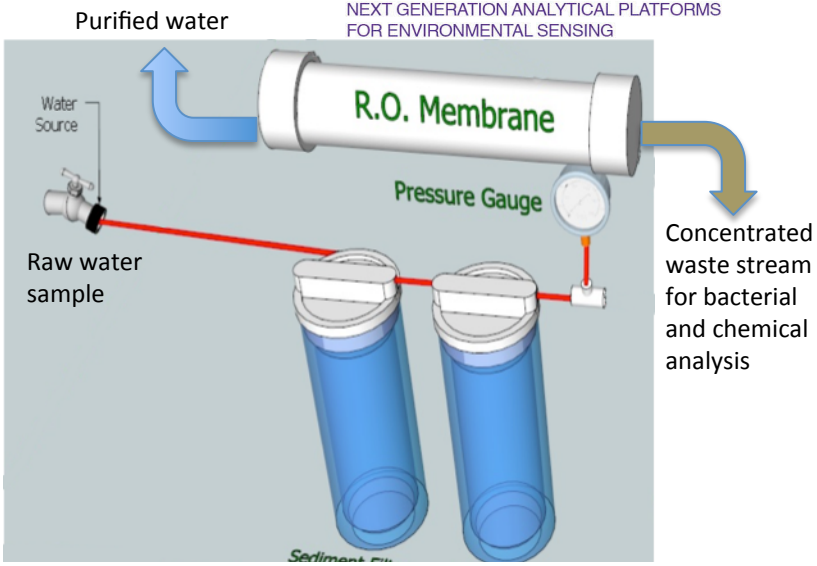
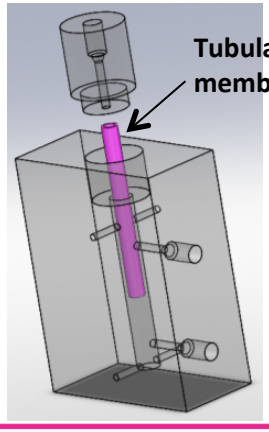
Reverse Osmosis (RO)

- RO system using “waste” stream for sample concentration
- Concentration increases of chemical components 1.5x –3x
- Volume throughput: 15L/hour (purified water)
- Final volume (concentrated chemical/biological targets): approx 2-5L



Tubular Membrane Filtration (TF)

- Ceramic membrane system.
- Concentration increases of up to 50X
- Volume throughput:1mL/minute
- 50% (5 mins) - 500% (1 hr) reduction in volume related to processing time
- Final volume (conc. chemical/biological targets): 100-500 µL



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Smart Materials for fluid Handling

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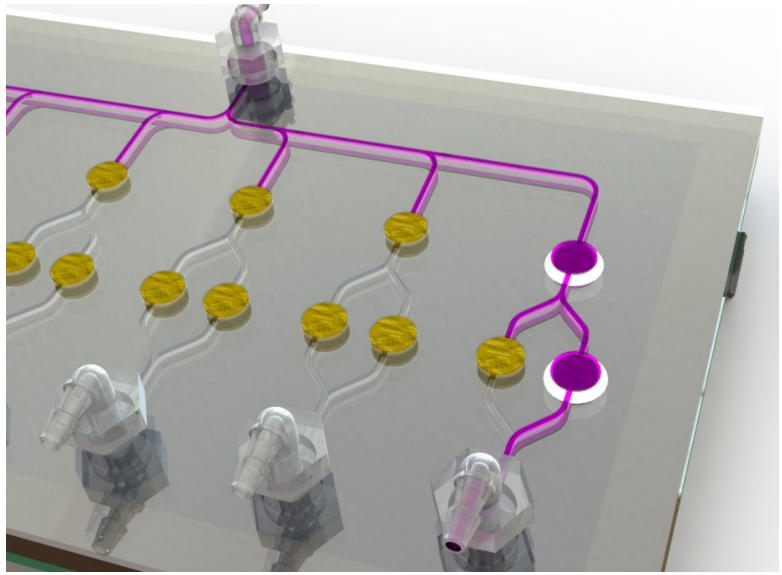
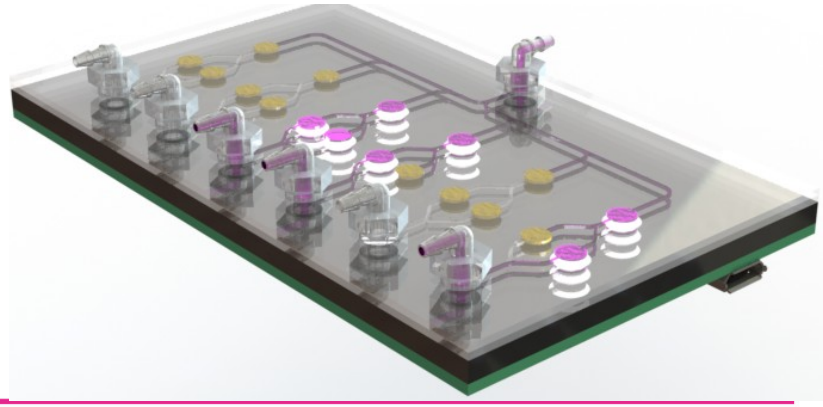
- Production of stimuli responsive materials for microfluidic applications.
- Microvalves allow for complex and precise control over fluid flow across microfluidic platform.
- Micrometer dimensions allow for complex arrays of valves, not currently possible with conventional valves.
- Low energy requirements through LED functionality.
- Low cost, no maintenance





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Smart Materials for fluid Handling

Light actuated polymer valves

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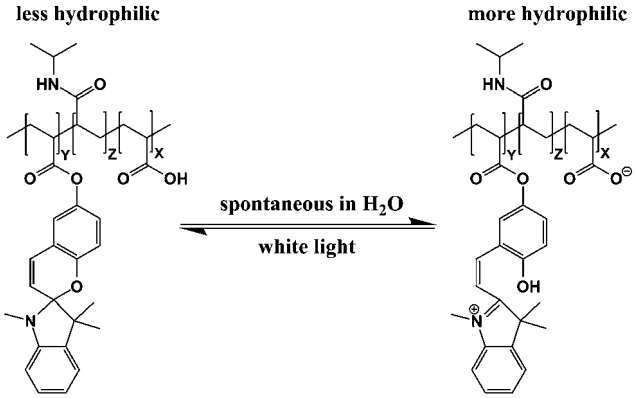
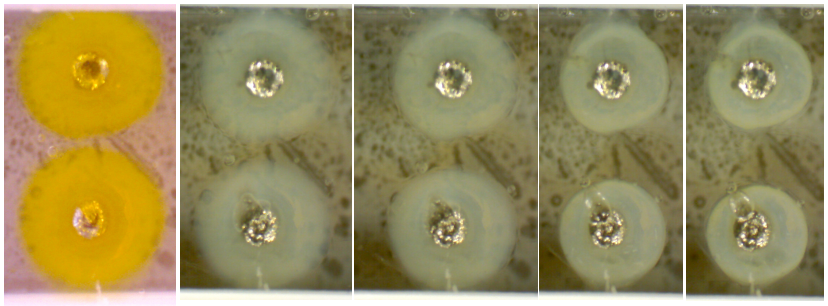
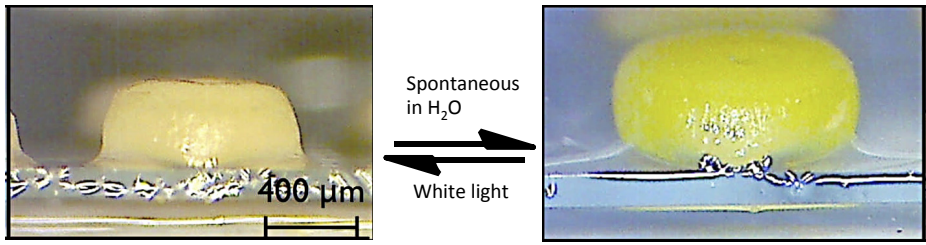
- DCU has developed light actuated polymer valve systems based upon spiropyran
- Shrinking upon exposure to white light. Spontaneous re-swelling due to self protonation (acrylic acid)
- Reproducible actuation effects over several cycles
- Approx. 10- 25% shrinking in 5mins (depending on gel size)
- Work in neutral (pH 7) and acidic (pH 1) conditions.



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





Czugala et al., Sens. Act. B, 2013, DOI 10.1016/j.snb.2013.12.072.

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Smart Materials for fluid Handling

Photoresponsive coatings

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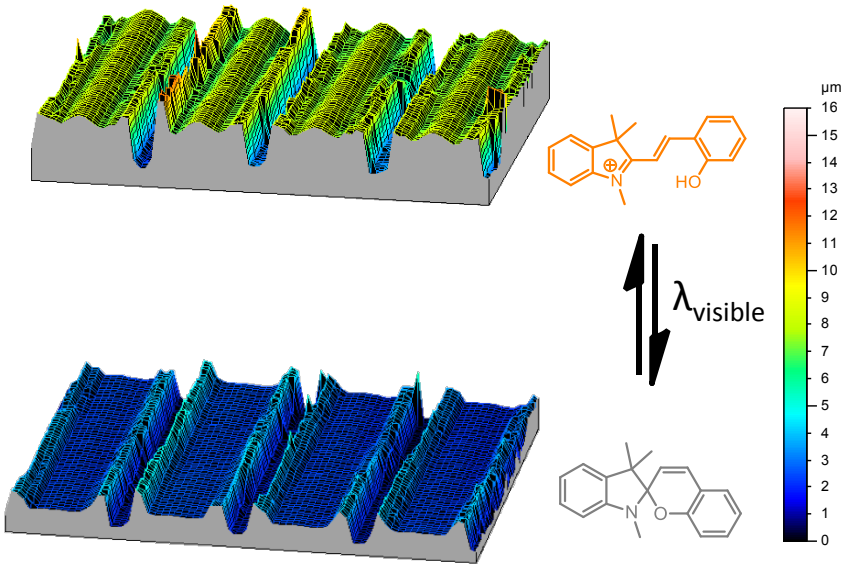
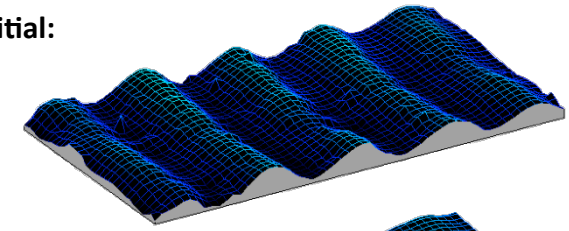
In water, pH = 2.7



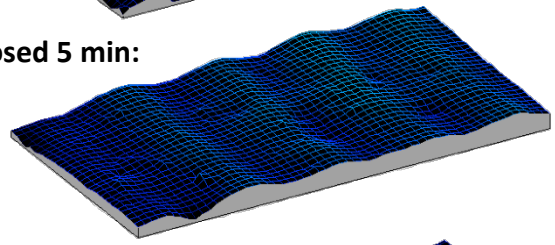
In water, pH = 7.0

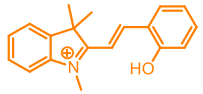
Microscale mixing

Initial:

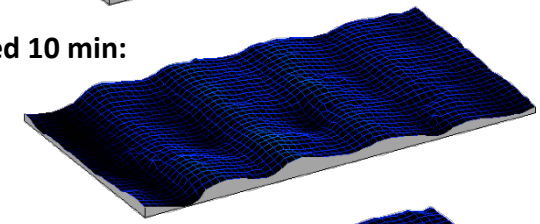


Exposed 5 min:

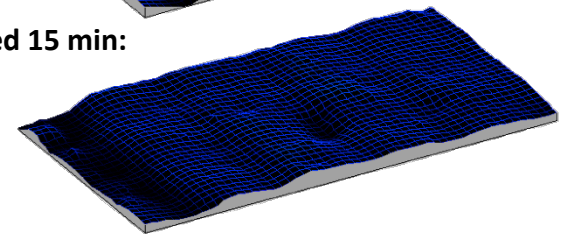


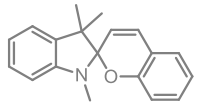


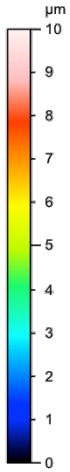
Exposed 10 min:



Exposed 15 min:







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Smart Materials for fluid Handling

Thermoresponsive ionogel valves and integration of valves into microfluidic platforms

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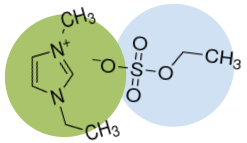
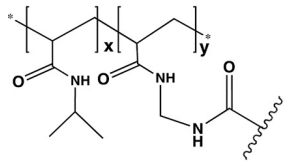
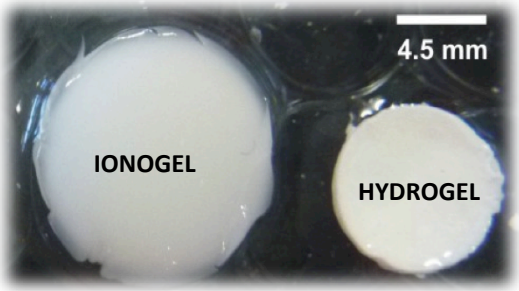
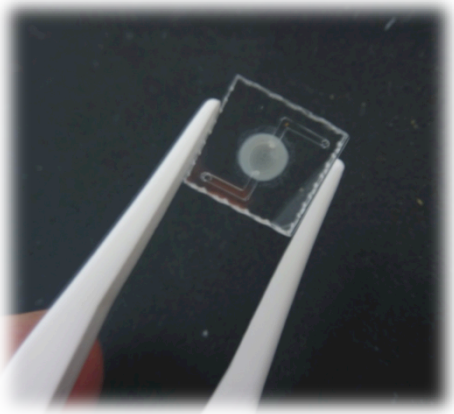


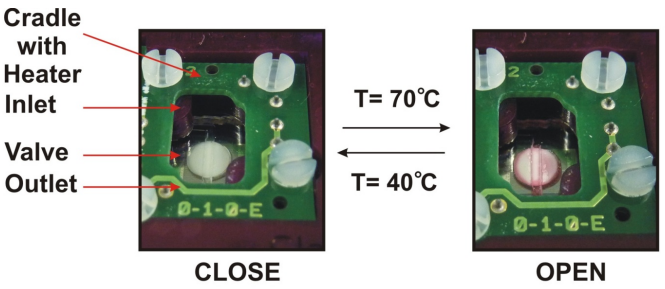
Ionic Liquid

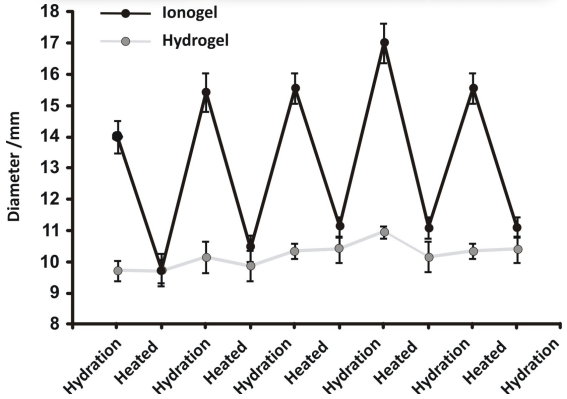


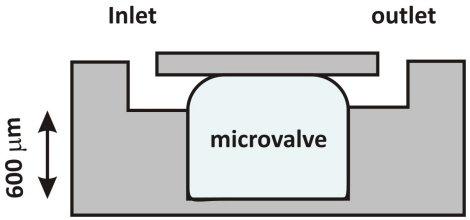
Polymer matrix

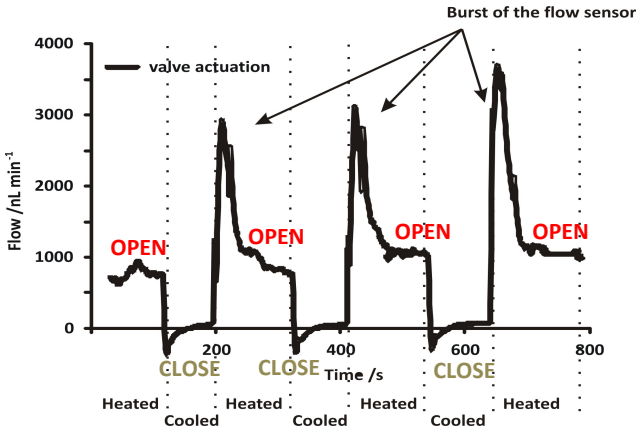












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Innovative Detection Platforms

Highly specific bacterial detection: Lectin microarrays and phage display

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- Selection of lectins to be selected that can discriminate between strains of bacteria
- Production of Bacteriophages expressing specific binding for pre-selected strains of bacteria.
- Both approaches will detect ***E.coli*** **O157:H7,** ***E.coli*** **O6, Enterbacter spp and Pseudomonas aeruginosa** and additionally the potential to examine shiga-like toxins produced by *E.coli* O157:H7 will be examined by phage display.
- Optimised lectin and phage derivatives will be used in conjunction with MMBM and UMIL detection platforms

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Innovative Detection Platforms

Lectin microarray analysis of two strains of C. Jejuni

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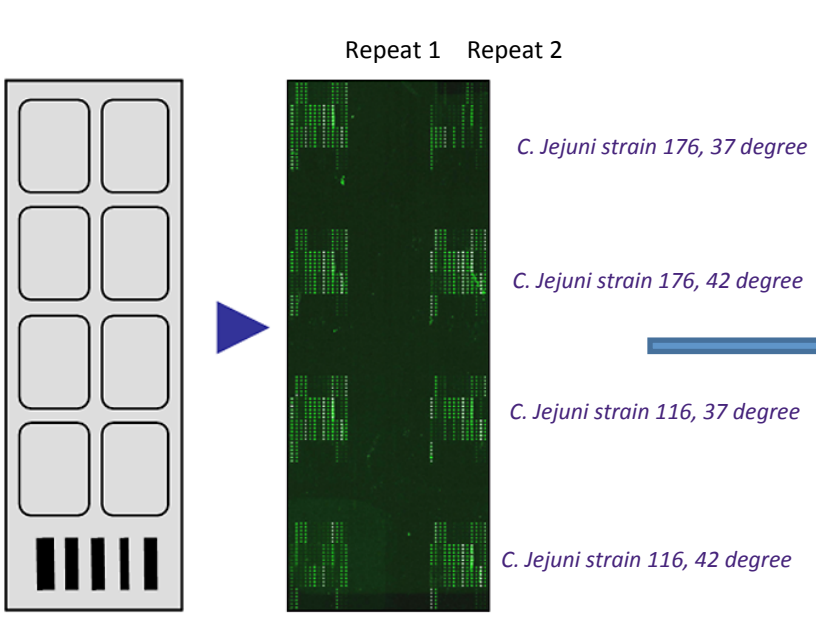
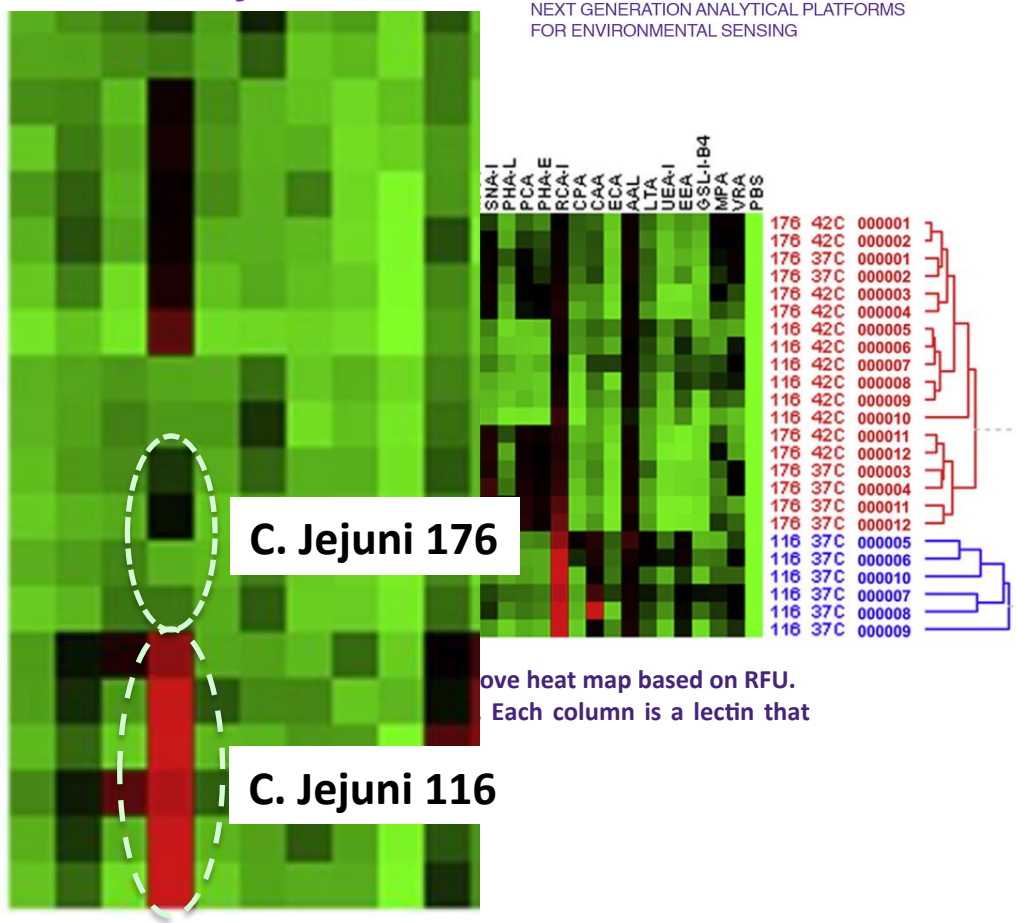


Glass slide
8 lectin arrays
Per slide.

42 lectins in 6x replications;
256 spots per array

Stained bacteria incubated on lectin array resulting in a specific glycosignature



ove heat map based on RFU.
Each column is a lectin that

At 37 degree celcius 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).

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Innovative Detection Platforms

On-chip bacterial detection using magnetic bead system

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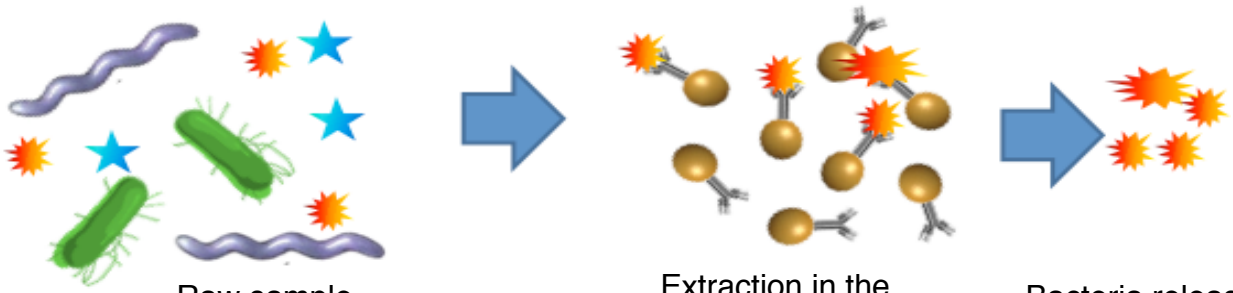

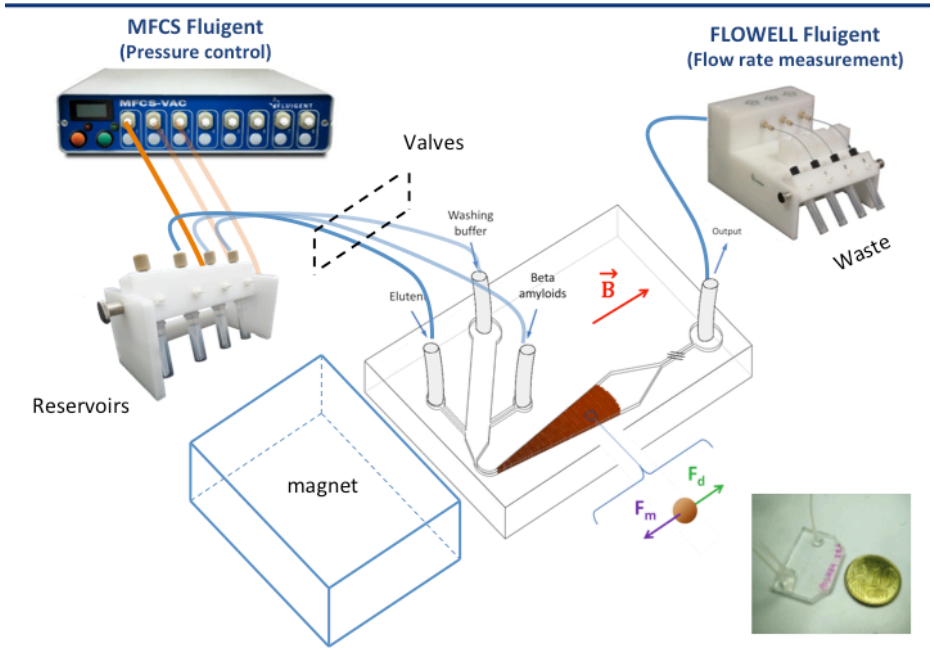

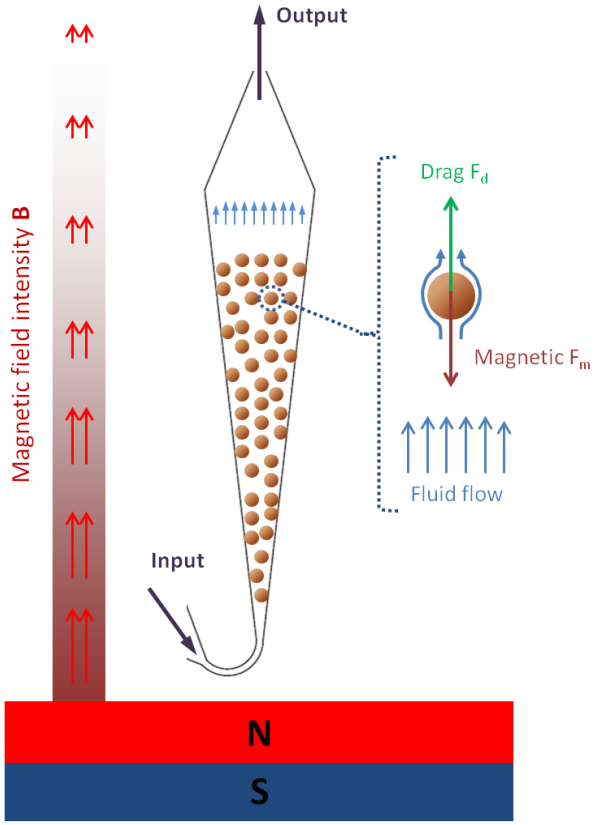

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Innovative Detection Platforms

Reflective Phantom Interface (RPI) Method

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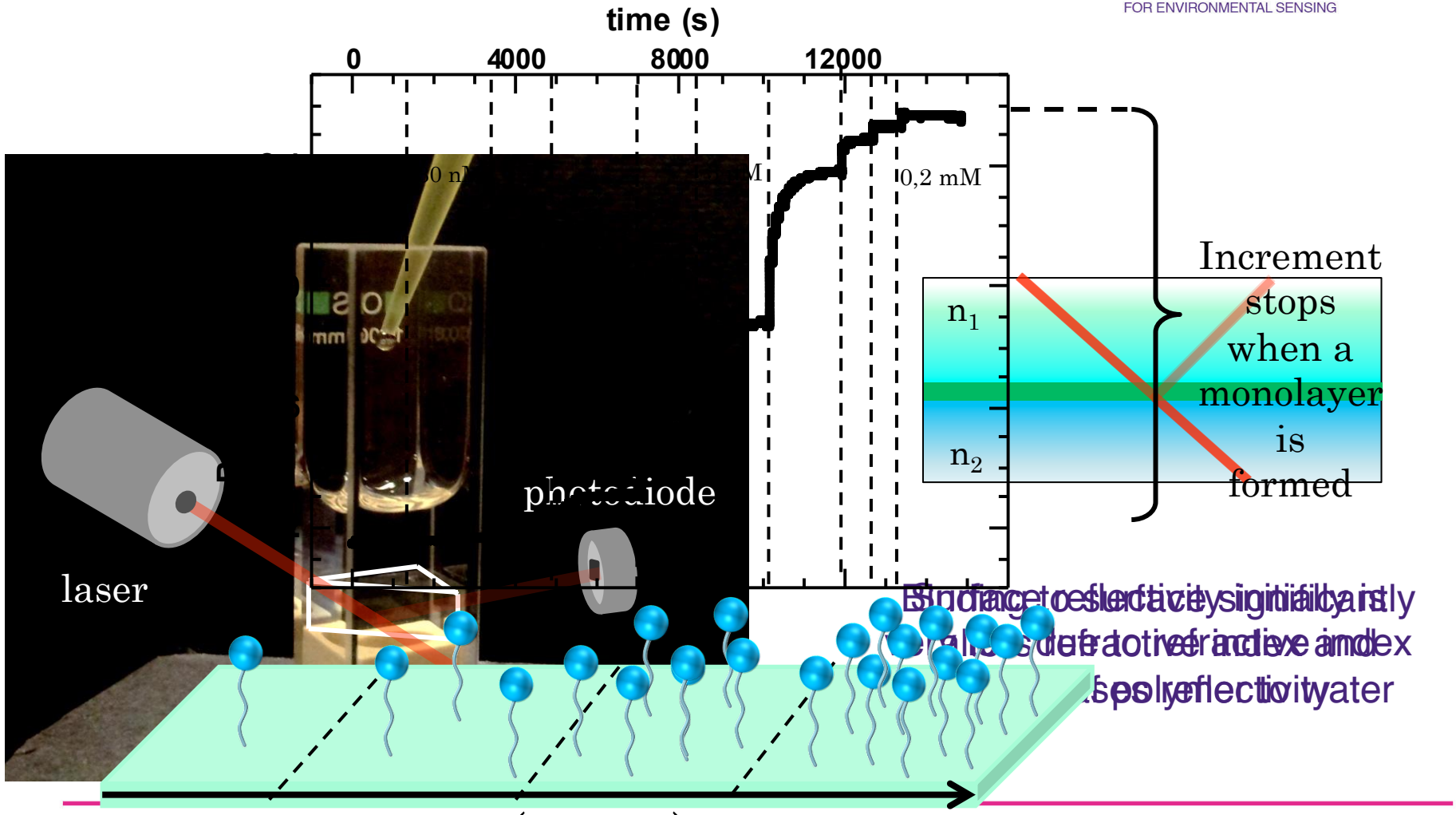

Surfactants (Tween 20)
concentration from 10^{-8} M to 10^{-4} M

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- 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

Bacteria detection by RPI (UMIL)

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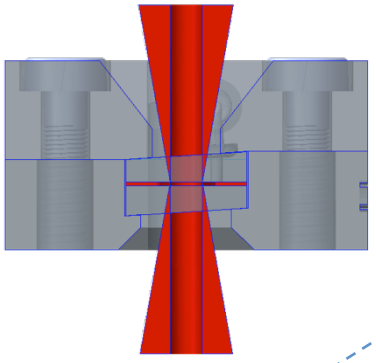
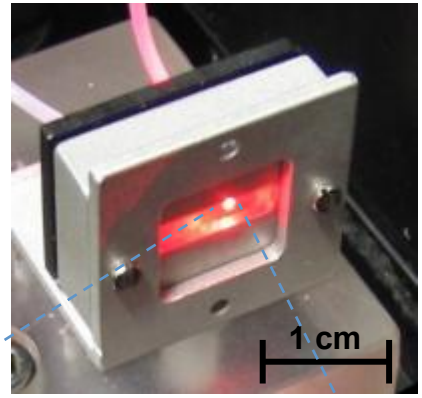
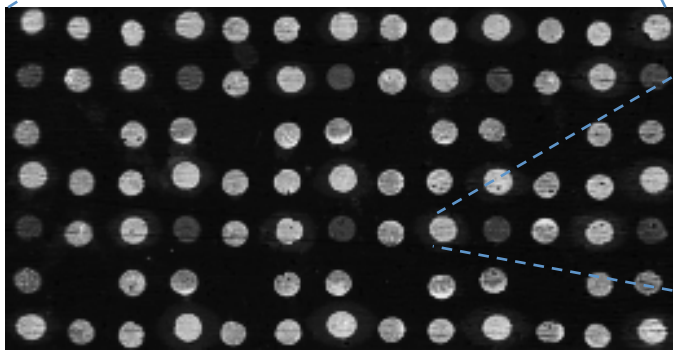
Design and realisation of the fluidic module



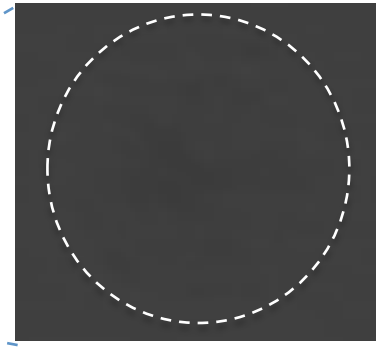


- ABL and UMIL will produce RPI surfaces with strain specific bonding based upon lectin and phage development

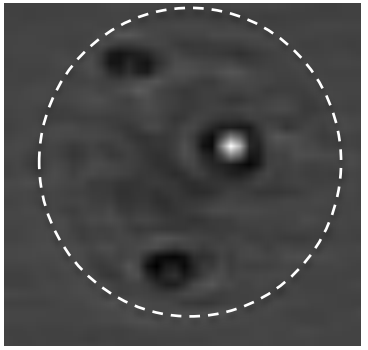
Preliminary data on bacteria detection (6 hours flow analysis) :



Unbound spot



Bacteria bound



Evaluation of the optical platform

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Prototype development and deployment

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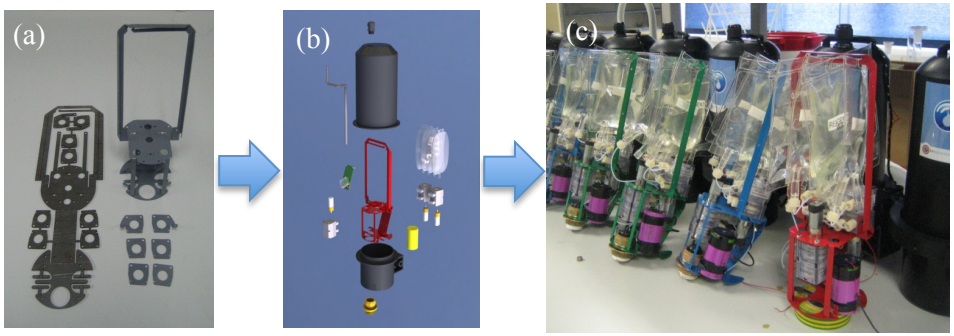
Prototype development

- DCU will lead the production of prototype platforms
- Design and engineering of platform for scalable production and commercialisation activities in parallel with TEL



Prototype deployment

- TEL and WIS will assist DCU in Prototype testing and deployment at Irish sites.
- Lab based testing of prototypes (phase 1) and Field trials at Waste water treatment plants and water supply reservoirs (phase 2)
- Potential for deployments outside of Ireland with partners

Example of DCU coordinated deployment of autonomous phosphate system

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Concluding remarks

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- Bringing together **novel materials technologies** to create platforms with lower energy demand and significant size reduction.
- **Highly sensitive and specific bacterial detection** platform for detection of pathogenic bacterial strains and chemical contaminants.
- Innovative sampling and pre-concentration methods for **increase in sample volume** and **larger representative samples** for broader testing of water source.
- Autonomous, reliable platforms for long-term deployment with **significant reduction in unit cost** relative to existing platforms.

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Acknowledgements

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Project partners:
Eindhoven University of Technology (NL)
Institute Curie, Paris (FR)
CIC Microgune (ES)
TE Laboratories (IE)
Williams Industrial Systems (UK)
University of Milan (IT)
Aquila Biosciences (IE)

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Sergey Gordeyev, NAPES Project Technical Officer

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