PORTABLE LAB-ON-A-DISC SYSTEM FOR IN-SITU AQUATIC ENVIRONMENTAL MONITORING

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MicroTAS 2012

Presentation outline

- **Introduction**
- **Water quality analysis techniques**
- **Our challenge**

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- **Centrifugal Microfluidic Analysis System (CMAS)**
- **Centrifugal platform design**
- **Photoswitchable valves**
- **CMAS performance**

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- **Photoswitchable valves**
- **CMAS performance**

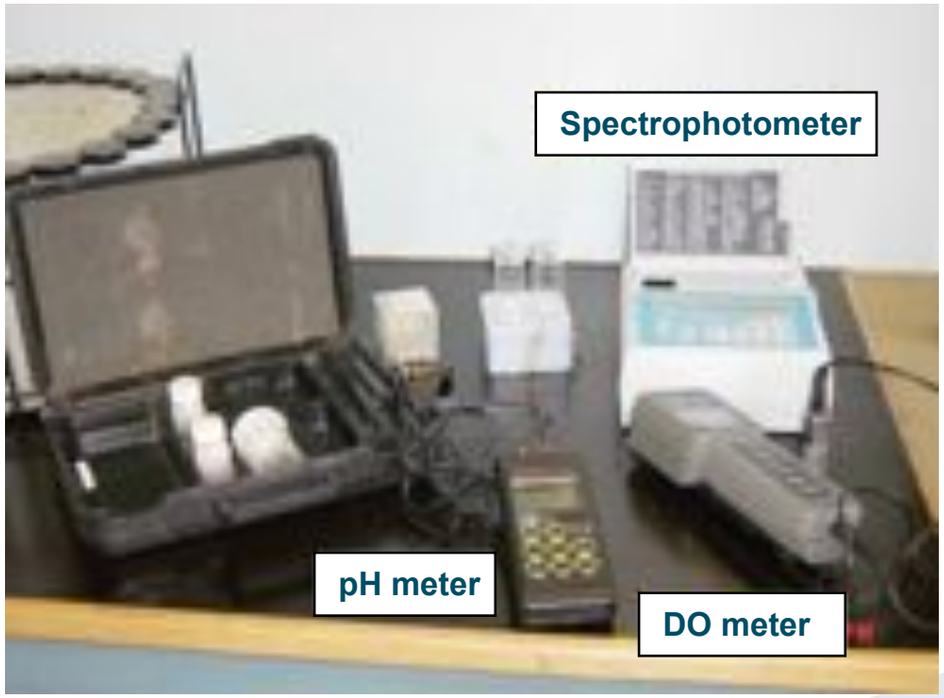
- **Nitrite ions detection in water samples**
- **Conclusions**

Water quality analysis techniques

Traditionally

- Current norm: manual grab samples 3 or 4 times a year.
- **Disadvantages:**
  - ✗ Low stability of natural water samples during long-term storage.[1]
  - ✗ Expensive, time consuming and requires highly trained staff.

In situ measurements

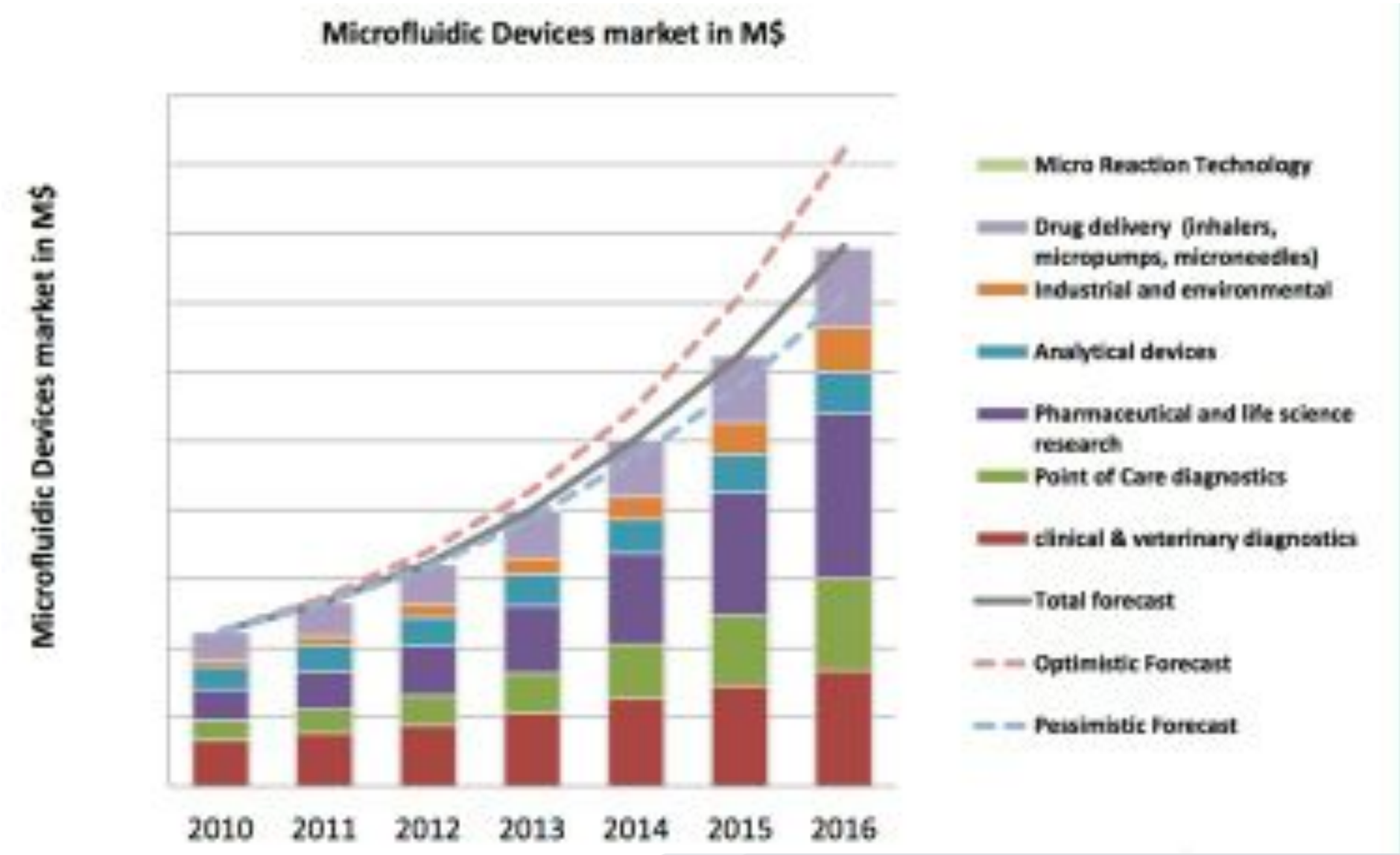


✓ portable
✓ inexpencive
✗ single probe
✗ no data saving

✓ multiprobe (temperature, pH, redox, DO, turbidity (TSS), NO_3, Na, F, etc.)
✗ €7000
✓ hand-held device

[1] G. Hanraham, J. Environ. Monit. 6, 2004, 657.

Our challenge



[2] Yole Development market report 2011

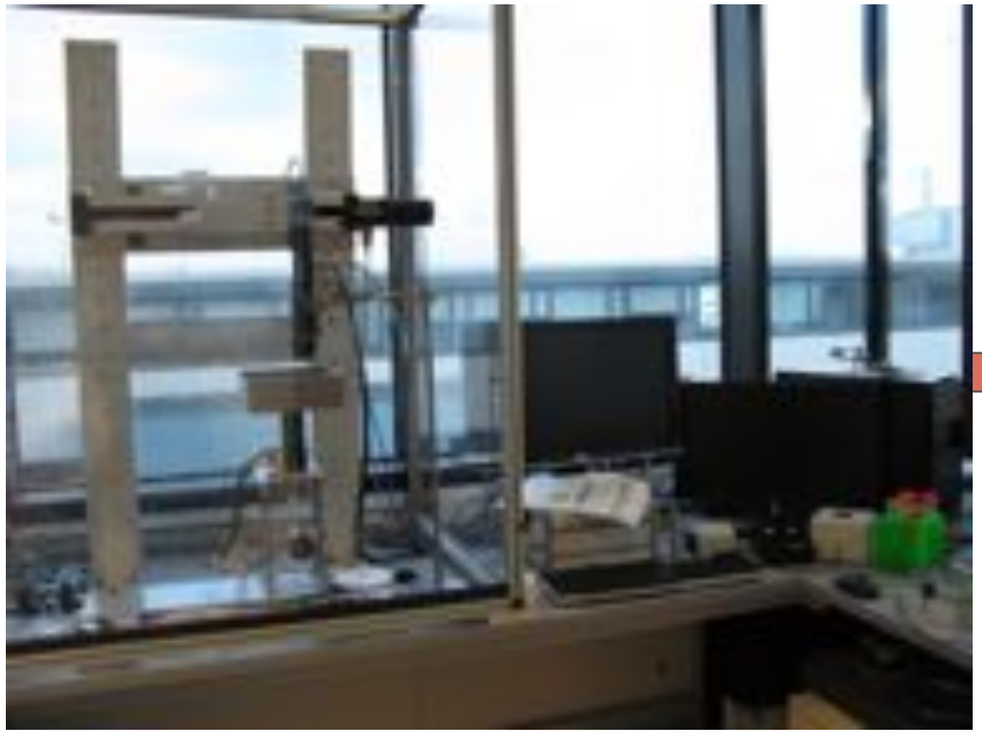
Our challenge

WHY CENTRIFUGAL DISC (CD)?

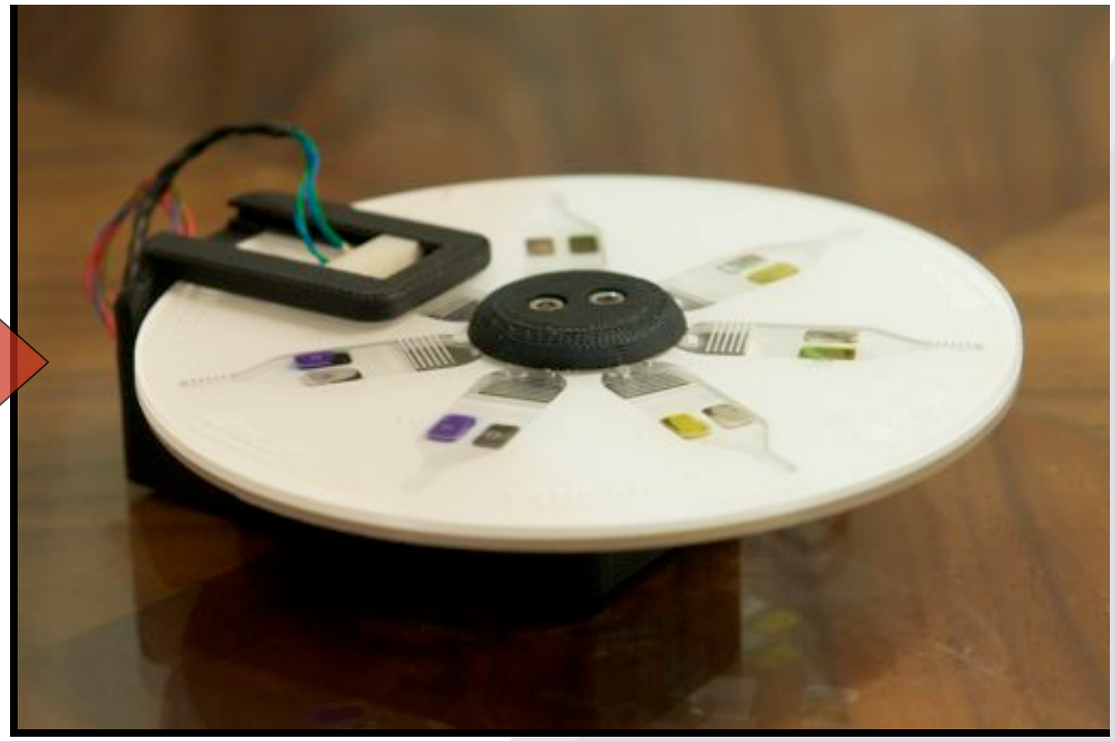
- Elimination of large power supplies and external pump[2].
- Provides forces across the entire length of a fluid element.
- Multiple individual micro-fluidic systems can be placed on a single CD.
- Potential to include multi-parameter assays and / or multiple replicate assays with calibration.
- Potential for multi-stage assays involving several fluidic sub-compartments.

[2] Siegrist et. al., Lab Chip 10, 2010, 363.

Our challenge



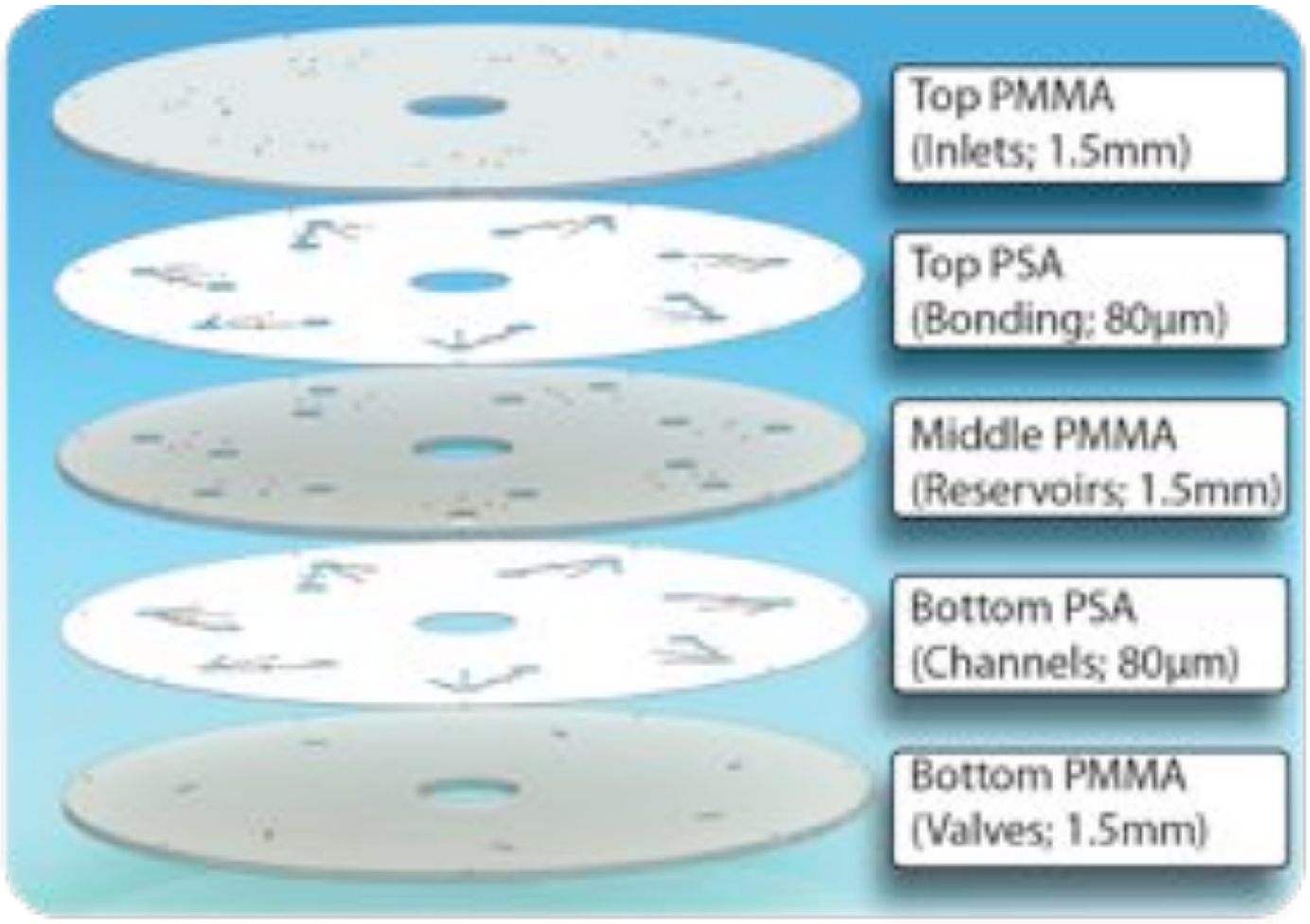
Fluid Manipulation



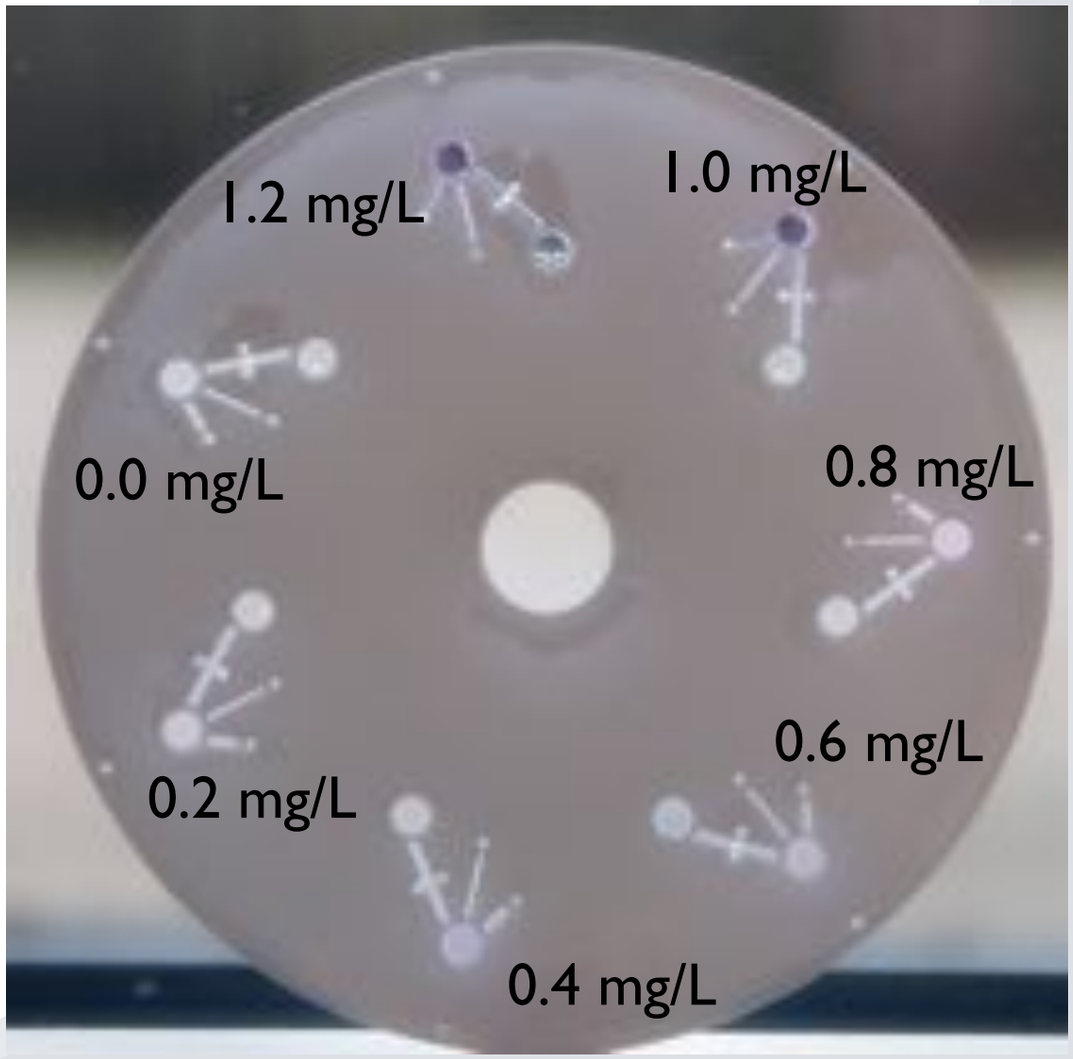
Colorimetric Analysis[2]

[2] M. Czugala, *Lab Chip*, 2012, DOI: 10.1039/C2LC40781G

Centrifugal Platform for Nitrite Detection

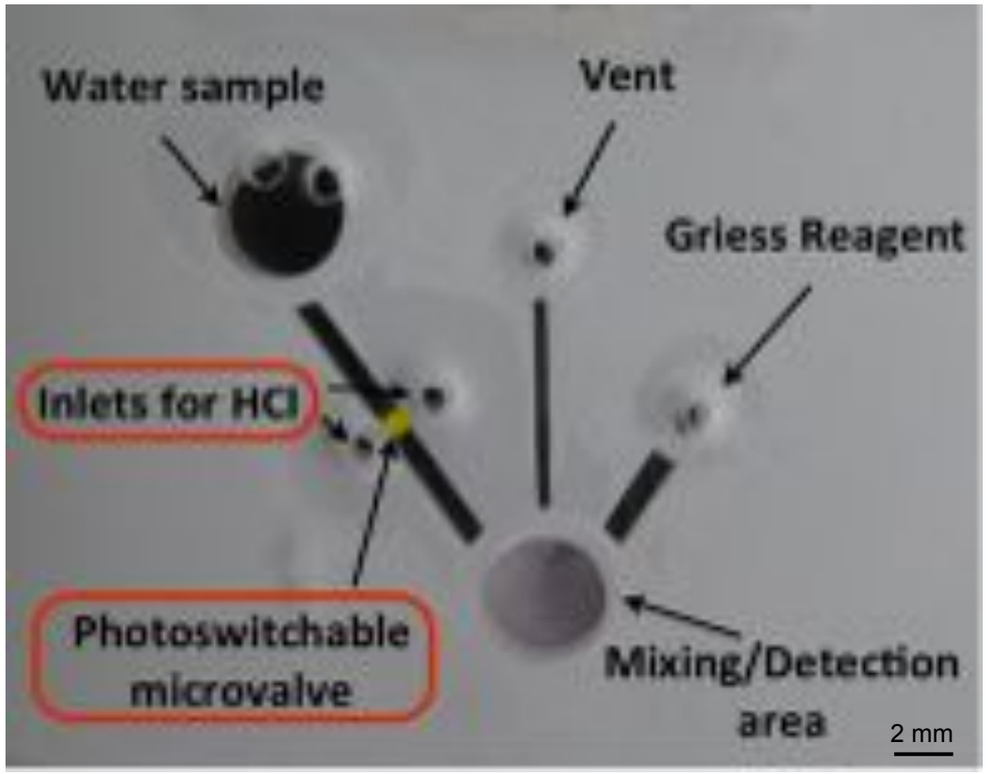


Assembly of the microfluidic CD



Lab-on-a-Disc

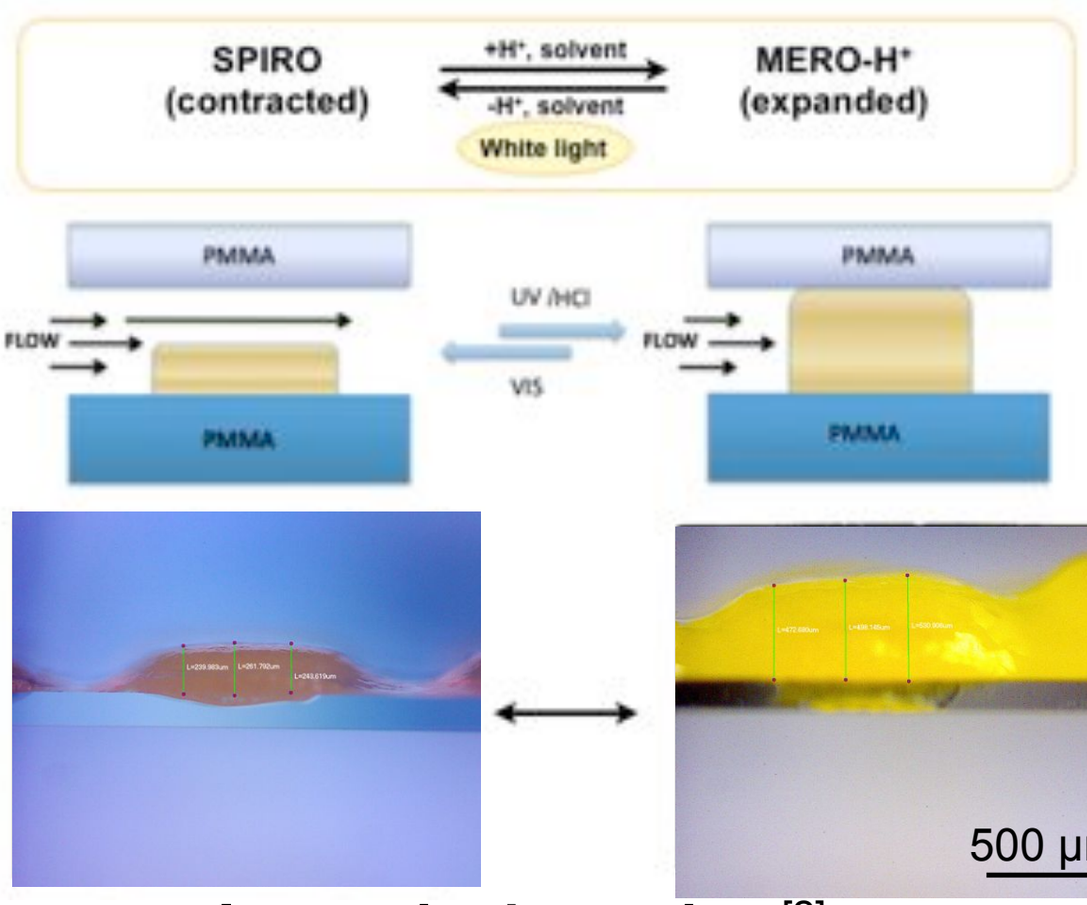
Single Microfluidic Design



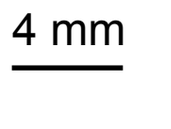
- Standard solution/Sample reservoir - 31.5 µL
- Air vent (bubble prevention)
- Griess Reagent reservoir - 2.1 µL
- Microchannels - 1000 µm width
- Mixing/Detection area - 33.5 µL

Single chip consisting of three chambers.

Photoswitchable microvalves



Ionogel microvalve [2]
shrunk (left) and swollen (right) state



Valve actuation at 600 rpm

[2] M. Czugala *et. al*., Proc SPIE. 8107, Nano-Opto-Mechanical Systems (NOMS), 2011.

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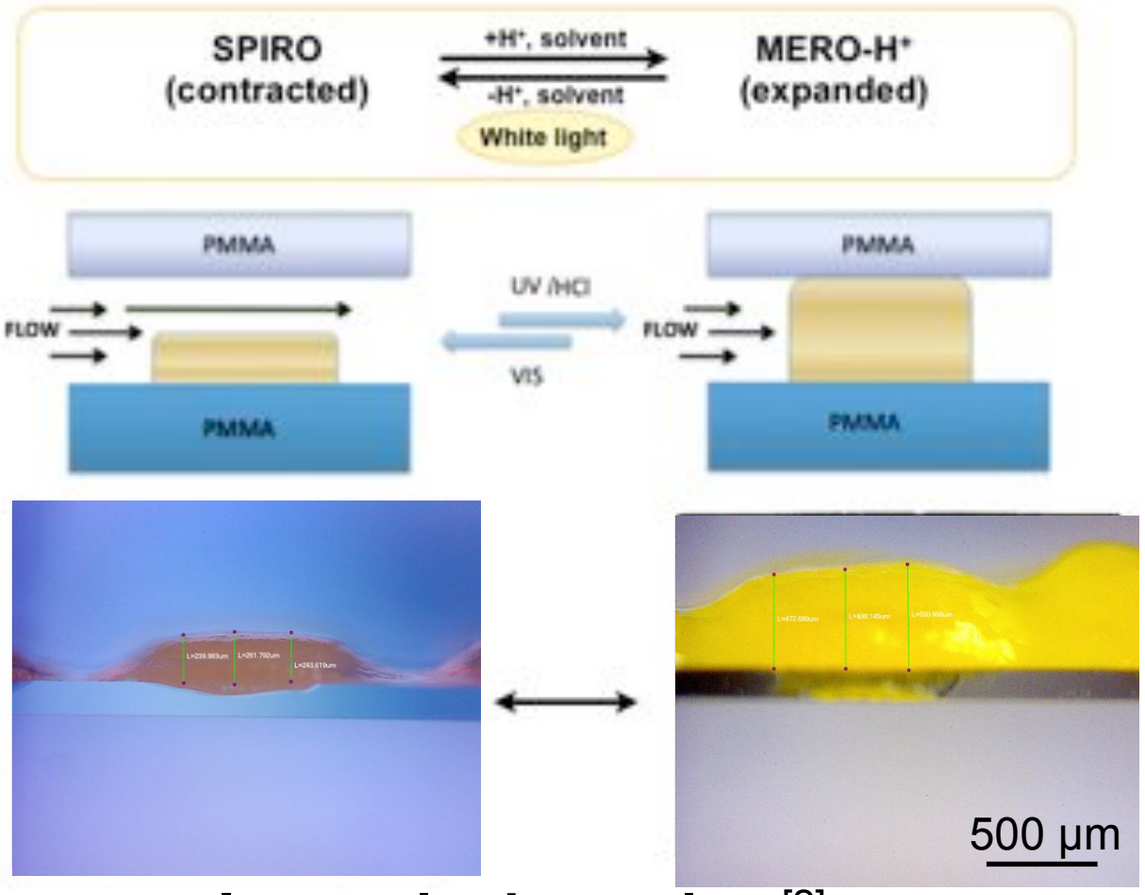

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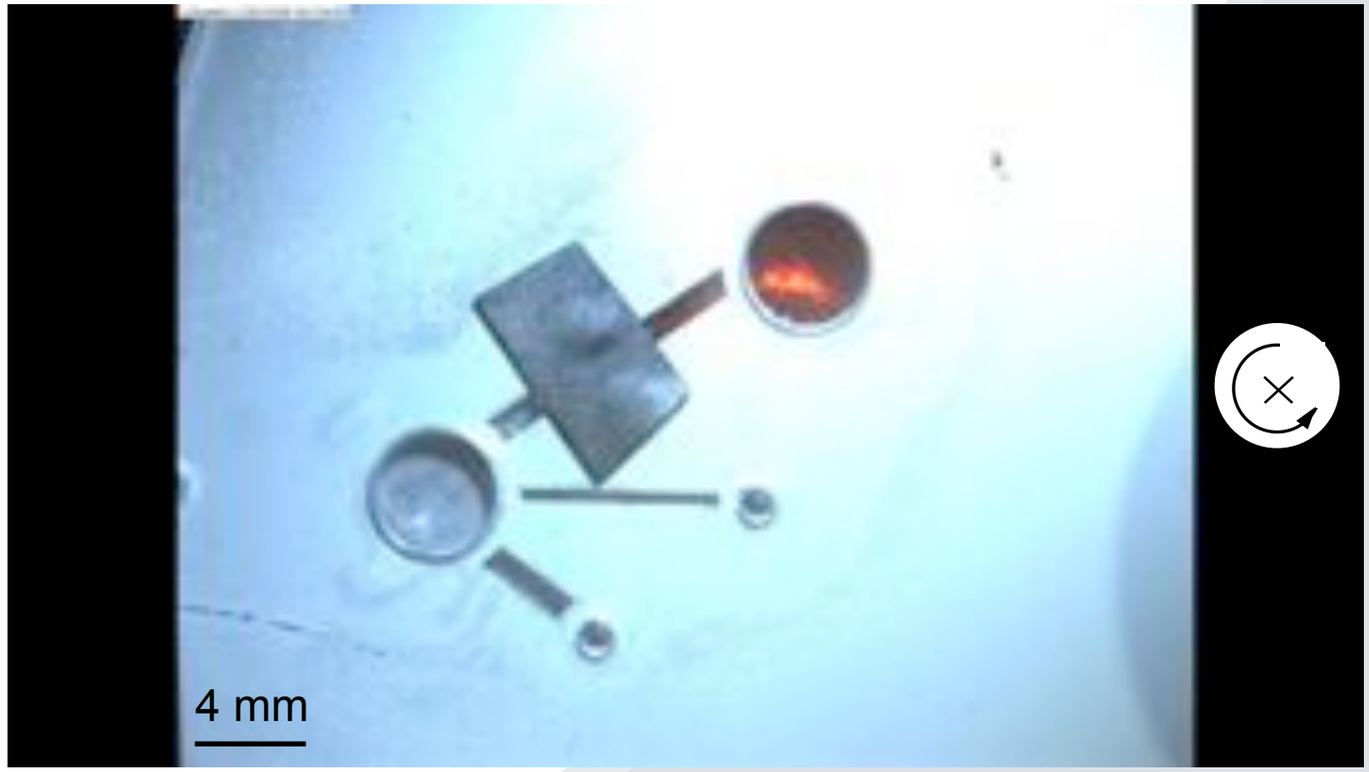

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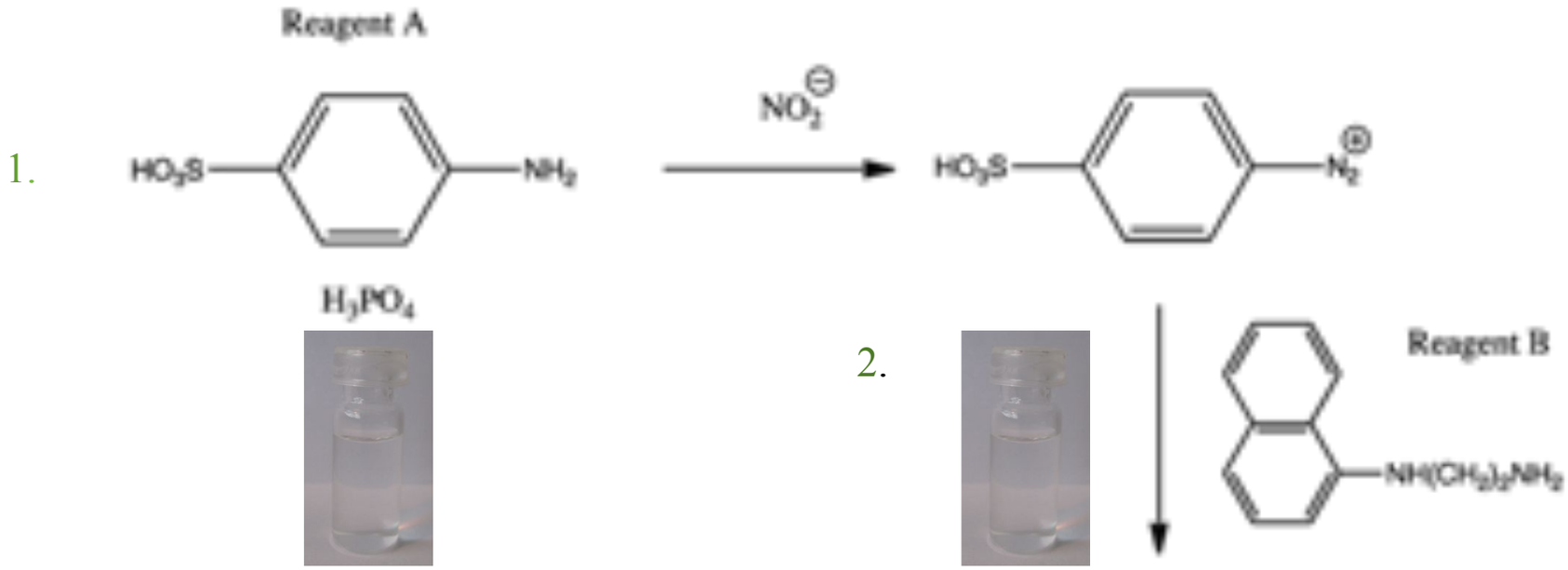
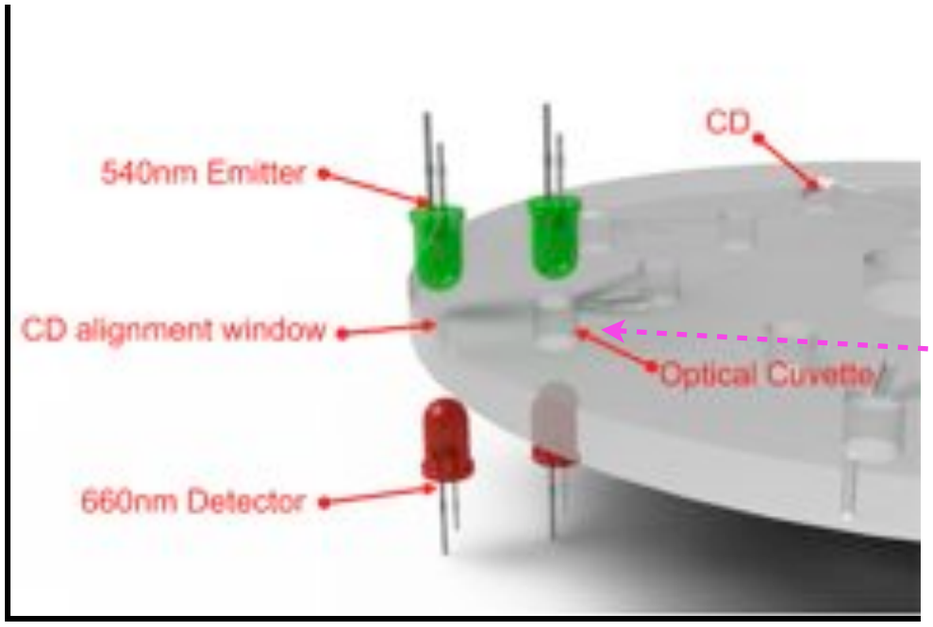
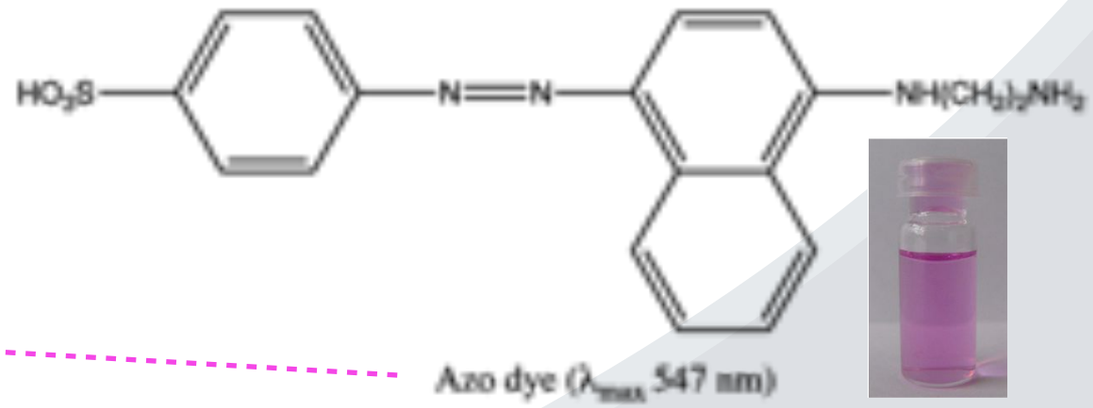
Mechanism of the Nitrite Detection







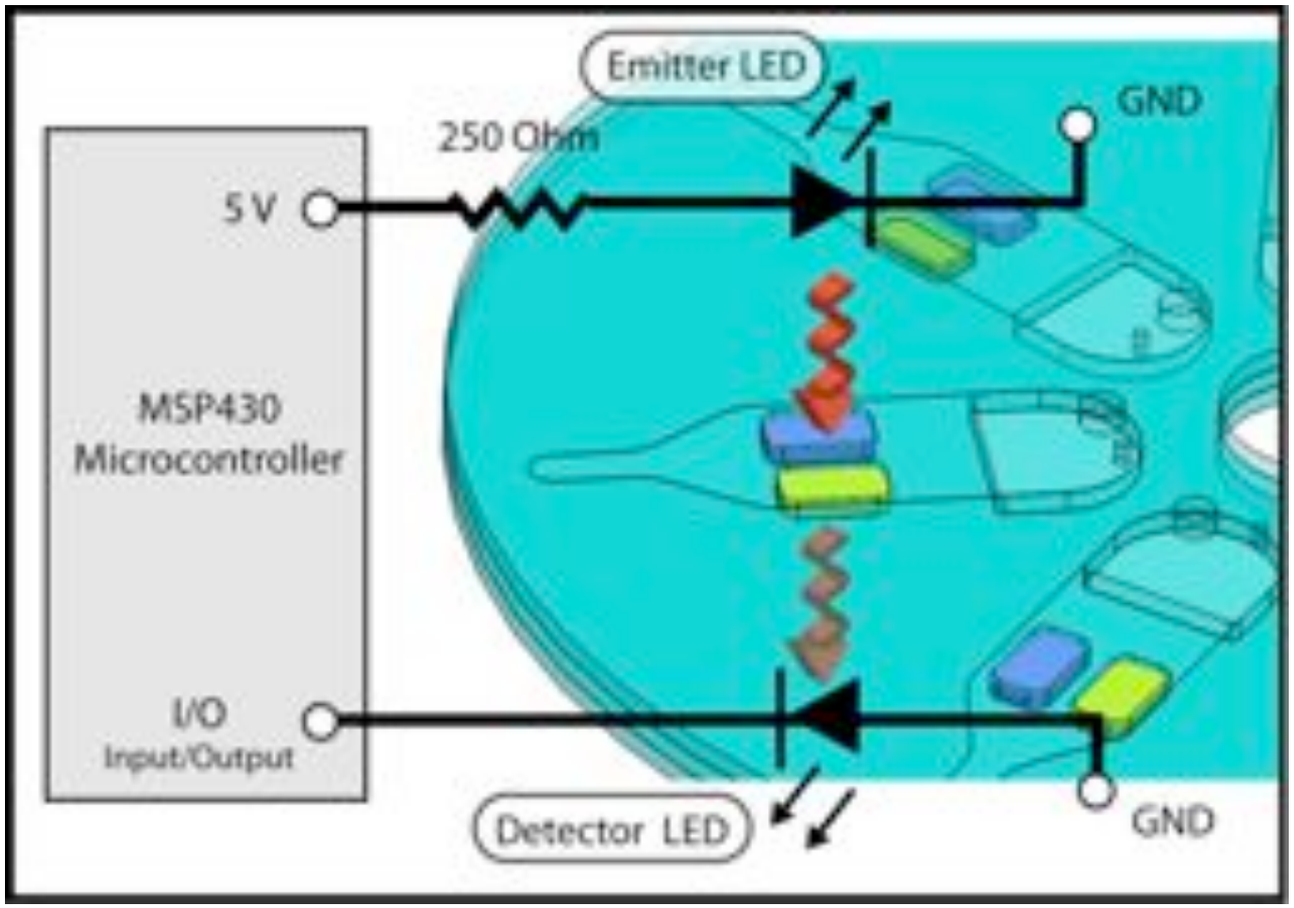
1. sulfanilic acid (Reagent A) $\xrightarrow{NO_2^-}$ diazonium salt

2. diazonium salt + *N*-(1-naphthyl)ethylenediamine (Reagent B) $\longrightarrow$ azo dye

[3] J. MacFaddin, 3rd ed. Lippincott Williams & Wilkins, Philadelphia, 2000, 348

Mechanism of the Colourimetric Detection

Paired emitter detector diode (PEDD)



[4] M. O'Toole *et. al*., *Anal. Chim. Acta*, 652, 2009, 308.

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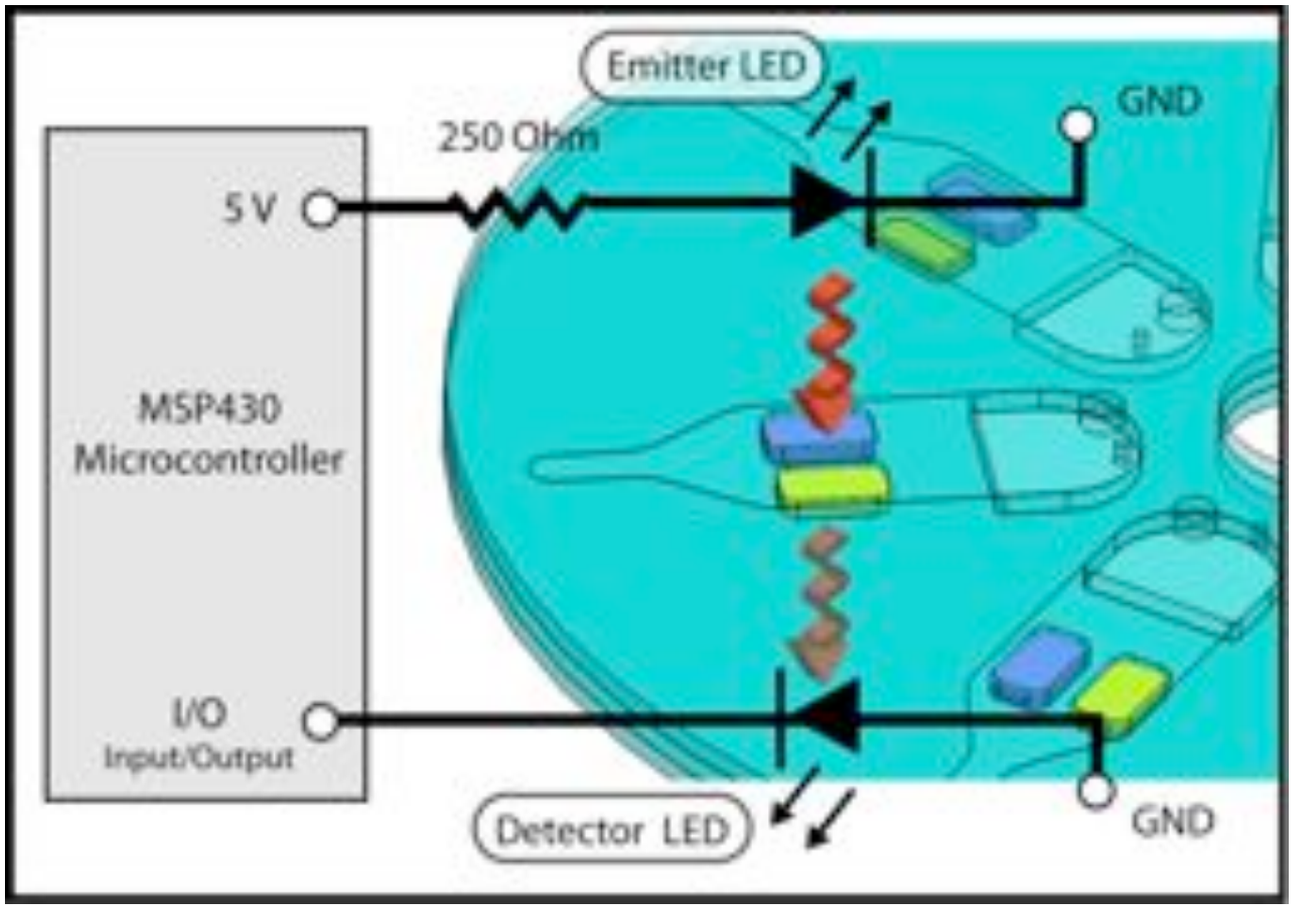
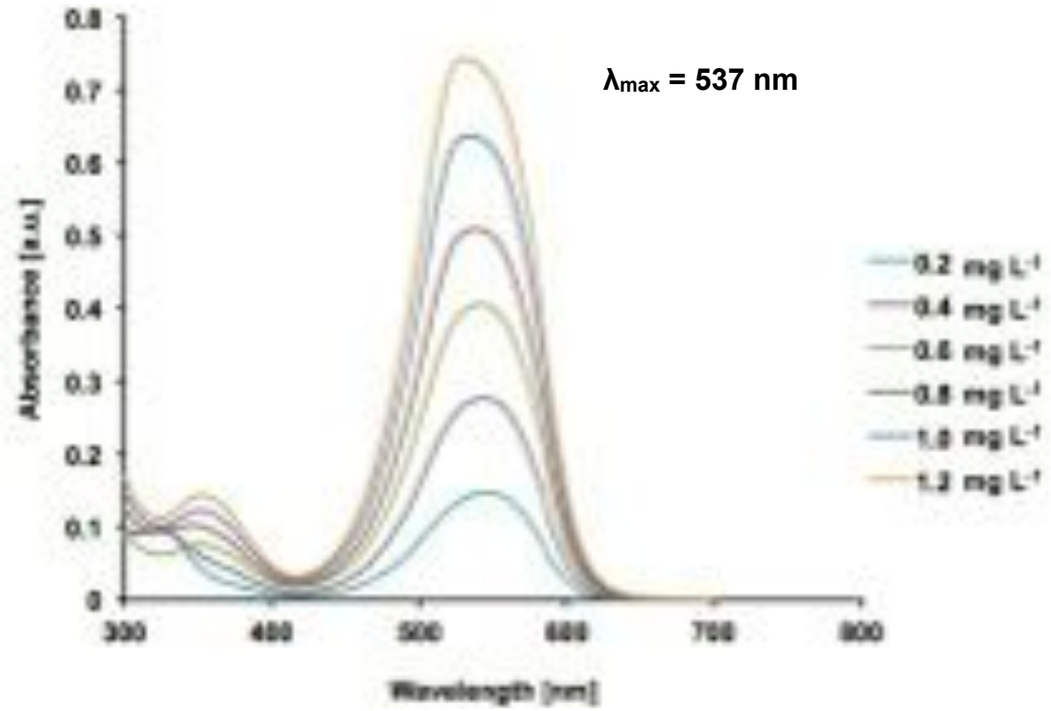


- Excellent sensitivity and signal-to-noise ratio [4]
- Low power consumption
- Increasing spectral range coverage
- Intensity and efficiency
- Low cost
- Small size
- Ease of fabrication
- Simplicity
- AND adjusts ideally to the system based on centrifugal Lab-on-a-disc!

[4] M. O'Toole *et. al*., *Anal. Chim. Acta*, 652, 2009, 308.

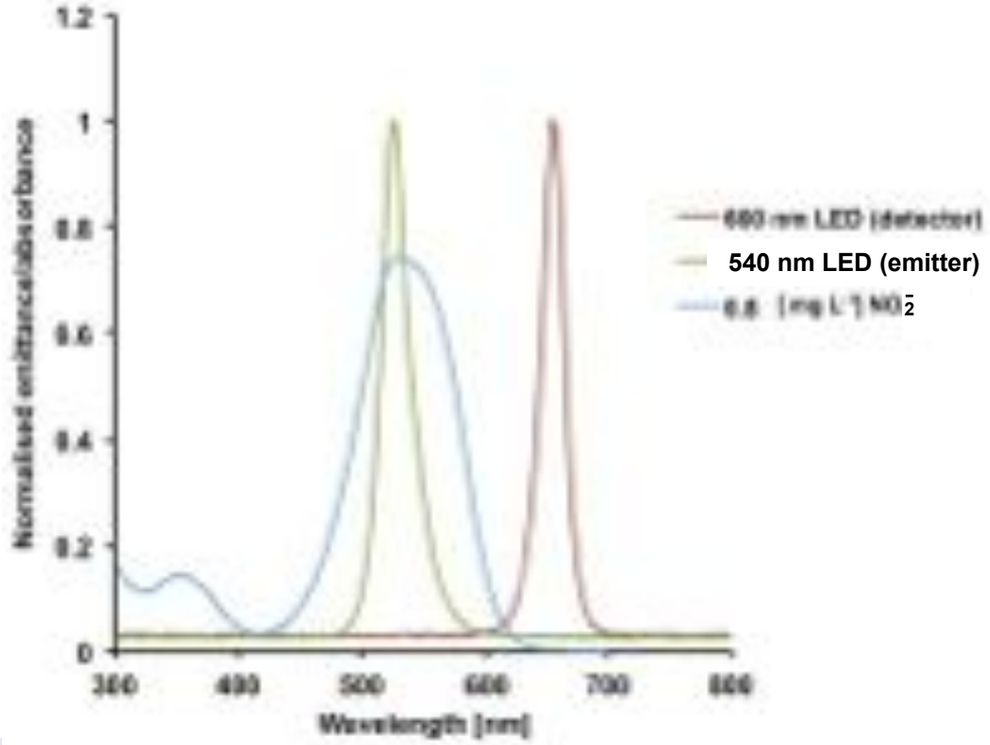
Mechanism of the Colourimetric Detection

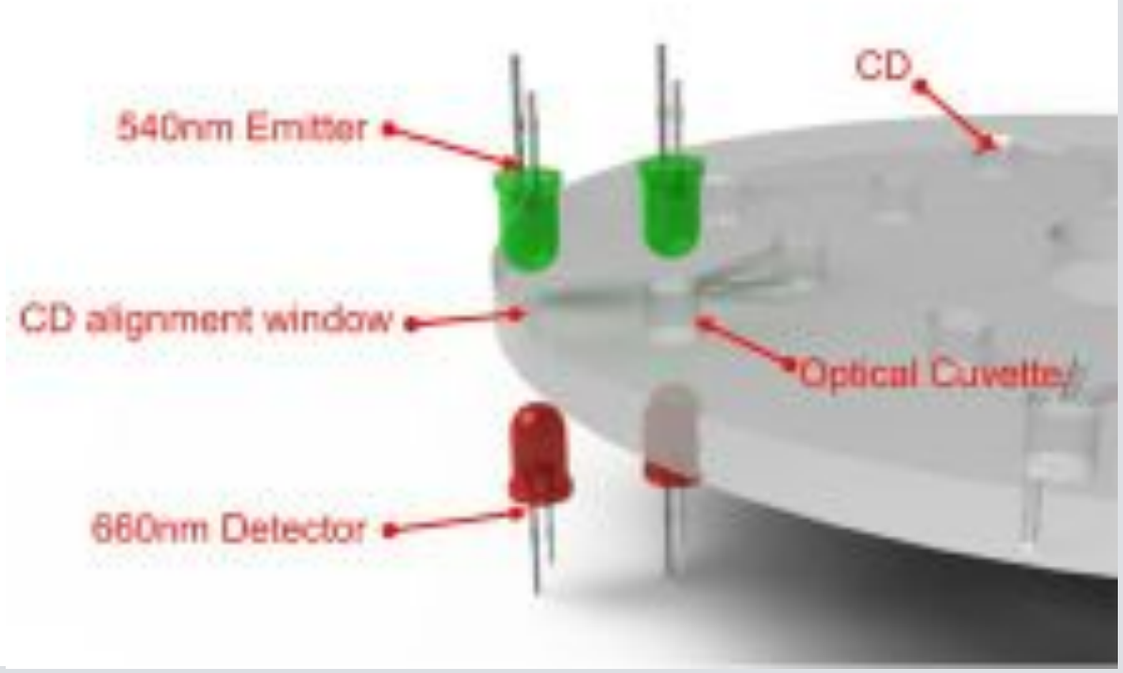
1



λ_{max} = 537 nm

2





Centrifugal Microfluidic Analysis System (CMAS)

Spinning + Colorimetric Analysis

Patent Pending: Centrifugal Microfluidic Analysis System, K. J. Fraser, M. Czugala, D. Maher, F. Benito-Lopez, D. Diamond, 25 April, 2012, (GB)

Centrifugal Microfluidic Analysis System (CMAS)

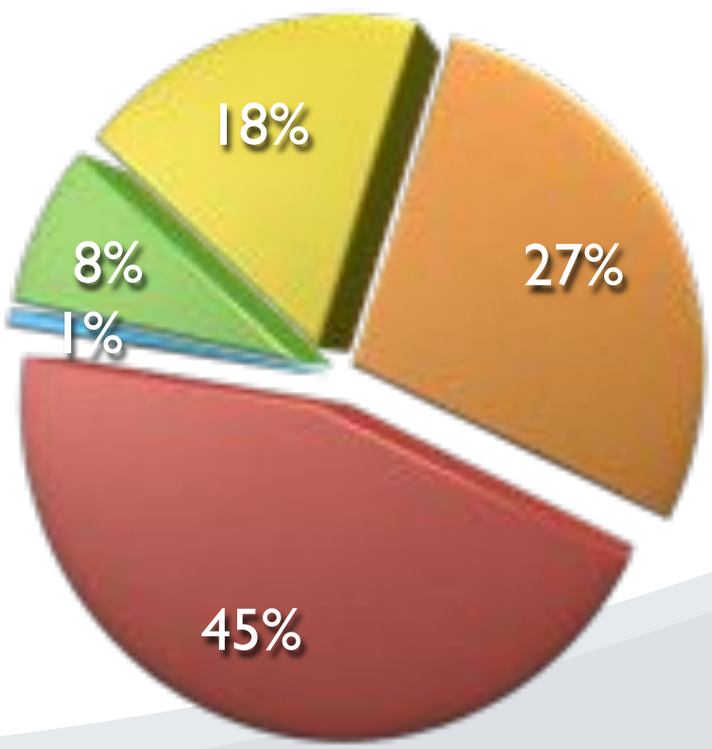
Advantages:

- Low cost single use micro-fluidic device
- Multiple samples analysis in a single microfluidic device
- Multiplexing capabilities (pH, turbidity, nitrite,...)
- Portable system: sample analysis at the point-of-need
- Wireless communication system - including cloud integration!

Patent Pending: Centrifugal Microfluidic Analysis System, K. J. Fraser, M. Czugala, D. Maher, F. Benito-Lopez, D. Diamond, 25 April, 2012, (GB)

Centrifugal Microfluidic Analysis System (CMAS)

In collaboration with Prof. Smeaton's group
(School of Computing, DCU)

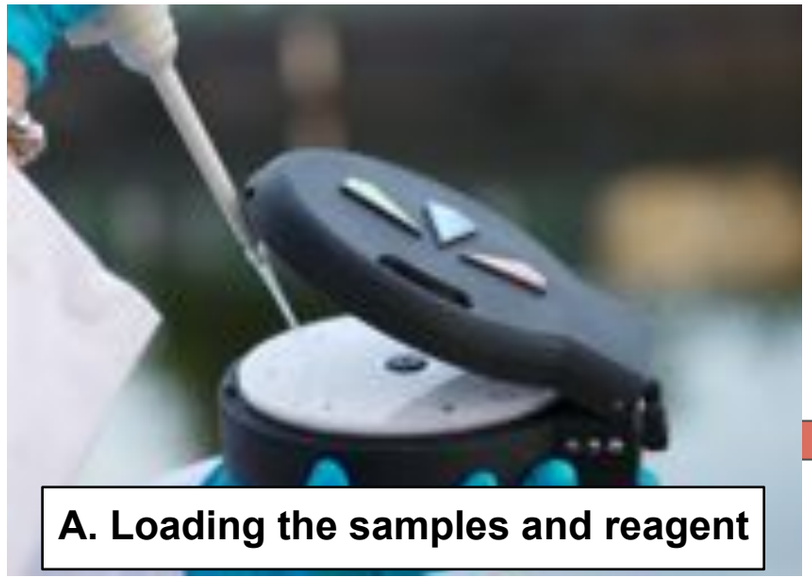


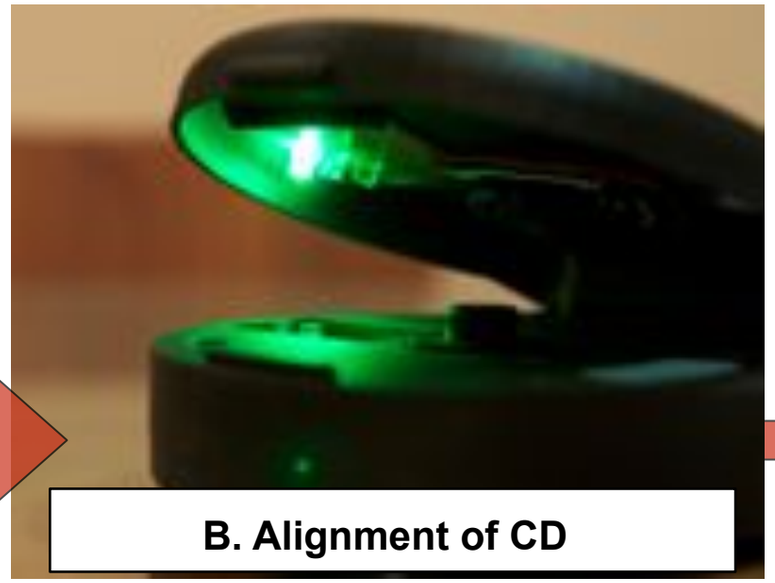
- LED's € 2.00
- Batteries € 18.60
- Misc Electronics € 40.00
- Custom PCB Board € 59.94
- Printed ABS case € 100.11

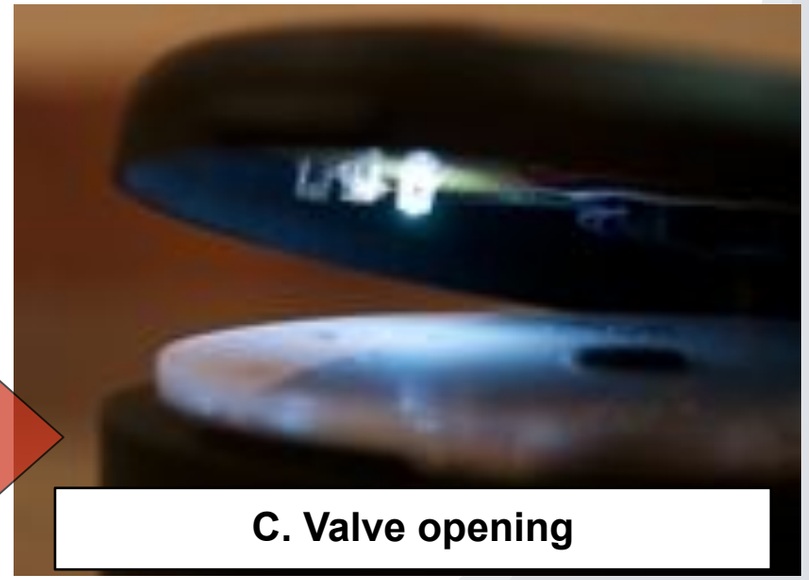
TOTAL: ~ €200

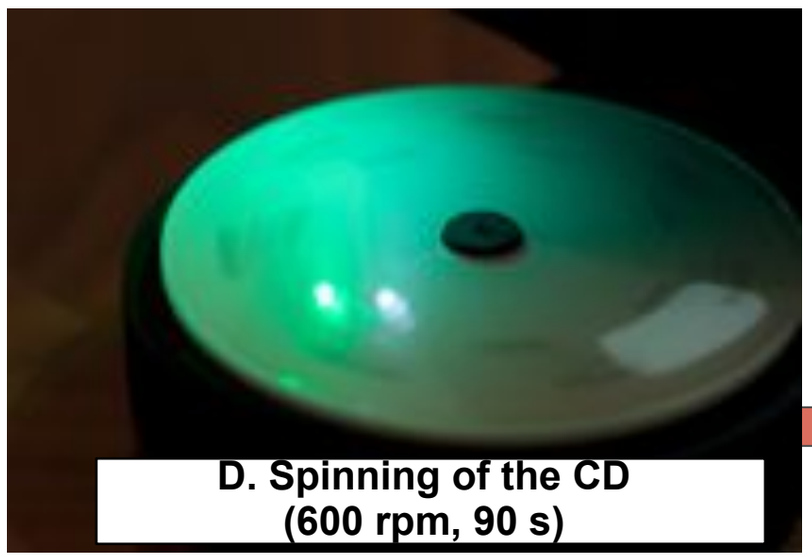
Patent Pending: Centrifugal Microfluidic Analysis System, K. J. Fraser, M. Czugala, D. Maher, F. Benito-Lopez, D. Diamond, 25 April, 2012, (GB)

Centrifugal Microfluidic Analysis System (CMAS)

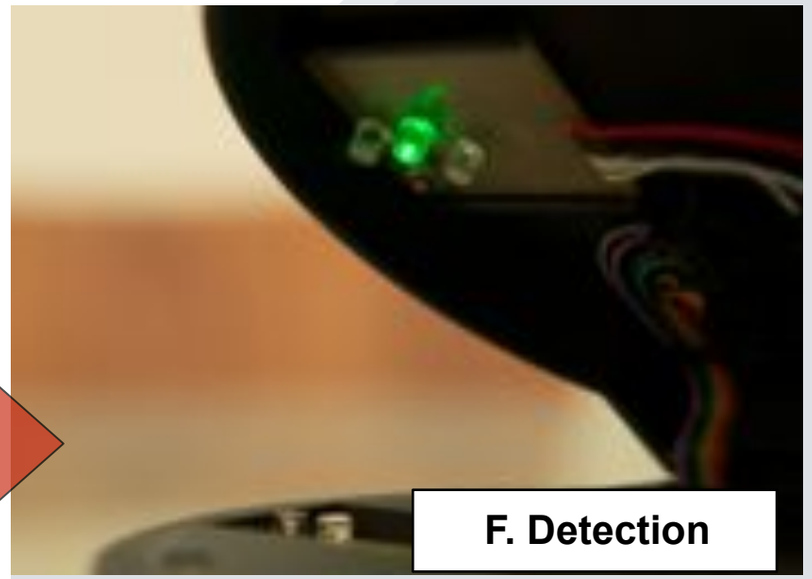

A. Loading the samples and reagent


B. Alignment of CD


C. Valve opening

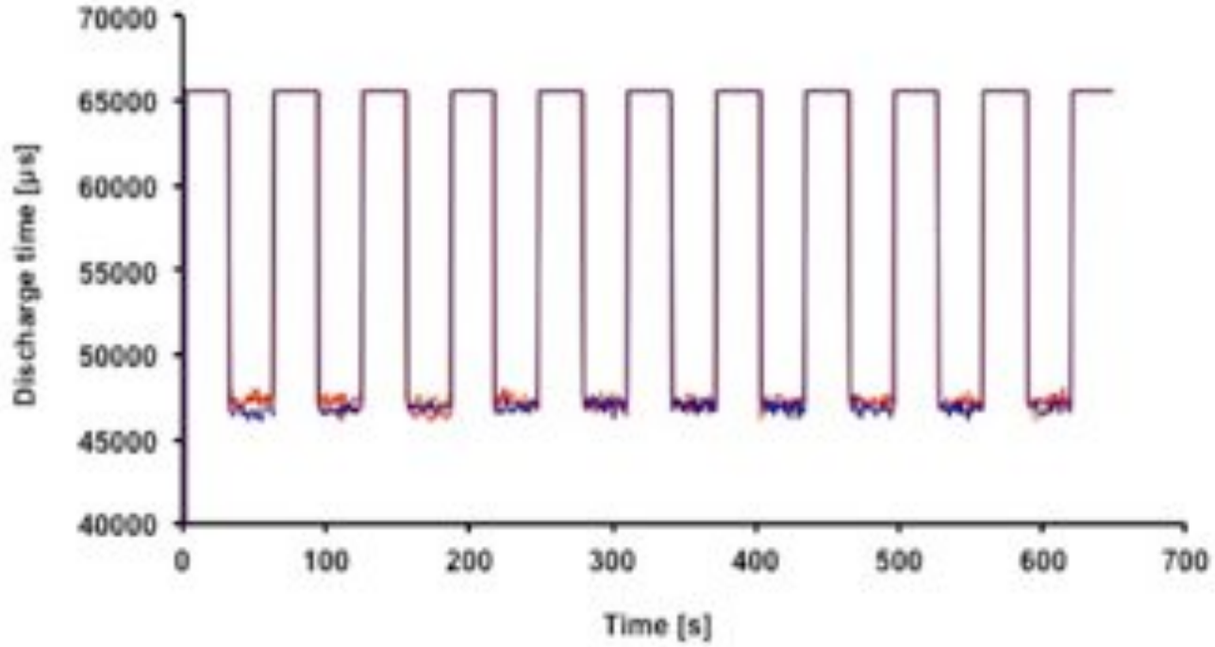

D. Spinning of the CD (600 rpm, 90 s)


E. Alignment of CD


F. Detection

Reproducibility tests

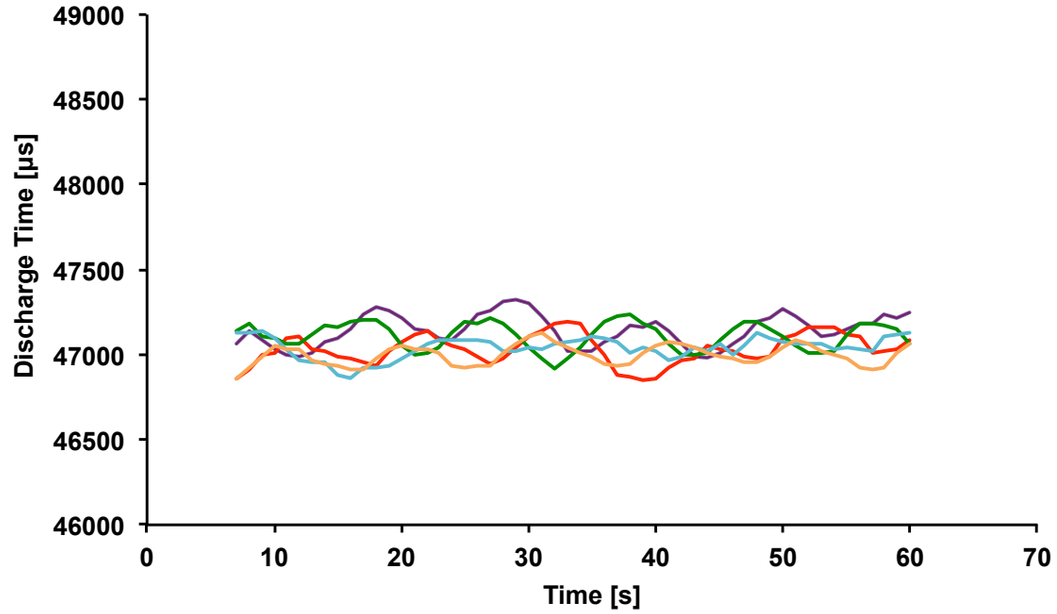
Reproducibility of the PEDD



Detection of 0.2 mg/L NO_2^- Griess reagent complex (n = 10)

RSD = 0.36 %

Reproducibility of the CDs



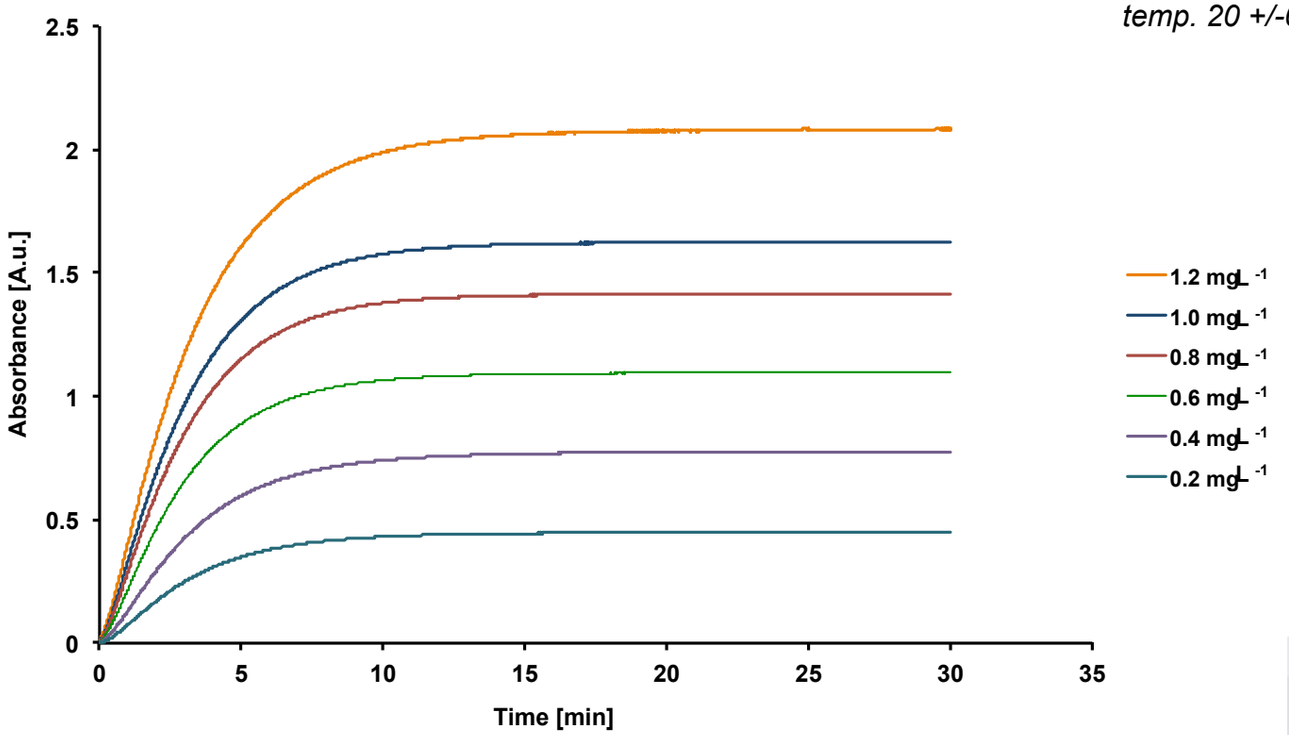
Detection of 0.2 mg/L NO_2^- Griess reagent complex (n = 6)

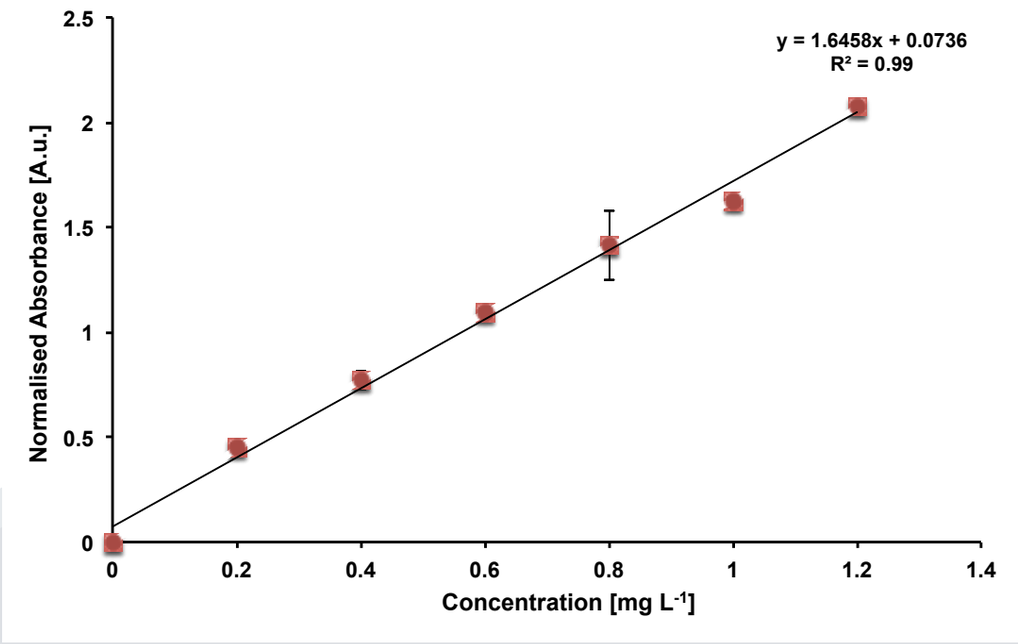
RSD = 0.26 %

Validation of the method - UV/Vis spectroscopy

UV-Vis

temp. 20 +/-0.5°C



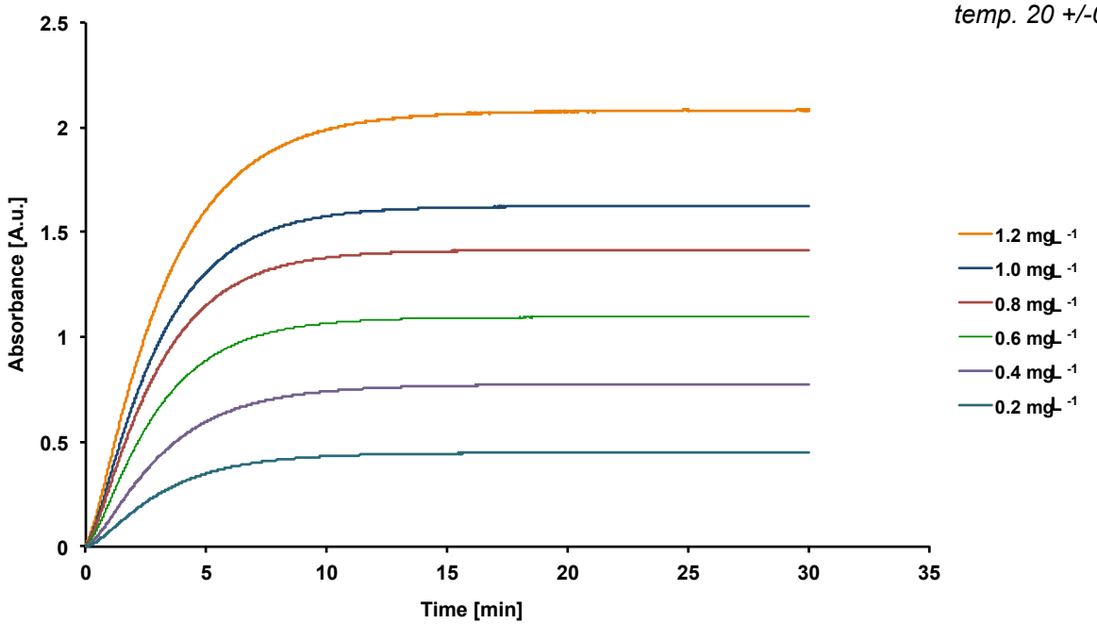


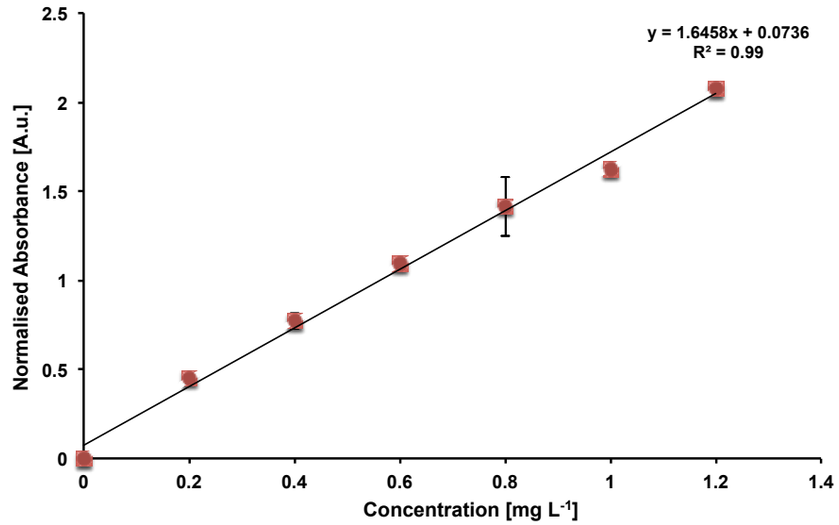
Study of the colour formation between NO_2^- and Griess reagent (left side) and absorbance *versus* nitrite Griess reagent complex concentration (right side) using a UV-Vis spectrometer.

Validation of the method - UV/Vis spectroscopy

UV-Vis

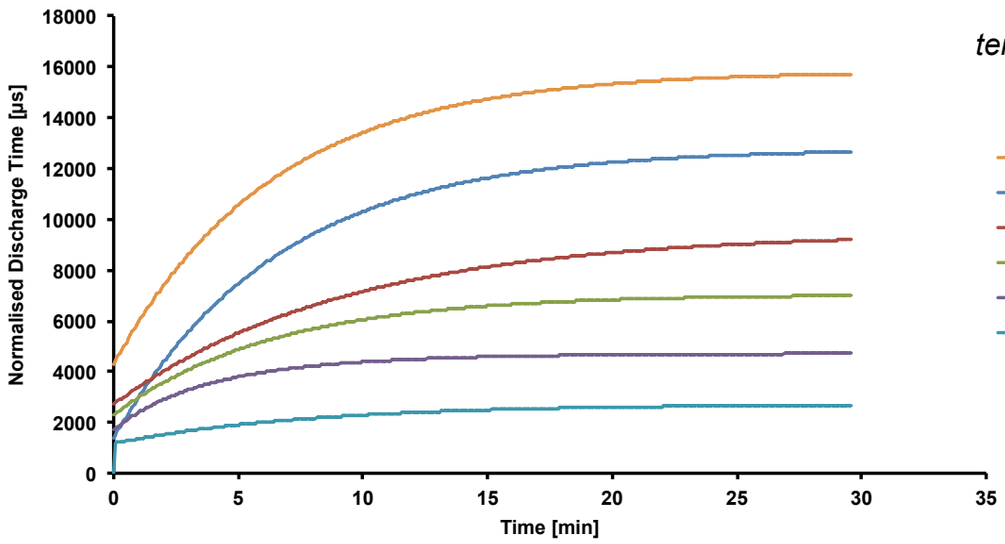
temp. 20 +/-0.5°C

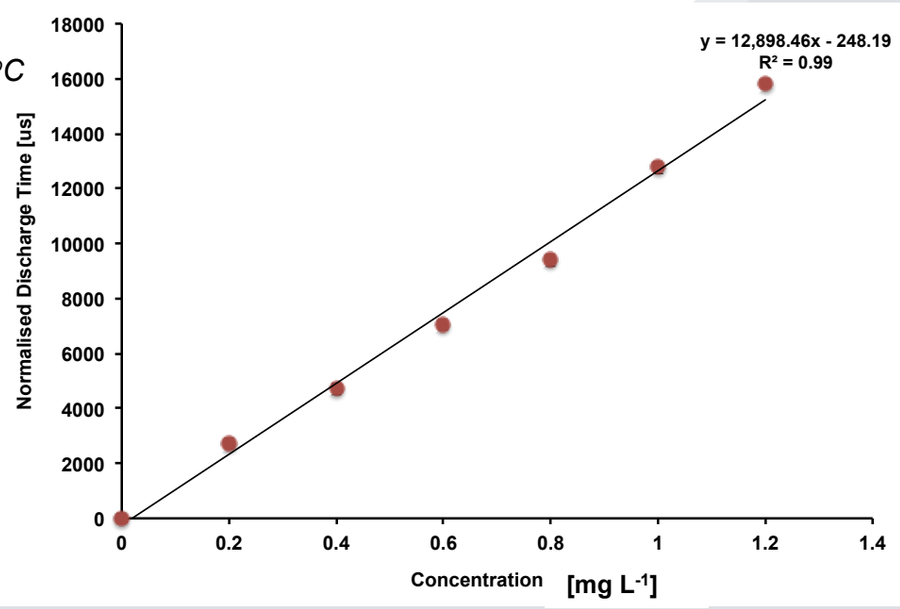




CMAS

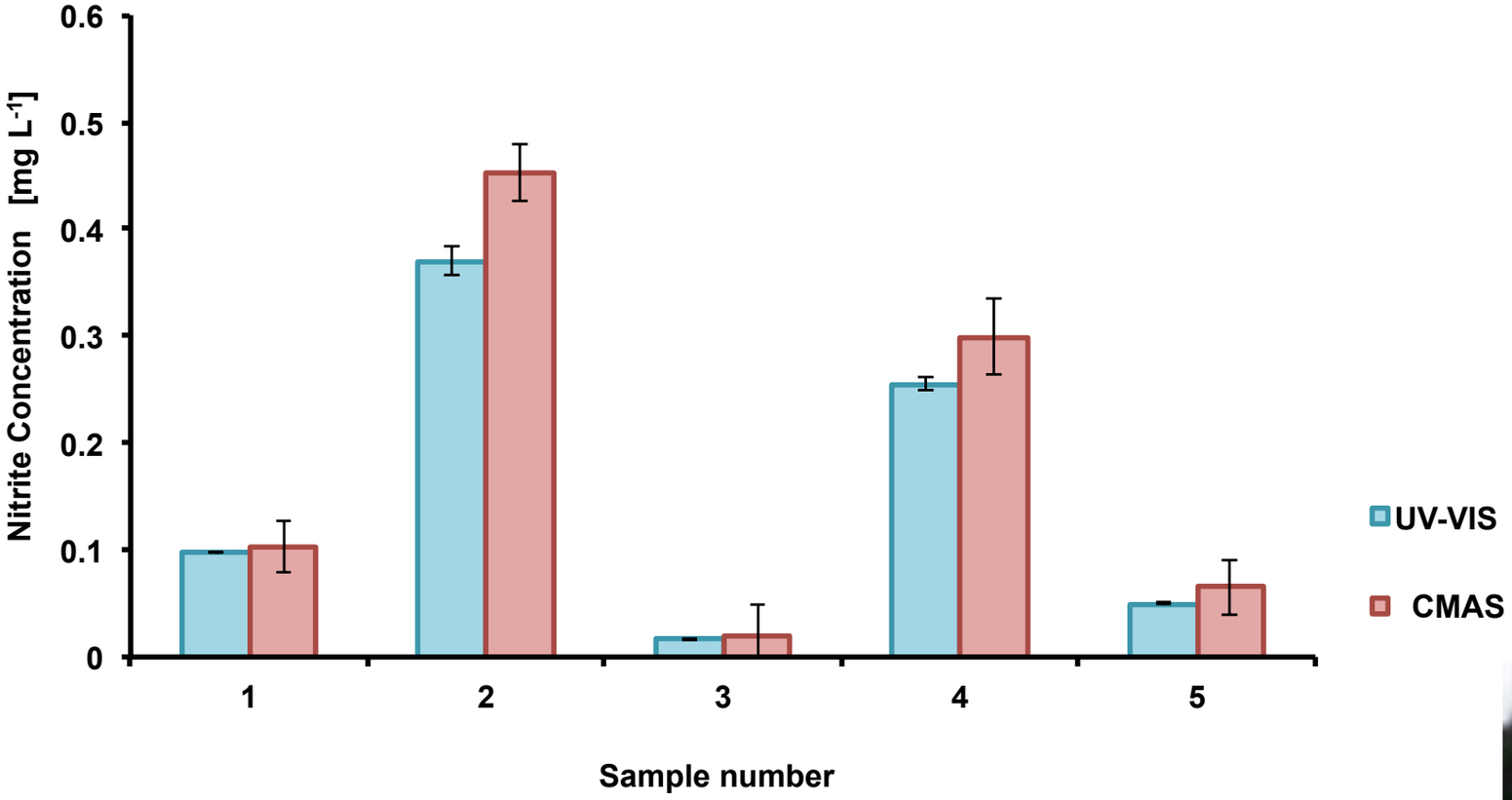
temp. 20 +/-0.5°C

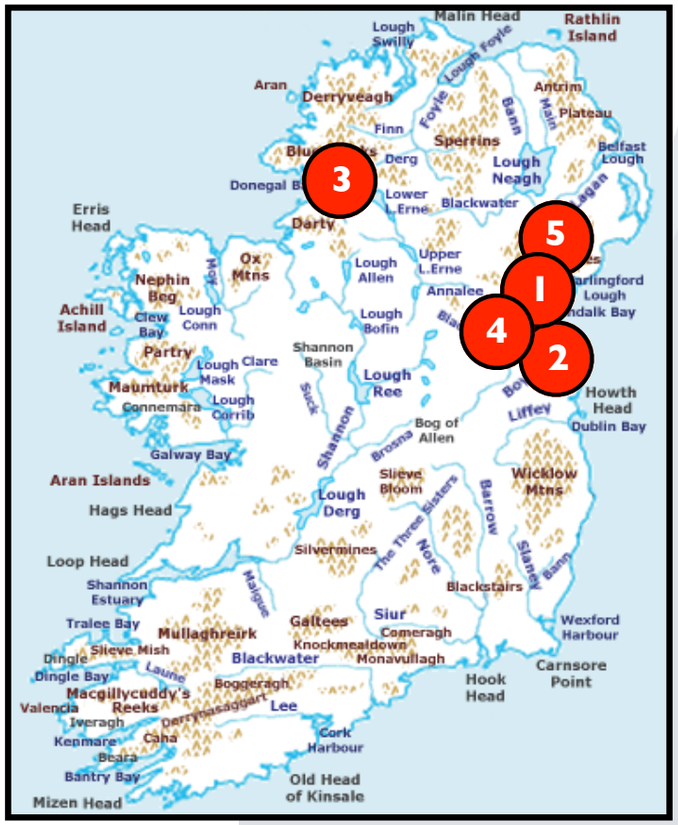




Study of the colour formation between NO_2^- and Griess reagent and absorbance *versus* nitrite Griess reagent complex concentration using spectrophotometer (up) and the CMAS system (bottom).

Nitrate detection in real water samples





Water nitrite analysis using a bench-top UV-VIS spectrometer and the CMAS (n = 3)

Conclusions

Design

- A fully integrated, portable system for *in-situ* colorimetric water quality analysis has been developed.
- Easily interchangeable PEDD boards allowing a wide range of centrifugal microfluidic layouts to be implemented.
- Integration of a wireless communication device allows data acquisition according to individual needs.
- Cloud Integration / data management via Android tablet.
- Successful application of photoswitchable microvalve on the centrifugal platform.

Functionality

- We present the huge potential for the CMAS to be a cheap and versatile alternative as point-of-need optical detector for lab-on-a-disc applications.
- On site detection of nitrite with a LoD = 40 ppb.

Acknowledgements

- Dr. Damien Maher
- Dr. Robert Burger
- Dr. Fiachra Collins
- Thomas Phelan
- Dr. Kevin J. Fraser
- Prof. Jens Ducrée
- Prof. Dermot Diamond
- Dr. Fernando Benito-Lopez
- Prof. Alan Smeaton's group
- Adaptive Sensors Group, Dublin City University
- Marie Curie ITN funded by the EC FP7 People Program
- Science Foundation of Ireland under grant 07/CE/I1147

Thank you for your attention!

- Centrifugal platform design
- Photoswitchable valves
- Paired emitter detector diode (PEDD)
- Alignment of CD
- CMAS performance
- Reproducibility
- Validation of technique
- Water samples testing