Design features for enhancing optical detection on Lab-on-a-disc platforms

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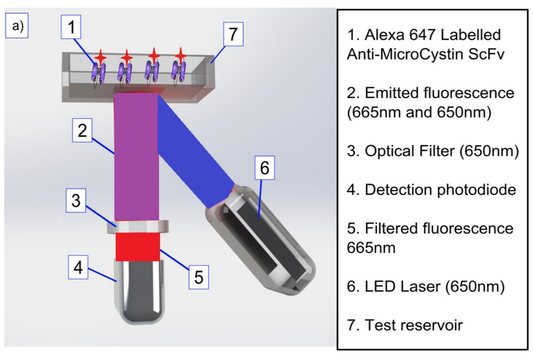
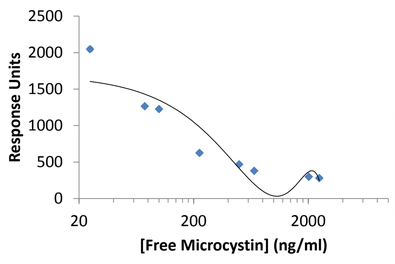
Introduction

Centrifugal microfluidics has undergone a massive growth surge over the past 15 years, evident by the number of comprehensive reviews currently available, with special regard towards Lab-On-A-Disc (LOAD) diagnostic solutions.[1–3] The potential of a LOAD system is dependent on its ability to mimic the specific laboratory protocols with which are required to conduct sample-to-answer analysis. This would include sample handling and manipulation (such as mixing and separation), sample modification (including heating and redox reactions), as well as reaction detection (such as optical, electrochemical, or as required by user). Optical detection strategies on LOAD platforms has been largely successful in both the fields of biological and chemical sensing.[4] Herein, will demonstrate the optical optimisations which were carried out on a biological fluorescent-based[5] and a chemical absorbance-based[6] LOAD detection platforms. This will include the identification and optimisation of LED-photodiode selection, the effects of detection orientation and pathway-length fluorophore selection. Also covered will be a comparison between the microfluidic architecture for incorporating either detection methods as well as their reported limits of detection.

Bottom-up ToxiSense





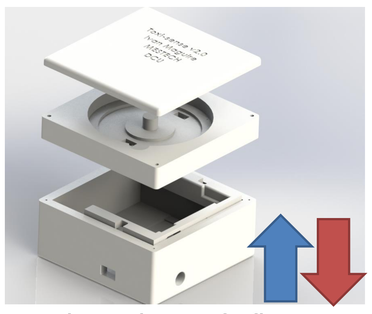
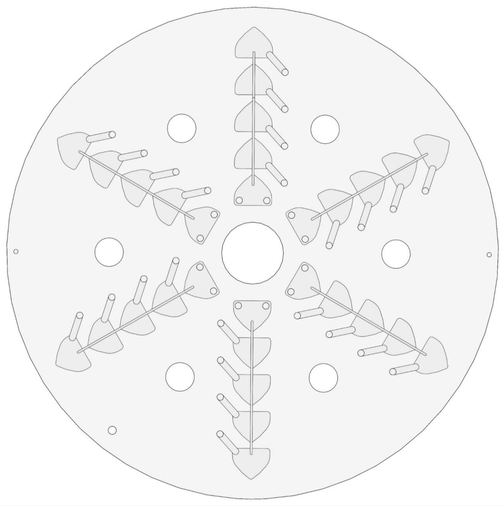


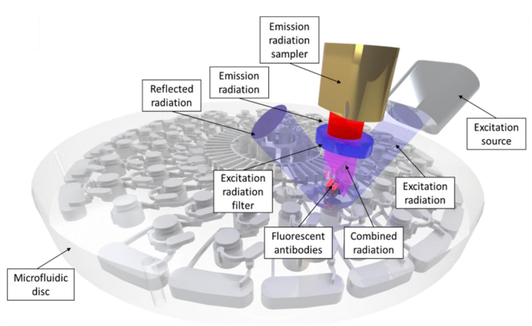
***Fig 1**. Bottom-up fluorescent detection of fluorescent antibody technology on a LOAD platform. In this example, due to trying to detect through the sample resulted in a poor calibration curve*

Fluorescence spectroscopy

Bottom-up (fig.1) vs. Top-down (fig.2) orientations of the ToxiSense fluorescent detection system demonstrated significantly better calibration curves, as demonstrated by the standard 'S-shape'. This was due to the systematic noise gained from transducing through the often non-uniformly coatings of the biosensor materials, rather than observing the fluorescence on top of the coatings.



Top-Down ToxiSense



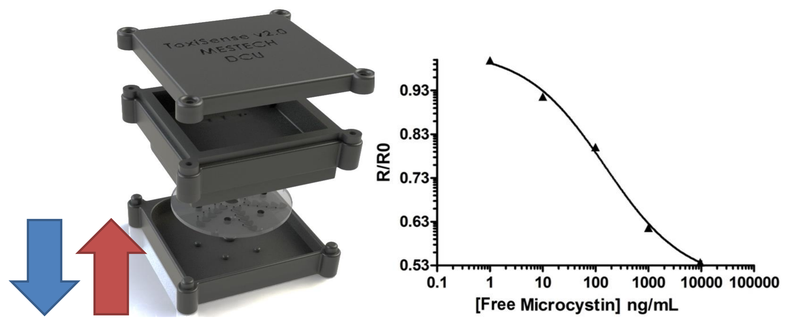


Fig 2. Top-down fluorescent detection of fluorescent antibody technology on a LOAD platform. This orientation resulted in a significantly better calibration curves.

PhosphaSense

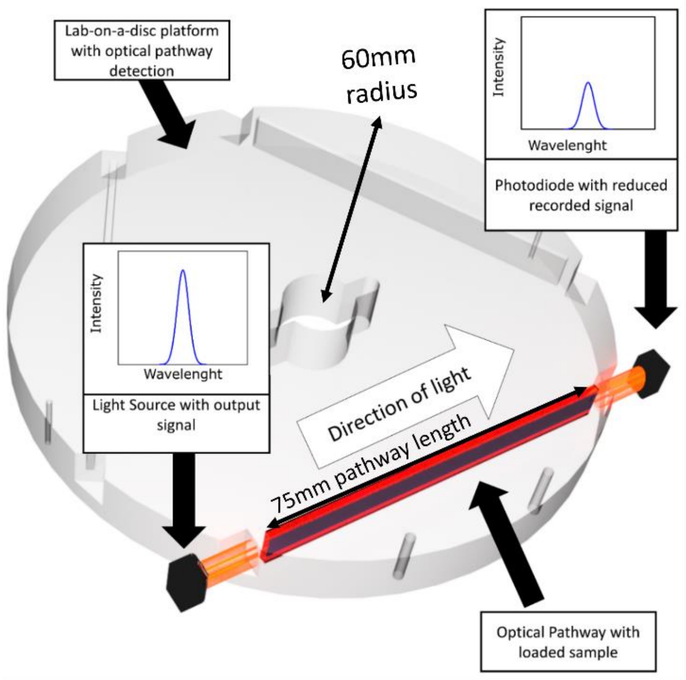
Table 1. *Absorbance-based colourimetric analysis conducted through an optical pathway detection zone on a LOAD platform for phosphate detection.*

Analytical method	Path length (mm)	Slope AU.L.µg^{-1}	LOD µg.L^{-}1.PO_4-P	LOQ µg.L^{-}1.PO_4-P	Linear range µg.L^{-}1.PO_4-P	R^2
PhosphaSense	75	0.003	5	14	14–800	0.9958
Spectrophotometer	10	0.0006	10	150	150–1300	0.9995

Fig 3. *The microfluidic system which allowed 3-fold measurements on a single microfluidic disc using a path length of 75 mm.*

Absorbance spectroscopy

PhosphaSense (fig.3) vs. ChromiSense (fig.4) illustrates the maintaining of absorbance-based detection sensitivity with a reduced path length through widening of the detection reservoir.



ChromiSense

Table 2. *Absorbance-based colourimetric analysis conducted through an optical pathway detection zone on a LOAD platform for chromium detection, where Cr(VI) is in µg.L^{-1} and Cr(III) is in mg.L^{-1}.*

Analytical method	Path length (mm)	Slope	LOD	LOQ	Linear range	R^2
ChromiSense						
Cr(VI)	50	0.0013	4	14	14–1000	0.996
Cr(III)	50	0.0014	21	69	69–1000	0.9957
Spectrophotometer						
Cr(VI)	10	0.0005	7	23	23–800	0.9976
Cr(III)	10	0.0003	6	19	19–1000	0.9931

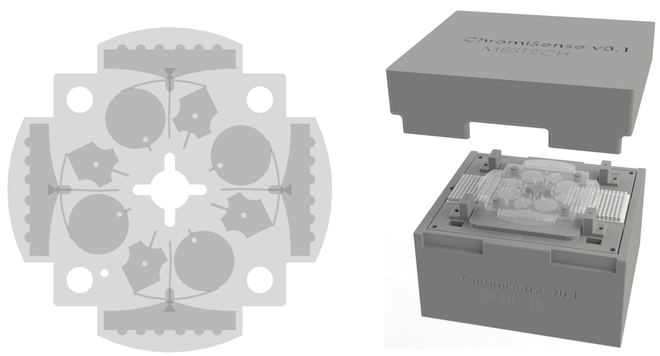


Fig 4. *The microfluidic system which allowed 4-fold measurements on a single microfluidic disc using a path length of 50 mm.*

Conclusion

Optical orientations and detection chambers play an important role the maximum achievable system sensitivity. As evident by the fluorescent based example, inconsistent coatings upon the biosensor surface are often gained through during application. Therefore a more appropriate optical orientation is top-down to prevent systematic noise gained through shadowing of the fluorescent signal. The geometric parameters of the detection chamber is also vitally important in optimising system sensitivity. As demonstrated in the Absorbance example, a shortening of the microfluidic channel would normally result in reduced detection sensitivities, however, through widening of the chamber to the beam width of incident light, sensitivity was maintained. This optimisation also allows incorporation of more analytical test iterations.

Acknowledgments

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