Continuous monitoring of micropollutants and nutrients in surface water with an optical multiparameter sensor platform

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Motivation

Water contamination in surface water is a critical and growing environmental challenge, threatening ecosystems and clean water supplies. Traditional laboratory-based water monitoring techniques face significant limitations, such as time delays between sample collection and analysis, low sensitivity to contaminants at trace concentrations, and interference from other substances in complex samples. These methods are also prohibitively expensive, hindering widespread and continuous monitoring of water quality.

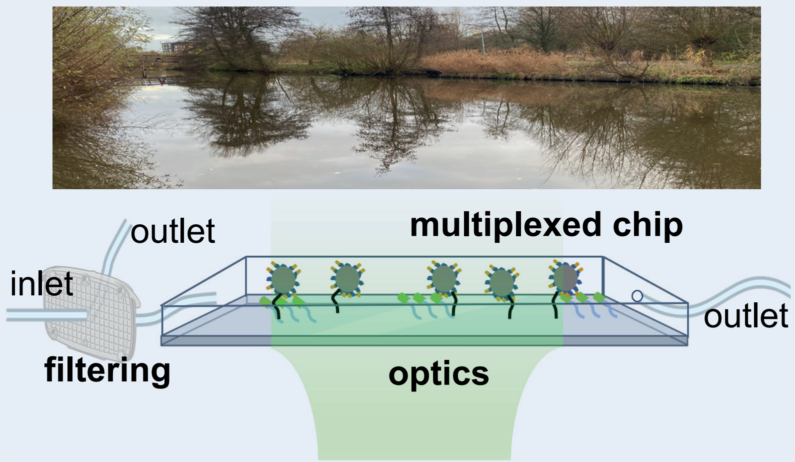

Fig 1. Graphical abstract of the project

Technological challenge

This project seeks to address these challenges by developing a novel, cost-effective sensor capable of real-time, in-field monitoring of water contaminants. The sensor[1,2] leverages biological interactions to ensure high specificity and minimal cross-talk. Its design includes reversible interactions, enabling continuous monitoring without requiring reagents. The miniature, all-optical system will target two critical contaminants—diclofenac, and phosphate—providing real-time data in diverse environmental settings.

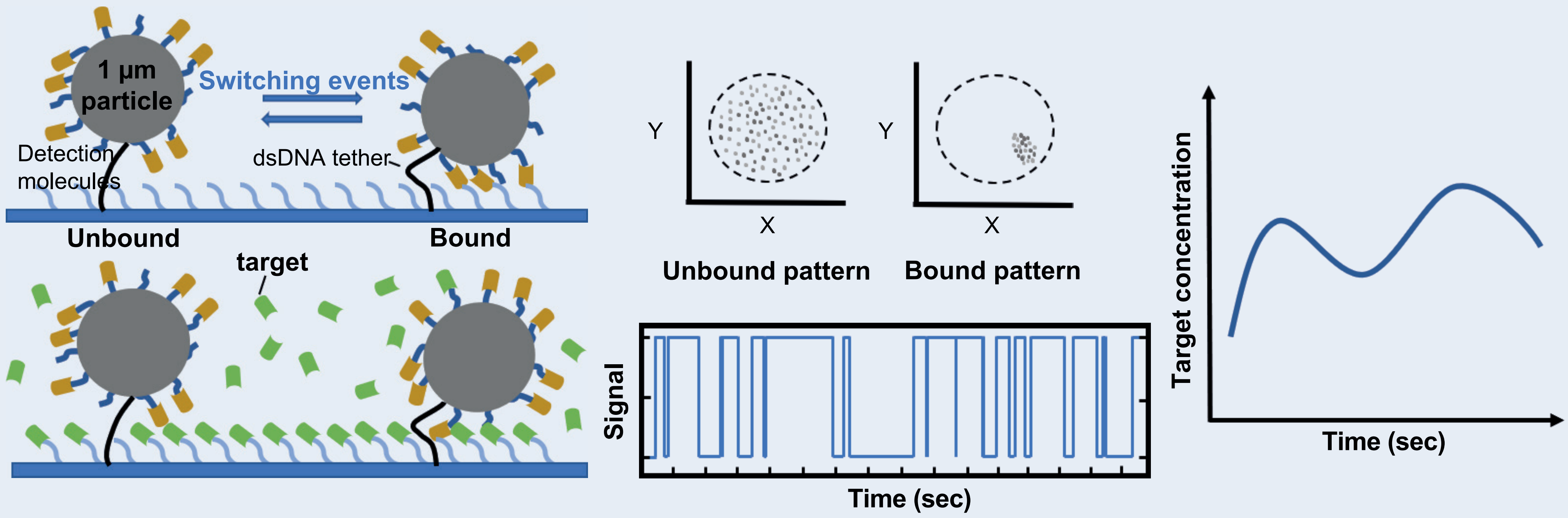

Fig 2. The sensing surface is functionalized with detection molecules and connected to particles via double-stranded DNA tethers. Particle motion alternates between unbound (disk-like motion) and bound (confined motion) states due to reversible interactions with the target analyte. Switching events are optically detected and tracked over time, generating a digital signal that reflects analyte concentration. The sensor's output parameter, is calculated from the number of switching events, enabling real-time monitoring.

Research goals

Specifically, this research aims to:

- Develop a miniaturized interferometric microscope (iSCAT)[3] capable of imaging across a large field-of-view, optimizing its optical design for multiplexing and integration into a portable sensor system.
- Design and integrate fluidic systems with actively cleaned membranes, ensuring long-term operational stability and antifouling performance in diverse environmental conditions.
- Conduct field testing to validate the sensor's functionality, benchmarking its performance in real-world scenarios such as sewage treatment facilities and agricultural sites.

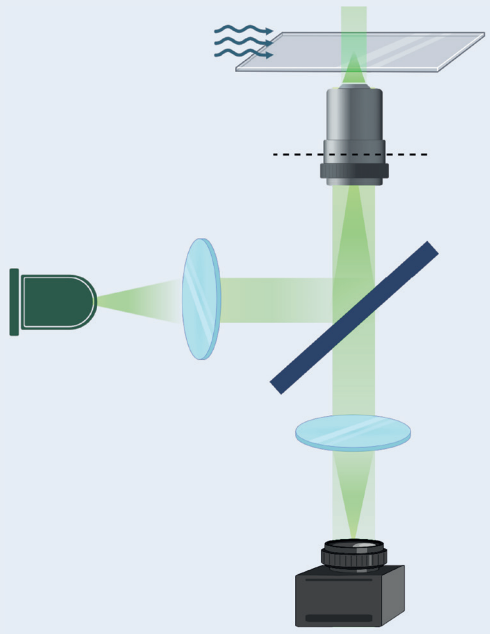

Fig 3. Illustration of the optical setup.

[1] Visser, Emiel WA, et al., Nature communications 9.1. (2018) 2541.
[2] Yan, Junhong, et al., ACS sensors 5.4 (2020) 1168-1176.
[3] Priest, Lee, and Philipp Kukura, Chemical reviews 121.19 (2021) 119374-11970

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