A Low-cost Novel Optical Sensor for In Situ Water Quality Monitoring

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Project Summary

Problem Statement

- In-situ sensors are **fundamental to the management of water systems.**
- Monitoring using in-situ sensors must be carried out in a **cost-effective way** and allow implementation at **larger spatial scales**.
- If networks of sensors are to become not only a reality but common place, it is necessary to produce **reliable, inexpensive, rugged sensors** integrated with data analytics.

Project Goal

- To design and develop a low cost, robust and reliable optical sensor which capable of continuous measurement of multiple chemical and physical parameters in aquatic environments**.**

Outcome

- The sensor's **analytical performance** was demonstrated in the laboratory, for detection and quantification of **turbidity** using analytical standards and in the field by **comparison with a commercially available sensor**(YSI, EXO 2). The sensor's **multiparameter measurement** ability was also tested in field.
- The laboratory and field trials demonstrate that the sensor is **fit-for-purpose** and to provide **high frequency time-series data**, **multiparameter measurements** and **operate unattended** in-situ for extended periods of time.

Sensor Design & Features

Fig 1. Iterations between sensor design and prototypes over period of time.

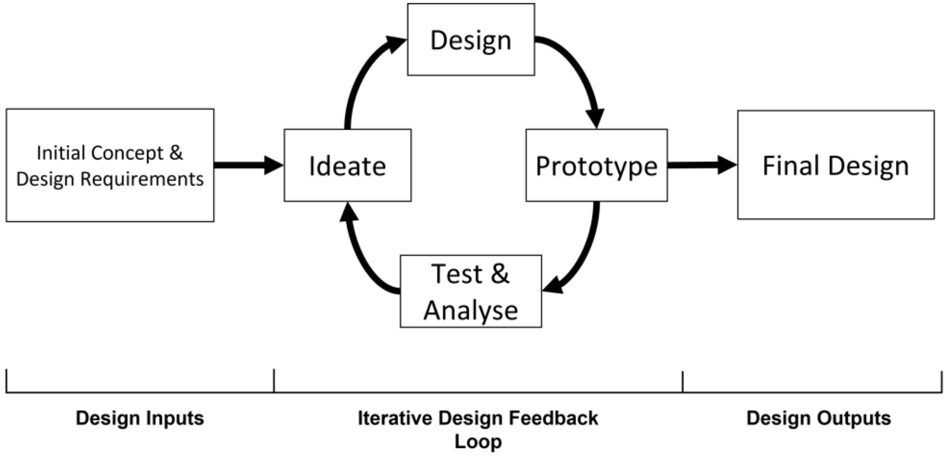


Fig 2. Iterative Design process flow chart.

An iterative engineering design method cycling between sensor **design**, **prototyping** and **testing** was used for the realisation and optimisation of the sensor.

- The sensor can provide **absorption, scatter, and fluorescence** readings over a **broad spectral range (280nm to 850nm)** and **temperature** readings in real-time using **a suite of optical sensors** (CMOS Spectrometers and photodiode detector), **custom designed LED array light source** and a **digital temperature probe**.
- The **electronics** and **firmware** were developed to control the sensor and facilitate data collection with custom built datalogger or external network.
- Different **manufacturing techniques** were used to build a watertight housing for the electronics and sensing components including **CNC machining**, **FDM 3D** printing and **SLS 3D printing** combined with off the shelf components.
- Total materials cost of the sensor prototype is **<€2000.**
- The sensor is capable of measuring a range of optical parameters and temperature in a single measurement cycle.

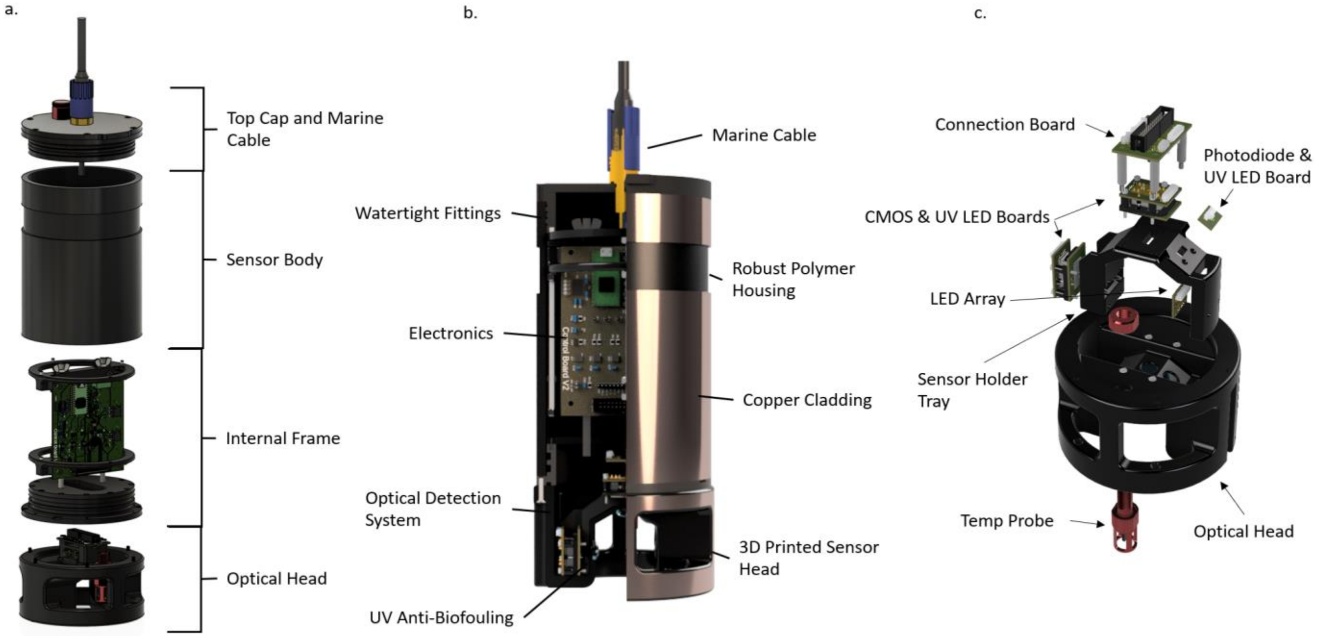
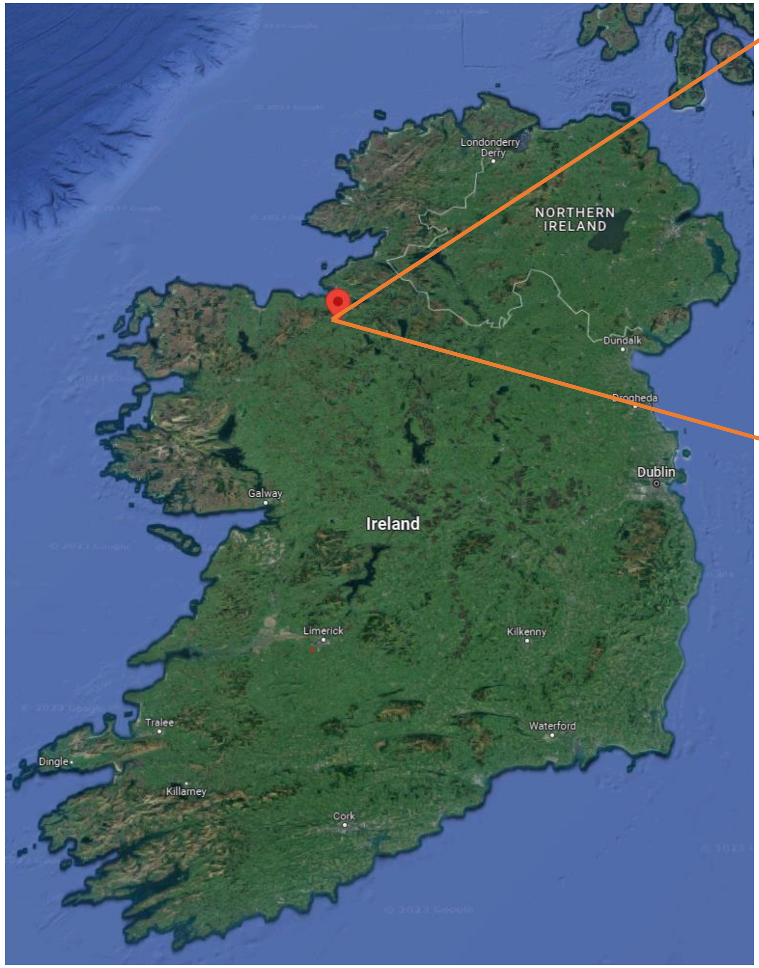


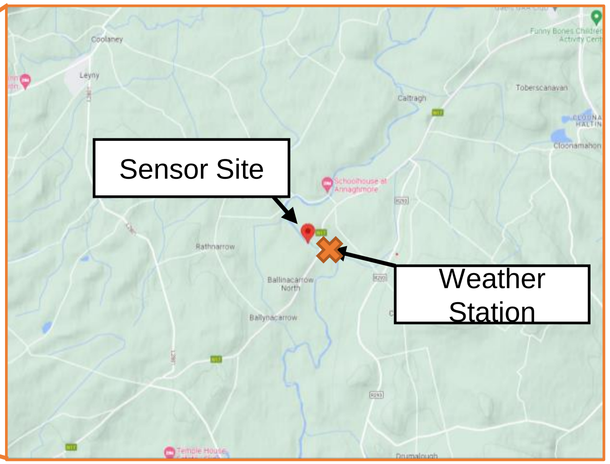
Fig 3. Finalised design of the sensor. A.) Exploded view of sensor sections. B.) Labelled features of the sensor. C.) Exploded view of the internals of the optical head with labelled components

Deployment Site

Site Location: Owenmore River, Co. Sligo, Ireland, 54°08'41.4"N 8°33'07.2"W

Deployment date: 27th March to the 20th of April 2023





Deployment Site Location

Deployment Site Setup

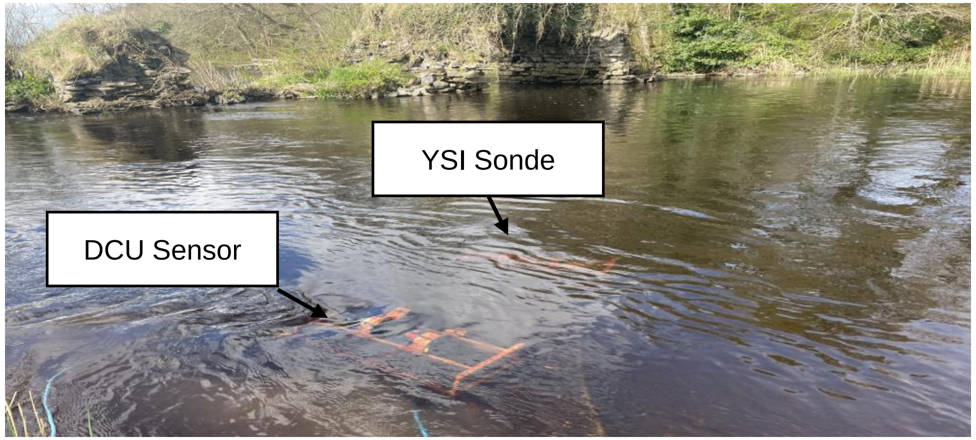


Fig 4. A collection of images outlining the location and setup of the deployment in the Owenmore River. The sensor site is located 50m downstream from the Owenmore Bridge weather station. The sensor is deployed attached to a steel cage and is positioned alongside the commercial sensor (YSI Sonde)

Turbidity Calibration & In Field Measurement

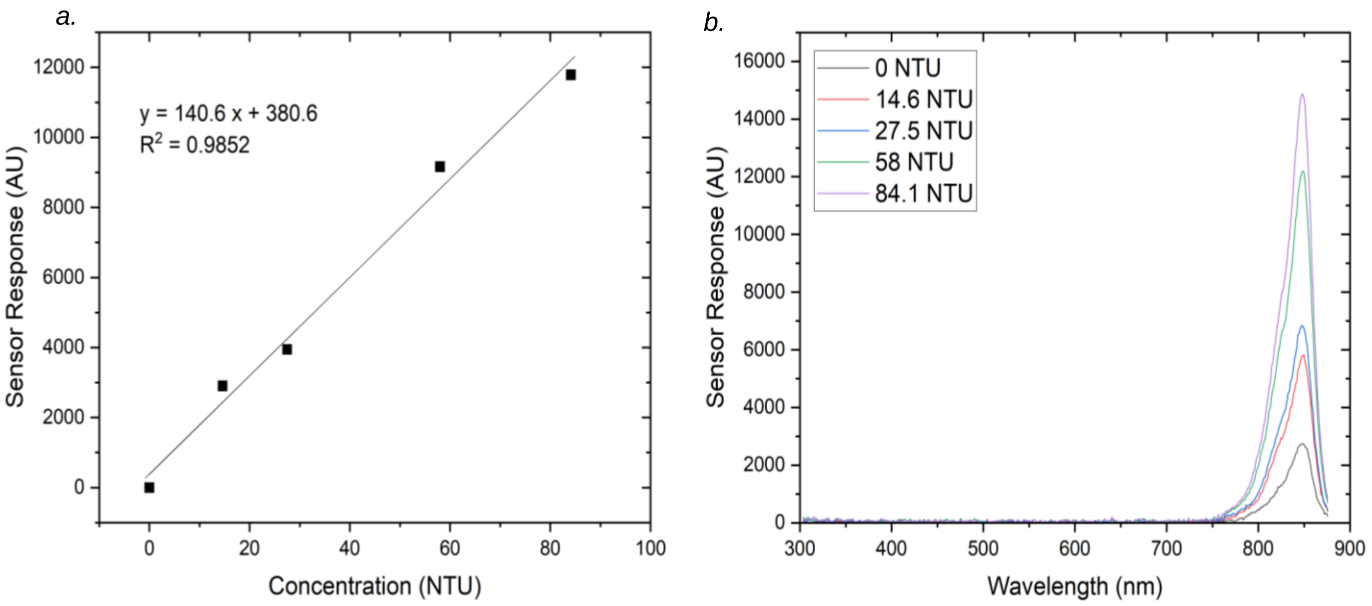


Fig 5. Turbidity calibration curve generated from the sensor using turbidity standards from 0 to 84.1NTU. A.) showing the linear calibration curve fitted. B.) showing the raw spectral output from the sensor's scatter spectrometer detector

- Turbidity is measured by the sensor using an IR LED (850nm) and the spectrometer detector positioned at 90 degrees to measure the scattering of light

- A calibration curve was generated for the sensor by measuring concentration of turbidity standard to convert the sensor response to NTU.

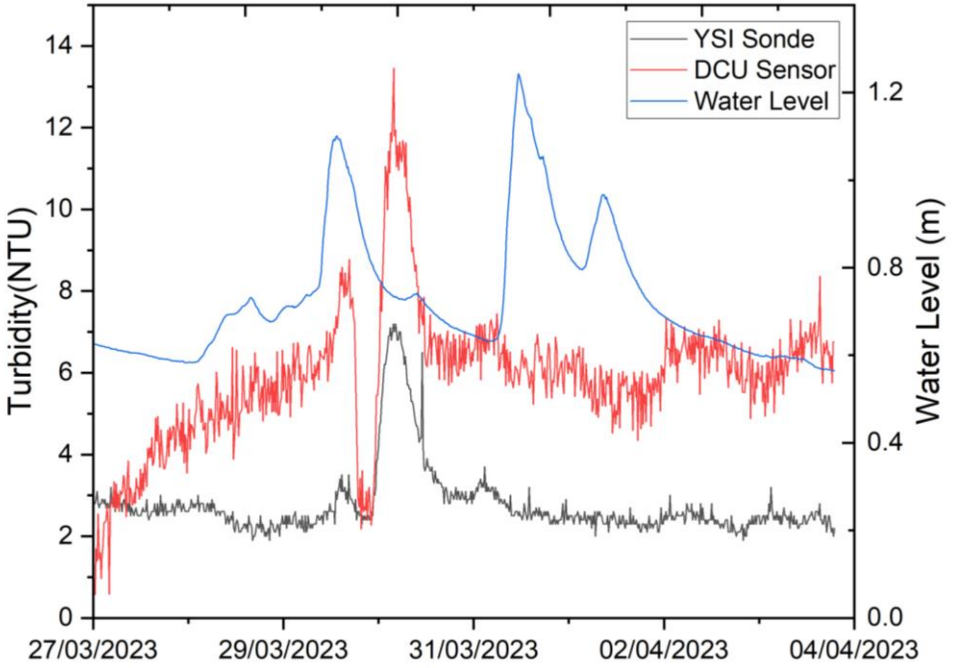


Fig 6. Turbidity data from the DCU sensor and the commercial YSI sonde sensor with water levels measured by the weather station upstream overlayed.

- The sensor developed was deployed along with a commercial sensor in the Owenmore river from the 27th of March to the 4th of April.

- The turbidity calibration curve for the DCU sensor is applied to the sensor response at 850nm.

- Both sensors gathered turbidity measurements at a frequency of 15 minutes.

- The weather station at positioned 50m upstream at the Owenmore Bridge provides water level measurements which is overlayed with the sensor's turbidity measurement.

In Field Multiparameter Measurements

The sensor was redeployed a few days later for a total of three days to **perform a multiparameter measurement cycle** using **three different LEDs** and **three different measurement modes**. The **850nm LED** was used for **scatter**, the **385nm LED** was used for **fluorescence** and a **430nm LED** was used for **transmittance** measurements.

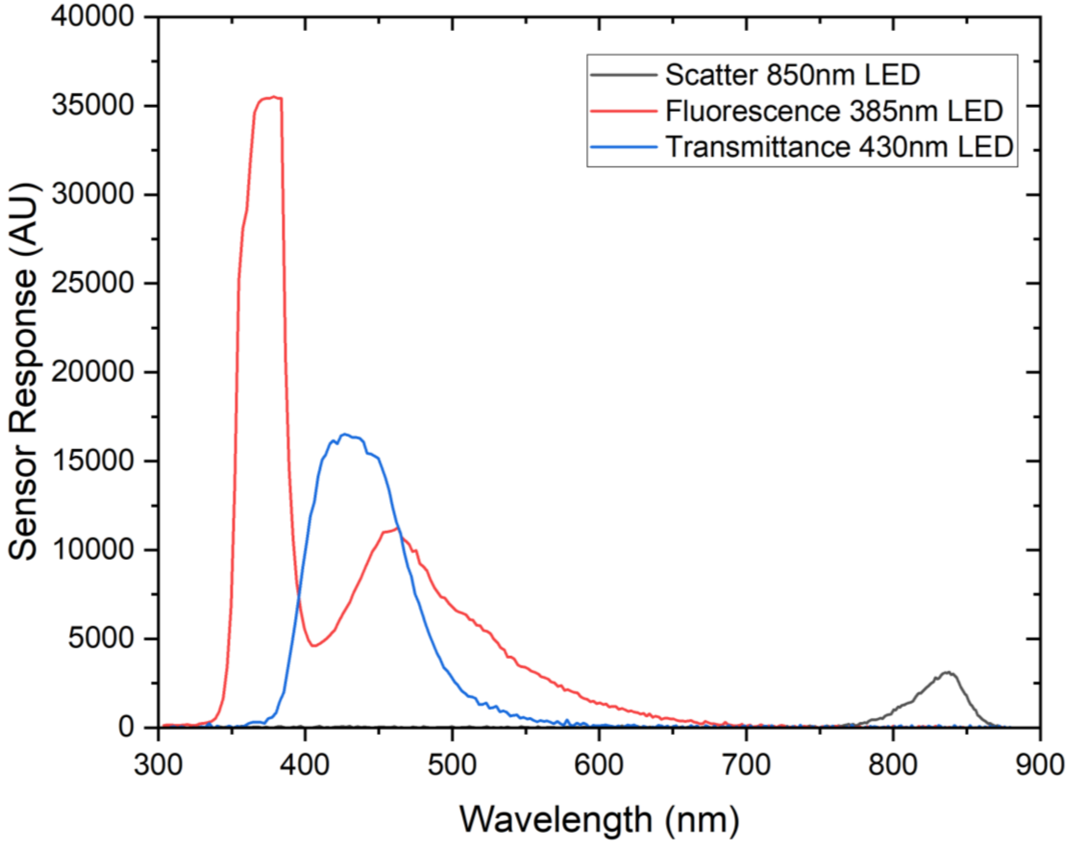


Fig 7 A sample measurement taken by the sensor in situ during the deployment with all three measurements overlaid. The black line showing the scatted signal from the 850nm LED, the red showing the 385nm LED signal as well as a potential fluorescence peak at 450nm and the blue line showing the 430nm LED signal transmittance

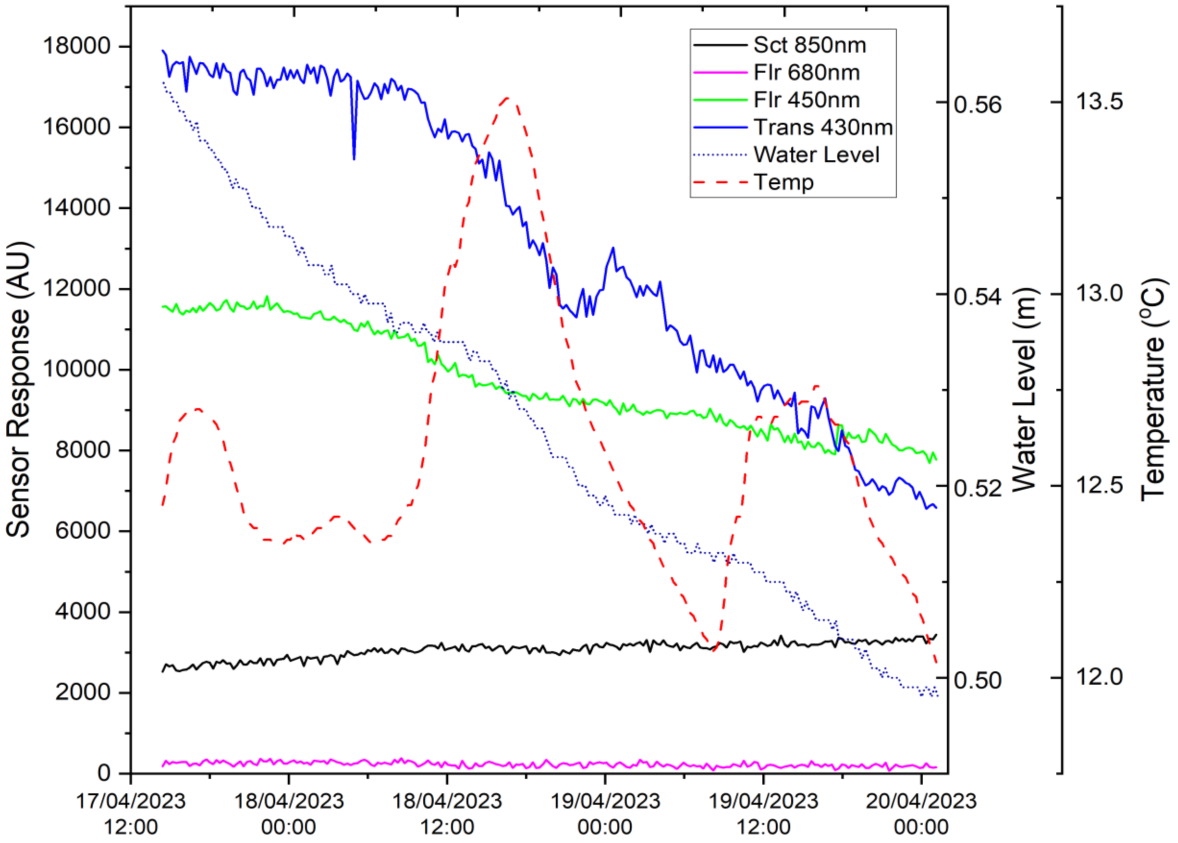


Fig 8. Data from the three-day deployment is shown in addition to the temperature measurement from the sensor's temperature probe and the water levels data from the nearby weather station. The signal intensity at 850nm was used for scatter, for fluorescence 450nm (fDOM emission) and 680nm (Chl a. emission) intensities were plotted and the signal intensity at 430nm was taken for transmittance.

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