

Exploring LiDAR as a Scalable Photonic Alternative to Turbidimeters for Water Turbidity Monitoring

Nur Aina Athirah Mohd Nizar, Juliza Jamaludin*, Marinah Othman

Faculty of Engineering and Built Environment, Universiti Sains Islam Malaysia (USIM), Bandar Baru Nilai, 71800 Nilai Negeri Sembilan, Malaysia

*Corresponding author: juliza@usim.edu.my

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Abstract

Water turbidity is a critical parameter for assessing water quality, conventionally measured using turbidimeters that rely on nephelometric light scattering. While effective, these instruments are constrained to labor-intensive sampling, limiting spatial and delayed data analysis. This paper explores the potential of LiDAR which a photonics-based ranging technology as an alternative method for turbidity assessment. Both turbidimeters and LiDAR operate on light-particle interaction principles. In this research, a compact TFmini-S LiDAR sensor was used in a controlled laboratory setup to observe signal strength changes in relation to turbidity levels measured by a conventional turbidimeter. Though limited in range, the sensor will be use to demonstrate a relationship between signal attenuation and turbidity. These results will provide foundational support for the future use of LiDAR in scalable, noncontact, real-time turbidity monitoring. The study invites further exploration into adapting LiDAR for broader environmental water quality applications.

1. Introduction

Water turbidity is conventionally measured using a device that evaluate the degree of cloudiness in water caused by suspended particles or known as turbidimeter. This measurement is crucial for drinking water treatment, river health assessment, and environmental monitoring. However, turbidimeters are limited in spatial scale and efficiency. They rely on extracting small water samples into cuvettes and performing point-based measurements, which is labor-intensive, time-consuming, and impractical for continuous, wide-area monitoring.

The integration of LiDAR technology into water quality monitoring systems represents a significant advancement in environmental assessment methodologies. LiDAR utilizes laser pulses to measure distances between the sensor and the water surface, enabling the creation of high-resolution elevation maps of rivers and their surrounding landscapes [1], [2], [3]. Both turbidimeters and LiDAR are rooted in the same core photonic principle: light-particle interaction. While turbidimeters use nephelometric methods to measure light scattered at 90°, LiDAR systems capture backscattered light and infer the presence of particulates by analysing signal strength produced by it [4]. This shared foundation opens the door for LiDAR to be considered as a turbidity-sensing tool, with the potential for real-time, non-contact, and spatially extensive data collection.

This paper explores the potential of using compact LiDAR systems to assess turbidity. Although this research focuses on a controlled, lab-scale experiment using a short-range TFmini-S LiDAR sensor, the goal is to validate the fundamental concept: that LiDAR signal strength correlates with turbidity levels measured by conventional turbidimeters. By demonstrating this correlation, the study lays the groundwork for future research and development of scalable, photonics-based water quality monitoring systems that go beyond the limitations of conventional methods.

2. Principles of Turbidity Measurement and Limitations of Conventional Methods

Water turbidity is typically measured using nephelometric methods, which depend on light scattering at a 90° angle from an incident beam. While widely adopted, these systems suffer from several limitations such as variability in calibration as shown in Table 1 and the inability to support continuous or remote monitoring.



Measurement units like NTU and FNU lack standardization across instruments, and external conditions like ambient light or suspended solid composition further reduce reliability.

Table 1. Comparison on conventional methods

Measurement Method	Output Unit	Description
Secchi Desk [5]	Depth (meters)	Measures the depth at which the disk disappears; indirectly related to turbidity
Nephelometric Turbidimeter [4]	NTU	Measures light scattered at 90° from the incident light; standard for low turbidity measurements
Electronic Nephelometer [6]	NTU	Measures scattered light intensity; commonly used for accurate turbidity assessments
ISO 7027 Method [7]	FNU	A method standard in Europe that measures turbidity using scattered light at 90°; outputs in FNU

Moreover, many conventional turbidimeters have low sensitivity at too low and too high turbidity levels, making it difficult to detect small changes in water clarity that could signal early environmental problems. They also require precise calibration especially at ultra-low levels since interference from ambient light or bubbles can cause inaccurate readings. In addition, most turbidimeters can only measure turbidity up to around 1000 NTU, which limits their use in extremely murky or polluted water where values may exceed this range [4].

3. Photonics in Environmental Sensing: The Role of LiDAR

Unlike conventional systems, LiDAR can assess turbidity by evaluating optical attenuation or backscatter strength. Integration with microcontrollers such as ESP32 enables low-cost IoTbased deployments. The proposed system employs LIDAR and IoT technology for real-time monitoring of water quality inspections as shown in Figure 1. The system uses a high-sensitivity optical sensor (LiDAR) to assess water turbidity. The data gathered by these sensors is processed by an ESP32 microcontroller, which transmits the information to the Favoriot IoT platform through Wi-Fi.

In Palmer et al. (2013), Ultraviolet Fluorescence LiDAR (UFL) demonstrated potential in monitoring turbidity, chlorophyll, and colored dissolved organic matter (CDOM) in turbid freshwater lakes, achieving strong empirical calibration against standard measurements [8].

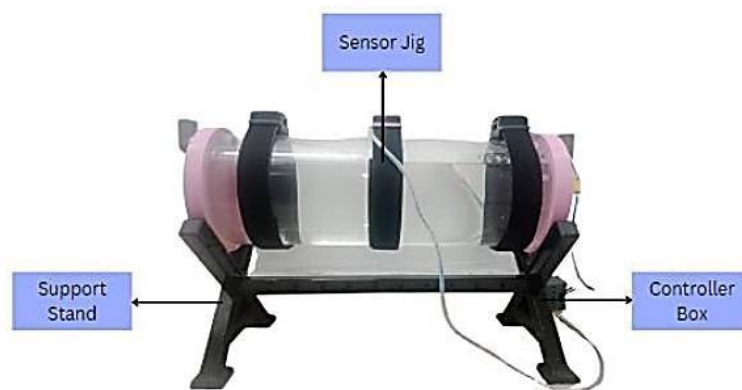


Figure 1. Tools of Real-time water turbidity monitoring using TF Mini-S LiDAR system

As a conclusion, this study demonstrated the potential of LiDAR technology specifically the TFmini-S sensor as a viable alternative for assessing water turbidity through non-contact, real-time measurements. By establishing a correlation between LiDAR signal strength and conventional turbidimeter readings, the research confirms the feasibility of photonics-based water quality monitoring. However, practical deployment in aquatic environments presents challenges such as signal interference from ambient light, limited detection in highly turbid or optically complex waters, and sensitivity to sensor alignment and platform stability. Field calibration is also essential to account for environmental variability. Despite these limitations, the findings highlight promising prospects for advancing scalable and efficient LiDAR-based turbidity monitoring systems.



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