NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

EEE24003 – Optical Water Quality Monitoring System

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1. Introduction

Ensuring a sustainable water supply is a priority for Singapore, where effective water quality monitoring plays a vital role. In collaboration with the *Nanyang Environment & Water Research Institute (NEWRI)*, this research aims to develop a miniaturized optical detection device as a proof-of-concept alternative to conventional UV/fluorescence-based water monitoring systems.

2. Objective

The main objective is to design & implement a system for analyzing water quality using both **UV absorbance (UVA)** and **fluorescence (FLU)**. Hence, the system consists of two parts: **optical** and **electrical**. The optical system design (Fig.1) focused on developing an elliptically cylindrical reflector that enhances the capture of low-intensity FLU light emitted from the UV-illuminated water sample while enabling UVA detection. The electrical system deals with the elements related to powering up the light emission source as well as the circuits for light detection and signal processing. Through systematic iterative simulations, this study evaluated various optical assemblies and designed an optimized system.

3. Methodology

1. 3D Design and Modelling – SolidWorks, Autodesk Fusion
2. Optical Simulation and Raytracing – ZEMAX
3. Electrical Circuit Simulation – Multisim

Targets: Perform iterative simulations and determine the optimized setup of optical components

4. Results

4.1 - Optical System

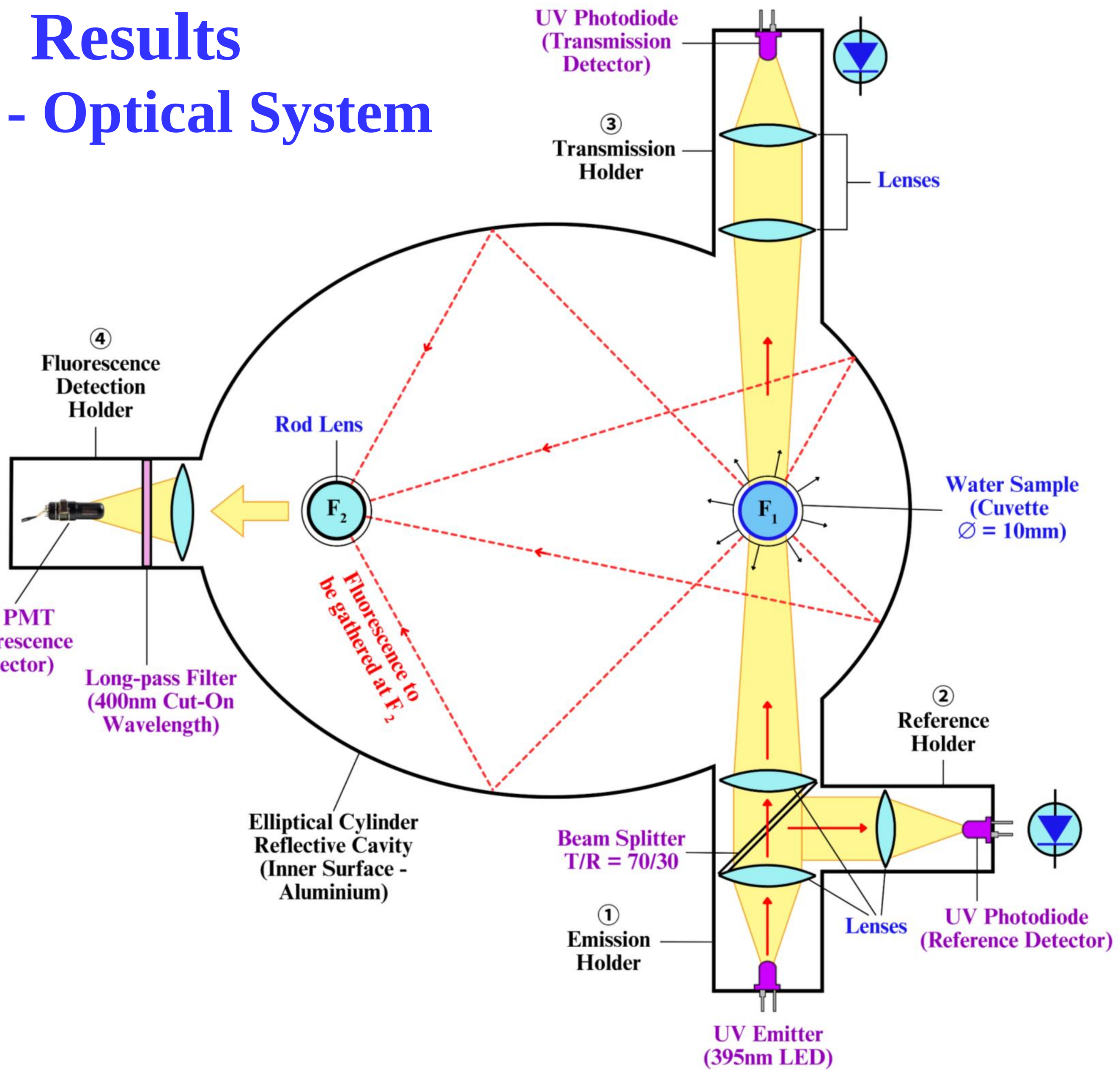


Figure 1. 2D representation of optical system

Due to the geometrical properties of an ellipse, the UV-illuminated water sample is placed at the 1st focal point, and its isotropically emitted FLU light is (ideally) all concentrated at the 2nd focal point of the reflector.

(1) At the **emission holder**, cylindrical lenses collimate and focus the UV beam onto the water sample.

(2) At the **reference holder**, a beam splitter splits a portion of the excitation UV beam to reference **photodiodes (PDs)**.

(3) At the **transmission holder**, PDs detect UV light transmitted through the sample and focused by lenses in the transmission holder. The detected signal is subsequently processed together with the reference signal to determine UVA parameters.

(4) At the **fluorescence detection holder**, a long-pass filter blocks excitation light, allowing only FLU light to be detected by a **photomultiplier tube (PMT)** after being transmitted from the 2nd focal point of the elliptical reflector.

4.2 - Evaluation of Fluorescence Capturing Performance

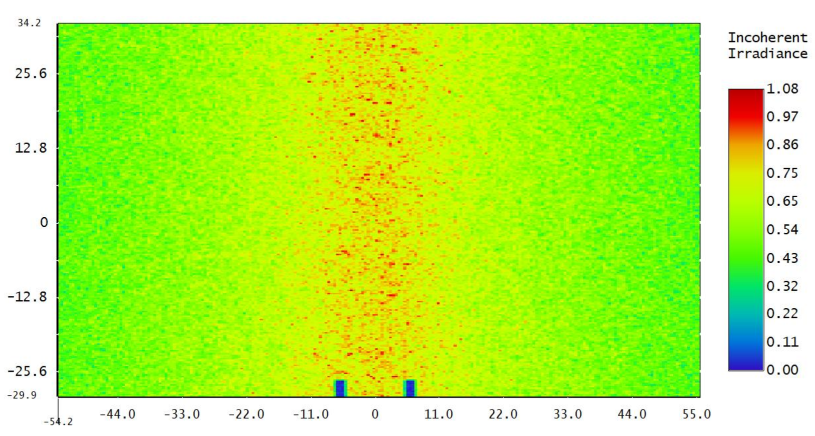


Figure 2. Irradiance map of FLU light arriving at the 2nd focal point of the reflector

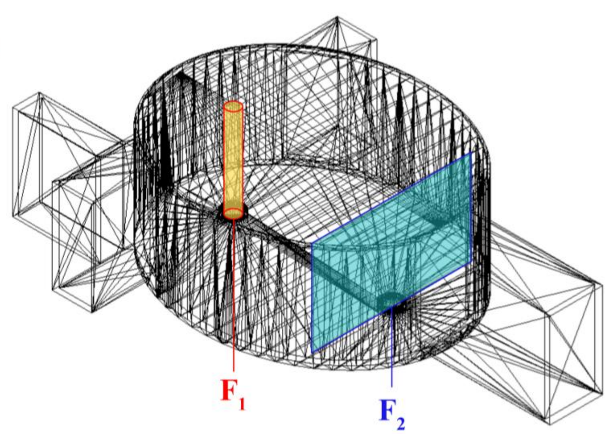


Figure 3. ZEMAX detector for FLU light (blue plane)

In ZEMAX software, Ray Trace and Irradiance Maps were used to simulate and visualize the light distribution.

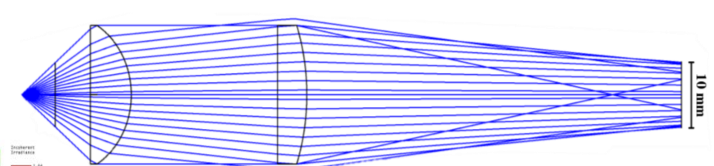
The prominent strip in the center of the image shown in Fig.2 proves that FLU light is gathered effectively at the 2nd focal point of the elliptical reflector.

4.3 - Maximizing UV Irradiance on Water Sample

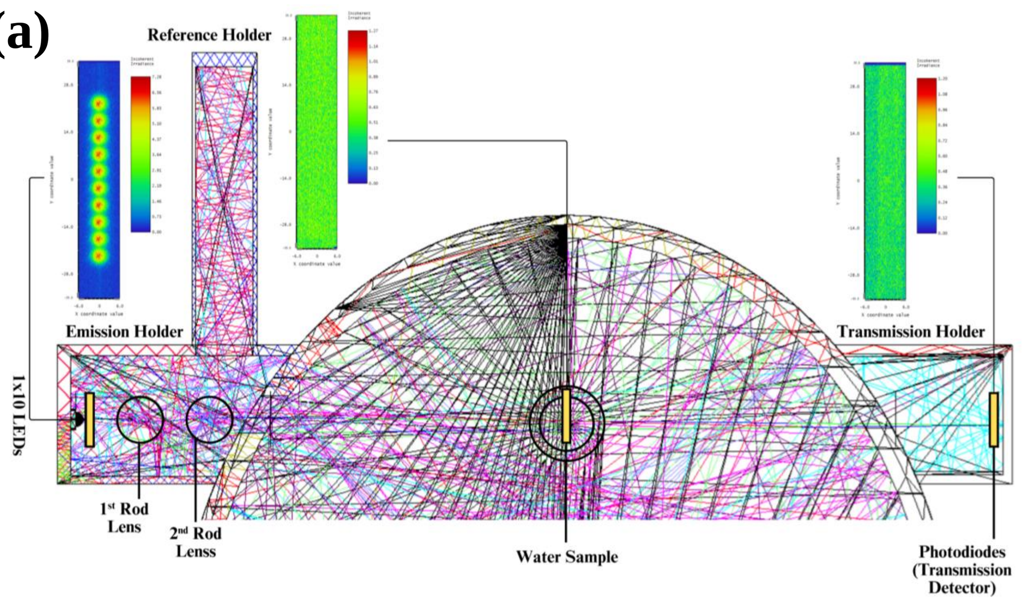
At **emission** and **transmission** holder, the optimal two-lens combination was determined by using the 1st lens to collimate the UV beam and the 2nd lens to focus it, thereby illuminating the largest cross-sectional area of the water sample to maximize FLU excitation in the sample. The cuvette's cross-sectional diameter is 10mm. We propose two types of lens combinations:

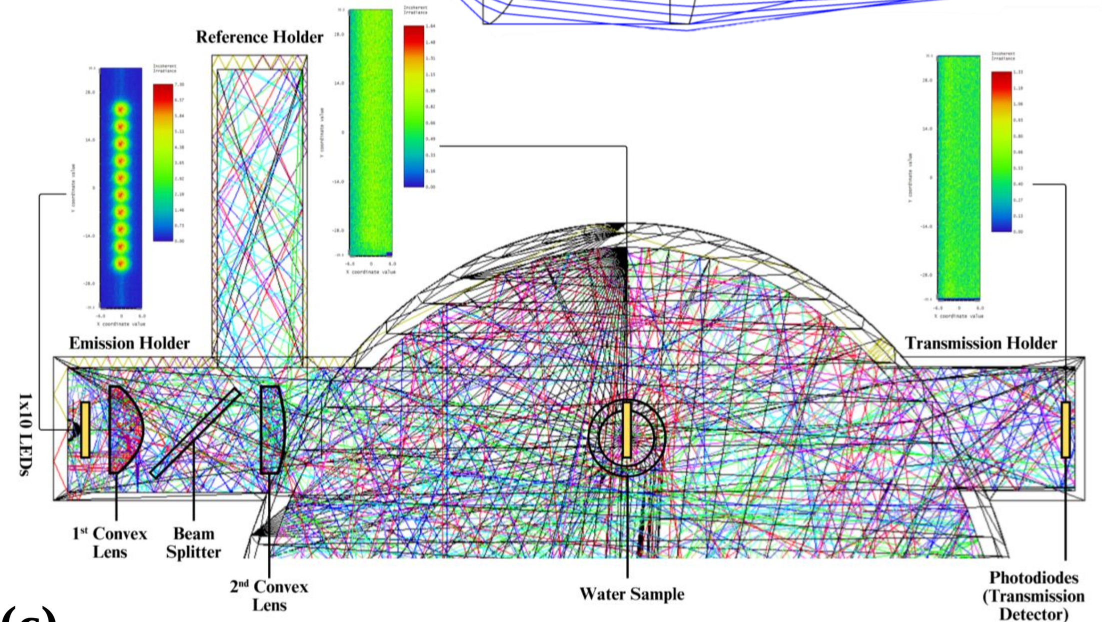
- Version A: 2 Rod Lenses
- Version B: 2 Cylindrical Convex Lenses

(b)



(a)





	Water Sample		Transmission Detector	
	Version A	**Version B**	Version A	**Version B**
Peak Irradiance (W/cm²)	1.2672	**1.6427**	1.1961	**1.3263**
Total Power (W)	4.4723	**5.7470**	3.0296	**3.8277**

Table 1. Performance parameters for the 2 versions of lens combinations for emission & transmission holders

Version B is chosen because of its higher UV irradiance power onto the water sample.

(c)

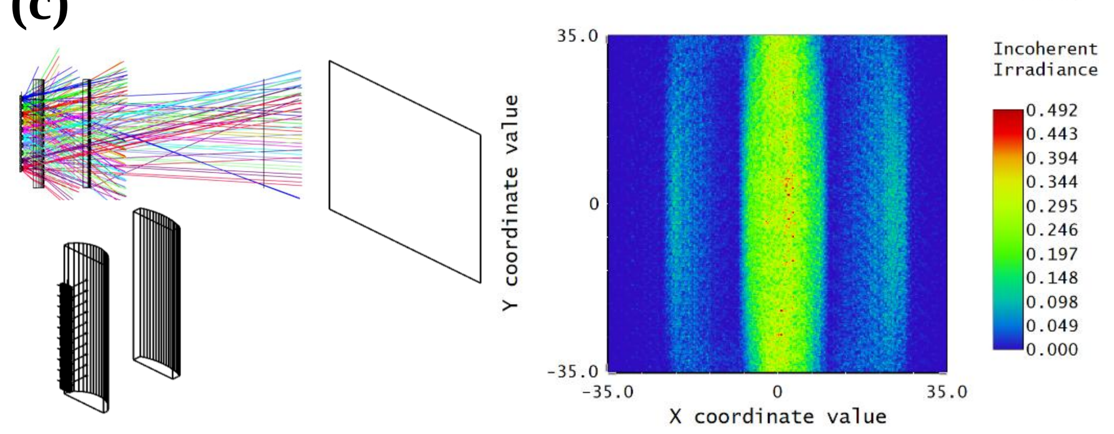


Figure 4: The 2 versions of lens combinations for emission & transmission holders: a) 2 rod lenses; b) 2 convex lenses; and c) simulation of focusing performance for version B

4.4 - Electrical System

The electrical system (Fig.5) consists of:

- **LED driver circuits**
- **Transimpedance amplifiers (TIAs)** convert photogenerated currents into voltage signals.
- **Lock-in amplifier (LIA)** extracts the weak FLU signal from noise by using the reference signal (R).

This electrical system thus obtains the UVA and FLU data necessary for subsequent water purity analysis.

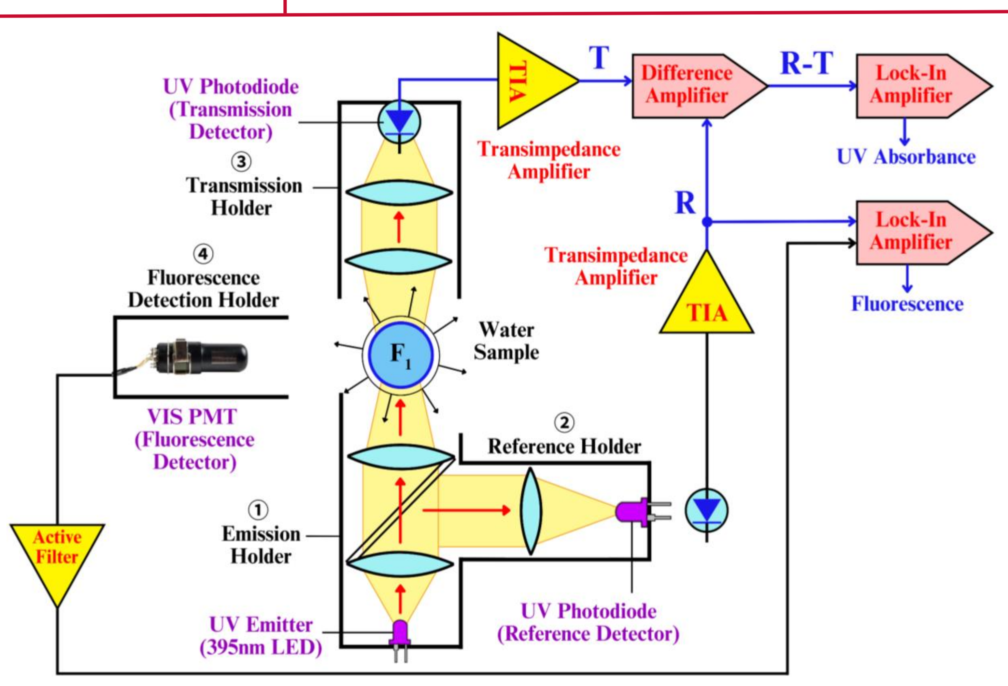


Figure 5. Electrical system design

5. Conclusion

Using ZEMAX simulations, we determined the optimal lens specifications and found that the system performance matches theory. A 3D-printed prototype is being designed. The ultimate goal is to demonstrate that this system can provide efficient and accurate real-time monitoring for water treatment facilities.

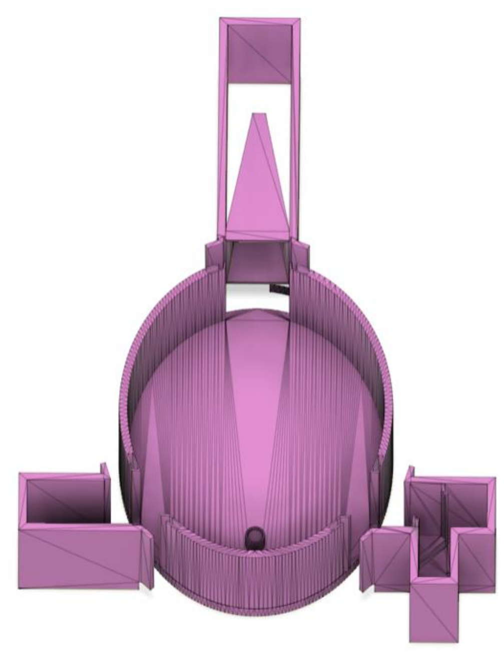


Figure 6. **3D system design**