Optically based sensor-platform for visualization and detection of bacteria and cryptosporidium in water

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Abstract

The process of detecting cryptosporidium and bacteria is an essential step to ensure clean water is introduced into a water supply. Cryptosporidium can cause major problems for both humans and animals. To track and quantify the parasite a sensor with a digital camera using Digital Inline Holographic Microscopy (DIHM) is used. The advantage of using this technique is the significant cost reduction compared to traditional microscopes.

Introduction

Cryptosporidium is a genus of parasites that can affect the health of humans and cause diseases. The World Health Organization (WHO) recently reported that only 5.2 billion people have access to safely managed drinking water (71% of the global population) [1]. Cryptosporidiosis is a result of ingesting cryptosporidium which is a gastrointestinal illness that can be fatal to newborns [3], the elderly [4], and the immunocompromised [5]. In 1993, the largest outbreak in history occurred in Milwaukee County, where there were at least 400,00 cases of cryptosporidiosis [2]. Early detection can give a city a specific view of how contaminated a water source may be. The sensor used for this detection only requires the device itself and a laptop. Images are taken using a complementary metal-oxide-semiconductor (CMOS) sensor 'camera'. The images are then processed by the software and the particles are analyzed by the sensor 15 times per second.

Design Overview

The DIHM design in depicted in Figure 1. The light from the laser in aimed into the cuvette that is holding the water sample.

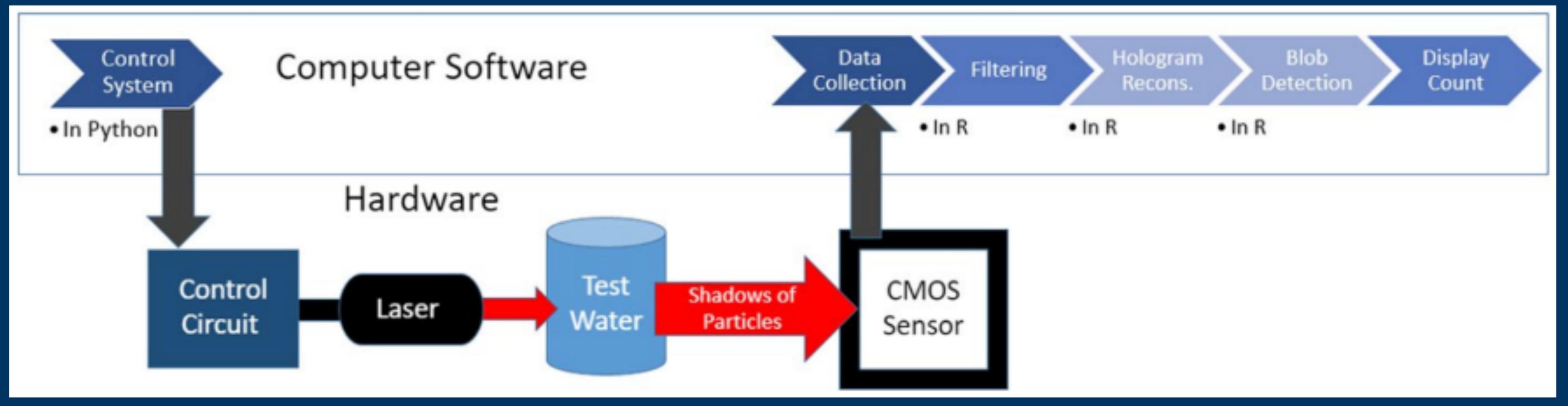

Fig.1 Particle sensor design

Methods & Materials

Three main components make up the sensor: a 650 nm laser, a complementary metal-oxide-semiconductor (CMOS) sensor 'camera'., a 10mm standard glass cuvette.

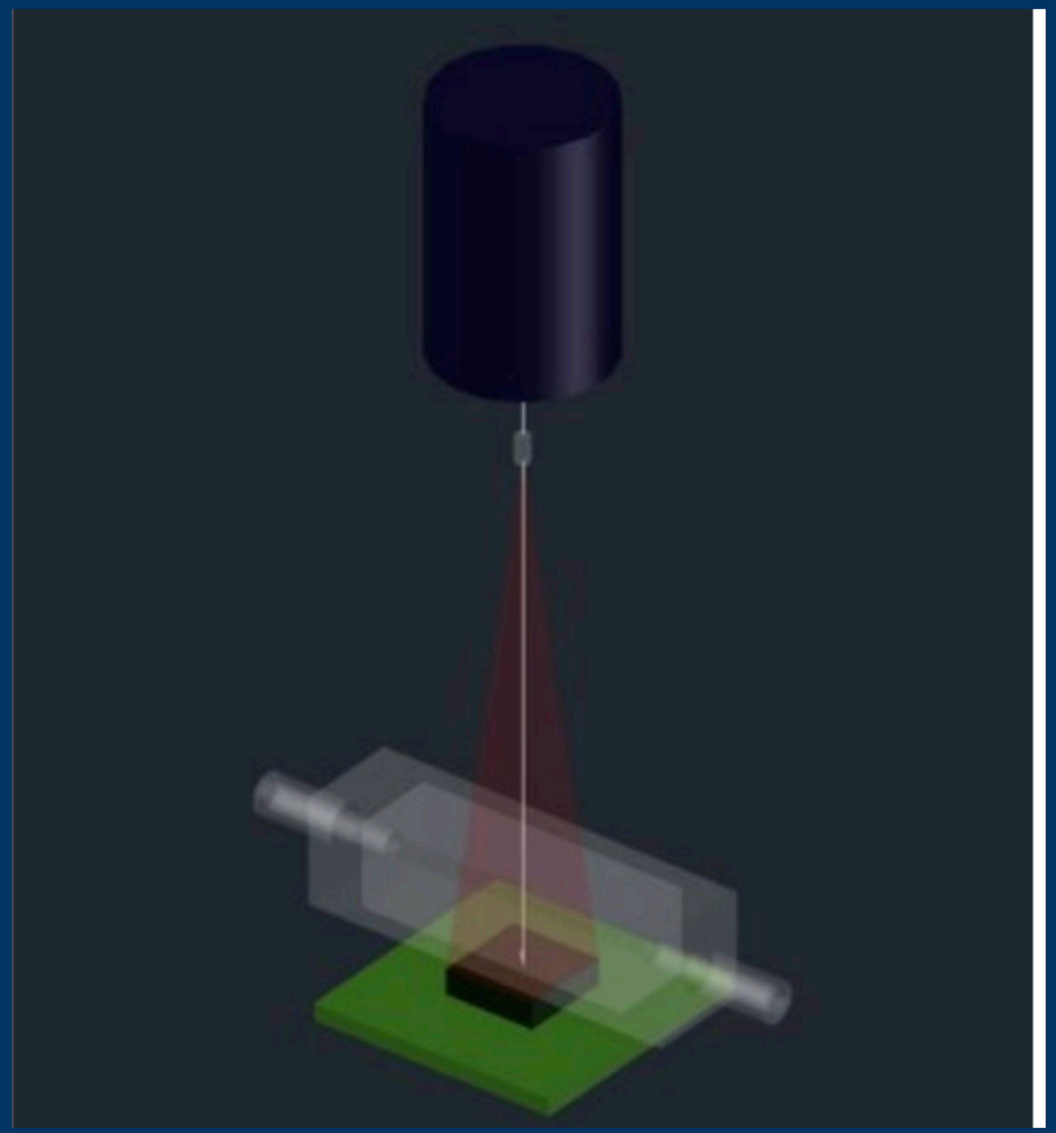

Fig.2 Laser (top), cuvette, and CMOS (bottom) work together

Methods & Materials

To power the laser in the DIHM process a custom-made circuit is used. The circuit consists of a 170 ohm resistor, the laser diode, and a modified USB-A to Micro-USB cable. The USB-A end is connected to the laptop and the Micro-USB end is used to power the circuit.

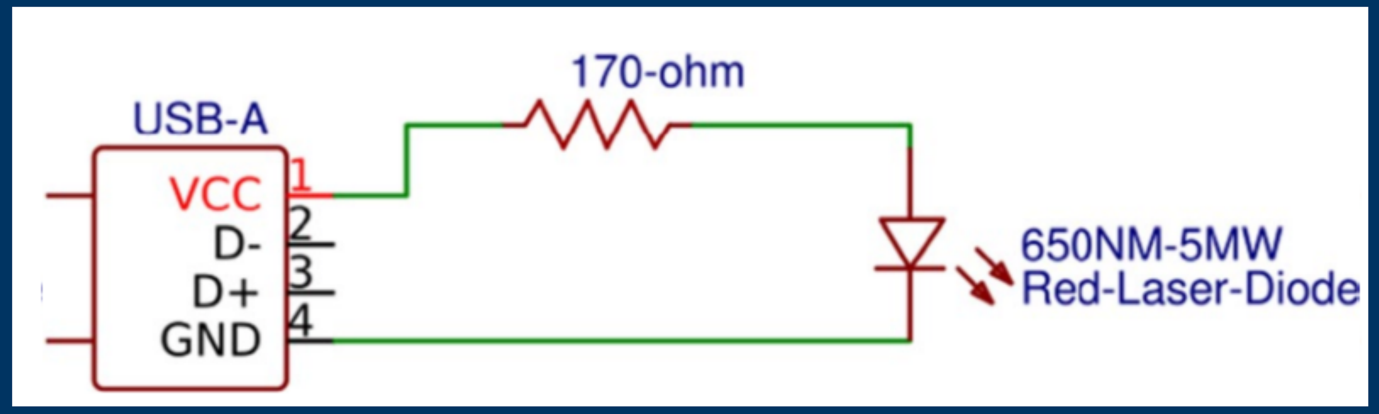

Fig.3 Custom-made circuit used to power the laser for DIHM

Results

Cryptosporidium oocysts were measured using the sensor by putting 3mL of the sample into the sensor's cuvette. After gathering data the first step is to remove all non-moving content. To do this the images must be filtered by subtracting one image from the previous image. Using "blob detection" a software process is ran to highlight points of interest at each increment. X and Y coordinates are given following the reconstruction including the depth coordinate. This gives the X, Y, and Z coordinates of each particle's three-dimensional position and size. Each of the samples in Table.1 were measured three times. "Count" is the cumulative number of pixels of particle in each sample. "Particle Value" is the brightness of the pixels. "Crypto" is the amount of cryptosporidium put in to be measured.

Source	Count/mL	Particle value / mL	Crypto / mL
A1	44,736.835	44,381.28677	3.33333333
A2	11,225.955	12,207.14716	3.33333333
A3	44,794.048	50,468.69097	3.33333333
B1	27,578.908	23,931.61726	333.333333
B2	37,645.851	25,514.85162	333.333333
B3	56,383.101	59,030.88099	333.333333
C1	13,143.589	16,323.57625	0
C2	33,013.434	26,901.99451	0
C3	37,975.402	31,228.02628	0
D1	74,453.938	90,055.06904	33.3333333
D2	21,892.923	20,237.97587	33.3333333
D3	19,809.555	24,330.43063	33.3333333
E1	30,597.196	22,533.42751	0.33333333
E2	36,467.942	21,422.90186	0.33333333
E3	26,102.541	16,194.10506	0.33333333
F1	56,765.791	48,464.83069	0
F2	21,917.469	18,669.69828	0
F3	1586.3086	763.7644728	0

Table.1 Particle counts

Figure 4. Shows the comparison between the sensor and the actual amount of Cryptosporidium / ML. As the sensor gets trained with larger datasets the standard deviation is expected to reduce.

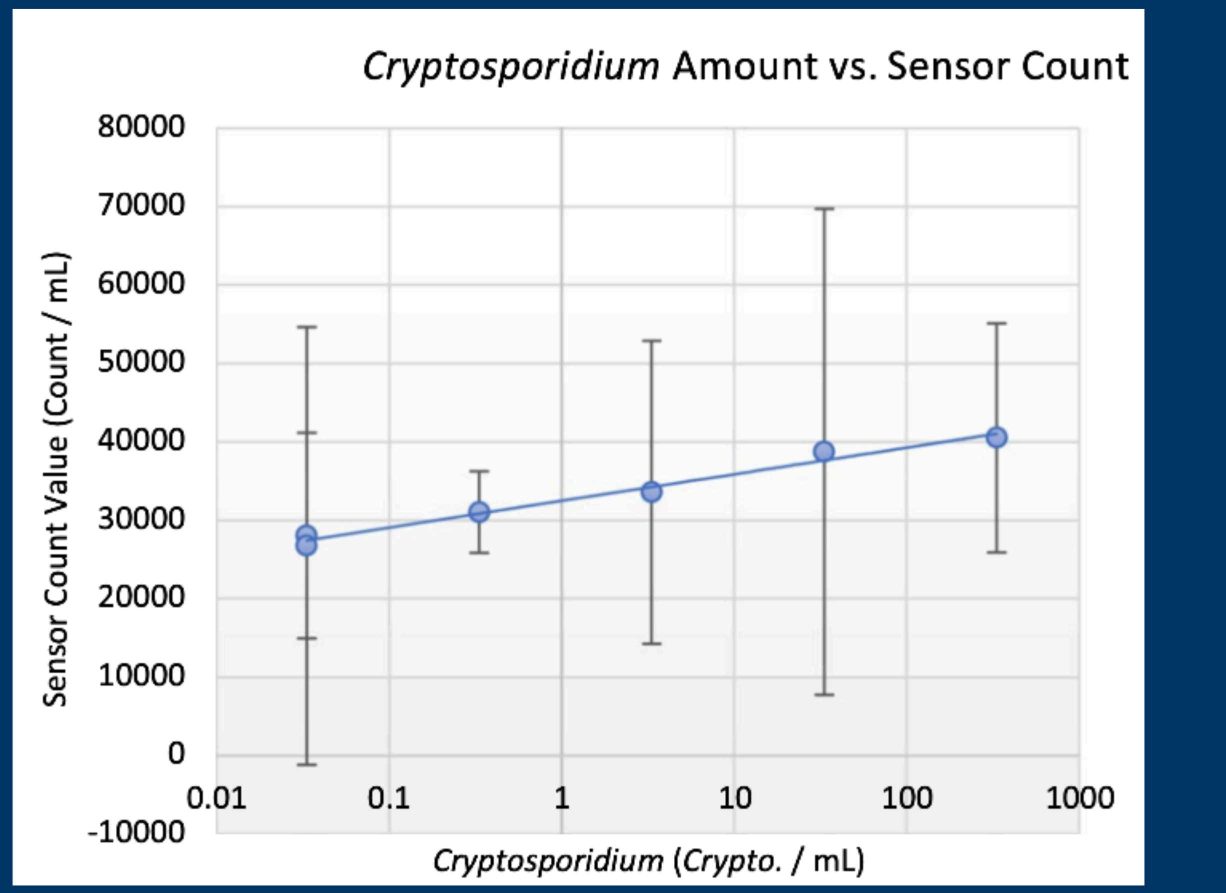

Fig.4 Standard method vs Sensor

Conclusion

The sensor detects Cryptosporidium in less than twenty minutes for an equipment cost of $300. The design of this sensor allows for Cryptosporidium in deionized water to be detected in a lab, public water system, or an individual household. In the future, the sensor will track specific families of pathogens to teach the sensor how to differentiate between various species of organism.

References

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