IoT Breakwter - Wave - Weave
Fiber optics sensing technology for geotextile tubes wave and dredge sensing application

Yuxin Yang

Abstract

Geotextile tubes as submerged breakwaters are the widespread shoreline climate-adaptive infrastructure. Integrating sensors with geotextile tubes weave an Internet-of-the-Thing (IoT) on the shoreline. Shoreline sensing measures volatile phenomena -wave, soil, and temperature, which facilitates the decoding of the coastal morphophonemics in the age of climate change. With fiber optics as sensors, the external environment changes affect light transmission through fibers in a way that can be detected at the other end. The environment modulates light passing through fibers by directly altering its intensity, affecting its polarization, or shifting its phase. Specially designed fibers sensitively capture environmental changes such as temperature, pressure, and other parameters. A thin, flexible fiber is easy to weave on high-tenacity fabric and resistant to extreme coastal weather with the proper coating.

The project proposes a shoreline environmental sensing technology, a weavable fiber optic sensor for geotextile tubes to monitor dredge and wave. The challenges include the followings. The first is to understand the relationship between the deformation behavior of the geotextile tubes and environmental changes and implement proper filters. Under various circumstances, the geotextile tube is deformable, such as storm surges or the dredge material property changes. Second, fiber optic sensors require accurate and robust connections to transmit light. Third, implementing sensors in a submersible and saltwater environment might affect light refractions, influencing the results.

Aims of the Research

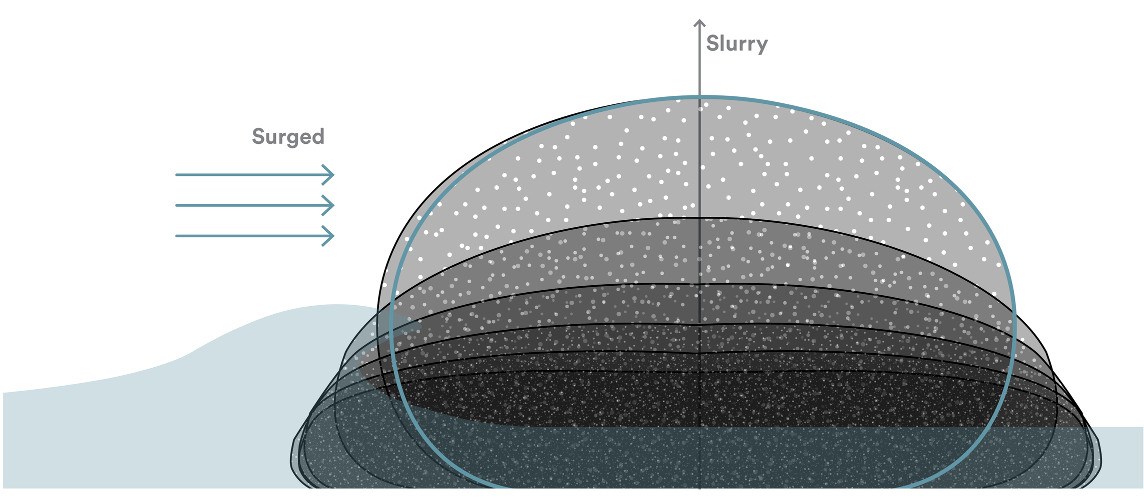
1. Develop fiber optics bend sensors and understanding the deformation performance.
2. Exploring the feasibility of fiber sensing in monitoring shoreline hydrology and soil condition.
3. Understanding the long-term and short-term environmental changes and how it modulates fiber optics sensing on the geotextile tubes.

Research Methodology

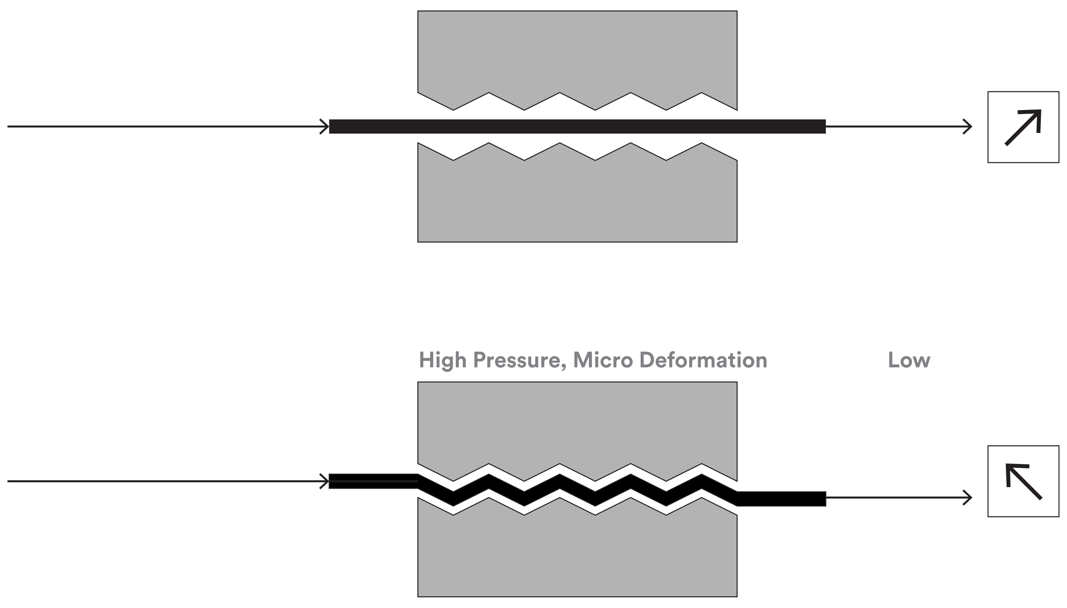
The research includes literature reviews and two sets of prototype experiments. The fiber sensing review is to understand the state-of-the-art fiber sensing technology and its capability to decode environmental changes. The geotextile tube review is to understand the deformation behavior of the bags. The first experiment is fiber optic deformation, which is implemented on fibers of varying diameters and treatment and light sources to improve fiber sensing sensitivity. The second is the water tank waves experiments on geotextile tube mockups. This experiment is to understand the fiber sensing underwater performance and further decode the relationship between wave and the signal.

Title image source: ACE Geosynthetics

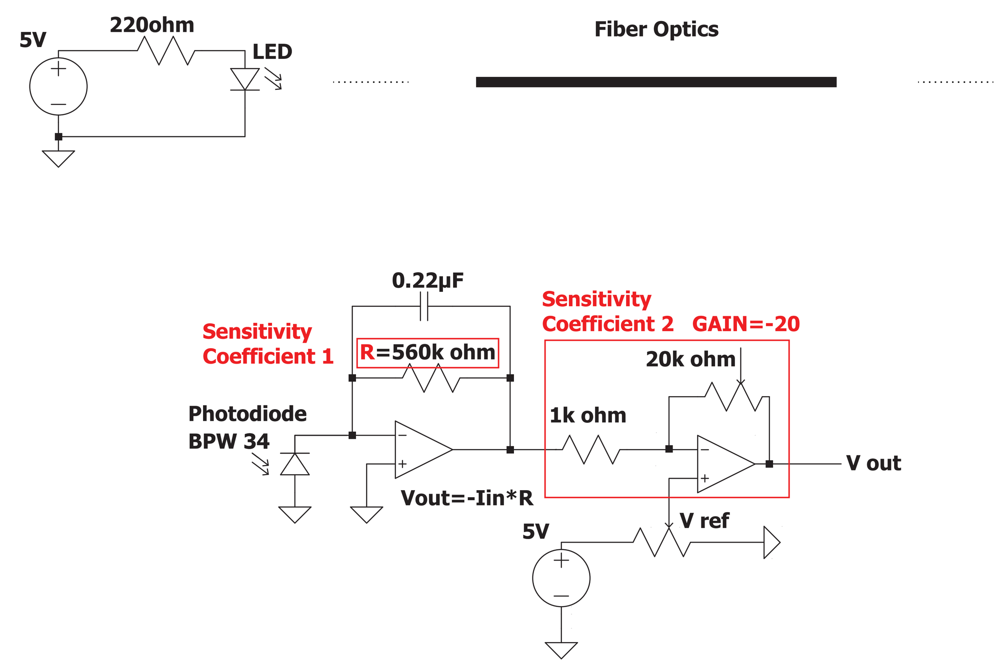
Concept



Sensing dredge and waves by sensing geotubes deformation →

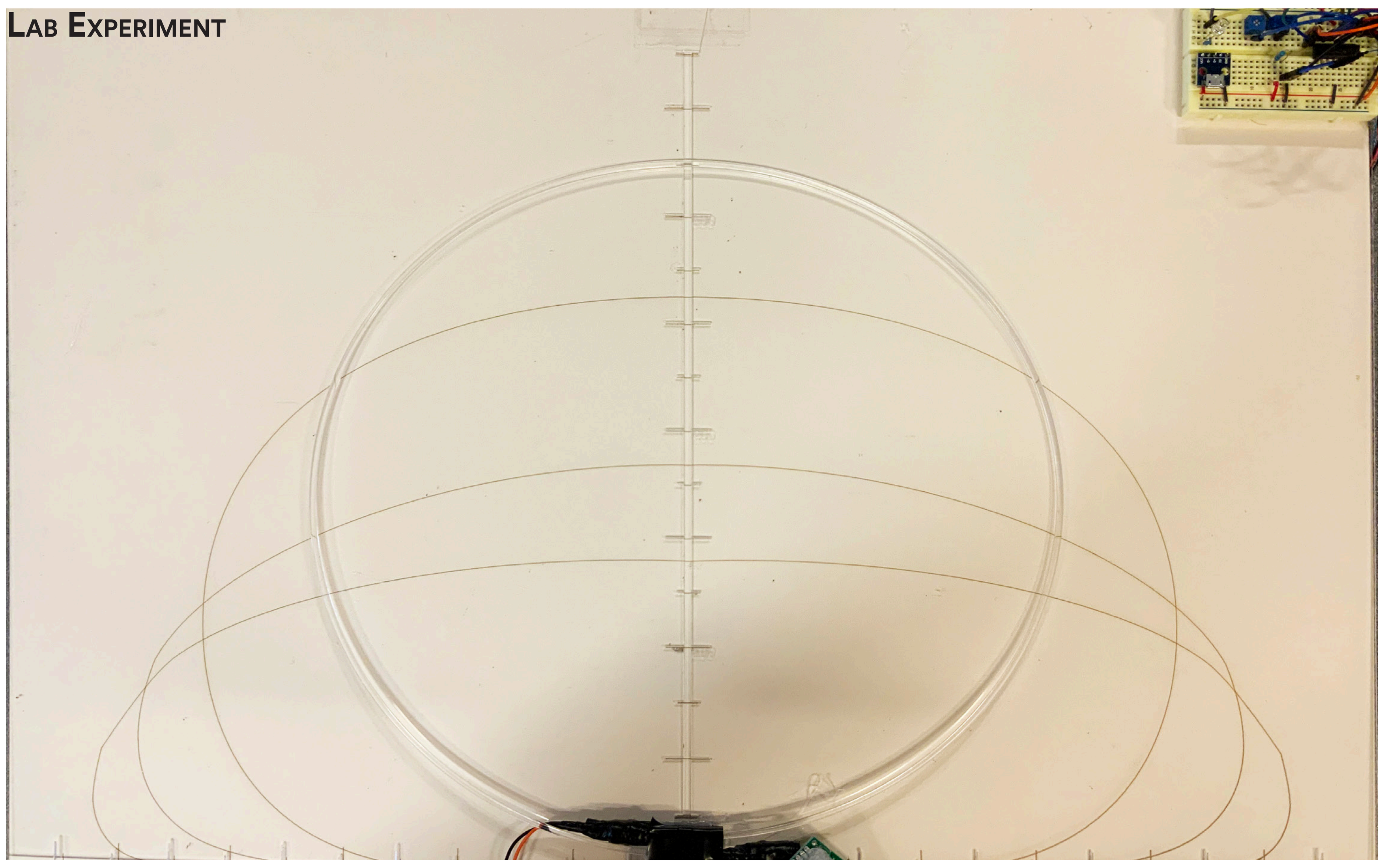


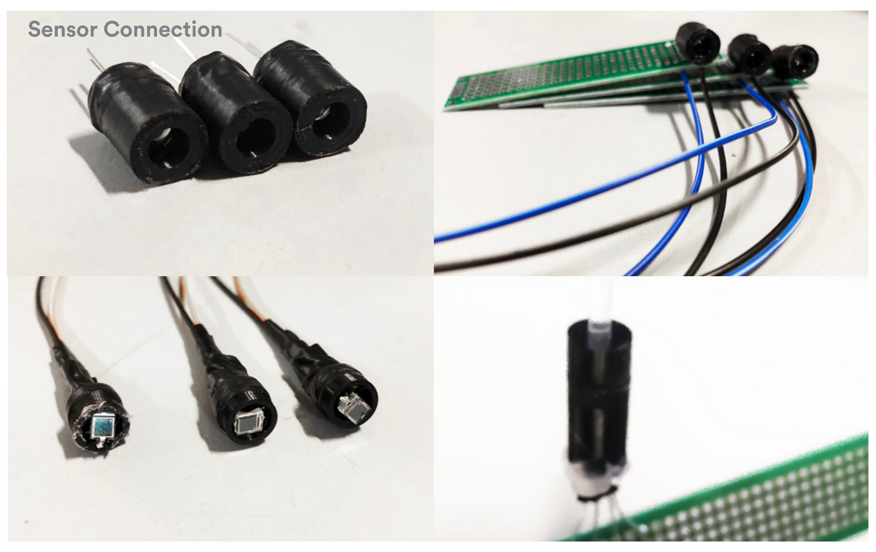
Fiber sensing captures environmental changes →



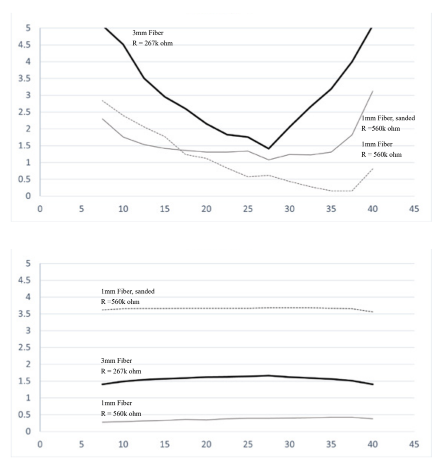
Exemplary Circuits

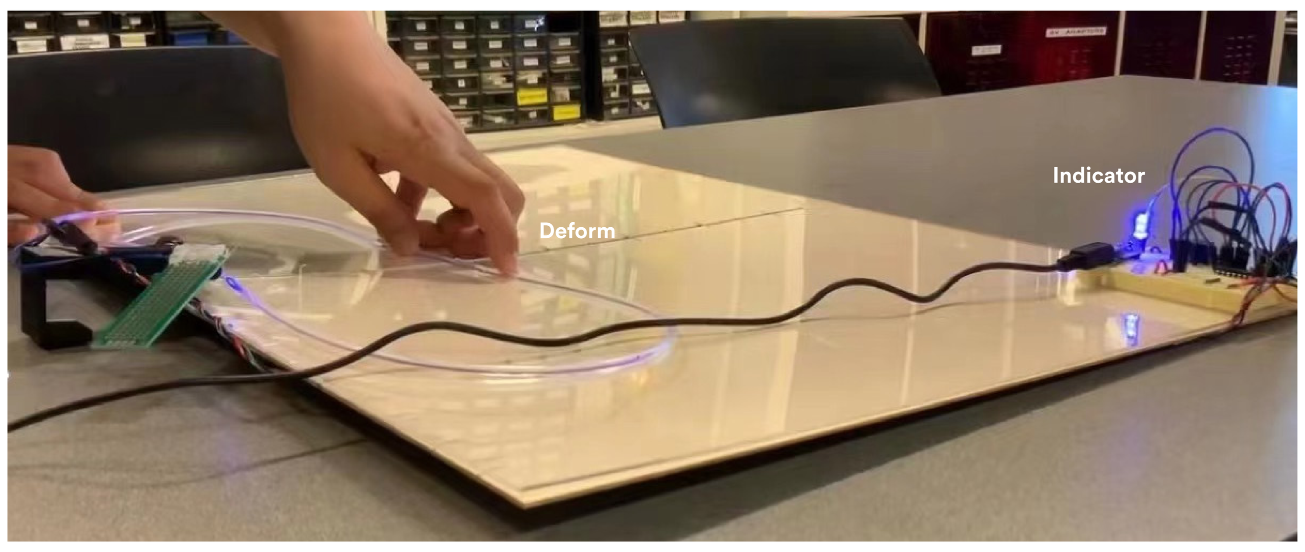
Lab Experiment





Signal (Voltage, V) to Vertical Deformation Distance (cm) Plot

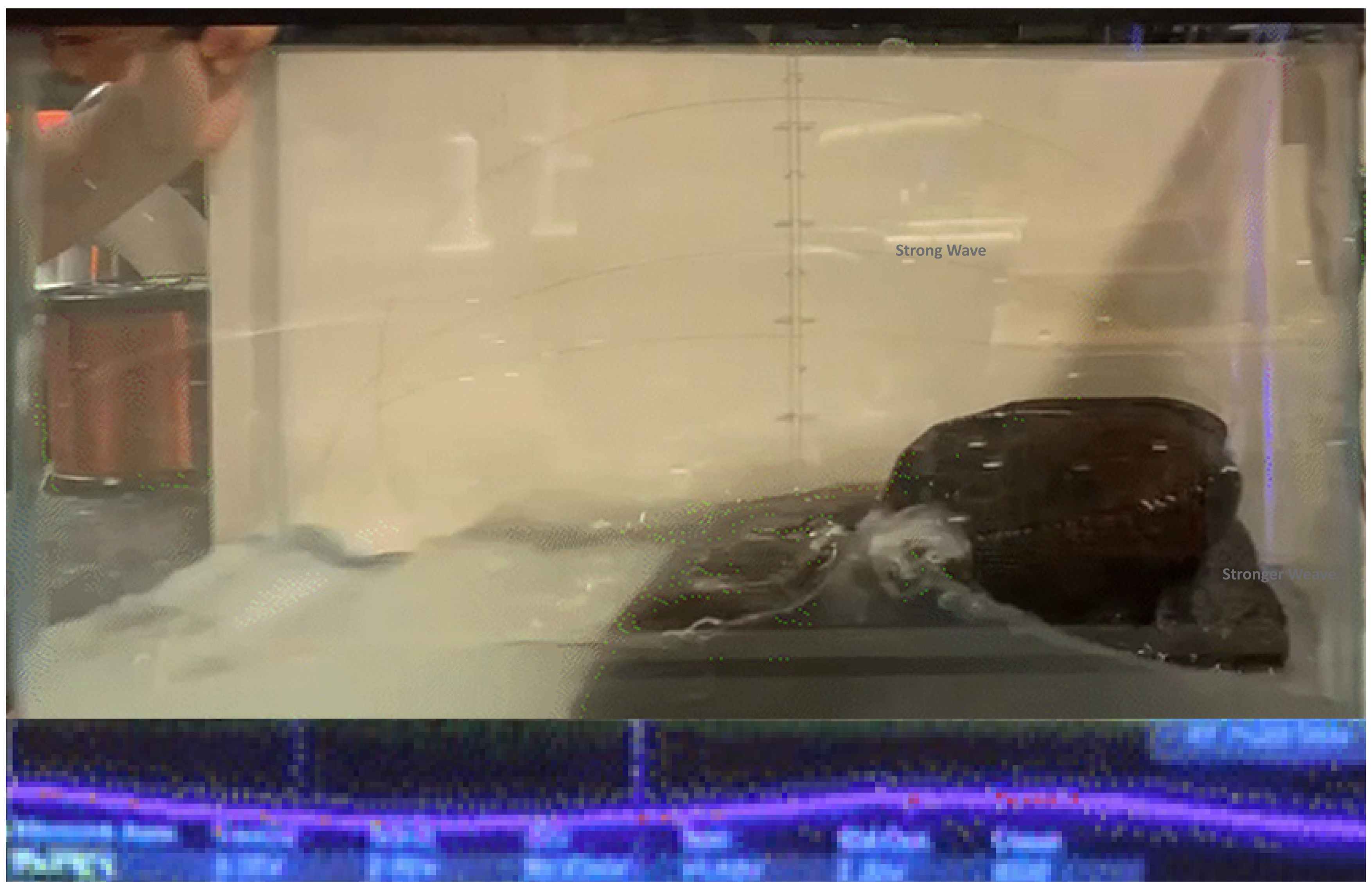


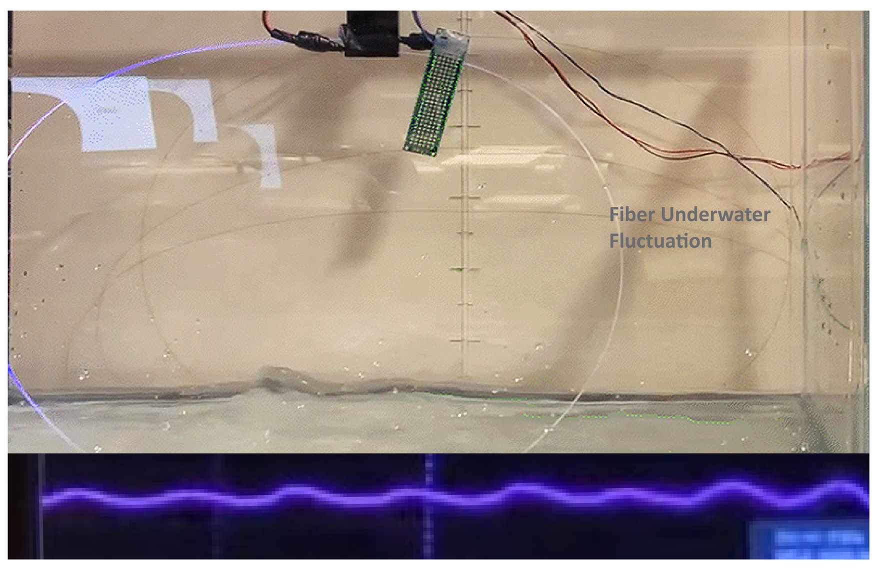


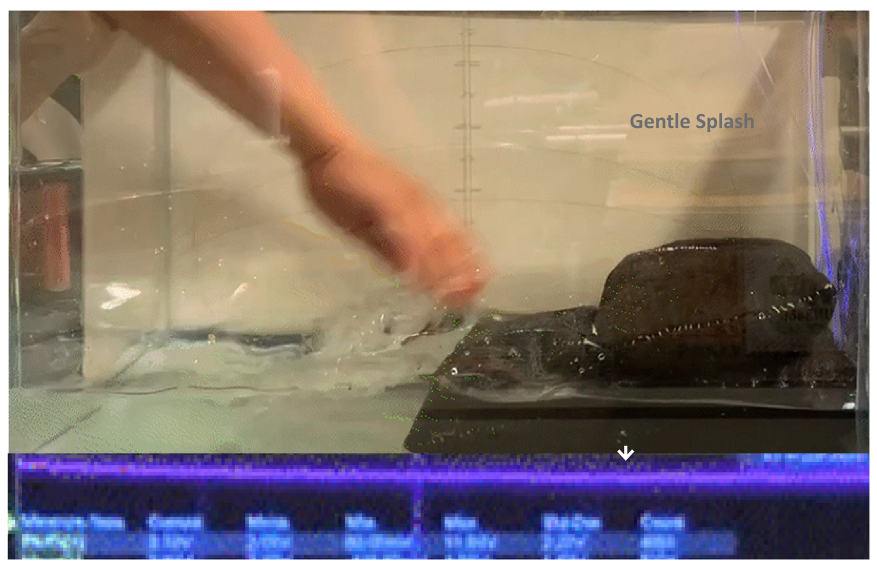
1 Fiber Optics Sensor Deformation Experiment

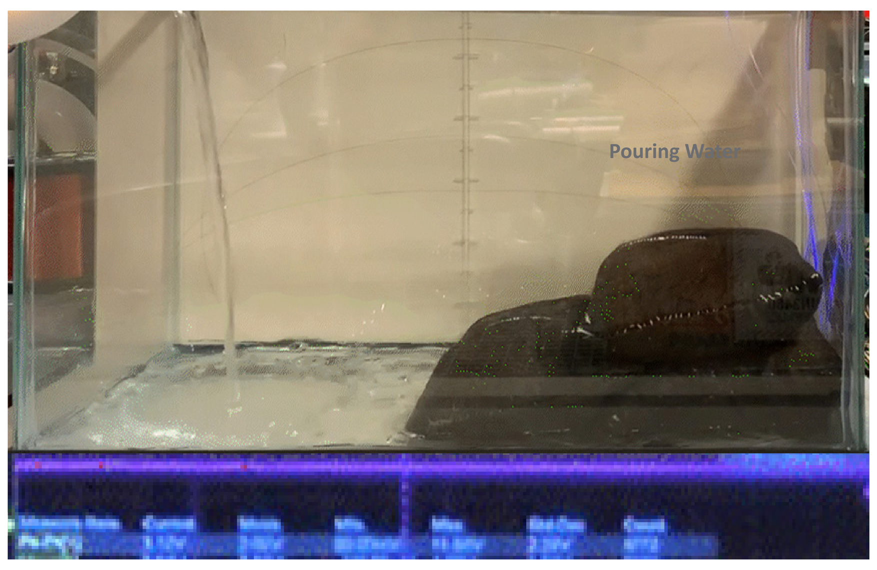
The first image shows the setup by varying the distances from the fiber top to the bottom. The experiment is replicated on three sets, 3mm core diameter fiber, 1mm core diameter fiber, and 1mm core diameter fiber, sanded. The result indicates

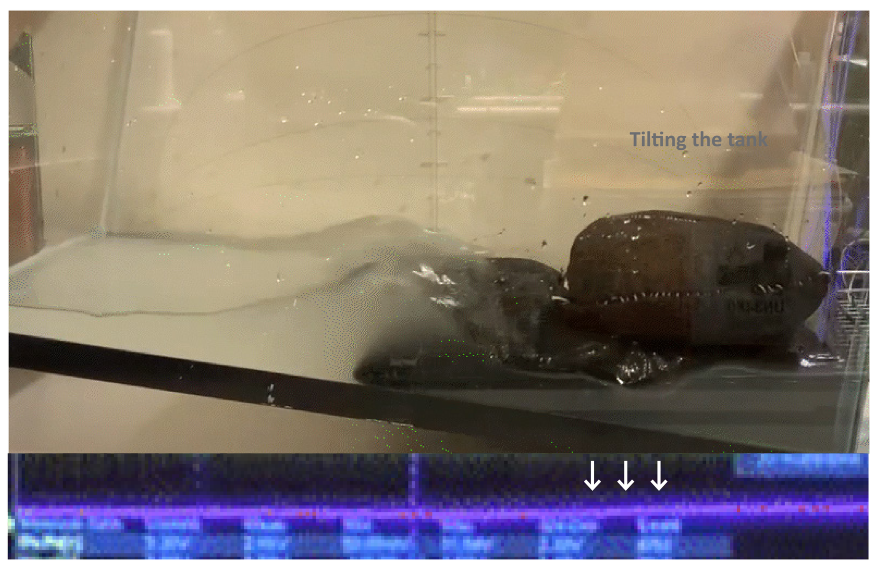
1. The "V" Plot: >30cm: the top is getting more curved, and the sides are flat. The larger the distance, the larger the signal. 25-30cm: fibers are overall round, smallest signal <25cm: the top is flat, and the sides are getting more curved. The smaller the distance, the larger the signal.
2. Sensitivity: 3mm Fiber > 1mm Fiber, sanded > 1mm Fiber.











2 Water Tank Wave Experiment

Weaving 1mm core diameter sanded fiber tested in the above experiment, this experiment is to understand the underwater performance of the fiber sensor and its signals' relationship with the wave. The result successfully generates wave-shape data, and the signal amplitude varies according to different splashing movements, promising a relationship between the wave amplitude and the geotextile tube deformation.

Harvard Graduate School of Design, Academic Work Advised by Dr. Joseph A. Paradiso during cross-registration at MIT Media Lab Responsive Environments Group