QUELL : Vessel-mounted Lidar – Quiet High Precision Bathymetry

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Overview

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2. Understanding turbidity
3. Full waveform lidar and water column profiling
4. Device design - QUELL
5. Motion compensation
6. Conclusion
7. Future work

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Context

A quick note about Envisioning Labs. We are a broadly focussed climate and environmental innovation firm developing a number of technologies to retool sustainable development.

- an award winning spinoff is developing novel communition strategies for the mining industry
- we have created a novel underground fire suppression capability currently being extended to address the issues of early fire detection
- the depth finder project is a priority area of development for which we secured over 3 years of financing to date

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1-Context

While sonar is a powerful tool for assessing the ocean environment, it contributes in important ways to noise pollution that affects negatively marine species such as whales, dolphins and certain fish species

Sonar interferes with communications, navigation, hunting and mating among whales in particular

In 2021, Envisioning Labs successfully bid on a call for proposals from Transport Canada to develop a quiet alternative to sonar based on lidar, that is, laser detection and ranging, and we later secured funding for the second phase of development

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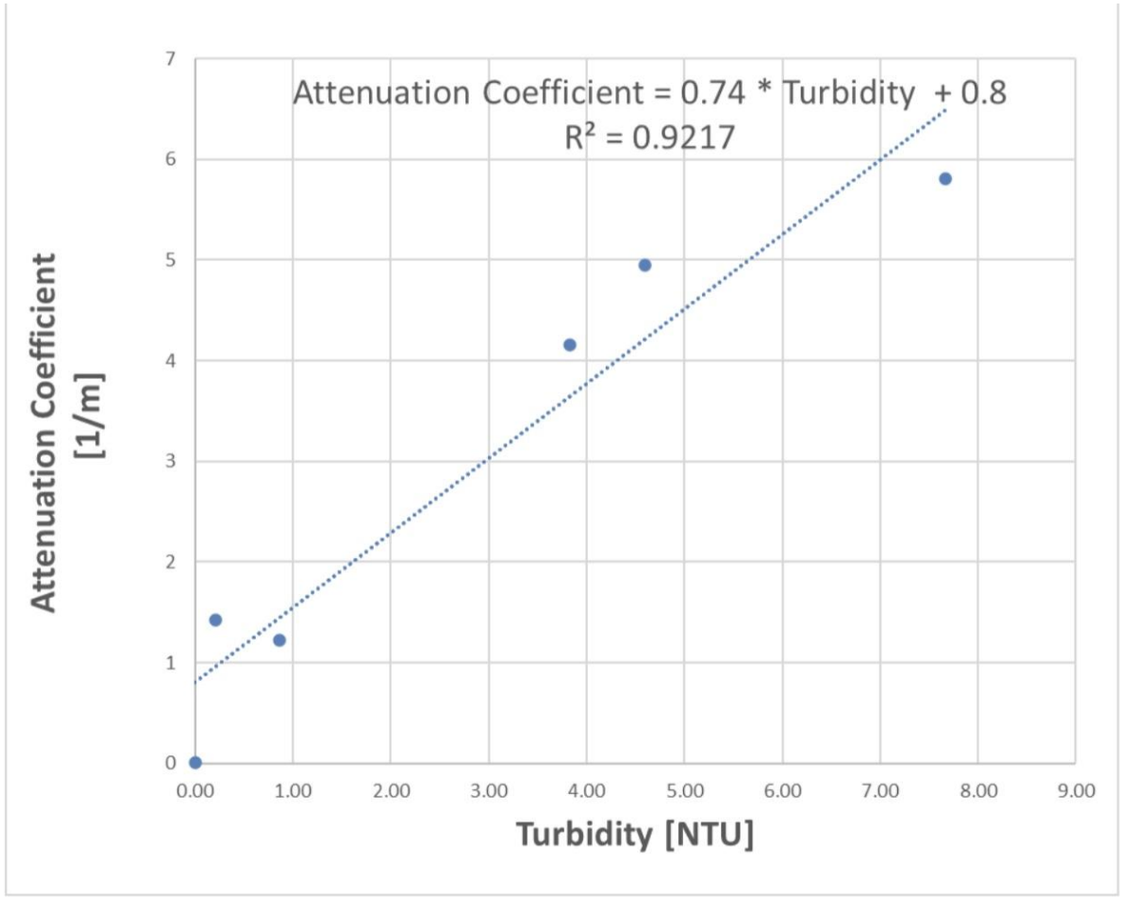
2-Understanding Turbidity

Our first effort was to develop an understanding of how turbidity affects laser-based measurements underwater



Note that when we started, in 2021, there was still a lot of confusion between the various means of measuring turbidity. Ultimately we wanted estimates of the absorption coefficient Kd and scattering coefficients. These are more widely available now

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2-Understanding Turbidity-2

We estimate that for a moderate power laser, we should be able to measure depth up to about 20 meters in clear water, with decreasing results as turbidity increases

For coastal regions, turbidity varies considerably from one location to another, depending on a wide range of local conditions

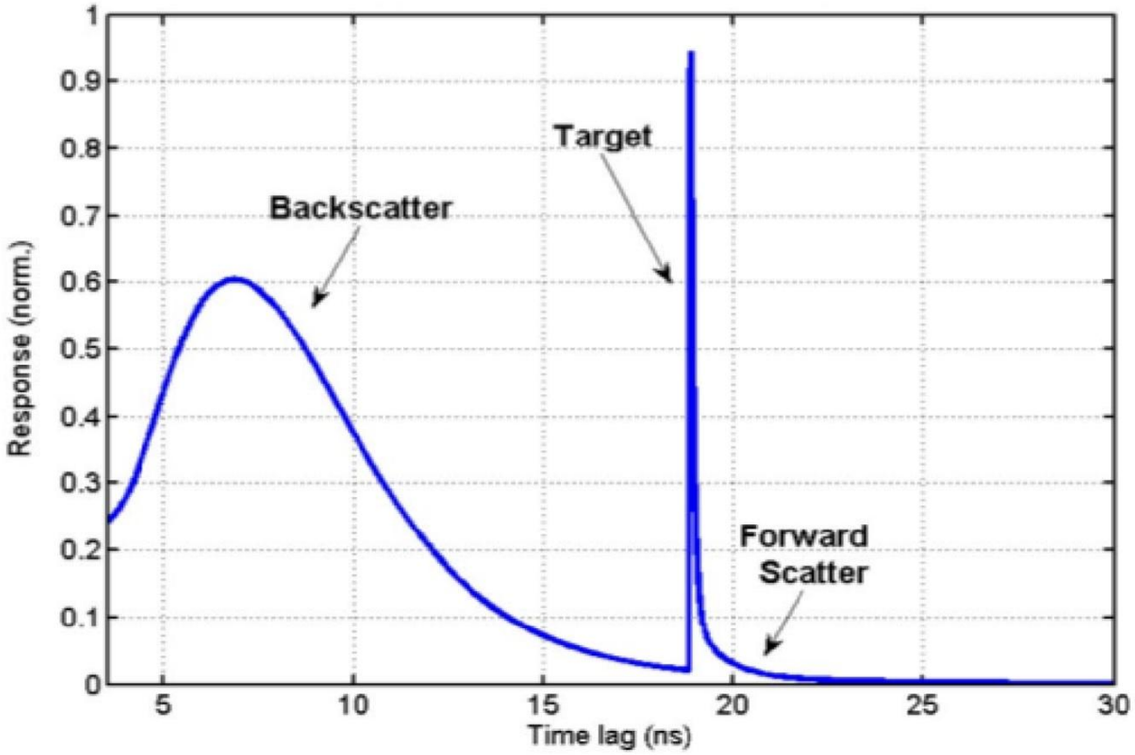
We propose a hybrid lidar/sonar approach for depth finding in the context of navigation, privileging lidar over sonar whenever turbidity is moderate to low

3-Full waveform lidar

We adopted a full waveform solution after experimenting initially with a gated pulsed time-of-flight system

Full waveform lidar means sampling the returning signal fully rather than extracting only the first return. Point clouds generated by lidar systems above ground are generally based on the first return. Full waveform analysis means dealing with the whole range.

Studies indicate that the use of full waveform enhances the precision of depth estimates; in addition, full waveform sampling allows one to obtain a profile of the whole water column



Components of underwater full waveform

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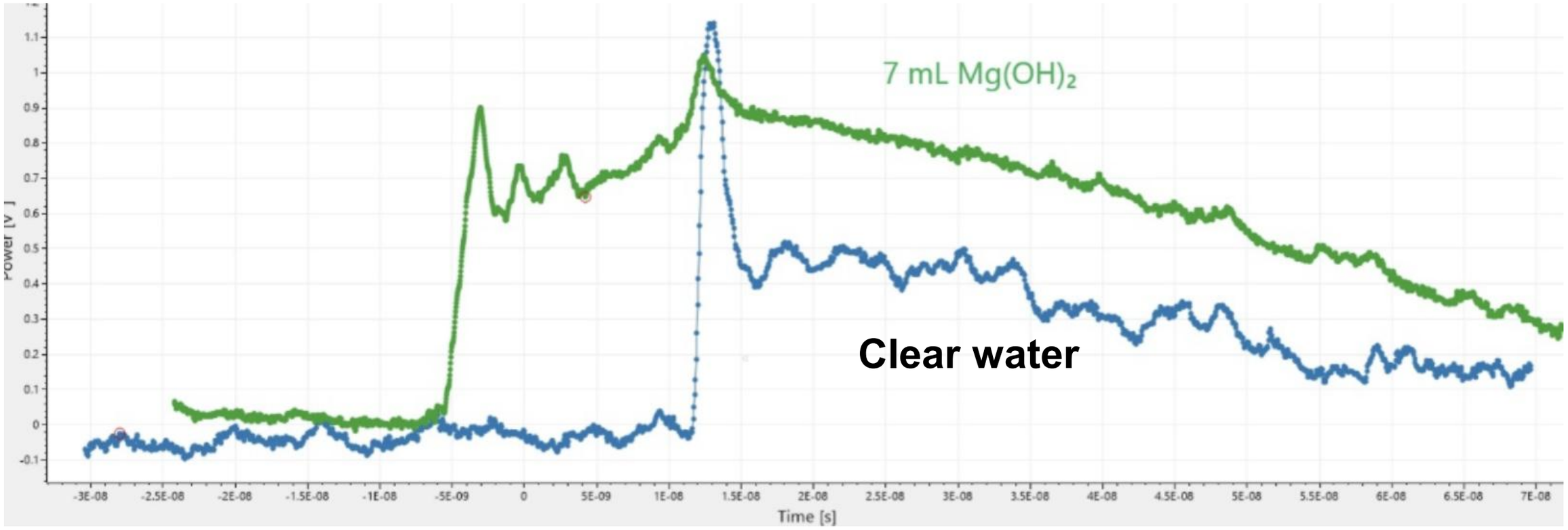
3 - Full Waveform: QUELL



Full wave form comparison of clear water vs. mildly turbid water with sand target at 2 meter distance

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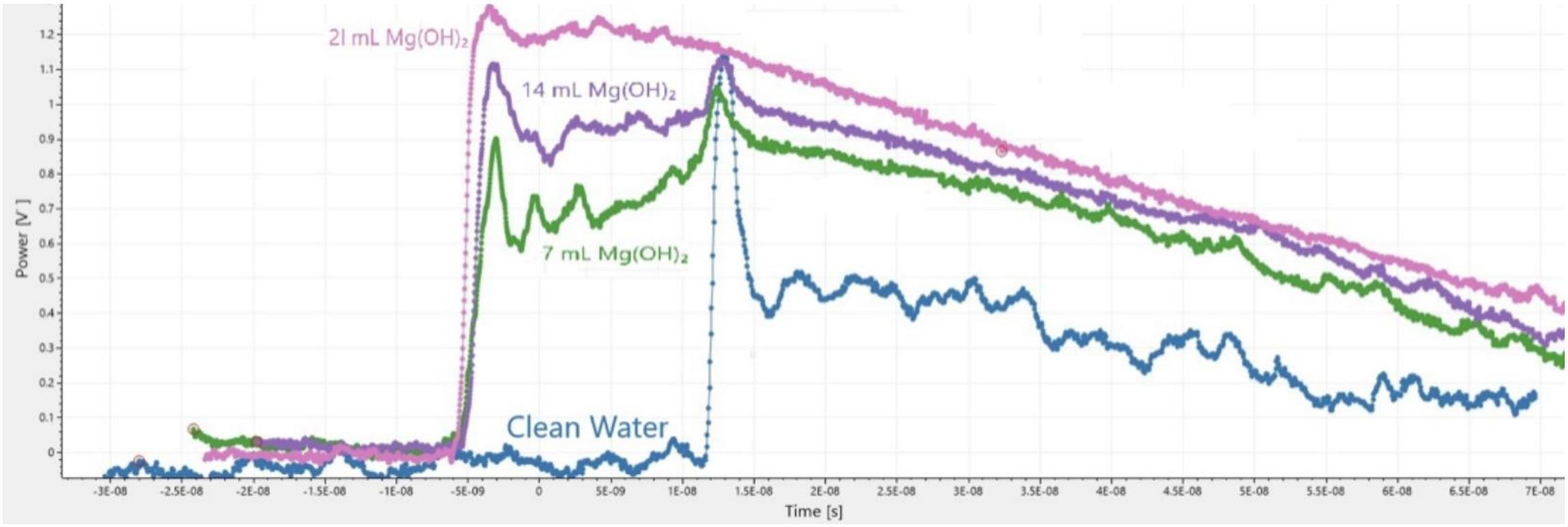
3-Full Waveform: QUELL



- Full wave form comparison of clear water vs. 3 degrees of progressively more turbid water with sand target at 2 meter distance (turbidity introduced as milk of magnesium)
- Analysis requires complex signal processing, including gaussian modeling, deconvolution, noise suppression and other methods

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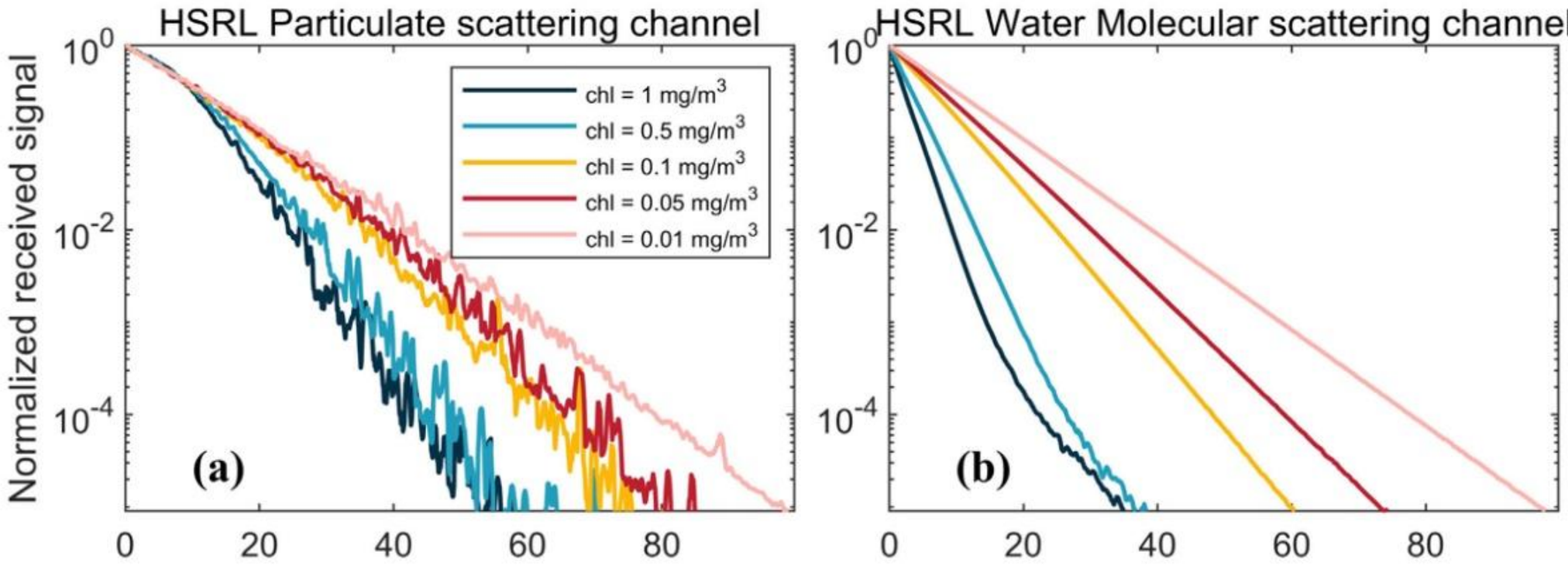
3-Full Waveform: QUELL



- Example of evidence suggesting lidar sensitivity to suspended chlorophyll in the water column as a function of depth in meters - other studies demonstrate effects from suspended beads and of course fish

Chen , S., P. Chen , W. Kong ,R. Shu, and D.Pan, A Semianalytical Method for Ocean LiDAR Radiative Transfer Considering Inelastic and Polarized Scattering, IEEE Transactions on Geoscience and Remote Sensing, Vol. 63, 2025.

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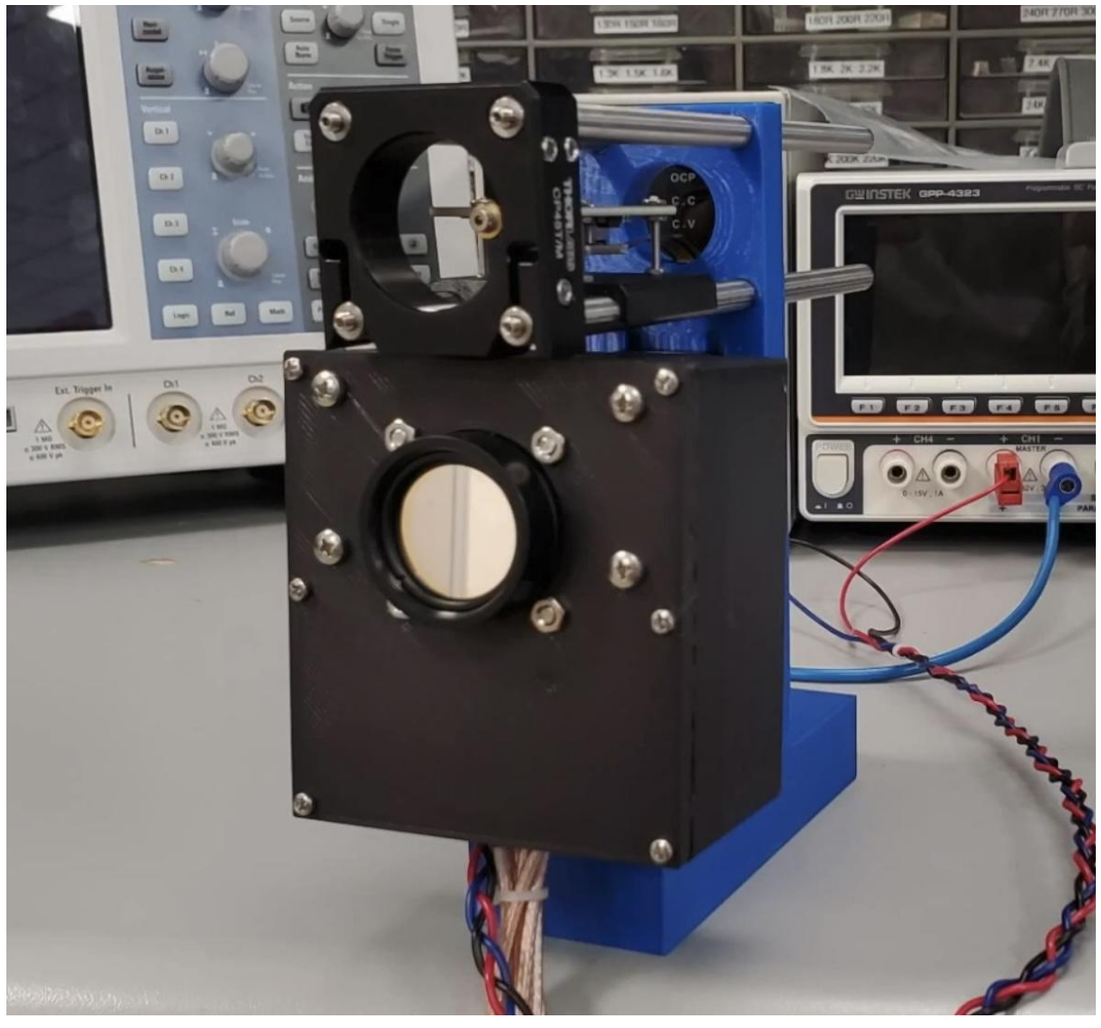
4-Device Design: QUELL

- We at Envisioning Labs have designed and developed a first functional prototype of our QUELL system (Quiet Underwater Environmental Linear Lidar) in response to these challenges

- We are using a linear array of single photon avalanche detectors (SPADs) matched to a high performance 520 nm laser diode developed in collaboration with TRIUMF, delivering a full waveform return



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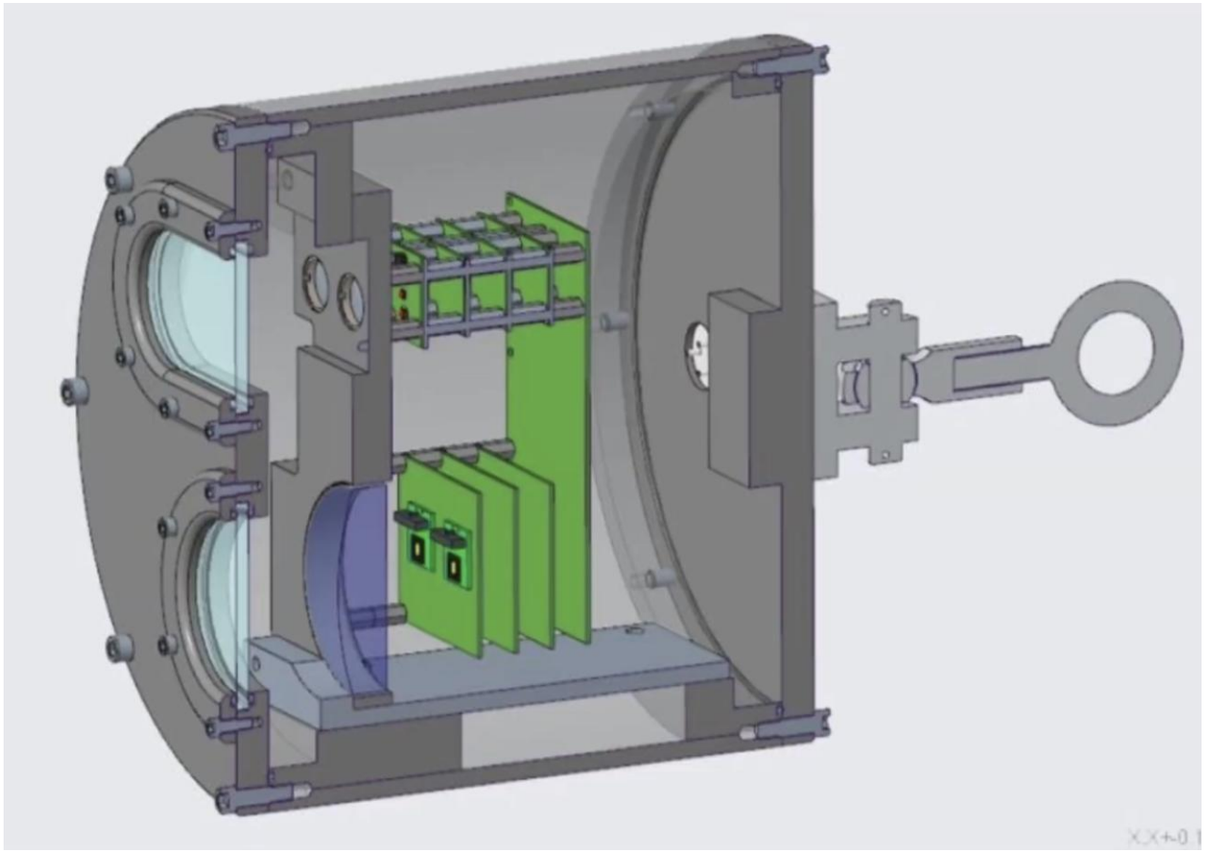
4-Device Design: QUELL

- We are embedding the lidar into an enclosure so that it can be suspended of the side of a boat

- We are aiming for pixels in our current design to be at the scale of a few tens of centimeters at 20 meters, and the temporal resolution of our sub-nanosecond pulse will provide depth resolution of similar level



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5-Motion Compensation

- In order to achieve the highest precision with our vessel-mounted lidar, it is critically important to install motion compensation sensors and correction methods

- While high-end IMU units may be the most precise, their exorbitant costs precludes their use in many contexts. We believe that the use of IMUs at more moderate costs are still relevant to the QUELL system

- We have developed a motion simulator that allows us to vary GPS and IMU configurations and assess positional accuracy as a consequence

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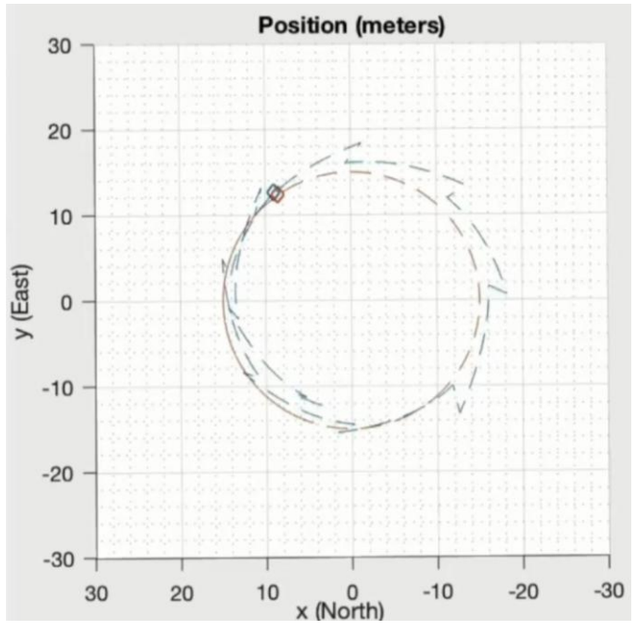
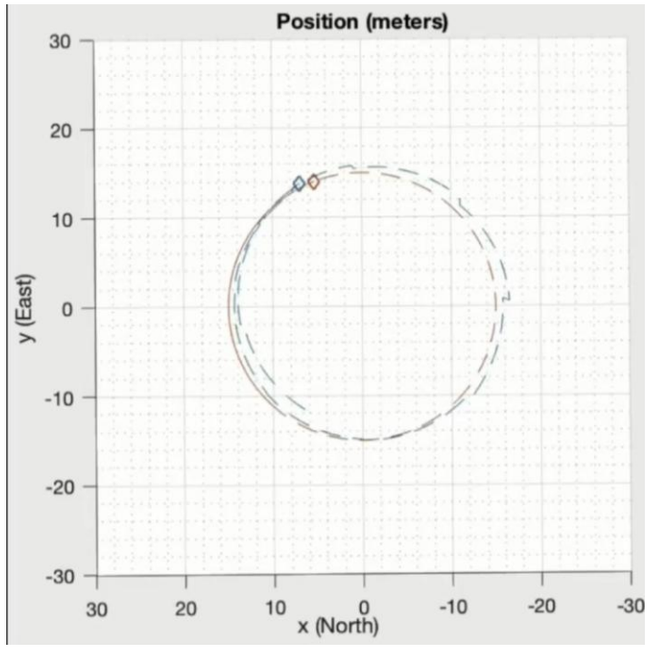
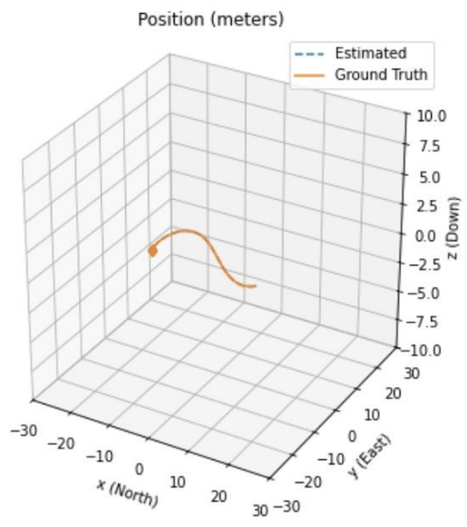
5-Motion Compensation Simulator

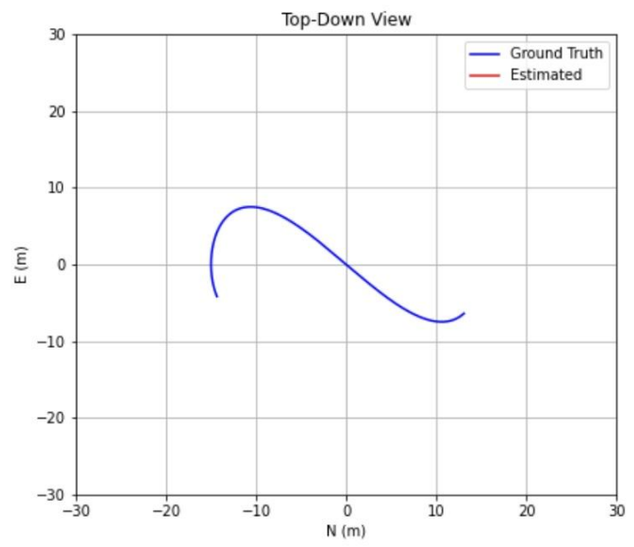


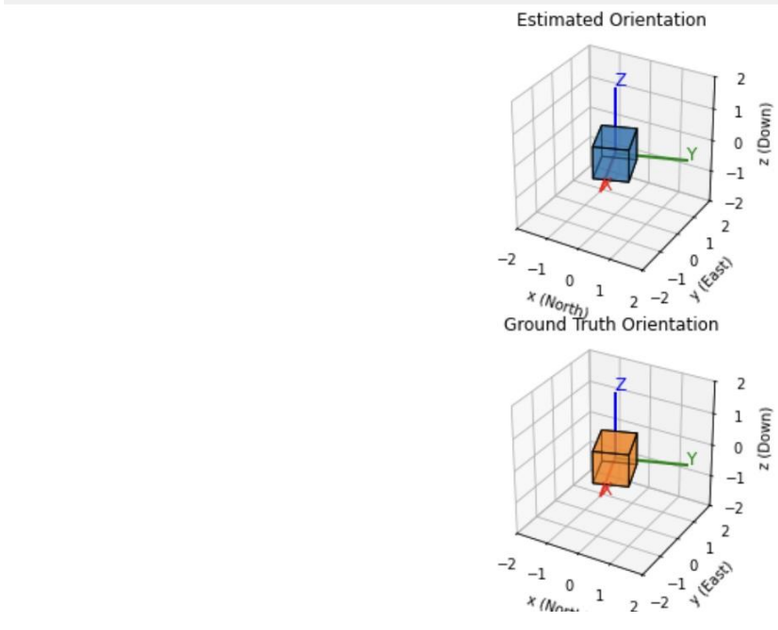
GPS

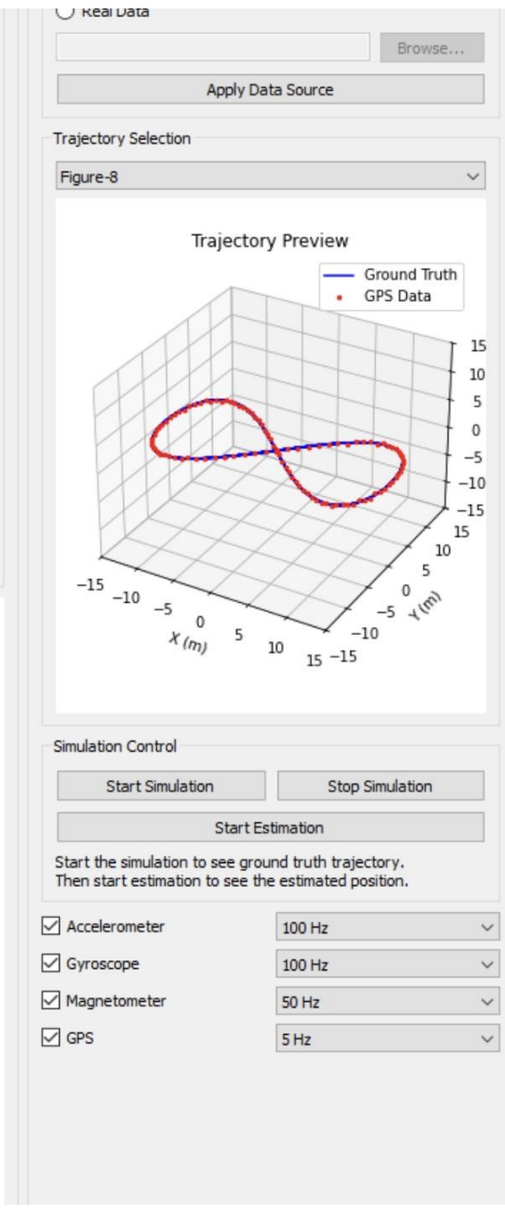


GPS+IMU









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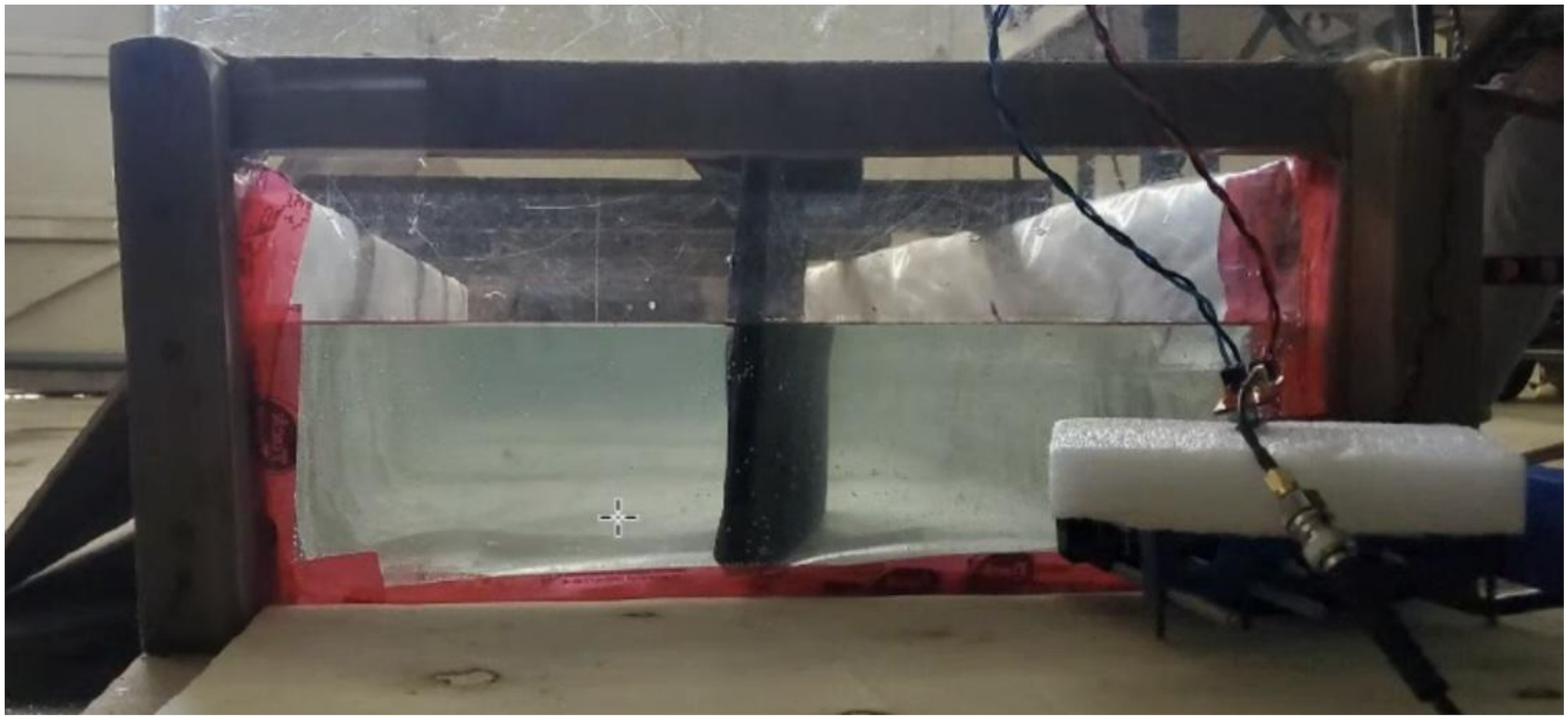
6-Current Status



- A 4-channel version of the QUELL system has been tested extensively in the laboratory environment under controlled conditions of turbidity (see end view of 3 meter long testing channel)

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6-Conclusion

- A 4-channel version of our QUELL system is undergoing extensive testing both in laboratory settings and in the field

- Although full waveform data of the underwater environment is still not common, our testing suggests that extraction of information about the water column is indeed a viable goal

- Studies undertaken elsewhere suggest that fish identification, the characterisation of suspended particles and the characterization of vegetation near the bottom are all within the realm of full waveform lidar

- At spatial resolutions in the tens of centimeters or less, and depth resolutions of commensurate size, high precision mapping of both the seafloor and water column are within reach

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7-Future Work

- We will be looking to increase the width of our swathe, either by increasing the size of the linear arrays or by introducing a rotational scanning mechanism via MEMS technology; we are currently assessing both options
- We are investigating ways to increase the power of the laser
- We plan to integrate the motion compensation methods in the near future
- We are looking for potential collaborators to work on modeling the water column - it seems clear that modeling will be an important component of full waveform data analysis
- We are seeking partners to extend the range of testing conditions
- We are also looking for funding to finance the next phase of development

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Partners and Collaborators

- We thank our partners and collaborators in this development, the MITACS team at the Geomatics Department and Centre de recherche des données et intelligence géospatiales at **Laval University** headed by Dr Mir Mostafvi, the team under the leadership of Fabrice Retière at the Tri-University Meson Facility (**TRIUMF**) in Vancouver, and the folks at the Institut National d'Optique (**INO**) based in Quebec City.
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