Monte Carlo modelling of elastic and Raman returns from the water column

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Light Detection and Ranging (LiDAR) is a mature technology for remote sensing of ocean and coastal waters. While conventional LiDAR detects elastic scattering of the excitation laser beam as it propagates through the water column, a small amount of the beam will be inelastically scattered such that it is frequency shifted *via* the process of Raman scattering. In the case where a natural water sample is excited by short ($\sim$ 1 ns) laser pulses at 532 nm, Raman-scattered photons have wavelengths centered at around 650 nm. Analysis of the Raman spectrum has enabled accurate lab-based determination of water temperature [1], and it is our long-term goal to develop methods and instrumentation for systematically mapping and monitoring subsurface water temperature and salinity in coastal and ocean waters.

Numerical modelling is a valuable development tool for predicting the LiDAR signals expected for different laser properties, water types and optical designs. In particular, Monte Carlo methods for simulating elastic LiDAR returns are well developed, tracking the random paths of a large number of photons packets as they propagate, scatter, and undergo absorption events in the water column [2]. While Raman scattering is sometimes included as a loss process, to our knowledge, there has been no published work on predicting Raman LiDAR returns.

Here we describe the first Monte Carlo simulation of both elastic and Raman returns from the water column. We compare and contrast the elastic and Raman returns, with a focus on showing how the predicted Raman returns vary between different natural water types. We found that for oceanic waters, the time of flight of Raman photons is proportional to the depth from which they have been inelastically scattered; however the situation for coastal (more scattering) waters is considerably more complex and depth resolution becomes degraded. The insights and implications of the modelling will be discussed in the context of our longterm goal for measuring subsurface water properties.

[1] A. de Lima Ribeiro and H. Pask, *Front. Mar. Sci.* **7**, 183 (2020).

[2] C. Mobley, B. Emmanuel and C. Roesler, *Ocean Optics Web Book* (accessed online on July 5 2022).