Turbidity - Correction for Raman Spectroscopy in Diffusive Media: Simulations and Phantom Validation

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1. Research Challenge & Solution

Introduction:

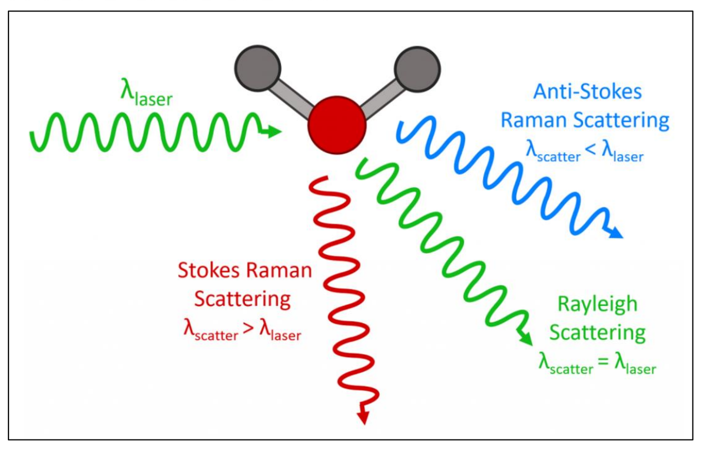
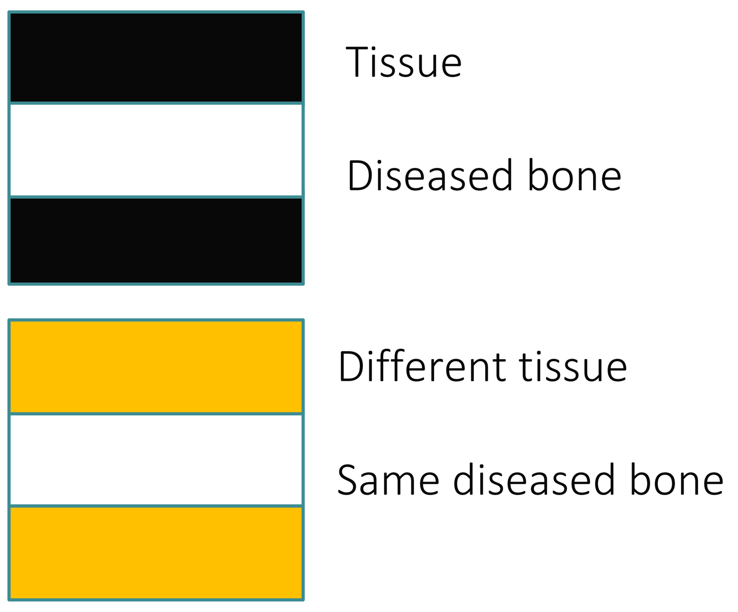


Figure 1: Raman Spectroscopy[1,2].

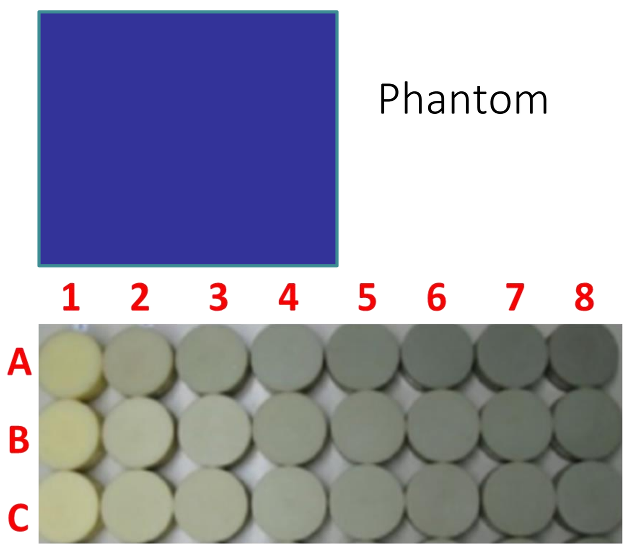
Research Challenge:

- In quantitative biological Raman spectroscopy, especially for transcutaneous measurements, the challenge lies in overcoming the distortions caused by tissue turbidity. Scattering and absorption events in the surrounding medium can significantly alter the Raman spectra, reducing the accuracy of predictive models.
- The variations in tissue turbidity lead to inconsistencies in Raman spectral intensities, even for tissues with the same concentration of Raman scatterers.



- Same rotten bone.
- Different age profile.
- Different racial profile.
- No accurate knowledge of absorption or scattering coefficients or concentration of Raman scatterers.
- Obtain different Raman signal intensities

Solution:



- Use phantoms where the absorption and scattering coefficients and concentration of Raman scatters is known.
- Reflected light gathered by DRS to help determine how much of the light is scattered by the phantom.

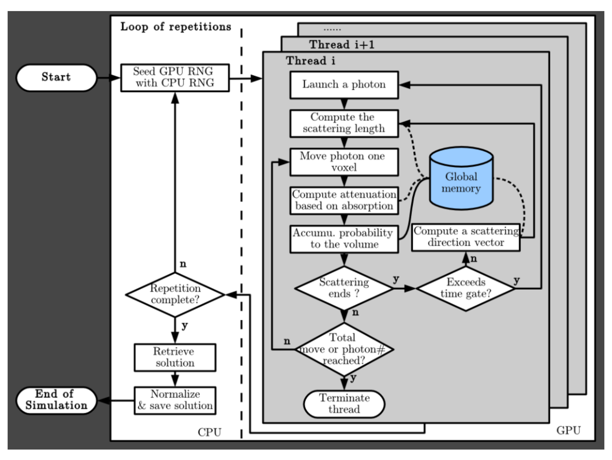


Figure 2: MCXLAB flow chart[3].

- MCXLAB which is a Monte Carlo simulation tool which was used to model photon paths through tissue, considering scattering and absorption events, allowing for the investigation of these interactions and their effects in diffusive media further.

2. Outputs & Results

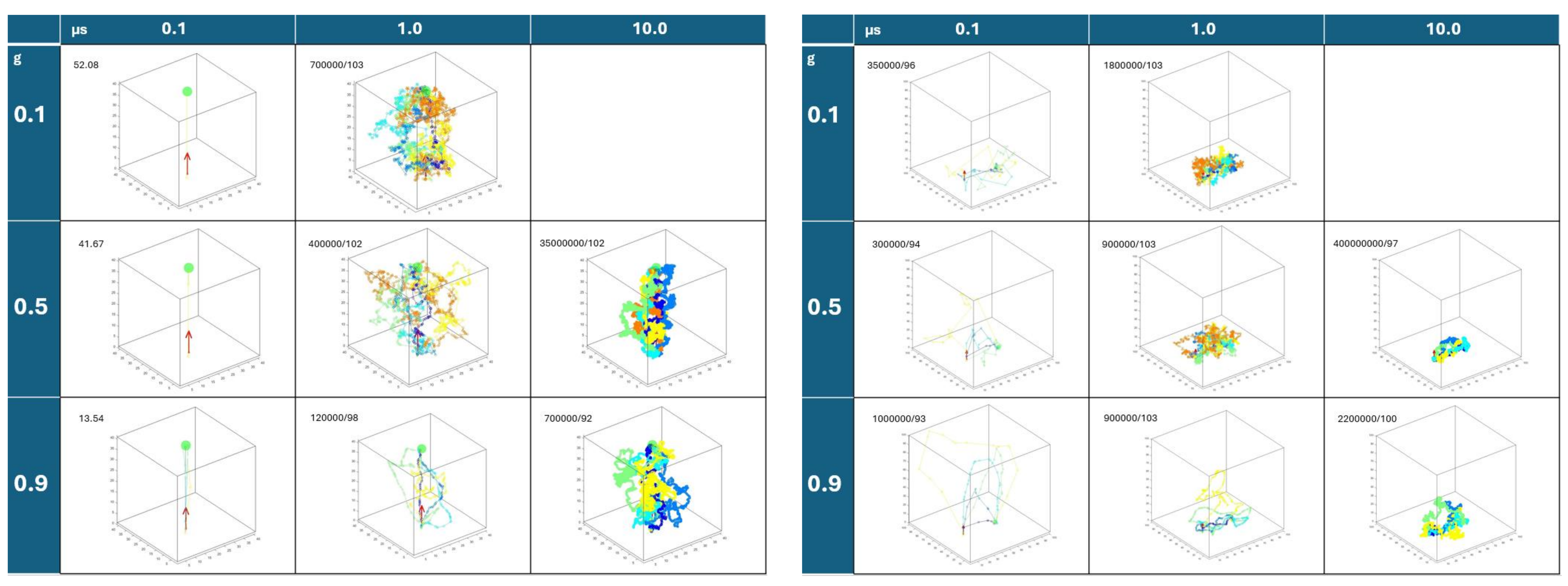


Figure 3: Photon reflection and transmission trajectories with varying parameters within non – absorbing cube.

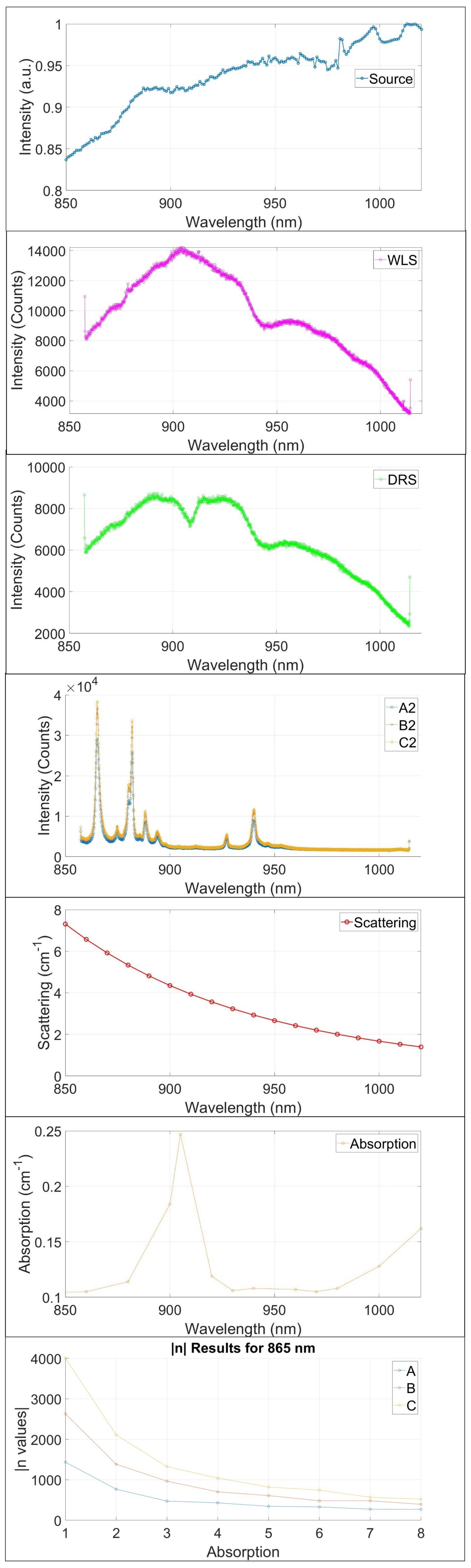


Figure 5: $|n_{RAMAN}|$ plotted against absorption for all phantoms. Different spectrums with parameters of interest shown above.

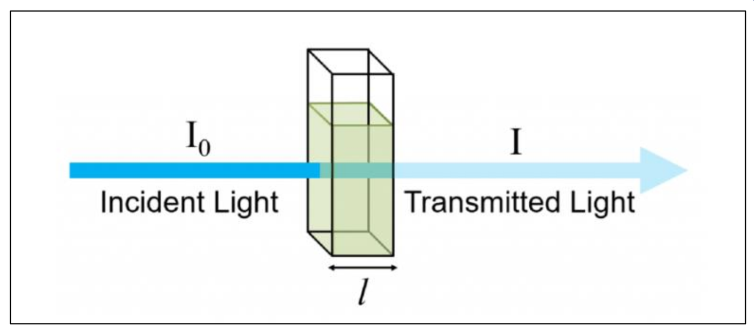


Figure 4: Beer – Lambert's Law[4].

Beer – Lambert's Law

$$\frac{I}{I_0} = e^{-\mu_a . PL}$$

$$PL = n.MFP$$

$$MFP = \frac{1}{\mu_s' + \mu_a}$$

$$\mu_s' = \mu_s(1-g)$$

$$\mu_s' = A\left(\frac{\lambda}{\lambda_{EXC}}\right)^{-b}$$

$$\mu_s' \gg \mu_a$$

$$MFP = \frac{1}{\mu_s'}$$

$$PL = \frac{n}{\mu_s'}$$

$$\frac{I}{I_0} = e^{-n\frac{\mu_a}{\mu_s'}}$$

$$I_{RAMAN} = I_{0_{RAMAN}} e^{-n_{RAMAN}\frac{\mu_a}{\mu_s'}}$$

$$-log\left(\frac{I}{I_0}\right) = \mu_{\text{det, effective}}$$

$$I_{0_{RAMAN}} = e^{-\mu_{\text{det, effective}}}$$

$$n_{RAMAN} = \frac{\mu_s'}{\mu_a} ln\left(\frac{e^{-\mu_{\text{det, effective}}}}{I_{RAMAN}}\right)$$

3. Conclusions & Future Work

- The turbidity of the Raman scattering medium has a strong influence in the accurate recovery of the Raman Signal.
- In this work, a modification of the Beer Lambert's Law was employed to recover the number of Raman scattering interactions experienced within samples of different color (absorption) and turbidity (scattering).
- The number decays exponentially with absorption and increases linearly with scattering suggesting that this influence can be offset with the knowledge of the accurate optical properties.
- We also aim to test this hypothesis on an MCXLAB based code for modelling the Raman data.
- If successful, the goal is quantifying hydroxyapatite for bone issues and methemoglobin for blood bags.

4. References

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