Low-cost Non-invasive Diagnosis of Malaria Infected Red Blood Cells

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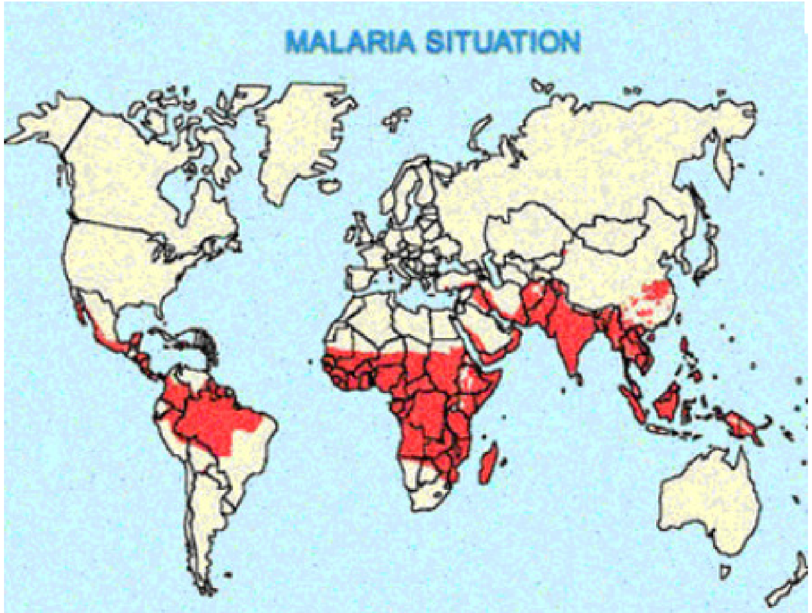
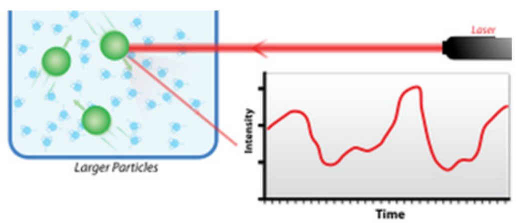
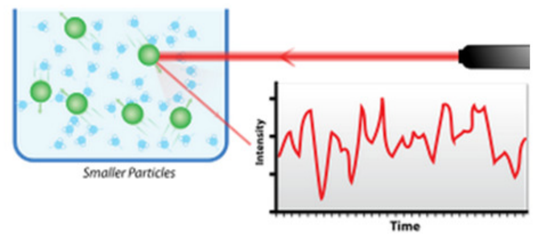
Motivation

- Malaria is a potentially fatal blood-borne disease.
- Available diagnosis approaches require extensive lab equipment and fresh blood samples.
- Victims in impoverished regions do not have access to costly treatments.
- Research aims to create diagnostic device using elastic light scattering.



Elastic Light Scattering

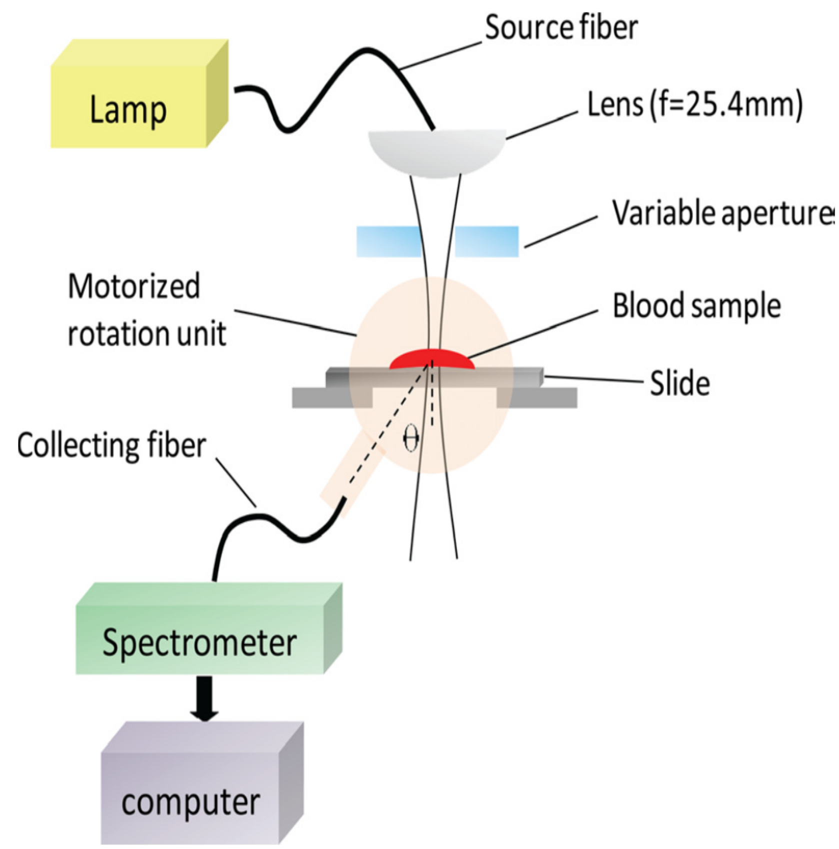




- Elastic light scattering can detect particles' properties.
  - Spatial distribution of a particle's scattering spectrum forms a complex spatial pattern.
  - Incident electromagnetic wave encounters molecules' electron orbits.
  - Induces oscillating dipole moments and scattered light.
- Pattern is dependent on composition of particle.

Experiment Setup

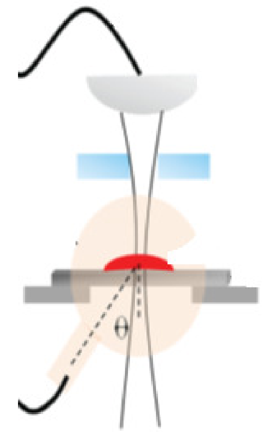
- Optical components arranged vertically.
- 400µm optic fiber and plano-convex lens.
- Computer motorized rotation stage controls deflection angles.
- Variable aperture adjusts light and creates separation.

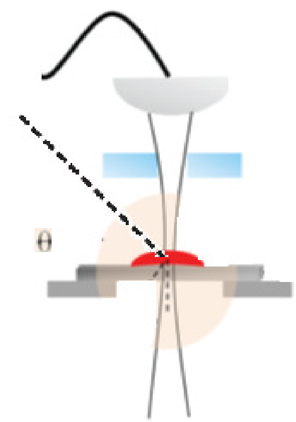


Schematic Setup of elastic light scattering

Optimal Condition

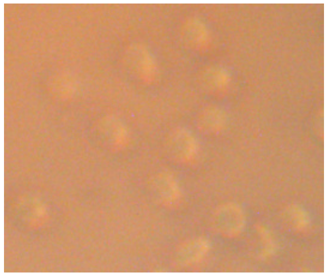
- Forward Elastic Light Scattering
  - Five angles between 10 to 20 degrees were tested.
  - Magnitude of angle increases as scattering intensity decreases.
- Backward Elastic Light Scattering
  - Strongest intensity: collecting fiber closest to incident beam.
  - Due to limited setup, optimal angle is 163 degrees.
- Optimal Time is 15 minutes after dilution.



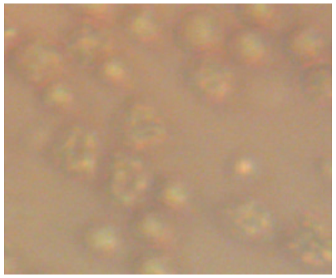


Procedure and Data Collection

- Blood sample is diluted in five saline concentrations.

(a) 

0.9%

(b) 

3.0%

- Calculations
  - $I_{particle}(\theta) = [I_{sample}(\theta)-I_{background}(\theta)]/I_{reference}(\theta)$

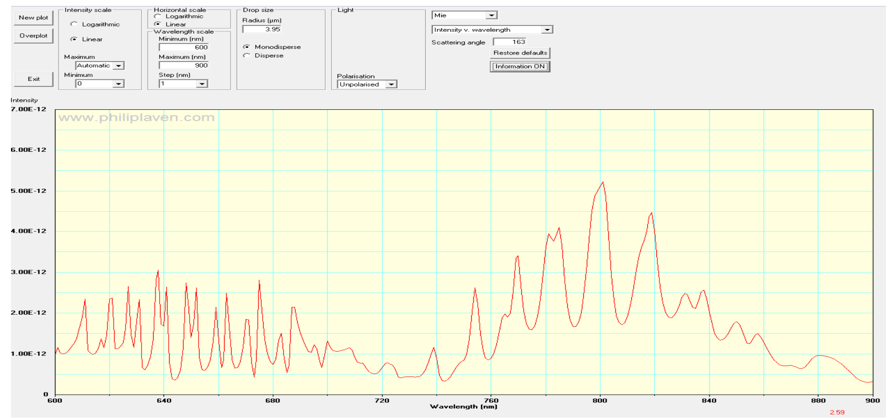
    $I_{sample}(\theta)$: intensity of blood sample

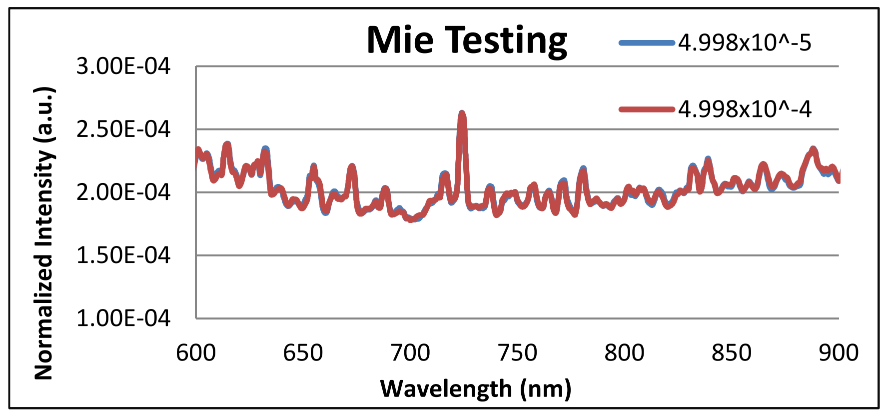
    $I_{reference}(\theta)$: intensity of light source at $\theta = 0$ degrees

    $I_{background}(\theta)$: intensity of empty glass slide at angle θ
  - Calculated particle intensities are normalized

Setup Validation

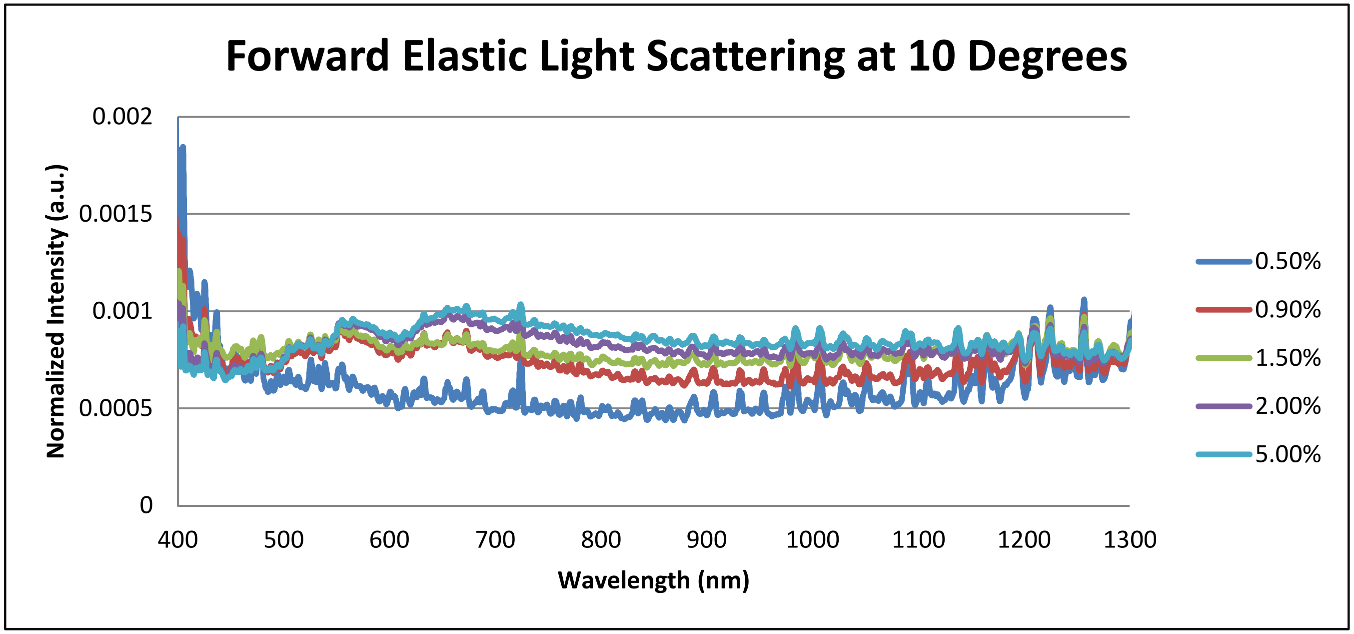
- Polystyrene microspheres of diameter of 7.9 µm.
- Scattering data collected at 163 degrees.
- Microsphere diluted to concentrations of $4.998 * 10^{-3}\%$ and $4.998 * 10^{-2}\%$.
- Valley appears at 700nm.
- Negative slope at 900nm.
- Repetitive waves from 600 to 700nm.





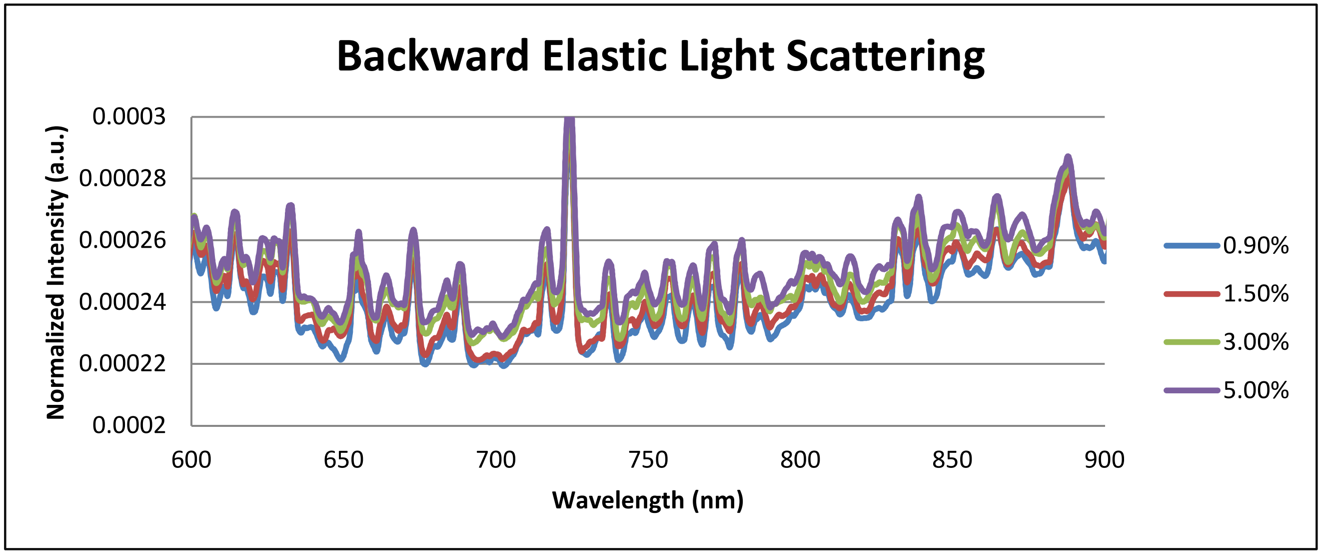
Comparison of Mie theory calculations and experimental measurement of polystyrene microspheres

Forward Scattering



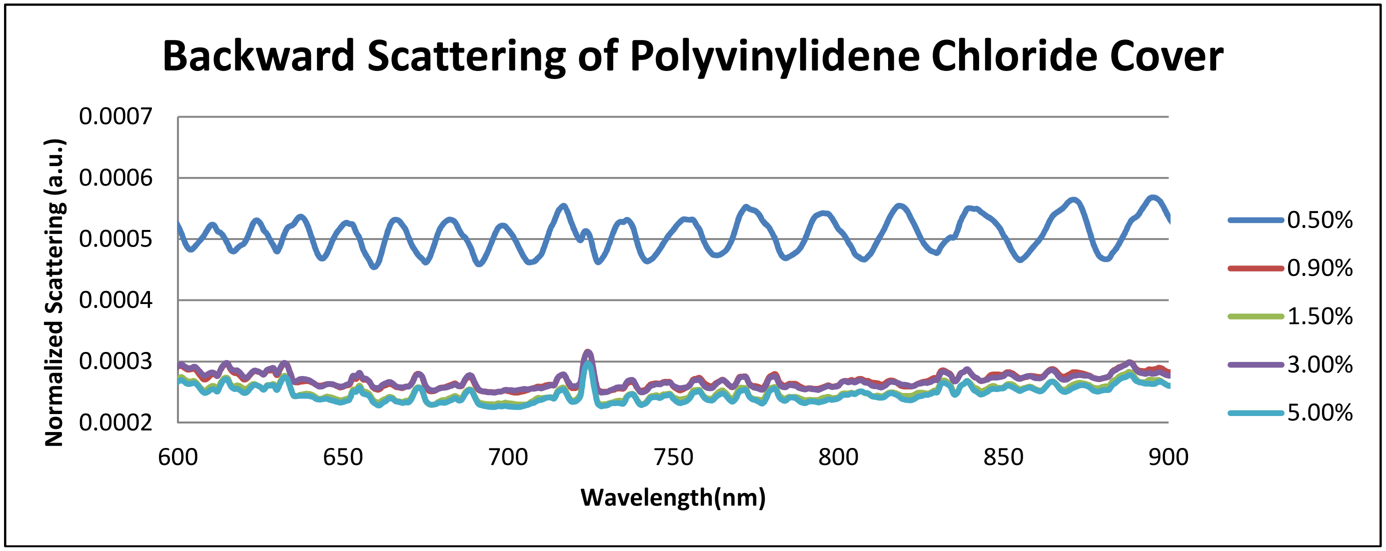
- Significant and consistent correlation between intensity and concentration.
- Similar peaks and valley: similar experimental condition.
- Most significant difference at wavelengths between 600 and 900nm.
- Inverse relationship between intensities and concentrations.

Backward Scattering



- Blood sample
- Weaker backward scattering
- Significant difference in valleys and peaks.
- Inverse relationship between intensities and concentrations.

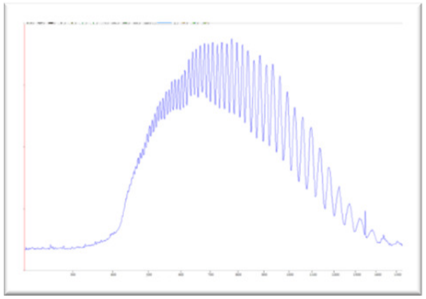
Polyvinylidene Chloride Cover



- Polyvinylidene Chloride causes random scattering.
- Possible explanations:
  - Uneven distribution of blood under cover
  - Transparency of cover
  - Reflection of cover

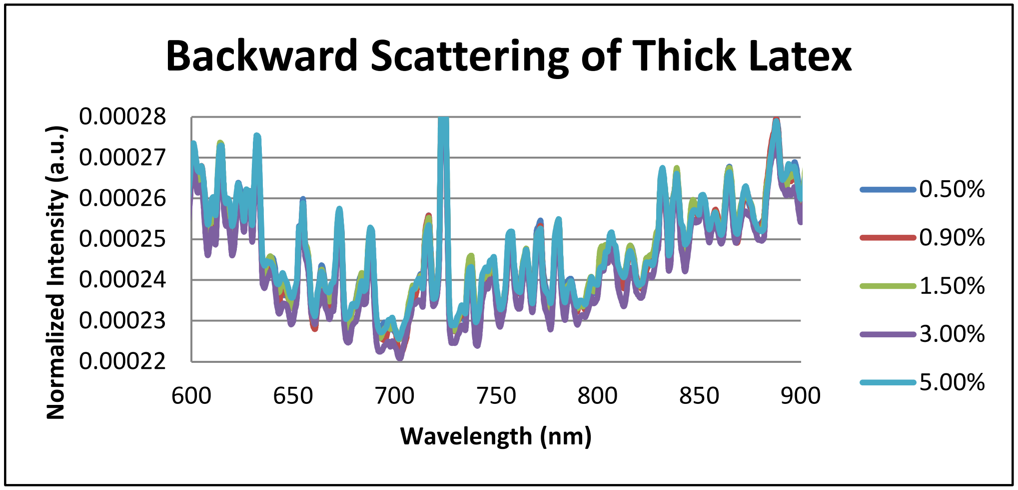
Polyvinylidene Chloride Cover

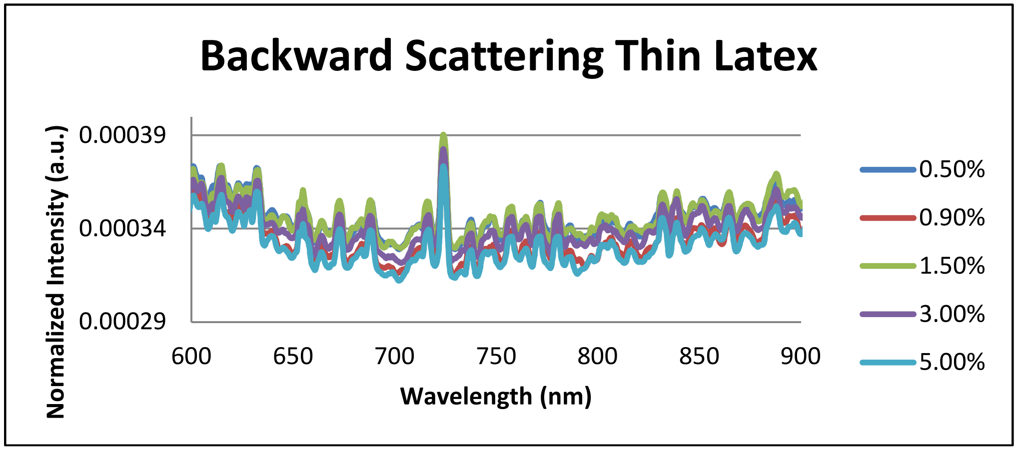
- Cover glass used to evenly distribute sample
  - Effect of cover glass eliminated through calculation
  - Unsuccessful
- Polyvinylidene Chloride Cover is thin
- Reflection caused unsuccessful results



Scattering comparison of two different locations on one sample

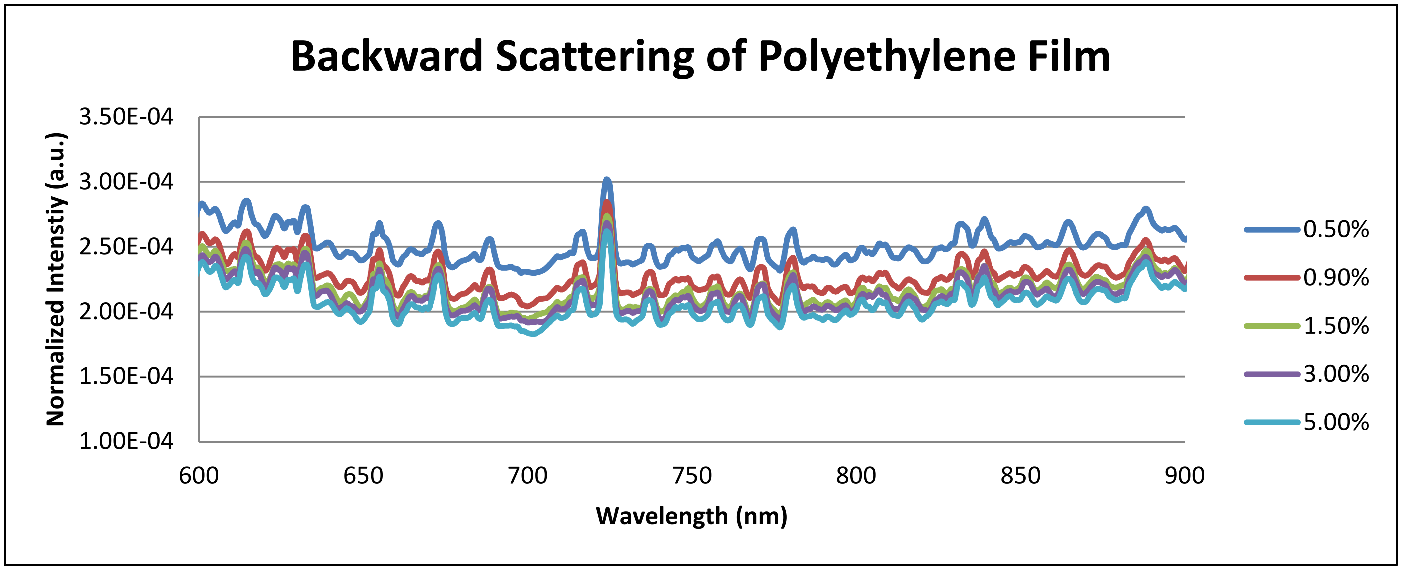
Latex Material





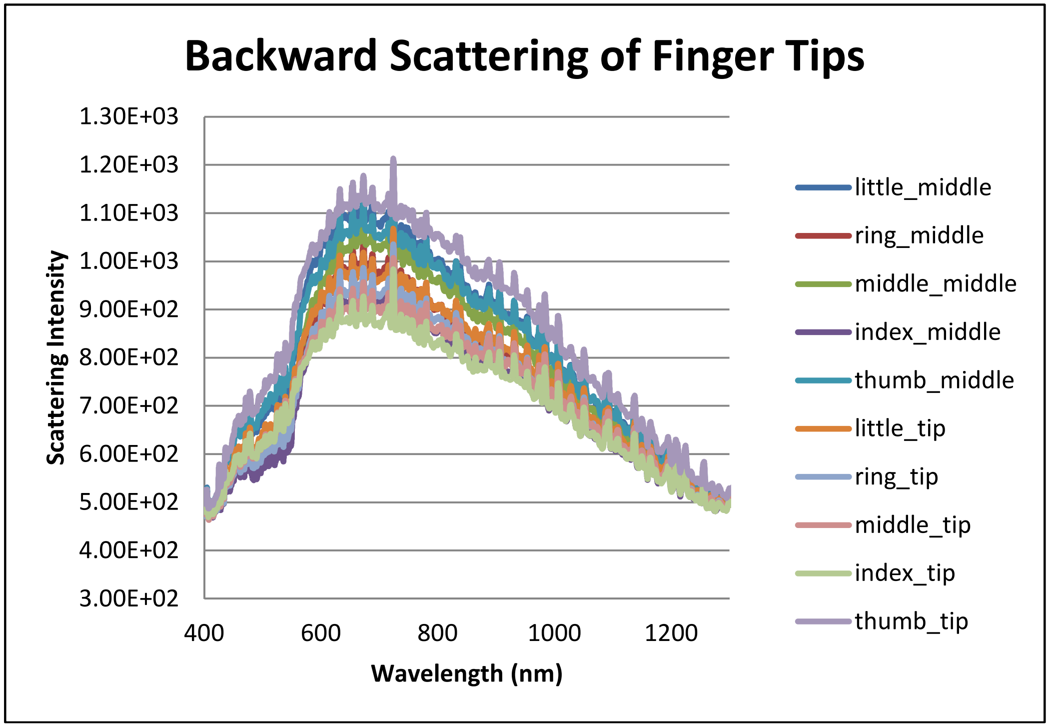
- Inconsistent intensities for both the thin and thick latex.
- Tried using the same latex for different trials.
- Incident light was unable to go through the materials.

Polyethylene Film



- Polyethylene Film is relatively thin and non-reflective.
- Saline concentrations are consistent with scattering intensities.
- Direct relationship between concentrations and intensities.

Finger Tips



- Scattering taken from different locations on the fingertips.
- Strong, relatively uniformed backward scattering.
- Promising approach to diagnose cell properties through the fingernails.

Conclusion

- Elastic scattering as an intrinsic noninvasive approach is effective in detecting red blood cells at different states.
- Existence of a thin film can affect the scattering signal from red blood cells.
- Identified a promising approach to detect scattering signals of red blood cells through the fingertips.

Future Work

- Isolate signals of polymer films from that of the red blood cells by examining the scattering signature of films alone.
- Test other materials of polymer film that mimic skin and calibrate the sensitivity of the approach.
- Experiment on malaria-infected cells and identify the signature spectrum for diagnosis.
- Develop diagnostic device that detect malaria infection and other blood-borne diseases through signature scattering.

Reference

- S. Lee and W. Lu, “Backward elastic light scattering of malaria infected red blood cells,” *Appl. Phys. Lett.,* vol. 99, p. 073704, 2011.

- S. Lee and W. Lu, "Using Elastic Light Scattering of Red Blood Cells to Detect Infection of Malaria Parasite." *IEEE Transactions on Biomedical Engineering.,* vol. 59 no.1, 2012.

Thank You!

Questions?