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
  
  $I_{\text{particle}}(\theta) = \frac{I_{\text{sample}}(\theta) - I_{\text{background}}(\theta)}{I_{\text{reference}}(\theta)}$

  $I_{\text{sample}}(\theta)$: intensity of blood sample
  $I_{\text{reference}}(\theta)$: intensity of light source at $\theta = 0$ degrees
  $I_{\text{background}}(\theta)$: intensity of empty glass slide at angle $\theta$

  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 $4.998 \times 10^{-3}\%$ and $4.998 \times 10^{-2}\%$.
- 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 900 nm.
• 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


Thank You!
Questions?