Early Malaria Detection using the Magneto-Optical Properties of Malaria Pigment

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Introduction

• Malaria caused 660,000 deaths in 20122.
• This makes diagnosing the parasite in the field important, hence the need for a compact, low cost alternative to present methods, such as microscopy, which requires a trained technician.
• Malaria parasite converts hemoglobin into hemozoin crystals, which are dichroic, birefringent and paramagnetic.
• Applying a magnetic field causes the paramagnetic crystals to orient themselves perpendicularly to the magnetic field lines.
• Because of the dichroism of the crystals, when the magnetic field is applied, light polarized parallel to the magnetic field lines is attenuated more than light polarized perpendicularly to the magnetic field lines.
• By measuring the degree of attenuation of two linearly polarized laser beams with mutually orthogonal polarizations, the concentration of hemozoin, and hence the degree of infection, can be determined.

Device

• 2-650nm diode lasers (1) are switched on and off such that only one laser is on at any given time.
• Light from (1) pass through polarizers (2) and through a beam splitter (3).
• One path through (3) hits the reference diode (4).
• The other path passes through the sample (7) held between the magnet wheels (6).
• The two wheels (6) each contain a pair of 1.5” permanent magnets, which create a 0.5 T field housed within a 4” steel wheel on ball bearings.
• Beam bounces off the mirror (8) and back through the sample (7).
• Light hits signal diode (5).
• The photo-current from each diode passes through a 20K resistor and the voltage drop is measured.

Signal Processing

• Normalize Diode voltages.
• (2) and (3) are averaged in sets of 50 points.
• (3) is divided by (2) to generate (4) to remove laser drift.
• (4) is split into Horizontal and Vertical polarization states according to the value of (3).
• Values of (4) when (1) is between states are discarded.
• List of values for each state is averaged.
• The difference between averaged Vertical and Horizontal values is the reading for that magnetic field state.
• Take difference between readings with magnetic field on and off.

Results

The device has been tested with samples of β-hematin (synthetic hemozoin). Dilutions were made of a known concentration to obtain a range of concentrations that successively decreased by a factor of two. The plots below shows the signal versus the concentration of β-hematin. The signal is linear with concentration, which agrees with the data from Butykai3. For the graphs, error bars were determined by doing five runs and calculating the average and the standard deviation. For low concentrations (lower graph), the error bars are a significant fraction of the signal. This large range of values is the result of drift in diode outputs over time. Shortening the time period over which the data is taken should reduce the error bars.

Future Work

The long term goal is to make the device more compact and more sensitive. Currently, we have a preliminary device which can measure the concentration of hemozoin in PBS down to 4.9 ng/mL. Automating more of the data taking and analysis will reduce the time period of data taking and therefore should reduce the error bars for low concentrations. We will test blood samples as well to measure the full capabilities of the device.

References

2 Jones et. al. Studying the magnetic and optical properties of Malaria for use in early detection. CWRU Senior Project Thesis, 2012
3 Butykai et. al. Malaria pigment as magnetic micro-rotors. Scientific Reports 3 (2013)