Instrument to Detect Thromboemboli in Blood

Project Background

The heart is a mechanical organ that serves to pump blood throughout the human body. The left ventricle within your heart is primarily responsible for completing this task. When the left ventricle is unable to produce the necessary pressure rise to circulate the blood it is said that a patient has Congestive Heart Failure (CHF). The RIT Blood Pump laboratory has developed a ventricular assist device to treat CHF patients. When the pump components come in contact with the blood, fluid stresses arise and aid in the generation of thromboemboli.

Project Application & Objective

The main focus of this project was to develop a device to help detect and characterize thromboembolic particles.

Needs & Specifications

Overall Need: A working instrument for detecting emboli in blood.

Summary of Needs

- Detect individual emboli that are 50micro (e-6) m or larger
- Characterize the size of the emboli
- Estimate the validity of the emboli detection (% Error)
- Count the number of emboli detected in a time period
- Maintain a record of detected emboli and their size

Light Scattering Theory

Equation 1 is the one-speed transport equation given by Martin[1]. It provides a theoretical estimate as to how much light will be reflected off of a high concentration of particles.

\[
\frac{1}{\mu_f} \nabla \cdot (\mu_r \nabla \psi) + \sum_j \left( \nabla \cdot (\mu_r \nabla \psi_j) \right) - \sum_j \left( \nabla \cdot (\mu_r \nabla \psi_j) \right) = 0
\]

In this analysis, a far field assumption was made in order to simplify equation 1. Equation 2 determines the intensity of light from all particles in a given domain and was used to estimate the light scattered from the red blood cells.

\[
I_{\text{scattered}} = \frac{D_{\text{scattered}}}{D_{\text{incident}}^{\text{1}} - D_{\text{incident}}^{\text{2}}}
\]

In addition to the scattering that occurs at the embolus, the effect of the surrounding medium on the incident and reflected light must be characterized. The first loss occurs when the light passes through a boundary between two different materials. The differing indices of refraction cause some percentage of the light to be reflected away, reducing the amount that reaches the particle or detector. The reflected (R) and transmitted (T) percentages are determined as follows:

\[
R = \left( \frac{n_1 - n_2}{n_1 + n_2} \right)^2
\]

\[
T = 1 - R = \left( \frac{4n_2}{n_1 + n_2} \right)^2
\]

Design Overview

The final design involves a laser diode that will send light at a wavelength of 830nm through a test section of our fluids rig. Light will be collected via fiber pig tailed optical cables. This light will be sent to a photo diode on an integrated circuit board specially designed to filter the signal and determine whether or not an embolus is present in blood.

Team Members

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Further testing and experimentation will be necessary to validate the particle characteristics.