

Introduction

Micro-bubbles of different sizes are formed in the blood vessels due to the sudden pressure drop. These micro-bubbles can spread throughout the body leading to severe diseases such as decompression sickness (DCS), venous gas emboli and barotraumas. Divers, pilots and space scientists, who experience the afore mentioned pressure variations are the most vulnerable to such diseases. By diagnosing these diseases at early stages physicians can prevent potentially severe consequences. We are developing a novel noninvasive method capable of imaging and assessment of circulating microbubbles under human skin. During our pilot experiments, we have generated micro-bubbles and injected them into a capillary tube containing blood using a peristaltic pump and are imaged and quantified using a phase stabilized swept source optical coherence tomography (PhS-SSOCT). Results suggest that, the PhS-SSOCT is capable of detecting and quantifying the micro-bubbles in blood. In future, PhS-SSOCT would be utilized to monitor the microbubbles in animal blood vessels by obtaining 3D images and their corresponding phase responses. Thus, PhS-SSOCT has a strong potential to be utilized as a diagnostic device to detect micro-bubbles in blood and tissues and also diagnose decompression-related diseases such as decompression sickness, gas embolism or barotraumas.

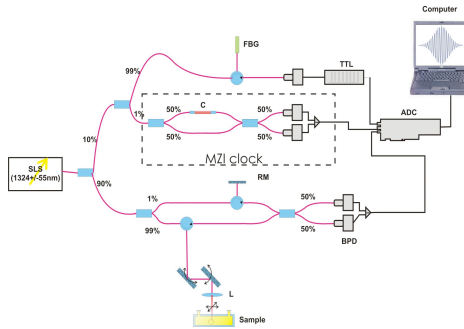
Techniques/Approach

PhS-SSOCT:

- Phase stabilized swept source optical coherence tomography
- Interferometer, calibration optics and trigger and data acquisition constitutes the system
- Calibration optics contains MZI-OC
- Phase-stabilization by triggering the data acquisition using fiber Bragg grating reflection.

Parameters:

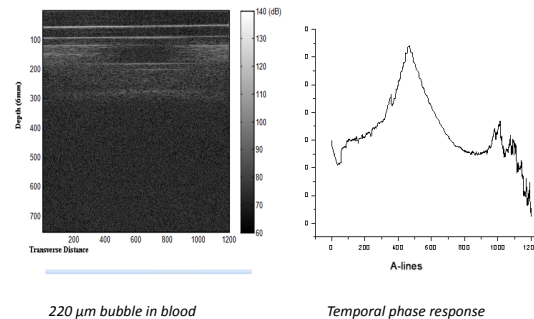
- $\lambda = 1310 \pm 55 \text{ nm}$ ➔ axial resolution around $10 \mu\text{m}$.
- coherence length 13 mm ➔ max imaging depth 6 mm .
- speed of laser 20 kHz ➔ A-line scan speed 20 kHz
- transverse resolution = $25 \mu\text{m}$.



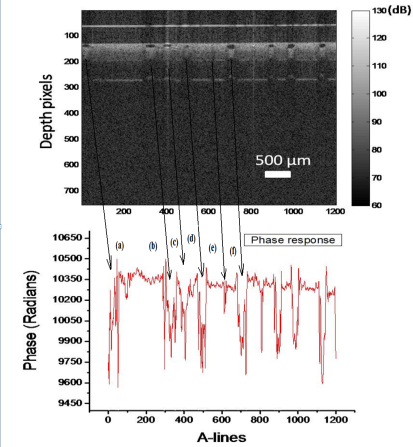
Methods:

- change in refractive index is reflected in the temporal phase response at the self-interference peak
- The bubbles are quantified using $l = \lambda/4\pi * dp/dn$.

Results



Microbubbles (a),(b),(c),(d) and (f) are of the following sizes $264 \mu\text{m}$, $228 \mu\text{m}$, $208 \mu\text{m}$, $291 \mu\text{m}$ and $187 \mu\text{m}$ respectively are shown. The Phase difference at the beginning of the graph between 75 A-lines to 250 A-lines indicates that there could be some ultra small bubbles that could not be detected using the imaging capability of the system. Moreover, a shadow of a bubble (e) is observed at around 600th A-line; the phase response is so sensitive that the presence of the bubble is clearly indicated in the phase graph.



Bubbles of different diameters in blood

Conclusion

In this study, PhS-SSOCT was used for real time monitoring, imaging and quantifying of microbubbles in blood. The results suggest that small microbubbles with diameter beyond imaging capabilities of the system can be detected and quantified using the PhS-SSOCT. Our future studies will focus on the generation, imaging and quantifying microbubbles of different diameters in mice tissues.

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