Using Optical Coherence Tomography for Measuring Nanoparticle Diffusion in Biological Tissues

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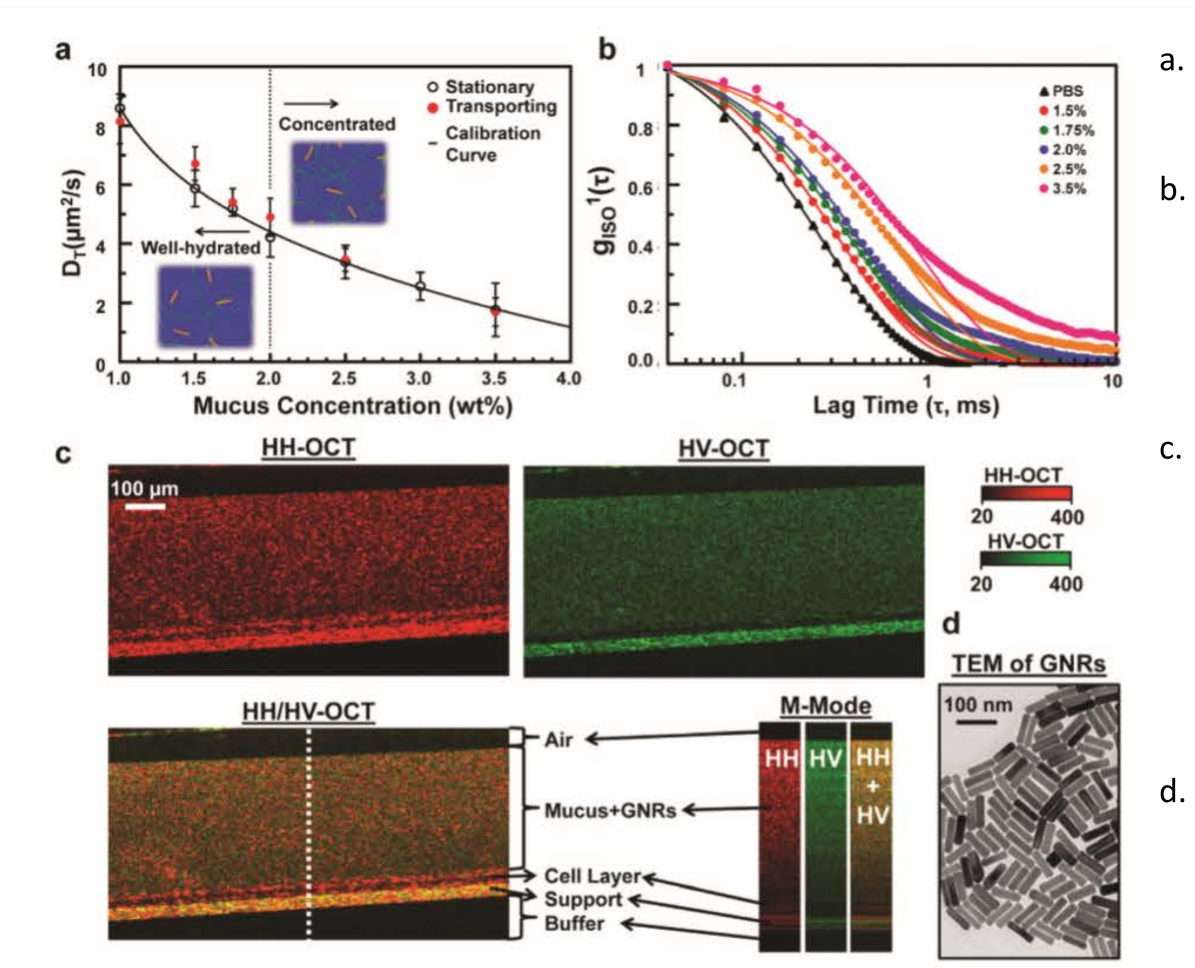
Background and Motivation

- Mucus is viscous fluidic biological tissue that is used for protecting airways by trapping and clearing pollutants and protecting from other viruses
- In respiratory diseases such as CF and COPD mucus becomes dehydrated resulting in breathing difficulty and increased infection
- Measuring mucus concentration (wt%) allows for diagnosing disease and monitoring disease treatment
- Previously, Diffusion-Sensitive OCT (DS-OCT) has been used to track gold nanorod (GNR) diffusion (D_T), which can measure mucus concentration in real-time and *in situ*



a. Translational diffusion coefficient at different mucus concentrations
b. Autocorrelation of OCT signals for varying mucus concentrations, showing signals decay faster for faster moving particles in less concentrated mucus
c. Co- and cross-polarized images taken using DS-OCT and when overlaid the different layers of the sample, including mucus+GNRs, epithelial cells, and the membrane support are clearly visible
d. Transmission Electron Microscopy image of the GNRs that are used in the mucus

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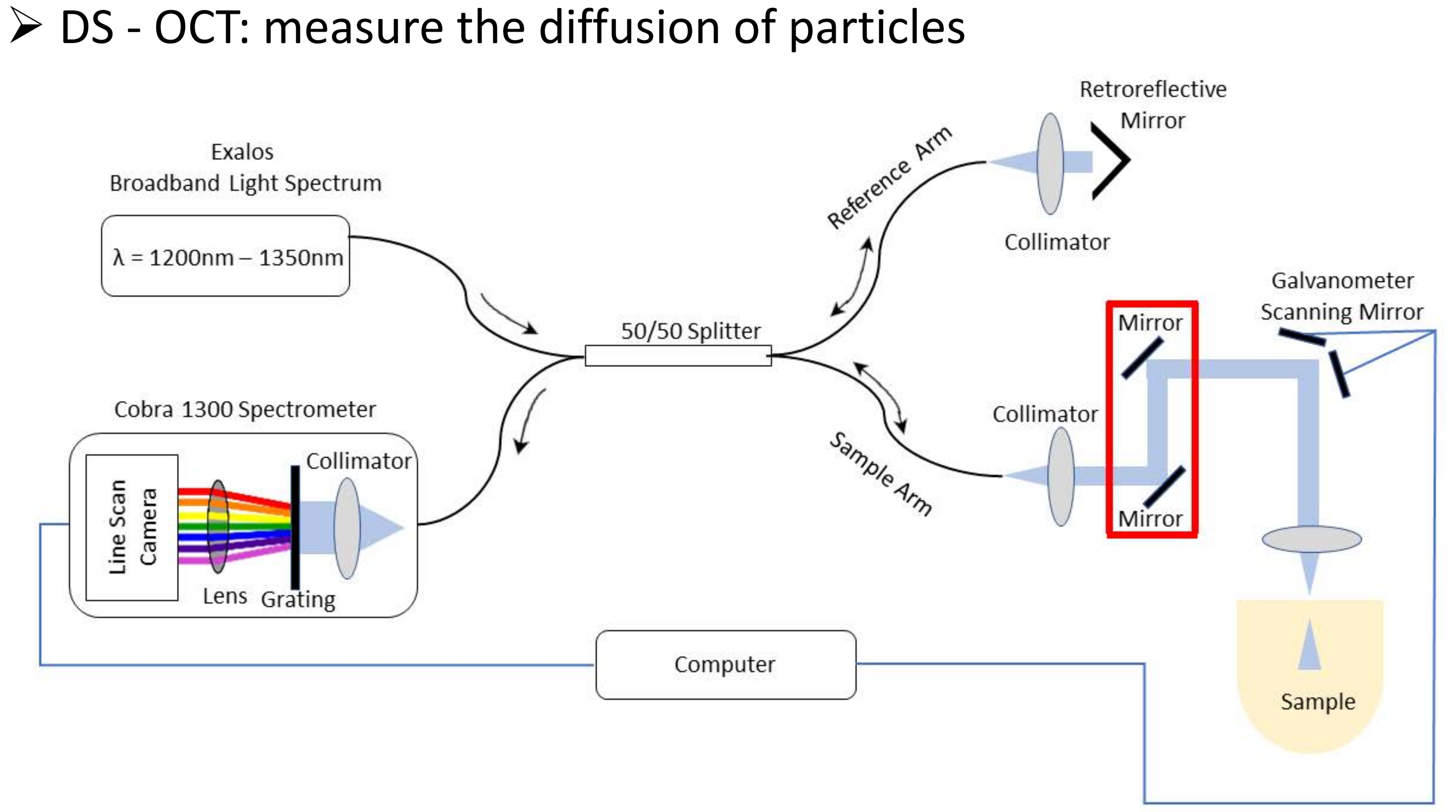
Goals

1. Align fiber-optic laser in reference arm and sample arm
2. Continue development of user interface in LabVIEW
3. Confirm diffusion rates can be measured using DI-OCT measure diffusion of particles in different ratios of glycerol-water solutions and comparing to Stokes-Einstein Equation

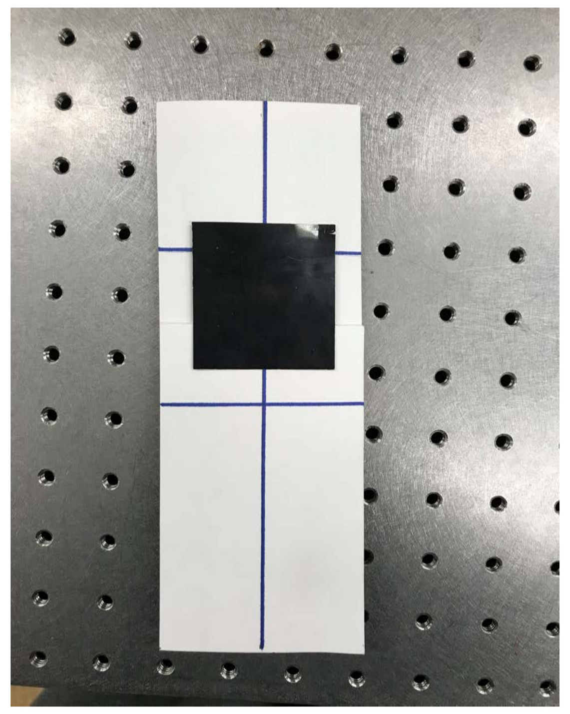
DI-OCT System

- Deep Imaging Optical Coherence Tomography
  - Allows for images to be taken deeper into the cell tissue because of longer wavelength and less light absorption in tissue at that wavelength
- Previous technologies
  - DS - OCT: measure the diffusion of particles

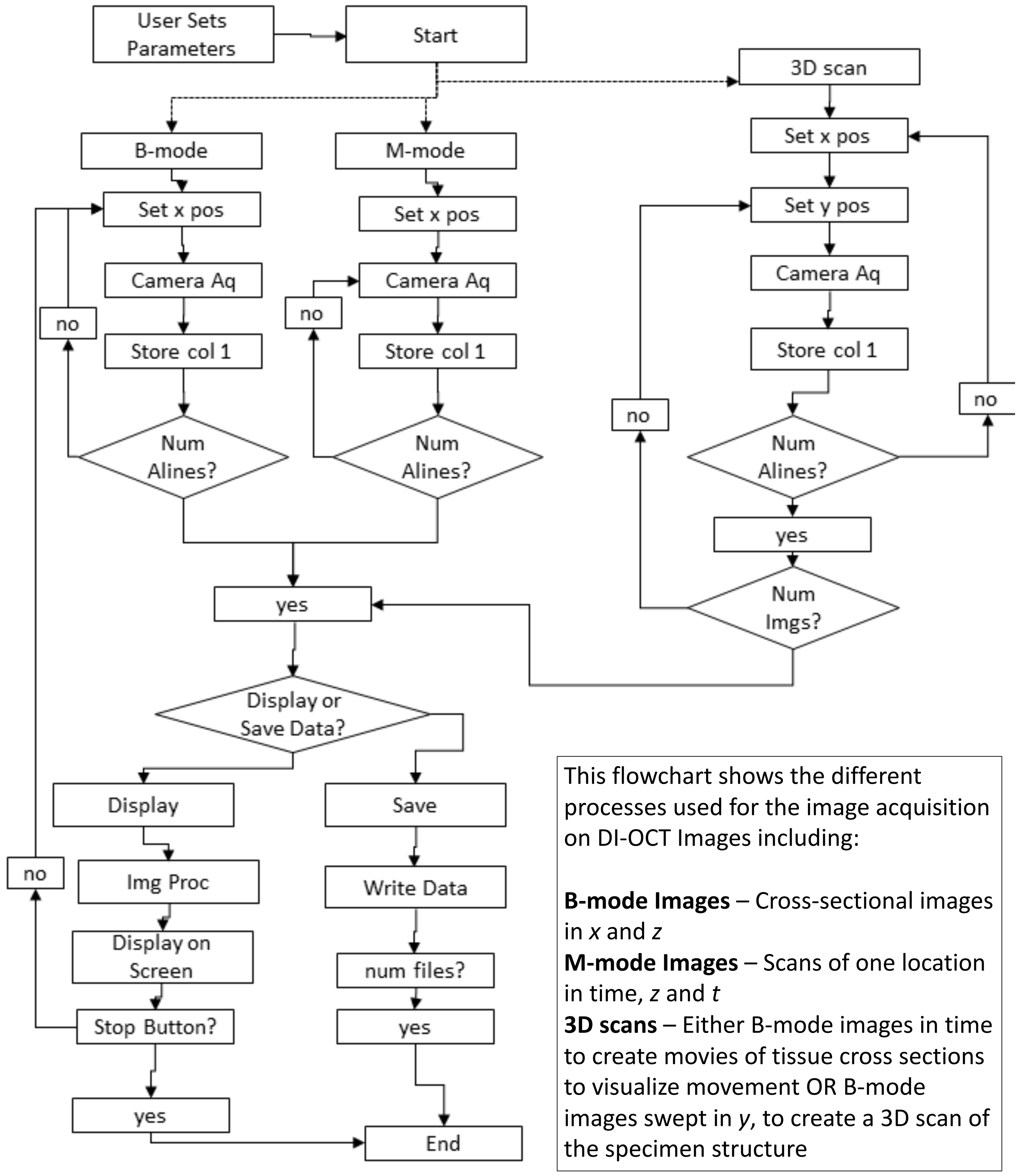


Approach

- Fiber Optic Laser Alignment
  - Use an alignment tools (below) to monitor the lateral displacement of the laser beam at varying distances
  - Add periscope (one mirror at a time) and use same alignment tools to make sure that laser beam is still going in a straight line
  - Direct beam to galvos and make sure that beam is hitting as close to the center of each mirror as possible by slightly moving periscope mirrors
  - Use heat sensitive paper to find the reflective beam and trace it back to the original light source by manipulating periscope mirrors



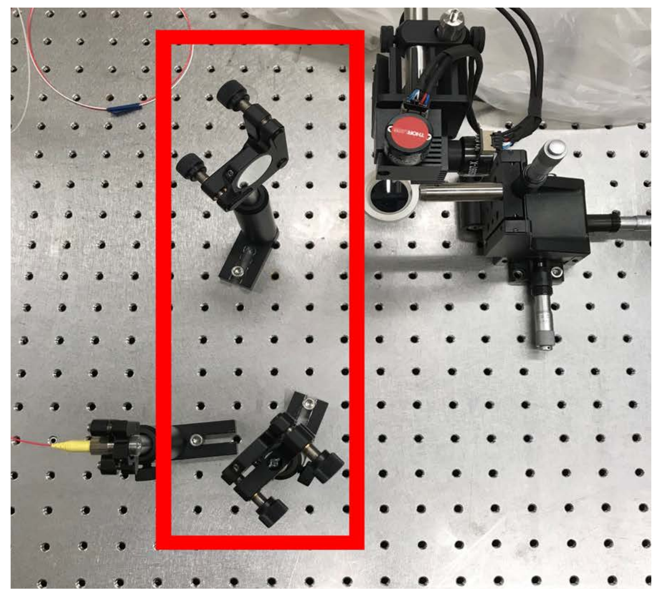
- Flowchart for Deep Imaging Optical Coherence Tomography



This flowchart shows the different processes used for the image acquisition on DI-OCT Images including:

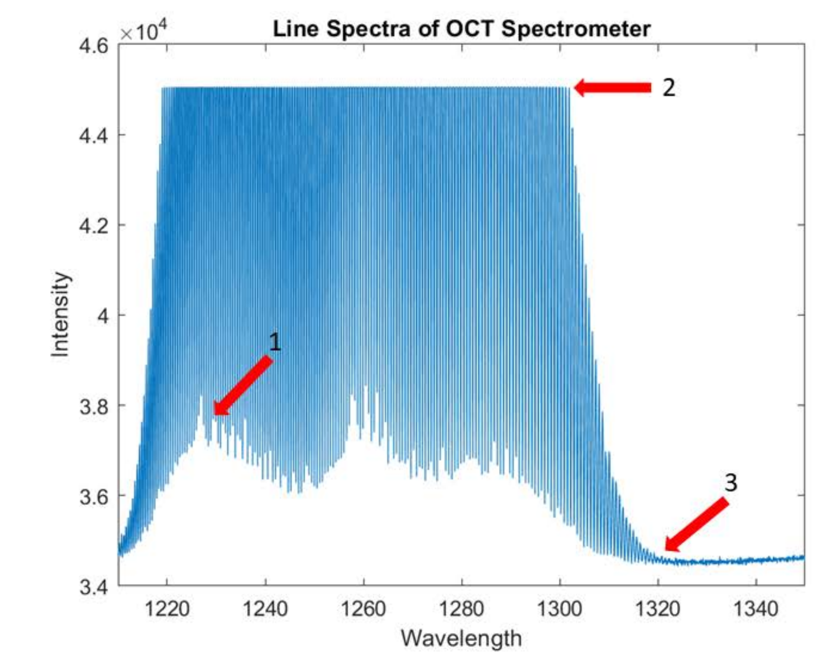
B-mode Images – Cross-sectional images in *x* and *z*
M-mode Images – Scans of one location in time, *z* and *t*
3D scans – Either B-mode images in time to create movies of tissue cross sections to visualize movement OR B-mode images swept in *y*, to create a 3D scan of the specimen structure

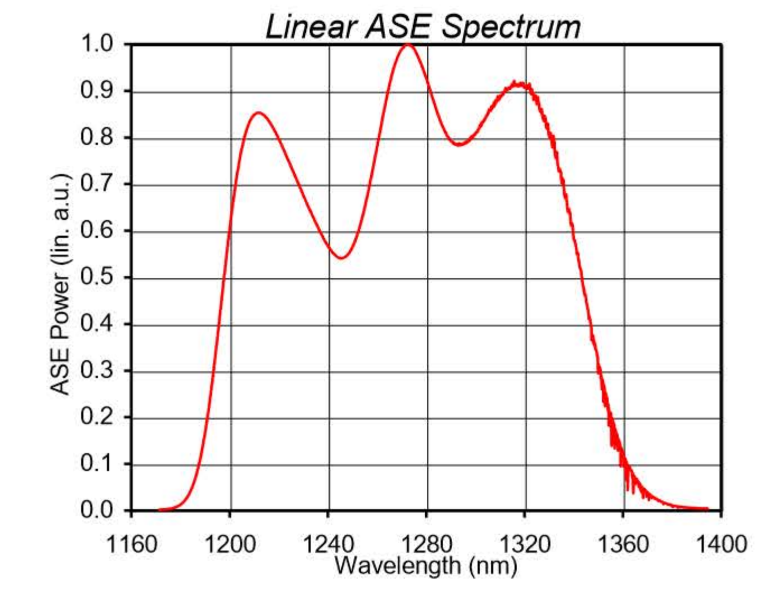
Results



Left – Periscope used to steer the laser beam to the sample for imaging. This enabled the precise alignment required to couple laser energy scattered from the sample back into the interferometer.

Bottom – Spectra of the laser source for this imaging system. Left is the spectrum measured with the new GUI, right is the expected spectrum based on laser specifications from the manufacturer.

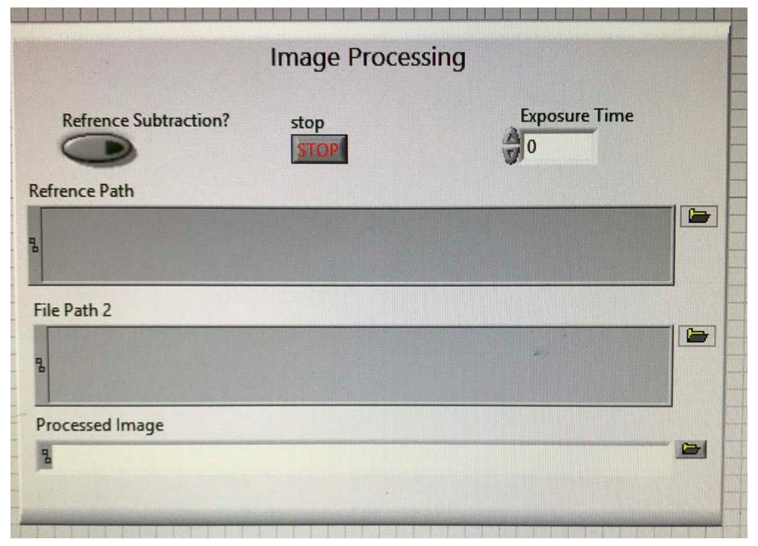




1. Profile of expected line spectrum, but a significant amount of noise possibly indicates the need for more precise alignment
2. Light is saturating camera due to high camera exposure time
3. Spectra is not spread over entire range

Moving Forward

Finishing the development of DI-OCT software using LabVIEW and creating user-friendly interface so that images of samples can be taken

1


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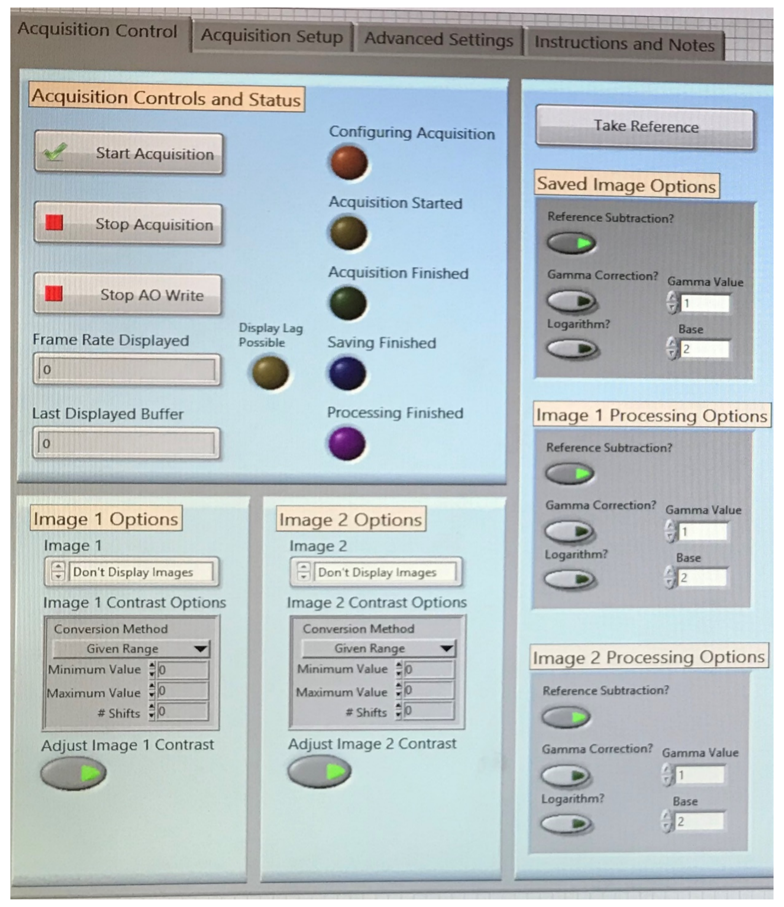

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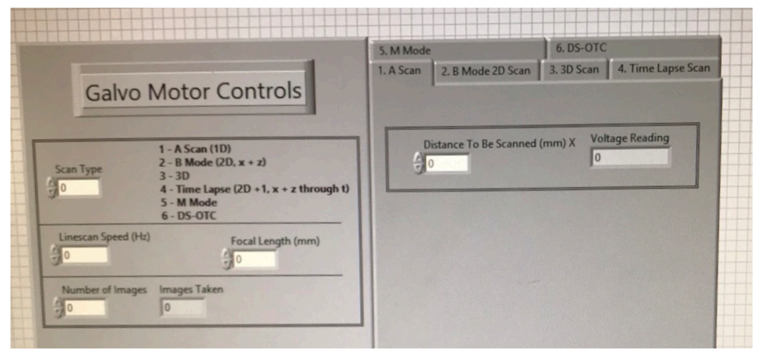

Above are two different GUIs for the DI-OCT System GUI; Images 1 saves images to the computer and 2 control the image scanning technique, Image 2 shows a GUI of a similar systems showing what the end product for DI-OCT should look like. Ultimately, the sub-GUIs such as those in Images 1 and 2 will be combined into a master GUI such as that in Image 3.

Acknowledgments

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