Project Statement & Specifications
Near Infrared Imaging System

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**Statement of Need**

This project aims to create a near-infrared source system using laser diodes for imaging biological tissue. Optical methods and devices have been used for a variety of biomedical applications for about twenty years for chemical analysis - colorimetry and spectrophotometry. More recently instruments for direct chemical analysis in tissues have been developed, and at the beginning of the twentieth century instruments based on the use of visible light began to be used. Through a lot of research, it has been found that the near infrared part of the electromagnetic spectrum has the ability to penetrate deeper into biological tissues compared to visible light. This method allows achieving safe and noninvasive monitoring of important variables in a variety of clinical applications.

**Introduction and Overview**

Near-infrared (NIR) spectroscopy is an imaging method based on molecular overtone and combination vibrations. Such transitions are forbidden by the selection rules of quantum mechanics and as a result, the molar absorptivity in the near IR region is typically quite small. One advantage is that NIR spectroscopy can typically penetrate much farther into a sample than mid infrared radiation. Near-infrared spectroscopy is, therefore, not a particularly sensitive technique, but it can be very useful in probing bulk material with little or no sample preparation.

The molecular overtone and combination bands seen in the near IR are typically very broad, leading to complex spectra; it can be difficult to assign specific features to specific chemical components. Multiple wavelength calibration techniques such as principal components analysis, partial least squares and artificial neural networks are often employed to extract the desired chemical information. Careful development of a set of calibration samples and application of multivariate calibration techniques is essential for near-infrared analytical methods.

Near-infrared spectroscopy imaging uses near infrared light between 650nm and 950nm to non-invasively probe into biological tissues. Some medical applications include probing the concentration and oxygenation of hemoglobin in the brain, muscles, and other tissues. NIR spectroscopy imaging can also be used to detect changes induced by brain activity, injury, or disease. In brain research it complements functional magnetic resonance imaging (fMRI) by providing measures of both oxygenated and deoxygenated hemoglobin concentrations and by enabling studies in populations of subjects with experimental paradigms that are not amenable to fMRI.

When considering using NIR for imaging biological tissue, it is important to understand the absorption coefficient of a given specimen. Due to the fact that the absorption coefficient of a tissue is a function of the wavelength in which it is being imaged, it is necessary to understand the specific range in which tissues absorb the most. This range is called the near-infrared window.

The goal of this project is to create a device that will be used to image biological tissue. The device will provide multiple inputs from a probe of 10 centimeter in diameter that
contains multiple laser diodes. The client wants the diodes to be able to operate at two different optical wavelengths, 780nm and 830nm, and the probe to potentially contain up to eight different laser diodes. To operate at these wavelengths the system will be operating in accordance to the International commission on Illumination (CIE) at IR-A infrared radiation or Near-infrared wavelengths.

Each laser diode will be modulated at different frequencies to enable a spatial coding system. An optical detector channel will be designed with this device to detect signals from all the laser diodes and reveal their spatial locations. The client also wants the system to be able to identify the states of the laser diodes. A system needs to be devised in which reports which diodes are on, being able to handle multiple diodes being in the on state, and which diodes are off. This can become rather complicated because there are quite a few signals being introduced simultaneously into the system. A filter needs to be designed to detect which signal correlates to which diode separating all signals or lack thereof to identify the laser diode states. Figure 1 below shows a working flow chart of the light signal from the laser diode to the photo receptor and the software filter.

![Flow chart of laser signal to digital signal](image)

**Figure 1.** Flow chart of laser signal to digital signal

**Realistic Constraints**

As with any project in the field of science and medicine, there are multiple realistic constraints that will affect the results and overall effectiveness of this project. Economic constraints tend to make up the bulk of most problems that arise in the field of medicinal research. In regards to this project, many of the parts that are needed to construct the imaging probe, such as the laser diodes, current drive, and photo detector can be purchased commercially for a relatively low price. Other hardware requirements, such as the National Instruments Data Acquisition (DAQ) device and DC/AC power source, are already provided through the research laboratory. Software requirements such as LabVIEW and MultiSim are also provided. The majority of our economic constraints will depend highly on the amount of prototypes we render and the amount of hardware instruments that are necessary to completely build the probe.

Environmentally, there are only a few constraints that we will have to deal with, specifically electronic waste. Electronic waste, or e-waste, is becoming a problem in many industrialized countries such as the United States and China. The disposal of our completed project should be handled with care and done under environmentally complaint conditions.

Sustainability and manufacturability are not going to be a problem due to the nature of the project. As of now, there are also no ethical constraints involved with laser imaging on
biological tissue. Health and safety concerns would only be a problem if the project were to involve human test subjects. Our test specimen will only include biological tissue which has been extracted from a human subject and has been legally donated for the purpose of this project. The fact that we are not using live human test subjects also carries over to the fact that we will have no social or political constraints.

**Questions**

What type of biological tissue will we be using to test our laser probe on?
How does special coding operationally impact our experiment, and what type of effects will it have on our results?

**Operational Specifications**

A schematic for the laser probe must be created and tested through circuit design software, after which it will be sent out for product development. The probe will contain multiple laser diodes spaced equally apart from each other, which will be purchased separately and soldered onto the circuit. The probe will be powered with direct current and alternating current power in order to allow the laser diodes to transmit light at different wavelengths (780 nanometers and 830 nanometers). An optical detector will be hooked up to a data acquisition device and transmit analog data which will then be converted to digital data for analysis. The analysis will be done using software which will graph the different input frequencies and the amount of diodes emitting those frequencies. This data will later be used for spatially coding and imaging the biological tissue.

**Technical Specifications**

**Material Specifications**

- **Physical:**
  - Laser diodes
- **Electrical:**
  - Microchip controller/circuit
- **Environmental:**
  - Operating Environment:

**Software:**

- **User Interfaces:** Graphical User Interface (LabVIEW)
- **Hardware Interfaces:** Monitor, 10 cm Laser Diode Probe
- **Communication Protocols:** National Instruments DAQ
- **Features:** Sample tissue imaging and graphing of input laser wavelengths
- **Computer Requirements:**
  - Operating System: Microsoft Windows 7 x64
Processor: 1.5 GHz Dual-Core Processor Memory: 4 GB DDR2-SDRAM